WHEN WORDS FAIL

The not-so-secret connection between music, language, and the brain

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MUSIC IS A LANGUAGE

Everyone loves music. It's culturally universal. It resonates deep within us. It is, along with language, the most important form of communication we have. Despite this, for many people music is something that they experience, but do not believe themselves able to produce or express. Formal music training can seem like a daunting but necessary precursor to musical expression.

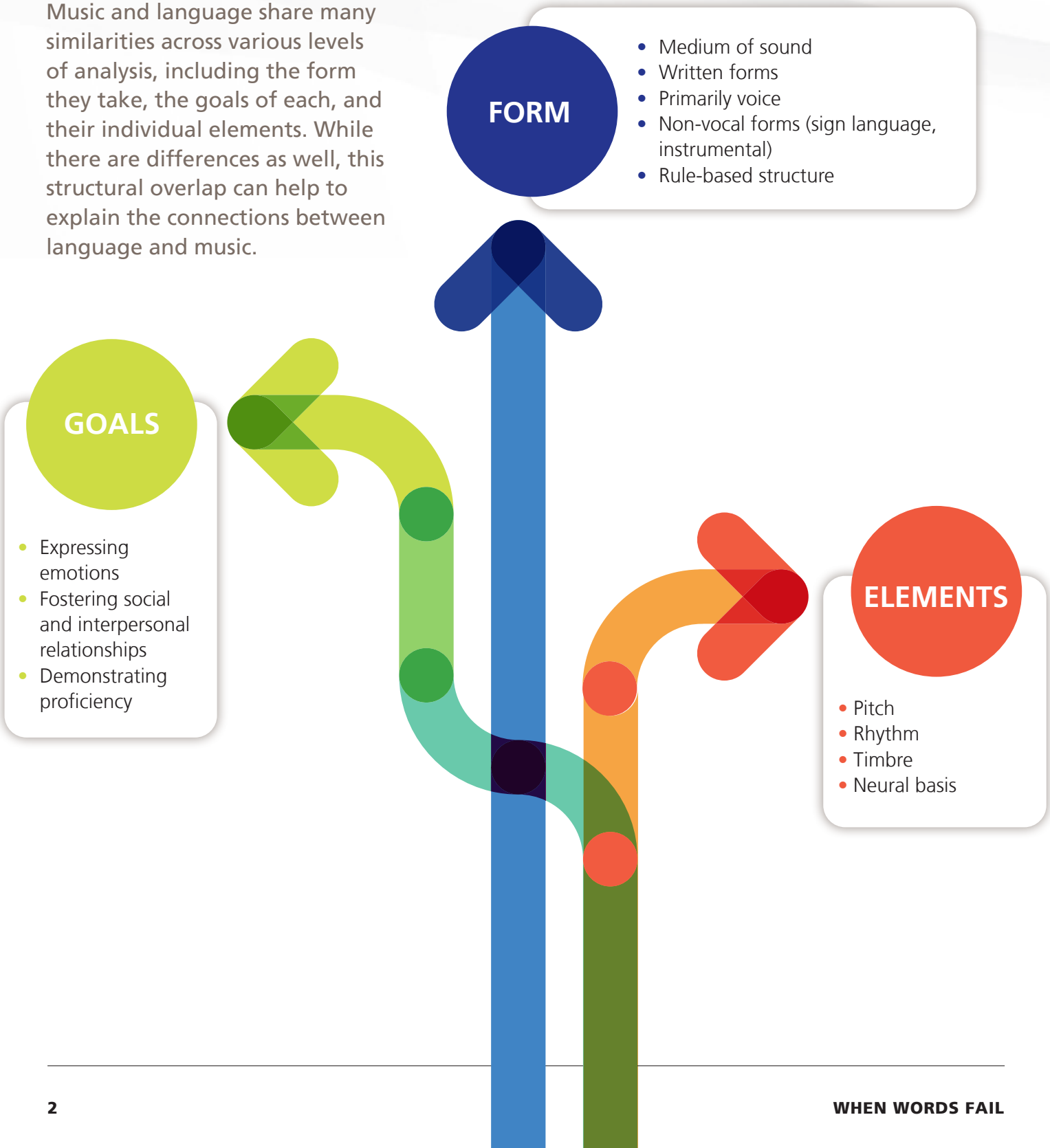
In contrast, speech and language come naturally; though we may spend time crafting our words, we don't feel we need years of training to get our ideas across. Most people feel comfortable expressing themselves in words. But speech is about more than just words. In fact, speech and music are more closely linked than we might first consider.

