# Neurodynamics of Language and Music symposium

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Speaker abstracts

## Music Emotions and Aesthetics in the Brain

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While not having any obvious survival value for humans, aesthetic music enjoyment can be regarded as a basic phenomenon of human life. Even infants seem to enjoy music; for example, they are calmed down by the tunes sung by their own mothers. The feelings of pleasure triggered by music processing (similarly to other arts) must have a biological basis, i.e., must be founded on specific brain structures solely or mainly devoted to this experience. Considerable body of scientific research, which investigates the benefits of music on health and wellbeing, has begun to emerge. But why has music such a deep impact on our emotional and aesthetic life? What are the biological determinants of musical emotions and enjoyment? Why are some people touched by music more than others? In this talk I will present neuroimaging studies revealing the brain functions enabling us, and some individuals more than others, to experience musical emotions and enjoyment. In this framework, the modulatory role of person-related variables, such as familiarity, personality and expertise, in experiencing musical emotions will be discussed.

## Auditory and speech perception before school age – implications for language and reading development

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First years of life are important for brain development in general and also for auditory and speech perception. At birth, infants are equally capable of discriminating all speech sounds, but during the first year perception of native language speech sounds become preferred over non-native speech sounds. This process occurs gradually over the first year of life. Our results of 6-month-old typically developing infants show that they process voice-onset-time contrasts in native and non-native speech sounds differently. Event-related potentials were localized to auditory cortices and frontal area near anterior cingulate cortex. Time-frequency analyses of the source activity showed native-stimulus specific processing already at the age of 6 months. Further studies of infants from Jyväskylä Longitudinal Study of Dyslexia and preschool children showed that the processing of speech and tone stimuli is associated with sentence repetition, letter naming and phonological skills as well as school-age reading skills. These studies together with earlier studies suggest that processing of speech sounds at an early age can have an important effect on later language development.

## Sounds in psychiatric disorders

Kenneth Hugdahl
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In my talk I will present an overview of recent research in our laboratory on cognitive and brain markers of auditory hallucinations in schizophrenia. Auditory hallucinations are conceived of as the perception of "voices" that do not exist acoustically. The research is funded by an Advanced Grant from the European Research Council (ERC). The research extends from a theoretical model of auditory hallucinations (Hugdahl et al., 2009) that sees hallucinations as perceptual experiences caused by neuronal hyperactivation in the speech areas in the upper posterior temporal lobes, that are mis-attributed to an external source, using

functional and structural MR measures. Once initiated the hallucinations draw all available cognitive resources, in particular turning attention inwards to the "voices" rather than outwards to the voices, that may have a parietal lobe localization. The "voices" are also experienced by the patient as out of cognitive control, and is phenomenologically experienced as that the they control the patient rather than the other way around. The failure of cognitive inhibition and of executive functions are suggested to be due to frontal lobe hypo-activation. The presentation will end by presenting new research that extends the model by looking for transmitter and receptor correlates of neuronal hyper- and hypo-activation in the critical brain areas, using MR spectroscopy and PET measures.

Music in Healthy and Developing Brain

Minna Huotilainen
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Music is important to us throughout our development. Recent research shows how effortlessly music is perceived and learned in infancy and even prior to birth. Music serves several developmental goals. In emotional and physiological regulation, singing is a powerful means in helping an infant to calm down or stay alert. In language learning, musical activities provide a versatile playground for learning the low-level tasks shared by music and language: perception and memory for pitch, timbre, duration, temporal structure and rhythm, etc. The motor system is stimulated by music already in infancy. According to recent longitudinal studies, involvement in different types of musical activities accelerates the development of perceptive, memory-related, attentive, and executive functions in 2-15-year-old typically developing children and adolescents.
For children and adolescents with specific problems in language, attentive or behavioural development, these results raise the question of potential positive effects of musical activities. Indeed, several studies show that musical activities may alleviate some developmental problems. Specifically, children with reading difficulties benefit from musical activities, and children with hearing problems, resulting in delays and impairments in their language development, benefit from singing-related musical activities. These examples highlight the possibilities of using musical activities to support brain development.

