MIB 2016

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

MIB Annual Report 2016

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

Annual Report 2016

Center for Music in the Brain
Department of Clinical Medicine, Health, Aarhus University &
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WORDS FROM THE DIRECTOR

2016 was The Danish National Research Foundation's Center for Music in the Brain (MIB)'s first full year - a year of building up in terms of personnel, collaborations, projects, administrative procedures and music-specific infrastructure.

To support the core research in the four strands of the centre, Perception, led by Lauren Stewart: Action, led by Peter Vuust: Emotion, led by Morten Kringelbach and Learning, led by Elvira Brattico, MIB started up one associate professor, one assistant professor, one postdoc, two PhD students, 1 research assistant and two half-time technicians.

A constant influx of international guest professors and graduate and postgraduate students from abroad has been aiding the MIB research greatly. Supported by Aarhus University Research Foundation (AUFF) and the Lundbeck foundation, Professor Mikko Sams from Aalto University and Professor Risto Näatänen both visited MIB for three months, giving exciting lectures, writing papers and initializing a number of research collaborations with MIB researchers. Dr Mari Tervaniemi from CBRU at Helsinki University was visiting professor at MIB with the agreement to visit regularly to follow the longitudinal and developmental studies as scientific advisor for the duration of the funding period.

MIB furthermore hosted a number of prominent guest speakers and collaborators, such as Jean-Claude Dreher, Predrag Petrovic, Lauri Parkkonen, Stefan Kölsch, Virginia Penhune and many more. During the fall of 2016, Bjørn Petersen arranged MIB's first web-streamed course in experimental musicology attracting almost 30 Master's and PhD students from Aarhus University (AU), the Royal Academy of Music and abroad.

Translating the MIB research into clinical applications is an important goal for MIB. This line of research, coordinated by associate professor Line Gebauer, was able to attract considerable external funding. The Tryg Foundation, Aage og Ejnar Danielsens Fond, Folkesundhed i Midten, and Fonden til Lægevidenskabens Fremme generously funded the PhD of Mette Kaasgaard, who will be starting January 2017, on singing training of patients suffering from chronic obstructive pulmonary disease. This project is a collaboration between MIB and Næstved Sygehus and was granted 1.7 million DKK in 2016. MIB received further funding from FKK, FSS, and Neurelec S.A.S. (totalling 2.5 million DKK) for projects on music in relation to autism/ADHD, sleep, and cochlear implant users. We were furthermore involved in a number of externally funded up-starting PhDs from Denmark and abroad.

Highlighting MIB's high research quality, we

MISSION STATEMENT

The Danish National Research Foundation's Center for Music in the Brain (MIB) is an interdisciplinary research centre aiming at addressing the dual questions of how music is processed in the brain and how this can inform our understanding of fundamental principles behind brain processing in general.

With a strong foundation in music practice and theory at the highest level, and a focus on clinical application of music, MIB combines neuroscientific, musicological and psychological research in music perception, action, emotion and learning, with the potential to test the most prominent theories of brain function, and to influence the way we play, teach, use, and listen to music.

received cofounding (1/3) of four PhD stipends in 2016 from the Graduate School of Health, assurance for one fully financed mobility stipend at Health, co-financing of one PhD student from the Graduate School at Arts, as well as a number of smaller grants for travel and conferences from the Lundbeck Foundation and FENS.

A scientific highlight in December 2016 was the publication of papers in two consecutive issues of Scientific Reports both building on original MIB paradigms (described later in this report). New developments of these paradigms, the Musical Multi-feature Paradigm and the dual tapping paradigm, are currently pursued by PhD students from different MIB strands, as well as by researchers at labs in Finland and Germany. Also worth mentioning is Gustavo Deco and Morten Kringelbach's work on brain connectivity and meta-stability, published in Trends in Neuroscience, which forms the basis of several up-coming MIB papers (see contributions from Maria Witek and Morten Kringelbach in this report). Importantly, most of the MIB papers in 2016 are co-authored by researchers from more than one MIB strand and includes international collaborators. This is in line with MIB's ambition of being a truly cross-disciplinary, international centre with a strong internal coherence between the different strands.

The societal and educational relevance of the research remains fundamentally important to MIB. Together with ASTRA and *Dansk Naturvidenskabsfestival* we initiated and concluded data collection and preliminary analyses from more than 30,000 school children reporting listening habits, musical activities and performing musical ear training tests and working memory tests - some of these before and after an app-based musical training program. These data will allow us to determine whether there is a causal effect of musical training on working memory, which until now has been a generally held belief among music educators, but remains an open question. This study is part of MIB's growing interest in studying development in children, which is also evident in the initiated longitudinal studies of MIB's learning strand which uses brain scanning to investigate the influence of long term intensive musical training on children's development in other cognitive areas (see later in this report).

In 2016, Niels Christian Hansen received a one year postdoc position at David Huron's lab in Ohio, USA, and Christine Parsons received a grant from The Tryg Foundation to investigate treatment adherence in Mindfulness-Based Stress Reduction using wearable technology, together with researchers at Interacting Minds Center, AU. Both CP and NCH will remain close MIB collaborators. NCH has had his contract renewed for another year after which he will continue his postdoc studies at the MARCS Institute for Brain, Behaviour and Development Sydney, Australia, funded by the Carlsberg Foundation in collaboration with Peter Vuust at MIB.

With this annual report we wish to highlight the scientific progress and key events in 2016 and to thank MIB and CFIN scientists and collaborators, the Danish National Research Foundation, Central Denmark Region, the Department of Clinical Medicine at Aarhus University, The Royal Academy of Music Aarhus/Aalborg, Aarhus University and our other generous funding sources for their continued support.

On behalf of MIB,
Peter Vuust

Center for Music in the Brain at the MIB's Make Time to Think retreat at Samsø where MIB researchers develop novel innovative research projects in groups that transgress the boundaries between the different MIB strands.

Photo: Ole Heggli

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 upcoming 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 strand is led by Prof Lauren Stewart (who holds a dual position between MIB and Goldsmiths, University of London). In its current form, its members comprise PhD students Rebeka Bodak, Suzanne Ross and Cecilie Møller (collaboration with Dept of Psychology and Behavioural Sciences, AU), Asst Prof Boris Kleber and visiting lecturer Marcus Pearce (Queen Mary University of London). Marie Dahlstrom has received a prestigious PhD mobility fellowship from AU and will be joining the centre in 2017.

Music as a model of perception/action coupling

Building on previous work, which demonstrates obligatory mappings between sound and action in skilled musicians (e.g.[1,2]), 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, co-supervised by Prof Vuust, is a collaboration with Prof 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. Data collection is in progress, and results will be presented at the Neurosciences and Music Conference VI in Boston in 2017.

Ross's PhD work concerns the predictions that musicians generate in the course of performance. Co-supervised by Prof Brattico and Dr Herrojo-Ruiz (Goldsmiths), the project uses pianists as a model to ask whether pianists (who do not have absolute pitch) are nevertheless able to accurately predict the pitch of the note they are about to play. Following on from a behavioural pilot study last year, an electrophysiological study is now underway to investigate pitch-action prediction in expert musicians. The predictive coding of music hypothesis suggests that prediction underlies musical perception, action and learning[3], making musicians the ideal model for studying perception-action prediction. Accumulating evidence shows that humans can predict specific physical characteristics of the sensory consequences of action (e.g. frequency) via an internal forward model, and that feedback deviations from this elicits a prediction error (Fig 1+2), which is indexed by ERPs such as N1 and P3[4-5]. Yet traditional reductionist N1-suppression paradigms cannot probe what form these predictions take or

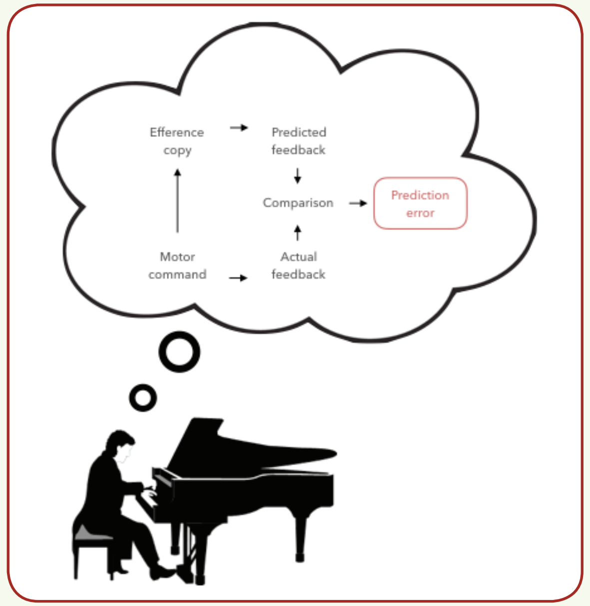

Figure 1. A schematic representation of prediction via an internal forward model

According to the comparator model, when a motor command is executed, a copy of the command (efference copy) is used to predict the upcoming sensory feedback. The predicted feedback is then compared to actual sensory feedback. If a mismatch between predicted and actual feedback is detected, a prediction error occurs.

what mechanisms govern prediction specificity. A novel paradigm has therefore been developed to investigate prediction in real-world learning, taking advantage of musicians' long-term learning of pitch-action associations to investigate the following: 1) Can musicians accurately predict the pitch of notes resulting from action?, 2) is pitch prediction categorical or continuous?, and 3) is pitch prediction governed by cognitive or perceptual factors? Results of this study – again, to be presented at the Neurosciences and Music Conference, will generate new hypotheses about how perception-action prediction operates generally, and will have important implications for understanding predictive mechanisms in brain function.

Exploiting musical perception/action coupling in rehabilitation

The interface between perception and action as applied in rehabilitation contexts is of special interest to the strand, and Bodak's expertise as a music therapist is of particular relevance. Following on from our empirical study concerning the impact of active music making on visual attention in patients who suffer from unilateral neglect: contralateral visual-attentional deficits following stroke[6] work is ongoing within the strand to systematically review the wider evidence base concerning the potential of music to aid in rehabilitating visual attention in this syndrome. In addition, Bodak has been collaborating with Goldsmiths based PhD student, Pedro Kirk, to explore the potential of creative digital technologies for physical rehabilitation in in-patient as well as community groups of stroke

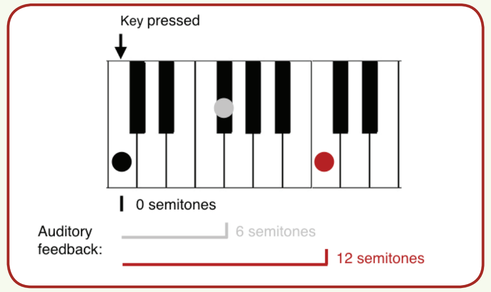

Figure 2. A novel pitch-shifting paradigm to induce prediction error

Pianists play keys on the keyboard and feedback is either unaltered (0 semitones) or manipulated by 6 semitones or 12 semitones. If pianists can predict the absolute pitch of notes they play, we expect to see larger amplitude N1 and P3 components for manipulated feedback versus unaltered feedback.

survivors[7] as well as contributing to the development of clinical tools to aid in the assessment of Huntington's disease[8]. This direction of work continues to be a strong nexus for collaboration with practitioner collegues in the clinical neurology and music therapy community, with a recent perspectives paper achieving an impact milestone of 5000 views over the last year[9]. In addition, Stewart has given prestigious keynote addresses within these communities as well as being interviewed for a high profile podcast for the Guardian.

Music perception and perceptual learning in special populations

Building on Stewart's previous work surrounding the disorder of congenital amusia[10-12] a recent study from Stewart's group examined socio-emotional processing in individuals with this disorder[13]. Previous studies found that amusia can be associated with other impairments outside music, but they have typically focused on speech processing rather than other visual and auditory cues. In contrast, the study by Lima et al. required 24 participants (11 with congenital amusia and 13 matched controls) to judge the emotion in extracts of emotional speech, based on the patterns heard in the tone of voice. Emotions included amusement, anger, disgust, fear, pleasure, relief and sadness. They were also tested using nonverbal vocalisations such as crying or screams as well as a series of silent facial expressions. Compared to the control group, those with amusia were impaired for all stimulus types, including vocal and facial expressions. In addition to showing reduced accuracy, amusic participants gave more ambivalent responses. The results represent the first evidence for a modality-independent impairment in socio-emotional processing in amusia. This does not question the ideas that the most prominent manifestations of this disorder are music-specific, and potentially related to a core fine-grained pitch processing deficit. Rather, they suggest that, throughout development, abnormalities in musical and pitch abilities may lead to subtle abnormalities in socio-emotional abilities that generalize beyond the auditory domain.

The interplay between modalities in fine-grained pitch perception is also the topic of Møller's PhD work. She has been investigating visual gains in pitch discrimination in musicians and non-musicians, and how reliance on visual cues declines with increasing levels of auditory expertise. Using behavioural measures, MEG and DTI, this project has taken full advantage of the possibilities afforded by the MIB core experimental facilities, and the access to expert musicians at the Royal Academy of Music.

International synergies

Additional strands of Stewart's work, conducted at Goldsmiths, continue to offer the potential for development and expansion within the remit of MIB. Of particular note is a collaborative project with Prof Glover (Imperial College, London) and Goldsmiths based PhD student, Katie Rose Sanfillippo, exploring the impact of music listening on antenatal mental health. Building on a pilot study showing significant effects of music listening in pregnancy on anxiety, a large clinical study is planned to contrast the impact of music listening with guided relaxation in pregnant women diagnosed with clinical depression.

Related to this strand of work focusing on music and perinatal health concerns an innovative project on which Stewart served as scientific consultant, alongside infant psychologist Dr Addyman. Collaborating with renowned composer, Imogen Heap, along with Cow and Gate Baby Club, advertising agency BETC and music agency FELT, Stewart and Addyman advised on the creation of a new song to 'make babies happy'. The creative process was an iterative one, where the scientists advised the composer on the musical perceptual capacities of infants, as well as the affective properties of musical features and sounds. Heap responded by writing prototype songs which were tested on 50 infants visiting Goldsmiths' BabyLab, to determine which of the candidate songs were most effective. By focussing on the infants' behaviour (movements, gestures, vocalizations), the scientists gave further advice to the composer on how to refine and develop the musical material, and the final product ('the Happy Song') was launched, arriving at no.1 in the iTunes Kids chart, attracting coverage in the international media, including the BBC World Service. This collaborative project has sparked several spin off projects, to investigate the relationship between musical features and affective responses in infants. Projects such as these 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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PERCEPTION

Do we feel the sound? Evidence for altered sensorimotor integration in musicians

By Boris Kleber

Predictive coding is an increasingly influential framework for explaining how the brain learns statistical regularities during sensory perception in order to reduce redundancies by separating predictable from unpredictable components of the input. This concept has been mostly tested for individual sensory modalities, thus treating our sensory systems as separate entities based on their corresponding physiological processes. For example, the external oscillatory structure of acoustic events that is converted into neural activity in the cochlea will be processed in parallel within specific (lemniscal) and non-specific (extralemniscal) afferent subsystems to form musically relevant percepts of pitch and timbre on the one hand and their temporal organization on the other hand[1]. In reality, however, perception rarely relies on isolated analysis of individual sensory events but rather on the simultaneous integration and segregation of multisensory information. This allows the formation of a more coherent percept and reduces uncertainty about the world's causal structure[2]. A famous example is the cocktail party effect, in which visual information from the speaker's face boosts hearing capabilities of the listener, thereby facilitating the understanding of speech in noisy environments. By the same token, manipulating the patterns of facial skin deformation that would normally accompany speech production changes what people hear while they listen to spoken words[3]. Taken together, multisensory integration can either deteriorate or improve perceptual performance, depending on whether its components coincide with expectations following prior associative learning of action/perception relationships[4].

With respect to action, music provides us with a particularly interesting framework for studying multisensory processing, due to the high demands on temporal and spatial precision of multisensory integration[5]. Among the sensory modalities, auditory integration is regarded as the most crucial process for the learning and production of music and speech[6,7]. However, we often tend to neglect the fact that somatosensory feedback from the body is highly correlated with sound production[8]. This is also expressed in current models of speech motor control, which propose that the time course for the development of precise sensory-motor maps is more protracted in the somatosensory than in the auditory domain, as the identification of adequate somatosensory targets first requires the correct acoustic monitoring of one's own self-productions[9]. Based on this notion, we tested the idea that the relative contribution of somatosensory and auditory modalities to vocal motor control changes with experience in singing. We assessed this in groups of trained classical singers and non-singers by employing a pitch-singing paradigm in combination with functional magnetic resonance imaging (fMRI)[10,11] and transcranial direct current stimulation (TMS; Kleber et al., submitted for publication).

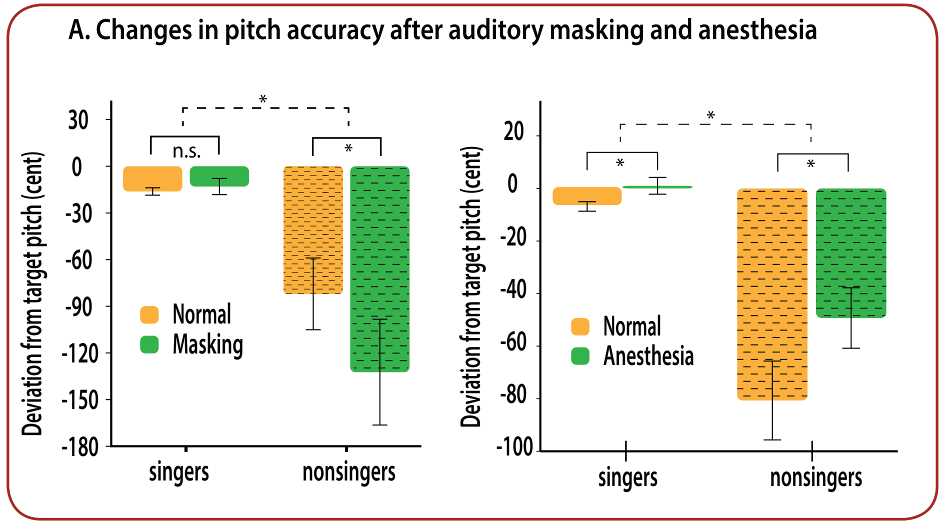

Figure 1A

Mean deviation from target pitch across the two tones of the interval measured in cents (100 cents=one semitone). Orange color indicates singing with normal feedback. Green indicates singing with masked auditory feedback (left image) and singing with vocal fold anaesthesia (right image). A main effect of group indicated that singers sang more accurately than nonsingers in all conditions. Auditory masking reduced pitch matching accuracy only in nonsingers but not in trained singers. Anaesthesia reduced pitch accuracy in both groups, yet less so in trained singers.

The pitch-singing paradigm required participants, while lying in the MRI scanner, to sing back musical intervals that have been presented via headphones. Sung renditions were recorded in order to analyze pitch-matching accuracy at a later point. For each of the 36 singing trials per session, we acquired whole-head functional brain scans to detect corresponding brain activation. Participants performed the singing paradigm on separate days in order to allow for the controlled interference with auditory and somatosensory feedback processing. That is, in the auditory condition, we selectively inhibited the perception of pitch information from auditory feedback by playing loud masking noise through the headphones while participants were singing. Conversely, we interfered with somatosensory feedback from the larynx by applying a topical anesthetic agent onto the vocal-fold surface under visual control with a transnasal laryngoscope. This reduces activity in touch sensitive receptors located in the vocal fold mucous, which are crucial for adjusting vocal fold stiffness during vocal production, affecting the control of vibration frequency and thus pitch.

