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

MIB Annual Report 2018

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

Annual Report 2018

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

The Danish National Research Foundation's Center for Music in the Brain (MIB) has now existed for three and a half years, and we are by now fully settled in terms of organization, research infrastructure and administrative and project related procedures.

Central to the MIB research is the idea that music, structured around the unifying theme of prediction, can advance our understanding of prediction as a fundamental brain principle across a range of functional domains as in our predictive coding of music (PCM) model. Briefly, PCM proposes that music perception, action and learning are recursive Bayesian processes by which the brain attempts to minimize the prediction error between lower-level sensory input and the brain's top-down predictions.

In 2018, we achieved a theoretical breakthrough publishing a new model for predictive coding of rhythmic incongruity (PCRI) in Annals of the New York Academy of Sciences. This model allows for operationalization of PCM into concrete musical experiments with clearly defined hypotheses for behavioural data as well as for neuroscientific measurements. It has proven important for understanding the brain and cognition, being the central tenet for synergising the strands and thus further development of MIB. In 2018, the model was also centrally featured in an important review paper in one of the foremost high-impact journals, Trends in Cognitive Science, written by Peter Vuust in collaboration with Stefan Koelsch and Karl Friston, two of the most cited researchers within the field of cognitive neuroscience. Other scientific 2018 highlights include the acceptance for publication of Angus Stevner's PhD work on music and sleep in Nature Communications.

We kicked off 2018 with the PhD defense of Kira Vibe Jespersen on music and sleep. The year's second PhD defense took place in June when Cecilie Møller defended her thesis on multimodal processing. They were both subsequently employed as postdocs at MIB. Manon Grube was hired as assistant professor, Jan Stupacher as postdoc and we welcomed three new PhD students: Victor Pando, Davide Ligato and Marianne Tiihonen. In September 2018, we hired Marcus Pearce - world-leading expert on modelling musical prediction - as new professor at MIB. Marcus had already spent much of his time at MIB, residing in Aarhus with his family since April 2017, and his presence adds valuable music modelling competence to the center complementing PIs Morten Kringelbach and Elvira Brattico's expertise in modelling brain activity.

MIB has positioned itself as the leading research center of its kind in Europe, an international hotspot where you can always find internationally acclaimed guest professors as well as students from

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.

abroad in the offices. Funded by Aarhus University Research Foundation (AUFF) Dr Ignasi Cos from Universitat Pompeu Fabra, Barcelona visited MIB for 2 months, Dr Andrea Ravignani from Sealcentre Pieterburen, The Netherlands visited us twice, and a number of PhD and postgraduate students from abroad have stayed at MIB for longer or shorter periods of time. Furthermore, MIB hosted a number of prominent guest speakers and collaborators, such as professors Petri Toiviainen, Asoke Nandi, Fred Dick, Gunter Kreutz and Bjorn Bjorvatn.

In 2018, MIB researchers received several prices, awards and stipends. In a highly competitive field, Assistant Professor Boris Kleber won the Susanne Klein-Vogelbach Prize for his paper ”Experience-dependent modulation of right anterior insula and sensorimotor regions as a function of noise-masked auditory feedback in singers and nonsingers.” Postdoc Jan Stupacher was awarded a 3 year fellowship from the Austrian Science Fund to work on his project ”In time with music: A multi-level entrainment framework”.

The huge MIB potential for outreach and the growing recognition of MIB both nationally and internationally was highlighted by the request from the Danish Minister for Health, Ellen Trane Nørby to visit us followed by a request from the Ministry of Health for a recommendation regarding singing and stress to the Danish “Stresspanel”. Even more prestigious, the journal Nature approached center leader Peter Vuust to feature him in an article describing his career in which he has been able to combine work and passion.

As a futher substantial international knowledge of MIB's research, we have been selected to host the Neurosciences and Music conference in 2020. This is the key conference in the field of neuroscience and music, promoted by the Mariani Foundation, and will be a unique possibility for further research outreach. Organizing this conference is well underway, and the call for the conference is now available at www.fondazione-mariani.org

In connection to this conference, we are currently planning an annual summer school in Neuroscience and Music, which will be held the first time in the summer of 2020. This summer school is part of a special focus to ensure formalized possibilities for our PhD students to teach. We have also implemented a course “Introduction to Music in the Brain” which in the fall of 2018 attracted almost 60 Master's and PhD students from Aarhus University (AU), the Royal Academy of Music and abroad.

We also took part in organizing a summer school at University of Almeria, Spain, the conference ”The Sound of Music i Sundhedsvæsenet” in The Concert Hall and ”Worlding the Brain 2018: Tools of Collective Prediction: Music, Art, Literature, Religion” at AIAS, AU.

With this annual report we wish to highlight the scientific progress and key events in 2018 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 Make Time to Think retreat in Grenå where MIB researchers develop novel innovative research projects in groups that transgress the boundaries between the different MIB strands. *Photo: Ole Heggli*

PERCEPTION

Peter Vuust, Elvira Brattico, Morten L. Kringelbach

By Boris Kleber

The Perception strand focuses on the tonal, timbral, temporal, and intensity aspects of music as a multifaceted auditory phenomenon that allows us to pinpoint the hierarchical organization of higher-order predictive and lower-order error detection mechanisms in the brain. In 2018, this strand has seen important developments. We further refined our Musical Multifeature (MuMUFE) paradigm, using MMN and MEG to investigate the neural basis of auditory prediction violations. Specifically, we focused on (a) reducing the predictability of acoustic information in a realistic musical context, (b) extending its scope by using MuMUFE to investigate a proposed relationship between sensory and working memory in the processing of auditory information, (c) employing the shorter and more efficient no-standard version of the MuMUFE MMN paradigm, and (d) optimizing a more musical sounding dual-stream MuMUFE to identify context dependent effects of musical expertise.

To investigate subtle differences in the predictability of acoustic information in a musical stream, we combined the MuMUFE with the Information Dynamics Of Music or IDyOM software, which was developed by Prof Marcus Pearce[1]. IDyOM generates predictive statistical models of musical structure by estimating the likelihood of each note in a melody in the context of preceding musical information using Shannon entropy, thus providing measures of uncertainty about the next note and information content, which reflects the unexpectedness of the note that actually follows (see page 38).

PhD student David Quiroga performed a MuMUFE MEG project in which he determined the predictability and information content of musical features using IDyOM, in order to assess how subtle changes in the unexpectedness of sounds can modulate the MMN responses in a realistic musical stream. The results extended our knowledge of the predictive processes that underlies the perception of complex music, and allowed us to perform a more fine-grained investigation of expertise effects related to both implicit and explicit musical knowledge (see page 10).

In the same line, Assistant Prof Massimo Lumaca examined how the MMN as a neural index of prediction error is weighted by the precision (inverse of entropy) of rhythmic predictions. This study revealed that by decreasing the precision of predictions (i.e. increasing the entropy of rhythms), the MMN also decreased, which supported the precision-weighting hypothesis of predictive coding (PC) in the temporal domain of music[2].

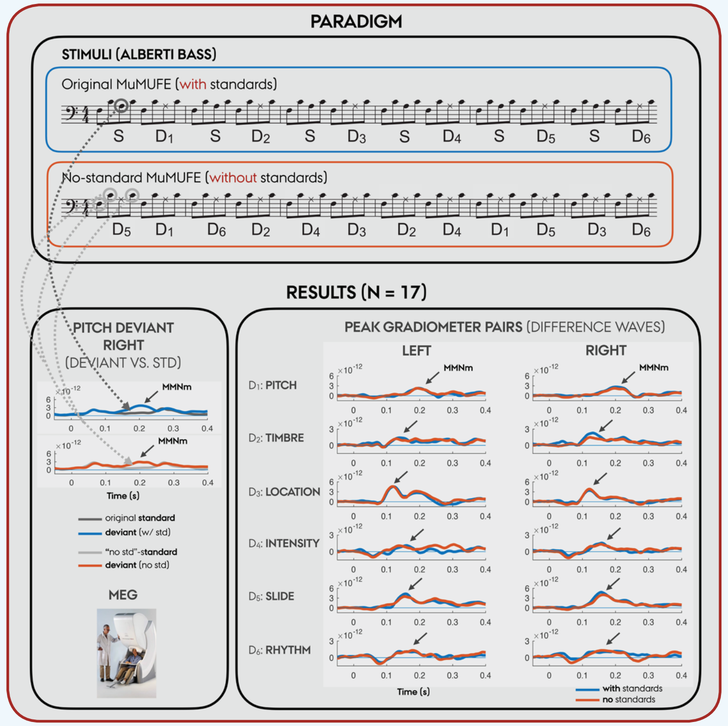

Figure 1. The MuMUFE paradigm assesses neural responses to prediction violations embedded in a musical context for six different features: pitch, timbre, intensity, location, rhythm, and slide deviants. It differentiates auditory processing according to e.g. musical ability, practiced musical genre, or hearing impairments in CI-users. The no-standard MuMUFE version has a shorter duration of only 10 minutes, yet eliciting reliably MMNms to all six features without any differences compared to the standard MuMUFE paradigm.[3]

The MuMUFE was moreover applied within a broader context, following the notion that the MMN component may be useful for studying cognitive abilities in the auditory domain. PhD student Leonardo Bonetti performed an experiment in which the MuMUFE MMN was tested in a large group of 70 healthy participants and related to the outcome of the Wechsler Memory Scale-II for evaluating working memory (WM). In line with the hypothesis, these data demonstrated a connection between auditory sensory memory traces indexed by the MMN response to auditory feature changes and WM abilities, suggesting that even pre-attentive sensorial processes can be linked to conscious cognitive abilities[4]. This has implications for a large variety of disorders related to cognitive abilities involving the auditory domain, as the sensitivity to auditory feature changes in the environment may be linked to enhanced prediction and error detection of future events, which in turn is related to cognitive abilities.

The non-standard MuMUFE (see Fig. 1), which triggers MMN responses as reliable as the standard MuMUFE, has also been used in two studies investigating the interaction between auditory prediction error with the level (i.e., musical expertise) and nature (i.e., active or passive) of engagement with music. These studies characterized a more detailed relationship between musical learning and predictive processes, beyond the traditional dichotomy of comparing expert musicians with non-experts. By investigating a larger spectrum of both actively and passively developed musical skills and by taking musical style into account, postdoc Marina Kliuchko found not only increased prediction error responses as a function of formal and active learning in classical and jazz musicians but also as a function of musical style (i.e., related to specific sound features). Interestingly, similar differences were found among amateur musicians, depending on whether or not they still practiced their

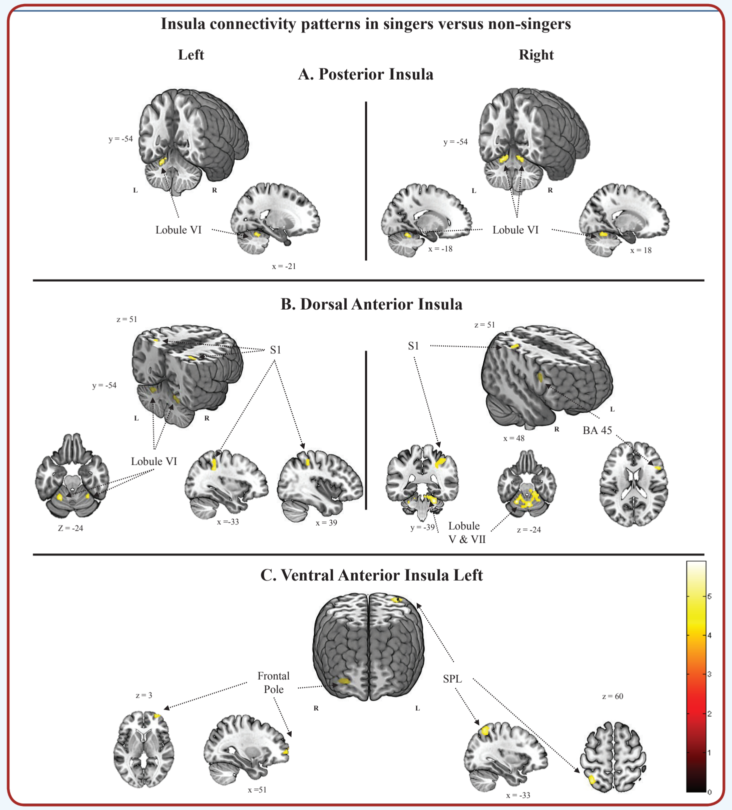

Figure 2: Regions involved in feedback and feedforward sensorimotor control showing significantly increased functional connectivity with the dorsal anterior insula (dAI) of trained singers relative to non-singers. Connectivity maps for left hemisphere seeds are shown left; maps for right hemisphere seeds on the right. Significance thresholds of peak t-values within the singing mask were set at p=.001 (10 voxels extent threshold).

instrument. Together, these data highlight a role of active musical learning in the development of auditory prediction models (see page 34).

The benefits and the synergetic effects of combining work related to perception and learning also led to new and exiting posibilities for future research. For example, conventional research into perception and sensation treats sensory systems as separate entities that serve specific purposes. However, music is a multimodal phenomenon, and the neural processes for hearing perception can undergo significant modulation by other sensory systems, such as vision and somatosensation. Postdoc Cecilie Møller investigated audio-visual interactions by comparing the benefits of multisensory relative to unisensory stimulation on pitch discrimination accuracy in musicians and non-musicians[5] . Results indicate that visual cues only induce stronger enhancements of pitch discrimination skills in participants with poorer auditory-only abilities, as reflected by enhanced MMN responses (MEG) and increased fractional anisotropy (FA) values in white matter tract, which connects auditory and visual areas of the cortex (see page 60).

A very promising and novel line of research has been developed by Assistant Prof Boris Kleber, studying cross-modal predictive processes underlying singing expertise. Previous studies with trained singers indicated an experience-dependent role of the insula in the segregation and integration of signals of salience to support task performance in the presence of sensory feedback perturbations[6]. The insula is an integral hub for mediating the interaction between motor, multisensory, and cognitive networks to guide behavior. In line with this reasoning, a recent resting-state fMRI study with classically trained singers and non-singers identified increased insula connectivity in singers with cortical regions involved in feedback and feedforward sensorimotor processes underlying vocal production[7]. This difference may best be described as an indicator of experience-related cortical plasticity that reflects the repeated history of task-related co-activation between brain regions. Dedicated singing training may therefore trigger adaptive neuroplasticity in brain regions that support enhanced processing of multimodal signals (see Fig. 2). These results have led to the development of a novel fMRI paradigm, which elegantly perturbs the link between action-perception during singing by unexpectedly altering the acoustic pitch feedback from participants' own voice up- or downwards in real-time. These data, which are currently being analyzed, will allow for a more detailed differentiation of expertise-related effects on predictive coding mechanisms in a perception-action context at both the behavioral and neural levels. The lines of cross-modal and singing research will be further developed in the upcoming Research Plan 2021-25.

Lastly, a very fruitful collaboration has been established between MIB and The Danish National Research Foundations's Centre for Neuroplasticity and Pain (CNAP, Prof Thomas Graven-Nielsen) at Aalborg University, in which CNAP postdoc Anna Zamorano together with Assistant Prof Boris Kleber investigates how extensive sensorimotor training may alter somatosensory and pain processing in musicians. After indicating several relevant differences at both the perceptual and neural levels in musicians with and without chronic pain[8], the current project aims at identifying the neurophysiological mechanisms underlying these experience-dependent changes.

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MIB Assistant Prof Boris Kleber and postdoc Anna Zamorano meeting Plácido Domingo before his concert in Aarhus

PERCEPTION

Predictive processing of music in more complex and real-sounding contexts

By David Quiroga

Prediction is a fundamental aspect of music listening. As a piece of music unfolds, we create expectations about the forthcoming sound events, based on the statistical regularities of the piece itself and our life-long knowledge of musical styles. These expectations, as well as their fulfillment or violation, are essential for music perception and the emotional and aesthetic experiences that we derive from it[1]. In the last couple of decades, researchers have tried to unveil the neural underpinnings of music predictive processing. For example, some studies have shown that the electrophysiological responses of the brain are larger for unexpected as compared to expected sounds[2]. This phenomenon can be understood in the light of predictive processing theories, which propose that unexpected sensory information generates prediction error responses that propagate forward in brain hierarchies to drive perceptual inference, learning and action[3].

Most of the research on the neural correlates of musical expectations employs stimuli that are far from resembling real music. In a typical experiment, a repetitive sequence of simple sound patterns is interrupted by highly violating sounds. While this kind of manipulation maximizes the contrast between expected and unexpected sounds, in real music, such repetitive patterns are rather uncommon, and differences in sound expectedness are much more subtle. Consequently, current methods reveal only one side of the picture and preclude the possibility to study how contextual factors, such as complexity, familiarity and musical style, affect music predictive processing.

In our work, we looked into predictive processing in more complex and real-sounding contexts. We created tone sequences that resemble real melodies and avoid the repetition of a reference pattern. Our first goal was to determine whether subtle differences in the expectedness of sounds are reflected in neural activity. Consequently, we used Information Dynamics of Music (IDyOM)[4], a computational model of musical expectations, to estimate the expectedness of individual sounds in a continuous scale. IDyOM assigns information content (IC) values to each tone of a melody. These values are inversely related to expectedness so that the more surprising a sound is, the higher its IC value will be. We grouped individual tones into ten quantiles according to their IC value and computed the average neural activity for each quantile, as measured with magnetoencephalography. As shown in Figure 1, the higher the information content, the larger the peak of the brain's magnetic activity around 100 ms after sound onset. This finding is consistent with a modulation of the N1 component of the auditory response, which is similar to the results of a previous experiment[5].

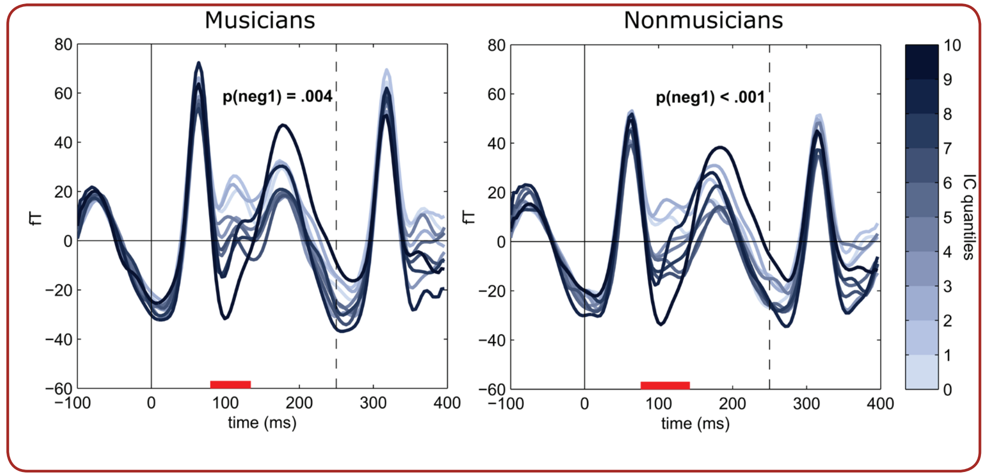

Figure 1. Magnetic N1 responses to subtle modulations of sound expectedness, quantified as information content (IC) with IDyOM. Red horizontal lines show the time where the effect was significant. The displayed activity corresponds to the average of the four right temporal magnetometers with the largest effect. Dashed lines indicate the onset of the next tone.

Therefore, our data suggest that IDyOM is a robust tool to study musical expectations at the neural level in more real-sounding settings.

In our experiment, we were also interested in how musical expertise affects the responses to sounds with different expectedness levels. For this reason, we compared musicians and nonmusicians and hypothesized that if, due to intensive training, musicians generate more accurate expectations, then the relationship between IC values and neural activity would be stronger in this group. Surprisingly, IC values predicted neural activity similarly well for musicians and nonmusicians. A likely explanation for this result is that nonmusicians are so exposed to Western tonal music - which is the style that we modeled with IDyOM - that they acquire sophisticated implicit musical knowledge of it. If this is the case, musical training does not seem to improve this knowledge further. Moreover, since some behavioral studies have shown differences in expectedness ratings between musicians and nonmusicians, our results also hint at the interesting possibility that both experts and non-experts possess detailed implicit musical knowledge of tonal music, but only the former might have conscious access to it.

Another question of relevance is how the complexity of musical sequences affects neural responses to unexpected sounds. This is of interest since current theories propose that the precision of our expectations plays a fundamental role in perception. Here we understand precision as the specificity and certainty of predictions, which can be driven both by the statistical properties of sensory signals and by internal factors, such as attention. Precision has been proposed to modulate the strength of responses to unexpected sounds so that they are stronger in perceptual contexts with low as compared to high complexity. This mechanism, known as precision-weighting of prediction error[6], would ensure that only reliable perceptual contexts drive learning and behavior.

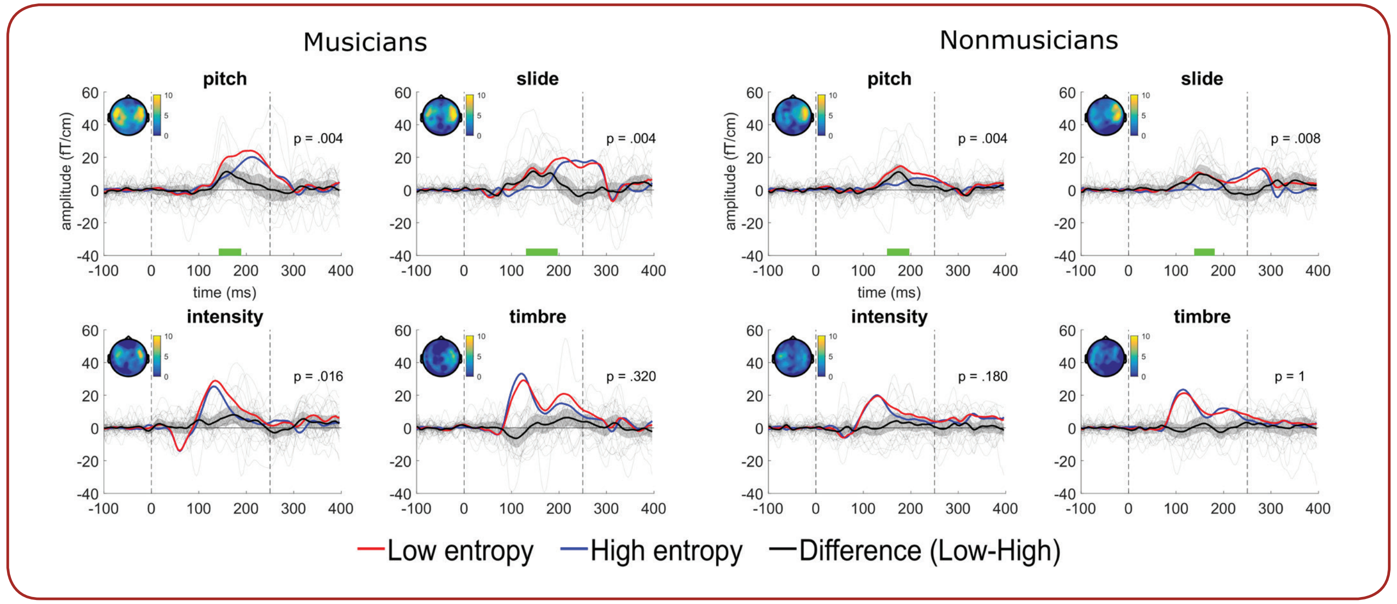

Figure 2. Magnetic MMN responses to pitch, slide, intensity and timbre deviants in simple (low-entropy) and complex (high-entropy) contexts, for musicians and nonmusicians. The displayed activity corresponds to the average of the four right temporal combined gradiometers with the largest responses. Green horizontal lines show the time where differences between conditions were significant. Topographic maps depict the average difference between conditions +/- 25 ms around the peak. Gray lines represent individual difference waves. Shaded gray areas indicate 95% confidence intervals. Dashed lines mark tone onsets.

In the experiment, we compared our complex melodic sequences with a much simpler type of auditory sequence: a four-note repeated pattern. In this case, we looked into low-level unexpected sounds consisting of mistuning, slide (pitch-glide), intensity and timbre deviants, which are known to elicit a specific brain response, the mismatch negativity (MMN). We found that the MMN was reduced in the complex condition, especially for pitch and slide deviants (see Fig. 2). This provides evidence for the precision-weighting mechanism in musical contexts. Furthermore, since stimuli became complex in the pitch dimension, and the difference was found mainly for pitch-related deviants, the results hint at the possibility that the modulation is feature-selective. Interestingly, the effect did not seem to be substantially affected by musical training.

