Citation for published version:

This is a pre-publication version of the following article:

Rose, D., Jones Bartoli, A., & Heaton, P., 'Music in our minds and bodies matters', *PsyPAG Quarterly*, Issue 103, June 2017.

Published version available online at:

http://www.psypag.co.uk/wp-content/uploads/2014/08/PsyPag-103_WEB-002.pdf

Document Version:

This is the Accepted Manuscript version.

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Discussion Paper for PSYPAG Quarterly

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Acknowledgment: With thanks to Dr Jason Lim for his help discussing earlier drafts.

Title: Music in our Minds and Bodies Matters.

Abstract

This paper aims to convey an introduction to the psychology of music. At a very basic level, sound informs our model of the world, aiding survival. Musical sound and practice further offers a merging of exogenous and endogenous temporal states and templates, employing multiple complex neural mechanisms. Here we provide an overview of the literature exploring why music matters to our minds and bodies.

Music appears to serve a broad range of linked functions for human beings. Not only can our brains process the sonic information via spectral-temporal analysis (a sense-datum), we further apprehend this experience as having consciously accessible autotelic (*an end to itself*) value. We listen and make music in a variety of ways, individually and together in a range of group sizes creating connections through shared and often nonverbal experience.

Sound (and therefore music) is perceived in the superior temporal cortex, or Brodmann's Area 41 and 42 - the primary auditory cortex (PAC). Multiple sources of information (such as: direction of projection, frequency, timbre and duration) are integrated early en route to the medial geniculate nucleus in the thalamus, which also receives input from the PAC in a pathway known as the efferent corticofugal pathway. The PAC projects into the secondary auditory cortex where sounds are tonotopically organised (mapped from the hair cells innervated from the basilar membrane in the cochlear) in the lateral aspects of Heschl's Gyrus (HG). This hierarchical activation continues into the anterior and posterior superior temporal gyrus (STG; Plack, 2013).

German surgeon Sigmund Auerbach (1890-1923) first observed a noticeable bulge in the STG of five musicians on whom he conducted post-mortems (Williamson, 2014). In recent years, in vivo brain scanning techniques have provided unequivocal evidence of neural change occurring as a result of occupational specialisation. Early studies showed significantly larger anterior corpus callosum (CC) in musicians compared to 'non-musicians'. The CC maintains a balance between the facilitation and inhibition of information transfer between hemispheres. The enhanced motor skills in the non-dominant hand, for example playing the violin or piano, are thought to be the reason for these observable differences. Further structural differences between musicians and 'non-musicians' have been observed in motor areas of the brain, such as increased grey matter volume in left inferior frontal gyrus, and increased length in the precentral gyrus (PCG) and depth of the central sulcus correlated with age and onset of training (Schlaug, 2001).

Being a musician has been described as a ‘superskill’ due to the complexities involved in planning and executing complex motor sequences, simultaneously coordinating and controlling independent movements with multiple body parts, and integrating auditory, visual, tactile and proprioceptive information in a constant dynamic monitoring mode. The notion of ‘metaplasticity’ has also been supported by evidence emerging from diffuser tension imaging (DTI) methods that study and model white matter connective tracts, essential infrastructure enabling functional connectivity in the brain. Although evidence is currently mixed regarding the internal capsule, there seems to be agreement regarding higher levels of fractional anisotropy in the CC and superior longitudinal fasciculus correlating positively with the number of practice hours recorded in childhood. Overall, the higher density observed in white matter has led to a proposed specialised *hearing-doing, seeing-doing* network identified in the frontotemperoparietal regions, which also contains the mirror neuron system (Wan & Schlaug, 2010)

