Conference Report: The Neurosciences and Music - IV – Learning and Memory

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INTRODUCTION

2011 saw the fourth in a series of conferences on Neurosciences and Music organised by the Mariani Foundation (Fondazione Pierfranco e Luisa Mariani), and hosted this year by the Institute for Music in Human and Social Development (IMHSD) at the University of Edinburgh. Within IMHSD, Katie Overy led a panel of international experts on the scientific committee. The aim of the triennial conference is to promote the dissemination of knowledge in research fields related to neurobiology, physiology, psychology and neuropsychology applied to music, emphasizing developmental issues. This year's theme was Learning and Memory and the conference brought together neuroscientists, psychologists, cognitive scientists, musicians, musicologists, clinicians and therapists for 50 presentations spread over 9 symposia, 2 workshops and a keynote lecture, along with a further 243 posters across 3 sessions, all held between the 9th and 12th of June 2011.

Constraints of time and space make it impossible to include all presentations, so we have aimed to give a narrative overview of the event tying together three themes that caught our attention: (i) perception of basic musical structure (rhythm and meter) and musical imagery; (ii) the production of music (memory, learning and plasticity induced by musical training); and (iii) music in the context of psychological disorders. Further details are available from the Mariani Foundation (http://www.fondazione-mariani.org), in a blog reviewing the conference, from the perspective of music psychology (http://musicpsychology.co.uk), and another from the perspective of neuroaesthetics (http://neuroaesthetics.net).

MUSIC PERCEPTION

Bottom-up: Processing of basic musical structure

The first symposium examined mechanisms of rhythm and meter learning where a key theme of recent research has been the differences between beat-based and interval-based processing in terms of cognitive and neural processing. Contributing to these issues, J. Devin McAuley from Michigan State University showed that individual differences in beat sensitivity are related to differential activation in the basal ganglia and cortical motor areas (Grahn & McAuley, 2009). Several presenters at the conference focused on implicit learning in music perception and production, the first being Henkjan Honing from the Universiteit van Amsterdam who examined a range of research suggesting that pre-attentive hierarchical representations of rhythm are actually learned implicitly through mere exposure rather than through explicit musical training. This suggest that exposure might be a crucial source for interindividual differences in rhythm and metre learning (Winkler, Haden, Ladieig, Sziller, & Honing, 2009).

Top-down: Musical imagery

Another symposium focused on higher-level processes involved in the perception of music with no bottom-up auditory input. Andrea Halpern from Bucknell University presented fMRI data showing that increased vividness in musical imagery correlates with increased activation in motor areas such as SMA and basal ganglia but not, interestingly, in sensory cortex (Leaver, Van Lare, Zielinski, Halpern, & Rauschecker, 2009). Conversely, in a study presented by Robert Zatorre from McGill University, Montreal, mental transformations of music (another kind of musical imagery: recognising reversed and transposed melodies) were found to activate intra-parietal sulcus implicating the dorsal auditory pathway – i.e., enhanced sensory processing - during manipulation of musical material. These diverging results in terms of sensory processing during musical imagery may be due to differences in the paradigms used or to familiarity with the musical stimuli.

Turning to interindividual differences in musical imagery abilities, Peter Keller from the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig presented a series of studies on action simulation suggesting that better anticipatory auditory imagery ability helps prediction and synchronization in social situations, especially when both participants are good predictors. This evidence points towards improved ensemble coordination and performance when the musicians are particularly skilled in auditory imagery and prediction of other musicians' subsequent musical actions (Pecenka & Keller, 2011).

PRODUCTION OF MUSIC

Effects of musical training on language processing

We turn now from perception to the effects of music performance and, in particular, to a series of presentations examining the enhancing effect of musical training on language processing. Nina Kraus from Northwestern University presented a range of evidence, including EEG studies of brainstem responses, suggesting that musical training improves neural encoding of speech in noise (Skoe & Kraus, 2010). Further evidence for the positive effects of musical training on neural processing of language were provided by Martin Meyer from the University of Zürich who reported differences between musicians and non-musicians in N1 responses to voiced and unvoiced auditory sequences. In a similar vein, Daniele Schön, from the University of Marseille presented evidence from a longitudinal study of children showing that musical training improves the ability to learn statistical regularities in the pitch and linguistic structure of sung syllable sequences. Finally, Stefan Koelsch and Katrin Schulze from the Freie Universität Berlin examined a range of neuroimaging evidence on working memory in music, concluding that musical training establishes two distinct but overlapping systems: a phonological loop, for rehearsing verbal stimuli, and a tonal loop for rehearsing pitch information (Schulze, Mueller, & Koelsch, 2011). Altogether, these results suggest that musical training has beneficial effects on development of language processing.