To sum up, in our research we have shown that subtle increases in the unexpectedness of sounds lead to larger neural responses, and that this phenomenon can be reliably studied with the help of computational modeling with IDyOM. Using this approach, we have shown that nonmusicians' expectations do not seem to be very different from musicians' expectations, pointing to the existence of sophisticated implicit musical knowledge in the former. Furthermore, we have shown that the complexity of musical sequences modulates neural responses to unexpected sounds, and that this effect seems to be feature selective and not very affected by expertise. Consequently, our research paves the way to the investigation of predictive processing in more complex and real-sounding contexts. For example, one could use these methods to ask if a particular cultural background affects expectations when listening to a particular musical style, or whether the effect of precision on prediction error responses is related to individual cognitive skills. Overall, this work moves us a step closer to understanding auditory predictive processing in the rich environments of daily life.

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FUNDING FOR RAMA/MIB RESEARCH RROJECT

RAMA trumpet professor Kristian Steenstrup is a world-leading expert in the teaching of brass instruments and has published two books of which his second "Blow your mind" draws extensively on evidence from the literature on the neurobiological basis for music learning. In 2018, Steenstrup initiated a new research project on mental practice in close cooperation with Drs. Bjørn Petersen and Boris Kleber from MIB. The project examines the efficacy of different mental practice strategies, including mental imagery and absolute solmization, and received a grant of 776,000 DKK from the Danish Ministry of Culture's research board.

MIB AT THE DHL RELAY RACE

It has become a tradition for MIB members, together with CFIN colleagues, to participate in the annual DHL Relay Race in Aarhus.

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.

ACTION

Peter Vuust

In 2018, the Action strand - centered around music production, performance and interaction with a special focus on rhythm - tested the model of predictive coding of rhythmic incongruity (PCRI) proposed by PV[1], and further developed in a Trends in Cognitive Science paper by Koelsch, Vuust & Friston[2]. This model is beautifully able to account for our previously observed inverted U-shaped relationship between syncopation (rhythmic predictability) and musical pleasure/wanting to move. Using the mismatch negativity (MMN) recorded by EEG, a proxy of neural prediction error, we showed a gradual decrease in MMN amplitude as a function of entropy for small timing deviants (see Fig. 1)[3]. This is consistent with PCRI, which predicts that high-entropy stimuli are more difficult to model for the brain than low-entropy stimuli, resulting in less precise predictions yielding smaller prediction errors for deviant sounds.

Further expanding on PCRI, in collaboration with Prof Virginia Penhune, Concordia University, inspired by our previous studies using rhythm in isolation, we found that the pleasurable desire to move to music, also known as groove, is influenced by other musical features than just rhythm[4], such as harmonic complexity (see Fig. 2). Whereas rhythm showed an inverted U-shaped relationship with ratings of pleasure and wanting to move, the pleasure induced by low and medium harmonic complexity exerted an indirect effect on wanting to move. High complexity chords attenuated the effect of rhythm. This suggests that while rhythmic complexity is the primary driver, harmony, by altering emotional valence, modulates the attentional and temporal prediction processes that underlie rhythm perception. Furthermore, investigation of the effects of musical training with both regression and group comparison showed that musicians exhibit an increased inverted U effect for harmony and rhythm, respectively. A subsequent fMRI study shows that the effect of groove is related to brain structures specialized for motor and pleasure processing, while musicians showed enhanced activity in premotor brain areas (in submission) (see Fig. 3). Interestingly, when musical harmony is presented in isolation at four different levels of complexity, there is a pronounced U-shaped relationship between harmonic complexity and pleasure ratings, and musicians prefer higher levels of complexity than non-musicians. In a cross-cultural study, we subsequently found that Ghanaians are better than North Americans at synchronizing to syncopated rhythms but that there was no group difference in the shape of the inverted U-formed relationship between syncopation and sensation of groove.

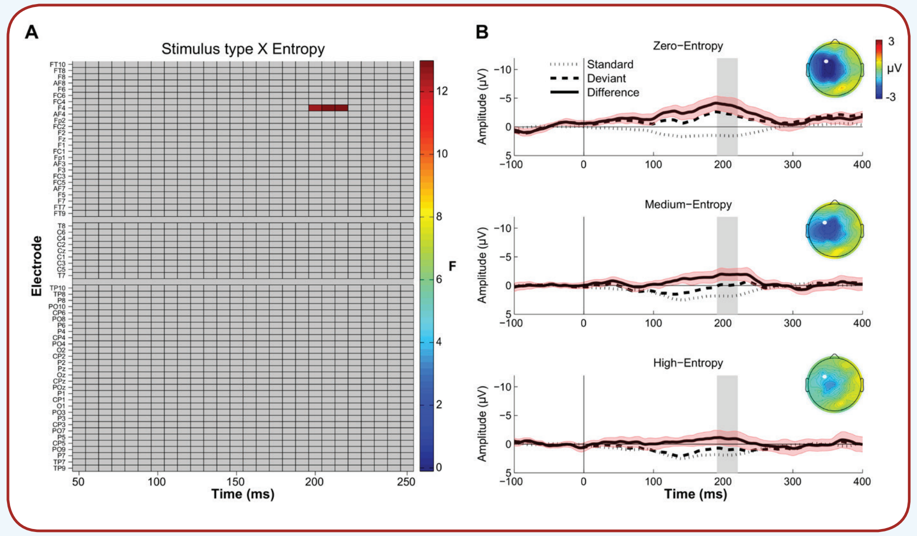

Figure 1. Our results show that the MMN amplitude decreases as the entropy of the rhythmic patterns increases. (a) Raster diagram showing in the red rectangles the time points and electrodes where the grand-average ERP decreased as a function of rhythmic entropy. (b) Grand-average standard (dotted), deviant (dashed line), and difference wave ERPs (solid line) and their decrease from zero-entropy (top-row) to high-entropy (bottom-row).

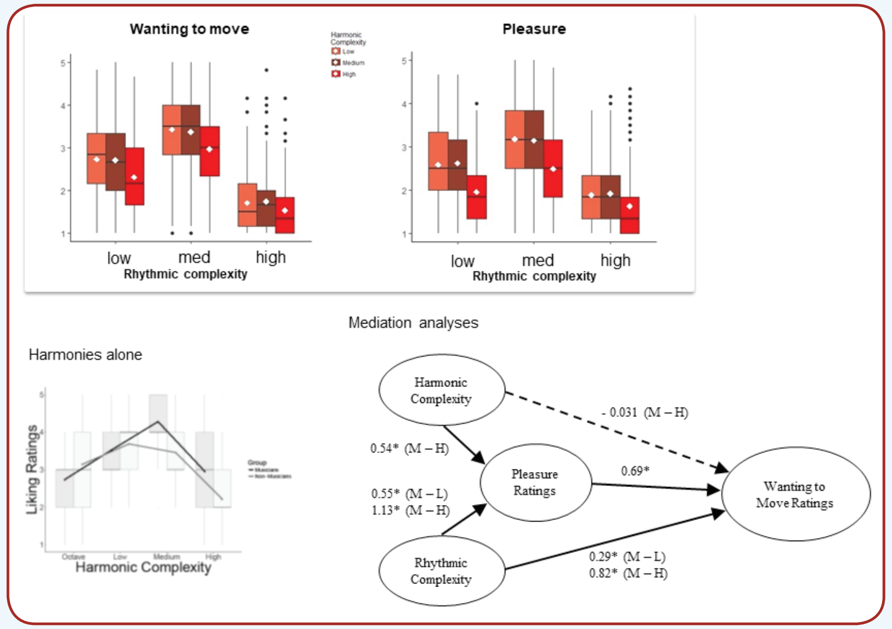

Figure 2: The influence of complexity on "move" and "pleasure"[4]

Cultural differences in predictive coding of rhythm was also the target of an EEG study exploiting the relative difference in typical subdivisions of the beat between Sub-Saharan African music (often triplet-based) and Western music (dominated by even subdivisions)[5]. Comparing event-related potentials in a Western group of listeners mainly exposed to Western music and a bicultural group of listeners exposed to both Sub-Saharan African music and Western music, we found higher amplitude of the MMNm to deviant tones on odd compared to even metric positions in the Western group, but not in the bicultural group. In support of this finding, there was also a trend in the Western group to rate omitted beats as more surprising on odd than even metric positions, whereas the bicultural group seemed to discriminate less between metric positions in terms of surprise ratings. Also, we observed that the overall latency of the MMNm was significantly shorter in the bicultural group compared to the Western group. Furthermore, source localization analyses suggest that auditory, inferior temporal, sensory-motor, superior frontal, and parahippocampal regions might be involved in

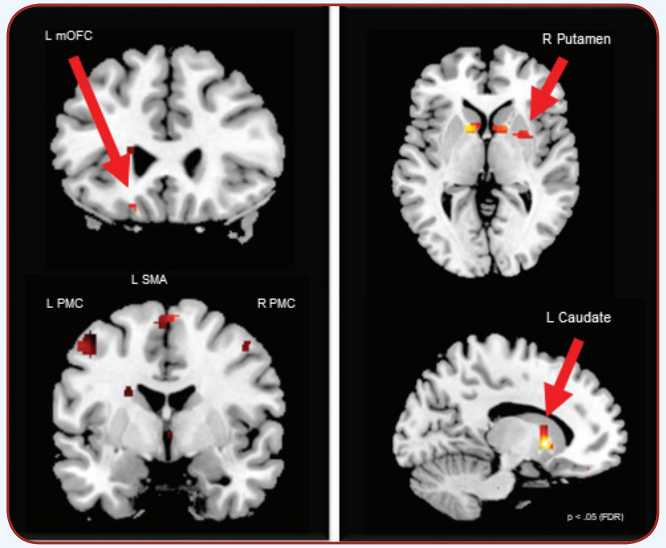

Figure 3: Main effect of rhythmic complexity (medium vs high): Witek, Matthews, Lund, Penhune, Kringelbach, & Vuust, In submission

eliciting the MMNm to the metric deviants. These findings suggest that effects of music enculturation can be measured on MMNm responses to attenuated tones on specific metric positions.

Social interaction is an increasingly interesting line of research in the action strand. In dual-tapping paradigms, in which two individuals are placed in separate rooms with ear phones and possibly EEG equipment and asked to tap together in different conditions[6], we showed that interpersonal musical actions depend on predictive coding processes in music. We recorded dual-EEG in musicians with corresponding or conflicting predictive metric models (different musical meters), showing how musicians adapt differently to each other depending on their underlying internal predictive model and instrumental expertise. In terms of musical interactions, we found that the behaviourally observed tapping patterns can be modelled with a simple, yet elegant, oscillatory model including four oscillators corresponding to one external and one internal Kuramoto oscillator in each of the two tappers (see page 18).

This minimalistic tapping paradigm is only one of a number of MIB paradigms on social interaction. We are currently testing the hypothesis that regularities in the temporal organization of signaling sequences arise in the course of cultural transmission as adaptations to aspects of cortical function[7-8], studying social entrainment[9] using a within-subjects design in which participants watches videos of two figures walking side by side but timed differently to music, and using behavioral measures and fMRI experiments to study embodied constraints on the simultaneous production of rhythm and meter. These studies are all borne out of the predictive coding of music theory suggesting that part of social interaction can be explained through mutual minimization of precision-weighted prediction error.

The Action strand enjoys strong synergy with the other strands, collaborating with the Perception, Emotion and Learning strands on studies of piano improvisation[10], singing related predictive coding in audio-motor coupling[11], crossmodal (audio-visual) enhancement of pitch discrimination[12, 13], different implementations of the musical multifeature paradigm (MuMufe)[14-16], musicianship[17] and the hedonia (pleasure) and eudaimonia (well-being) related to music, dance and other art forms[18].

Importantly, the research in the Action strand contributes to several clinical studies (see page 42). For instance, in 2018, we initiated a study on people suffering from Parkinson's disease with the goal of finding out which music to use for obtaining the maximal effect of entrainment as well as the neural mechanisms behind this effect. This study exploits directly the knowledge gained from our studies on the influence of harmonic and rhythmic complexity and predictability on the pleasurable wanting to move (groove) in normal participants. Hereby, we strive towards the MIB goal of translating our basic research, grounded in the predictive coding of music hypothesis, into clinically important applications.

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ACTION

Interpersonal synchronization in musicians

By Ole Adrian Heggli

We humans have an extraordinary ability to align intentions and actions towards shared goals[1]. This is evident in the ease and fluidity at which we perform social interactions involving coordination of simultaneous cooperative behaviours.

Perhaps the most striking aspect of coordinating actions between individuals is found in musical performance. Here, musicians coordinate their individual actions towards the shared goal of producing sounds that when perceived together form cohesive auditory patterns[2].

The process of making music together necessitates shared alignment towards goals in multiple dimensions. On a lower level the musicians need to agree on basic features of the music in question, such as the beat and the tempo. Decision on a higher level are also necessary, such as jointly choosing who is the next soloist in a jazz improvisation. These decisions occur dynamically, and often without verbal communication[3]. Hence, successful musical interaction relies on a brain that is capable of predicting, anticipating, and deducing the intent of others based on limited information[4]. An interesting question here is then, how much do musicians rely on such predictive models when they are interacting? To explore that question we designed a joint finger-tapping experiment[5]. Here, participants are paired up in dyads and asked to tap rhythms together. While this type of paradigm may sound simple, complex behaviour still arises. In particular, previous research have shown that different synchronization strategies occur, such as leading/following where one dyad member becomes a leader, or mutual adaptation, wherein both dyad members continuously adapt to each other on a tap-by-tap basis[6-8].

We used a polyrhythm to construct two tapping tasks that resulted in the same inter-tap interval (ITI), yet were rhythmically dissimilar. A polyrhythm is a rhythm that can be perceived from the point of view of two different meters[9]. Now, if one instructs a participant to tap the triplet in a 3-against-4 rhythm at 160 beat-per-minute (BPM), this leads to an ITI of 500 ms, which is exactly the same as tapping a simple 4/4 straight rhythm at 120 BPM, as shown in Fig. 1a. This allowed us to create a task where one member of the dyad is tapping the straight rhythm, and the other member is tapping the triplet of the polyrhythm, without being aware that they are tapping different rhythms. Hence, we were able to create a task wherein the musicians do the same, but think differently. In this sense, the dyad holds a non-shared predictive model, which we contrasted against a shared predictive model wherein both dyad members tapped the same rhythm.

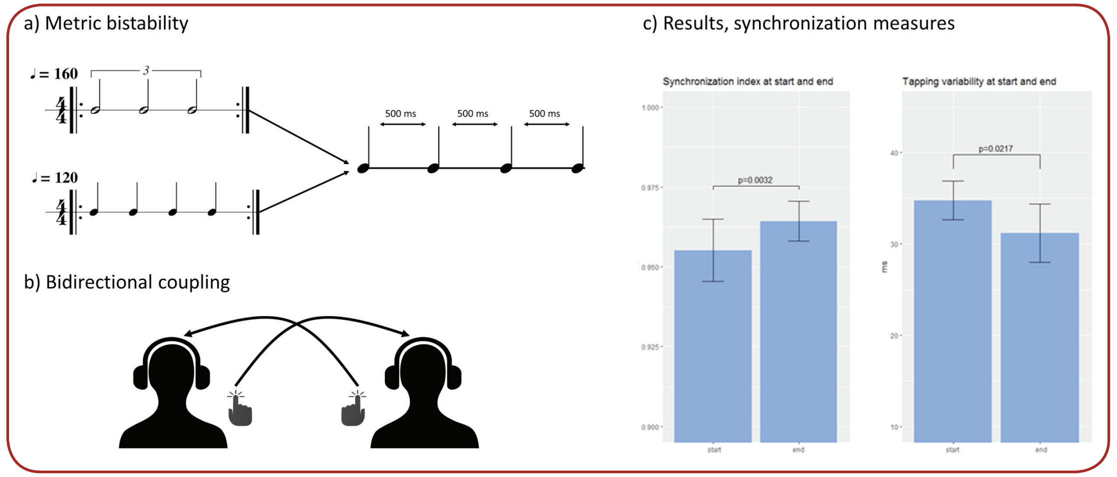

Figure 1. A) Here we use musical notation to show how the triplet of a 3-against-4 rhythm at 160 BPM and a straight 4/4 rhythm at 120 BPM leads to an isochronous sequence of equal inter-tap intervals. In B) we illustrate how the bidirectional coupling works. The participant on the left hears the taps from the participant on the right, and vice-versa. The behavioral results from our study is summarized in C). On the left we see the synchronization index at the start of the trials compared to the end of the trials. On the right we see tapping variability, defined as the standard deviation of the asynchrony.

Since musical interaction relies on musicians holding similar predictive models of the music to be performed, we hypothesized that interactions with a non-shared predictive model would result in a less successful interaction. We measured the interaction in terms of synchronization, using well-established measures, such as the synchronization index (SI) and tapping variability. Furthermore, we expected to see a higher occurrence of the leading/following synchronization strategy in trials with a non-shared predictive model. Twenty-too musicians were included in the study. For further details, see Heggli et. al. 2018[10].

Our results confirmed our first hypothesis. We found that the dyads exhibited a significant decrease in synchronization measures when they had a non-shared predictive model. In these trials, the dyads had reduced synchronization and increased tapping variability in the first 25% of tapping part of the trials compared to the last 25% (see Fig. 1c). Thus, we concluded that while having non-shared predictive models negatively impacts synchronization, the musicians were highly resilient to such effects.

In terms of synchronization strategy, we found no effect of the predictive model. A clustering analysis showed that two subsets consisting of most of the dyads used the mutual adaptation strategy, but a third subset exhibited a strategy that had not been reported before. This subset of participants reached good synchronization, yet showed no directionality in their interaction. The group was predominantly composed of drummers paired with drummers. We named this synchronization strategy “leading/leading”, as it seems that the dyad members both tried to lead the interaction by not adapting to the other. This type of behaviour can be explained by the drummer’s role in normal musical performance, where they are responsible for being the timekeeper of the ensemble, and hence needs to resist too much adaptation to the other musicians[11,12]. Thus, with sufficient skill, these dyads maintain good synchronization without the need to adapt to each other.

To further explore how these synchronization strategies occurs and what could be the underlying cause of such a leading/leading strategy, we decided to use computational modelling. Here, one designs a model and performs simulations which are compared with the experimental results. This way one can establish how different parameters influences the process. We went for a coupled oscillators approach, which has successfully described synchronization behaviour such as fireflies flashing in synchrony or the pacemaker cells in the heart[13]. Our model consisted of two units, each with two oscillators representing the

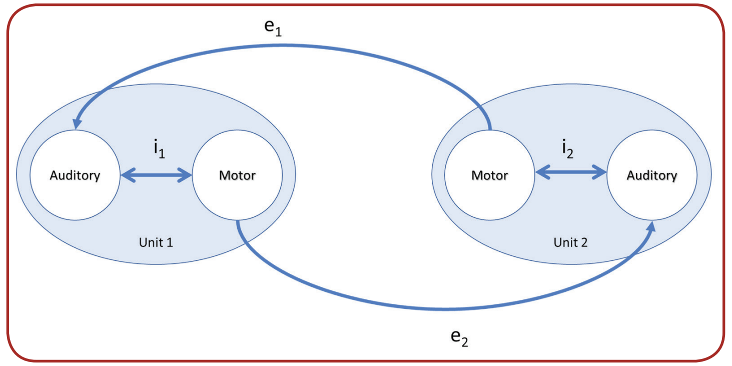

Figure 2. An illustration of the coupled oscillator model. The white circles represent the four oscillators, and the blue ovals the two units. Coupling term i is the within-unit coupling, and coupling term e is the between-unit coupling. Note that only the time series produced by the two motor oscillators are considered for analysis.

main processes of interpersonal synchronization – auditory perception and motor action. We modelled four coupling terms, two within-unit couplings and two between-unit couplings (see Fig. 2). Using the cluster computation facilities at CFIN, we ran simulations of differing coupling strengths and compared the simulation results with the experimental data.

We found that our model provided a good fit with our experimental data, with an average Bhattacharyya coefficient of 0.96. Furthermore, we found that mutual adaptation was defined by the two modelling units having a stronger between-unit coupling than the within-unit coupling. This is in line with recent research suggesting that mutual adaptation requires a downregulation of one's own internal representation of the task at hand[14]. For leading/leading our findings are mirrored, showing a strong within-unit coupling and a much weaker between-unit coupling. This finding is consistent with our behavioural explanation of this strategy, showing that with sufficient expertise synchronization can be stable with a minimal amount of attention spent on monitoring the other[10].

As we also recorded EEG during the experiment, this gave us the opportunity to explore if the two synchronization strategies were reflected in the EEG recordings. We used a recently developed data-driven approach, which aims at identifying recurrent phase coherent networks between brain areas[15]. We found that the musicians exhibiting the leading/leading strategy had a significantly

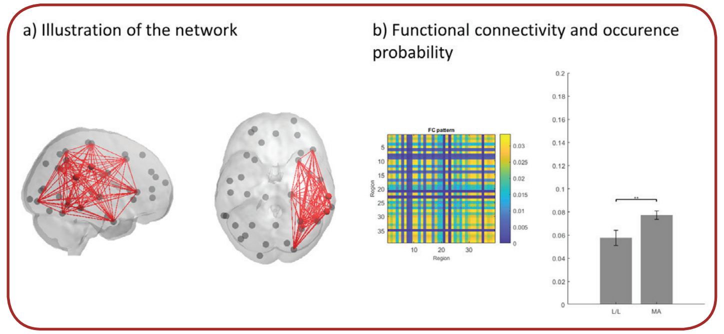

Figure 3 . In A) we see the network exhibiting a differing occurrence probability between the group exhibiting leading/leading and the mutual adaptation group. The network is plotted as red links between its constituent nodes in the brain. In B) the functional connectivity pattern and the occurrence probability of this network is shown.

less occurrence probability of a temporo-parietal network (see Fig. 3). This network consisted primarily of auditory and motor regions, and the temporoparietal junction, an area linked to social processing. This suggest that leading/leading requires less coherence between representations linking one's own model of a task with social information from others.

To summarize, our results show that rhythmic interpersonal synchronization is affected by the predictive models held by its partakers, and that musicians are resilient to negative effects caused by holding non-shared predictive models. In addition, we report the first new synchronization strategy, leading/leading, since Konvalinka and colleagues' seminal work on mutual adaptation in 2010[6]. We furthermore find that rhythmic interpersonal synchronization may be sufficiently modelled using a simple two-unit coupled oscillators model. This model gives us insight into the parameters and processes responsible for the emergence of synchronization strategies, and show that complex rhythmical behaviour may arise from simple components.

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EMOTION

Morten L. Kringelbach

Music can seem different from other pleasures such as coffee or chocolate; not just pleasant but often deeply meaningful[1]. We continue to explore how music is intimately linked to emotion and – to borrow a phrase from Aristotle – eudaimonia, the life well-lived[2, 3]. Crucial to this link is the ability of music of bringing people together as for example found in the vital relationship between infants and caregivers, which we explore in the ERC CAREGIVING project. Importantly, there is emerging evidence that this link can be strengthened through singing as demonstrated in the feature on page 26 by PhD student and singer Maria Dahlstrøm. But it is also clear that there is something within the music itself that can create deep emotion, as for example shown in the research by PhD student Leonardo Bonetti on the effects of listening to Bach.

The research is facilitated by the strong collaborative links between MIB, Oxford and Barcelona, which have allowed us to develop new groundbreaking whole-brain computational models with Prof Gustavo Deco, based at University Pompeu Fabre. As such this enable us to study music with methods from many disciplines, including psychology, neuroscience, physics, engineering and computer science, to create groundbreaking science.

Here we highlight two exciting new findings which have both been published in Nature Communications that draw on these very strengths. First, we present a new exciting method for discovering the 'brain songs' that promotes the fast processing of conscious processing[4]. Second, we have discovered the complex choreography of the sleep cycle. Taken together, these findings provide the necessary novel tools that could be used to reveal the underlying mechanisms by which music can elicit emotion, change lives and contribute to a flourishing life[5].