In this paper, we'll show the similarities between music and language — from their structure and usage to their neural underpinnings. We'll discuss the ways they work together, and the surprising ways that music can help language ability. Most importantly, we'll show the ways that even non-musicians can incorporate music into their daily lives, and express their music through language.

"When words fail, music speaks."
– Hans Christian Andersen

OVERLAP OF MUSIC AND LANGUAGE

Music and language share many similarities across various levels of analysis, including the form they take, the goals of each, and their individual elements. While there are differences as well, this structural overlap can help to explain the connections between language and music.



RHYTHM IN SPEECH AND MUSIC

One of the most important shared characteristics between music and language is rhythm. Even though we don't normally think of language as having a rhythm, speech itself can have a series of strong and weak beats — as anyone who has familiarity with poetry can tell you. In fact, an entire musical genre, rap, is built from the fusion of the rhythmic elements of speech and music.

Even in everyday speech, language has a characteristic rhythm. In English, different syllables can vary in stress, leading to alternation of strong and weak beats. You can see this limerick-like pattern across whole sentences, but rhythm can also distinguish between two words, as in OB-ject vs. ob-JECT.

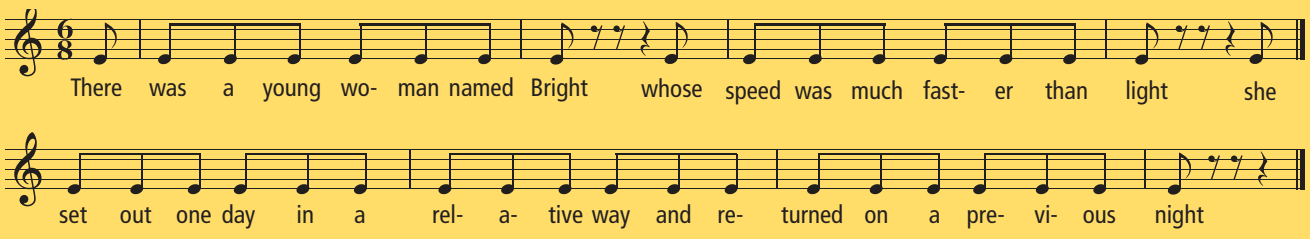
It turns out that not every language has the same rhythm, though. English is a "stress-timed" language, where strong beats tend to come in a predictable rhythm. In contrast, "syllable-timed" languages, such as French, don't use this pattern of strong and weak beats, but tend to time every syllable roughly the same. And this makes a difference to listeners. You can tell the difference between languages from the rhythm alone. In fact, we might have more practice with this than any other part of language. Although a fetus cannot make out individual words in utero, the rhythm of speech comes through clearly — just like the beat of a noisy neighbor's stereo from the next apartment.

What's your Style?

What's more, studies have found that a composer's native language can influence the type of music they write. A 2003 study showed that English composers were more likely to write music with more rhythmic variability compared to French composers. This mirrors the greater rhythmic variability in English than French speech. What's incredible is that this holds up *even for music without any words*! Your native language can influence your musical style.

The musial poetry of limericks

Many types of poetry use strong musical rhythms, but this is particularly clear in limericks, which use a strong 6/8 meter with a regular pattern of strong and weak syllables.



PITCH IN SPEECH AND MUSIC

Just like rhythm, pitch is an important part of speech and music. The rise and fall of the voice can change the meaning of an utterance, and speech without changes in pitch can quickly sound dull and robotic.

