Music for Every Child

a special report for parents, educators, community organizers, policy-makers and citizens of the world

SFCM
SAN FRANCISCO CONSERVATORY OF MUSIC

Ann and Gordon Getty Foundation

Our Mission

To ensure that every child in the US has access to a quality music education.

Executive Summary

Music-making is an essential part of a child's growth

It shapes our minds, develops our brains, unites our communities, and brings us joy.

Music-making is fundamental to our humanity. The oldest known artifacts in history, dating back 40,000 years, include musical instruments. Music is central to how babies learn to communicate because they respond meaningfully to *prosody* — rhythm and tone — well before they understand spoken words.

Neuroscientists, educators and psychologists have all provided compelling evidence that music training can improve attention, memory, language, social skills, creativity and *executive function*—that set of mental skills that helps us get things done.

Musicians show greater connectivity in the brain as well as other *structural* and *functional* differences compared with non-musicians.

Music programs pay for themselves by ensuring better attendance in school and higher graduation rates. Students who have music training as an integral part of their overall education are better equipped to contribute to the workforce, especially because theirs is a future where innovation will be the key to finding solutions for increasingly complex problems.

Yet public school music programs are being cut across the United States. These cuts disproportionately affect under-privileged students because these kids show the biggest gains in academic success when given access to public music programs. Even limited music training can improve reading and language skills, particularly for those who struggle or have learning disabilities.

This paper will describe the primacy of music in our culture, review the effect of music education on children in PreK-12 schools, and make the case for music programs in every school.

Music training can enhance attention, memory, language, social skills, creativity and executive function — the skills that help us get things done.

Contents

Note: All scientific terms are shown in *italics* and defined in the Glossary at the back.

Version 1.0 published August 2020

"The theory of relativity occurred to me by intuition and music is the driving force behind this intuition. My parents had me study the violin from the time I was six. My new discovery is the result of musical perception."
— *Albert Einstein*

Music is fundamental to who we are

The discovery of man-made musical instruments dating back as far as 40,000 years indicates that music has been a part of our history for as long as we can measure.

Just like the discovery of fire, music profoundly increased the potential of our species.

Fire helped our ancestors prepare better meals with less effort and gave them more leisure time. Music helped them use that extra time to exchange ideas, gain a deeper understanding of themselves and others, teach their children, and forge relationships.

Did music give early humans advantages that Neanderthals lacked? Without music, would our species have evolved with the ability to live in large groups — a feat that no other primate has mastered?

Through language, we share, debate and refine our ideas. In fact, how we think is framed by the languages that we speak. Much of the work in neuroscience demonstrates that music and language processing overlap — both in *neuroanatomy* and in cognitive skills.

There are also many differences. However the underlying reality is that both language and music support communication. Both play distinct roles in our evolution as a species, our development as individuals, and our capacity to build communities.

Given how important communication skills are in the workforce, interventions that improve speech and language processing are highly valuable, particularly in populations where traditional methods of teaching these skills have fallen short.

Music unlocks a child's potential by enhancing the development of fundamental skills required in language communication such as auditory processing, comprehension of speech, speech production, abstract thinking, and emotional understanding.

Music is a tool that has shaped human development through millenia. In our modern age, music gives educators a mode through which they can reach students who are otherwise difficult to engage and improve their communication skills via multiple different circuits. It also provides the neuroanatomical and functional foundation on which our complex minds are built. A child's brain is especially malleable, and music not only enhances existing connections but also creates new ones.

Both music and language play distinct roles in our evolution as a species, our development as individuals, and our capacity to build communities.

Shaping brain development

Building babies' brains

Even before a fetus has left the womb, music is a part of its life. Newborn babies recognize melodies played in utero and show measurable brain changes in response to them.[1] There is even evidence that playing music in the neonatal intensive care unit accelerates the functional development of preterm baby brains, making them more similar to the brains of babies born full-term.[2]

While the brain is undergoing rapid growth in the first year — tripling in size — exposure to meaningful sound can have a lifelong effect on brain development and cognitive functions like language processing and social interactions.

In fact, a recent study[3] has shown that infants as young as nine months old can benefit in measurable ways from a musical intervention. (See sidebar "Music training improves language ability" for more details.)

For as long as we have recorded human history, and likely long before then, humans have used music to communicate with their babies — singing lullabies to lull them to sleep or playing songs to entertain and teach them. Only recent advances in technology give parents the option to shift from active participation in music-making to passive listening through a device.

Are there consequences? Are there any measurable benefits to live singing and music-making rather than listening to a recording? Indeed there are, and these benefits appear as early as six months of age.