Brain songs reveal the timescale of conscious processing in the human brain

How quickly do we become conscious of signals in the environment? We show that the human brain has a fundamental timescale of around 200ms where information is optimally broadcast across brain regions (see Fig.1). The question of timescale is a fundamental question in many sciences. As an example, think of the difference between weather and climate, where some experimental data such as rain is measured on the timescale of minutes and hours, while wet seasons are measured on the timescale of months, and climate change on the timescale of decades. Thus, if we are interested in the prediction of rainfall, the relevant timescale of experimental data is over minutes and hours, while measurements taken over, say, seconds, months or years are not particularly helpful.

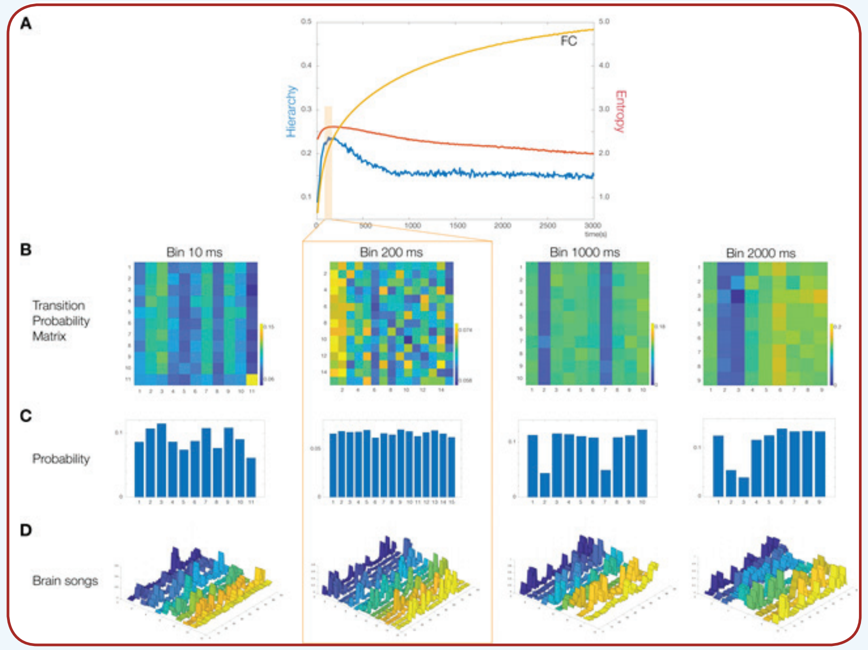

Figure 1. *Brain songs. As can be seen, the brain songs unfolding across the whole brain at a timescale of 200ms exhibit maximal entropy and hierarchy, suggesting that they are optimal for propagating conscious processing.*

In the brain the fast timescale is very important for conscious information processing as proposed by Stan Dehaene and Jean-Pierre Changeux in their very influential global workspace theory[6]. Once information enters the brain, it has quickly to be made available for many regions across the brain in order to be consciously perceived. For instance, a recent study in primates recorded from a few brain regions found that the ignition of visual stimuli is associated with strong sustained activity in prefrontal cortex around 200-250ms when consciously reported by the animal, while this frontal activity was weaker and quickly decayed for unreported stimuli[7].

In a technical tour-de-force, we were able to further significant advances in our understanding of the timescale activity of whole-brain dynamics. This new framework, which we poetically call brain songs, sheds new light on the whole-brain networks involved in broadcasting information at this fast timescale. As such it supports and extends current accounts of when information becomes consciously available in the human brain.

More generally, brain songs could be used to understand why the timescale of conscious processing changes in diseases and as such the new findings could have important implications for understanding changes in neuropsychiatric disease – and perhaps even the nature of consciousness.

The complex choreography of the sleep cycle

In many ways sleep remains a scientific mystery, despite taking up about a third of our lives. The current understanding hinges inseparably on our ability to categorise, and derive patterns from, brain activity. This in turn started in the 1930s when it became possible for the first time to record scalp potentials during sleep using electroencephalography (EEG). This led to the first attempts at describing sleep as a consequence of different brain states. The current consensus reduces human sleep to four stages of rapid-eye movement (REM) and non-REM configurations of

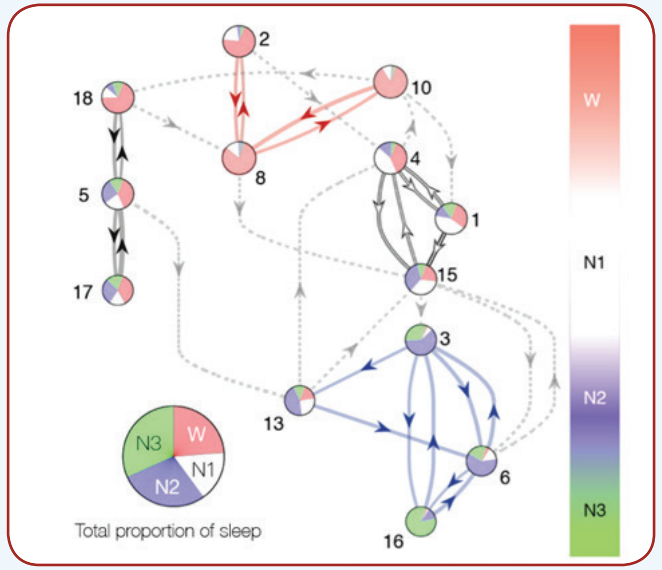

Figure 2. Choreography of the human sleep cycle[5].

brain activity, based on measurements in a few EEG electrodes of frequency and amplitude patterns, many of which were already described in the original studies of the 1930s. In spite of great advances in modern techniques for recording brain activity, tradition has kept our view of brain activity during sleep unnecessarily narrow.

We used functional magnetic resonance imaging recordings to discover more about the complex choreography of sleep and the whole-brain activity underlying the conventional stages of human sleep. Whereas the definitions of the traditional sleep stages routinely rely on expert human observers inspecting traces of EEG and identifying patterns of amplitude and frequency, we instead used a completely data-driven analysis of fMRI data to reveal recurring states of unique configurations of interactions between brain regions and transitions between these, not unlike the choreographies used to describe music and dance (see Fig. 2.).

When comparing these data-driven fMRI states with the conventional EEG sleep stages, the findings show how a higher-resolution picture of brain activity portrays human sleep as vastly more complex than what traditional accounts have suggested. Rather than being reduced to a matter of overall changes in EEG frequencies, we show how the difference between wakefulness and sleep is reflected in large-scale reorganization of brain networks (see Fig. 3). The boundary between wakefulness and sleep, the loss of awareness that we experience every night, has challenged the conventional sleep staging for decades, and the data-driven results confirm that the current definitions are inconsistent. A result that could change the way we understand sleep and not at least the way we approach disorders of sleep, such as insomnia.

Sleep is not just a topic of scientific puzzlement; it represents a vital need for healthy functioning. We still lack a consistent understanding of what happens in the brain when sleep suffers, in conditions such as insomnia but also in psychiatry where sleep disruption is ubiquitously present. It is our hope that a more complete and data-driven representation of whole-brain network changes during sleep can assist in the development of better models of the role of sleep in such disorders.

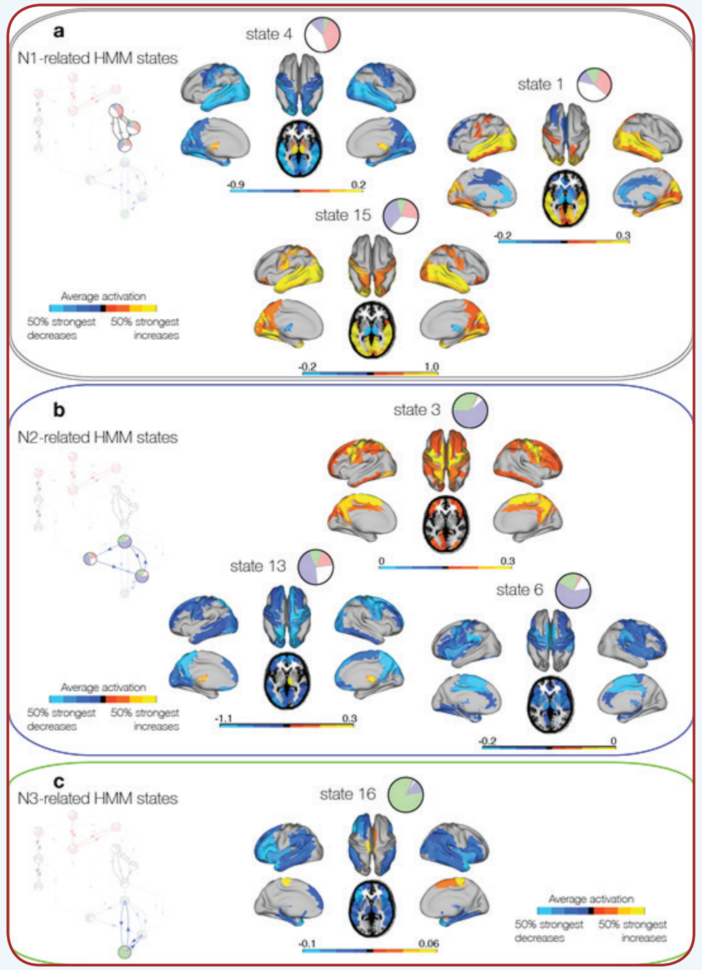

Figure 3. Networks involved in various parts of the sleep cycle.

Continued development of novel methods

We are continuing to develop new methods to study the dynamic effects of music on emotion. In particular we have developed whole-brain computational modelling for revealing the underlying causal brain mechanisms[8]. These developments will help us identify how music evokes emotion and how music can best help emotion regulation. One pertinent finding is the role of music in controlling sleep which can contribute to regulate overall mood in neuropsychiatric disorders.

Overall, careful experimental methods combined with novel analysis methods including connectome-harmonics and causal whole-brain modelling are helping to reveal the brain mechanisms of music and emotion, potentially opening up for new treatments; perhaps even eudaimonia and better lives - especially if coupled with early interventions.

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EMOTION

Learning to sing: potential impact on parental sensitivity

By Marie Dahlstrøm

The parent–infant relation is a highly dynamic and intensely social template of all later human relations. For infants, this dynamic starts with basic orienting and recognition processes and culminates in attaining higher socioemotional and cognitive capacities. This process is shaped by social interactions with primary caregivers, typically parents, who in turn rely on infant signals to guide their interactions. Becoming a parent can be daunting at first, but parent–infant interactions are full of reciprocal influences and each party comes to the task well equipped. Just as infants have excellent attributes and competencies, such as cuteness and crying, that elicit attention and care, parents equally have capacities that facilitate optimal care. To be able to provide this care, at least three ‘parental capacities’ have to develop: a) a focus of attention on the infant and an associated contingent responsiveness; b) emotional scaffolding, especially when the infant is distressed; and c) behavioural sensitivity to attachment cues and mentalisation (i.e., the capacity to treat an infant as a psychological agent[1]. The antecedents to these capacities, particularly attentional focus, are even found in the brain processes of nonparents[2].

Parents are naturally sensitive to the acoustic parameters of the communicative cues from the infant. During parent-infant interaction, musical features such as rhythm, pitch and imitation form a key part of the interaction. The voice of a crying infant is a signal of a need for urgent care. Infant cry elicit caregiver instincts and provide evidence that our brains are designed to respond rapidly, whether parent or non-parent. The urgency in the signal distress is, amongst other signals, expressed in the pitch, which for healthy infants typically is ranging between a fundamental frequency of 200–600 Hz[3].

We are interested in looking at ways of stimulating parents’ perceptual abilities in the auditory and visuals domains, to stimulate parental responsiveness and engagement, in situations where these innate abilities may have been weakened. Given the heightened auditory perception in musicians, the shared acoustic and neural mechanisms between emotion perception and musical engagement[4], and the use of singing for caregiving purposes throughout history (e.g. lullabies and playsongs), I am particularly interesting in focusing on the likely protective mechanisms of the voice.

Musical training provide clear advantages in pitch processing compared to non-musicians[5] and these advantages extend to processing of non-musical information. For example, musicians are better equipped when interpreting emotional intend in speech[6], and in non-speech salient sounds[7].

In previously published MIB studies, musical training was identified as a potential precursor for parental sensitivity, when adults with depression were asked to interpret the level of distress in experimentally manipulated infant cry[8]. Adults with musical training showed enhanced discriminative sensitivity to manipulated changes in distress, compared to adults without.

Parental sensitivity can be disrupted, not only in the auditory domain, but also in the visual and olfactory domains. Some studies evaluating parents’ response to manipulated imagery of infants with medical conditions altering facial structure, such as cleft lip, identified that parents respond differently to imagery of infant faces with abnormalities[9] than to imagery of normative infant faces. In correlational studies, mothers of perceived ‘cute’ children behave more affectionately than mothers with less ‘cute’ children. These findings show that physical features are implicated in our natural caregiving instincts, directing adults attention towards the infant. So, to what extent can these tendencies be manipulated for the better?

MIB research has demonstrated that cuteness can be modified through experience. Parents’ perception of their infant’s temperament play an important role when judging physical features; the happier the infant, the cuter the infant is perceived and the more motivation the adult show to look at the infant[10]. This loop has implications for the contingency in the parent-infant interaction. As mentioned in the beginning, infants look at their parents to match their emotional expression. Therefore, the quality of care is reflected directly in the mood and responsiveness from the parent when communicating with the infant, which often is mediated by the beliefs parents hold about their capabilities of successfully executing parenting tasks.

Emotional intention in the voice is located in the non-verbal subtle elements of communication[11]. Musicians heightened sensitivity to emotion is observed in the functional and structural changes at a cortical level in the brain. Within the functional network, the cortical areas recruited for sensory-motor control of pitch, are sensitive to the amount of voice training one receives. Kleber[12] demonstrated this by showing increased activity within the primary somatosensory cortex as a function of training. This is not surprising, as communication in speech and music rely on visual and auditory cues; both languages (music & speech) requires structuring of phrases, dependent on time, rhythm and pitch in order to convey emotional intention. Therefore, accurate pitch coding is critical for successful human communication.

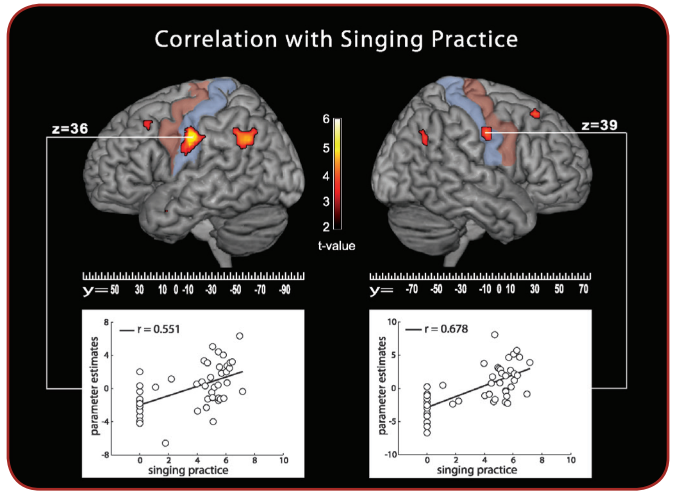

Figure 1. The Control of Vocal Pitch in Human Laryngeal Motor Cortex [12]

Together with an experienced vocal coach and opera singer, I have designed a 10-day voice training intervention, where female adults will attend structured singing lessons specifically designed to improve voice awareness, pitch, range and rhythm, and confidence in singing through group lessons. The vocal coach will guide the participants through a master class, as well as focusing on participants individually.

The progress will be evaluated through a number of tasks to determine training effects on pitch matching and discrimination ability, resonance, rhythm, melody, emotionality & vocal fold movement. This will be achieved by comparing their final performances with their initial performance on a familiar song (e.g happy birthday) and a training song. The test song will be used to analyse the emotionality of the performance before and after the intervention. This will be achieved using the algorithm CUEX[13], designed to extract expressive tone parameters from acoustic signals to objectively analyse recordings of solo performances. The acoustic parameters (e.g. tempo, articulation, onset velocity, spectrum, vibrato) of each tone can predict the expressive intentions of the performer, as the audio is segmented into tones on the basis of fundamental frequency contour & volume envelope.

Secondly, I will be measuring the closed quotient (CQ) via an electrolaryngography whilst the participants sing on vowels. Lastly, I will be using the Musical Ear Test (MET)[14] to evaluate musical competence in rhythm and melody.

The second part of my research seeks to identify if voice training, achieved through the intervention, will effect parental understanding of infant communicative cues in an at-risk cohort of new mothers with insomnia. Sleep deprivation is linked to new mothers experiencing depressive symptoms[15] and can greatly influence the ability to process emotional information[16], critical for a healthy dyadic mother-infant interaction. This will be achieved by exposing participants to two behavioural paradigms a) an probabilistic infant social reward task[10] based on a commonly used learning paradigm[17] and b) novel baby morph task developed by MIB PhD student Nadia Høgholt, before and after having taken part in the voice intervention. Both paradigms include

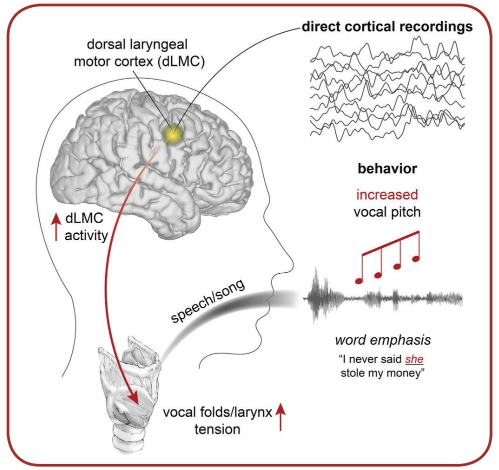

Figure 2. Singing related activation, correlated with the amount of accumulated singing training[12].

experimentally manipulated changing infant vocalisations and facial expression.

Based on the evidence discussed, highlighting the likely protective mechanisms of musical engagement, we predict that voice training may stimulate parental sensitivity in new mothers.

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LEARNING

Elvira Brattico

The grasshopper and the ant

In 2018, the Learning strand of MIB grew to maturity. Our studies in children and adults reveal how predictive processes related to perception, emotion and action in music are continuously updated after exposure to new sounds over different temporal courses, from seconds up to an entire life. From Aesop's fable the epicurean grasshopper spending her summer singing is a metaphor for immediate learning and enjoying of music during ongoing listening, whereas the clever ant storing provisions for the winter is a symbol for months- or years-long musical training.

The grasshopper: Listening in the present moment

While listening to music we are exposed to thousands of sounds succeeding each other with various acoustic parameters, such as timbre, durations, loudness, pitch and so on. In spite of this richness and complexity we are able to make sense of these sounds by extracting salient features, learning the repetitive patterns, and forming memories of them that are used to predict the incoming sounds. MIB wanted to tackle the neural activity and communication enabling us to memorize and make sense of sounds during the course of listening.

PhD student Leonardo Bonetti used magnetoencephalography (MEG) to study 70 healthy participants while they listened to a whole Prelude by J.S. Bach and later recognised short excerpts of it interspersed among novel Bach-like excerpts (see Fig. 1). Results evidenced a stable integrated network during Bach recognition in the alpha band connecting auditory regions with hippocampal and inferofrontal areas.

The ant: Storing a new skill and making use of it

Learning to play a musical instrument is a lifelong process entailing many skills: fine-motoric, perceptual, interoceptive, social and even emotional. It is not without reason that, when the famous cellist Pablo Casals was asked why he continued to practice at age 90, he replied "Because I think I'm making progress". MIB unveils how and where these skills are stored in the brain, how they are used in daily life, and how they affect our behavior and well-being.

Our latest findings on music experts are exciting[1-5]. From a meta-analysis of 21 neuroanatomy studies including 1221 participants[6], we identified neural signatures of musical expertise in focal brain structures involved in audition, fine movement and bimanual coordination control. Moreover, we refined the view on predictive coding processes in the auditory cortex by discerning priors derived from active vs. passive experience (see page 34)[5]. All these neural differences are mirrored in behavior. In 106 adults, we found a clear relation

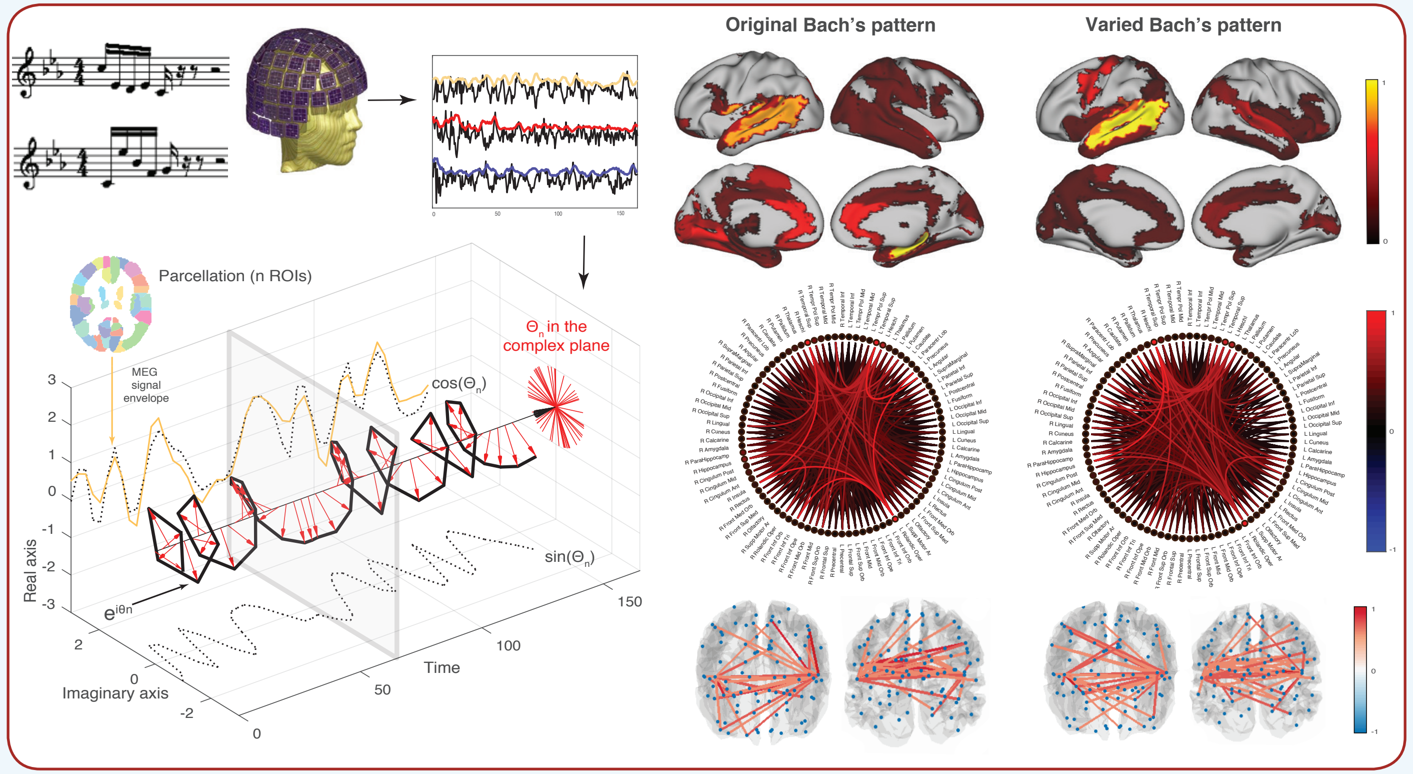

Figure 1. Left. Representation of the MEG raw data reconstructed in source space and then converted into analytic signals by applying the Hilbert transform. Right. Representation of the most central areas within the whole-brain network and their connections for original and varied musical sequences. The brain areas are depicted in brain layouts and schemaball graph.

between musical training and general intelligence, and between the duration of such training and attentional skills[7].

PhD students Maria Celeste Fasano and Pauline Cantou successfully completed data collection for challenging longitudinal studies with school-age children and a new longitudinal study is initiated with RAMA students (see page 37). The first longitudinal study, conducted with 113 Italian children (8-10 y.o.) showed that only those who attended three months of intensive orchestral training (El Sistema-inspired) including a final concert (see Fig. 2) – but not the control children - reduced their impulsive behaviors[8].