Although English does not use pitch alone to distinguish between different words, many world languages do. These languages, called tone languages, include Mandarin, Thai, Yoruba, Navajo, and hundreds of others. In Mandarin, for example, the syllable /ma/ can mean *horse, mother, scold* or *hemp* depending on the rise and fall of the voice (which must have led to many embarrassing situations for people learning the language). Tone languages can use pitch height to distinguish between words, or they can use pitch rise and fall within a word, as in Mandarin. Speakers of languages that use tones are more likely to develop perfect pitch, showing yet another crossover between speech and language processing.

Singing: The Best of Both Worlds

Music and language are not separate domains. Singing provides a great example of how music and language can co-exist and enhance each other. In good vocal music, the notes and the lyrics serve to accentuate each other, and the rhythms, pitches, timbres, and dynamics all work together to create something greater than the sum of its parts.

"Music is the universal language of mankind."
– Henry Wadsworth Longfellow

Music to our Ears

Have you ever repeated a word so many times that it starts to sound weird? Well, it turns out that with some types of speech, listening to it over and over can actually make it sound like singing! This is known as the Speech-to-Song illusion, discovered by Diana Deutsch. Composer Steve Reich used this phenomenon in his Grammy-award winning piece "Different Trains," created from taped interviews.

Spoken phrases that have more regular rhythms and steadier pitches within each syllable are more likely to be perceived as singing, especially after being repeated. Auto-tuning builds off of the same insight; if you've ever heard music created from auto-tuned voices (for example, Auto-tune the News or T-Pain), its musicality comes from the steadier pitch and more regular rhythm that the voice is made to fit into.

PROSODY: THE MUSIC OF SPEECH

Have you ever written a text message that has been misunderstood? Do you ever wish there was a sarcasm font? The written word cannot express the same nuance that we can convey through spoken language because, unlike speech, writing lacks prosody.

Prosody deals with the pitch, duration, loudness, timbre, and emotion of speech — everything that makes it musical and that *can't* be captured in writing.

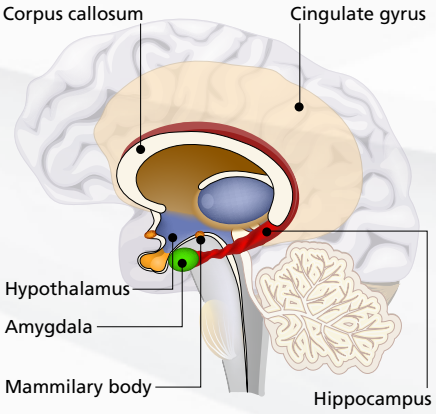
One common way we use prosody to express meaning is when we raise or lower the pitch of our voice to indicate a question or a statement. The pitch of an utterance can often rise by as much as an octave when asking a question. Another example is when we want to express emphasis – pitch, timing, and loudness can be used to indicate a particular word's importance. Consider the difference between "Give DAPHNE the grapes" versus "Give Daphne the GRAPES" – the focus of each is different and would be spoken in distinct ways.

Musical cues

Even the emotion of a sentence is largely conveyed through these musical cues. A sentence like "The Maple Leafs won tonight" will have quite a different tone depending on whether the speaker cheers for Toronto or Montreal. Whereas a Toronto fan may say this quickly, with a high pitch and bright timbre, a Montreal fan might use the same words but say them slower, with a lower pitch and darker tone. The same cues that express emotion in speech also have musical counterparts. Studies of emotion in music show that artists can use similar variables to add nuance to their performances. For listeners and performers, an understanding of prosody leads to a diversity of interpretations and gives music a complexity beyond what is simply written on the page.

Quickly, with a high pitch and bright timbre

Slower, with a lower pitch and darker tone



Neural Responses to Emotional Cues

Music and language can even trigger the same areas of the brain when they are eliciting emotional responses. One study has shown that fearful music and fearful vocalization can both activate the amygdala neurons in the brain; other studies have shown similar effects with other neural circuits in the limbic system (the part of the brain that deals with emotions, memory, and stimulation). Scientists have suggested that our neural processing of musical emotions may have evolved out of brain systems originally adapted for vocal emotions, explaining the link between the two.