When evaluating pitch accuracy, we found that trained singers were superior across all conditions, as expected (Fig 1A). More interestingly, however, noise-masked auditory feedback decreased pitch-matching accuracy only in non-singers but not in singers. Anesthesia affected pitch accuracy in both groups but to a lesser extent in singers. Together, these behavioral effects suggest that due to their experience, singers rely less on auditory feedback and more on somatosensory feedback for controlling their singing voice, whereas the opposite effect was true for non-singers.

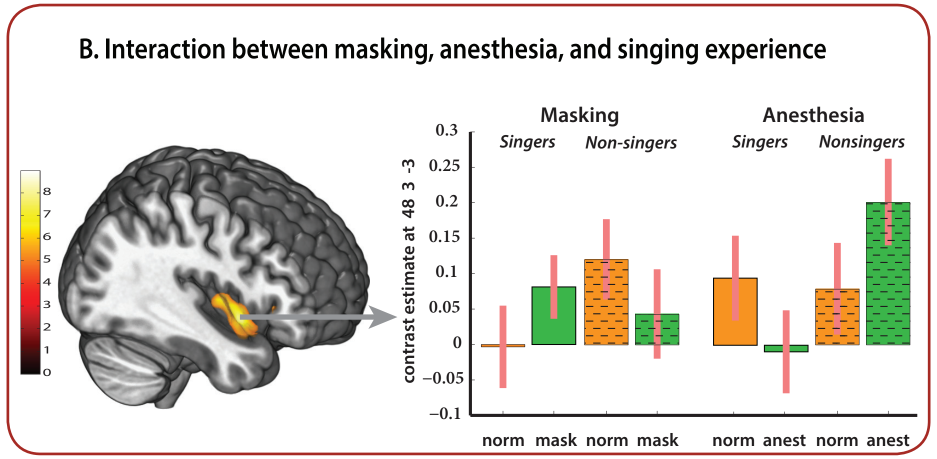

Figure 1B

The brain area that modulated the effects of singing with auditory masking, singing with a topical anesthetic to the vocal folds, and singing with normal feedback was the right anterior insular cortex, indicating mirror-reversed insula activation patterns as a function of singing expertise and feedback condition (i.e., normal feedback, auditory masking, and anesthesia) during overt singing. Bar graphs show contrast estimates and 90% confidence intervals.

Brain activation patterns finally confirmed this conclusion, demonstrating a distinct pattern of increased and decreased activation within cortical and subcortical sensorimotor regions in singers and non-singers respectively. Accordingly, singers showed cross-modal compensation in form of enhanced somatosensory-motor network activation, which might allow singers to control pitch levels even in the absence of auditory feedback. Conversely in non-singers, masking deactivated auditory, somatosensory, and motor regions of the brain, indicating a destabilization in the motor control system of amateurs when being deprived of auditory feedback.

This is well in line with predictions from speech motor control models, which suggest that somatosensory-motor coordination only develops precision with increased experience. A stronger weighting of somatosensory feedback in experienced singers was confirmed in the anesthesia experiment. Here, we found that anesthesia reduced activation in cortical sensorimotor regions also in singers. Curiously, however, instead of compensating anesthesia with auditory control, singers limited the integration of sensory feedback altogether and relied on automatized (feedforward) motor patterns. Intriguingly, the right anterior insula cortex, a gateway to human awareness and a critical hub for the integration and cognitive processing of sensory information[12], was the main area that modulated the above-mentioned interactions between expertise and feedback perturbation (Fig 1B).

In a recent study (Kleber et al., submitted for publication), we followed up on these results by directly facilitating cortical processing of sensory information from the larynx using TMS in non-singers. The goal of this approach was to explore whether the enhancement of somatosensory feedback at the cortical level would be sufficient to improve singing in untrained singers. The same pitch-matching paradigm than before was employed, once prior and immediately after application of intermittent theta-burst TMS to the right primary somatosensory cortex (representing the larynx) and a control area. Measurements of pitch-accuracy before and after TMS showed initially no effects, perhaps because untrained singers relied exclusively on auditory feedback. After we removed auditory feedback by presenting loud noise during singing, we found that only TMS over right primary somatosensory cortex improved overall pitch-stability as well as the initial 150ms of pitch accuracy. Improvement of initial pitch accuracy and pitch stability may be explained by enhanced processing of body signals prior to voice onset and a more efficient somatosensory-brainstem motor loop respectively.

A more detailed understanding of the interactions between body and sound perception is only now beginning to emerge. Future studies at MIB aim at testing these models within the conceptual framework of predictive coding.

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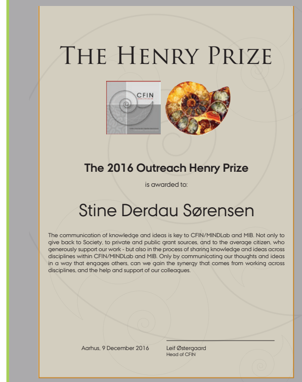
THE HENRY PRIZE



The Henry Prize is awarded every year, during a ceremony taking place at the annual joint CFIN & MIB Christmas Dinner. It constitutes 5000 DKK, to be used for work-related travel or equipment in the widest sense at the recipient's discretion, provided that this activity/need is not currently funded from other sources.

In 2016 The Outreach Henry Prize was awarded to MIB PhD student Stine Derdau Sørensen.

ACTION

Peter Vuust

In 2016, the Action strand - centered around music production, performance and interaction with a special focus on rhythm – initiated a number of studies aimed at illuminating various aspects of the predictive coding of music theory[1], which entails that action is the active engagement of the motor system to resample the environment in order to reduce prediction error. These studies are based primarily on five different paradigms - the dual-tapping paradigm, the musical Multi-feature MMN paradigm (MuMUFE), the syncopation paradigm, The Musical Ear test (MET) and the interlimb coordination paradigm - originally developed by MIB researchers, but with important new additions and further developments.

The dual-tapping paradigm[2,3] (Fig 1), in which two individuals are placed in separate rooms with ear phones and possibly EEG equipment and asked to tap together in different conditions, is an excellent model for studying musical as well as social interaction[4]. In December 2016 we published in Scientific Reports a new study showing that participants receiving oxytocin – a hormone known to promote social bonding – are more synchronized when finger-tapping together, than participants receiving placebo[5]. This effect was observed when pairs of participants were tapping together in a leader/follower relationship. The study shows that oxytocin's social effect may be explained by its role in facilitating prediction in interaction, even in the absence of subjectively experienced social affiliation. The ability to synchronise to a musical beat is a largely human skill. This study contributes to our understanding of how this form of human behaviour is affected by socio-biological factors, such as oxytocin and leader-follower relationships. It also highlights how music creates and maintains social cohesion in an evolutionary perspective.

Currently, PhD student Ole Adrian Heggli is taking these ideas further by analysing connectivity measures recorded by dual-EEG of tappers with similar or different predictive metric models (different musical meters, Fig 2). These measures will allow us to gain a more refined understanding of the predictive coding of rhythmic interaction (Fig 3). In a slightly different version, involving among other things a virtual partner developed by the MARCS Institute in Sydney, Niels Christian Hansen, who defended his PhD from MIB in 2016, intends to further test the hypotheses that oxytocin enhances prediction of externally generated auditory signals, a study that has been granted funding from the Carlsberg Foundation.

Another important paradigm - the MuMUFE-paradigm[6], developed in collaboration with the Learning strand, has been undergoing significant developments in 2016. This EEG/MEG paradigm is originally developed for testing participants' predictive coding of melodic events. Using a multi-level version of the MuMUFE paradigm, we showed that MuMUFE provides an extensive, objective measure of auditory discrimination profile for different sound features embedded in a complex sound context[7]. Using this paradigm, we can study the auditory capacity for prediction of individuals with music processing difficulties[8] or with special musical skills[9]. We are currently using different variations of MuMUFE to study low-level prediction in autism (by Assoc Prof Line Gebauer), in cochlear implant users (by Asst Prof Bjørn Petersen), and multimodel perception (by PhD student Cecilie Møller). Newly hired PhD student David Quiroga is developing a dichotic MuMUFE version introducing the first paradigm, which enables the collection of mismatch negativity (MMN) responses in realistic sounding music. Furthermore, PhD student Iris Mencke from Max Planck Institute, Frankfurt, co-supervised by Elvira Brattico, is developing a twelve-tone version of the MuMUFE paradigm to test the specific skills of expert listeners and performers of contemporary classical music.

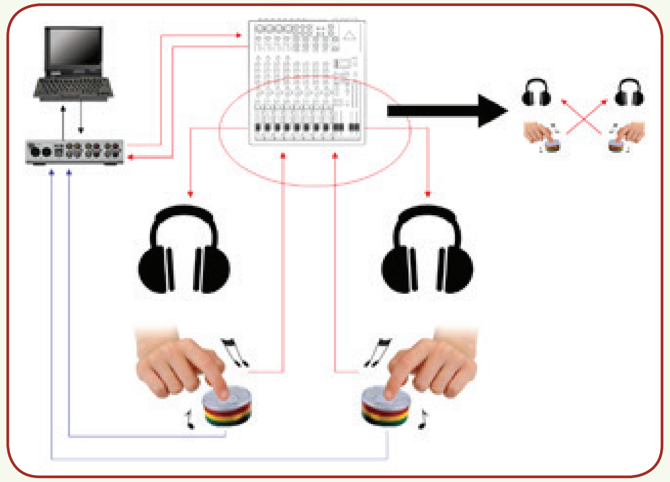


Figure 1. *The dual tapping paradigm: Two participants are placed in separate rooms and asked to try to synchronize as well as to keep the tempo.*

Using the syncopation paradigm, developed in collaboration with the Emotion strand, we have previously found an inverted U-shaped relationship between syncopation/rhythmic prediction on musical pleasure and wanting to move[10]. This shows that individual pleasure and urge to move increases the more unpredictable a rhythm becomes until a certain point from which is decreases. In the light of the predictive coding of music framework this can only be true if the underlying predictive brain model (the meter) breaks down at the point at which the inverted U-shape starts to decline[11,12].

That this is indeed so was shown by a motion capture study, in which we showed that the ability

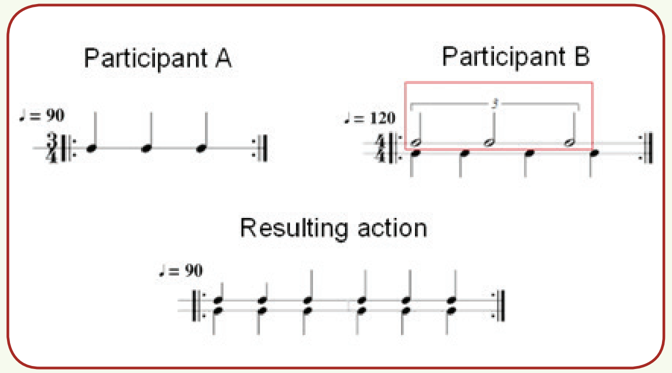


Figure 2. *Even though participant A and B are tapping at the same speed, they hold different predictive models (meters) in their minds while doing so.*

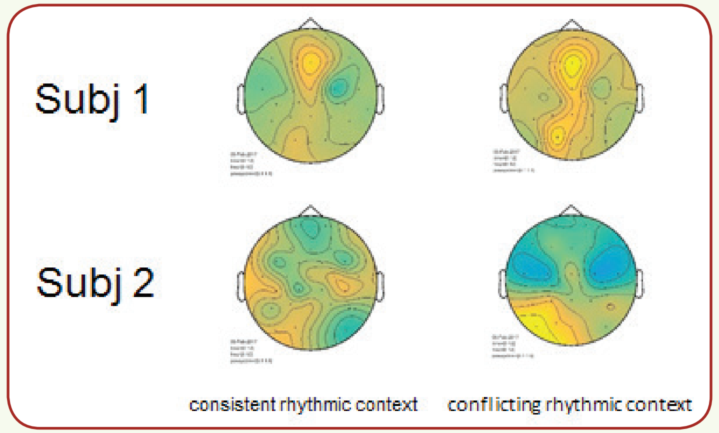


Figure 3. *EEG pilot data (alpha band activity, 8-12 Hz) from two participants while synchronizing with the same or different predictive models in their minds.*

to dance to a musical rhythm is equally good for low and medium syncopated rhythms but deteriorated for highly syncopated rhythms[13]. In a collaboration with Virginia Penhune, Professor and director of the Laboratory for Motor Learning and Neural Plasticity at Concordia University, this paradigm has been further developed so that it now incorporates three levels of rhythmic and harmonic complexity. With Virginia Penhune's PhD student Tomas Matthews, who spent 6 months in Aarhus, we have collected fMRI on 60 musicians and non-musicians, using this paradigm. The data will be analysed using whole brain computational modelling and presented at a symposium at the Neurosciences and Music VI conference in Boston (see also feature by Maria Witek in this report).

As illustrated by the interpersonal tapping paradigm, which serves as a musical model for how competence, social context and predictive metric framework influence predictive brain processing in general[14], the research in the Action strand extends outside the field of music. Understanding the relationship between rhythm and motor behaviour, and the role of rhythm in interpersonal relations relates directly to the role of music as a biological[15] and social phenomenon[16]. In 2016, initiated by Prof Morten Kringelbach, we established two new collaborations, with Victor Jirsa who is director of the Institute de Neurosciences des Systèmes at University of Marseille, and Gustavo Deco who is leader of the Computational Neuroscience group the Pompeu Fabra University (UPF) in Barcelona. Using the above-mentioned paradigms, we wish to study cortical connectivity through direct recordings in the brains of patients suffering from epilepsy. Using whole-brain computational modelling we hope to use these very special patients to understand the dynamics of the cortical activity at rest and during musical tasks, which has clinical as well as basic research perspectives.

The knowledge of how rhythmic expertise, complexity, and social status influence interaction strategies is equally important for music pedagogy. This is evident by the results of the Mass Experiment, performed by first year PhD student Stine Derdau Sørensen in collaboration with the Learning Strand. Collecting data from more than 30,000 school children (age 6-18y) with a novel musical ear test for children (the MiniMET), we have unequivocally shown that music abilities correlate with auditory working memory regardless of grade level. Further analyses of more than 3,000 of these children before and after training for two weeks using an iPhone app especially developed for the purpose of enhancing musical abilities, will allow us to assess the causality of the relationship between music and working memory abilities in children. This research may thus prove essential for guiding the use of music within clinical and educational contexts.

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MIB ON SOCIAL MEDIA

MIB utilises social media to dissimnate news about publications, talks, people, experiments etc.

MIB has had a Facebook page for several years with more than 1100 likes at the end of 2016. The number is increasing every week, and many of our posts reach more than 1000 people - the most popular one even 3000!

In the beginning of 2016 we created a Twitter account which had around 500 followers at the end of the year.

ACTION

Effective Brain Connectivity in Motor and Reward Networks during Musical Groove

By Maria Witek, Matthieu Gilson, Eric Clarke, Mikkel Wallentin, Mads Hansen, Gustavo Deco, Morten Kringelbach & Peter Vuust

Throughout much of human history and across a variety of cultures around the world, people have been expressing their pleasure from music by moving their bodies to the beat. The study of groove – a musical quality associated with a pleasurable desire to move – attempts to understand what it is about certain musical structures that make us want to dance and why it feels good[1,2]. We have previously shown that intermediate levels of syncopation – a common form of rhythmic complexity in groove – promote the most pleasure and the most desire to move[3,4]. A growing body of research is demonstrating that rhythmic music stimulates the brain's motor system – particularly the basal ganglia and premotor and supplementary motor cortices[5]. Activations of the reward network[6] has been shown in many music studies[7], but we do not yet know its role in movement-inducing music.

Whole-brain computational modelling (WBCM) is a relatively new method, which allows us to estimate the effective connectivity (EC), i.e. the causal relationships between the networks of the brain during a particular task[8,9]. In this way, the spatial as well as temporal dynamics of the brain's activity fluctuations can be studied. With this approach, it has been shown that the brain is the most functionally flexible when it is metastable[10], i.e. it is able to rapidly switch between different dynamic states without becoming locked into a specific system[11]. However, we don't yet know whether musical experiences, such as those afforded by groove, are supported by such metastable brain dynamics.

We measured blood-oxygenated-level-dependent (BOLD) responses of 26 participants with fMRI and used WBCM to estimate the spatiotemporal dynamics of the brain during listening to groove music. Participants heard rhythmic patterns varying in three levels of syncopation – low, medium and high – and rated their experiences of pleasure and desire to move. Constrained by structural connectivity information obtained from diffusion-tensor imaging[12] parcellated into 90 areas, our recently developed noise-diffusion WBCM[13] was used to estimate the effective connectivity (EC) during musical groove. Compared with previous methods, this approach models EC by comparing the functional connectivity (FC) of both instantaneous and time-shifted BOLD data, thus providing both spatial and temporal information about the propagation of neural information throughout the brain (Fig 1).

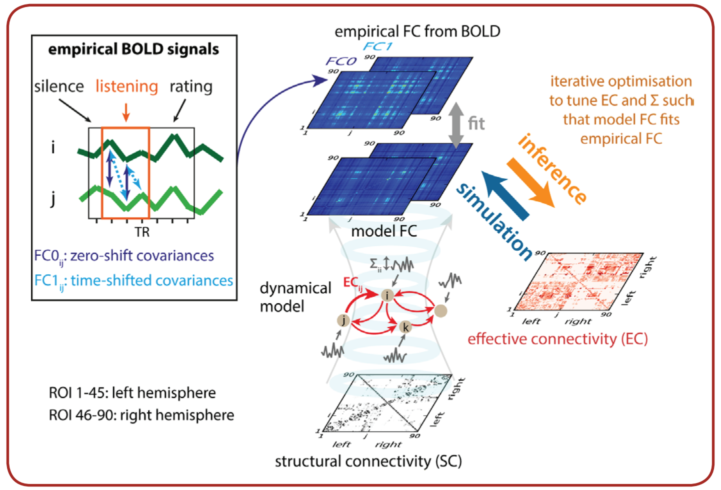

Figure 1. *Summary of our novel estimation method for the effective connectivity of different brain states: Briefly, we use whole-brain computational modelling with time-shifted functional connectivity FC. Two covariance matrices are produced from empirical BOLD signals, FC0 (zero time-shift) and FC1 (time-shifted). Using a noise-diffusion model, we constrain our model with a structural connectivity SC matrix, and estimate the modelled FC0, FC1 and the effective connectivity EC of the brain. The model is tuned by iteratively optimizing the fit between the model and empirical FCs.*

We hypothesised that medium syncopation – i.e. optimally pleasurable and movement-inducing rhythmic patterns – would be associated with increased effective connectivity in the brain's reward and motor systems. Furthermore, by modelling network cortical shuffling speed, we investigated the extent to which syncopation affected neural metastability.

