

## Music at the Heart of the Matter

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### Highlights

- anecdotally, the link between musical training and auscultation ability has been suggested since the nineteenth century
- more recently, experimental evidence has found that both long-term and short-term musical training leads to significant changes in neural activity and behavioral performance during auditory perception tasks
- current methods that encourage labeling of sounds with musical terms (pitch, intensity, timbre, duration) may facilitate perceptual encoding of sounds and improved performance during subsequent identification
- novel methods that engage auditory–motor networks by vocalizing and tapping heart sound patterns may further facilitate learning, encoding, and subsequent discrimination

### Introduction

Discussions of the relationship between music and auscultation of the heart date back to the middle of the nineteenth century. The four cardinal dimensions of music—pitch, loudness, timbre, duration—have long been used to describe heart sounds (e.g., Ballard, 1854<sup>1</sup>; Fagge & Pye-Smith, 1888<sup>2</sup>; Allbutt, 1898<sup>3</sup>). Other physicians have commented anecdotally on the connection between musical expertise and auscultation skill (e.g., Flint, 1883<sup>4</sup>; Quimby, 1898<sup>5</sup>).

The present chapter evaluates both of these connections (musical properties and musical training) from the perspective of *music psychology*: the empirical study of the perception, cognition, and response (emotional and physical) of individuals or groups of individuals to music or music-like stimuli (for recent in-depth volumes on the topic, see e.g.<sup>6-9</sup>). Specifically, it will (1) review recent evidence that musical training changes brain structure, brain function, and performance on auditory tasks; (2) discuss the use of musical dimensions, musical accents, and musical rhythms as mnemonic devices to enhance the perceptual representation of heart sounds; and (3) propose the application of learning strategies that engage *auditory–motor networks* in the brain to further solidify students' ability to identify and differentiate heart sounds. Together, the latter two strategies (listening mnemonics and auditory–motor network engagement) may help reveal a richer acoustic picture and perceptual experience that may translate into increased sensitivity during auscultation.

### Musical Training and Auditory Abilities

#### *Long-Term Musical Training*

One of the dominant research questions within music psychology is to understand how a lifetime of intensive musical training changes the brains of musicians compared to non-musicians<sup>10-12</sup>. Structural

imaging studies have found that musicians have increased gray matter in auditory, motor, and visual-spatial regions<sup>13,14</sup> and increased connectivity between the two hemispheres via the corpus callosum<sup>15</sup>. Functional imaging studies have shown that adult musicians show more elaborate patterns of activation—in both perceptual and motor areas of the brain—than adult non-musicians when listening to music<sup>16-19</sup>. Electrophysiological studies have revealed that musicians show enhanced cortical representation of musical stimuli<sup>20-22</sup>, speech stimuli<sup>23</sup>, and emotional vocalizations<sup>24</sup>; and also show enhanced sensitivity to acoustic stimuli presented within a noisy background<sup>25</sup>. These results suggest that a lifetime of musical training does not just selectively enhance sensitivity to music itself, but has facilitatory *transfer effects* into broader cognitive processes such as attention, language processing, and memory<sup>26</sup>.

### *Nature and Statistics*

Long-term, explicit musical training is not the only route by which listeners acquire musical knowledge. Human listeners come into the world with highly developed auditory processing abilities<sup>27,28</sup>. Furthermore, from their earliest days<sup>29</sup>, human listeners engage *statistical learning* mechanisms<sup>30</sup> to passively and tacitly glean rules and regularities about musical and linguistic structures. These statistical learning mechanisms are enhanced by early musical training, as illustrated by the case of *absolute pitch* (or “perfect pitch”) abilities. By convention, musical pitches are “absolute”—for example, the A above middle C is tuned to a value of 440 Hz. A small proportion of individuals in the population have the ability to tap into this absolute mapping of pitch to pitch label, and can effortlessly hum or sing a requested pitch, or label a heard pitch<sup>31</sup>.

The importance of statistical learning is evident when examining the relationship between absolute pitch ability and the age of onset of musical training<sup>32</sup>. A survey of 600 musicians found that over 40 percent who had begun training before the age of four reported having AP, whereas only three percent of musicians who had begun training after the age of nine reported having AP<sup>33</sup>. Furthermore, work by Schlaug et al<sup>34,35</sup> has subsequently shown that a well-known,

left–right asymmetry in the size of a cortical region referred to as the *planum temporale*<sup>36</sup>—an asymmetry which itself predicts individual differences in dyslexia<sup>37</sup> and the hemispheric lateralization of language<sup>38</sup>—is further enhanced in musicians with AP. This example serves to illustrate the profound ways in which early, intensive exposure to music can change the brain.

