Playing music to improve hearing in noise and tune the brain

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None declared.

Musical training has a pervasive positive effect. This is manifested in a number of interesting ways. First, unsurprisingly perhaps, musicians excel at pitch and rhythm perception and discrimination. Likewise, instrumental musicians tend to have superior fine-motor skills. More intriguingly, musicians outperform non-musicians in ways that are farther removed from those that might be expected from exposure to the acoustics and mechanics of playing an instrument. For example various studies have found that musicians excel in vocabulary, reading, non-verbal reasoning, perception of speech in background noise, auditory memory and attention [1].

With all of these perceptual and cognitive advantages, there must be underlying neurological changes that the brain undergoes with music training. There is evidence of this from a number of sources. A classic example is the reorganisation of motor cortex that takes place in string-instrument players. The representation in the somatosensory cortex of the fingers of the left hand, the hand in extensive intricate use in string playing, is larger in string instrument players than in non-musicians. This difference is not present in right-hand representation, consistent with the smaller motor demand arising from bowing [2]. In keyboard players, grey matter is larger in visiospatial, motor and auditory brain centres, consistent with the demands of the task [3]. Greater white matter volume, representing increased connectivity between and within cortical areas, is found in musicians, as well. This has been seen in the corpus callosum and other structures [4,5].

There are other examples of brain changes in musicians explicitly involving auditory centres. In both adult and child musicians, there is evidence of structural and functional reorganisation of cortex [6]. For example, in a magnetoencephalography (MEG) study, adult musicians have an increase in auditory cortical activation to piano tones relative to pure tones that is not seen in non-musicians [7]. Evoked electrical responses corroborate an effect of music training these cortical findings neurophysiologically [8].

Arguably more interesting – because they involve less-obvious cause and effect outcomes than the somatosensory, motor and auditory examples that might be predicted from the inherent demands of mastering an instrument – are behaviour and brain changes in farther-afield areas. For example, music training is associated with increased vocabulary, reading, phonological processing, attention and reasoning skills in children [9-11]. A particularly compelling attribute of musicians is their superior ability to listen to speech in noise. The ability to track a conversation amid competing noise is driven by the ability to segregate the desired speech stream into one object distinct from other auditory objects. This segregation depends, in large part, on the fundamental frequency, or voice pitch, of the target stream. The tie-in between voice pitch and hearing in noise has a neurophysiological basis: the representation of a speech-sound's fundamental frequency in the neural response is directly related to hearing in noise ability [12-13].

In my lab, I have been building upon the body of research briefly reviewed above by examining the biological changes that accompany music training in a variety of populations, using both cross-sectional and longitudinal designs. The particular physiological metric I employ is the auditory brainstem response to complex sounds (cABR) [14]. The auditory brainstem is a central hub of sound processing. It is at the crossroads of the ear and the cortex and the response that is recorded from it is deeply tied to the rich acoustics of the evoking sound. At the same time, it is influenced by factors of experience and training. These attributes, as well as its