EMOTIONS IN MUSIC

One of the biggest differences between speech and music is that, unlike musical notes, words can refer to concrete, tangible things in the world. Emotions in language can come from the meaning of the words: A sentence like "I dropped my ice cream cone" conveys a negative emotion simply through the meaning of the words, even without any speech prosody. So how does music convey emotions without the aid of tangible meanings? There are three major ways: Resemblance, piggybacking, and self-reference.

Perceiving emotions

First, musical sounds may physically resemble things in the world. A flute may sound like a chirping bird, or a driving rhythm may resemble a moving train. The similarities between these things can evoke an emotional response, based on our feelings towards birds or trains.

Second, music may evoke emotion by piggybacking off of other forms of communication. The same tools that allow us to understand prosody in speech help us to use similar cues in music. Music can also piggyback off of visual art, body language, or movement. Compare the way that people slow down as they reach the end of a physical movement to the way that a musician slows down as they reach the end of a musical phrase — the association between these things can help us to perceive the emotion in a piece.

Finally, music can evoke emotions simply through self-reference. In short, musical structures and patterns set up expectations that the patterns will continue. When these expectations are violated, we experience an emotional reaction — similar to how we might react to a magic trick or a joke. This means that greater understanding of music (and thus stronger expectations) can lead to heightened emotional responses.

"After silence, that which comes nearest to expressing the inexpressible is music."

– Aldous Huxley

INFANT-DIRECTED SPEECH

One of the most striking examples of the musicality of speech occurs when we speak to infants. People have a natural instinct to adopt a sing-songy voice when a baby is around; this speech pattern is colloquially called "Motherese" or "Baby-talk," but scientists who study the phenomenon (yes, there are scientists of baby-talk) refer to it as infant-directed speech.

Infant-directed speech has several characteristics that make it more musical than a normal speaking voice. It tends to be higher in pitch, and involve more changes in pitch that we would otherwise use. It also exaggerates the dynamics of the voice, with louder louds and softer softs. The phrases, too, tend to be different, with shorter overall utterances, a slower rate of speech, and longer pauses between each phrase. This has the effect of emphasizing both individual words and the structure of the shorter phrases, making it easier to pay attention and remember the words and phrases. This is thought to provide scaffolding for babies as they develop language skills. In essence, the musicality of the voice is helping the child learn their language.

Bonding through emotion

Studies have shown that infants prefer being spoken to this way, and will not respond as well to people speaking in an adult-directed manner, even their own mother. Even if the words are not meaningful to the infant, the emotions conveyed through the prosody are, and can help the child and caregiver bond.

This speech prosody is cross-cultural, and isn't limited to just mothers or babies. Fathers will use the same speaking style with infants, as will siblings, or even unrelated adults. Infant-directed speech is also quite common when speaking to animals ("Who's a good doggie? Yes you are!"), perhaps due to us unconsciously projecting child-like characteristics onto animals.

Infant-Directed Singing

Adopting this style around babies isn't just limited to speech; there's evidence that caregivers also change the way they sing to babies. Infant-directed singing has similar characteristics to infant-directed speech, including higher pitch, slower tempo, and more dynamic range. The timbre of the voice changes as well, including a warmer, "smiling" sound. Just like with infant-directed speech, babies prefer infant-directed singing to adult-directed singing, and can tell the difference between the two. What's more, they can tell if you're faking it – just pretending there's a baby there won't help most caregivers get the right tone. Like in most performances, authenticity matters!

LANGUAGE ABILITIES OF MUSICIANS

One of the most interesting implications of the links between music and language is that abilities seem to be able to transfer between domains. Over the past two decades, numerous studies have shown that musicians outperform non-musicians in language-related tasks.

At a basic level, musicians show better abilities to recognize speech in a noisy context (like you'd find in a crowded party), and better phonological processing (recognizing and manipulating the basic sounds of speech).

Musicians also perform better at more complex speech tasks. When it comes to recognizing emotions in speech prosody, remembering lists of words, or learning a foreign language, it pays to have some musical training.