Other two longitudinal studies were conducted with around 50 Danish early adolescent children (10-13 y.o.) learning to play the violin, the guitar or the piano, and included psychological questionnaires, behavioral tests and neuroimaging recordings. Our first exciting

Figure 2. The final performance of the children orchestra at the end of the school year in a theatre. The children here took part in our study showing improvements in inhibitory control and reduction of impulsivity[8] (musicaingiocobari.wordpress.com).

finding concerns the communication patterns within orbitofrontal regions happening in children's brains while they listen to pleasurable music (see Fig. 3). Next step is to examine whether these neural communication patterns in early adolescents predict the outcome of learning a musical instrument.

The moral clause: Personality, intelligence and brain physiology matter

It was the coming of winter, though, that

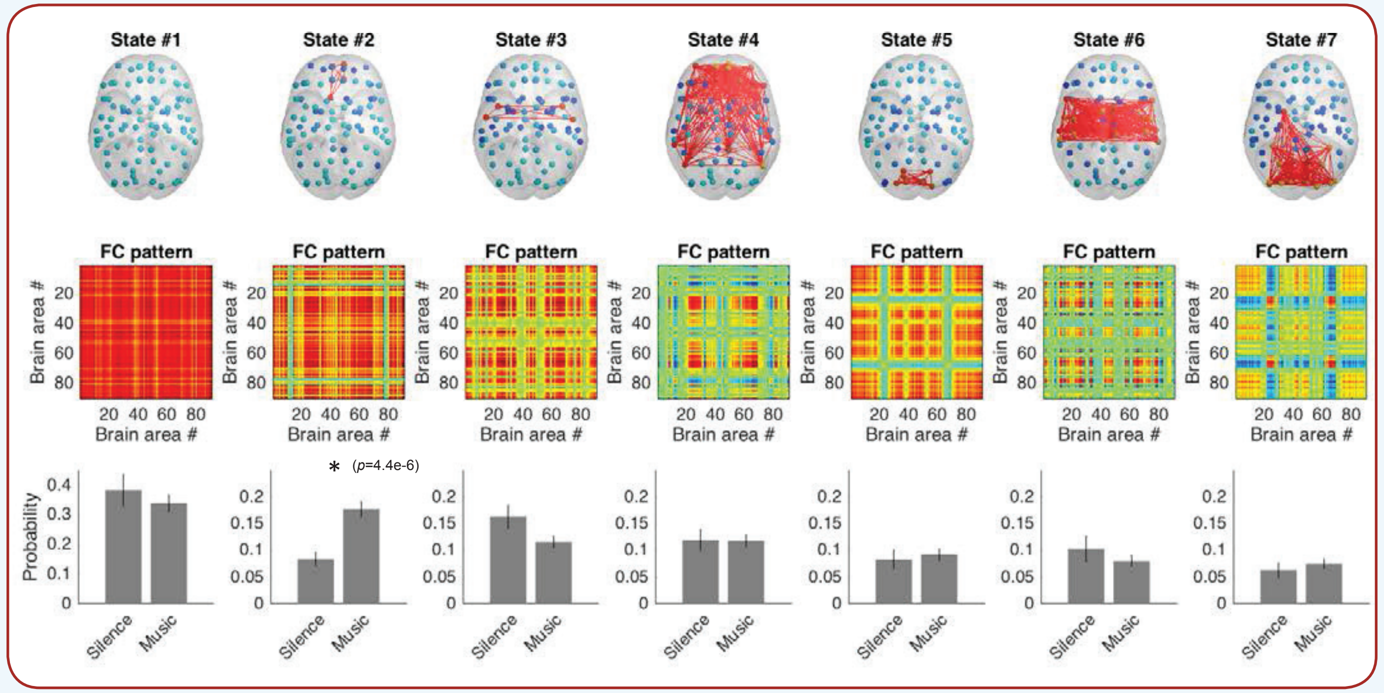

Figure 3. Top – The spheres are plotted at the center of gravity of each brain area and colored so that lighter and darker colors show stronger and weaker phase coherence, respectively, within the positive (yellow-red) vs the negative (cyan-blue) communities. Middle – Each NxN matrix represents a recurrent dominant phase coherence pattern. Bottom – Probability of each functional connectivity state in each experimental condition (music and silence), with asterisks (*) denoting statistical significance with p < 0.05/k in the probability of occurrence between conditions. Only one state (2) involving the orbitofrontal cortex shows significant difference in probability between music and silence.

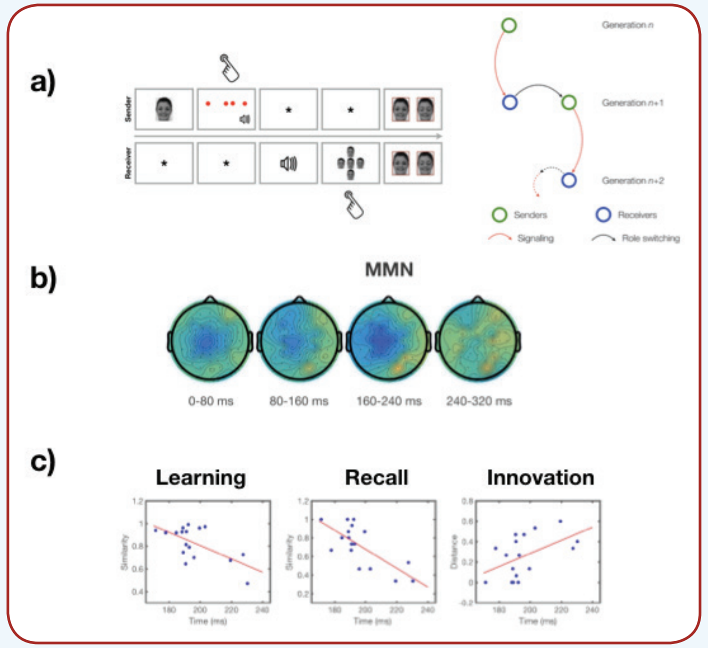

Figure 4. Left: a trial example of signalling games[10]: the sender composes rhythm sequences and signals the receiver about the emotion he sees on the screen, then the receiver selects one of the five emotions, the one s/he thinks the sender has seen. A feedback follows on both screens. Right: design structure of transmission, illustrating how the receiver in one game (blu circle) turns role into sender in the next game (green circle). B) Scalp topography of MMN responses to temporal deviations of rhythm patterns in four 80-ms windows. C) Correlations between rhythm MMN latencies and indexes of rhythmic learning and recall. MMN latencies recorded on day 1 could predict measures of learning, recall, and innovation in the signalling game on day 2.

taught the lesson to both the grasshopper and the ant: learning depends on the initial conditions of the individual. The functional properties of the human brain affect personality traits[9], noise sensitivity[9], and cognitive abilities[1], and these in turn modulate music perception and learning[11]. For instance, auditory-cortex functionality predicts how well participants learn and recall rhythmic patterns over the course of an experimental session[10] (see Fig. 4).

The implications and applications of our research on individual sound-related dispositions can lead to beneficial outcomes, such as the possibility to identify musical predispositions in a pedagogical setting, or to provide some forms of training or remediation for individuals with percepto-cognitive difficulties in a rehabilitative setting.

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LEARNING

Neural encoding of music across musical backgrounds

By Marina Kliuchko

Professional musicians spend a substantial amount of hours focusing their attention on music, studying its theory and mastering the performance. This active engagement with music increases the accuracy with which the musician's brain is able to predict the upcoming events in a musical stream and generate stronger error signals if a violation of a prediction occurs. However, it is not only musicians but nearly all people in modern days are surrounded with music daily and engage with it on various levels spanning from passive exposure and casual listening to having music as their hobby or passion. In our two studies, we asked how auditory predictions are modulated by the level and nature of engagement with music and what we can learn about the process of forming the auditory priors from amateur music enthusiasts.

First, using the no-standard multifeature mismatch negativity (MMN) paradigm[1] we showed that not only professional musicians have stronger error responses to deviant notes than non-musicians, as indexed by MMN (see Fig. 1), but that their auditory priors are shaped in a specific manner depending on the musical style they are trained and perform in[2]. As such, the greatest ability to discriminate rapid changes in music was observed in jazz musicians, whose improvisational music tradition requires to quickly evaluate and respond in an interactive manner to the music produced by others. Yet, laypersons who like jazz music and are familiar with it show smaller MMN responses for sliding pitch (a sound feature commonly present in jazz music), higher the preference for jazz they reported (see Fig. 2). These findings suggest that the active practicing of a musical style and formal knowledge of its stylistic features is crucial for developing accurate predictions of the musical sound, in contrast to mostly listening experience with it.

In another study[3], we used the melodic multifeature MMN paradigm[4] consisting of short melodies with deviants representing simple acoustic features (e.g., timbre) and features related to preceding context and musical knowledge (e.g. out of key). We found that amateur musicians showed advantages over non-musicians in neural processing of essential music features, such as mistuned sounds and change of a musical key (see fig 3). However, in non-professional music players who reported to still practice music, the MMN to mistuned sounds is indistinct of that in professional musicians while those who had only played music in the past demonstrated comparable MMN to that of non-musicians. Thus, ongoing musical practice makes a difference for the accuracy of neuronal discrimination of mistuned sounds. Besides, P3a response – a component thought to reflect involuntary switch of attention – elicited to the melody transposition differentiates professional musicians from amateur players in addition to MMN (see Fig. 3). This advocates for facilitated processing of the key change in professional musicians, and that this musical event has higher importance to them than to the other groups since it was catching musicians' involuntary attention.

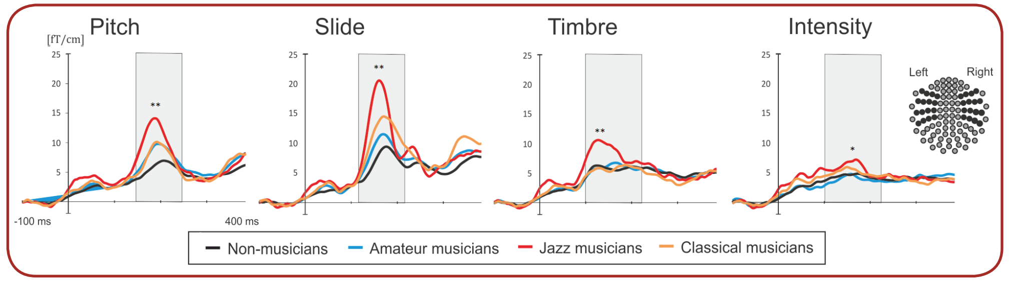

Figure 1. *Jazz musicians show an overall higher MMN than non-musicians and amateurs with the most apparent enhancements seen for spectral features, such as timbre, pitch and pitch slide, as well as sound intensity[2].*

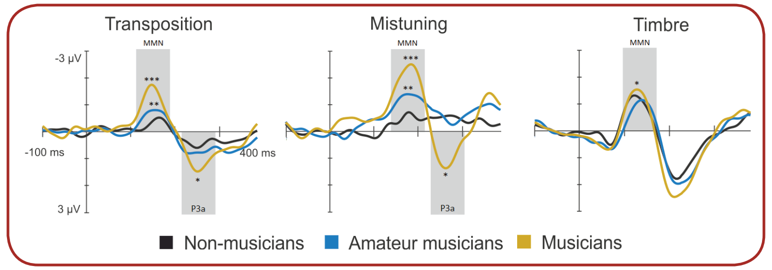

Figure 3. *Enhanced music-sound encoding in musicians as compared to non-musicians is manifested in MMN and P3a responses to mistuning, timber and transposition deviants[3].*

Taking a step away from the role of musical training, learning the rules on which music is built happens also implicitly, meaning that the knowledge about the musical structure and its conventions (e.g., for rhythm patterns[5]) is acquired in an unintended way without an exact understanding of what is being learnt[6]. This year in MIB we initiated a project that investigates how exposure to the tonal regularities of either Western or Chinese musical cultures[7] that utilize different tonal scales influences pitch prediction in the brain.

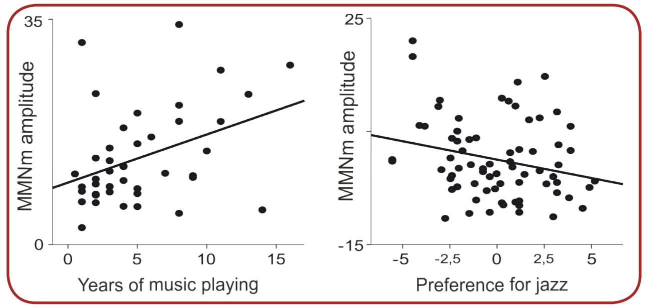

Figure 2. *In subjects without professional musical background, MMN to sliding pitch increases as a function of years of music playing experience, however, their preference for jazz music (familiarity and liking) negatively correlates with the MMN strength[2].*

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LEARNING

Tracking the beat in behaviour and brain - and over time

By Manon Grube

Rhythm is inherent to music and speech. While music typically has a clear metrical beat and speech a less clear “pseudo-regular” one, both rely critically on our rhythmic timing skills. This line of research looks at rhythm perception, links to language skill, underlying brain mechanisms, and effects of musical training, in adolescence and early adulthood. The relevant measures of rhythm perception are illustrated in Fig. 1 a,b,c.

Links between rhythm and language

In a series of school-based studies with the Newcastle Auditory Group, we previously established a prominent correlation with language skill for our basic rhythm task (see Fig. 1a) in 234 early adolescents[1,2] (age 12; see Fig. 1d). Consecutive work in mid-adolescents (age 14) demonstrated an emerging correlation for the more abstract regularity task (see Fig. 1c), toward that seen in adults[3,4]. For the more musical metrical task (see Fig. 1b) the link was slightly weaker. In sum, the observed correlations support rhythmic regularity to be a shared relevant feature of music and language, with promising potential for future rehabilitative training programs against language disorders.

Looking for the beat in the brain

One structure that has been reported active and critical in rhythm is the cerebellum: an ancient part in the back of the brain. A first MRI study carried out in 42 early-adolescents yielded a significant correlation in cerebellar grey-matter[5] specifically for the performance on the basic and most language-relevant rhythm task (see Fig. 1e).

In search for the “feeling of the beat”, EEG work presented metrical rhythms to non-musicians. Even in their “naïve” brains we found evidence of subconscious entrainment with the beat[6], consistent with Assistant Prof Massimo Lumaca’s recent MMN study[7], and the predictive encoding of rhythm[8]. These brain responses are indicators but not the core mechanism of entrainment with the beat.

A participant in the MEG.

Photo: Manon Grube

One candidate for the neural origin of “feeling the beat” is oscillatory brain activity, known to entrain with a regular beat[9]. In on-going analyses of existing EEG data and newly acquired MEG data, we aim to decode the activity of sources whose activity entrains

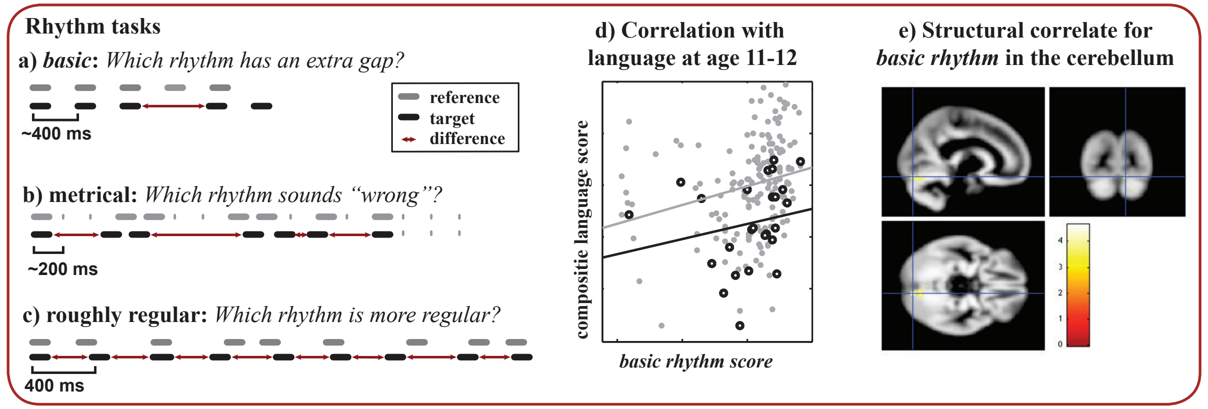

Figure 1. Three rhythm tasks[1]: a) basic: detecting a deviation in short 5-tone sequences with a perfectly regular beat; b) musical: detecting a perturbation in 7-tone sequences with a metrical beat; c) speech-oriented: detecting a roughly regular beat in longer sequences. d) Correlation with language skill in typically developing 11-12-year olds (grey)[1] and those with dyslexic traits (black)[2]. e) Structural brain correlate for the basic rhythm task in a subgroup of 42 ($p<.05$, FWE corrected)[3]

with the beat and test their relevance to perception, using customized algorithms from the TU Berlin Machine Learning Group[10].

Following the beat into the future

Together with Prof Brattico, PhD student Leonardo Bonetti and postdoc Marina Kliuchko, we initiated a set of studies where we record the MEG of RAMA students at the start of their course and again after one year. Our goal is to examine the effects of expert musical training on beat-based entrainment processes as well as on predictive processing of melody, in a longitudinal approach that enables us to address the question of causality.

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COMPUTATIONAL MODELLING

Marcus Pearce

Testing computational models of music cognition

Computational modelling is not a new theme within the Center for Music in the Brain (MIB). Predictive coding, which forms a central part of the underlying approach taken within the centre, is based on a mathematical model of perceptual inference, implemented in cortical layers[1]. Whole-brain connectome analysis uses graph theory to understand dynamic connectivity between brain regions in functional or anatomical MRI data[2]. However, until recently, research within MIB had not incorporated computational models of music cognition on a large scale to generate and test hypotheses about neural processing of music.

IDyOM[3,4] is a computational model of auditory expectation which uses statistical learning to acquire knowledge about the syntactic structure of music and uses this knowledge to generate probabilistic predictions for the notes in any given piece of music. IDyOM reflects a number of characteristics of human perception of music. First, it bases its predictions on both long-term exposure to music in a given style and local structure learned while listening to an individual piece of music. Second, its predictions are based on the likelihood of different continuations of a piece of music, taking into account the preceding musical context. Third, it is able to represent and predict both pitch and timing of musical events and, in doing so, can draw on representations of multiple different aspects of music, such as pitch interval, pitch chroma, scale degree and contour. As a model of human cognition, IDyOM suggests several different testable hypotheses about music perception. While previous research has focused on behavioural evaluation of the model, recent work at MIB has begun to use neuroimaging, MEG in particular, as a way of testing three of the hypotheses suggested by IDyOM.

First, on the basis of general predictive coding theory, we would hypothesise reduced prediction error responses in unpredictable contexts. PhD student David Quiroga-Martinez has tested this hypothesis by constructing stimuli with varying alphabet sizes and degrees of predictable structure[5]. IDyOM was used to confirm that the stimuli indeed differed in terms of pitch predictability (information content, the negative log probability) and uncertainty (entropy, the expected value of the information content over all possible continuations). The results of an MEG study showed that the amplitude of the MMN was reduced in the high-entropy compared to low-entropy condition but only for pitch and slide deviants, not for amplitude and timbre deviants. A separate behavioural study was run examining deviance detection in stimuli covering a more complete range of entropy levels (5 vs 2) and

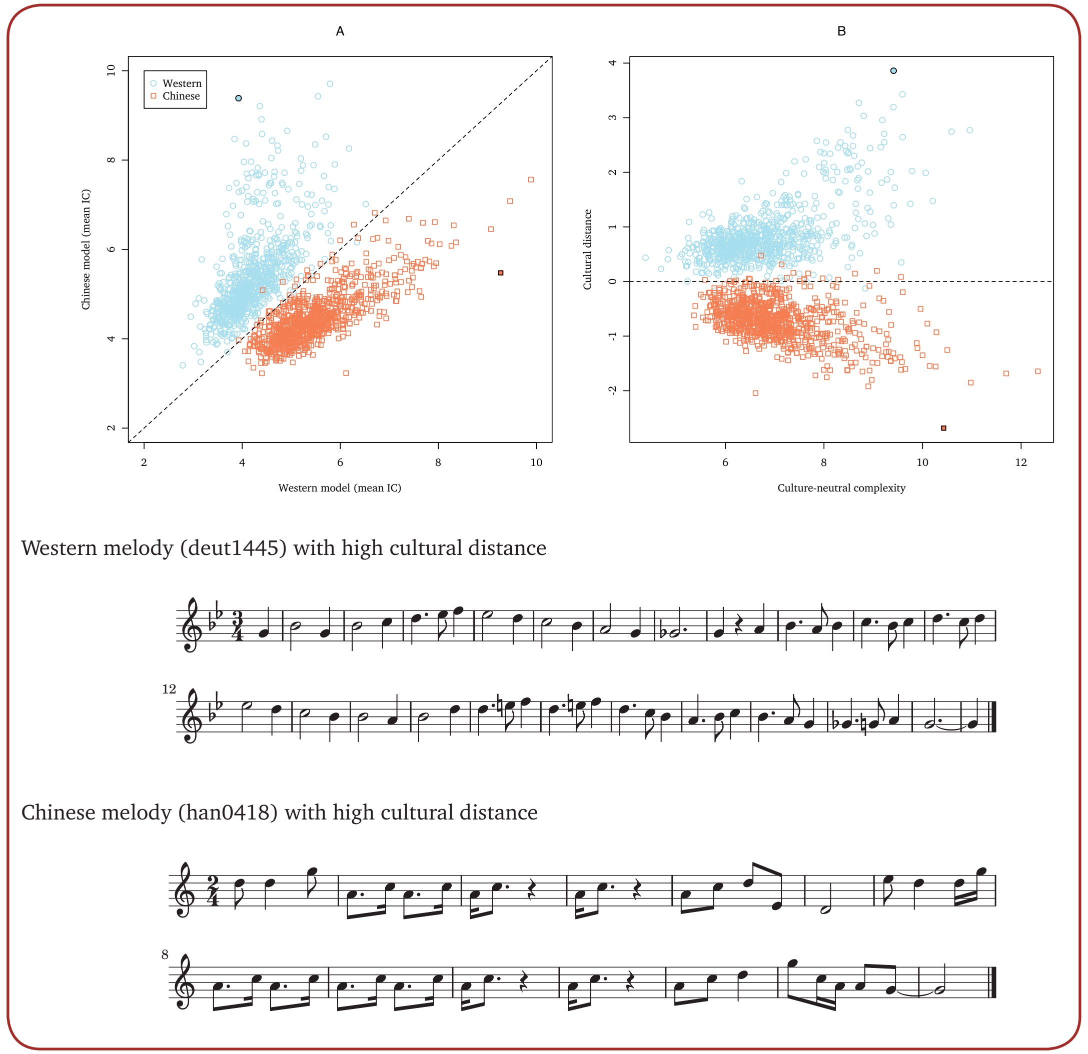

Figure 1. Simulating cultural distance between Western and Chinese listeners. A: the information content of the Western model plotted against that of the Chinese model with the line of equality shown. B: a 45˚ rotation of A such that the ordinate represents cultural distance and the abscissa culture-neutral complexity. For each style, the composition with most extreme cultural distance is highlighted and corresponding musical scores are shown for these two melodies. The Western corpus consists of 769 German folk songs from the Essen Folk Song Collection (datasets fink *and* erk*). The Chinese corpus consists of 858 Chinese folk songs from the Essen Folk Song Collection (datasets* han *and* natmin*). In a prior step, duplicate compositions were removed from the full datasets using a conservative procedure that considers two compositions duplicates if they share the same opening four melodic pitch intervals regardless of rhythm. IDyOM is configured to predict pitch with an attribute linking pitch interval with scale degree and onset with the ioi-ratio attribute using the long-term model only trained on the Western and Chinese corpora respectively for the Western and Chinese models. Reproduced from Pearce (2018, Figure 4).*

importantly controlling for alphabet size amongst the middle levels. The results indicated reduced accuracy and confidence for deviance detection in conditions with greater entropy. Finally, an analysis of non-deviant notes in the MEG data allowed a replication of a previous EEG study[6] showing that information content parametrically modulates the amplitude of the N1 component, with no difference apparent between musicians and non-musicians (see page 10).