Our WBCM showed that medium syncopation – associated with the most pleasurable desire to move (Fig 2) – elicited more and stronger driving connections across the brain (Fig 2). A majority of these connections involved motor areas as receiving nodes (Fig 3); left premotor cortex (precentral) and bilateral supplementary motor area (SMA), receiving information from thalamus. The left pallidum of the basal ganglia was a significant driving as well as receiving node, mediating information between the supramarginal gurys and the occipital lobe. Effective connectivity to reward areas – the middle orbitofrontal cortex (midOFC) and amygdala – also increased for medium syncopation. The amygdala also drove neural activity, specifically to the middle temporal lobe. Finally, we found increased cortical shuffling speed between successive brain patterns of activity

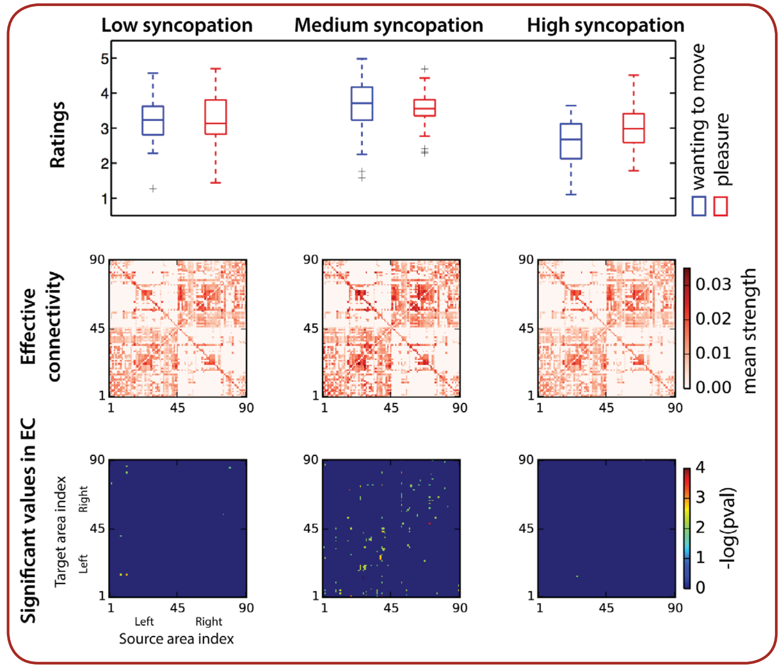

Figure 2. *Medium syncopation in groove is associated with increased ratings of wanting to move and pleasure (top panel), increased sum of effective connectivity (middle panel) and more statistically significant effective interactions (lower panel). Area index 1-45 = left hemisphere; 46-90 = right hemisphere.*

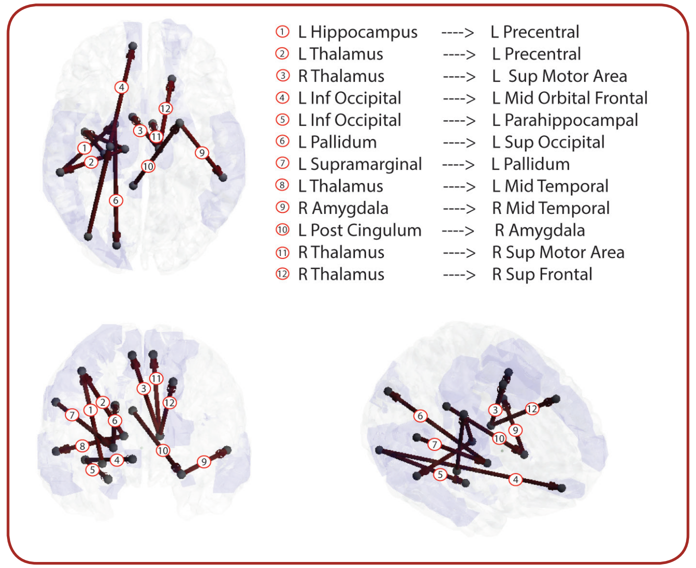

Figure 3. *Directions of significant effective connectivity in the brain associated with medium syncopated rhythmic patterns and increased pleasurable desire to move. Areas listed in order of significance.*

for medium syncopation, suggesting that the system is metastable during musical groove. Our results show that during pleasure- and movement-inducing musical groove, both motor and reward areas play integrative roles in the brain's dynamic network. We support previous findings[14,15] by showing that the basal ganglia are central in the neural network underlying rhythm perception, adding that the pallidum in particular plays an important role in pleasure- and movement-inducing rhythms. Furthermore, we show that a central emotion processing area – the amygdala[16,17] – both sends and receives information during listening to groove rhythms. However, there was no direct connectivity between motor and reward areas, suggesting that the roles of the two systems are relatively independent.

Finally, we show that the brain is metastable during medium syncopated rhythms, potentially explaining the conscious state associated with highly pleasurable and movement-inducing music. The groove state is often described as a temporal equilibrium, associated with feelings of unity and cyclicity, due the high degree of repetition. We suggest that these experiences are in fact the subjective counterpart to neural metastability, which itself involves 'a delicate equilibrium'[18] in its spatiotemporal dynamic configuration. Our findings thus serve as a starting point for further investigating the highly meaningful embodied-affective states afforded by music and may also provide insights into musical eudaimonia – the meaningfulness of music.

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Center for Music in the Brain. *Photo: Hella Kastbjerg*

NEW FACE AT MIB

David Quiroga, **MA, PhD student.**

David graduated with honours as a Classical Guitarist from Eafit University in Colombia. Then he completed his Master's degree in Psychology of Music at the University of Sheffield, UK, where he conducted research on the relationship between music and language, focusing on syntactic processing. Moreover, he took part in a project that sought to assess the benefits of music interventions in a care home for people with dementia.

With personal interests ranging from emotional responses to music to therapeutic musical interventions, he is currently working on a project that aims to develop a new multifeature EEG/MEG paradigm for the recording of mismatch negativities (MMN) with more real-sounding musical stimuli. Such a paradigm will allow the assessment of auditory perception in a complex sound context and could be used for the evaluation of musical expertise, musical learning, auditory deficits in medical conditions and perceptual effects of selective attention.

EMOTION
Morten L. Kringelbach

In the Emotion strand of MIB we continue to draw inspiration from the ideas of Aristotle, who proposed that the good life consists of hedonia (hedone, the ancient Greek word for pleasure derived from the sweet taste of honey, hedus) and eudaimonia (a life well-lived)[1].

Music is a perhaps uniquely human way to engage and reveal the underlying, core brain processes constituting and underlying emotion[2-6]. The strong collaborative links between MIB, Oxford and Barcelona enable us to combine music with methods from a number of disciplines including psychology, neuroscience, physics, engineering and computer science to create groundbreaking science.

As a result, already in the first year of MIB the on-going projects have started to yield significant experimental findings. Importantly this has also been accompanied by the continuing development of novel tools for causal whole-brain computational modelling of neuroimaging data, which are beneficial to all of the four strands in MIB.

Recently published music findings
Here two findings related to music and auditory processing are highlighted. First, together with Maria Witek and Peter Vuust we have investigated how music moves us[7]. One of the most immediate and overt ways in which people respond to music is by moving their bodies to the beat. However, the extent to which the rhythmic complexity of groove—specifically its syncopation—contributes to how people spontaneously move to music is largely unexplored. We measured free movements in hand and torso while participants listened to drum-breaks with various degrees of syncopation.

We found that drum-breaks with medium degrees of syncopation were associated with the same amount of acceleration and synchronisation as low degrees of syncopation. Participants who enjoyed dancing made more complex movements than those who did not enjoy dancing. While for all participants' hand movements accelerated more and were more complex, torso movements were more synchronised to the beat.

Overall, movements were mostly synchronised to the main beat and half-beat level, depending on the body-part (Fig 1). We demonstrated that while people do not move or synchronise much to rhythms with high syncopation when dancing spontaneously to music, the relationship between rhythmic complexity and synchronisation is less linear than in simple finger-tapping studies.

Second, linked to the ERC consolidator grant CAREGIVING we also continue to study the influence of emotional vocalisations. We have further developed, tested and validated new behavioural tools for testing infant sensitivity in adults, both non-parents and parents. We have published a unique public available OxVoc database of infant and adult emotional vocalisations[8].

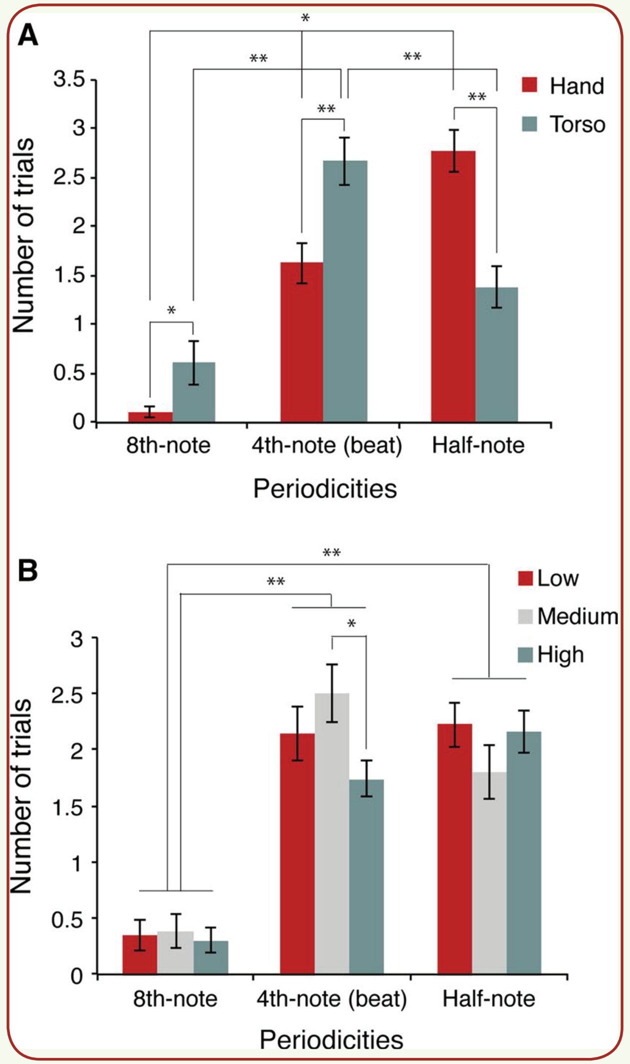

Figure 1. **Moving to a different beat**. *A) Proportion of trials with metric periodicities in hand and torso. B) Proportion of trials with metric periodicities in Low, Medium, and High syncopation conditions.*

In addition to our demonstration of brain responses to these vocalizations[9-10], we have also further validated this database in a large sample of 562 participants, where we demonstrate that adults can reliably categorize these sounds (as 'positive,' 'negative,' or 'sounds with no emotion'), and rate valence in these sounds consistently over time[11].

In an extended sample of 945 participants (including the initial sample), we also investigated a number of individual difference factors in relation to valence ratings of these vocalizations. The results demonstrated small but significant effects of symptoms of depression and anxiety with more negative ratings of adult neutral vocalizations. In addition we found gender differences in perceived valence such that female listeners rated adult neutral vocalizations more positively and infant cry vocalizations more negatively than male listeners.

Of note, we did not find evidence of negativity bias among other affective vocalizations or gender differences in perceived valence of adult laughter, adult cries, infant laughter, or infant neutral vocalizations. Together, these findings largely converge with factors previously shown to impact processing of emotional facial expressions, suggesting a modality-independent impact of depression, anxiety, and listener gender, particularly among vocalizations with more ambiguous valence.

Figure 2: *In-house built MRI compatible keyboard used by Patricia Mota in her project.* Photo: Patricia Mota.

On-going research

In addition to these published findings, we have a number of other exciting on-going projects. In this Annual Report, we have highlighted separately two projects: One is the project by PhD student Patricia Mota who is using neuroimaging to explore the underlying neural mechanisms of spontaneous musical composition in jazz musicians (Fig 2). Another significant strand of research is the development of whole-brain computational methods.

In addition, one novel project is a collaboration with researchers at Imperial College, London, UK who have collected the first double-blind neuroimaging data of LSD and music in healthy participants. This dataset provides a unique opportunity to explore the synergy between a psychodelic drug and music, potentially improving our understanding of this powerful connection which influenced much the musical landscape of the 1960s.

Conclusion

Overall, combining careful experimental methods using music combined with state-of-the-art causal whole-brain modelling can perhaps for the first time reveal the brain mechanisms for any form of brain processing including that of music, opening up for new treatments; perhaps even eudaimonia and better lives - especially if coupled with early interventions.

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By Morten L. Kringelbach

Aristotle has not only been an inspiration in terms of studying the pleasure of music, but also in the development of our novel whole-brain computational methods. Specifically we have drawn inspiration from the ideas of the medieval philosopher Thomas Aquinas who, in the spirit of Aristotle, wrote "Quidquid recipitur ad modum recipientis recipitur", i.e. the container (or recipient) shapes the content.

Together with our close collaborator Prof Gustavo Deco (Barcelona, Spain), who holds the ERC Advanced grant DYSTRUCTURE, we have started to explore this dynamical, causal relationship between the brain and its content. We are building whole-brain computational models that take their inspiration from the Aristotelian idea of how containers shape content or how spontaneous brain activity must be tied to the underlying structure of the anatomical connections linking them. In a series of state-of-the-art studies we have demonstrated that these dynamical models can describe the spontaneous or intrinsic activity of the brain with high accuracy[1-4].

Further to this simple structural insight, it has become very clear that time plays a crucial role in the human brain, giving rise to the time-critical neural computations allowing organisms to survive[4]. The complex brain activity during rest and cognition plays out on the background of the brain's structural connectivity, and crucially has to balance the exploration of this dynamical potential to ensure stability in the long-term. We have shown that the brain has to balance integration and segregation processing in order to function optimally[3].

We have developed methods to extract the anatomical structural skeleton of the individual brain, i.e. the structural connectivity (SC) that can be expressed in terms of a structural connectivity matrix. This can be mapped in vivo in humans on the scale of millimetres using diffusion weighted/ tensor imaging (DWI/DTI) which can measure the white-matter fiber tracts constrained by the diffusion of water molecules and where the connectivity between brain regions can be reconstructed by probabilistic tractography.

Whole-brain computational models combine brain structure and activity dynamics to explore and explain the emergence of resting-state networks mechanistically. Until recently, the models have typically been either oscillatory or asynchronous. These models use different strategies to explain the functional connectivity of the data over time, either, in the case of oscillatory models, by maximizing the metastability of the dynamics, or, in the case of asynchronous models, by working

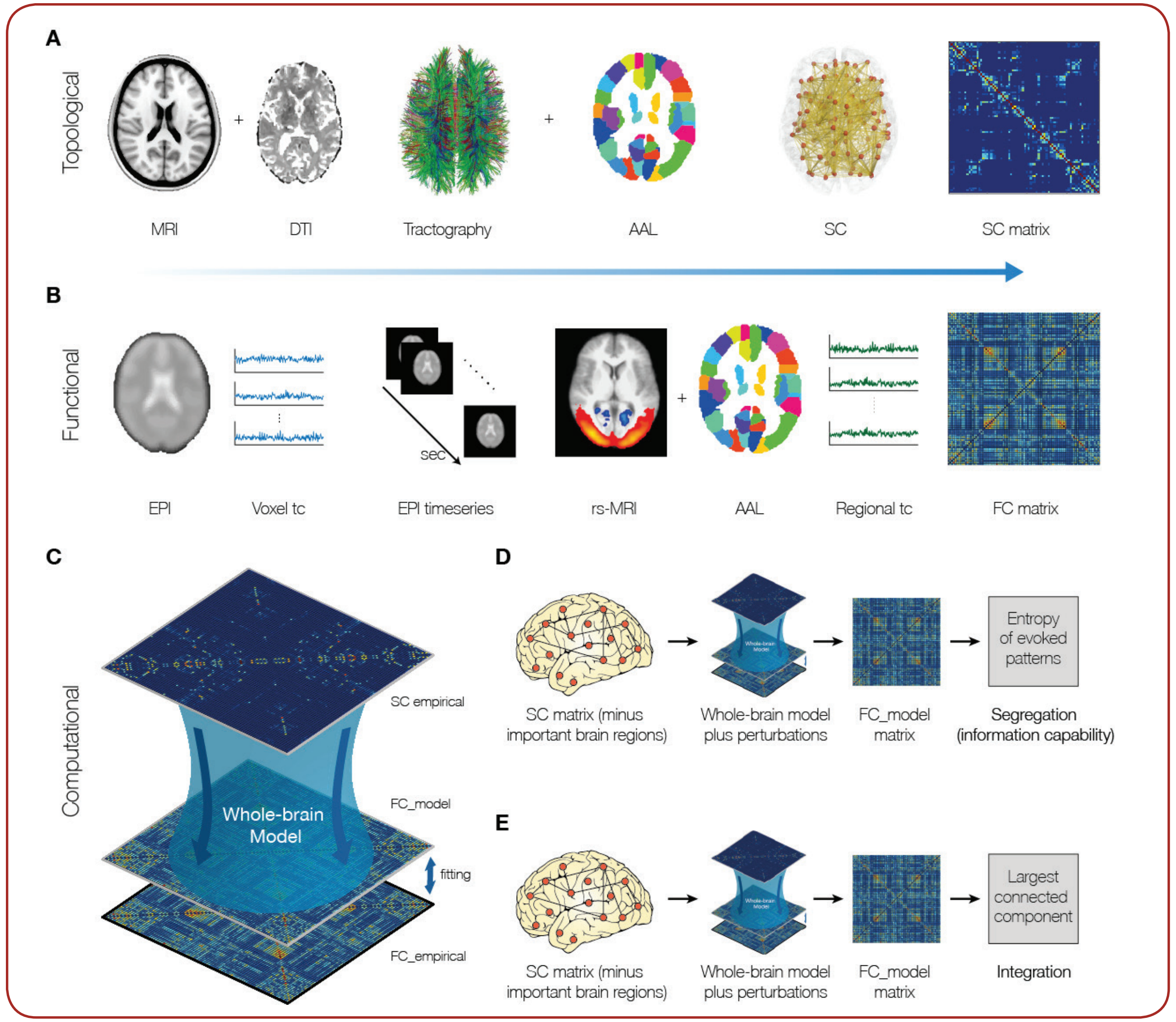

Figure 1. **Overview of whole-brain computational connectomics.** *A) First extract the container, ie the topological measure of the structural connectivity (SC) matrix by combining structural MRI, DTI, a given parcellation scheme and tractography. B) Then derive the content, ie the functional connectivity (FC) matrix by extracting the BOLD resting state data with the AAL parcellation and correlating the time courses. C) Combine the structural and functional data by fitting this to a whole-brain computational model. D) This model can be used to estimate the causal influence of individual regions by computing the segregation (or information capability) of a given SC as the entropy of the set of evoked patterns assuming a Gaussian distribution averaged over a large number of external stimulations. E) Similarly, the model can be used to estimate the integration as the length of the largest connected component in the functional connectivity matrix, averaged over a large number of external stimulations.*

at the border of multistability, i.e. at a dynamical point at the edge of the bifurcation where the trivial spontaneous state loses stability.

The stability of whole-brain computational models hinges on different concepts from dynamical systems. The asynchronous models provide evidence that the simulated functional connectivity best matches empirically observed functional connectivity when the whole-brain network is subcritical, meaning that when there are stable attractors states, with a spontaneous state with low activity in all regions, and several excited states with high activity between selected regions. In other words, multistability around a spontaneous state defines an operating point such that system activity stochastically explores the dynamic repertoire inherent to the structural connectivity.

Similarly, the oscillatory models provide evidence for the importance of metastability, which is a measure of how variable brain states are as a function of time; e.g. how the synchronization between the different brain regions fluctuates across time. These concepts of multi- and metastability for describing the dynamical systems in the brain are possible scenarios for the resting state. It remains an active area of research to determine which is a more accurate description.

Further, we have recently demonstrated the potential for using whole-brain computational modelling for revealing causal brain mechanisms[5]. We introduced a promising new measure of binding in the human brain, by which brain regions are ranked according to their level of temporal integration. We were able to lesion the model to demonstrate a causal relationship between these binding regions and brain activity.