The acquisition of skills specifically associated with music has been shown in studies in which musicians not only show increased auditory evoked potentials for complex musical tones, but are also able to ‘tune in’ to the timbre of their own instruments (Pantev et al., 2001). Studies have also demonstrated that musicians listening to their own instrument are primed to a specific motor response (Haueisen & Knösche, 2001). Rhythm is known to have a powerful entraining effect, which also appears to engage the mirror neuron system and cerebellum. The coupling between musical perception and action has been argued to be a function of rhythm, associated with the evolutionary embedding of motor actions mirrored in others. This key neural phenomenon, known as audio-motor coupling, has been utilised therapeutically to help people with Parkinson's and Huntingdon's diseases manage their symptoms (Herholz & Zatorre, 2012)

One reason for the surge of interest in music psychology is due to the belief that 'music makes you smarter'. However, this is only partially supported empirically (e.g. The 'Mozart' effect, c.f., Hetland 2004). Where benefits of musical learning have been observed, they have typically been described as either 'near' or 'far' transfer effects. Near transfer effects are where learning a musical skill also improves a closely related non-musical ability, such as playing the piano aiding fine motor ability. In contrast, 'far transfer' effects for musical learning have been reported for general IQ, spatial skills, language, literacy and mathematical skills. Schellenberg (2004) reported a significant increase (7 points) in full scale IQ for a musical training group in comparison to control groups. Musically trained children have also been shown to possess superior pitch and rhythm discriminatory acuity as well as enhanced fine motor sequencing (c.f., Hyde *et al.,* 2009). We have recently provided evidence supporting Schellenberg's findings and extending the near transfer connection to an effect on hand/eye coordination as seen in the aiming and catching component of the Movement ABC-2 (Rose, Jones Bartoli, & Heaton, 2015).

One aspect of learning is working memory (WM), an umbrella term for several separate systems including echoic memory trace, a visuo-spatial sketchpad, a phonological loop, a central executive and an 'episodic buffer'. Cross-modal binding involves executive functions, attention and inhibition (Baddelely, Allen, & Hitch, 2010). There appears to be some overlap between WM, music and language skills, perhaps explaining why children learning musical instruments possess superior verbal memory skills. The richness of musical learning, experienced as cross-modal multi-sensory incoming information is thought to re-calibrate templates already held and it is these associations which may strengthen early anticipatory mechanisms, potentially linking memory to intelligence (Turner & Ionnides, 2009).

In the separate yet connected domain of reward, musically evoked emotion has been used to study experiences such as hedonic response, joy and fear, tension and violations of expectancy, consonance and dissonance and levels of conscious awareness. Psychologically emotions are understood to be percepts (or pre-verbal subjective feelings; Koeslch, 2014, p. 171) of affect-generating systems in the brain regulating and modulating emotional effector systems (i.e. interoceptive, proprioceptive and cutaneous exteroceptive information). Three limbic areas are particularly important with regard to music and emotion. The amygdalae respond to emotional valence stimuli, and activating appropriate approach-withdrawal mechanisms. The nucleus accumbens appears to regulate intensity between anticipation and experience with regard to primary rewards and dopamine availability. The hippocampus extends emotional capacity beyond reward into learning, memory and spatial orientation and is also implicated in stress response due to its role in regulating the hypothalamus-pituitary-adrenal (HPA) axis. The social aspects of music and emotion can be demonstrated by different, yet related mechanisms. For example, soothing a crying baby with the musical contours of Motherese (the sing-song voice carers use with infants) is a potent combination of vocal communications. Emotions have also been found to transfer from performers to the audience, perhaps illustrating how we (or rather great composers!) can later manipulate this for effect. As Huron

(2006) posits, there are intrinsic reward systems for correct predictions, returns us to the brain and its function as an anticipation machine.

There are substantial overlaps in the psychoacoustic cues that convey emotions in music and human vocalisations. For example, musical and vocal expressions of fear are characterised by similarities in speed (tempo and speech rate), in fundamental frequency patterns and pitch contour, in micro-structural irregularity, and in low intensity and little high frequency energy. Patel (2007, p. 267) refers to the distinct and domain-specific, yet integrated system as the ‘syntactic architecture’ of musical and linguistic sequencing.