Second, we hypothesise that more stylistically unpredictable stimuli should be more difficult to retain in memory. PhD student Leonardo Bonetti ran an MEG study to investigate this question that used the C major and C minor preludes from the Well-tempered Clavier by J. S. Bach and a non-tonal version of the C major prelude in which the pitches had been remapped. Pianists, non-pianist musicians and non-musicians listened to these three pieces four times each before undertaking a recognition memory paradigm in which excerpts were presented alongside foils. The results showed a characteristic neural signature in temporal sensors corresponding to recognition of familiar musical phrases, with a peak about 1 s after the beginning of the phrase. Preliminary analysis suggests that the amplitude of this peak may be greater for high information content phrases, especially in the left hemisphere. These phrases are stylistically unpredictable, which may increase their salience within the piece and therefore make them easier to remember.

Third, if human perception of music is based on structural knowledge of musical styles derived from statistical learning, we would expect to observe characteristic differences in perception between listeners enculturated in different musical styles.[7] IDyOM can be used to predict these differences by training models on two different musical styles and then plotting the unpredictability of music in the two styles for one model against the other, as shown in Figure 1. This yields a measure of cultural distance such that pieces with high cultural distance in one style are very stylistically extreme relative to the other style. Pieces with high incongruent cultural distance should be difficult to process for listeners not enculturated in the style while pieces with lower cultural distance or high congruent cultural distance should be easier for listeners to process. Postdoc Marina Kliuchko is running an MEG project to test this hypothesis using Western and Chinese participants listening to Western and Chinese folksongs selected for low and high cultural distance using IDyOM. Data collection is nearly complete but results from this project are not yet available to share.

These projects serve two scientific ends. First, they establish neuroscientific evidence for a computational model of music cognition based on statistical learning and probabilistic prediction. Such evidence complements existing behavioural research using neural signatures that may be more sensitive and less influenced by subjective bias than behavioural ratings. Second, this research furthers our understanding of how the brain processes musical events dynamically in time, learning online models of musical structure and generating expectations based on prior experience over a range of timescales.

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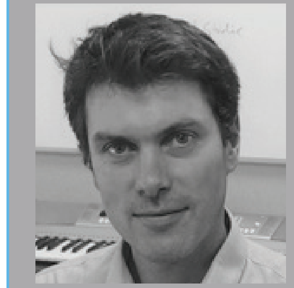
NEW FACE AT MIB



Marcus Pearce was appointed professor of cognitive neuroscience at Aarhus University in 2018. Educated in experimental psychology and artificial intelligence at Oxford and Edinburgh, Marcus received his PhD from City, University of London in 2005, before continuing as a post-doctoral research fellow at Goldsmiths and University College London. Before joining MIB, he was Senior Lecturer in Sound and Music Processing at Queen Mary University of London where he was leader of the Music Cognition Lab, director of the EEG Laboratory and co-director of the cross-faculty Centre for Mind in Society.
His research interests cover computational, psychological and neuroscientific aspects of music cognition, with a particular focus on dynamic, predictive processing of melodic, rhythmic and harmonic structure, and its impact on emotional and aesthetic experience. He is the author of the IDyOM model of auditory expectation based on statistical learning and probabilistic prediction.

CLINICAL APPLICATIONS OF MUSIC

Kira Vibe Jespersen

The potential benefits of using music for healthcare purposes are receiving increasing attention in society. The media tells promising stories, and there is a growing interest in implementing music interventions in both the private and public sector.

At MIB we aim to contribute with state-of-the-art research to ensure evidence based use of music in health care settings. We thoroughly evaluate potential music interventions and use our basic research skills to assess the mechanism involved to further increase our knowledge on when and why clinical applications of music may be useful.

In 2018, a number of MIB studies evaluated the effect of carefully designed music interventions. Dr Margrethe Langer Bro completed her PhD project on live and recorded music for reducing anxiety during chemotherapy in collaboration with Prof Peter Vuust. Interestingly, the results suggest a 7% reduction of anxiety in patients listening to preferred live music, but no effect of pre-recorded music[1].

Similarly, PhD student Mette Kaasgaard is conducting an extensive randomized controlled trial to assess if persons with Chronic Obstructive Pulmonary Disease can benefit equally well from group singing compared to standard physiotherapy for improving physical and psychosocial measures.

The project involves patients from 11 municipalities, and the last of the 300 participants were recruited in January 2019.

Another clinical trial was conducted by postdoc Kira Vibe Jespersen in collaboration with researchers from the Danish Technical University. The aim was to assess the feasibility and effect of using bedtime music for improving sleep problems in elderly persons with dementia. The project was funded by Innovationsfonden and involved collaborations with the Municipality of Struer and a number of private companies contributing with equipment and music for the study. The results were presented at a national Sound and Health conference in Aarhus in November, and they showed that the music was very well liked by the participants, and around half of them showed improvements in sleep[2].

A patient is listening to live music during chemotherapy

Music for sleep improvement is also part of Nadia Flensted Høgholt's PhD project. She focuses on pregnancy related insomnia, and music may be an important tool for improving sleep in pregnant women, as pregnancy-related insomnia is a risk factor for developing post-natal depression and thus, alleviating insomnia symptoms is important for optimizing caregiving skills[3].

In addition to evaluating the effects of music interventions, MIB researchers are also working on disentangling the different mechanisms involved to better understand how music may be beneficial in different clinical domains. PhD student Sigrid Juhl Lunde from the Department of Psychology is looking into the mechanisms behind the pain relieving effects of music. In a recent review, she and her collaborators Prof Lene Vase, Dr Eduardo Garza-Villareal and Prof Peter Vuust discuss how both music and non-music specific factors may explain music-induced analgesia[4].

In addition, Dr Ana Zamorano and Assistant Prof Boris Kleber have initiated a project to investigate the effects of musical training on pain processing in collaboration with Center for Neuroplasticity and Pain, Aalborg University. The aim of the project is to understand the role of biological factors associated with sensorimotor training that may lead to alteration of pain processing in musicians. Music has also been proposed as a beneficial tool in the rehabilitation of movement disorders, such as Parkinson's Disease (PD). The mechanisms involved in the putative effect of music on PD are investigated by PhD student Victor Pando-Naude using neuroimaging methods to assess how rhythmic complexity, movement and pleasure are related in PD (see page 46).

Similarly, Assistant Prof Bjørn Petersen and his MIB collaborators have many years of expertise in researching the auditory rehabilitation of patients who receive a cochlear implant (CI). For this purpose they use both behavioral and EEG methods to understand the basis of music appreciation in CI users (see page 50).

MIB researchers also consider perceptual alterations in persons with autism spectrum disorder (ASD). PhD student Rasmine Holm Mogensen is investigating the association between sensorimotor abilities and social interaction skills in children with ASD in collaboration

The interactive musical sensory device.

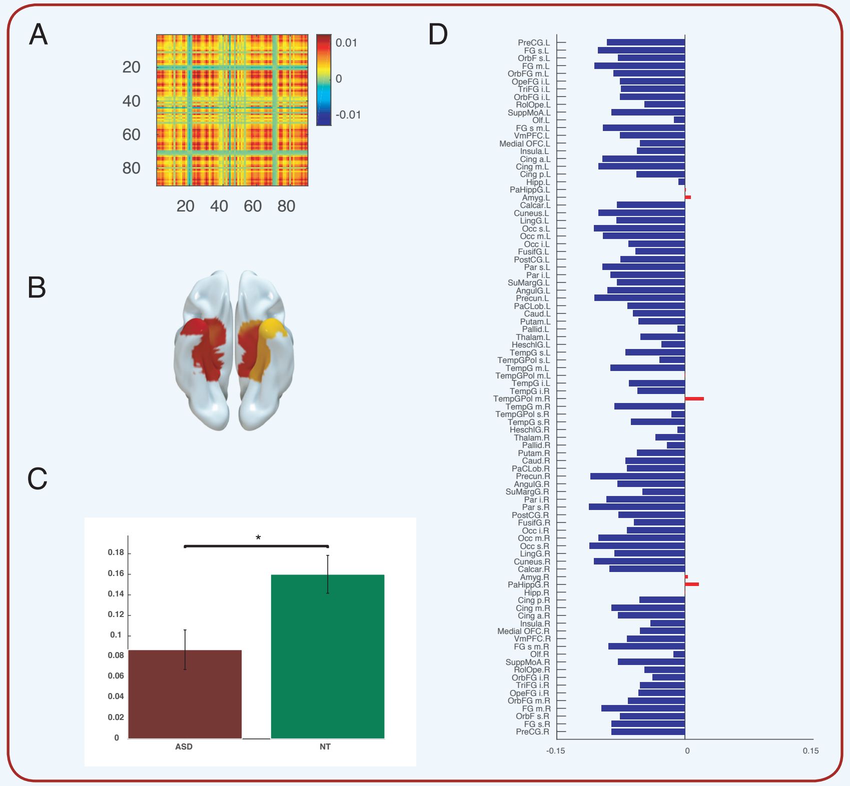


Figure 1.The dynamic repertoire of FC states is altered in ASD compared to NT, during the listening of familiar music. A) The whole-brain FC pattern for State 3, represented as a matrix with 90 AAL brain areas, is accompanied by the correspondent B) 3D brain axial view of the functional network forming the cluster centroid vector (Vc). C) The bar plot shows that the probability of occurrence of State 3, while listening to familiar music, is significantly altered (p<0.05) in ASD compared to NT. D) The horizontal bar plot represents the contributions of each AAL brain region to the FC state of interest (Vc(n)>0 in red, blue otherwise).

with Associate Prof Line Gebauer. Rasmine also collaborates with e-composer Clara Chill from the Royal Academy of Music who is working on the development of an interactive musical sensory device (based on technology by inmutouch) specially for individuals with ASD that is currently being tested in a pilot study.

In addition, PhD student Patricia Da Mota explores the neural dynamics underlying music perception in ASD compared to matched controls (NT). Using a leading eigenvector dynamics analysis (LEiDA)5, she recently discovered that when listening to familiar music, a brain network comprising limbic and paralimbic areas (amygdala, hippocampus, parahipocampal gyrus, and temporal lobe) had significantly higher probability of occurrence in NT compared to ASD (fig 1)[6].

All these studies represent examples of how MIB researchers contribute to a better understanding of how music may be beneficial for different patient groups and thereby improve the existing evidence base for music interventions.

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VISIT BY MINISTER FOR HEALTH

Friday March 23, we were proud to host Ellen Trane Nørby, Minister for Health who was very interested in hearing about our research. Trane Nørby, who was accompanied by Anders Kühnau, Chairman of the Regional Council in Central Denmark Region, first heard short talks by Prof Peter Vuust, Assistant Prof Bjørn Petersen, Prof Morten Kringelbach and Prof Leif Østergaard. Afterwards Prof Elvira Brattico gave our guests a tour in the lab to see some "live" research.

From left: Anders Kühnau, Elvira Brattico, Ellen Trane Nørby and Peter Vuust.

PhD student Ole Heggli demonstrates his EEG study.

Ellen Trane Nørby is listening to the pitch shift of a subject being scanned in the 3T MRI scanner. PhD student Davide Ligato is explaining his project that investigates how the perceptual system interacts with the motor system to control vocal production.

PhD student David Quiroga is talking about his project that combines MEG and MRI to understand when and where in the brain musicians and nonmusians process different musical features

Photos: Lars Kruse, AU Foto

CLINICAL APPLICATIONS OF MUSIC

Victor Pando-Naude

Musical rhythm and pleasure in Parkinson's disease

Parkinson's disease (PD) is a neurological condition resulting from dopaminergic dysfunctions in the basal ganglia (BG) of the brain, with devastating consequences for motor and cognitive functioning. The most common type of parkinsonism syndrome is the idiopathic presentation of PD, affecting 1-2 per 1000 of the world population at any time, increasing its prevalence with age, affecting 1% of the population above 60 years[1]. The BG is an organized network, in which different areas activate for specific functions, such as movement control, associative learning, working memory, planning, and emotion[2] (see Fig. 1). Thus, dopamine loss in this system promotes not only movement disorders, but also cognitive and emotional deficits such as depression, attentional dysfunction, reward deficiencies, and dementia rising to 80% of patients in late stages of the disease[3]. Such dysfunctions involve not only the BG, but key areas such as primary motor cortex, premotor cortex, supplementary motor area, primary somatosensory cortex, prefrontal cortex, thalamus, and cerebellum, as seen in diverse neuroimaging studies[4] (see Fig 2).

The method 'rhythmic auditory cuing' has been shown to improve motor deficits in patients with PD, due to the ability of rhythm to stimulate the basal ganglia[5]. However, this method may be limited by a rather simple rhythmic complexity, and therefore restricting its benefits to the motor domain.

In music, rhythms are patterns of discrete durations that depend on perceptual mechanisms of grouping. Meter refers to the temporal framework to which rhythm is perceived by the brain. Syncopation is a rhythmic structure defined by its violation of metric expectation (see Fig. 3). This form of musical complexity has been related to pleasure and synchronized body-movement, referred to as groove[6].

An inverted U-shaped curve reflects the relationship between subjective experience of a pleasurable desire to move and rhythmic syncopation in music in healthy adults, indicating that listeners prefer medium syncopation, i.e. a balance between rhythmic complexity and metric expectancy violation in music[7]. This relationship seems to comply with the predictive coding theory. At low degree of syncopation, there is little incongruence between the rhythm of the groove (the input to the model) and the meter (the predicted model). At high degree of syncopation, the degree of rhythmic complexity deviates too much from the metric framework causing the model to break down. However, at intermediate degrees of syncopation in groove, the balance between the rhythm and the meter is sufficient to elicit positive affective and embodied responses, yet not so complex as to cause the meter to break down[8].

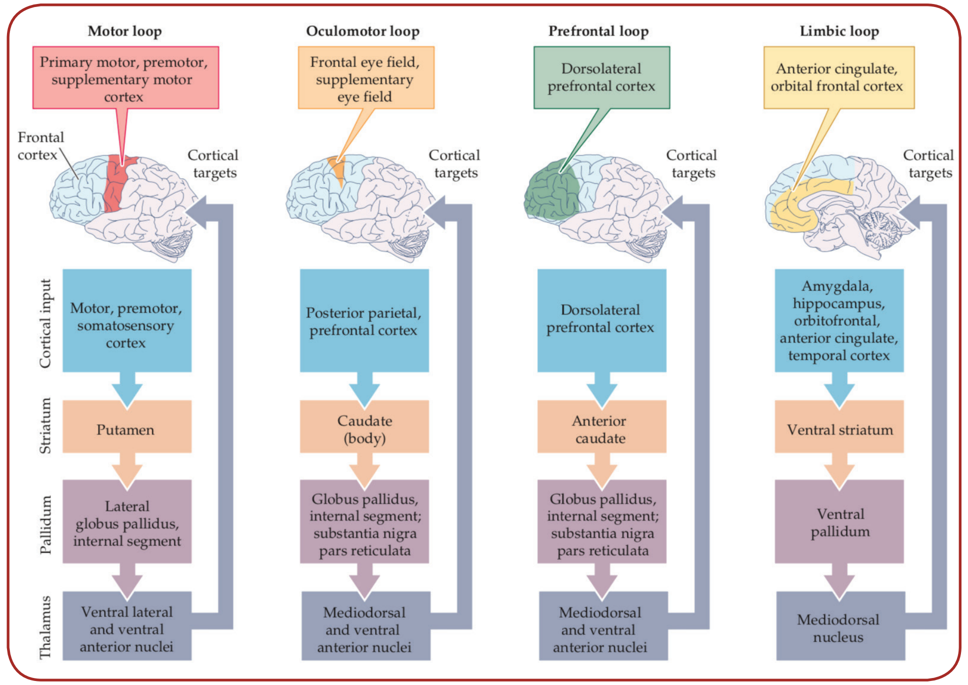

Figure 1. *Basal Ganglia Loops (from Purves, Dale. (Eds.) (©2012) Neuroscience).*

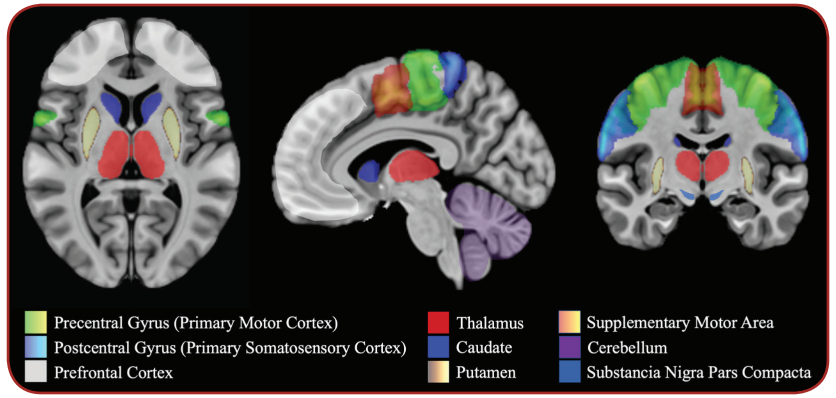

Figure 2. *Affected brain areas in Parkinson's disease (Harvard-Oxford Cortical and Subcortical Structural Atlas).*

Other characteristics of music may impact the experienced pleasurable desire to move, such as harmonic complexity. This music composition strategy creates tension between consonance and dissonance, and it has been shown that listeners also prefer a medium level of harmonic complexity. Although a non-rhythmic factor, harmony may play an important role creating a pleasurable desire to move. Thus, the interaction between syncopated rhythm and harmonic complexity appears to be a key feature of groove[9], giving rise to the "sweet spot" of musical enjoyment.

While healthy adults experience a pleasurable desire to move to stimulating music, we do not know if patients with PD respond in the same way. Does PD affect the pleasure experienced from rhythmically complex music? Can musical complexity be used to treat motor, cognitive and emotional deficiencies in PD, and what level of rhythmic complexity would be most effective?

In our current study, we want to study behavioral differences between patients with PD and healthy controls (HC) when presented with different degrees of musical complexity. We wish to test how rhythmic syncopation in music affects the subjective experience of pleasure and wanting to move in PD patients. Our hypothesis is that patients will not experience as much pleasure and desire to move as healthy controls. In other words, we predict that PD patients will prefer lower musical complexity.

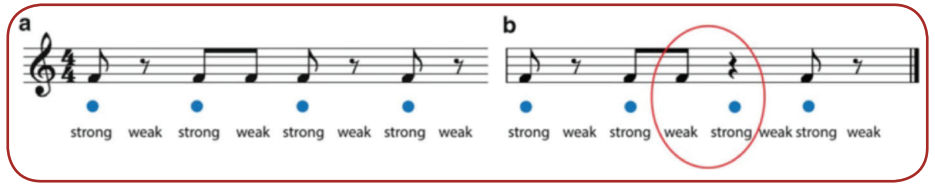

Figure 3. *(a) Pattern with no syncopation. (b) Pattern with syncopation, in red circle. Blue dots designate the main pulse, and metric salience indicated above (strong/weak)[8].*

The sample for this study consisted of three groups: Parkinson's disease patients without dopamine-agonist (DA) medication, Parkinson's disease patients with DA medication, and a healthy control group. DA medication has shown to produce alterations in inhibition and

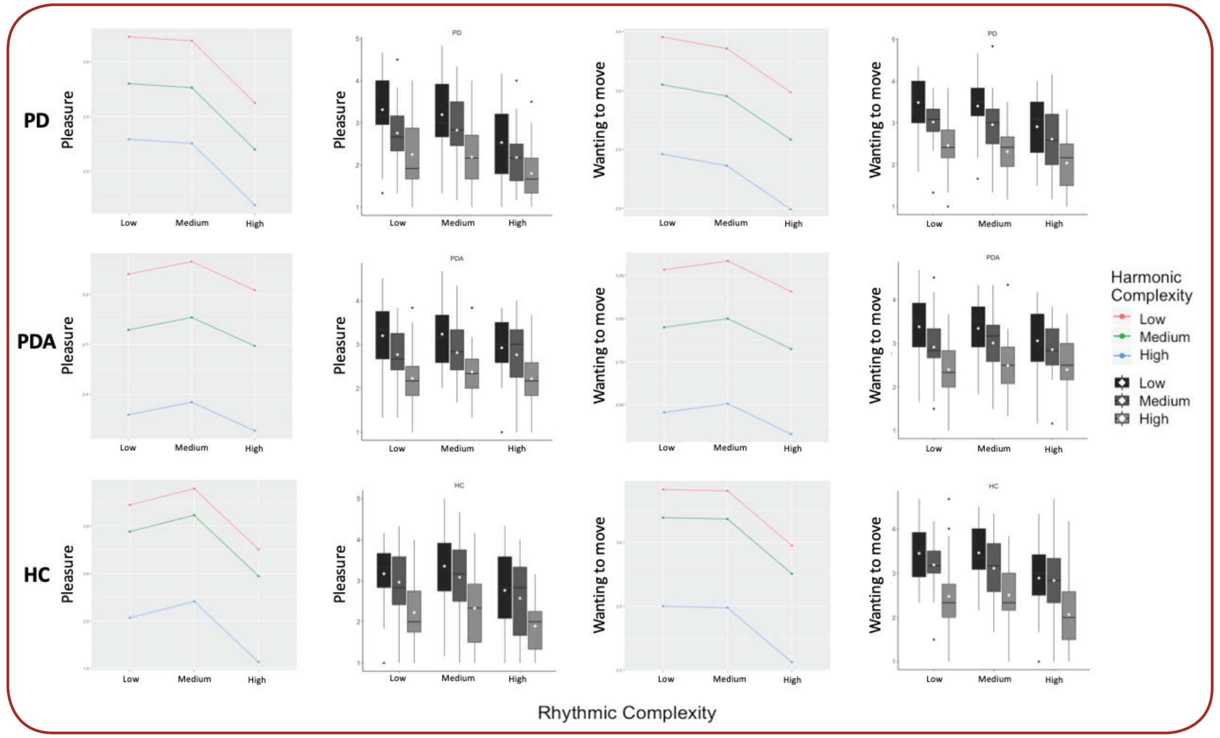

Figure 4. *Linear mixed effects of rhythmic and harmonic complexity on pleasure and wanting to move ratings. PD, Parkinson's without dopamine agonist; PDA, Parkinson's with dopamine agonist; HC, healthy controls.*

impulsivity processes, as well as reward-seeking behaviors[10], thus, if not accounted and controlled for, DA may influence the results in both pleasure and desire to move.

The experiment consisted of three sessions. During the first session, participants answered demographic and behavioral questionnaires. During the second session, participants performed the experimental paradigm in which they listened to short musical sequences (10 seconds) that varied in both rhythmic and harmonic complexity with three levels of each (low, medium, high), and rated experienced pleasure and wanting to move on a 5-point Likert scale (0 = no pleasure / not wanting to move, 5 = very pleasurable / wanting to move). The third session consisted on performing the musical ear test[11], in order to stratify the participants' musical competences (professional musicians, amateur musicians, non-musicians).

Our preliminary results show that patients with PD without DA medication rated higher scores on pleasure and wanting to move for the low rhythmic complexity. PD patients under DA medication rated higher scores for the medium rhythmic complexity on both pleasure and wanting to move. HC preferred medium complexity for pleasure, and low complexity for wanting to move. In the case of harmony, all participants preferred the low harmonic complexity in both pleasure and wanting to move (see Fig. 4). In conclusion, it seems that PD patients may benefit from low complexity in music, which appears to represent their musical sweet spot.

In this project, we aim to provide a preliminary behavioral insight of cognitive and emotional abilities of PD patients, before extending the research into studying the neurobiological correlates of musical complexity in PD by investigating brain activity, functional connectivity, and coupling, using both fMRI and MEG.

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CLINICAL APPLICATIONS OF MUSIC

Bjørn Petersen and Niels Trusbak Haumann

Try to see it my way,
only time will tell if I am right or I am wrong
(Lennon/McCartney 1966).

We can work it out
- perception and discrimination of music in experienced and recently implanted CI users

A longstanding relationship

One significant aspect of MIB's engagement in clinical applications of music is the study of how music plays a role in the lives of patients with profound hearing loss who have received a cochlear implant (CI). Previously, we examined the effect of musical ear training in pediatric, adolescent and adult CI-users as well as music listening habits, music enjoyment and quality of life in experienced CI-users (see MIB's annual report 2016 p. 39-42). The study of brain plasticity and neural discrimination of features of music formed part of these studies, initially using PET[1], but recently also using EEG, measuring the Mismatch Negativity (MMN) response[2,3].