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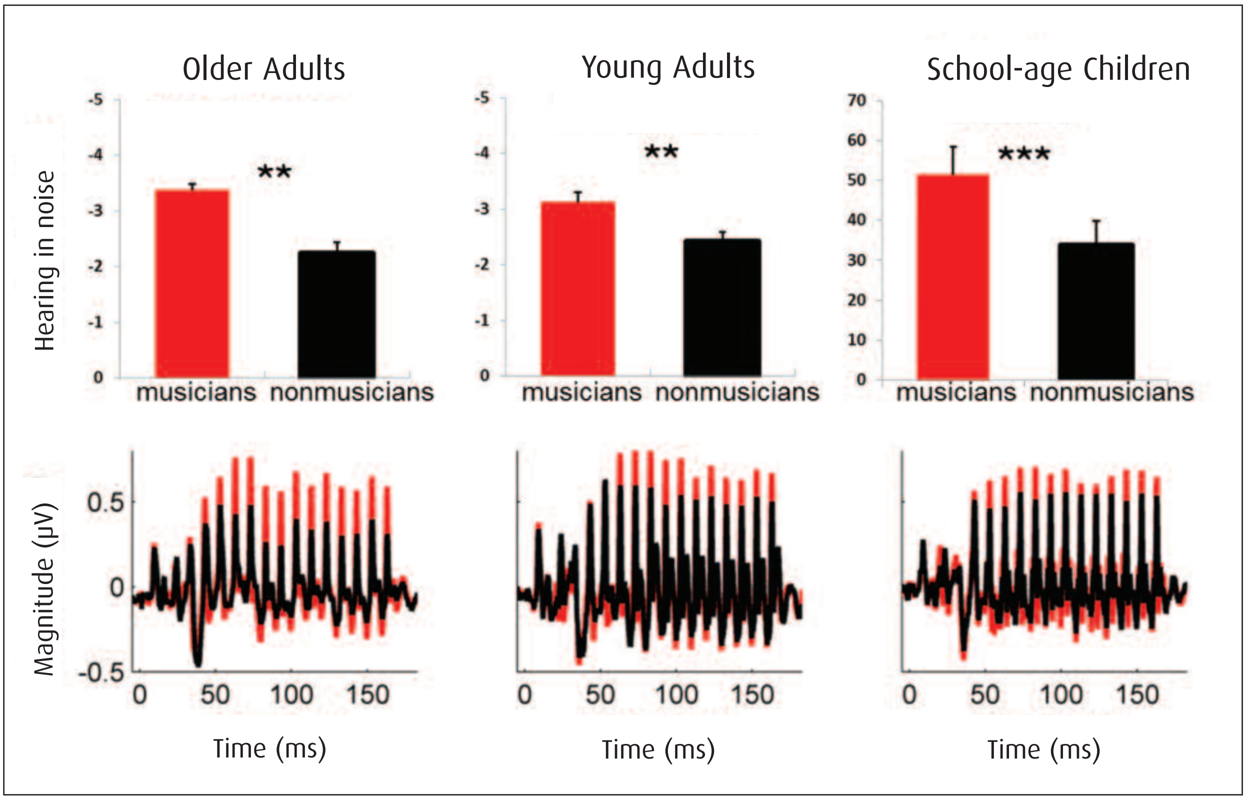

Figure 1: Hearing in noise ability plotted on the top and cABR plotted on the bottom for musicians (red) and non-musicians (black) across three age ranges.

ability to be reliably recorded in individuals, make cABR a valuable addition to the arsenal of the auditory neuroscientist studying experience-dependent brain effects of music training.

The cABR to speech sounds offers a rich approach to studying the neural changes experienced by musicians because of the tie-ins between music and communication skills such as hearing in noise [15]. The ability to segregate sounds from a complex soundscape is a primary accomplishment of musicians, and it follows that this ability might have neural correlates. One finding from my lab is that the representation of the fundamental frequency (F0) of a speech syllable differs depending on whether the sound is presented in a repetitive string of syllables versus when mixed in amid a train of different syllables. Specifically, musicians have larger F0 representation in their cABR in the repetitively-presented stream. Non-musicians do not show this distinction. The extent of the difference between responses to the two conditions is correlated with standardised hearing-in-noise tests [16]. Other cABR enhancements, across the lifespan, are related to both hearing in noise and musical training, including response timing and precision, response consistency, and robust encoding of harmonics [17]. Figure 1 shows across three age ranges, hearing in noise ability for musicians and non-musicians. Musicians have both superior perceptual ability and increased neural response robustness.

The implications of these findings are of a deep interconnection between music and language abilities including hearing speech in noise. A purported commonality between brain regions and mechanisms between music and language is confirmed by findings from my lab and others using cABR and other methods. The strengthening of brain pathways in musicians, as revealed by cABR, point to an underlying physiological connection between auditory function and the ability to hear speech in noise.

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