Another musical dimension that human listeners show an early sensitivity to is *rhythm*. Human infants show preferential responses to different musical rhythms<sup>27</sup>, and synchronizing movements to musical rhythms has been regarded as a cultural universal<sup>39</sup>. Interestingly, a few other animal species show synchronization abilities. Most famous among them, perhaps, is the case of “Snowball.” Snowball is a male sulphur-crested cockatoo with a penchant for “dancing” to the Backstreet Boys (a feat which has garnered him over 4.5 million hits on YouTube<sup>40</sup>). He also attracted the attention of researchers at the Neurosciences Institute in San Diego, who found that Snowball did indeed synchronize to the beat of the music, at a variety of tempos<sup>41</sup>. More striking still was that Snowball was not alone: Schachner et al.<sup>42</sup> found over a dozen other species—primarily birds—which exhibited evidence of beat synchronization. Notably absent from the list were nonhuman primates and domesticated species. These findings are consistent with Patel’s<sup>43</sup> hypothesized relationship between species that exhibit *vocal learning* (i.e., vocal mimicry as a key feature in the acquisition of auditory communication skills) and species that exhibit beat synchronization.

### *Short-Term Musical Training*

Long-term musical training is not the only method by which listeners develop enhanced perceptual capabilities. A number of studies have revealed that short-term pitch discrimination<sup>44,45</sup>, phoneme discrimination<sup>46,47</sup>, or motor<sup>48-50</sup> training in adults (as well as children<sup>51,52</sup>) mirrors—at the neurophysiological level—the effects of long-term musical training on neural responses to auditory stimuli. In the studies cited here, training ranged from five to 20 days. Furthermore, all these studies reported improved performance after training. This suggests that, while not all individuals become expert

*musicians*, a lifetime of musical exposure (e.g., statistical learning) and brief but intensive training can contribute to make them—at least for a time—expert *listeners*.

### Musical Dimensions and Auditory Patterns

The dimensions of pitch, loudness, timbre, and duration share a common ability to create accents. An accent refers to an element (e.g., a tone) in a sequence of elements that stands out along some auditory dimension. More concretely, an accent is a “deviation from a norm that is contextually established by serial constraints”<sup>53</sup>; thus, an accent acquires its status from surrounding elements<sup>54</sup>. In musical contexts, accented (*A*) versus unaccented (*u*) tones help create the percept of rhythm and meter<sup>53,55,56</sup>. In linguistic contexts, accents create poetic feet: for example, the iamb (*u A*), trochee (*A u*), spondee (*A A*), dactyl (*A u u*), and anapest (*u u A*).

Patterns of accents create patterns *of time* and patterns *in time*<sup>57</sup>. Patterns of time refer to patterns of event durations: for example, differences in note lengths that distinguish between, say, “Frère Jacques” and the “Toreador” song from Bizet’s *Carmen*. Patterns in time refer to patterns based upon distinctions in pitch, loudness, and/or timbre<sup>55,58</sup>.

#### Strategy 1: Listening to the Heart with a Musical Ear

Pitch, loudness, timbre, and duration have long been used to characterize heart sounds and murmurs<sup>1-3</sup>. In the context of the preceding discussion on short-term auditory training, however, it can be hypothesized that practiced use of (1) the mnemonic application these labels to heart sounds and murmurs, (2) listening for patterns of time and patterns in time, created by accents within these musical dimensions, will lead to a richer, more explicit perceptual representation of the sound itself. As a result, it could further be predicted that this enriched perceptual experience will result in improved behavioral performance during identification, discrimination, and classification of heart sounds.

### Engaging Auditory–Motor Networks

Another area of research with relevance to auscultation training is the role of multi-sensory learning and auditory–motor networks in the brain. An ever-growing body of research consistently points to a powerful effect of music making on brain plasticity<sup>10,11,59,60</sup>. Auditory–motor network engagement is a key component of clinical interventions for language recovery<sup>61</sup> and gait rehabilitation<sup>62</sup> in stroke patients, exercise efficacy in patients with dementia<sup>63</sup>, and language acquisition in nonverbal children with autism<sup>64</sup>. Schlaug et al.<sup>65</sup> have undertaken an extensive evaluation of Melodic Intonation Therapy (MIT)<sup>66</sup>. MIT was developed out of observations that patients who have suffered a left-hemisphere stroke resulting in Broca’s aphasia (i.e., severe or complete loss of language production abilities) are often still able to produce well-articulated, linguistically accurate words while singing. The intervention is designed to engage right-hemisphere homologues of left-hemisphere language regions that had been compromised as a result of the stroke.