The biological background of dyslexia

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Developmental dyslexia (DD) is known to have a strong genetic etiological component exceeding 50-70%, and altogether nine genomic loci have been linked to DD. Our group identified the first two susceptibility genes for DD, DYX1C1 (Taipale & al., PNAS 2003:100:11553) and ROBO1. We have studied the biological roles of these and other genes (DCDC2, KIAA0319, C2Orf3) using cell and animal models. Others and we implicated the DYX1C1, DCDC2 and KIAA0319 genes in neuronal migration in knockdown models of rat brain development. Recently, we implicated DYX1C1 and DCDC2 as genes playing important roles in regulating the structure and functions of cilia, cellular organelles with signaling functions on the surface of neurons and other cells. For example, knockdown of the zebrafish orthologous gene dyx1c1 in developing fish results in situs inversus totalis as well as brain and kidney malformations, all typical features of ciliopathies (Chandrasekar & al., PLoS One 2013:8:e63123). We have also combined brain imaging with molecular genetics to understand the role of the dyslexia susceptibility genes in different brain regions. Taken together, our studies pave a way to an integrated understanding of dyslexia as a largely genetic disturbance involving genes that regulate early brain development, specifically neuronal migration, through the functions of cilia, and resulting in variations in white matter structure in the human brain.

Auditory processing and its plasticity in dyslexia

Teija Kujala
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Developmental dyslexia is a remarkable cause of learning problems, which has a high prevalence. While several diverse symptoms are associated with dyslexia, problems in phonological processing are thought to be its main cause. Dyslexia is associated with a variety of impairments in speech and auditory processing, originating from low-level neural systems. Pre-attentive phonetic-acoustic neural discrimination and memory trace formation for novel words is deficient in dyslexia. Effective means for early dyslexia intervention should be developed in order to alleviate learning backwardness and motivational problems. Auditory and audiovisual training programs were shown to improve reading or pre-reading skills in children with or at risk for dyslexia. Furthermore, the intervention facilitated cortical auditory processing, suggesting intervention-induced plastic neural changes in the brain of dyslexic children.

Neurocognition of Bilingualism

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Neurocognitive research on bilingualism investigates, e.g., how words in two languages are represented and processed in the brain and how the two language systems are controlled. Accumulating evidence indicates that words in both languages are stored in a common lexicon, and both languages are constantly active. This suggests that we need effective mechanisms that help us use the appropriate language in a given situation and prevent the less relevant language from interfering. The mechanisms that control the use of the languages and the possible factors which can lead to changes in their activation levels are not yet well understood. Using MEG, we studied the management of the activation levels and the effect of language context on auditory word recognition. In an fMRI study, we investigated the neural correlates of sentence translation, a language task that sets high demands on language control processes. Furthermore, the “weaker links” hypothesis states that early balanced bilinguals may be at a disadvantage in contrast to monolinguals: using two languages constantly leads to receiving less exposure for words in one language. We studied the behavioral and ERP responses of visual word recognition to three fundamental psycholinguistic factors in early balanced bilinguals vs. monolinguals in order to examine this hypothesis.

Plasticity in audition – past, present and future

Josef P. Rauschecker
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Plasticity is a ubiquitous feature of the brain. It enables us to learn throughout our lifetime and to adjust to changing environments. Plasticity is particularly important in audition with its higher cognitive functions of language and music. While humans have a predisposition to develop the ability for both of these functions, specific languages and musical pieces have to be learned. Learning to play a musical piece or dancing to a tune depends to a large extent on motor plasticity, but the feat cannot be accomplished without auditory feedback. Amongst the two auditory processing streams, the dorsal stream is crucial for sensorimotor learning and the retention of sound sequences, such as musical melodies. I will discuss how the dorsal stream is conserved through evolution and how it engages during development. Finally, I will consider how plasticity is involved in the reorganization of the auditory system during sensory deprivation.