Beyond language learning, participating in music-making also helps infants make sense of social cues.[4] Six month old babies exposed to active participatory music classes could communicate better using gestures and other social behavior than their control group counterparts after only half a year of training. Making music helps babies interact with others even before language abilities come online.

Early music education for infants has real developmental benefits.

Music training improves language ability

For some time, early childhood educators have been aware that music training improves a child's language ability. In 2016, researchers Christina Zhao and Patricia Kuhl proved that a musical intervention of teaching babies waltz time improved their ability to learn speech.

The babies took part in 12 sessions of about 15 minutes over four weeks. Sessions were modeled on typical infant music classes. Caregivers synchronized their baby's movements with the music. Sometimes they used percussive toys like shakers, while other times they just bounced to the music.

Researchers found the "music class babies," who were bounced or whose movements were in sync with the music, showed enhanced neural responses to violations of temporal structure. In other words, they noticed when something didn't sound "right." This skill underlies our ability to recognize the temporal aspects of speech, like syllables belonging to the same word.

What's more, the babies' new skill bled over to speech perception. The music classes helped babies develop the foundations that underlie language skills.

Source: Zhao, T.C. and Kuhl, P.K. (2016). Musical intervention enhances infants' neural processing of temporal structure in music and speech. Proceedings of the National Academy of Sciences, 113(19), 5212-5217.

Amplifying development in toddlers, children, and teens

The powerful effects of music training continue through toddlerhood, childhood and adolescence.

Music-making can help toddlers find ways to self-soothe. Any parent whose child sings in the crib has likely noticed this effect. Toddlers also feel more attached to their caregivers when sung to, and they build self-esteem and confidence by learning to participate in group music-making.

Music helps children understand different emotions and recognize these emotions in others. It's the musical quality of infant-directed speech that provides babies with the information they need to understand the emotional content of what is being communicated.[5] Kids as young as four can recognize emotions such as happiness, anger, sadness and fear in music.[6]

Children who make music with others also learn to cooperate since this activity involves taking turns, listening and replying.

> Music training is particularly effective in driving the plasticity of *white matter* pathways between and within brain hemispheres.

When it comes to brain development, music education that begins in childhood and continues during adolescence can amplify developmental changes. (See sidebar on p. 7 "How the brain develops," for an explanation of brain development through childhood.)

Music training is particularly effective in driving the plasticity of *white matter* pathways **between** brain hemispheres as in the case of the *corpus callosum*, the broad band of nerve fibers that joins the two cerebral hemispheres.

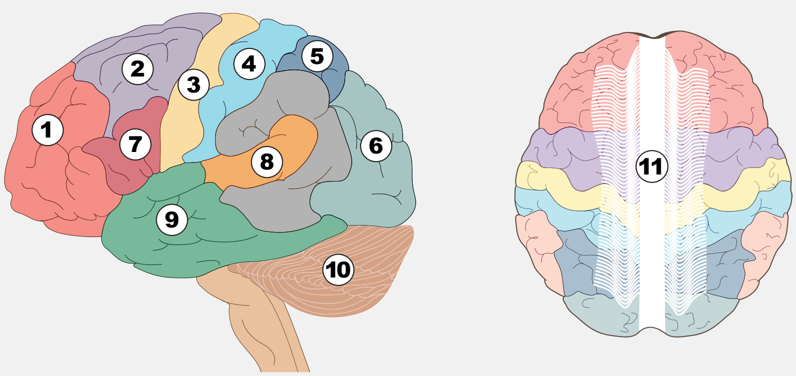
Music training is equally effective at driving plasticity **within** the hemispheres as seen in the *arcuate fasciculus*, the *white matter* pathway connecting the *temporal lobe* to the *frontal lobe*.

There does seem to be an important sensitive period in childhood, somewhere between six and eight years of age, when these changes are most likely to happen and as neuroscientist Christopher J. Steele and others note, "serve as a scaffold on which later training continues to build."[9]

In high school, the social effects of music programs seem to be the most helpful. Music helps anchor teens who are particularly vulnerable to poor choices such as substance abuse, delinquency and absenteeism. (See "Music-making improves social skills" on p. 17.)

Yet students who have had earlier musical training will show even greater benefits as their brains are better able to accommodate and take advantage of training later in life.

Music training impacts development from the womb through to adulthood. The earlier that children start music education, the more they'll benefit throughout their lives.