Effects of musical training on the brain

As to music performance itself, Virginia Penhune from Concordia University, Montreal presented data comparing music performance ability between early (before seven years of age) and late (after seven) trained musicians. Results indicated a critical period for musical training around the age of seven; the earlier trained being more skilled. Meanwhile, Peter Vuust from Aarhus University Hospital introduced the results of a study using a novel multi-feature mismatch negativity (MMN) paradigm which demonstrated that jazz musicians show greater sensitivity and earlier responses to outliers in several auditory dimensions than classical and pop musicians. Vuust explained these results in terms of distinctive characteristics of jazz music and performance. Finally, Lutz Jäncke from the University of Zürich showed that more skillful pianists exhibit greater coupling between premotor and auditory cortex which he related to a dynamic internal rhythm generator.

These three convergent lines of evidence show explicit musical training enhances various aspects of the neural processing of music both in perception and performance.

Negative effects of musical training

Conversely, several talks reminded us that the effects of musical training are not always positive. Eckart Altenmüller from the University of Music, Drama and Media in Hannover presented the research of his lab on musician’s dystonia, showing that extrinsic triggers may result from impaired lateral inhibition causing blurred neural sensorimotor representations. Pianists with focal hand dystonia have greater grey matter volume in the right middle putamen corresponding to worse timing in performing overlearned motor sequences (Granert, Peller, Jabusch, Altenmüller, & Siebner, 2011). María Herrojo Ruiz from the Charité-University of Medicine in Berlin continued the theme of anticipatory processing introduced by Peter Keller in a fascinating presentation of research on electrophysiological signatures for error prediction and control in healthy and dystonic pianists which could have clinical implications for early diagnosis.

Towards the end of his talk, Professor Altenmüller reflected on the difficulty of using available evidence to benefit the affected musicians. He argued that less perfectionism and more focus on the expressive intention of the music would help prevent musicians becoming obsessed with ever more perfect execution of the musical movements, which may trigger a latent predisposition for dystonia.

MUSIC AND PSYCHOLOGICAL DISORDERS

Music in stroke rehabilitation

On the final day, the conference moved on to beneficial relationships between music and psychological disorders. One salient theme was the therapeutic role of music in rehabilitation of stroke patients. Antoni Rodriguez-Fornells from the University of Barcelona presented the results of fMRI and TMS studies showing the efficacy of music-supported therapy in reorganizing sensorimotor cortex in chronic stroke patients (Rojo, Amengual, Juncadella, Rubio, Camara, Marco-Pallares, et al., 2011). Complementing this research, Takako Fujioka from the University of Toronto showed changes following music-supported therapy in auditory evoked responses (N1m, MMN) and beta band oscillations in chronic stroke patients with motor impairment.

Turning from theory to clinical practice, Concetta Tomaino from the Institute for Music and Neurologic Function in New York, followed by Raymond MacDonald and his group from Glasgow Caledonian University presented inspiring practical demonstrations of the music-supported therapies they have developed, respectively, for aphasics and individuals with impaired arm movement following stroke (e.g., Cassidy & MacDonald, 2009).

Clear therapeutic effects of music on devastating pathological conditions such as stroke are shown by these studies, suggesting a still largely unexplored potential of this essentially human art form to enhance and optimize human body and brain function.

Music perception in Autism

Another significant theme explored within this session concerned the effects of autistic spectrum disorder on music perception. Pamela Heaton and her colleagues from Goldsmiths, University of London presented research suggesting that children with autism have heightened sensitivity to pitch in musical sounds, while they have difficulty understanding pitch-mediated linguistic cues. Even more surprisingly, further studies showed that autistic children were able to recognize emotion in music (Heaton, 2009). Meanwhile, Kristina Hyde from McGill University presented research showing that ASD individuals are better in the spatial dimension of pitch perception than in the temporal dimension and have a pitch direction advantage. She also presented evidence from neuroimaging studies showing anatomical differences and characteristic functional processing of auditory stimuli in ASD, both in primary auditory cortex and higher auditory areas such as Planum Temporale. She proposed interpretations of these results within the scope of the Enhanced Perceptual Functioning Hypothesis (Mottron, Daveson, Soulières, Hubert, & Burack, 2006) and the Neural Complexity Hypothesis (Bertone, Mottron, Jelenic, & Faubert, 2005).