A new paradigm

In a cooperation with the Danish CI manufacturing company Oticon Medical we have developed a novel MMN 'Musical Multifeature' paradigm (CI MuMuFe) to be used both in CI research and in clinical context. The paradigm integrates only deviants and presents no standard stimuli. Deviants in pitch, timbre, intensity and rhythm are embedded in an Alberti bass pattern and presented randomly at four levels of magnitude (S, M, L & XL; see MIB's annual report 2016, p. 42). Here we report preliminary results from experienced and recently implanted CI-users at the group level as well as in individuals.

A brief overview

Eleven experienced CI users (CIex), 11 recently implanted CI users (CIre) and 14 normally-hearing (NH) controls underwent EEG-recording while subjected to the CI MuMuFe paradigm. To monitor the CI adaptation process, CIre were measured twice: shortly after switch-on (T1) and after three months (T2). In addition, all participants completed a behavioral discrimination test.

Account of highlights

a) CIex vs NH

Across levels, the CI MuMuFe paradigm elicited significant MMN responses to all deviants in NH controls and to all deviants in the CIex group except for the rhythm S and timbre M deviants. In NH listeners, MMN amplitudes for the intensity deviant were significantly lower than for pitch and timbre deviants. In CIex, MMN amplitudes did not differ significantly between any of the deviants. Furthermore, across deviants, the overall relationship between MMN amplitudes and

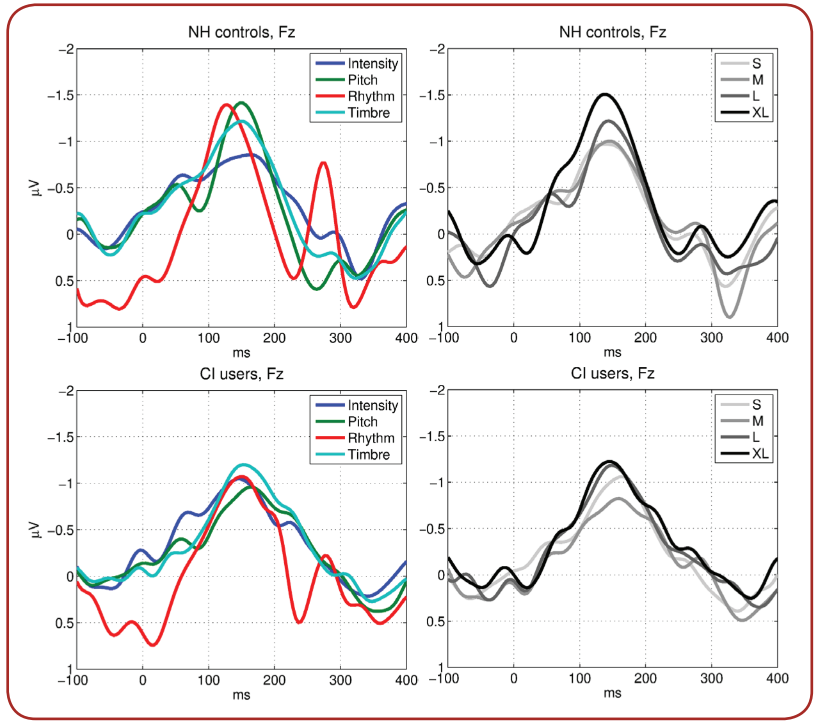

Figure 1. *Left: MMN difference waves for all four deviants across levels in the NH (top) and CIex groups(bottom); right: MMN difference waves across deviants as a function of deviation magnitude levels.*

deviation magnitude was consistent, a trend also reflected in behavioral measures (see Fig 1).

While NH controls showed a differentiated discrimination of the pitch deviant, CIex showed no discrimination between any pitch levels. By contrast, the CIex group showed an abnormally higher MMN amplitude in response to the brighter timbre deviant S than the darker variation M, not observed in NH. Similarly, for rhythm, the CI users' response to the L deviant was abnormally higher than to S, M and XL.

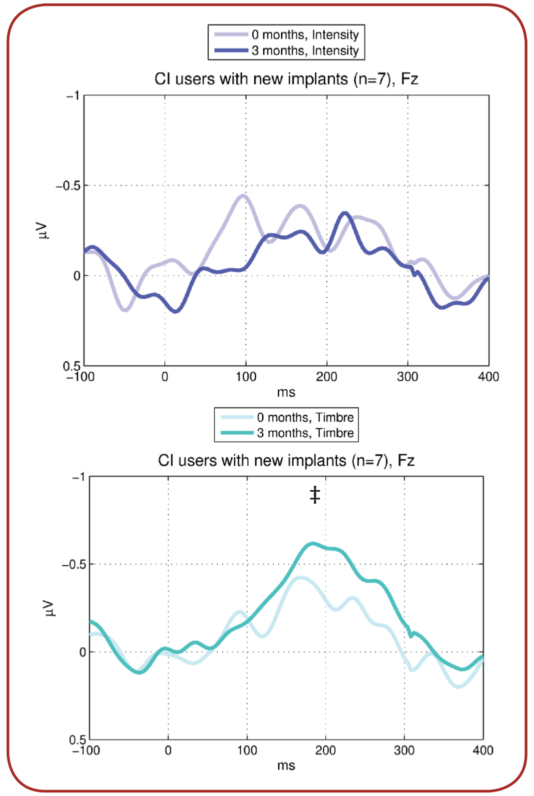

Figure 2. *CIre difference waves illustrating the negative ERP responses to the intensity (top) and the timbre deviants (bottom) at T1 and T2.*

b) CIre

The CIre-group displayed MMN-like negative ERPs for all deviants, even after a short duration of experience. For pitch and timbre especially, the T2 amplitudes of these ERPs indicated a strong effect of time. This may suggest that the auditory training linked to the adaptation process is manifested stronger in the discrimination of the spectrally complex rather than in the more basic features of music (see Fig. 2).

A single case

Spike density component analysis (SCA) is a novel methodology for analyzing MMN data, developed at MIB in 2018[4]. The method has proven particularly useful in analyzing single subject MMN responses. Results extracted in a single CIex and a NH control, respectively, are shown in Fig. 3.

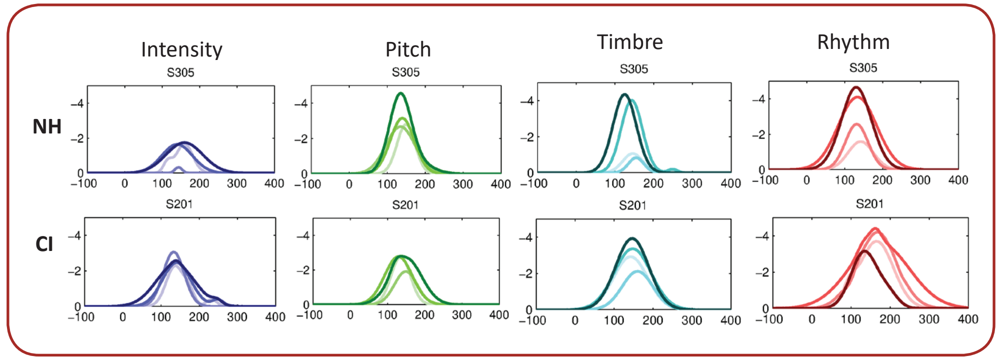

Figure 3. MMN responses to the CI MuMuFe paradigm in a single NH (top) and a single CIex listener, xtracted by SCA.

A close connection

Prediction of CI outcome.
Using the SCA method, we categorized MMN amplitudes from individual CIre participants according to strength and correlated with behavioral performance. The analysis revealed a strong relationship between MMN amplitude and behavioral hit rates, indicating the method's potential to predict CI performance (see Fig. 4).

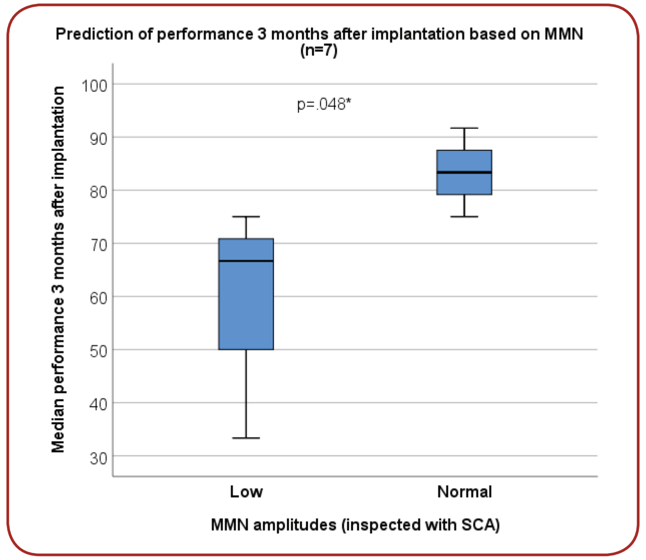

Figure 4. Box plot showing the relationship between low and normal MMN amplitudes and behavioral hit rates in the CIre group.

In one single subject, we observed abnormally low MMN amplitudes as well as poor behavioral performance. Subsequently, we learned that the patient had been reimplanted due to a physiological change in the inner ear. Such an association suggests the potential of both the paradigm and the SCA as tools for objective diagnostic and prognostic measures in a clinical context.

A final wrap-up

The preliminary findings of this study are encouraging. Despite a high complexity, the CI MuMuFe paradigm may provide objective and detailed evidence of CI users' musical discrimination abilities. Furthermore, in naïve CI users, the paradigm traces basic advances in detection of complex musical features, reflecting functional changes in the auditory system.

Finally, applying the SCA approach, the paradigm may provide identification of reliable MMN-responses in individual CI patients. The latter is an encouraging indication of the potential application of the new methodologies as prognostic and diagnostic tools in clinical settings. With presumed inclusion of future new CI users, we anticipate further support of our findings.

Acknowledgement

Recruitment, scheduling, EEG-recording and testing of participants was carried out by research year student Anne Sofie Friis Andersen and research assistants Alberte Seeberg and Monica Ipsen.

Parts of this study were presented at MMN 2018 in Helsinki and the Oticon Medical Scientific Meeting in Copenhagen, 2018 and will be reported in[5].

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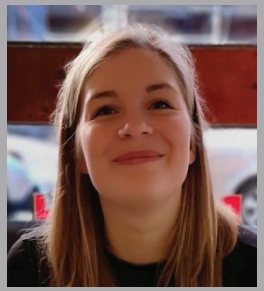


Alberte Baggesgaard Seeberg is enrolled in the BSc programme 'Cognitive Science' at Aarhus University.
In 2018, Alberte has been involved in MIB's study on Music and CI .
For her BA thesis, Alberte incorporated and analyzed anonymized data, collected in discrimination tests and questionnaires from experienced and recently implanted CI users. The following summarizes some of her findings.
1. Age at CI-implantation seems to correlate negatively with discrimination performance. This could indicate that the plastic changes taking place post-implantation occur faster in the brain of people implanted at a younger age.
2. Poorer performance is associated with a longer duration of deafness. This is particularly true for recently implanted CI-listeners, suggesting that the amount of years with hearing loss influences the time it takes to regain the ability to discern between different properties of sounds.
3. Time spent listening to music is significant to performance. If this is true, CI users could benefit from musical training programs post-implantation, increasing their ability to perceive and enjoy music.

EDUCATIONAL ACTIVITIES

Elvira Brattico and Bjørn Petersen

In 2018, MIB further strengthened its efforts to convey and share knowledge within the field. Both in terms of new knowledge disseminated by visiting international scholars to MIB associates and in terms of knowledge conveyed by MIB researchers to undergraduate students within universities and music academies.

Long-term as well as new collaborators from UK, Finland, and USA gave several talks on topics related to neurophysiology, (auditory and brain) signal processing and music psychology. Furthermore, MIB continued its cooperation with CFIN organizing shared seminars. A list of shared CFIN&MIB talks as well as MIB guest talks can be seen on page 58.

Featuring some of our visiting researchers

In January 2018, MIB hosted Prof Asoke K. Nandi from Brunel University for a week. He illustrated clustering techniques that have been developed and applied for several decades in brain signal processing. Furthermore, he highlighted the issue that it is often difficult to select an appropriate clustering algorithm and evaluate the quality of clustering results due to the unknown ground truth. Moreover, it applies to multiple datasets, which may have been generated either in the same laboratory or different laboratories at different times and with different settings yet trying to conduct the similar experiments. In such a scenario, the challenge is how to reach consensus conclusions. In his presentation Prof Nandi addressed novel Bi-CoPaM and UNCLES consensus methods used to analyse fMRI data producing robust patterns of neural activity in response to music.

In December, MIB had a visit by Rosie Kay, choreographer and research associate to the University of Oxford. From her starting point as a dancer and choreographer, Kay gave an inspiring and breath-taking presentation of her many-faceted work and her exploration of the relationship between the dance, the music and the audience's perception.

Featuring some of our young visitors

In March, Dr Martin Nørgaard from the Music

Students from Georgia, USA accompanied by Dr Martin Nørgaard at the RAMA roof in front of Aros..

Department at Georgia State University (GSU), USA visited MIB together with 11 undergraduate students. The students who represented a range of different studies followed a program that was arranged by MIB and included several educational sessions one of which was an exchange between MIB researchers and GSU students. In addition to a visit to the Royal Academy of Music (RAMA), the program also included a workshop in which GSU students gave accounts of topics discussed in online videos from MIB's 2016 course which they had studied in advance.

MIB staff teaching activities and materials

New course for university and music academy students

In the fall of 2018, MIB launched a new free course for university students and students at RAMA. The course, titled Introduction to Music in the Brain, aimed at "enabling students to acquire basic knowledge and understanding of the multidisciplinary research field "Music in the Brain," on which MIB is founded." The course featured 17 lectures given by MIB PhD students, postdocs and assistant professors, adding to a total of 28 hours. The program represented a broad spectrum of topics from clinical applications of music and musical expertise over psychoacoustics and audiology to improvisation and computational modelling of music. The full program can be viewed on the MIB website.

The course fulfilled two goals. On one side it aligns with MIB's educational outreach ambitions and obligations, on the other side it supports PhD students' demand for teaching hours and explicit request to achieve teaching experience. A great case of win-win.

Dr Bjørn Petersen kicking off the Introduction to Music in the Brain course. Photo: Hella Kastbjerg

To put it mildly, the number of applicants for the course exceeded our expectations. The course attracted almost 60 students from a wide range of educational disciplines: Cognitive Science (34), Music Performance and Teaching (RAMA, 6), Musicology (7), Psychology (6), Health (3) and three students from Sociology, Religion and Music Therapy, respectively. In response to the large crowd, the MIB administration swiftly decided to move the course to a larger venue, taking advantage of our proximity and access to AUH auditoriums M and K. Of the 32 students who completed more than 75 % of the lectures, 19 requested and received a course certificate.

A subsequent evaluation survey showed that a large majority of the participants found that the course was relevant for their studies, was well organized, had an adequate level and provided a deeper understanding of the Music in the Brain research field. All lectures were recorded, and recordings and presentation slides are accessible online for all participants who request the link and password, a possibility open also for future students.

The course was initiated by Assistant Prof Bjørn Petersen who was also responsible for recording, editing and web-dissemination of video and presentations material. Organization of the program, including collection of titles, abstracts and agreements from all lecturers was carried out by PhD student Christine Ahrends, while MIB research secretary Hella Kastbjerg was responsible for design and layout of course materials and all correspondence and announcements related to the administration of the course. PhD student Marianne Tiihonen designed and finalized the post-course evaluation survey.

Course on programming and audio engineering
In a more methodological line of topics, PhD student Ole Adrian Heggli launched two courses, each including four lectures and workshops. The first course introduced programming in the PsychoPy/Python software platform, whereas the second course provided an insight into and hands-on experience with visual programming and audio engineering using the Max/MSP platform. Both courses attracted enthusiastic participants from MIB, CFIN and RAMA and finely illustrated the wide-ranging potential of knowledge sharing and interdisciplinarity within the center.

Top: RAMA students from the course Colloquium on Music and Science visiting the MRI lab at DNC.
Bottom. RAMA students and PhD student Pauline Cantou (front right) preparing for a course session at MIB on the 5th floor of DNC.
Photo: Elvira Brattico

Colloquium course for music academy students and music practitioners
In November and December 2018, Prof Brattico initiated, organized and led a course entitled "Colloquium on Music and Science – How scientific findings can support music practicing, teaching and performing", which had a non-conventional format where the teachers acted as facilitators and guides for the open discussion and the students contributed actively with their own experiences and thoughts in a mutual exchange of knowledge.

In 6 weekly meetings at RAMA lasting 2 hours 10 motivated RAMA students discussed with Prof Brattico and PhD students Marianne Tiihonen and Pauline Cantou about topics such as behavioral advantages from music training, stage fright, the importance of visual cues in music performance and neuroenchantment. The last meeting included a tour of the MIB labs where some of the students wanted to try to lie down on the bed in the MRI scanner.

RAMA/MIB symposium on music learning
In January 2018, RAMA's annual conference on "Music and Learning" took place in the Small Hall at Aarhus Concert Hall with live streaming to the Chamber Music Hall, addressing a total of 425 music teaching professionals. Day one of the conference presented a Music Learning and Neuroscience Symposium organized by MIB with Assistant Prof Bjørn Petersen and Prof Peter Vuust as leading forces. The symposium presented four different views on the implication of recent neuroscientific research on the teaching of music, presented by some of the leading scholars within the field. The program also included workshops at which the audience had the possibility to ask further questions directly to the presenters and discuss the raised issues. Several MIB researchers also had the opportunity to join the symposium.

The sound of music in the health sector
Postdoc Kira Vibe Jespersen played a key role in the organization of the whole-day symposium The Sound of Music in the Health Sector which took place in RAMA's Chamber Music Hall November 26. The symposium was part of the project Sound and Health Care, a cooperation between private and public partners which brings together knowledge and technology within sound and music that meet the requirements of the health care sector. Kira has represented MIB in the project, and at the symposium, she presented her work under the title "Bedtime music for dementia-related sleep problems: a feasibility study". In addition, Prof Peter Vuust gave a talk on "Groove on the Brain", and PhD student Mette Kaasgaard presented her work on singing training with COPD patients.

Neurosciences and Music VII 2020 in Aarhus
The preparations for the main conference in our field Neurosciences and Music VII in June 2020 in Aarhus are proceeding hectically. In September we had the pleasure to host a team from the Mariani Foundation who is the main organizer, promoter and founder of the conference and will co-organise it with us. We welcome all to visit us here!

The organisers of the Neurosciences and Music VII conference in Aarhus 2020, including the committee from the Mariani Foundation, MIB personnel and VisitAarhus officer.

Guest speakers 2018

Prof Asoke Nandi
Brunel University
Consensus Clustering Paradigms and Findings from fMRI Data

Prof Eckart Altenmüller
Institute of Music Physiology and Musicians' Medicine, Hannover University of Music, Drama and Media
Making music as a model for adaptive and maladaptive plasticity

Prof Bjørn Bjorvatn
Department of global public health and primary care, University of Bergen
Sleep medicine - focus on insomnia and circadian rhythm sleep-wake disorders

Prof Daniel Müllensiefen
Music, Mind and Brain research group, Goldsmiths, London
The psychology of musical experience from three angles: Stimulus features, psychometrics and behavioral economics

Prof Catherine Tallon-Baudry
Visual Cognition Group, Laboratoire de Neurosciences Cognitives (LNC), Paris
Visceral inputs, brain dynamics and subjectivity (MIB/CFIN)

Prof Fred Dick
Birkbeck, University of London/UCL Centre for NeuroImaging
Expert auditory skills: plasticity and stability in cognitive and neural mechanisms (MIB/CFIN)

Prof Gunter Kreutz
Universität Oldenburg
Music for better lives? - Current prospects and challenges (MIB/CFIN)

Dr Martin Nørgaard
Georgia State University - School of Music, Atlanta
Why learning to improvise may enhance inhibitory control and cognitive flexibility

Dr Andrea Ravignani
Sealcentre Pieterburen, The Netherlands, and Vrije Universiteit Brussel
Vocal learning, group chorusing and the evolution of rhythm

Dr Ben Gold
McGill University, Canada
Prediction and Surprise in the Pleasure of Music

Dr Renee Timmers
Department of Music at The University of Sheffield
The role of audio-visual information in playing along with a co-performer: A TMS study

Professor Peter Keller Photo: Hella Kastbjerg

Dr Ignasi Cos Aguilera
Center for Brain and Cognition, Pompeu Fabra University, Barcelona
The influence of Motivation onto Movement Precision: A computational Approach

Prof Petri Toiviainen & Dr Vinoo Alluri
University of Jyväskylä, Finland and IIIT Hyderabad, India
Dynamics of interaction in spontaneous dancing

Chris Corcoran
University of Cambridge
Keeping score: Notation-based responses to swing music in unenculturated musicians

Dr Andrew Dykstra
University of Western Ontario
No-Report and Partial-Report Paradigms in Audition: Implications for the Neural Correlates of Consciousness (MIB/CFIN)

Prof Richard Bowtell
Imaging Centre, School of Physics and Astronomy, University of Nottingham, UK
Moving magnetoencephalography towards real-world applications with a wearable system. (MIB/CFIN)

Prof Peter Keller
MARCS Institute for Brain, Behaviour and Development at Western Sydney University
From sensory-motor to social influences on human interaction through music. (MIB/CFIN)

Artistic Director and Research Associate Rosie Kay
Rosie Kay Dance Company and University of Oxford
Dance to the Rhythm? Finding new ways to combine dance, music and audience perception to highlight empathic connection.

PHD FEATURE

Cecilie Møller

Ceci n'est pas une pitch change: Linking perceptual amplification of audiovisual events in brain and behavior to auditory sensitivity and musical expertise

Traditionally, most research on perceptual processing has investigated the senses in isolation, although very rarely do environmental events give rise to activity in only a single sense[1]. The complementary nature of audition and vision was the subject of this PhD project, co-supervised by Klaus B. Bærentsen (Dept. of Psychology, AU), Andreas Højlund (CFIN, AU), and Peter Vuust (MIB). The three studies conjoined in the dissertation were designed to shed light on the benefits of multisensory compared to unisensory processing, and on the inter-connections and inter-dependence of behavior (Study I), neurophysiology (Study II), and neuroanatomy (Study III).

Musicians and non-musicians were recruited, the former in virtue of their superior pitch discrimination abilities, as the project explored visually induced enhancements in pitch discrimination, and how the size of these enhancements relate to individual differences in auditory sensitivity and musical expertise. Motivated by the multisensory *principle of inverse effectiveness*[2] and a great deal of common sense derived from years of music teaching experience, we expected to see less reliance on visual cues in pitch discrimination in participants with more refined auditory-only abilities.

In Study I[3], we quantified visually induced gains in behavioral pitch discrimination by comparing sensitivity to subtle pitch changes in conditions with and without visual cues (an image of a disc moving up, down, or maintaining its position in the center of the screen). We found stronger gains in participants with poorer auditory-only abilities, i.e., pitch discrimination thresholds (See Fig. 1, left), and score on the Musical Ear Test (See Fig. 1, right). Furthermore, we found significantly better performance when the audiovisual stimuli were crossmodally compatible, i.e., followed the rule "higher pitch = higher visually perceived vertical position", than when the mapping was reversed. This congruence effect, in turn, was robust to variations in auditory sensitivity and musical aptitude.