1. **prefrontal cortex:** supports executive functions
2. **premotor cortex:** involved in controlling motor function
3. **primary motor cortex:** music training enlarges regions that control muscles involved in playing
4. **primary somatosensory cortex:** receives sensory input from body; areas devoted to parts of the body used by skilled musicians grow larger with training
5. **parietal association area:** combines information across senses and modulates attentional focus
6. **visual cortex:** processes visual information
7. **Broca's area:** involved in speech production
8. **auditory cortex and Wernicke's area:** processes of auditory information and speech comprehension
9. **temporal lobe:** contains hippocampus and amygdala, long-term memory and emotional modulation
10. **cerebellum:** involved in fine motor coordination and other functions
11. **corpus callosum:** fiber tract joining the left and right hemispheres

How the brain develops

The early years of childhood have an outsize influence on brain development. By age six, children's brains have reached about 90 percent of the size they will be as adults.[7]

But there are still many changes that occur in the process after age six.

One is synaptic pruning — the purging of unnecessary synapses. Pruning is a sign of learning, as brain cells establish meaningful connections with each other.

Another change is *myelination*, in which *axons*, the highways along which electrical impulses flow, become enveloped in a fatty sheath. This speeds up *neurons* communicating with each other. The fat in myelin looks white, which is why these fiber tracts are called *white matter.* The cell bodies, *dendrites* (the receiving ends of *neurons*) and glial or support cells make up *gray matter*.

One of the last parts of the brain to become fully myelinated is the *prefrontal cortex*, the region implicated in planning actions, decision-making, and social behaviour.

That's why adults tend to show better judgement, reasoning, and *emotional regulation* than adolescents.[8]

Boosting *neuroplasticity*

Dramatic brain changes

Our nervous system is remarkably malleable. This *neuroplasticity* allows experience to mold us. Our past leaves indelible marks on how our *neurons* are shaped, how they connect with each other, and the types of signals that they send.

Neuroplasticity even affects the support cells that provide our workhorse *neurons* with the energy, nutrients and building blocks they need to do their important jobs.

There is no question that musicians show *structural* and *functional* differences in *neuroanatomy* compared with non-musicians.[10] Whether these differences are learned or innate is an oft-posed question. Yet the evidence that music training shapes brains in observable ways is unequivocal.

In fact, the musician's brain is the poster-child for *neuroplasticity*.[11] What's more, these differences often track the extent of musical training. That is, the more training a person has engaged in, the greater the changes.

There are a few general principles that apply to the changes we see with musical training:

- The timing of training during development affects both the extent and type of differences between musicians and non-musicians.
- At first, training affects brain regions and circuits that are closely tied to the specific functions being trained. That is, auditory regions involved in listening and motor regions involved in playing are the first to demonstrate changes. With more training, skills transfer to more general functional improvement in domains such as *executive function* and *working memory*.
- Brain changes reflect the particulars of the training, including genres (free improvisation vs interpretation of composed music for example), instrument, training methods, and so on.

Musicians are better at multitasking

Making music is an all-encompassing experience that requires doing many complex tasks at once:

- listening
- imagining
- creating
- executing complex movements
- coordinating many different body parts
- adapting to changing circumstances.

Humans are generally not very good at multitasking. Our brains aren't well-equipped to focus on many things at once, even though our modern lives demand it.

Music-making prepares us for exactly this type of work. Musicians tend to show better *working memory* and better performance on tasks of *executive function* that require rapid shifts of attention.

Music training is also used to study *neuroplasticity* because of how quickly changes can be observed. In as few as five days, study participants who learned an exercise on the piano showed expansions in the *cortical representation* or "brain map" for their finger muscles.[12]

In line with this idea, there is an anatomical landmark in the motor cortex called the *omega sign*, where the fingers and hand are represented. In pianists, the *omega sign* is larger in the left hemisphere, which controls the right hand that plays the melody. In string players, it's larger on the right, corresponding to the precise movements required by the left hand in these musicians.

> Musical training not only accelerates brain development, but also produces long-lasting changes even in the mature adult brain.

It's not just size that matters: These changes translate directly into better fine motor skills that are apparent even in non-musical tasks. Children with instrumental music training are more dexterous than their non-musical counterparts, even with as few as two years of training.[13]

Other regions involved in auditory processing such as *Heschl's gyrus*, or the *primary auditory cortex*, *Broca's area*, known for its role in speech production, and the rest of the surrounding *inferior frontal gyrus* have been shown to be larger in musicians. It has been found to be more pronounced in those whose training started earlier in childhood and those who reported practicing with greater intensity.[14]

Musicians extract more meaning from sound

Neuroscientists can measure how responsive brain cells are to certain stimuli using an *electroencephalogram* or *EEG*. This tool involves placing electrodes near the scalp and measuring small but distinctive electrical changes related to underlying *neural activity*.

When these changes occur after the experimenter has done something specific, like playing a tone, we call them event-related potentials (ERPs).

One such ERP is called the *mismatch negativity* or *MMN*. The MMN is interesting because it's *pre-attentive*: Scientists can observe it before the conscious mind has registered the event that triggered it.