These effects aren't just limited to professional musicians, either. Rather, anyone with a considerable amount of formal music study (10 years or more) demonstrates these increased abilities.

Never Too Late to Study Music

One common question parents have about music lessons is when is the right time for their child to start. Although there are still unanswered questions about how music and language skills develop together, it's clear that the earlier a child starts, the greater the benefits. What's more, these benefits can last a lifetime. As musicians age, their hearing and language abilities show less decline than those of non-musicians. One study showed aging musicians with perceptual abilities matching those of non-musicians 15 years their junior.

Even if you've never had the opportunity to study music as a child, all is not lost. A recent study of older adults taking piano lessons for the first time showed improvements in word recognition in a noisy environment, accompanied by stronger neural responses to attentive listening. The upshot? It's never too late to start taking music lessons.

BENEFITS OF EARLY MUSIC TRAINING

Children taking music lessons show improvements in many of the same areas that we see in adult musicians: They learn to better recognize emotions in speech; are helped in learning a second language; and can more easily perceive words and sentences in a noisy environments. Evidence also shows that music training in childhood can be linked to vocabulary size, grammar, and reading abilities, as well as overall IQ.

Mastering language

One of the most robust findings that scientists have seen is an improvement in phonological processing. The ability to recognize different sounds of the language, and to connect letters with the sounds that they make, is crucial to children mastering language. This phonological skill is linked to reading ability, and children with music training tend to show better reading abilities as well. Poor phonological skills are often indicative of speech or reading disorders, such as dyslexia, and while music training shouldn't be thought of as a cure for these problems, it is true that basic musical skills, such as pitch and rhythm, are associated with enhanced phonological skills.

Benefits to language processing may also lead to improvements in other fields as well. Children who can better understand their teachers may be able to learn more in a classroom setting, across different subjects. By requiring less mental energy to simply understanding the words in a noisy classroom, children may have more mental energy to devote towards learning the material itself. The benefits of language processing can cascade across a child's entire life.

THE OPERA HYPOTHESIS

Why do skills gained through music training benefit language abilities? And why does much of this transfer go only in one direction? One answer is the OPERA hypothesis, first advanced by noted scientist Ani Patel. The OPERA hypothesis suggests that there are five relevant factors:

Music requires precision

Together, these factors can explain why musicians tend to outperform non-musicians on tasks like hearing speech in noise, phonological processing, and learning a foreign language. These tasks use the same basic acoustic processing as music, but music requires much more precise processing in order to achieve competence. Hearing a semitone difference, for example, is crucial in music, though unlikely to make a difference in speech processing.

Thus, when musicians practice, it trains those neural processes to an even higher degree than needed for normal language processing. This also explains why music training tends to benefit language processing, but we don't see the converse effect. What's more, a high level of practice is both effective and sustainable because music creates positive emotions with high levels of attention – without eliciting boredom. Music is practice for your brain that is actually fun to do!

"Music expresses that which cannot be said and on which it is impossible to be silent."