Figure 1

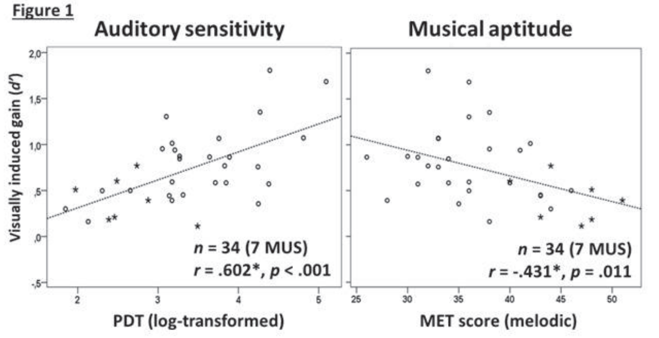
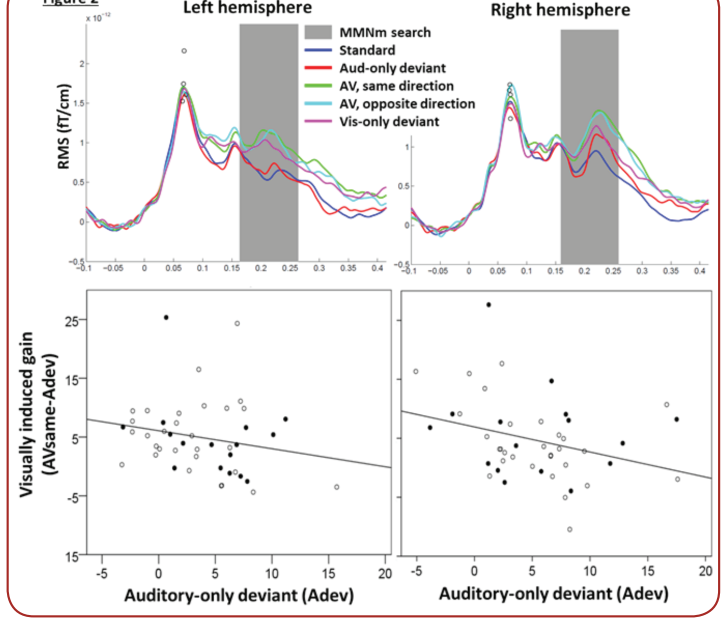


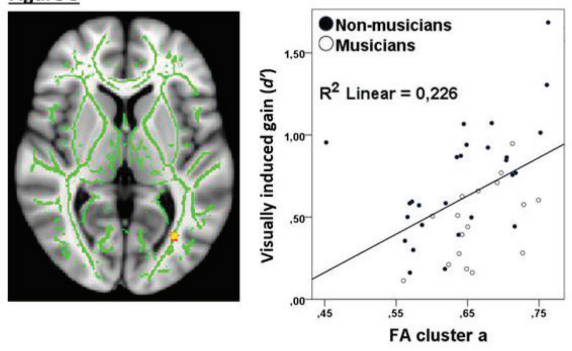
Figure 2



In Study II (pre-print available at https://doi.org/10.1101/604165), we used MEG to measure participants' pre-attentive brain responses to similar stimuli. The visual dimension of the stimuli enhanced the mismatch negativity response measured above the auditory cortex (See Fig. 2, top), and again we saw a pattern consistent with the principle of inverse effectiveness, where individuals with weaker responses to auditory-only deviants showed larger visually induced gains in the audiovisual condition (See Fig. 2, bottom).

Study III used MRI and DTI in combination with the behavioral measure of visually induced gain derived from Study I. This measure was directly associated with fractional anisotropy (FA) values in a significant cluster in the occipital part of the left inferior fronto-occipital fasciculus, a white matter tract that connects auditory and visual areas of the cortex (See Fig. 3), suggesting that lateral neural connections support the variable dependence on visual cues in pitch discrimination across participants.

Figure 3



Taken together, the studies show behavioral, neuroanatomical and neurofunctional correlates of visually induced gains in auditory pitch discrimination and suggest an inverse relationship between the size of the gains and the individual sensitivity and expertise measured in auditory-only conditions. In the quest towards understanding hearing as it unfolds in natural environments, the findings highlight how we may gain substantially by paying attention to the possibility that hearing is related in systematic ways to other factors than sound waves. With this PhD project, we attempted to do exactly that.

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2. Stein, B. E., & Meredith, M. A. (1993). The merging of the senses. Cambridge, Mass: MIT Press.
3. Møller, C. et al. (2018) Atten Percept Psychophys 80: 999.

PHD FEATURE

Kira Vibe Jespersen

Music for insomnia

Insomnia is a major health concern in modern society with around one third of the general population experiencing insomnia symptoms, such as difficulties initiating or maintaining sleep, and around 6% to 20% fulfilling the criteria for insomnia disorder. Persistent insomnia is related to reduced quality of life as well as cognitive and emotional impairments, and more treatment options are needed in order to accommodate the needs of the many people suffering from insomnia.

In my PhD, I examined if music may be a useful tool for alleviating insomnia. We assessed the effect of music listening for improving insomnia using different methods including randomized controlled trial and systematic review. In addition, we used neuroimaging techniques to assess insomnia-related alterations of structural brain connectivity. The thesis was supervised by Prof Peter Vuust and co-supervised by Profs Morten Kringelbach and Eus Van Someren (Netherlands Institute for Neuroscience).

In the first study we investigated the effect of music as a tool to improve sleep in traumatized refugees with sleep problems. Using a repeated measures design, we found a significant effect of the three-week music listening intervention on subjective sleep quality and well-being. There were no changes in trauma symptoms in any of the groups[1].

The next step was to assess the existing evidence base in the field of music and insomnia through a systematic review. We included six randomized or quasi-randomized controlled trials investigating the effect of music for improving sleep in adults with sleep problems. The meta-analysis (n = 264) showed a consistent and clear effect of the music listening interventions on subjective sleep quality (Fig. 1), but few studies reported other outcomes of interest such as objective sleep measures or quality of life[2]. The included studies were limited by substantial risk of bias, and the quality of the evidence was low to moderate. Still, the results indicate a positive effect of music on sleep quality.

To address the shortcomings identified in the systematic review, we used an assessor blinded randomized controlled trial design to assess the effect of music for insomnia disorder (n = 57). The music listening intervention was compared to audiobook listening and a waitlist control group and outcomes included both subjective and objective measures of sleep as well as quality of life. The analyses showed no interaction effects on insomnia severity, but within group analyses revealed a significant improvement in the music group[3]. A significant interaction effect was found for psychological quality of life with the music group showing greater improvements than the two other groups. The study revealed no effect of the music intervention on objective measures of sleep.

Participants listened to music music every night at bedtime through a music player designed to be used in bed.

The results suggested that the effect of the music intervention might be larger for those with less severe sleep problems and those suffering from sleep initiation difficulties.

The final study was a neuroimaging study investigating brain alterations in structural connectivity related to insomnia disorder. Using diffusion tensor imaging, we found that participants with insomnia disorder (n = 16) were characterized by a sub-network of significantly reduced connectivity compared to matched controls with no sleep complaints (n = 14)[4]. The network included the left insula and fronto-subcortical connections. The results suggest that insomnia disorder is linked to a dysfunctional network involved in interoception, emotional processing, stress responses and the generation of slow wave sleep.

In summary, these studies add to the evidence base of the effect of music for insomnia and the understanding of the neurophysiological underpinnings of insomnia disorder. The results suggest that music may be an efficient tool for alleviating insomnia and related daytime impairments. Music provides a safe intervention that is easy to use, and it may serve as a preventive self-help tool, an adjuvant intervention to enhance the effect of other treatments, or as an intervention for vulnerable populations that are not eligible for other treatments.

References

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3. Jespersen KV, Otto M, Kringelbach M, Van Someren E, Vuust P. A randomized controlled trial of bedtime music for insomnia disorder. J Sleep Res.0(0):e12817.
4. Jespersen K, Stevner A, Fernandes H, et al.Reduced structural connectivity in Insomnia Disorder. bioRxiv. 2019:510784.

	Music listening			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Harmat 2008	3.27	1.8	35	5.9	2.193	29	39.4%	-2.63 [-3.63, -1.63]
Jespersen 2012	11.89	4.11	9	12.67	2.16	6	3.8%	-0.78 [-3.97, 2.41]
Kullich 2003	5.8	3.2	32	8.1	3.4	33	15.2%	-2.30 [-3.90, -0.70]
Lai 2005	7.13	3.19	30	10.07	2.75	30	17.2%	-2.94 [-4.45, -1.43]
Shum 2014	5.9	2.4	28	9.5	2.6	32	24.4%	-3.60 [-4.87, -2.33]
Total (95% CI)			**134**			**130**	**100.0%**	**-2.80 [-3.42, -2.17]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 3.59$, $df = 4$ ($P = 0.46$); $I^2 = 0\%$

Test for overall effect: $Z = 8.77$ ($P < 0.00001$)

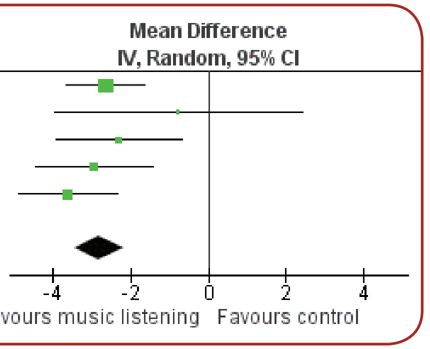


Figure 1. *The meta-analysis showed a consistent and highly significant effect of the music intervention on sleep quality*

VISITING PERSPECTIVE

Ignasi Cos

I came to MIB in November 2018 on a two-month visit from my home institution, the Pompeu Fabra University of Barcelona, where I work as a research scientist at the Center for Brain & Cognition. Although I had briefly visited Aarhus during the previous summer, this visit was intended to develop new collaborative research projects with researchers at MIB, to combine some ideas of movement modelling with the expertise of MIB in music perception and production. This was generously supported by an Aarhus University grant (AUFF Visiting Researcher) that provided funding for accommodation, travel and expenses.

Visiting MIB was an easy decision, which I can never thank enough for. I had little reservation that I indeed wanted to work with a group of scientists that distinguish themselves not only because of their excellence in the study of the brain, but because of their profound passion for music. If science is an activity of interdisciplinary nature, MIB makes it all about those common elements of life that make science a fun experience, complementing it with a palpable aesthetic element that overarches every aspect of their research, ultimately enriching their lives.

Before I arrived in Aarhus, the MIB staff and the International Office at Aarhus University greatly facilitated finding accommodation on a short notice, and helped enormously with general advice as to what life is about in Aarhus. Coming from Barcelona, one first comes to admire the more paced (and spaced) livf at Aarhus. Although both towns are by the sea, Aarhus is a lively cultural town where most of it is human-sized. Framed between Risskov's forest, an emergent harbour area and Marselisborg, each district of Aarhus emerges as a particular flavour of a balanced town. From Frederiksbjerg with its splendid modern art museum (the ARoS) and its Konservatorium, where one may get a glimpse of the surrounding landscape, to the outgoing Latinerkvarteret with its canal, little streeets, and warm coffeeshops, to an attractive bay and harbour for sailing lovers, Aarhus is an attractive town where life is hyggeligt. Finally, Aarhus is also a student city, hosting one of the most internationally reputed universities in Europe, Aarhus University.

One of the groups that undeniably magnifies the character of Aarhus University is MIB. MIB is a vibrant and engaging place one wishes to be part of and to participate in, with an open research space with scientists of every culture, all in tune with expanding the boundaries of our understanding of the aesthetic experience of music within brain science. From the same day I arrived, I found myself immersed in their group dynamics, where I had many stimulating discussions with various members of the centre, ranging from corridor conversations to detailed design and planning of

Wintery sight of the Åboulevarden street and promenade at Aarhus.

experimental studies. From questioning our understanding of how specific aspects of musical performance and coordination are represented in the brain to presenting and discussing novel ideas that could contribute to understand how musical expression is conveyed through movement. Some of these gave rise to standing collaborations with some members of the group, and to the proposal of novel projects currently in their early stages of development. I also became part of a study on musical learning, during which I was given some very needed singing lectures, which made me feel a lot more part of the group.

Despite all the meetings, in the brief time I was there I could not meet everyone at MIB, but I was lucky enough to visit at the time of candlelight, while approaching the winter solstice. This is a time for several get-togethers, to socialise, family reunions, enjoying the local delight of æbleskiver, and most importantly, time for the second yearly MIB gathering, the Christmas Party, which is a good opportunity to get everyone together all in one place, enjoy each other company, a genuine pleasure for music and conversation, and indeed, for some drinking.

The time passed quicker than I could count on, but I take good friends with me. I look forward to meeting them again soon, and to continue the collaborations started during late 2018, hopefully by visiting again in the near future.

VISITING PERSPECTIVE

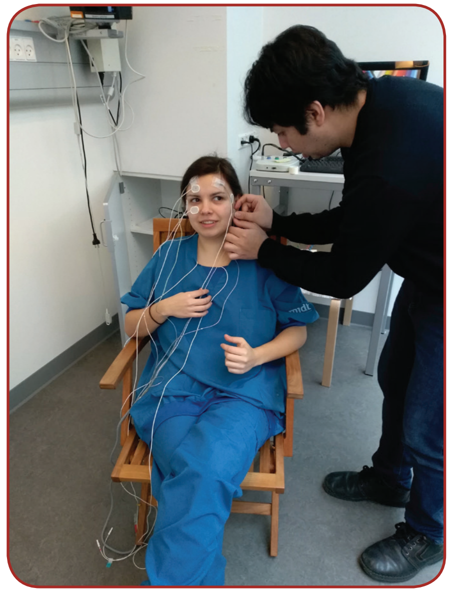
Ulrikka Varankeite

As a Lithuanian PhD student I had the opportunity to use the ERASMUS+ program for a scientific internship abroad and for this experience I chose MIB in Aarhus. My choice was mainly based on two reasons: I always wanted to visit and explore Denmark (I had never been to the country before) and I already knew Professor Elvira Brattico, who was assigned to supervise me at MIB, from my previous internship at CBRU in Helsinki in 2015, although we did not work together back then.

My visit at MIB started in February 2018 and lasted for two months. Of course, two months may not seem to be enough for an in-depth learning. However, I feel that I learnt a lot and had not only theoretical, but – and mainly – real hands-on experience. I was originally assigned to help with data acquisition in a MEG study, but I was very happy that I could also assist in another project that involved fMRI measurements - as I always wanted to see how MRI equipment is used for experiments and actually work with it.

It is important to mention that I am very happy and grateful that the colleagues who I worked with at MIB trusted me by giving me responsible tasks: I could work with participants and use the equipment in most stages independently. Even other colleagues were very friendly and willing to help anytime – I could boldly ask any questions (even those that I thought were stupid) and I would always get the needed answers. I will never forget busy data collection periods when the teams of the mentioned projects would spend all day down in the basement where the equipment was situated: we would get tired after long days of scanning but we also had a lot of fun cheering up and motivating each other. At MIB I noticed the general warm atmosphere amongst all staff members and strong teamwork, so MIB was a real and amazing example of international people from different scientific backgrounds getting along and working effectively.

The first thoughts that come to my mind when I think of Aarhus as a city: cold, windy and a lot of



bicycles. I was used to snowy and cold winters, but in Aarhus for me it was at another level - extremely cold, and it was strange to see people cycling in such weather. However, the more I explored the city, the more I liked it: somehow, I could feel a vibe similar to my home city – Kaunas – in Lithuania. Even some facts show similarities: both cities are the second biggest in their countries and they are considered to be "cities of students".

I also found Aarhus very cozy and this is probably my most favorite feature about the city. I really loved the central part, my favorite spots – Salling Rooftop and, of course, Aarhus street food place.

I really enjoyed my internship at MIB and my stay in Aarhus in general: I met wonderful people, I gained neuroscientific knowledge and practical experience. I expanded my general knowledge in music perception which was very useful for my thesis reinforcement - especially for the interdisciplinary part because formally my research field is humanities (art research).

Furthermore, after my internship I was invited to write a paper together with Prof Brattico. And, interestingly, since I mainly worked with Italians at MIB, it encouraged me to take a Italian language course – and I've been learning Italian since my return from Aarhus.

Taking all these experiences into account I can conclude that my stay at MIB had a quite significant and, most importantly, positive impact on my development, not only as a researcher, but also as a person.

I would like to thank everyone at MIB for giving me the opportunity to meet and even work with such nice people who are ones of the best scholars in the field of neuroscience of music. And I wish MIB to continue its successful work.

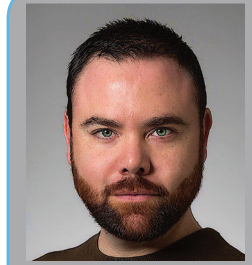
NEW FACES AT MIB

Jan Stupacher is new postdoc at MIB. His academic path has been driven by his fascination with cognitive and social backgrounds of rhythm perception and production, groove, and entrainment. This path started in 2006, when he began his study of psychology at the University of Tübingen, Germany, and continued with an internship (2010) and diploma thesis project (2011) in the Music Cognition and Action research group at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany. Guided by these interests, Jan continued to study the perception of musical rhythm during his doctoral studies in Psychology at the Section Neuropsychology, University of Graz, Austria, which he completed in December 2017. Between 2015 and 2017, Jan was also a fellow of the Austrian Academy of Sciences and received funding for his project “Auditory-motor interactions in music perception: Neural correlates and social effects of rhythmic entrainment”.

During his 3-year postdoc at Center for Music in the Brain, Jan will compare and contrast neural, physiological, and social levels of entrainment to musical rhythm based on EEG, MEG, fMRI, and behavioral measures. For this project he recently received a postdoctoral fellowship from the Austrian Science Fund (FWF).

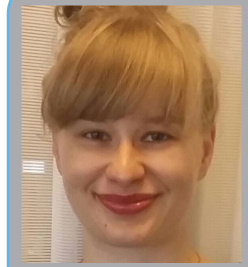
Manon Grube is new assistant professor at MIB. Being fascinated when learning about neural firing patterns as the basis for our perceiving the world around us led Manon to study biology and specialise in Cognitive Neuroscience at the Universities of Göttingen, Santa Cruz, California, and Leipzig. She developed a keen interest in auditory processing, allowing music and speech to “happen” in our brains. As a postdoc at Newcastle, Manon became intrigued with time and rhythm processing, and developed her own line of research in perceptual timing, which she has been continuing and expanding as an IPODI fellow at TU Berlin and now at MIB.

In her research, Manon combines cross-lingual behavioural work in large cohorts of children, healthy adults and neurological patient populations with multimodal neuroimaging, neurostimulation, and machine-learning based modelling techniques into one coherent line of research. Her foci in her current work at MIB are on i. the duration of the felt present; ii. the neural correlates of the feeling of the “beat”, and predictive timing; iii. the effects of plasticity and expertise. Her main long-term direction is toward the development of EEG- and rhythm-based brain-computer interfaces (BCIs), coming neurofeedback and behavioural training to mitigate neurological and developmental timing disorders.

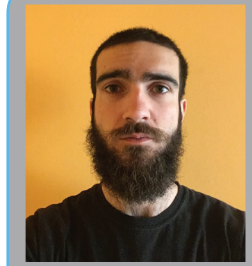


Victor Pando-Naude is a medical doctor from Mexico, recently awarded a Master´s Degree in Neurobiology, studying the effect of music in the management of chronic pain. Victor´s recent studies include a systematic review and meta-analysis of music-induced analgesia in chronic pain conditions and the neural correlates of music-induced analgesia in fibromyalgia patients using behavioral measures and resting-state functional MRI. Victor has now started as a PhD Fellow at MIB, His project will focus on the neural correlates of experienced musical pleasure during rhythmic musical stimulation in Parkinson’s disease patients.

In parallel with his post-graduate studies, Victor is a trained pianist from the Music Academy of Puebla, Mexico.



Marianne Tiihonen is here at MIB to finalize the last year of her PhD studies. Marianne has a master´s degree from the University of Vienna, Austria where she studied musicology as her major and psychology as her minor. Currently she is also finalizing her second master´s degree in cognitive science, also at the University of Vienna. Marianne´s main interest is in the neuroscience of affect and in critical neuroscience; which neural mechanisms underlie emotions? How emotion and cognition interact? How should the emotion related concepts be updated with the increasing empirical knowledge? In her PhD she is interested in the cross-modal interaction of visual and auditory cortices in regard to affect processing, and in particular, in that how those modalities interact neuronally and behaviourally.



Davide Ligato has started his PhD studies at MIB. His project will focus on the vocal motor control and proposes an original set of studies to address this understudied subject. These are aimed at scrutinizing the multisensory cortical mechanisms involved in controlling and monitoring vocal behaviour, their modifications related to individual experience/learning and emotion-action interactions in the vocal control. He obtained his Master’s Degree in Biomedical Engineering at the Center for Sensory-Motor Interaction (SMI), Aalborg University. He then continued to work at SMI as a researcher for more than two years, specializing in the field of pain. In particular, he succeeded to demonstrate that analgesia is mediated by the peripheral as well as by the central mechanisms.

MIB ANNUAL RETREAT 2018 - GRENÅ

Make Time to Think

Associate Prof Mikkel Wallentin from CFIN was one of our guest speakers

Social activities: RAMA professor Jim Daus Hjernøe demonstrates his vocal painting method (left) and Anne Lise Fuglsbjerg guides the MIB group through a music-in-the-body experience (right)

Making time to think

Time for dinner, music and fun

The winners of our Make Time to Think Competition:
Angus Stevner, Ana Zamorano, Christine Ahrends and Davide Ligato, flanked by the firm but fair judges Marcus Pearce and Henriette Vuust.
The winning project was titled ”Plactic brain networks in vibrotactile musical experience in deafness.”

Photos:
Hella Kastbjerg

PEOPLE

Peter Vuust
Professor
Director
Principal investigator

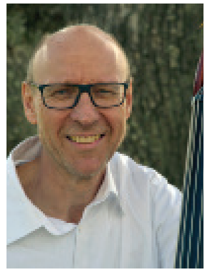
Morten Kringelbach
Professor
Principal investigator

Line Gebauer
Associate professor

Boris Kleber
Assistant professor

Elvira Brattico
Professor
Principal investigator

Marcus Pearce
Professor



Bjørn Petersen
Assistant professor

Manon Grube
Assistant professor

Massimo Lumaca
Assistant professor

Cecilie Møller
Postdoc

Jan Stupacher
Postdoc

Kira Vibe Jespersen
Postdoc

Angus Stevner
Postdoc

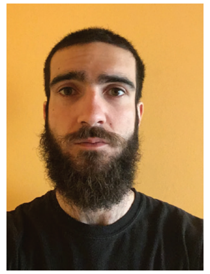
Henrique Fernandes
Postdoc

Joana Cabral
Postdoc

Marina Kliuchko
Postdoc

Selen Atasoy
Postdoc

Christine Ahrends
PhD student

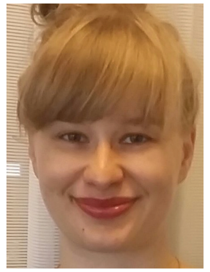


Davide Ligato
PhD student

David Quiroga
PhD student

Leonardo Bonetti
PhD student

Maria Celeste Fasano
PhD student



Marianne Tiihonen
PhD student

Marie Dahlstrøm
PhD student

Mette Kaasgaard
PhD student

Nadia Høgholt
PhD student

Ole Adrian Heggli
PhD student

Patricia Alves da Mota
PhD student

Pauline Cantou
PhD student

Rebeka Bodak
PhD student

Rasmine Mogensen
PhD student

Signe Hagner Mårup
PhD student

Stine Derdau Sørensen
PhD student

Victor Pando-Naude
PhD student

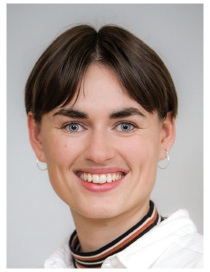
Pauli Brattico
Technician

Tina Bach Aaen
Centre administrator

Suzi Ross
PhD student

Niels Trusbak Haumann
Technician

Hella Kastbjerg
Centre secretary



Laura Vestergaard
Student worker

INTERNATIONAL GUEST RESEARCHERS

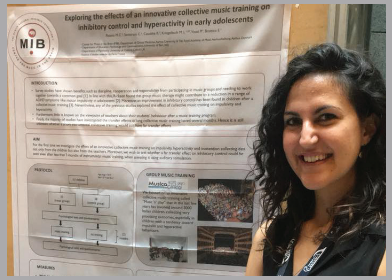
Postdocs
- Andrea Ravignani, Italy
- Ignasi Cos, Spain

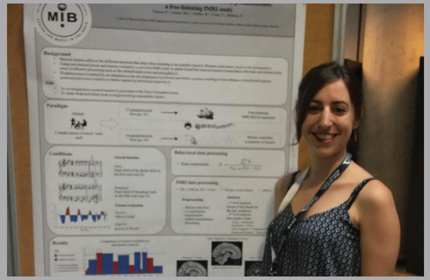
PhD students
- Ulrika Varankaite, Lithuania
- Marta Jaskiewicz, Poland
- Ruijiao Dai, China
- Antonieta Martinez, Mexico

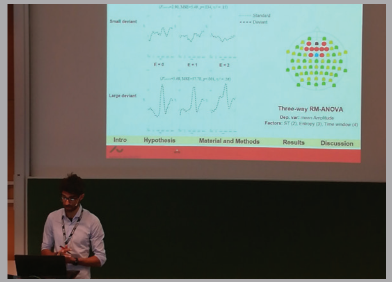
Interns
- Claudia Iorio, Italy
- Riccardo Proietti, Italy
- Giulio Carreturo, Italy
- Giulia Donati, Italy
- Simjon Radloff, Germany
- Anastasiia Popova, Ukraine

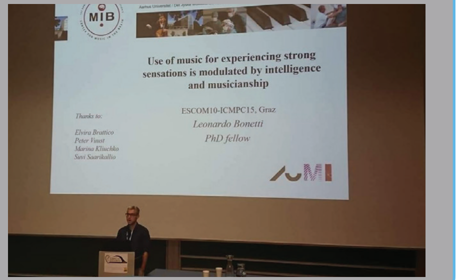
Assistant Prof Manon Grube with some of our international guests.