Overall, these new methods provide powerful ways of understanding and probing the fundamental mechanisms underlying whole-brain activity and connectivity as demonstrated in the features by Patricia de Mota and Maria Witek. In the years to come, this may even allow us to understand the causal mechanisms of joy of music in the brain.

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EMOTION

The Neural Signatures of Creativity in Jazz Improvisation

By Patricia Mota

Musical improvisation consists of generating and evaluating melodic and rhythmic sequences, coordinating performance with other musicians in an ensemble, and executing elaborate fine-motor movements – all with the overall goal of creating aesthetically appealing music. However, studying improvisation has the challenge of controlling and identifying the manifold simultaneous processes in real-time. This includes sensory and perceptual encoding, motor control, performance monitoring, and memory retrieval, amongst others. As such, the question of how musicians improvise is not only relevant in the context of unravelling the psychological basis of music, but also as it is expected to have significant implications in the psychology of creativity.

Research on improvisation may thus help to shed new light into basic cognitive neuroscience, by providing a unique perspective to how acquired expertise may shape brain structure and function. Current literature in music improvisation includes ten studies, from which only two were conducted on a population of jazz musicians[1,2]. The lack of fundamental convergence across these studies, due to the use of different experimental designs, exploration of different properties of music improvisation, and use of different types of participants[3], is indeed not optimal for a robust and comprehensive understanding of the neural mechanisms underlying musical improvisation.

In this project we aim to explore music improvisation in jazz by combining multiple previously validated experimental designs[1,2,4]. As such, we propose to study the neural signatures of memory retrieval, improvisation modes (e.g. melodic), reading score and free improvisation.

Is jazz improvisation an entirely free and boundless process?

This project aims to unravel the brain mechanisms underlying the outstanding ability of jazz musicians to improvise. Such unique capabilities (e.g. memory, visual and cognitive) are believed to require a high-level of network organisation

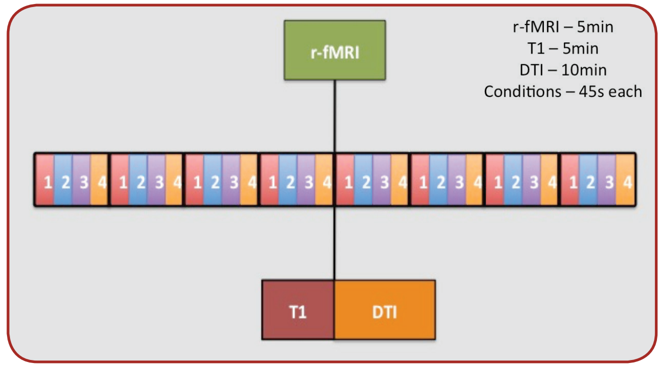

Figure 1: Jazz Improvisation Paradigm. *Jazz musicians are asked to play four different randomized conditions - play by heart, read a score, improvise by the melody and free improvisation - inside the MRI scanner. In addition to this, they undergo a resting-state fMRI sequence and structural sequences (T1 and DTI).*

and selective interaction. To test this, experienced jazz pianists will undergo neuroimaging (MRI) and will be asked to explore their expertise in jazz improvisation, through a variety of tasks mentioned above. For this, an in-house-built MRI compatible piano with 25 keys will be used.

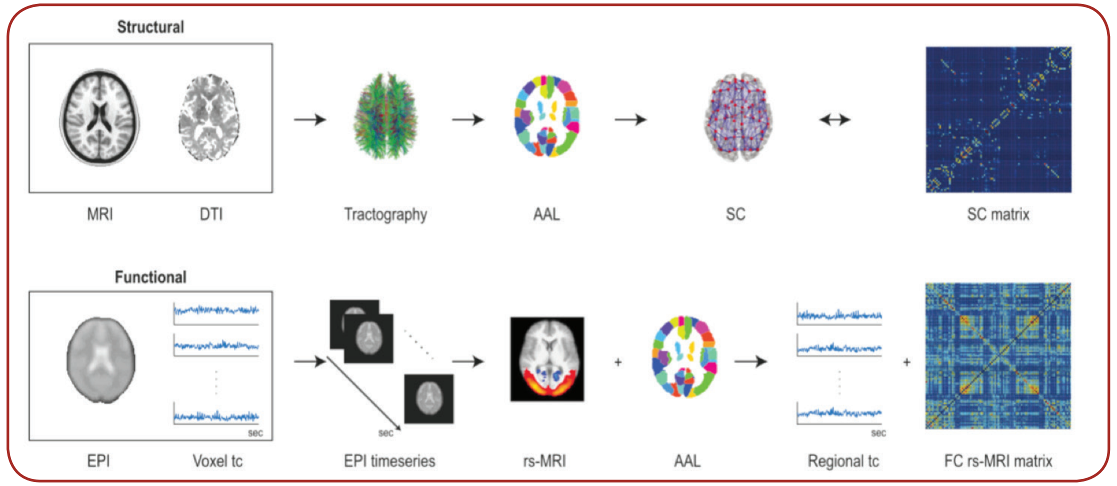

Figure 2: Connectomics using neuroimaging techniques. *A. Mapping the structural connectivity of the human brain (SC) using structural MRI (DTI and T1) combined with a parcellation template (eg. AAL). B. Mapping the functional connectivity (FC) of the human brain using resting-state MRI combined with a parcellation scheme[5].*

Measures of functional brain connectivity linked with each of these tasks will be estimated. Lastly, findings from both functional and structural brain connectivity will be combined with whole-brain computational modelling in order to identify the fundamental brain networks underlying improvisation, and thus help shed new light into the neural mechanisms underlying jazz improvisation.

In order to achieve desired statistical power we aim to collect neuroimaging data from 20 experienced jazz musicians. So far, 15 participants have completed all tasks and scanning procedures. It is our plan to validate the results of Limb & Braun[2] and Donnay et al[3], with an increased population size. Furthermore, the larger range of specific modes of improvisation shall provide a broader and more accurate picture of what is really happening in the brain when we are being creative.

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LEARNING
Elvira Brattico

Investigating a virtuoso loop

During a musical experience (whether it being playing or listening), perceptual, cognitive, motor, affective, and evaluative – in a word, aesthetic – processes all take place. As a final output an individual might feel content, interested, satisfied and might issue positive judgments ("I loved that song" or "I had so much fun playing that"). Hence, this person might want to repeat the same experience all over again, having memorized expectations and predictions for what is going to happen and might even select the type of experience based on those expectations[1]. Each musical aesthetic experience molds the mind/brain/body of the individual at various time scales[2]. In the brain these modifications determine what is called neuroplasticity, which can occur either very rapidly, in the course of listening when models of the auditory events are continuously stored and updated, or over months and years, such as in those individuals that become passionate musicians. The goal of the Learning strand is to study whether and how these neuroplastic changes related to a musical aesthetic experience are developed in the course of minutes, months or years in the different stages of human life. The best methods are selected to measure objectively these plastic changes, by removing non-encephalic noise and other confounding factors, as well as by assessing modulatory factors such as the biological repertoire and the listening biography of the individual.

Internationalization

The research agenda is carried out in synch with several national and international researchers as a natural outcome of the background of Learning's PI Prof Brattico, an Italian pianist and philosopher formed as neuroscientist in Finland. In Italy, several projects related to the development of musical skills and aesthetics are under progress in coordination with the University of Bari, Bicocca University of Milan and the University of Bologna. In Finland, at the University of Helsinki Dr Mari Tervaniemi, Dr Minna Huotilainen and Prof Tiina Paunio from Faculty of Medicine synergetically investigate the neural predictive processes in perception and how they are influenced by musical background and genetic repertoire. At the University of Jyväskylä collaborative projects focusing on the impact of musical expertise on brain connectivity are conducted with Prof Petri Toiviainen and Dr Tiina Parviainen. In turn, studies on musical pleasure as compared with pleasure induced by visual arts in laypersons and experts are conducted with Dr Suvi Saarikallio, also from the University of Jyväskylä. Outside Finnish-Italian ties, projects are also joined by Prof Thomas Jacobsen (Helmut Schmidt University, Hamburg), Dr Melanie Wald-Fuhrmann (Max Planck Institute for Empirical Aesthetics, Frankfurt), Prof Asoke Nandi (Brunel University), Dr Eduardo Garza-Villarreal (National Institute of Psychiatry, Mexico City), and Prof George Rauschecker (Georgetown

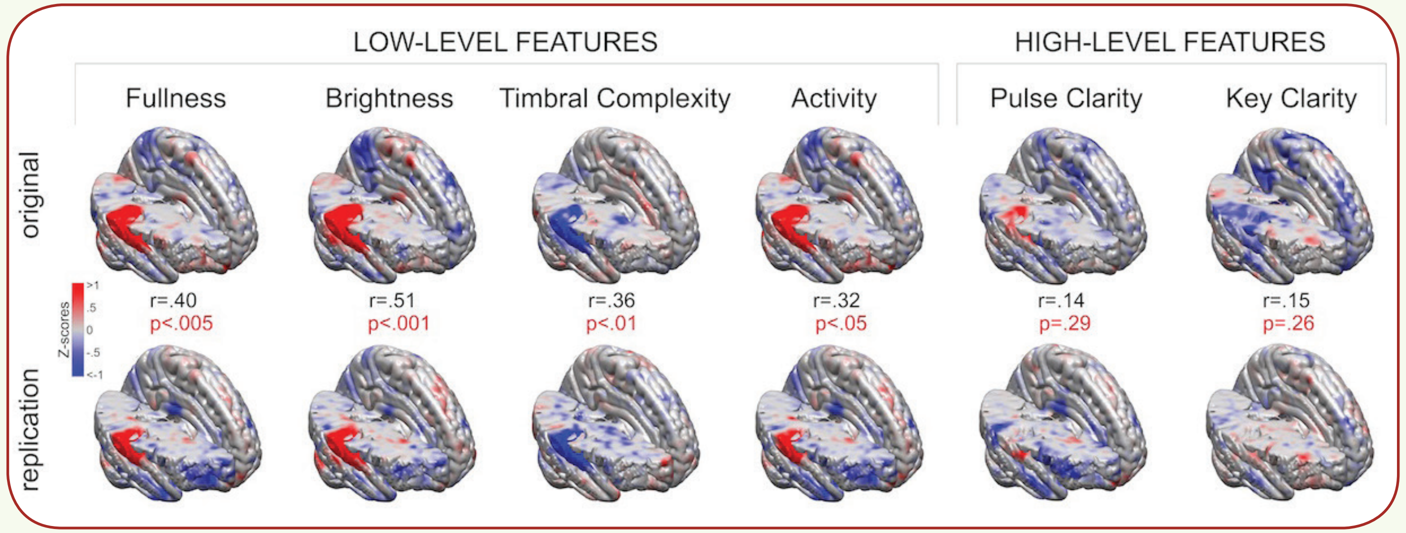

Figure 1. *Illustration of the results reported in [4] showing the continuous Z-maps of brain responses to acoustic features extracted computationally from the piece Adios Nonino by A. Piazzolla. On the top row entitled 'original' the Z-maps are computed from the brain responses of the dataset published in [5]. On the bottom row entitled 'replication' the Z-maps are computed from the brain responses of a new dataset with separate subjects listening to the same Piazzolla stimulus but in a different MRI scanner. In the middle are showed the Pearson's r and p-value of interclass correlations between original and replication datasets, indicating high replicability particularly for the timbral features 'fullness', 'brightness', 'complexity' and 'activity'. A second replicability approach reported in [4], using the Dice coefficient for measuring the voxel overlaps between the two databases, showed a certain amount of replicability also for the high-level features of 'pulse clarity' and 'tonal clarity'. Hence, the processing of high-level features might be subject to variation as a consequence of the state and traits of the individuals, as well as of their listening background.*

University). Furthermore, 8 graduate students and 4 senior researchers (Italy, Germany, Finland, UK, Spain) obtained mobility awards to work at MIB under the research agenda of the Learning strand.

Optimizing methods for investigation of learning and individual differences

To study learning and how it depends on the person's characteristics, it is pivotal to fix the methodological premises. After the recent debate on the high risk of false positives in neuroimaging, it has become more crucial than ever to invest efforts to demonstrate the reliability and validity of the findings. Three papers are dedicated to this problem. In [3] we demonstrated moderate to strong consistency of cognitive brain processes measured by visual magnetoencephalographic evoked responses using the N-back paradigm. In [4] we showed the higher replicability of fMRI responses to timbral features computationally extracted from a piece of music, as compared with that to rhythmic and tonal features. This study represents a remarkable validation of the naturalistic free-listening paradigm combined with acoustic feature extraction (Fig 1)[5]. Furthermore, a collaborative study with Brunel University[6] introduced a groundbreaking tool for finding a consensus among different data-driven computations of neural connectivity during processing of subjective musical emotions.

Innovation of protocols has been another methodological focus. Close attention is put to cover all possible measures for assessing the idiosyncratic profile of a participant and identifying the factors that modulate music-induced changes in the brain[2, 8-9]. Under this framework, we published the first study of imaging genetics in music neuroscience, reporting a link between dopamine receptor genes and the impact of sound background on mood and emotions[9]. Improvements of stimulation paradigms are also under way. For instance, the Multi-feature MMN paradigm (MuMUFE) has been extended to the parametric measurement of several levels of acoustic features to obtain a comprehensive profile of the auditory predictive coding skills. A recent MuMUFE development consisted in the removal of the standard tones, allowing for an even faster measurement of MMN brain responses to prediction errors[10]. Together, these innovations of the MuMUFE paradigm make it even more prone to applications in clinical and educational settings. PhD student Iris Mencke will further adapt the MuMUFE paradigm to study the development of neural predictive skills specific to contemporary classical music, a genre characterized by unconventionality and low predictability.

Methodological innovations in brain signal processing are also incorporated in a series of cross-sectional studies aimed at discovering the long-term neuroplastic changes in music experts, namely as a consequence of several years of musical training. The application of graph theory to whole-brain network analysis of an fMRI dataset with 18 musicians and 18 nonmusicians presented with the naturalistic free-listening paradigm revealed closer connections between neural cerebral and cerebellar structures of the temporal and frontal cortex in musicians and more connections in medial structures for nonmusicians[7]. Another connectivity analysis method, Independent Component Analysis (ICA), applied to the same fMRI dataset and combined with computational extraction of the rhythmic feature of pulse clarity, evidenced group differences between musicians and nonmusicians in action-perception brain networks covering auditory and motor areas (see feature article).

Studying brain changes from music training in children

Starting from these methodological foundations, we are establishing a series of longitudinal studies to investigate the development of musical skills in the brain of children, and how they transfer to other non-musical cognitive, affective and social abilities.

A first set of longitudinal studies conducted by PhD student Maria Celeste Fasano in collaboration with Pauline Cantou required the implementation of a new protocol at the Danish Neuroscience Center for the recordings of anatomical and functional MR images (fMRI) of 9-12 years old children (Fig 2). Some of these children take part in a special music training program organized by

Figure 2. *Photos taken at the magnetic resonance imaging (MRI) laboratory of the Danish Neuroscience Center during the brain measurements of a 10 years old child while listening to violin tunes. The photo at the left shows the anatomical scout MR images of the child in the front and the MR scanner with the child lying on the bed in the back. The photo at the right shows PhD student Maria Celeste Fasano in the front and trainee Laura Risager Ubbesen in the back while monitoring the MRI data acquisition.* Photo: Elvira Brattico

Aarhus Music School. These children participate in four experimental sessions, two happening before the training and two happening several months later, after the training period is over and after having given a final concert in front of an audience. Two of these sessions (one before and one after training) happen at the children' school, when a team of psychologists administers them tests and questionnaires assessing their executive functions, impulsivity, empathy, and motivation for the music training program. The other two sessions (again, one before and one after training) are held at the Danish Neuroscience Center and include recordings of functional and anatomical MRI while children listen to music with the naturalistic free-listening paradigm or while they watch cartoons. In a previous study in collaboration with Aalto University (Finland) and Georgetown University (USA) with adult pianists who learned to play a piano sonata in 4 weeks, we demonstrated the feasibility of combining the naturalistic free-listening paradigm with subjective self-report measures of learning and motivation. In the current longitudinal study with children we further introduced a qualitative and quantitative evaluation of the individual commitment in the music training program by video recordings and self-report questionnaires. Hence, the pioneering aspect of the protocol with children consists in the use of both quantitative and qualitative measures related to the impact of internal person-related variables, such as motivation, on the neuroplastic changes consequent to music training.

A second set of longitudinal studies benefits from an important collaboration between PhD student Stine Derdau Sørensen with collegues and many primary schools in Denmark as detailed in the article of the Action strand. Such collaboration gave the opportunity to conduct a mass experiment with 30,000 children collecting a range of measures about their musicality abilities, emotional reactivity to music and working memory skills. Part of this experiment involves the assessment of the changes in musical abilities after an intensive targeted training with a mobile phone app in the course of two weeks.

To conclude, in 2016 we moved towards a paradigm shift combining sophisticated quantitative measures of brain function and anatomy during ecological listening conditions with person-related data, and with qualitative descriptions of the learning process. The final goal is to obtain a 360° picture of the effects of music training on the aesthetic mind/brain.

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NEW FACE AT MIB

Pauline Cantou, Msc, Research Assistant/ PhD student from 2017. Pauline graduated with a Bachelor's degree in Biology at the university of Toulouse and afterwards obtained her Master's degree with honors in Cognitive Sciences at the University of Caen, Normandy. During her Master's thesis and then as a research assistant, she conducted a neuroimaging study investigating the neural substrates of new musical abilities in Alzheimer's patients. Later on, she took part in a research project assessing the effects of meditation training on the ageing brain.
In parallel with her university studies, she completed a post grade of classical flute at the conservatory of Toulouse.
Pauline's PhD project aims to explore the neural basis of behavioral transfer effects observed from musical practice to other domains in early-adolescence using structural and functional MRI. More specifically, she will examine how musical training may affect the maturing brain and the cognitive performance of healthy preadolescents in the prospect of supporting therapeutic musical intervention in children with learning difficulties, ADHD or autism.

LEARNING

Brain Connectivity Patterns During Music Listening: Evidence for Action-based Predictions in Musicians

By Vinoo Alluri & Leonardo Bonetti

Musical expertise is visible both in the morphology and functionality of the brain. The transfer effects of music manifest even as changes in non-auditory brain functions, such as attention, verbal intelligence, academic performance. Hence, it is vital to investigate how musical training changes the complex brain architecture and network during rest as well as during music- and non-music related task performance. Within the Learning strand, two studies have been conducted in collaboration with Finnish universities (Jyväskylä, Helsinki, Aalto) to investigate the brain connectivity patterns in musicians during music listening by using the naturalistic free listening paradigm and functional magnetic resonance imaging (fMRI).

Connectivity patters in musicians during continuous listening to music

In a recent study by Learning PI Prof Brattico, MIB Director Prof Vuust and Finnish collaborators[1], fMRI was combined with graph theoretical approaches to model information exchange in the brain during continuous music listening (according too the naturalistic free listening paradigm) and to study the effect of musical training on whole-brain networks and important hubs thereof. This approach permits the identification of networks in the entire brain involved in the concurrent processing of music in a setting that is more ecologically valid than hitherto used controlled settings.