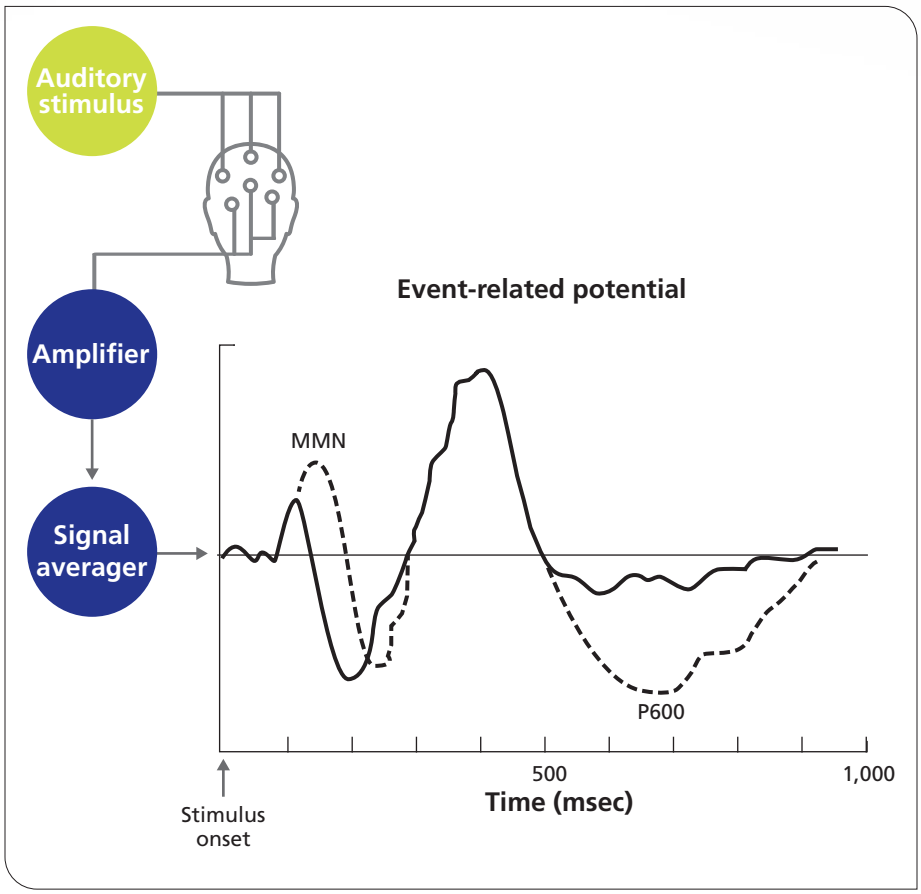
– Victor Hugo

NEURAL OVERLAP

One of the assumptions of the OPERA hypothesis is that there is overlap between brain areas that process music and language. Both MRI and EEG studies have shown evidence for this neural overlap at several different levels of processing.

The auditory brainstem response (ABR) is one of the earliest levels of acoustic processing in the brain. This is a small signal that can be found in the brainstem, the oldest area of the brain, starting about one one-hundredth of a second after a sound is heard. The ABR can track the pitch of sounds, including syllables and notes. Not only are speech and music sounds processed by the same region, studies show that musicians' brains do a better job of tracking pitch in these sounds in both music and language. Thus, musicians' brains have a higher fidelity encoding of these sounds to work with.

Later stages of processing also show overlap between music and language. For example, the automatic brain response to an unexpected change (the mismatch negativity) is similar whether the sounds were speech or music. Even conscious processing, such as a late response to syntactic errors (over half a second, which is forever to the brain), can look similar in both domains.



Superior processing abilities

These responses often show neurological evidence for musicians' superior processing abilities, even for language stimuli. Similar evidence can be found in brain scans, too. The brains of musicians typically show more grey matter volume than those of non-musicians, especially in the temporal and frontal cortices, which are relevant to both sound processing and higher-level music and language processing. The brains of musicians show stronger connections between these regions, not to mention stronger connections between the left and right hemispheres, via the corpus callosum.

Left vs. Right Brain

While many of the left-brain vs. right-brain differences we hear about in popular media are more suited to an online quiz than a scientific journal, speech vs. music processing may be one area where these differences hold up. It all comes from a mathematic limitation called the time-frequency tradeoff. In short, the more precise you want to get in tracking the frequency of something, the less precise you can be in time, and vice-versa.

In understanding speech, we need to be able to process very quick changes in sound — a few dozen milliseconds can make a big difference — but tracking the exact pitch isn't very important. In music, on the other hand, a quarter-tone can make a huge difference in tuning, but pitches don't tend to change as quickly as speech syllables do.

To be able to process both signals, the brain uses different hemispheres to make different tradeoffs: the left hemisphere goes for greater timing precisions, whereas the right hemisphere goes for better pitch precision. Thus, while the left side of the brain is more used for language, the right side of the brain really is more musical!