These results indicate, not only that music as an art form has the potential to capture the attention of individuals with ASD where other social stimuli do not, but also, that individuals with ASD actually perceive music differently due to the anatomical and functional organization of their auditory systems.

Congenital amusia

The final symposium of the conference focused on disorders of musical perception. Simone Dalla Bella from WSFiZ in Warsaw, presented research on individuals with congenital amusia suggesting that memory is an important factor in poor production ability which may be improved if imitation tasks are used instead of recall tasks. Lauren Stewart from Goldsmiths, University of London, argued that explicit conscious perception may be more impaired in congenital amusia than implicit abilities and presented preliminary research suggesting that singing lessons can improve the performance of amusic individuals. The two final presentations of the conference examined implicit statistical learning of auditory sequences in congenital amusia. Isabelle Peretz from the University of Montreal and Jenny Saffran from the University of Wisconsin presented evidence (using similar tasks to those of Daniele Schön) that statistical learning is impaired for tone sequences but intact for syllable sequences in amusia. Interestingly, these results contradict those reported recently by Omigie and Stewart (2011) perhaps because these authors used non-words as their foils, making their task slightly easier than that of Peretz and Saffran, who used part-words (and, interestingly, failed to replicate the original findings of Saffran, Johnson, Aslin, & Newport, 1999, Exp. 2).

Focusing at a more general level, Psyche Loui from Harvard Medical School demonstrated that amusics are less able than controls to learn the syntax of a finite-state grammar (composed of pitches from the Bohlen-Pierce scale consisting of a 13-fold logarithmic division of a 3:1 interval) and that learning performance correlated with reduced white-matter volume in the arcuate fasciculus (which is reduced in size in the amusic group overall). Together these results further our understanding of the disorder both in terms of extending its scope to statistical learning of pitch sequences and how its effects might be mitigated.

DISCUSSION AND CONCLUSION

To conclude our report, let's return to the beginning of the conference. Some very clear take-home messages were formulated on the first day during the very valuable workshops on methodological issues, which provided great inspiration for future research.

Sandra Trehub from the University of Toronto made a strong argument for the use of behavioral methods in developmental research. Paradoxically, for a conference on Neuroscience, this was a very important theoretical contribution since it reminds us of the dangers of recording neural responses without any behavioural data to help us understand what cognitive processes they reflect. In such cases, it is all too easy to fall back on reverse inference (Poldrack, 2006) which is dangerous for a phenomenon such as music which engages so many different kinds of bottom-up and top-down cognitive process and their corresponding cortical and subcortical networks at different levels in the neural hierarchy. These psychological processes can be very comprehensively studied using behavioral methods along with psychophysiological measures and neuroimaging techniques but the latter are less often useful without the former.

To conclude, two more presentations from the first day of the conference deserve special mention. The first was given by Nadine Gaab from Harvard Medical School. She outlined an effective experimental procedure for neuroimaging studies with babies and infants. It consists of three phases: (i) task training, (ii) movement prevention training and (iii) the use of presents, certificates etc. as motivators. She stressed the importance of well-trained staff using child-friendly concepts (e.g., “brain-camera” instead of “scanner”), equipment (e.g., whole hand response devices), and so on. Perhaps most importantly, the guidelines for this intuitive protocol are available online at: http://www.childrenshospital.org/research/gaab. More generally, this presentation reminded us of the importance of clear instructions and of looking after our participants if we want to get clean data.

The second presentation was by Nigel Osborne from the University of Edinburgh who spoke passionately about the use of music as an intervention tool with children suffering PTSD after wartime experiences. This breathtaking talk brought us firmly out of the controlled environment of the laboratory and reminded us of the genuine power of music to make significant changes in the real world.

Talking of the real world, no conference on music would be complete without a bit of the genuine article and *Neurosciences and Music* catered for all tastes with a Ceilidh, a concert of classical music and a scratch Jazz gig to finish off in style what had been a very successful and exciting scientific meeting.

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