At the Advanced Magnetic Imaging (AMI) Centre in Finland, the brain responses of 18 professional musicians and 18 non-musicians were recorded using fMRI while they were listening to three eight-minutes long pieces of music. Whole-brain graph-theory analyses were performed on participants' fMRI responses. Comparing functional connectivity between musicians and non-musicians during continuous music listening, using full-brain connectivity analyses, higher connectivity in action-related networks was obtained in musicians. Musicians' primary hubs comprised cerebral and cerebellar sensorimotor regions whereas non-musicians' dominant hubs encompassed medial brain related to the default mode network (DMN). Community structure analyses of the key hubs revealed greater consistency in coupling between the motor and somatosensory homunculi representing the upper limbs and torso in musicians while listening to music. Furthermore, musicians who started training at an earlier age exhibited greater centrality in the auditory cortex, and areas related to top-down processes, attention, emotion, somatosensory processing, and non-verbal processing of speech. In addition, community structure analysis revealed that non-musicians display a trend in terms of greater consistency in connectivity of DMN and

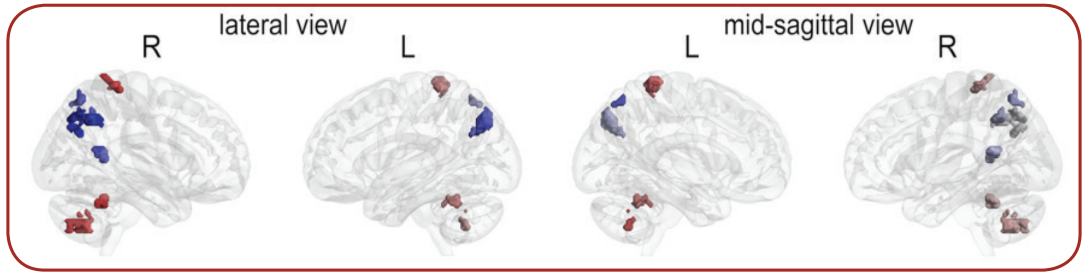

Figure 1: *Statistical maps depicted on a 3D transparent brain showing the node degrees for musicians (in red) and for non-musicians (in blue) found by using graph theory approach [1].*

central-executive-network (CEN) regions than the musicians during continuous listening to music. Music training may indeed cause changes in the connectivity of the regions belonging to the DMN and form new connections that are eventually enhanced as a result of longitudinal practice. In light of previous studies, the results by[1] indicate that musicians employ a more action-oriented approach, possibly one of minimizing prediction errors by internal motor simulation. In turn, non-musicians seem to rely more on a perception-based approach instead of an action-oriented one due to their very limited action repertoire of reproducing the incoming auditory stream.

Connectivity patterns in musicians associated with rhythm predictions

Another new study (Burunat et al, submitted) using the same sample as in[1] and carried out by researchers from the University of Jyväskylä in synergy with Prof Brattico, focused on revealing specific training-induced changes in neural connectivity that are particularly associated with processing rhythm during a free listening condition. A considerable number of experiments using controlled, artificial paradigms has demonstrated that rhythm perception involves a conjoined activation of various cerebral and cerebellar structures. In this study, Burunat et al. adopted independent component analysis (ICA) to investigate rhythm-related connectivity as a function of musical training and, furthermore, as a methodological innovation, compared the results obtained with ICA with those obtained with the classical General Linear Model (GLM) approach. The ICA is a computational method that aims to decompose a multivariate signal into independent subcomponents, assuming that each subcomponent has a non-Gaussian distribution and is statistically independent from the others. Participants took part in an fMRI session with the naturalistic free listening paradigm. Regions of interest (ROIs) previously associated with rhythm processing were defined, including somatomotor, basal ganglia, auditory and cerebellar areas. The ICA decomposition of brain signals was performed under different model orders, such as under a varying number of assumed independent sources, to avoid relying on prior model order assumptions. Subsequently, the best predicted components of the pulse clarity of music, which is a measure of rhythmic predictability, were extracted. At lower model orders, their corresponding spatial maps did not comprise a network of auditory (perception) and motor (action) areas in an excitatory inhibitory relationship, while at higher model orders they mainly constrained to the auditory areas.

Overall, the results showed that independent components (ICs) extracted in the sample of non-musicians were overall significantly better predicted by the stimulus' pulse clarity than in case of musicians. A possible explanation of this evidence could be a higher contrast between high and low pulse clarity reflected in non-musicians' brain activity when compared to that of musicians'. This interpretation is in line with the idea that non-musicians' internal model of pulse clarity relies on the acoustical content of the stimulus whereas the musicians' one seems to be based more on top-down processes such as attention or expectation of sounds, as a consequence of musical training. Indeed, an intense, lifelong musical training is able to influence beat processing, either by enabling better predictions due to a stronger internal representation and predictive model of beat induction, or by creating a more complete internal model constituted by explicit knowledge of musical rules. Furthermore, the ICA decomposition at different assumed dimensionalities revealed a hierarchical brain organization of the functional connectivity networks that underlie pulse clarity processing. This evidence, hidden from GLM approach, reveals the functional integration of action and perception networks involving auditory cortices, motor-related areas, basal ganglia and cerebellar structures, during pulse clarity perception.

A necessary future step of this series of studies towards understanding the brain connectivity changes after musical training is to take into account the causality aspect. PI Prof Brattico and other researchers working under the Learning agenda have already taken measures towards this direction with machine learning studies[2-3]. Furthermore, an exciting opportunity is offered by the recent implementation of whole brain computational modelling[4-6], a powerful tool that allows to model neural activity during both spontaneous resting-state and task-related activity.

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CLINICAL APPLICATIONS OF MUSIC

Line Gebauer

Music interventions – how does music do its magic?

Music can do more than just lift your spirit - its impact on our body, brain, and emotions has great potential for the development of music interventions for a range of clinical conditions. These effects are a central research interest to Center for Music in the Brain (MIB). At the moment, there is an increasing interest in the use of music in clinical contexts from pain management to sensori-motor rehabilitation and improved sleep quality across the health sector, research community, and industry as highlighted by the novel initiative "Music and Health" from the Danish Composers' and Songwriters' Association, which will be launched in 2017. The goal of MIB is to conduct research identifying evidence-based music interventions and to document the underlying mechanisms behind the putative positive effects of music.

Currently MIB researchers are working on a number of clinical projects related to: patients with cochlear implants (Asst Prof Bjørn Petersen, PhD student Cecilie Møller, PhD student Stine Derdau, Research Year Student Anne Sofie Andersen), pain management (Dr Eduardo Garza-Villarreal, Asst Prof Christine Parsons and PhD student Sigrid Juhl Lunde), neurodevelopmental disorders (Assoc Prof Line Gebauer, Research Interns Rasmine Holm Mogensen and Maja Hedegaard), dementia (PhD student Kira Jespersen, Assoc Prof Line Gebauer, Research Intern Maja Hedegaard), and sleep improvement (PhD student Kira Jespersen). Furthermore, Margrethe Langer Bro in collaboration with Peter Vuust is studying the effect of live music interventions on cancer patients undergoing chemotherapy in a large study funded by 'Kræftens Bekæmpelse'.

In 2016 MIB, in collaboration with DTU, received funding from Innovation Fund Denmark to undertake a study on music interventions for sleep problems in patients suffering from dementia. Besides this, the Tryg Foundation funded a project on the impact of singing on Chronic Obstructive Pulmonary Disease (COPD) which is to be undertaken by Mette Kaasgaard, who will begin her PhD in 2017 in a collaboration between MIB, Dr Ole Hilberg at Vejle Sygehus, and Dr Uffe Bødtger, Assoc. Professor at University of Southern Denmark.

MIB PhD student Stine Derdau and former MIB researcher Mads Hansen preparing a participant for the MuMUFE CI MMN paradigm.

Photo: Bjørn Petersen

CLINICAL APPLICATIONS OF MUSIC

Bjørn Petersen

The Sound of ~~Silence~~ Music

A paradox?

At a first glance, a coupling between music and hearing loss (HL) may appear rather paradoxical. Music has, however, historically been part of the lives of at least some deaf persons. The famous composer Ludwig van Beethoven composed his 9th symphony, despite a profound HL – based on well-established internal representation and musical imagination. Two hundred years later Evelyn Glennie, who is profoundly deaf, leads a career as a professional classical percussion soloist, relying on vibration cues from her bare feet. In the 70s and 80s, Danish music therapist Claus Bang included drumming in his work with deaf and hearing-impaired children. If unable to hear, the children could still make music together through visual cues and low-frequent vibrations. One of MIB's most important clinical research areas concerns music in the lives of persons who are deaf but able to hear by means of a cochlear implant (CI), an area of research that has gained wide global attention and in which MIB is at the forefront. As it appears, the phenomenon is not too unrealistic, let alone paradoxical.

Electric ears

The CI is a neural prosthesis that allows individuals with severe to profound HL to gain or regain the sense of hearing. Basically, a sound processor transforms acoustic signals into electric impulses, which are delivered to an electrode array implanted within the cochlea.
A rise in bilateral implantation together with technological refinements have improved implant outcomes, allowing adults with a postlingual HL to restore speech comprehension and congenitally deaf children to acquire spoken language. Correspondingly, the number of CI surgeries has risen exponentially and today more than 350,000 CI recipients worldwide use the device in their daily communication[1].

Technological amusia

Despite this immense technological and medical achievement, CI users face several limitations in their auditory perception. This is particularly true for perception of music which is severely compromised by the degraded spectral and temporal resolution of the implant. The American CI recipient and author Michael Chorost has compared his music listening experience to "walking colour-blind through a Paul Klee exhibit". To some it may well be far worse which is suboptimal, since music in many cases has been an essential part of their cultural and social life.

Looking back

In 2007, reports of local "super listeners" who had regained their music enjoyment through repeated playback of the same well-known album, and who at the same time exhibited excellent speech perception, came to the attention of MD and then PhD student, now deceased, Malene Vejby Mortensen. This inspired her and Peter Vuust to propose the hypothesis that musical ear training might be a way to strengthen not only perception of music but also perception of speech.

The hypothesis was based on two rationales. First, music and language rely on processing of fundamental aspects of sound, such as pitch, timing and timbre, and recent studies have shown that complex music tasks activate brain areas associated with language processing[2]. Thus, improved perception of music could generalize to linguistic skills, in particular perception of prosody. Second, adaptation to the CI is based on residual cortical plasticity in auditory brain regions which again may allow for further advances in performance, as a result of systematic training efforts.

Three experiments and a survey

In three different studies, we tested this hypothesis. 1) A longitudinal study involving recently implanted adult CI users (N=18; age: 21-73 years), 2) a short intensive study involving prelingually deaf adolescents (N=21; age: 16-18 years) and 3) a 3-month study with preschool children (N=21; age: 3-6 years) with CIs. In all three studies, the musical ear training had active music making, rather than passive listening, as the main components. In addition to the obvious beneficial rewarding and enriching effects such activities create, the reason for this was a wish to create and maintain motivation. Judging from the compliance of the participants, this was a wise strategy; in all three studies, all participants completed the programme. Alongside the training experiments we carried out a comprehensive survey (N=163). Our aim was to gather information about music listening habits, music enjoyment and quality of life (QOL) from a large, representative sample of adult CI users.

Highlights from the four studies include:
a) The music training had a significant effect on CI users' overall music discrimination skills. In particular, discrimination of rhythm, melodic contour and timbre showed a significant progress. By contrast, discrimination of pitch was poor and unaffected by training. This pattern was reflected also in MMN results done with EEG and emphasizes both the strengths and limitations of the implant and the learning potential.
b) According to feedback and observations, musical activities with a vocal aspect, such as singing and rapping, appeared particularly motivating and fruitful. This highlights the potential effect of music training on both impressive and expressive skills. Full circle.
c) Despite the technical disadvantages of the CI, a large majority of CI listeners listen to and enjoy music ranging from modest satisfaction to great enthusiasm; adolescents even listen at levels that are comparable to NH peers. In addition, average ratings for the quality of the sound of music with the implant was much higher in adolescents than in adults, indicating a strong psychological factor (Fig 1). Adults may tend to make comparisons with long lost music memories. Adolescents have only

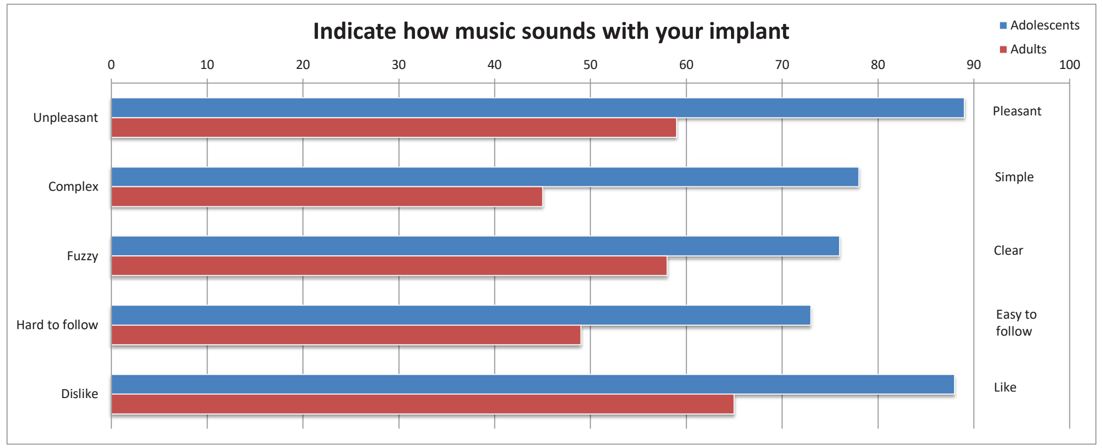

Figure 1: *Adolescent (blue) and adult ratings of the quality of the sound of music through their CI as indicated on a VAS scale of 0-100 with bipolar adjective descriptors. The average rating was 55 for adults and 81 for ados.*

heard sound through the implant and make their judgement without such reference. For details, see[3-7].

Looking forward

MIB's involvement in CI and music research has resulted in a line of new studies.

Music training app. The study with adolescent CI users suggested that our computer-based training applications had too little to offer in terms of motivation and excitement. Subsequently, this led to the development of a novel music training app for smartphone, Musicity (Fig 2), which is part of PhD student Stine Derdau Sørensen's work. The app uses a gamified approach which implies that users will be able to level-up, according to their performance, thus supposedly increasing motivation and, evenly important, training intensity. The app so far contains five different musical ear training games and has been tested by many different target groups, including approx. 3,000 school children as part of the nationwide Mass Experiment. The aim is that with this app, CI users worldwide will be able to improve their music discrimination skills and in the process potentially enhance their music enjoyment too[8].

Effect of sound compression. MIB's expertise in objective measurements in CI users done with EEG has led to a new study in cooperation with the Danish CI manufacturer Oticon Medical. The main goal is to examine the possible beneficial effect on CI users' music perception from a novel

Figure 2: *The front screen of the music training app Musicity, created and designed by MIB PhD student Stine Derdau Sørensen.*

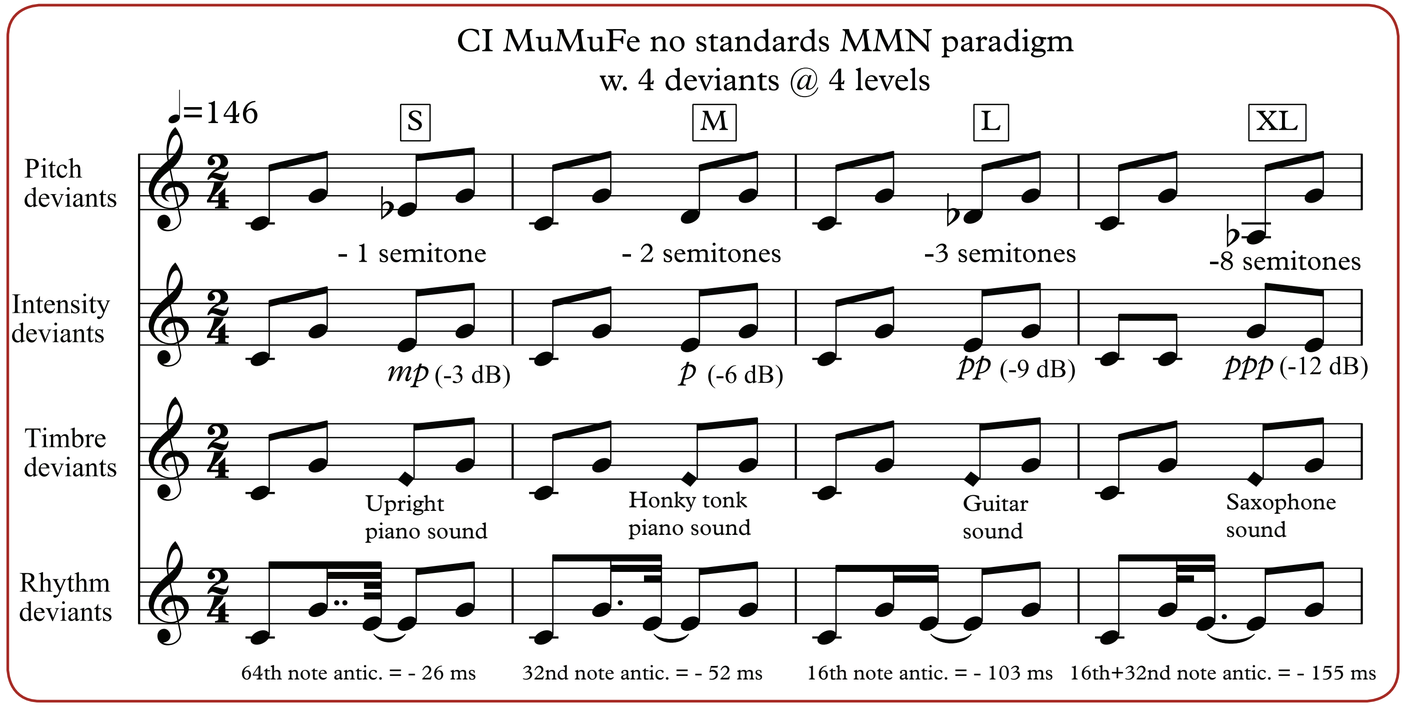

Figure 3. The modified CI MuMUFE MMN paradigm. *The paradigm presents 4 different deviants in up to 4 levels of magnitude: Pitch (-1 ST, -2ST, -3ST, -8ST), Intensity (-3 dB, -6 dB, -9 dB, -12 dB), Timbre (rock bright piano, ragtime piano, guitar, saxophone) and Rhythm (-26 ms, -52 ms, -103 ms, -155 ms). The paradigm is randomly presented in 4 keys: C, Eb, Gb and A major. Lowest note is Ab3 (208 Hz), highest note is E5 (659 Hz). S=small, M=medium, L=large, XL= extra large. Antic.=anticipation.*

sound compression strategy, which leaves room for a wider dynamic range as compared to the typical automatic gain control. An equally important goal is to validate two new EEG paradigms not used in CI users before: 1) an MMN paradigm which presents four different deviants (pitch, timbre, intensity and rhythm) at four different levels but contains no standards (Fig 3), 2) a naturalistic paradigm which presents entire pieces of music. The latter approach is based on a new methodology introduced by Poikonen et al.[9] and is based on an extraction of musical features done in the MIR-toolbox[10]. Both with regard to the aspects of music listening and to methodology, the study has the potential to bring important new knowledge to the field[11].