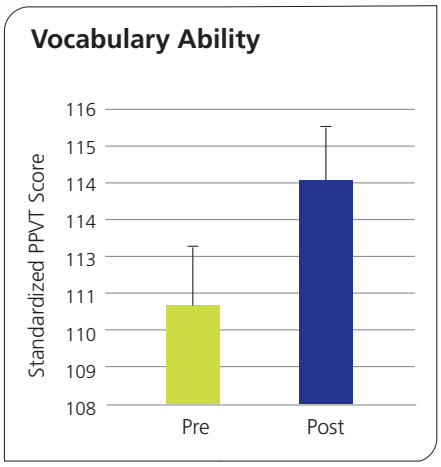
RCM RESEARCH

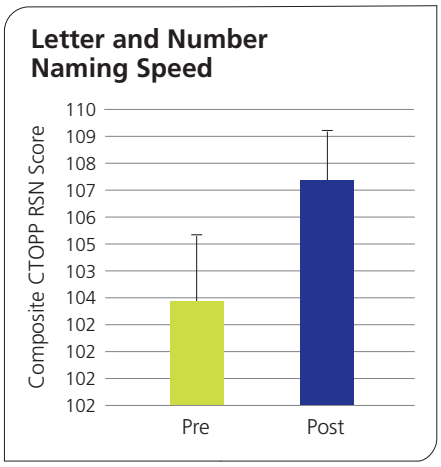
Here at the RCM Research Centre, we are conducting our own research into music and the brain, and much of it revolves around questions about the relationship between music and language.

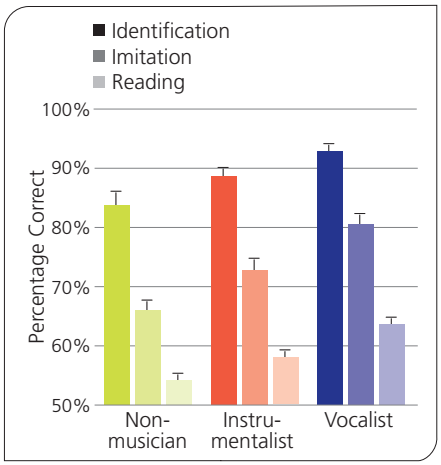
Our largest project has been a longitudinal study looking at the benefits of early childhood music education. Here, we are measuring musical and cognitive outcomes for children in our Smart Start™ program, group lessons for children age 0-6. This program also serves as an introduction to music theory, and uses a curriculum developed to promote the use of various cognitive skills such as attention, memory, and cognitive flexibility. We found that these children improved in both musical and linguistic ability over the course of a school year, and see benefits to both vocabulary size and pre-reading skills

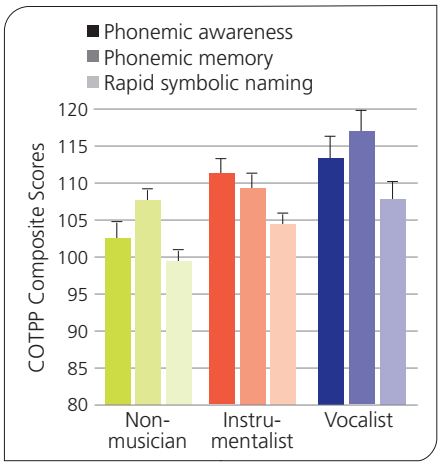
You can read more in our publication *Music Perception*. **rcmusic.com/musicandlanguage**

Another recent project at the RCM showed that this improved linguistic ability for musicians carries over into adulthood. Our study of university-level music students, including those at our Glenn Gould School, showed that they were better at many of the same phonological and linguistic skills that were improved among our Smart Start™ students. A test of ours even showed that musicians could understand foreign accents better than non-musicians — a useful skill in a multi-cultural world.









A related study also showed that musicians were better than non-musicians at both discriminating and imitating the pitch of spoken words — a factor that can help language comprehension and its use.

Our research is helping to learn more about the connection between music and language and why musical training can transfer across domains.

SUMMARY

Music and language are so closely related that it's sometimes hard to figure out where one starts and the other leaves off. Even though we think of them as separate, they often use the same physical and neural structures, and this comes through in the way they are used.