MIT translates a prosodic spoken phrase into a melodically intoned pattern on two pitches a minor third apart (e.g., an A to a C on a piano keyboard). The upper pitch is sung on accented syllables, and the lower pitch on unaccented syllables. At first, the therapist sings in chorus with the patient as they learn the intonation patterns, gradually decreasing involvement as therapy sessions progress (usually 75–80 1.5-hour sessions in total). Another component of MIT deemed critical to its efficacy is the rhythmic tapping of each syllable (using the patient’s left hand) while phrases are intoned and repeated. As hypothesized by Schlaug et al.<sup>67</sup>, this behavior activates a right-hemispheric sensorimotor network that jointly coordinates hand movements and orofacial and articulatory movements. Evidence that motor and linguistic cortical representations of objects are closely tied is supported by behavioral<sup>68</sup>, neurophysiological<sup>69</sup>, and functional magnetic resonance imaging<sup>70</sup> data. That the therapist mirrors the target actions along with the patient may also tap into the putative “mirror neuron” system jointly involved in action perception and performance<sup>71</sup>. More recently, a related therapeutic approach has been applied to nonverbal children with autism<sup>64</sup>, again designed to

tap into the rich cortical representations shared by the orofacial and articulatory control systems.

### **Strategy 2: Vocalizing and Tapping**

The above discussion leads to a second strategy that could be applied during auscultation training: recruitment of auditory–motor networks during the learning phase. Strategy 1 suggests the explicit labeling of heart sounds using terms derived from the musical dimensions of pitch, intensity, timbre, and duration. Next, Strategy 2 could be applied: students could reproduce the heart sound patterns with their voice (mimicking perceived pitch, intensity, timbre, or duration patterns) while simultaneously tapping the patterns. Use of these multiple afferent channels during learning should lead to a richer perceptual experience. Furthermore, consistent with previous studies investigating short-term musical training effects<sup>44-52</sup>, it could be hypothesized that the combined use of these two strategies during learning will translate into improved performance in identifying and discriminating heart sounds.

### **Conclusion**

The present chapter has reviewed experimental evidence supporting the effects of long-term musical or auditory training on neural responses and behavioral performance during auditory perception and production tasks. It is perhaps unsurprising that a lifetime of musical training leads to significant changes in both neural activity and behavioral performance during auditory perception and memory tasks. In the same vein, the connection between musical training and auscultation ability has been made anecdotally since at least the turn of the last century<sup>4,5</sup>. More recently, this association has been confirmed in a sample of over 400 physicians in training<sup>72</sup>.

As reviewed here, however, performance on auditory tasks also improves after short-term auditory training<sup>44-52</sup>, suggesting that the benefits acquired over years of training can, at least in part, be conferred relatively rapidly. Thus, with respect to auscultation, it could be predicted that focused, intensive training using the two

strategies described above may lead to a richer perceptual experience during the learning phase, translating into improved accuracy during subsequent identification and discrimination. Additionally, a hearing test might be administered to medical students prior to auscultation training, to make both students and their teachers aware of challenges that individual students might face during training (cf. <sup>73,74</sup>).

Music fills our lives (by choice or not) from the moment we awake until the moment we fall asleep. Every culture on the planet has vocal music, and nearly all have instruments<sup>39</sup>. Americans spend more money on music than on sex and prescription drugs, with album sales alone topping \$30 billion annually<sup>75</sup>. As of the first quarter of 2011, nearly 300 million iPods have been sold since the product's debut in 2002.<sup>76</sup> “The dissemination of music in places where the audience is not in voluntary attendance, but is captive, has increased tremendously in recent years,” wrote Hunter<sup>77</sup>—some 35 years ago. Thus, making use of our “musical sense” taps into a systematic and systemic response to auditory stimuli. This sense helps us comprehend and interact with a complex auditory world, from the pulse of the dance floor to the pulse of the heart.

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