Review paper on MMN and CIs. One side effect from MIB's engagement in Music and CI research is a new review paper on the global use of the Mismatch Negativity Response, recorded with EEG, in CI patients. The review[12] has been carried out in a new collaboration between MIB researchers Bjørn Petersen and Peter Vuust and Finnish researchers Professor Risto Näätänen and Lecturers Ritva Torppa and Eila Lonka.

Parental Singing. With a new original research proposal, MIB researcher Cecilie Møller has received 400,000 DKK to initiate the project Parental Singing. In brief, the project aims at teaching parents of children with CIs how to initiate and qualify musical interaction with their child, thus potentially stimulating the child's auditory and linguistic development. The programme is inspired by the Auditory Verbal Therapy method (AVT) applied by professional speech therapists worldwide.

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MIB AT THE DHL RELAY RACE

Photo: Hella Kastbjerg

In August 2016 MIB and CFIN participated with more than 30 runners and walkers at the annual DHL Relay Race.

The DHL Relay Race is the world's largest running event taking place in 5 Danish cities.

Participants can either participate in a 5 x 5 km relay race or a 5 km walk.

In Aarhus, 47,000 people participated over 3 days - 2,160 of those were from Aarhus University.

Photo: Niels Christian Hansen

CLINICAL APPLICATIONS OF MUSIC

Eduardo A. Garza-Villarreal

Music and Pain

Chronic pain is a condition, now even described as a disease itself, which affects 14 to 41% of the population in the world[2]. Of the people suffering from chronic pain, 10 to 50% can suffer mid to severe disability and they can also be in risk of opioid painkiller addiction, a known pathway to heroin addiction, due to the repetitive use of this medication[5]. Having a pain condition throughout life can have other serious consequences, such as increasing clinical anxiety, depression and risk of suicide. Therefore, there is a need in pain medicine to find adjuvant therapies that can reduce the use of painkillers and at the same time improve the patients' well-being.

Music is known to reduce acute pain, or immediate pain, in experimental conditions as shown by several scientific studies[7,8,10,13,14]. There have also been studies showing analgesia with music in chronic pain conditions, such as cancer pain, low back pain and fibromyalgia[6,11]. This analgesic effect has been called "music-induced analgesia" and has been found to be present in most people. The main hypothesis for this effect is that listening to music affects the descending pain modulatory system (DPMS), a system that controls the pain we feel[17]. The DPMS works at spinal and brainstem levels as a gateway that controls the "flow" of nociception (painful sensation) that is received and perceived by the brain. This gateway can be influenced to reduce or increase the perception of pain, depending on internal and external factors. For example, pain can be reduced by an active distraction, such as listening to engaging music or playing a game. A painful stimulation can also be perceived as less painful if you are happy, or it can feel more painful if you are sad. There are many factors, including genetics, which determine how the DPMS gateway will work[16]. In this context, music seems to represent and potentiate several internal and external factors that work together to reduce pain perception as well as depression and anxiety[3,15].

The music and pain research is coordinated by Eduardo A. Garza-Villarreal, an Asst Professor at the National Institute of Psychiatry "Ramón de la Fuente Muñiz" in Mexico City, who is also a Visiting Senior Researcher at Aarhus University and Center for Music in the Brain (MIB). He is a former PhD graduate and postdoc at MIB and now works together with Prof Peter Vuust, Prof Elvira Brattico and Prof Lene Vase (Department of Psychology) at Aarhus University. Eduardo also collaborates in this subject with Prof Fernando Barrios, Prof Luis Concha, Asst Prof Sarael Alcauter, and Asst Prof Erick Pasaye at the Neurobiology Institute UNAM in Queretaro, Mexico, and with Asst Prof Mallar Chakravarty at the Douglas Mental Health University Institute of McGill University, USA.

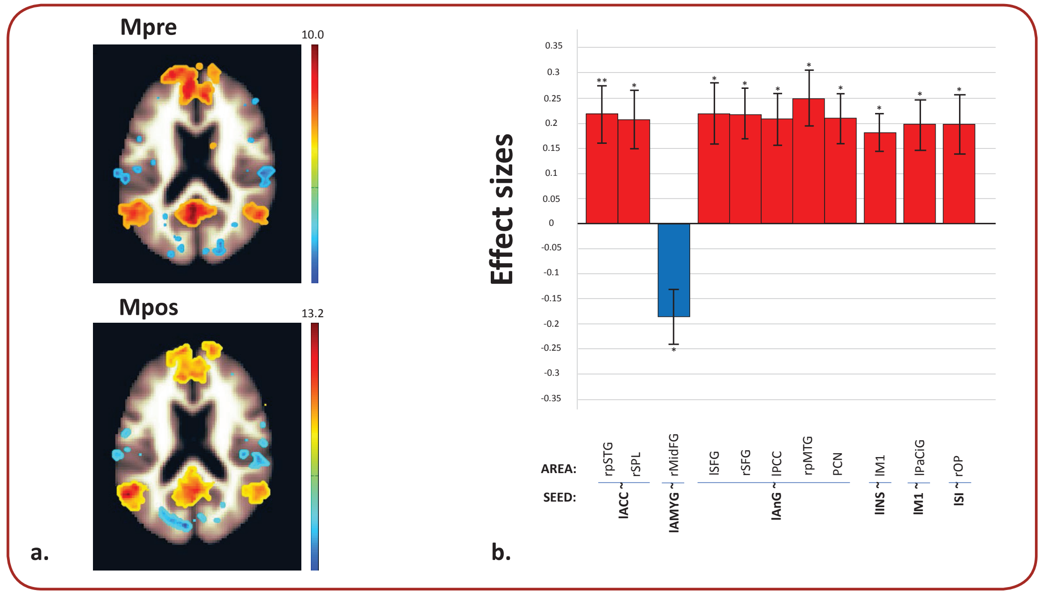

Figure 1. After listening to music, fibromyalgia patients show increase in resting state functional magnetic resonance imaging (rsfMRI) connectivity connectivity in several areas of the pain network, and decrease connectivity between left amygdala and the frontal gyrus. *a. Connectivity maps for the rsfMRI between PNN and Mpre (top) / Mpos (bottom) respectively. Colors show either positive (red-yellow) or negative (blue-light blue) correlations with the PNN. b. Significant seed-to-voxel rsfMRI connectivity. PNN, pain neural network; FM, fibromyalgia; rsfMRI, resting state functional magnetic resonance imaging. Seeds: lACC, left anterior cingulate cortex; lAMYG, left amygdala; lAnG, left angular gyrus; lINS, left insular cortex; lM1, left primary motor cortex; lSI, primary somatosensory cortex. Areas: rMidFG, right middle frontal gyrus; rpMTG, right posterior middle temporal gyrus; rOP right occipital pole; lPaCiG left paracingulate gyrus; lM1, left precentral gyrus; rPCN, right precuneus; lPCC, left posterior cingulate cortex; lSFG, left superior frontal gyrus; rSFG, right superior frontal gyrus; rpSTG right posterior superior temporal gyrus; rSPL right superior parietal lobe. *p<0.5, **p<0.001. All analyzed contrasts where corrected by multiple comparisons using the false discovery rate (FDR) at 0.05.*

Our research suggests that the music itself may not be relevant; the person's perception of the music may be what matters in music-induced analgesia[9]. However, we have found that several characteristics of the music relate to the analgesic effect: high familiarity, few beats-per-minute, and self-chosen music. These characteristics are known to elicit cognitive and emotional mechanisms that could be driving the analgesic effect such as: distraction, pleasure, sense of control and, perhaps, placebo-like effects. A placebo analgesic is an agent (a pill) that does not have any analgesic substances, but it elicits an analgesic effect only by the person's belief the pill will work[1,4,12]. The placebo effect has several mechanisms, similar to those involved in music-induced analgesia, and the effect is mediated by endogenous opioids and the neurotransmitter dopamine[18].

Our research is focused on studying music-induced analgesia as an adjuvant of the medical treatment for chronic pain, with the goals of finding: the precise neurobiological mechanisms of the effect; the extent of the beneficial effects, "dosage", and possible side effects due to its use. Since we started this line of research, we have published 3 scientific papers, and we have 1 in

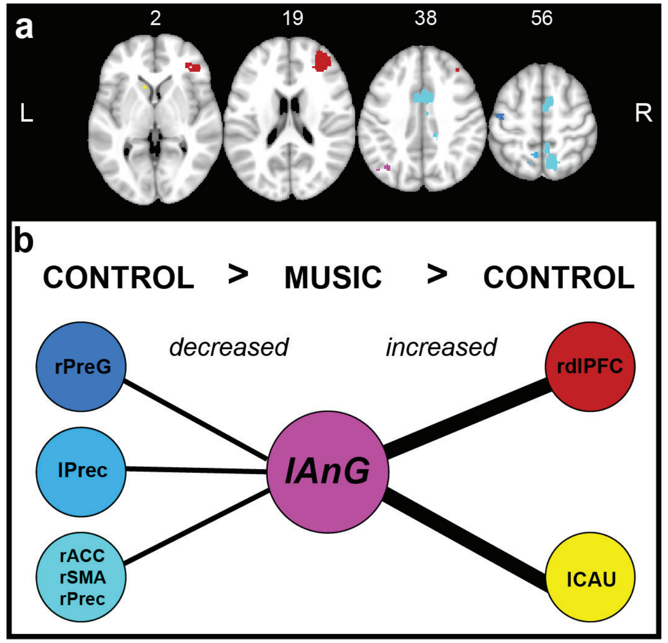

Figure 2. Functional connectivity of the left angular gyrus after listening to music in fibromyalgia patients. *a) Axial view of the brain regions with increased or decreased connectivity with the lAnG (pink). Numbers on top show the slice location in the z-axis. Blue group represents the areas with decreased connectivity and Red group represents increased connectivity. The colour intensity represents the t-values of the t-tests: blue (-1.93) – lightblue (-3.44), and red (1.76) – yellow (2.58). b) Schematic of the differences in connectivity of the lAnG with the other areas according to the statistical contrasts (post-Control > post-Music, and post-Music > post-Control). Thick lines represent increased connectivity and thin lines represent decreased connectivity. L = left, r = right, AnG = angular gyrus, PreG = Precentral gyrus, Prec = precuneus, ACC = anterior cingulate cortex, SMA = supplementary motor cortex, dlPFC = dorsolateral prefrontal cortex, CAU = caudate.*

review and 3 more in preparation for publication. We currently have 2 students working on our main projects: PhD student, Sigrid Lunde, from Aarhus University, who will study placebo-like effects in music-induced analgesia on the brain by using functional magnetic resonance imaging (fMRI) and pharmacological agents; and MSc student, Victor Pando, from the Universidad Nacional Autonoma de Mexico, who is currently working in brain connectivity of music-induced analgesia in chronic pain (fibromyalgia) patients.

Placebo effects are common in medicine and have to be taken into consideration with every studied treatment, and this would be the same for music. In fact, if a drug has the same effect as the placebo (usually a sugar pill), the drug is said to have no effect. The aim of our research is to disentangle the analgesic effect of the music and the effect of belief in the music as an analgesic. We have finished 2 studies that explore this problem behaviorally and with the use of fMRI. In both studies we found that music has a placebo-like effect that may be additional to the other mechanisms. The papers about these studies are under preparation. To truly study the precise brain mechanisms of music-induced analgesia, we need to “dig deeper” into the brain using non-invasive tools. Our current project aims at this by means of fMRI and pharmacological agents that block neurotransmitters related to placebo effects. With this project we expect to find out about the analgesic effect of the music that is mediated by endogenous opioids and dopamine.

Fibromyalgia is a chronic pain disease of unknown origin and not well treated[19]. The patients with this disease are usually women who suffer from mild to severe incapacitating pain throughout their lives, as well as other important comorbidities, such as depression. In our latest studies, we have found that listening to self-chosen pleasant music reduces pain in fibromyalgia patients to the point that the patients can walk with more ease immediately after the music exposure[10]. By studying the brain’s function and connectivity of these patients, we also found that the analgesic effect of music was related to changes in brain functional connectivity of several areas of the brain, by reducing or increasing connectivity with pain related areas[8]. Our findings suggest that fibromyalgia patients suffer from pain that can be reduced, at least in the short term, by listening to music, regardless of the genre. They also suggest that there are cognitive and emotion related brain areas working to reduce pain perception with music. We have published 2 papers of this project, and we are currently preparing 1 for publication.

Our work shows that music reduces pain and the main mechanisms are related to more than one cognitive and emotional process. There seems to be a clear beneficial effect in chronic pain that should make music an excellent adjuvant for regular medical treatment.

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Education, visits and seminars

Elvira Brattico and Bjørn Petersen

Educational activities by MIB personnel
During 2016 MIB personnel has been active with teaching both nationally and transnationally. In August, all PIs contributed to the course Experimental Musicology organized at RAMA by Dr Bjørn Petersen and coordinated by Dr Pauli Brattico. Dr Petersen has organized a methodologically-oriented continuation of the course in autumn 2016 including 11 lectures given by MIB PhD students and postdocs. The course attracted around 25 students from a wide field of educational disciplines: music performance and teaching, Psychology, Cognitive Science, Physics and Semiotics to name some. All lectures were recorded, and recordings and presentation slides have been made accessible online to all students, including those studying abroad.

PIs also provided teaching to visiting students and trainees from Europe and USA. From Italy 3 graduate students were offered the opportunity to have internships at MIB thanks to Erasmus+ funding. Additionally, 10 undergraduate students from the Music Department at Georgia State University, USA spent one week at MIB together with their tutor Asst Prof Martin Nørgaard, an expert in studies of jazz improvisation. PIs Prof Vuust, Stewart and Brattico gave lectures to illustrate the main topics studied at MIB. Brain-storming on how to investigate jazz improvisation with neuroimaging techniques followed.

External educational activities included in the case of Prof Elvira Brattico a full intensive course on imaging genetics at the University of Helsinki (June 2016), invited lectures at the Helsinki Summer School in Cognitive Neuroscience, at the Music & Dyslexia Workhop in Bosisio Parini, Italy and at the Aarhus University course E16-What Makes us Human. Prof Peter Vuust was invited to talk at the Enriched Learning with Music and Sports Workshop in Helsinki and Prof Kringelbach organised a workshop 'Dance, music and the brain' held 29-30th March 2016 at the Paris Institute of Advanced Studies, Paris, France.

MIB personnel disseminated knowledge also outside academia. A remarkable example was the SPOT Festival in April 2016 in Aarhus, where MIB was present with a symposium entitled "Music in the Brain", put together by Dr Petersen and listing talks by Prof Vuust, Prof Brattico, Dr Parsons and Dr Petersen, and also with a Pecha Kucha talk by Prof Brattico.

The students from Georgia and their MIB hosts.

Research training by visiting scholars
Besides these educational activities, MIB has hosted several visiting scholars (see next page), contributing to teaching, knowledge sharing, internationalization, and visibility of the center.

In this context, collaborators from Finland of Prof Brattico and Prof Vuust played a remarkable role, by providing lectures on past and future of neurophysiology, which were open also to students outside MIB, hands-on sessions on brain and auditory signal processing and by interacting during a number of individual meetings with student. More in detail, Prof Mikko Sams (Aalto University, Finland) stayed as visiting professor at MIB for three months during autumn 2016, sponsored by an AFF grant. His stay was pivotal for implementing and finalizing projects on brain-to-brain coupling during music listening/performing. Importantly, he helped opening new frontiers towards hyper-scanning (concurrent brain recordings using connected devices) of expressive interaction between two or more musicians.

Thanks to Prof Sams' stay, we launched plans for connecting MEG devices in Aarhus and Helsinki, following the protocols implemented by Aalto biomedical engineers from Prof Sams' group. In this context, MIB hosted for 2-days stays two guests from Prof Sams' group: Assoc Prof Lauri Parkkonen shared technical knowledge about internet-based connection for dual-MEG as well as on noise reduction of MEG signals; Dr Juha Lahnakoski (also in Max Planck Institute, Germany) gave hands-on session on inter-subject correlation analysis of neuroimaging data. Another visiting professor of MIB in June 2016 was Dr Mari Tervaniemi (University of Helsinki), former vice-director of the Finnish Center for Interdisciplinary Music Research and current Research Director of CICERO Learning network. During her stay, she gave talks and advised MIB doctoral students of the Learning strand on how to conduct high-quality longitudinal studies.

Long-term collaborators from the Finnish Center for Interdisciplinary Music Research (former center of excellence of Academy of Finland) have also been invited to MIB to give talks as well as hands-on sessions on audio and brain signal processing. Particularly, Prof Petri Toiviainen, Iballa Burunat, and Dr Vinoo Alluri provided teaching and hands-on sessions on neuroimaging signal processing to selected doctoral students. Dr Olivier Lartillot gave a hands-on session open to all MIB personnel on computational acoustic feature extraction.

As of fall 2016 a new collaboration between MIB and CFIN was established. In a shared aim to present high profiled researchers within scientific fields of interest to both MIB and CFIN students, a program was worked out with monthly guest talks first Mondays of the month. On the next pages these talks are categorized as MIB/CFIN. The collaboration has proven successful, resulting also in common scientific projects between MIB PIs and Prof Yuri Shtyrov from CFIN, so it will continue in 2017.

Guest speakers 2016

February
Assoc Prof Predrag Petrovic
Karolinska Institute, Stockholm, Sweden
Expectation effects in placebo and psychosis

Dr Jean-Claude Dreher
Cognitive Neuroscience Center, Lyon, France
From reward processing to social decision making: Insights from intracranial recordings and model-based fMRI studies in humans

March
Asst Prof Martin Nørgaard
Georgia State University, USA
The interplay between conscious and subconscious processes during expert musical improvisation

Leonardo Bonetti
University of Bologna
A psychologically-grounded way to compose for guitar

April
Prof Stefan Kölsch
University of Bergen, Norway
Processing syntax in music

Prof Tuomas Eerola
Durham University, UK
Structure of sadness associated with music

Assoc Prof Lauri Parkkonen
Aalto University, Finland
Two-person neuroscience: Why and how

Assoc Prof Marco Costa and Leonardo Bonetti
University of Bologna
Individual differences and cross-modal interactions in musical mode perception and evaluation

May
Dr Eduardo Garza-Villarreal
National Institute of Psychiatry, Mexico City, Mexico
Listening to music reduces pain in fibromyalgia: evidence from resting state brain connectivity

June
Dr Mari Tervaniemi
University of Helsinki, Finland
Neural evidence for music learning and rehabilitation across the life span – Results, implications and back stage views

Prof Tuomas Eerola talking about the structure of sadness associated with music

Photo: Hella Kastbjerg

Prof Stefan Kölsch talking about processing syntax in music

Photo: Hella Kastbjerg

Dr Sari Ylinen
University of Helsinki, Finland
Predictive coding in speech processing

Dr Jessica Grahn
Western University, London, Ontario
Rhythm and the brain: the role of neural motor areas in rhythm and timing

Professor Thomas Jacobsen
Helmut Schmidt University, Hamburg, Germany
On emotion and the psychology of aesthetics

September
Dr Chris Lee
Goldsmiths College, University of London, UK
The musical impact of Multicultural London English speech rhythm

Lecturer Maria Herrojo Ruiz
Goldsmiths College, University of London, UK
Cortical and basal ganglia contributions to the acquisition and monitoring of piano sequences

Dr Katherine Young
Oxford University, UK
The neural basis of responsive caregiving behavior – Temporal dynamics and experience-dependent plasticity in the parental brain

Dr Samuel Schwarzkopf
University College London, UK
How does subjective perception arise in visual cortex? (CFIN/MIB)

October
MIB seminar: Brain to brain coupling in social and artistic interaction
Prof Mikko Sams
Aalto University, Finland
Neurocognition of shared reality
Dr Juha M. Lahnakoski
Max Planck Institute for Psychiatry, Munich, Germany
Brain function in naturalistic conditions – Movies, music and beyond
Lecturer Guido Orgs
Goldsmiths College, University of London, UK
The neuroaesthetics of choreography

Dr Richard Kunert
Max Planck Institute for Neurolinguistics, Nijmegen, The Netherlands
Music and Language comprehension in the brain – a surprising connection

Prof Virginia Penhune talking about Musical rhythms and auditory-motor integration in the brain

Photo: Suzi Ross

Dr Matthieu Gilson
University Pompeu Fabra, Barcelona, Spain
Analysis of 'Effective Connectivity' from fMRI data to quantify brain dynamics

Prof Preben Kidmose
Aarhus University, Denmark
Recording EEG from the ear (MIB/CFIN)

November
Dr Olivier Lartillot
Aalborg University, Denmark
MIRtoolbox: A Matlab toolbox for audio and musical feature extraction & Hands-on session

Prof Mikko Sams
Aalto University, Finland
Early years of N100 and Mismatch Negativity Response in human auditory neuroscience (MIB/CFIN)

Prof Virginia Penhune
Concordia University, Canada
Musical rhythms and auditory-motor integration in the brain

December
Anna Zamorano, PhD
Research Institute on Health Sciences, Spain
Evidence for enhanced pain sensitivity and insula-based connectivity in healthy professional musicians

Prof Jonas Obleser
University of Luebeck, Germany
Neural solutions to the listening challenge (MIB/CFIN)

NEW FACE AT MIB

Pauli Brattico, PhD
Pauli earned his PhD in Cognitive Science from the University of Helsinki, Finland. He then worked as a post-doc researcher, Associate Professor and Professor in Cognitive Science, in various universities in Finland. He has published research on language, music and aesthetics. Pauli has also studied musical composition at the Sibelius-Academy, Finland.