We've seen that training in music can improve our abilities to work with language, from the basic neural level all the way up to emotional prosody and second languages. Scientists, including those at The Royal Conservatory, are learning more about the specific connections between music and language all the time. But what is already clear is that, no matter your native tongue, music truly is the universal language.

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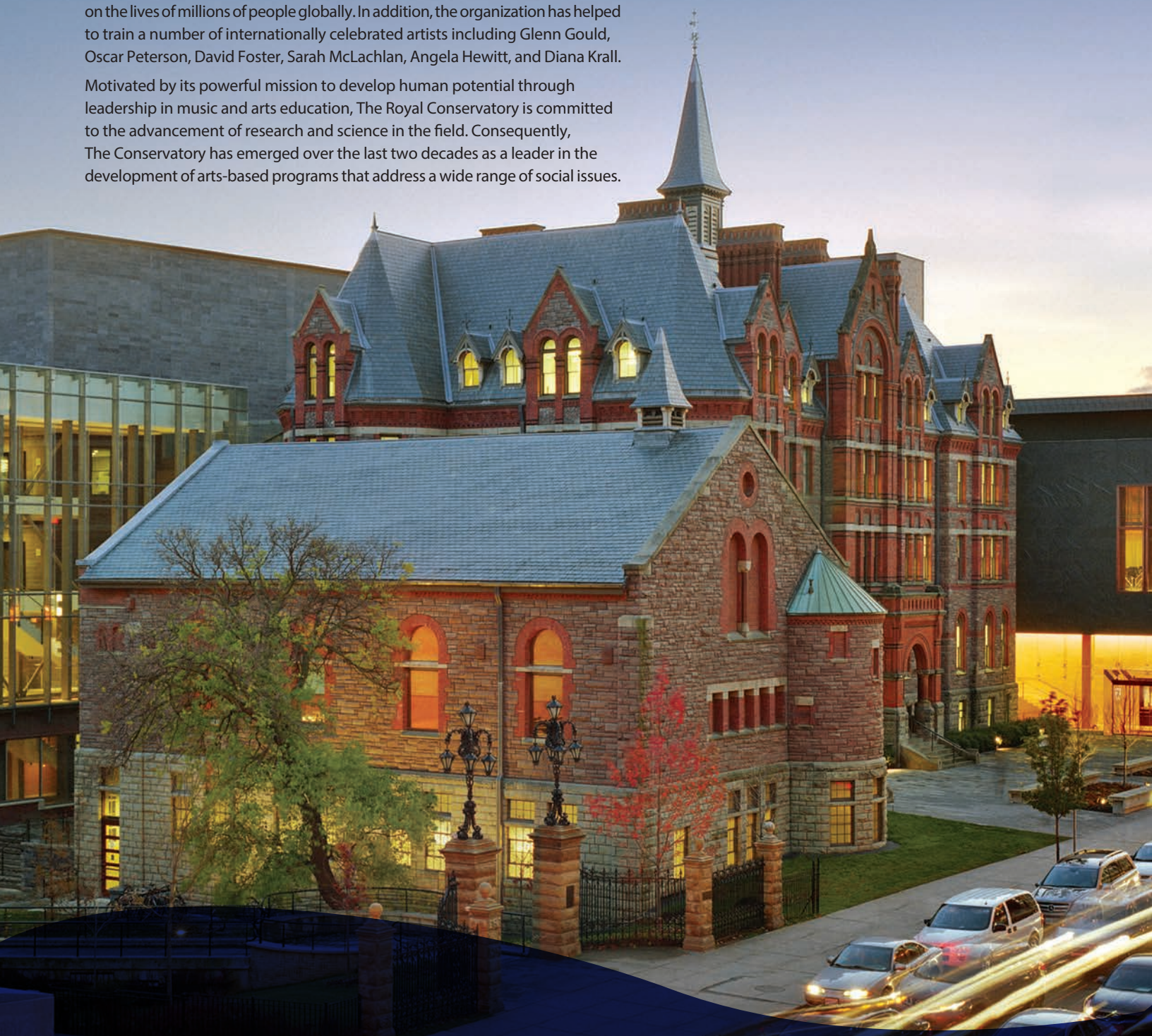

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