MIB RESEARCHERS AT ICMPC/ESCOM IN GRAZ, AUSTRIA









PUBLICATIONS 2018

Peer-reviewed articles

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Atasoy, Selen; Deco, Gustavo; Kringelbach, Morten L; Pearson, Joel. Harmonic Brain Modes: A Unifying Framework for Linking Space and Time in Brain Dynamics. Neuroscientist, Vol. 24, No. 3, 06.2018, p. 277–293.

Bonetti, L; Haumann, N T; Brattico, E; Kliuchko, M; Vuust, P; Särkämö, T; Näätänen, R. Auditory sensory memory and working memory skills: Association between frontal MMN and performance scores. Brain Research Reviews, Vol. 1700, 01.12.2018, p. 86-98.

Crisp, Roger; Kringelbach, Morten. Higher and Lower Pleasures Revisited: Evidence from Neuroscience.Neuroethics, Vol. 11, No. 2, 07.2018, p. 211-215.

Cruzat, Josephine; Deco, Gustavo; Tauste-Campo, Adrià; Principe, Alessandro; Costa, Albert; Kringelbach, Morten L.; Rocamora, Rodrigo. The dynamics of human cognition: Increasing global integration coupled with decreasing segregation found using iEEG. NeuroImage, Vol. 172, 15.05.2018, p. 492-505.

Daffertshofer, Andreas; Ton, Robert; Kringelbach, Morten L; Woolrich, Mark; Deco, Gustavo. Distinct criticality of phase and amplitude dynamics in the resting brain. NeuroImage, Vol. 180, 15.10.2018, p. 442-447.

Daffertshofer, Andreas; Ton, Robert; Pietras, Bastian; Kringelbach, Morten L; Deco, Gustavo. Scale-freeness or partial synchronization in neural mass phase oscillator networks: Pick one of two? NeuroImage, Vol. 180, 15.10.2018, p. 428-441.

Deco, Gustavo; Cabral, Joana; Saenger, Victor M; Boly, Melanie; Tagliazucchi, Enzo; Laufs, Helmut; Van Someren, Eus; Jobst, Beatrice; Stevner, Angus; Kringelbach, Morten L. Perturbation of whole-brain dynamics in silico reveals mechanistic differences between brain states.NeuroImage, Vol. 169, 01.04.2018, p. 46-56.

Deco, Gustavo; Cruzat, Josephine; Cabral, Joana; Knudsen, Gitte M.; Carhart-Harris, Robin L.; Whybrow, Peter C.; Logothetis, Nikos K.; Kringelbach, Morten L. Whole-Brain Multimodal Neuroimaging Model Using Serotonin Receptor Maps Explains Non-linear Functional Effects of LSD. Current Biology, Vol. 28, No. 19, 08.10.2018, p. 3065-3074

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Fjaeldstad, Alexander; Fernandes, Henrique; Nyengaard, Jens Randel; Ovesen, Therese. Bag om smag. Ugeskrift for Læger , Vol. 180, No. 18.

Fjaeldstad, A; Niklassen, A; Fernandes, H. Re-test reliability of gustatory testing and introduction of the sensitive Taste-Drop-Test. Chemical Senses, Vol. 43, No. 5, 23.05.2018, p. 341–346.

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Ravignani, Andrea; Thompson, Bill; Lumaca, Massimo; Grube, Manon. Why do durations in musical rhythms conform to small integer ratios? Frontiers in Computational Neuroscience, 2018, 12.

Jakubowski, K., Bashir, Z., Farrugia, N. Stewart, L.. Involuntary and voluntary recall of musical memories: A comparison of temporal accuracy and emotional responses. Memory & Cognition, July 2018, Volume 46, Issue 5, pp 741–756

Kliuchko, Marina; Puoliväli, Tuomas; Heinonen-Guzejev, Marja; Tervaniem, Mari; Toiviainen, Petri; Sams, Mikko; Brattico, Elvira. Neuroanatomical substrate of noise sensitivity. NeuroImage, Vol. 167, 15.02.2018, p. 309-315.

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Lumaca, Massimo; Baggio, G. Signaling games and the evolution of structure in language and music: A reply to Ravignani & Verhoef. Artificial Life, 2018, p. 154.

Lumaca, Massimo; Haumann, Niels Trusbak; Vuust, Peter; Brattico, Elvira; Baggio, Giosuè. From random to regular: Neural constraints on the emergence of isochronous rhythm during cultural transmission.Social Cognitive and Affective Neuroscience, Vol. 13, No. 8, 05.09.2018, p. 877-888.

Lumaca, Massimo; Ravignani, Andrea; Baggio, G. Music evolution in the laboratory: Cultural transmission meets neurophysiology. Frontiers in Neuroscience, 2018, 12 p. 246.

Møller, Cecilie; Højlund, Andreas; Bærentsen, Klaus B.; Hansen, Niels Chr.; Skewes, Joshua C.; Vuust, Peter. Visually induced gains in pitch discrimination: Linking audio-visual processing with auditory abilities. Attention, Perception & Psychophysics, Vol. 80, No. 4, 05.2018, p. 999-1010.

Niklassen, Andreas Steenholt; Ovesen, Therese; Fernandes, Henrique; Fjaeldstad, Alexander Wieck. Danish Validation of Sniffin' Sticks Olfactory Test for Threshold, Discrimination, and Identification. The Laryngoscope, Vol. 128, No. 8, 2018, p. 1759-1766.

Pearce, Marcus. Statistical learning and probabilistic prediction in music cognition: mechanisms of stylistic enculturation. Annals of the New York Academy of Sciences, Vol. 1423, 2018, p. 378-395.

Ravignani, Andrea; Thompson, Bill; Lumaca, Massimo; Grube, Manon. Why do durations in musical rhythms conform to small integer ratios? Frontiers in Computational Neuroscience, 2018, 12.

Reybrouck, M., Vuust, P., & Brattico, E. Brain Connectivity Networks and the Aesthetic Experience of Music. Brain Sci, 8(6), p 107.

Ryyppö, Elisa; Glerean, Enrico; Brattico, Elvira; Saramäki, Jari; Korhonen, Onerva. Regions of Interest as nodes of dynamic functional brain networks. Network neuroscience (Cambridge, Mass.), Vol. 2, No. 4, 2018, p. 513-535.

Saari, Pasi; Burunat, Iballa; Brattico, Elvira; Toiviainen, Petri. Decoding Musical Training from Dynamic Processing of Musical Features in the Brain. Scientific Reports, Vol. 8, No. 1, 708, 15.01.2018

Sauvé, Sarah; Sayed, Aminah; Dean, Roger; Pearce, Marcus. Effects of pitch and timing expectancy on musical emotion. Psychomusicology: Music, Mind, & Brain, Vol. 28, 2018, p. 17-39.

Sears, David; Pearce, Marcus; Caplin, William; McAdams, Stephen. Simulating melodic and harmonic expectations for tonal cadences using probabilistic models. Journal of New Music Research, Vol. 47, 2018, p. 29-52

Stark, Eloise A; Vuust, Peter; Kringelbach, Morten L. Music, dance, and other art forms: New insights into the links between hedonia (pleasure) and eudaimonia (well-being). Progress in Brain Research, Vol. 237, 2018, p. 129-152.

Stewart, Mary E.; Griffiths, Timothy D.; Grube, Manon. Autistic Traits and Enhanced Perceptual Representation of Pitch and Time. Journal of Autism and Developmental Disorders, 04.2018, p. 1350-1358.

Te Lindert, Bart H W; Itzhacki, Jacob; van der Meijden, Wisse P; Kringelbach, Morten L; Mendoza, Jorge; Van Someren, Eus J W. Bright environmental light ameliorates deficient subjective 'liking' in insomnia : an experience sampling study. Sleep, Vol. 41, No. 4, zsy022

Vuust, Peter; Dietz, Martin; Witek, Maria; Kringelbach, Morten L. Now you hear it: a predictive coding model for understanding rhythmic incongruity. Annals of the New York Academy of Sciences, Vol. 1423, No. 1, 07.2018, p. 19-29.

Zou, Lai-Quan; Zhou, Han-Yu; Zhuang, Yuan; van Hartevelt, Tim J; Lui, Simon S Y; Cheung, Eric F C; Møller, Arne; Kringelbach, Morten L; Chan, Raymond C K. Neural responses during the anticipation and receipt of olfactory reward and punishment in human. Neuropsychologia, Vol. 111, 03.2018, p. 172-179

Conference abstracts in proceedings

Vuust, Peter. Groove on the Brain.
Revised Selected Papers from Music Technology with Swing - 13th International Symposium, CMMR 2017, Springer, 2018. p. 101-110.

Heinonen-Guzejev, Marja; Kliuchko, Marina; Vuust, Peter; Tervaniemi, Mari; Brattico, Elvira; Shepherd, Daniel; Heikkilä, Kauko; Dirks, Kim N.; Hautus, Michael J.; Welch, David; McBride, David. Studying the origins of noise sensitivity - negative affect or biological factors. Proceedings of Euronoise 2018, Heraklion, Greece. Pp- 521-525,

Harrison, Peter; Pearce, Marcus. An energy-based generative sequence model for testing sensory theories of Western harmony. Proceedings of the 19th International Society for Music Information Retrieval Conference. Paris: IRCAM, 2018.

Harrison, Peter; Pearce, Marcus. Dissociating sensory and cognitive theories of harmony perception through computational modeling. Proceedings of the 15th International Conference on Music Perception & Cognition. Graz, 2018.

Stupacher, Jan Alexander; Wood, Guilherme. Effects of cultural background and musical preference on affective social entrainment with music. Proceedings of ICMPC15/ESCOM10. Graz, Austria, 2018. p. 438-441.

PhD thesis

Jespersen, Kira Vibe
Music for insomnia

Møller, Cecilie
Ceci n'est pas une pitch change. Linking perceptual amplification of audiovisual events in brain and behavior to auditory sensitivity and musical expertise

Book chapters (selected)

Atasoy, Selen; Vohryzek, Jakub; Deco, Gustavo; Carhart-Harris, Robin L.; Kringelbach, Morten L. Common neural signatures of psychedelics: Frequency-specific energy changes and repertoire expansion revealed using connectome-harmonic decomposition. In Psychedelic Neuroscience. Ed. / T Calvey. Elsevier, 2018. p. 97-120.

Morrison, Steven; Demorest, Steven; Pearce, Marcus. Cultural Distance: A Computational Approach to Exploring Cultural Influences on Music Cognition. In Oxford Handbook of Music and the Brain. Ed. / Michael Thaut; David Hodges. Oxford: Oxford University Press, 2018.

Rohrmeier, Martin; Pearce, Marcus. Musical syntax I: Theoretical perspectives. In Springer Handbook of Systematic Musicology. Ed. / Rolf Bader. Berlin: Springer, 2018. p. 473-486.

Pearce, Marcus; Rohrmeier, Martin. Musical syntax II: Empirical perspectives. In Springer Handbook of Systematic Musicology. ed. / Rolf Bader. Berlin: Springer, 2018. p. 487-505.

Reybrouck M, Vuust P, Brattico, E. Music and the plastic brain: How sounds trigger neurogenerative adaptations. In Neuroplasticity - Insights of Neural Reorganization, 2018

Posters/abstracts (selected)

Grube, Manon; Brandl, Stephanie; Kindermans, Pieter-Jan; Blankertz, Benjamin; Daehne, Sven; Mueller, Klaus-Robert. Can we "find the beat"? Searching the beta band in the human EEG as a function of acoustic rhythmic regularity and in correlation with behaviour.
11th FENS Forum of Neuroscience, Berlin, Germany.

Ajaj, Tamer; Blankertz, Benjamin; Alter, Kai, Grube, Manon. Event-related EEG correlates of the processing of a metrical beat: in search for components of entrainment and prediction. Neuroscience Day 2018, Aarhus, Denmark.

Kliuchko, Marina; Haumann, Niels Trusbak; Huotilainen, Minna; Vuust, Peter; Tervaniemi, Mari; Brattico, Elvira. Expertise-dependent sensitivity to mistuning and melody transposition: MEG study with melodic multi-feature MMN paradigm.
15th International Conference on Music Perception and Cognition & 10th triennial conference of the European Society for the Cognitive Sciences of Music, Graz, Austria.

Fasano, Maria Celeste; Semeraro, Cristina; Cassibba, Rosalinda; Kringelbach, Morten; Vuust, Peter; Brattico, Elvira. Exploring the effects of an innovative collective music training on inibitori control and hyperactivity in early adolescents.
15th International Conference on Music Perception and Cognition & 10th triennial conference of the European Society for the Cognitive Sciences of Music, Graz, Austria.

Tiihonen, Titta Marianne; Saarikallio, Suvi; Haumann, Niels Trusbak; Shtyrov, Yury; Brattico, Elvira. Interaction of Visually and Auditorily Derived Affect : An MEG Study.
European Society for Cognitive and Affective Neuroscience, meeting in Leiden, 2018, Leiden, Netherlands.

Ahrends, Christine; Bravo, Fernando; Vuust, Peter; Rohrmeier, Martin. Modulatory effects of tonality on decision making under uncertainty.
Computational Neuroscience of Prediction, Rungsted, Denmark.

Petersen, Bjørn; Friis Andersen, Anne Sofie; Dietz, Martin; Højlund, Andreas; Brattico, Elvira; Haumann, Niels Trusbak; Michel, Franck; Kamaric Riis, Søren; Vuust, Peter.
Musical Listening in Electric Hearing –Two Novel EEG Paradigms for Studying Music Discrimination in Cochlear Implant Users. 2nd International Music and CI symposium, Montreal, Canada.

Cantou, Pauline; Fasano, Maria Celeste; Alexander Kleber, Boris; Vuust, Peter; Brattico, Elvira. Musical tension processing in preadolescents: a free-listening fMRI study.
15th International Conference on Music Perception and Cognition & 10th triennial conference of the European Society for the Cognitive Sciences of Music, Graz, Austria.

Kliuchko, Marina; Puoliväli, Tuomas; Heinonen-Guzejev, Marja; Tervaniemi, Mari; Toiviainen, Petri; Sams, Mikko; Brattico, Elvira. Neuroanatomical correlates of noise sensitivity.
8th Mind Brain Body Symposium, Berlin, Germany.

Møller, Cecilie; Højlund, Andreas; Hansen, Niels Christian; Vuust, Peter. Pitch-related mismatch negativity as an index of musical aptitude.
MMN2018: The 8th Mismatch Negativity conference, Helsinki, Finland.

Kliuchko, Marina; Tervaniemi, Mari; Vuust, Peter; Brattico, Elvira. Probing the functional specialization of auditory encoding following musical training with multi-feature MMN paradigms.
MMN 2018: The 8th Mismatch Negativity Conference, Helsinki, Finland.

Mogensen, Rasmine Louise Holm; Bjerg Hedegaard, Maja ; Olsen, Ludvig ; Skewes, Joshua Charles; Gebauer, Line. Relational Memory in High-Functioning Children with Autism Spectrum Disorders.
NSAR 2018: Annual Meeting, Rotterdam, Netherlands.

Petersen, Bjørn; Friis Andersen, Anne Sofie; Dietz, Martin; Højlund, Andreas; Brattico, Elvira; Haumann, Niels Trusbak; Michel, Franck; Kamaric Riis, Søren; Vuust, Peter.
The CI MuMuFe - a new MMN paradigm for measuring music discrimination in electric hearing.
MMN 2018: The 8th Mismatch Negativity Conference, Helsinki, Finland.

Gebauer, Line; Højlund, Andreas; Vuust, Peter. The no-standard musical multi-feature paradigm (MuMUFE).
MMN 2018: The 8th Mismatch Negativity Conference, Helsinki, Finland.

Others

Ph.d-stafet: At høre med øjnene. / Møller, Cecilie. Psykologernes fagmagasin, Vol. 4. årgang, No. 10, 10.2018, p. 26-28.

KUV-netværkets årbog 2018. / Petersen, Bjørn (Editor). 2018. 34 p.

KUV på Det Jyske Musikkonservatorium. / Petersen, Bjørn. KUV-netværkets årbog 2018. 2018. p. 50.

Center for Music in the Brain. Photo: Hella Kastbjerg

OUTREACH 2018

Talks at international conferences

Bjørn Petersen
Oticon Medical Scientific Meeting, Copenhagen. Denmark

Boris Kleber
Voice Day 2018, Talin, Estonia

Elvira Brattico
MEG Nord 2018, Stockholm, Sweden
8th Mismatch Negativity Conference MMN2018, Helsinki, Finland
Worlding the Brain, Aarhus University, Denmark
Nordic Conference on Culture and Health, Stockholm, Sweden
The Open Seminar in Music Psychology, Uppsala, Sweden

Jan Stupacher
15th International Conference on Music Perception and Cognition & 10th triennial conference of the European Society for the Cognitive Sciences of Music, Graz, Austria

Kira Vibe Jespersen
The Sound of Music i Sundhedsvæsnet, Aarhus, Denmark
High Tech Summit, DTU, Lyngby, Denmark
International Association for Music & Medicine conference Barcelona, Spain

Marianne Tiihonen
The Second NorDoc PhD Summit "Think Open"

Massimo Lumaca
15th International Conference on Music Perception and Cognition & 10th triennial conference of the European Society for the Cognitive Sciences of Music, Graz, Austria

Morten Kringelbach
Dutch Society for Neuropsychology Amsterdam
Neuroscience day 2018, Aarhus University, Aarhus
10th Workshop on Biomedical Engineering, Lisbon, Portugal
Inaugural Symposium, "Jung, Trauma and Neuroscience: Pathways to Healing" CLA, USA

Peter Vuust
Worlding the Brain, Aarhus University, Denmark
Musik og Læring 2018, Royal Academy of Music, Denmark
Symposium: Modeling Rhythmic Complexity University of British Columbia, Canada
8th Mismatch Negativity Conference MMN2018, Helsinki, Finland
RITMO International Motion Capture Workshop, Oslo, Norway
The Sound of Music i Sundhedsvæsnet, Aarhus, Denmark

Prof Morten Kringelbach presenting at Folkeuniversitetet, Aarhus University. The talk was live-streamed to 10,000 viewers around Denmark.

Prof Peter Vuust presenting at the conference Musik og Læring 2018 at the Royal Academy of Music, Denmark

Other talks (selected)

Bjørn Petersen
Workshop Musik og Sundhed
Epilepsihospitalet Filadelfia

Boris Kleber
Almeria University Summer School
Lund University
University of the Balearic Islands
University of Almeria

Elvira Brattico
CBRU, Institute of Behavioural Sciences, University of Helsinki
Arpa Magica Centro di Ricerca Musicoterapeutica, Milano, Italy.
Aalborg University
Musicology Department, Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany
Nuroscience Department, Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany
Institute of Music, Carl von Ossietzky University of Oldenburg, Germany.
Almeria University Summer School
Department of Communication, Arts and Media, Free University of Languages and Communication IULM, Milano, Italy.
CiMeC, Centre for Mind/Brain sciences, University of Trento
Department of Basic Medical Sciences, Neuroscience, and Sense Organs, University of Bari, Bari, Italy

Kira Vibe Jespersen
Regionshospital Horsens
The Department of Neurology, Aarhus University Hospital

Leonardo Bonetti
Bologna University

Manon Grube
IPEM Institute for Psychoacoustics and Electronic Music, Ghent, Belgium
Center for Complexity Sciences, UNAM Main Campus, Mexico
UNAM Summer School of Science, Art and Cognition 2018

Prof Elvira Brattico presenting at Almeria University Summer School in Spain

Mette Kaasgaard
Lungeforeningen
Odense University
Østre Skole, Slagelse

Morten Kringelbach
Physiological Society, London
Carlsberg Foundation, Oxford
Masud Husain Lab, Oxford.
UCL Neuroscience Society
For Danish Minister of Research
Royal Institution, London
Institut d'études avancées de Paris
Wolfson College

Peter Vuust
Vlaamse Scriptieprijs, Belgium
McGill University and Montreal Neurological Institute
Videnskabernes Selskab
Lundbeck
DJØF chefkonference
Lægeforeningen
DNRF Annual Meeting 2018
Region Midtjylland
Dansk Sygeplejeråd
Dansk Selskab for Apopleksi
DUG´s Årsmøde
Tranquebar Rejseboghandel & Café
Sydjysk/fynske musik- og Kulturskole lederseminar
Herlev Musikskole
Dansk psykoterapeutforening
The 49th Sorø International Musicfestival 2018
Syddansk Musikkonservatorium
Den Jyske Opera
Randers Bibliotek
Dalgasskolen
Aros' Klean Masterclass
Østre Gasværk
Varde Bibliotek
Københavns Kommune's Faglighed i Teltet
Neuropædagogiske konference
Roskilde Bibliotek
Åben Campus 2018
Vejlby Højskoleforening
Dronninglund Gymnasium

Rasmine Mortensen
Vingstedkursus 2018 for foreningen af tale-høre-lærere i folkeskolen
Aarhuskonferencen 2018

Participation in TV and Radio (selected)

Angus Stevner
Go'morgen Danmark, TV2

Boris Kleber
DR Sundhedsmagasinet

Kira Vibe Jespersen
P1 Morgen
P1 - Kulturen på P1
Welfaretech youtube

Morten Kringelbach
BBC
BBC Radio 4
P1
DR TV-Avisen
DR P4-Aarhus

Nadia Høgholt
Go'morgen Danmark, TV2
DR

Peter Vuust
DR Sundhedsmagasinet
DR1 Kulturmagasinet Gejst
DRK: Live fra højskolesangbogen
DR podcast
P1 Musik i laboratoriet

DR P7 mix
Podcast Dopamine Release
Kulturen på P1
DR Sporten
Videnskab.dk Podcast
Radio 24-7: 24 Spørgsmål til professoren
Hjernekassen på P1
DR P6 Beat
DR P1 Kejser
DR P4 Formiddag

Prof Morten Kringelbach featured in Grazia
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Interviews in printed media/web (selected)

Angus Stevner
Vårt land
Aarhus Stiftstidende
www.videnskab.dk
www.dr.dk

Cecilie Møller
Politikken

Henrique Fernandes
Aarhus Stiftstidende

Kira Vibe Jespersen
Dagbladet Holstebro/Struer

Marina Kliucho
Weekendavisen

Morten Kringelbach
Vårt land
Corriere Della Sera
Aarhus Stiftstidende
Newsweek
New Statesman
Politikken
GeekWire.com
videnskab.dk
www.dr.dk
Vice.comInterview
PsyPost.org

Nadia Høgholt
Aarhus Stiftstidende

Peter Vuust
Nature
Gaffa
Jyllands-Posten
Uddannelsesbladet
Nordjyske Stiftstidende
Fit Living
BT
Politikken
Tjeck Magazine
Kristeligt Dagblad
Aarhus Stiftstidende
Flensburg Avis
Midtjyllands Avis
Magasinet Helse
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Livsstil.tv2.dk
Dagens Medicin.dk
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alt.dk
Epilepsiforeningen.dk

MIB Annual Report 2018

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

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