NEW FACE AT MIB

Boris Kleber, PhD, Assistant Professor.
Born into a family of professional artists (piano, violin, voice, dance, and composition), Boris grew up in an environment of opera and classical music. Following his high-school graduation at a music profile school, he first studied contemporary dance and dance pedagogy at the Tanzwerkstatt Konstanz (Graduate Diploma in 1995) and continued private lessons in classical guitar and music theory.
Boris completed a MSc (2002) in Psychology at the University of Konstanz, Germany, received a PhD in Neuroscience (2009) from the University of Tübingen, Germany, and was awarded a higher doctorate degree (Habilitation) in Psychology from the University of Tübingen (2016).
His scientific interest and passion for the singing voice is strongly influenced by his early musical experiences. An internship at the Lichtenberg Institute for Functional Voice Training in 1997 deepened his understanding of voice physiology, which motivated the development of his master's thesis in psychology, focusing on aesthetic perception of classical singing voices. A specialization in Clinical Psychology involved psychogenic voice disorders and musical performance anxiety. Post-graduate collaboration with Prof John Gruzelier (Imperial College/Goldsmiths - University of London) and Prof Aaron Williamon (Royal College of Music, London) finally fuelled his desire to perform research in the neurosciences of music.
This path involved several intermediate positions during which he was involved with Mismatch Negativity and Brain Computer Interface research, before Boris was awarded a self-authored PhD grant from the German Research Foundation, supervised by Prof Niels Birbaumer and Prof Martin Lotze at the Institute for Medical Psychology (University of Tübingen). During his PhD, he worked with EEG Neurofeedback and pioneered fMRI research with trained singers as a model for experience-dependent plasticity of the vocal motor system. This work was crucially developed during his post-doctoral research with Prof Robert Zatorre at the Montreal Neurological Institute (QC, Canada). When he returned for a faculty position to the Institute for Medical Psychology (University of Tübingen), he gained substantial experience in TMS and real-time fMRI neurofeedback as well as in teaching Psychology and Medical Psychology at the Medical Clinic and the Department of Psychology.
At MIB Boris integrates his previous work on vocal motor control in trained singers with the concept of predictive coding. This combination presents a new line of research in the speech motor domain. Singing furthermore allows investigating sensorimotor interactions without the necessity of building MRI compatible musical instruments. The basic knowledge of audio-motor and somatosensory-motor transformations in the context of vocal learning may also have significant ramifications for clinical applications in vocal production disorders.

PhD feature

Niels Christian Hansen

Predictive coding of musical expertise

The fascinating powers of musical expertise make it a natural object of scientific enquiry. Previous research on this topic, however, has been heavily underpinned by romanticised concepts of genius leading to a view of experts as blessed with skills that are elusive, innate, all-or-nothing, beneficial, and creative[1]. In contrast, my PhD dissertation "Predictive coding of musical expertise", which was successfully defended in April 2016, re-defines musical expertise in scientific terms. It is recognised to be empirically investigable, acquired, continuous and multidimensional, adaptive as well as potentially maladaptive, and relevant to both the production and perception of music[2].

By casting expertise as gradual optimisation of predictive mechanisms (Fig 1), this phenomenon becomes compatible with key theories in cognitive psychology and neuroscience, including predictive coding[3] and statistical learning[4]. It can, furthermore, be modelled computationally using information theory and investigated empirically with behavioural and neurophysiological methods. A novel framework is devised facilitating scientific studies of musical expertise through the lens of six analytical perspectives, relating to the origin of expertise, its cognitive representations, predictive uncertainty, predictive flexibility, its conscious availability, and neural correlates.

The first three studies used probe-tone methods to address predictive coding of musical expertise, focusing on its manifestation, specialisation, and acquisition. Study 1 found that predictive uncertainty of melodic pitch expectations can be characterised in terms of the Shannon entropy of conditional probability distributions acquired through statistical learning of music over long time spans[5]. Correlational fit between expectations and probabilistic structure in music was a linearly increasing function of experience, leading musicians to predict with lower uncertainty and experience greater prediction error than non-musicians, specifically when decodable structure was readily available.

Study 2 found that stylistic specialisation in jazz led to better access to conscious introspection of one's own uncertainty about the continuation of improvised solos by Charlie Parker[6]. In other words, professional jazz and classical musicians differed on explicit processing of uncertainty, but not of expectedness. Moreover, supporting the theory of cognitive firewalls restricting the scope of predictive processing[7], classical and non-musicians refrained from misapplying their knowledge of general tonal music in stylistically irrelevant contexts.

Study 3 found that statistical learning of musical sequences can be modelled as minimisation of the

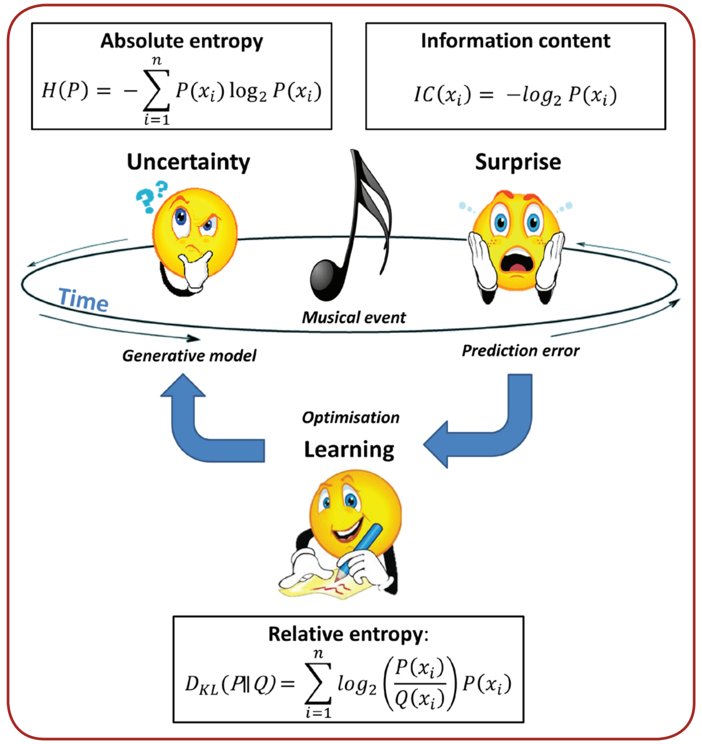

Figure 1. Predictive Coding of Musical Expertise. *This theory posits that musical expertise is acquired through a process where every musical event goes through a cycle of surprise, learning, and uncertainty phases. Following predictive coding theory, this corresponds to prediction error causing optimisation of the listener's internal generative model giving rise to new predictions. The predictive processing involved in these phases can be quantified in terms of information content, relative entropy minimisation, and absolute entropy.*

relative entropy between listener expectations and the probabilistic structure of music[8]. This process took place across timescales and exposure corpora and was not affected by musical expertise when controlling for prior long-term exposure.

Study 4, lastly, used magnetoencephalography (MEG) to show greater under-additivity of the mismatch response (MMNm) in musicians compared to non-musicians, specifically for the pitch component when sounds were presented in musical contexts[9]. This may be interpreted as training-induced plasticity of the neural mechanisms for auditory feature processing. Following up on the initial framework, it is concluded that musical expertise originates from statistical learning under (possibly) innate constraints. This manifests itself as sophistication of cognitive representations, minimisation of the uncertainty of musical predictions, development of specialised contextual knowledge, and greater explicit access to this knowledge. These changes do not only captivate audiences, but also shape the brains of experts themselves.

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PhD feature

Henrique Fernandes

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

Every conscious human experience of perceptions, memories and emotions relies on the flexible optimization of integration and segregation of information into highly coherent dynamical states.

Brain disease has been widely associated with unbalanced neural network organisation, which drives disruption of integrative processing. The early consequences of neurobiological disturbances in neuropsychiatric disorders remains, however, not well understood. Emerging evidence suggests that bipolar disorder (BPD) is linked to dysfunctional brain networks involved in cognitive and emotional processing and regulation. However, early changes in structural connectivity driving the affected neurobiology have not yet been identified. The success of potential therapeutic strategies to recover from abnormal dynamical behaviour relies greatly upon a comprehensive characterisation of its various effects in the human brain. Particularly, deep brain stimulation (DBS) has shown remarkable efficacy in modulating the oscillatory behaviour of disrupted neural networks in different neuropsychiatric disorders, such as chronic pain. Yet, the underlying mechanisms of DBS are still largely unknown, and its targeting has been based upon animal models and neurosurgical empiricism.

The ability to map the human connectome and predict the optimal balance of integration and segregation of information may hold the key for an efficient rebalancing of the brain in different neuropsychiatric disorders. It is therefore critical to develop new tools that may further elucidate and accurately predict the use of DBS as an efficient tool to modulate the dynamical behaviour of whole-brain networks. Mapping the human connectome has identified some of the crucial topological features of human brain architecture relevant for the functional integration and segregation of information. However, the relationship between the degree of a brain region and its relevance for the spatiotemporal integration of information processing is still unclear.

During my PhD we constructed a methodological framework to elucidate the fundamental principles of brain functioning in health and disease. Firstly, we identified new potential clinical biomarkers for early stages of BPD. Secondly, we developed a novel fingerprinting method to identify the necessary and sufficient fingerprint of stimulation spread underlying a successful outcome of DBS for chronic pain. Lastly, we proposed a new metric to evaluate the capacity of each brain region to bind information over time, which long-term can make a major contribution to our understanding of how functional and structural connectivity contribute to the unbalanced brain states found in neuropsychiatric disorders.

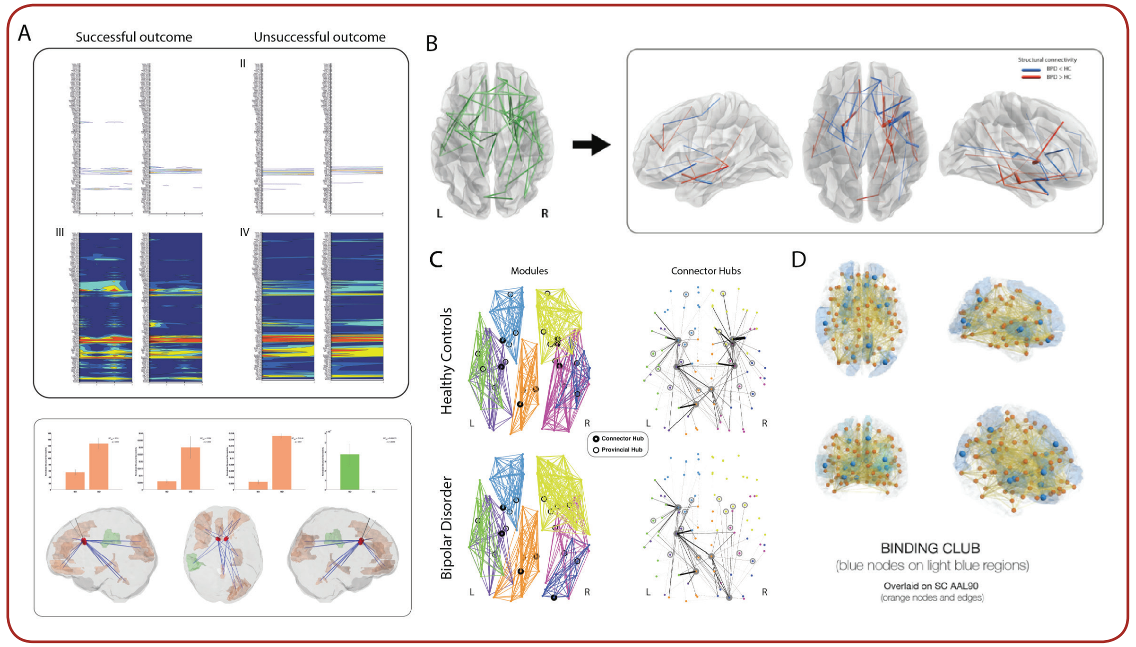

Figure 1. *A) Fingerprints of structural connectivity for patient groups with successful and unsuccessful clinical outcome of DBS for chronic pain, and significant differences in connectivity to target regions B) Between-group significant changes in structural connectivity. C) Modularity, hubs and connector-hub connectivity. D) Rendering of the binding club.*

Throughout this process, I was given the opportunity to embark on a beautiful and rewarding adventure into the deepest fundamental principles of brain dynamics. From static patterns to dynamical behaviours, we explored novel approaches to unravel some of the greatest mysteries of normal and abnormal brain functioning, as well as the neural mechanisms underlying an efficient rebalancing of the brain in different disorders.

In addition to the above, my current research focuses on studying how the brain changes when we become parents for the first time, how is flavour processed in the brain in health and disease and which specific musical features and patterns define the way we sense and appreciate music. On the last, I highlight my interest and contribution to projects involving neuroimaging techniques and advanced signal analysis, to: map how the brain of jazz musicians process creativity through improvisation; and identify which musical features and brain regions are main drivers and control centers for pleasure, expectation, beauty and arousal, while listening continuously to musical pieces of different styles.

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Visiting perspective

Mikko Sams - visiting professor at MIB

On August 30th 2016 I and my wife drove our full car to a ferryboat in Helsinki. After a nice boat trip to Stockholm and a boring drive from there to Southern Denmark we started our anthropological journey to Danish mentality, landscape and science. We had a very interesting and good time together, but in what follows I will share my personal impressions.

Biking

I am an all-year-round biker in Helsinki, riding a distance of 27 km when I go to my office in Aalto University. I use my bike always when it is possible, I truly love it. Biking starts to be quite OK nowadays in Helsinki and its surroundings, number of bikers is steadily increasing. However, it is quite a different thing in Aarhus! Bikers are everywhere, and there are many of them. It took me one week to learn to feel safe when walking around, I did not have my own bike with me (which was a big mistake). In spite of being worried about surviving, I loved to see people of different ages in motion. Bikers in Denmark are very conscious of their strong position in society, which means that they are also self-conscious. I am very interested in understanding mechanisms of consequences of forming groups of different kinds, in Denmark there certainly is a strong in-group of bikers and out-group of pedestrians and car drivers.

Jutland and Aarhus

This was my first visit to Jutland. Jutland is beautiful, much more cultural landscape than, e.g., Southern Finland. I had a wonderful hike with a younger colleague from MIB in Thy national park. It was awesome to hike on a shore of Atlantic Ocean, being a bit offended by huge waves, which could all of sudden grow to super waves and drag you in seconds to the middle of ocean! We also visited beautiful Ebeltoft (there is a very good brewery there) and its excellent Glassmuseet. On one of the few rainy days I visited the handsome and superinteresting KDM Jylland, a steam frigate. Just before returning home, we also visited Skagen (there is a very good brewery there). It is not a story but it really is true that you can see two oceans collide when you stand in the Northern-most part of Jylland. It is fun how much we love things like being in the uttermost something and having your two feet in two different oceans. Skagen, I will return!

Museums in Jutland and Denmark in general are amazing! Museum people are doing a very good job in making past alive and interesting and significant for the present and future. One of the great places to visit several times in Århus is Den Gamle By, a cultural deed indeed! You really feel like moved back in time. You can buy old-fashioned things and bakery. You can talk with professionals, I had an interesting discussion with a locomotive driver, my dad was one. We even found a bar full of people, an ensemble playing happy jazz, people talking, drinking beer and smoking (I used to be a smoker and sometimes miss it).

I lived in Nobel-parken, in the middle of the university. Almost every evening I walked down to Aarhus Gamle Stad. It is truly charming, full of life, many nice restaurants and wine bars. I actually thought that when I visit Aarhus next time, I might think of finding an accommodation down there.

MIB and Science

My other big love is music, both doing it (with guitars mainly) and understanding what it is about. It is not just a special and perhaps fun aspect of human life and field of human neuroscience, but a microcosmos of human behavior. If you are a neuroscientists and this is your mindset, then MIB is a correct address to you! Everybody there shares these both interests.

Knowing that I am going to have a sabbatical from my present position in Aalto University, Peter and Elvira kindly suggested me spending part of that in MIB. That fitted perfectly to my plans. Interestingly, MIB has exceptionally many visitor from Finland, demonstrating many mutual interests and usefulness of Nordic collaboration.

During my visit, I had many entertaining and stimulating discussions on mutual interests, planning experiments and finalizing some manuscripts made in collaboration. I was asked to give a talk about the early years of human auditory neuroscience as I see it. It was an interesting opportunity to revisit a set of papers I wrote with my colleagues in 1978–2002. Certainly it was a nostalgic experience, but also a good possibility to ponder what we learned and how that is related to what we are doing at the moment. We made many new discoveries, which have been important for the field and are worth remembering even now. Equipment we were using in the early years were simple, amplifiers and early computers were expensive. Most of the software had to be written by ourselves. Now we are much faster in making experiments and analyzing the data, which is great. This gives us more time to plan experiments and connect our new results to existing knowledge. In my other talk I tried to clarify my own thoughts in telling my view of the importance of ecological/ naturalistic psychological neuroscience.

There is another great center just on the other side of the street, the Interacting Minds Center. I also made several visits to listen to talks there and share my ideas. I believe that collaboration of MIB and IMC has a lot of potential.

Time flies, many things wait for finalizing. I hope I can return soon.

MIB Annual Retreat 2016
Make Time to Think



The retreat took place in August at the beautiful Vadstrup1771 in nice, sunny weather.

Travelling to Samsø with the new ferry from Aarhus.

Prof Leif Østergaard, Head of CFIN, sharing his many years' experience about "The good project".

Prof Peter Vuust, Director of MIB, introducing the "make time to think" concept.