Neural correlates of rapid word acquisition

Yury Shtyrov
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Humans are unique in developing large lexicons; to achieve this, they are able to learn new words rapidly. However, neural bases of this rapid learning, which may be an expression of a more general mechanism

rooted in plasticity at cellular and synaptic levels, are not yet understood. Here, we highlight a selection of recent EEG and fMRI studies that attempted to trace word-learning in the human brain non-invasively. They show a rapid development of cortical memory traces for novel wordforms over a short session of auditory exposure to these items. Moreover, they demonstrate that this effect appears to be independent of attention, reflecting a largely automatic nature of word acquisition. At the same time, it seems to be limited to stimuli with native phonology, likely benefiting from pre-existing perception-articulation links in the brain, which suggests different neural strategies for learning words in native and non-native languages. We also show a complex interplay between overnight consolidation, amount of exposure to novel vocabulary and attention on speech input, which all influence learning outcomes. In sum, the current experiments suggest that our brain may effectively form new cortical circuits online, as it gets exposed to novel linguistic patterns in the sensory input. A number of brain areas, most notably in (but not limited to) hippocampus and neocortex, appear to take part in word acquisition. Critically, the currently available data not only demonstrate hippocampal role in rapid encoding followed by slow-rate consolidation of cortical memory traces, but also suggest immediate neocortical involvement in the word memory trace formation.

Music in Neurological Rehabilitation

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The capacity of music to engage a myriad of auditory, cognitive, motor, and emotional processes in many cortical and subcortical brain regions and the relative preservation of music in ageing and dementia, makes it a very promising tool in the rehabilitation of ageing-related neurological illnesses, such as stroke and Alzheimer's disease. As the incidence and prevalence of these illnesses is increasing rapidly, it is important to develop music-based interventions that are enjoyable, effective, and can be used in the everyday care of the patients. Our recent two randomized controlled studies, which I will present in this talk, have provided some of the first experimental evidence that self- or caregiver-implemented common musical activities, such as music listening and singing, can have a long-term positive impact on cognitive, emotional, and neural recovery after an acute stroke and can also support cognitive, emotional, and social functioning and caregiver wellbeing in elderly persons with mild-moderate dementia.

Musical Expertise, Functional Evidence

Mari Tervaniemi
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In the neurosciences of music, musicians have traditionally been treated as a unified group as if the demands set by their musical activities would be more or less equal in terms of perceptual, cognitive, and motor functions. However, obviously, their musical preferences differentiate them up to high degree, for instance, in terms of instrument they chose, music genre they are mostly engaged with as well as their practicing style. This diversity in the musicians' profiles has been recently taken into account in several empirical endeavors. In my talk I will review the evidence available about the various auditory profiles these different musicians display.

Musical expertise - from neuroimaging to behavior genetics

Fredrik Ullén
Karolinska Institutet, Sweden

Musicians have become one of the most widely used model populations in psychological and neurobiological studies of expertise. Neuroimaging studies have demonstrated that brains of musicians show extensive anatomical reorganizations in brain regions involved in music processing. These effects typically show strong relations to measures of musical practice, and presumably reflect neural adaptations that enable an efficient perception, performance and creation of music. Here, I will summarize key findings

from the neurobiological literature on musicians, and also discuss recent findings from large-scale twin studies where we investigate genetic and non-genetic factors behind musical training and its correlates.

Prediction error as the key to understanding the pleasure of challenging rhythms

Peter Vuust
University of Aarhus, Denmark

A strong source of musical pleasure in contemporary music is the tension created between musical rhythm and the underlying pulse or metric framework. Leaving familiarity and other extra-musical explanations aside, three main expectancy-related mechanisms have been suggested as the source of this tension: micro-timing variations, repetition, and syncopation. This presentation reports the results of recent investigations, using behavioral measures and functional magnetic resonance imaging (fMRI) of brain activity to syncopated rhythms in which the degree of syncopation (prediction error) is systematically varied. The results implicate brain structures related to motion, emotion, and cognition and indicate that the perceived pleasure of rhythm depends on the balance of tension between musical anticipatory structures and predictive brain mechanisms in higher level areas for music processing. Similar brain networks were found in a recent fMRI study of emotional music on patients suffering from autism spectrum disorder (ASD). These brain activations in relation to emotional and pleasurable music will be discussed in the light of emerging theories of brain function such as Friston's predictive coding theory, and parallels will be drawn to a recent EEG- study, that indicates an effect of a short intensive musical training program on behavioral and neural measures of rhythm perception in adolescent cochlear implant users.