Explicating the potency of music-evoked emotions with regard to evolutionary survival mechanisms, Koelsch (2014) recently presented his seven social Cs as: social Contact (a basic human need), social Cognition (attempting to understand the intentions of others use of music), Co-pathy (a function of social empathy, reducing conflicts and enabling group cohesion), Communication (a primary, sometimes non-verbal, skill enhancing other aspects of social bonding), Coordination (not just of one’s own body but also with each other, synchronising movements to form a sense of group identity), Cooperation (implying shared goals and intentions inspiring trust and fostering future good relations) and finally social Cohesion (encapsulating the human need to belong, a strong motivation for personal attachments and increasing life expectancy). For each, Koelsch provides evidence of the neural correlates, finally presenting a physiological example in that music perceived as ‘pleasant’ music triggers zygomatic (cheek bone) muscle response whilst ‘unpleasant’ music activates the corrugator muscle (brow bone).

In fact, motor response to rhythmical sound is posited to also have strong survival coupling, gating between behaviourally antagonistic approach and withdrawal systems, with cerebral asymmetry diverging to the left for positive emotional responses, eliciting an approach reaction, and a right hemisphere negative response for withdrawal. Asymmetry in these areas in the left premotor and inferior parietal cerebrum and right anterior cerebellum developed over time is thought to be a function of goal-orientated action dynamics associated with emotional and musical communication (Novembre & Keller, 2014).

However, not everyone feels or enjoys music; a condition known as *amusia* (commonly referred to as being ‘tone-deaf’) is known to affect approximately 4% of the population. It can be either congenital or acquired. Defined by the co-occurrence of normal audiology and a lack of coherence when processing musical information, cases demonstrating dissociations have shed light on differences and similarities between speech and music perception and production, as the core deficit appears to be with the representation of melodic contour, one of the building blocks of which is being able to discriminate pitch direction. However, researchers have yet to identify networks associated with expressive (e.g. musical apraxia, agraphia or alessia) and/or receptive (such as amnesic or sensorial amusia) classifications (Stewart, 2008). With regard to developmental disorders, it is important to note that contrary to early theorising, there is robust evidence that individuals with autism spectrum disorder (ASD) do not typically have music perception impairments (e.g. pitch, melody processing) and are sensitive to the emotional and social aspects of music (Allen & Heaton, 2010). In contrast, individuals with William’s Syndrome manifest difficulties with global processing, specifically impairment in recognising changes in pitch direction but also with pragmatics (linguistically - how the context contributes to meaning), resulting in problems representing melody (musical contour), although much research remains to be done in this area. Interestingly, a specific rhythmic rapid processing (not metre which is spared) deficit is apparent in children with dyslexia, for which short term (15 week) remediation has been shown to be effective in improving phonological and spelling skills. Research further clarifying specific developmental difficulties in motor, sensory, perceptual and memory disorders has enabled the development of interventions for use in brain injuries, such as stroke (such as Auditory Motor Tapping Training and Melodic Intonation Therapy). Music and musical learning at any age can also help trigger autobiographical memories, providing enhanced quality of life for individuals with memory damage resulting from strokes or different types of dementia. Re-activated memories of earlier positive life events may serve to reduce agitation, depression and/or anxiety. Furthermore, music therapy has proved invaluable in providing differential diagnosis between vegetative state and minimally conscious state and has been highly effective in managing expectations (of family of friends) with regard to projected outcomes (Schlaug, 2015).

We have aimed to present an overview of how humans perceive, embody and generate music, and have considered the ways in which our brains adapt and specialise to acquired musical skills. It seems the more we understand about music; what it has done, does and is capable of doing, and how musical experience stimulates different aspects of the brain, through cognition and communication, in our memories, our motions and emotions, we will be able to see why music in our minds and bodies matters.

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