Photos:
Ole Adrian Heggli
& Hella Kastbjerg

Dorte Jensen giving an inspirational talk on creativity.

Making time to think.

Recording the MIB song!




Some of the groups presenting their projects.

Time to play golf - a first time for many.

Après-golf.....

Time to make music.

PEOPLE

Peter Vuust
Professor
Director
Principal investigator

Elvira Brattico
Professor
Principal investigator

Lauren Stewart
Professor
Principal investigator
(Masternity leave November-December)

Morten Kringelbach
Professor
Principal investigator

Line Gebauer
Associate professor
(Masternity leave January-June)

Bjørn Petersen
Assistant professor

Boris Kleber
Assistant professor

Christine Parsons
Assistant professor

Maria Witek
Assistant professor

Henrique Fernandes
Postdoc

Joana Cabral
Postdoc
(Maternity leave Januar)

Niels Christian Hansen
Postdoc

Tim van Hartevelt
Postdoc

Cecilie Møller
PhD student

David Quiroga
PhD student

Kira Vibe Jespersen
PhD student
(Maternity leave January-October)

Maria Celeste Fasano
PhD student

Ole Adrian Heggli
PhD student

Patricia Alves da Mota
PhD student

Rebeka Bodak
PhD student

Suzi Ross
PhD student

Stine Derdau Sørensen
PhD student

Pauline Cantou
Research assistant

Niels Trusbak Haumann
Technician

Pauli Brattico
Technician

Hella Kastbjerg
Centre secretary

Tina Bach Aaen
Centre administrator

Signe Nyboe Hagner
Student worker

GUEST RESEARCHERS AT MIB

Professors:
- Mikko Sams
- Risto Näätänen

PhD students
- Anna Zamorano
- Tomas Matthews
- Kristina Rapuano
- Marina Kliuchko
- Marianne Tiihonen

Master's students, Bachelor's students, interns:
- Anne Sofie Friis Andersen
- Leonardo Bonetti
- Elisabeth Nauerby
- Nadia Høgholt
- Lev Dadashev
- Ruy Rodrigues
- Alessandra Brusa
- Rasmine Mogensen
- Maja Bjerg Hedegaard
- Guilia Gaggero
- Sofie Simone Overgaard

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Niels Christian Hansen: Predictive coding of musical expertise.

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Ross, Suzi; Hansen, Niels Christian. Dissociating Prediction Failure: Considerations from Music Perception. Comment in: The Journal of Neuroscience, Vol. 36, No. 11, 16.03.2016, p. 3103.

Posters/abstracts (selected)

Brownlee, WJ; Alves Da Mota, Patricia; Prados, Ferran; S Solanky, Bhavana; Riemer, Frank; Cardoso, Manuel Jorge; Ourselin, Sébastien; Golay, Xavier; Gandini Wheeler-Kingshott, CAM; Miller, DH; Ciccarelli, O. Increased cortical and deep grey matter sodium concentration is associated with physical and cognitive disability in relapse-onset multiple sclerosis. 2016. Abstract from 32nd ECTRIMS Congress, London, United Kingdom.

Fasano, Maria Celeste; Glerean, Enrico; Gold, Benjamin; Sheng, Dana; Sams, Mikko; Rauschecker, Josef; Vuust, Peter; Brattico, Elvira. Neural changes after multimodal learning in pianists - An fMRI study. Poster session presented at 14th International Conference on Music Perception and Cognition (ICMPC), San Francisco, United States.

Hansen, Niels Christian; Højlund, Andreas; Møller, Cecilie; Pearce, Marcus; Vuust, Peter. Enhanced feature integration in musicians : Expertise modulates the additivity of the MMNm response. Poster session presented at 14th International Conference on Music Perception and Cognition, San Francisco, United States.

Højlund, Andreas; Horn, Nynne Thorup; Sørensen, Stine Derdau; Mcgregor, William; Wallentin, Mikkel. Foreign sound learning and mismatch negativity (MMN): a longitudinal ERP study. Poster session presented at SNL 2016, London, United Kingdom.

Petersen, Bjørn; Andersen, Anne Sofie Friis; Brattico, Elvira; Ovesen, Therese; Owenc, Hanne; Michelc, Franck; Sandahlc, Minna; Vuust; Peter. Effects of a Novel Sound Processing Strategy on Music Perception and Enjoyment in Cochlear Implant Users. The Music & Cochlear Implants Symposium, Snekkersten.

Prados, Ferran; S Solanky, Bhavana; Alves Da Mota, Patricia; Cardoso, Manuel Jorge; Brownlee, Wallace J; Cawley, Niamh; Miller, David H; Ourselin, Sebastien; Gandini Wheeler-Kingshott, Claudia AM. Automatic sodium maps reconstruction using PatchMatch algorithm for phantom detection.

Prados, Ferran; S Solanky, Bhavana; Alves da Mota, Patricia; Cardoso, Manuel Jorge; Brownlee, WJ; Riemer, Frank; Miller, DH; Golay, Xavier; Ourselin, Sébastien; Gandini Wheeler-Kingshott, CAM. Regional variation of total sodium concentration in the healthy human brain. Poster session presented at International Society for Magnetic Resonance in Medicine: 24th Annual Meeting.

Ross, Suzi; Chow, Karen; Jakubowski, Kelly; Pearce, Marcus; Müllensiefen, Daniel. The structure of absolute pitch abilities and its relationship to musical sophistication. Abstract from 14th International Conference of Music Perception and Cognition, San Francisco, United States.

Sørensen, Stine Derdau; Petersen, Bjørn; Brattico, Elvira; Ovesen, Therese; Vuust, Peter. Gamified Musical Ear Training for Cochlear Implant Users. HEAL Conference, Como, Italy; Summerschool in Helsinki; The Music & Cochlear Implants Symposium, Snekkersten.

During our Make Time to Think retreat at Samsø in August, we were lucky to see the aurora borealis sitting low in the northern sky. To capture it the photographer used a long shutter time on the camera and decided to light paint "MIB" at the same time. If you look closely, you can spot a person holding the light source, a mobile phone, at the start and end of the letters.

Photo: Ole Adrian Heggli

OUTREACH 2016

Invited talks/talks at international conferences

Bjørn Petersen
The Music & Cochlear Implants Symposium, Snekkersten, Denmark

Boris Kleber
8. Gesangspädagogisches Symposium, University of Music and Performing Arts Vienna, Austria
Pacific Voice Conference, Lublin, Poland
12 th International Voice Symposium, Salzburg, Austria
XXVIII. Jahreskongress des Bundesverband Deutscher Gesangspädagogen, Hannover, Germany
X Congreso de la Sociedad Española de Psicofisiología y Neurociencia Cognitiva y Afectiva, Palma de Mallorca, Spain
International Symposium on Music Performance: Art and Neuroscience in Dialogue, Tübningen, Germany

Christine Parsons
Conference on Learning and Plasticity, Helsinki, Finland

Elvira Brattico
Brain and Music Symposium, Nobel Forum, Sweden
Workshop on Auditory Neuroscience, Cognition and Modelling, Queen Mary University, London, UK
Symposium: Emotional Archetypes: Music and Neuroscience IRCAM Centre Pompidou, Paris, France
Diversabilia – Musica, tecnologia e comunicazione per le persone con disabilitá, Bari, Italy
XIV Conference of the International Association of Empirical Aesthetics, Vienna, Austria
The Music in the Development of Linguistic Abilities: Theoretic and Rehabilitative Perspectives, Bosisio Parini (Como), Italy
The Music & Cochlear Implants Symposium, Snekkersten, Denmark
Helsinki Summerschool in Cognitive Neuroscience, Finland

Lauren Stewart
Brain and Cognition Seminar Series, Geneva, Switzerland

Maria Witek
Body of Knowledge, Irvine, USA
Rhythm workshop, Oslo, Norway
14th International Conference on Music Perception and Cognition (ICMPC), San Francisco, USA
Music, Mind, Movement, Meditation: Interdisciplinary Approaches IMC seminar, Aarhus, Denmark

Morten Kringelbach
IAS Conference: The Pleasure of Music and Dance in the Brain, Paris, France
IAS Conference: Collective Emotions, Paris, France
2nd Conference of the European Academy of Neurology Copenhagen, Denmark
Symposium: Maturation of the Human Brain Connectome Nobel Forum, Sweden
Minho Medical Society Conference, Minho, Portugal
55th Annual Meeting of the American College of Neuropsychofarmachology, Florida, USA

Niels Chr. Hansen
14th International Conference on Music Perception and Cognition (ICMPC), San Francisco, USA

Peter Vuust
Culture and Brain Seminar, Karolinska Institute, Sweden
Brain and Music Symposium, Nobel Forum, Sweden
IAS Conference: The Pleasure of Music and Dance in the Brain, Paris, France

Workshop on musical rhythm, Oslo, Norway
Scandinavian Society of Neuro-Oncology, Copenhagen, Denmark
FENS - European Dana Alliance for the Brain, Copenhagen, Denmark
International Symposium on Music Performance: Art and Neuroscience in Dialogue, Tübingen, Germany
Enriched Learning with Music and Sports Workshop, Helsinki, Finland

Suzi Ross
14th International Conference of Music Perception and Cognition (ICMPC), San Francisco, USA

Other talks (selected)

Bjørn Petersen
Frijsenborg Efterskole, Denmark
Folkeuniversitetet, Denmark
DSOHH årsmøde, Denmark
International Summercamp for Unge Mennesker med Høretab, Denmark
SPOT Festival, Aarhus, Denmark
Faglig Dag for Medical Students, AU, Aarhus, Denmark

Christine Parsons
SPOT Festival, Aarhus, Denmark

Elvira Brattico
SPOT Festival, Aarhus, Denmark

Lauren Stewart
Upper Limb Rehabilitation Conference, London, UK
Clinical Neuroanatomy Seminar, Auditory Group Seminar, London, UK
Auditory Processing and Related Disorders across the Lifespan, London, UK

Morten Kringelbach
The Queen's College, Oxford, UK
Wycliffe Hall, Oxford, UK
Dept of Psychiatry Seminar, Oxford, UK
Lecture in connection with Danish parliamentary visit, The Queen's College, Oxford, UK
Zangwill Dept Seminar, Cambridge, UK
Faglig Dag for Medical Students, AU, Aarhus, Denmark
The Queen's College Symposia, UK
Oliver Sacks Memorial, The Queen's College, UK
New Scientist Instant Expert, Royal College of General Practitioners, London, UK
Circle of Willies, UK
Ryle Room, University of Oxford, UK
S'Agaro workshop, Spain
University of Barcelona, Spain
Public conversation with Dame AS Byant in The Hague, Holland

Peter Vuust
Undergrundsuniversitetet Hjortespring Søndagsskole, Denmark
The Royal Academy, Nordkraft Aalborg, Denmark
Parkinson Kender Ingen Grænser: More than Medicine, Denmark
Himmelev Behandlingshjem for Autisme, Denmark
Børneneurologisk Selskab, Denmark
Det Børnekulturelle Topmøde, Copenhagen, Denmark
Odder Gymnasium, Denmark
Dansk Oplysningsforbund, Denmark
Favrskov Lægeforening, Denmark
Kulturhuset Skanderborg, Denmark
Nationalt Videnscenter for Demens, Denmark
SPOT Festival, Aarhus, Denmark
Forskningens Døgn, Denmark
Gribskov Gymnasium, Denmark
Hjernetumordagen 2016, Denmark
Hammel Neurocenter, Denmark
Uddannelses- og forskningsministeriet, Denmark
Region Midstsjælland, Denmark

Stine Derdau Sørensen
Audiologisk Afdeling, Bispebjerg Hospital, Denmark

Participation in TV and Radio (selected)

Christine Parsons
BBC Radio 4: Interview

Lauren Stewart:
Guardian podcast: How music affects the brain

Morten Kringelbach
DR P1: Illeborg og de skøre briter - An Oxford education
BBC radio, News: Cuteness
BBC World Service: The Why Factor: Pleasure

Peter Vuust
P3 Nyhederne: Tusindvis af børn deltager i eksperiment med musik
P4 Radioavisen: Styrker musik arbejdshukommelsen?
TV2 Nyhederne: 30.000 elever deltager i eksperiment
TV-Avisen, DR1: Elever med i musiktest
P1 morgen: Om masseeksperimentet
Radio24syv Nyheder: Børn testes for musiks indflydelse på læring
Aftenshowet på DR1: At slippe af med en ørehænger
P2: Søndagsklassikeren
P4 Trekanten: Interview
TV2 Østjylland: Kulturkampen

Interviews in printed media/web (selected)

Boris Alexander Kleber
Vox Humana – Fachzeitschrift für Gesangspädagogik: Gesang im Kopf - Wie sich die Hirnforschung der Singstimme nähert
Vox Humana – Fachzeitschrift für Gesangspädagogik: Gesang und Körper im Fokus der Hirnforschung

Christine Parsons
Mother & Baby: Think You're the Boss?: Think Again!

Elvira Brattico
Politikken: Sørgelig musik rammer hjernen som en let orgasme
UnicusanoUP Alimentazione & Benessere: Ecco perché la musica riduce la fatica [This is why music reduces fatigue]
La Rondine: Cosa ci passa per la testa quando siamo esposti alla musica [What happens in our head when we are exposed to music]

Lauren Stewart
Rhinegold.co.uk: Amusics may struggle to read others' emotions, study reveals
Dailymail.co.uk: Are YOU tone-deaf? Then you may find it harder to tell if a laugh is fake or read facial expressions
Fastcompany.com: The happy song

Morten Kringelbach
Politikken: Jagten på at forstå vores nydelsesfulde hjerne
Politikken: Forskerportræt af Morten Kringelbach
The Independent: How cute things hijack our brains and drive behaviour
Politikken: Menneskehjernen er kodet til at reagere på babygråd
Newsweek: The Scientific Secret to Success at Euro
Washington Post: The sneaky way babies get inside our heads
Daily Telegraph: Why are babies and puppies so cute?
Oxford Mail: Chubby cheeks and big eyes make sure babies get well looked after, according to Oxford University study
Metro: Evil babies play up their cuteness to manipulate adults
Inverse: How Getting High and Listening to Music Games Your Dopamine Reward System
Vox: Babies' cuteness is key to their survival. What happens when they're not that cute?
Politikken: Mors stemme sætter sig på hjernen

Niels Chr. Hansen
Kristeligt Dagblad: Patriotism is expressed in musical speech rhythms
Politikken: Menneskehjernen er ikke kodet til at elske popmusik

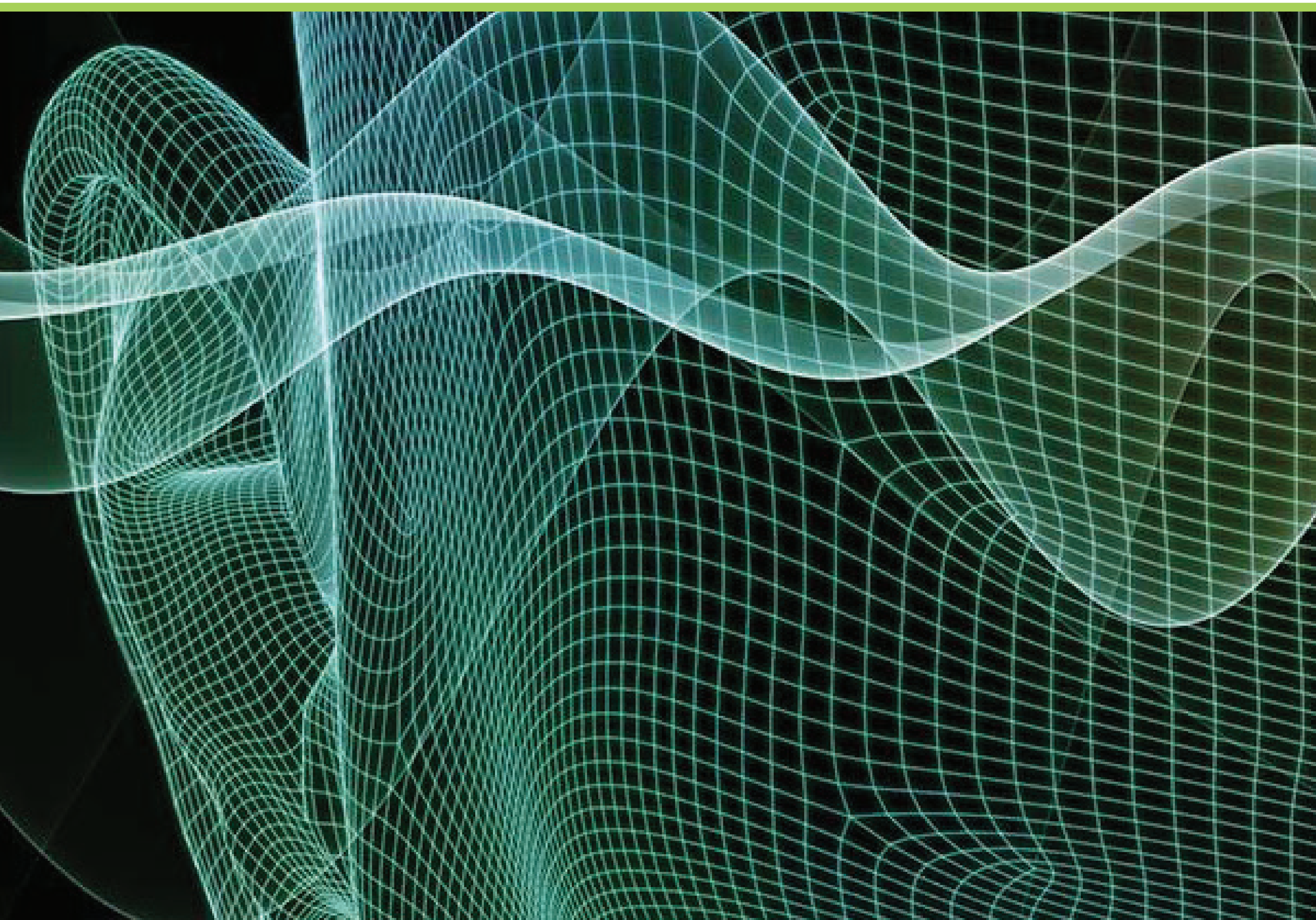
Peter Vuust
Videnskab.dk: Kærlighedshormon gør os bedre til at klappe i takt
Politikken: Hormoner får os til at klappe i takt
Krop & Fysik: Musik som medicin
Kristeligt Dagblad: Julesalmerne står stadig stærkt hos danskerne
Jyllands-Posten: 30.000 børn i musikeksperiment
Videnskab.dk: 30.000 danske børn testes: Påvirker musik hukommelsen?
Dr.dk: Hjerneforsker: Tyg tyggegummi eller nyn en anden melodi
Magasinet Pleje: Sådan påvirker musik hjernen
Aarhus Stiftstidende: Hvorfor danser vi?
Dr.dk: Hjerneforsker og bassist: Prince var synkopernes mester
Videnskab.dk: David Bowie lærte os, at musik kan lyve

Stine Derdau Sørensen
Hørelsen: Musik og CI

Science writing

Morten Kringelbach
Scientific American: Election Aftermath: The Value of Compassion and Reason
TheConversation.com: How cute things hijack our brains and drive behaviour (with A. Stein and E. Stark)
Newsweek: The Scientific Secret to Success at Euro 2016 (with P. Petrovic and T. Vestberg)
TheConversation.com: How to win the Euros – with a little help from neuroscience (with P. Petrovic and T. Vestberg)

2. edition



MIB Annual Report 2016

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