When trained musicians are listening to a series of tones interrupted by a slightly different tone, an MMN response occurs, even if they are not playing close attention.[15]

Musicians show MMN for tones mistimed by as little as 20 milliseconds, while non-musicians listen for twice as long before they register the response.[16] That means that musicians' brains can detect differences that non-musicians cannot hear.

Interestingly, these findings do not mean that musicians' ears are more finely tuned. Rather, their brains find more meaning in the signal, even before their conscious minds recognize it.

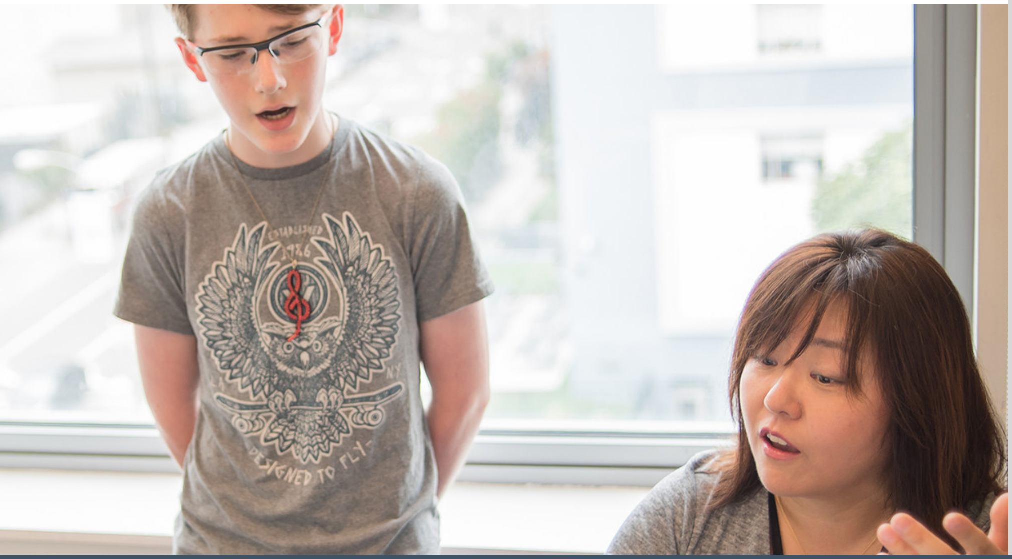
The breadth of cognitive, emotional and motor skills that music-making demands is mirrored by the sheer magnitude of ways in which brains are changed with musical training. That's why music-making and its effects on the brain are so interesting to neuroscientists mapping how experience shapes our central nervous system.

What other features of music training make it such an effective tool in shaping the brain?

Music requires integrating information across sensory and motor domains, and involves attention, creativity, memory and *emotional regulation*.[20] It's also highly rewarding, which is another driver of plasticity.[21]

The act of integration that music demands combined with its rewards make it a powerful way to shape the brain. The next question is whether these changes translate into advantages that extend beyond making music.

Even for students with no aspirations to become professional musicians, do the effects of musical training transfer to superior skills in other domains? That is, does a bigger *corpus callosum* or *omega sign* proffer any benefits beyond the ability to play a musical instrument?



Music training synchronizes left and right cerebral hemispheres

Recently, a group of Finnish scientists found that brain activation in musicians is more symmetrical than in non-musicians when listening to music. The same effect was seen whether they were listening to progressive rock, Argentinian tangos, or Stravinsky.[17]

This symmetry appears to be directly related to music training, as keyboardists, who engage in more *bimanual coordination*, showed larger effects than string players, for example.

Across all musicians, the *corpus callosum*, the band of *white matter* joining the two brain hemispheres, was larger than in non-musicians. This last finding replicates previous work showing that music training leads to more structural connectivity between the hemispheres,[18] particularly if students were exposed to training before age seven.

The *corpus callosum* is not the only *white matter* tract that differentiates musicians from non-musicians. There's evidence that the *arcuate fasciculus*, which connects sound comprehension with sound production within a hemisphere, is also more developed on the right side of the brain in musicians, particularly singers, who have to quickly translate thought into vocalization.[19]

Music training helps the brain coordinate both within and between the left and right hemispheres.

Boosting test scores and IQ

How music skills transfer to other parts of life

How did Einstein's music training help develop his genius?

Transferring skills from one domain to another comes in two forms:

- near transfer is when the learned skill is similar to the demands of the new domain
- far transfer is when there is a big difference between the training and its desired application in another domain.

An example of near transfer would be if a pianist wished to learn a complex motor sequence using her hands. Far transfer could be manifested in superior math skills in trained musicians.

Not surprisingly, near transfer effects of musical training are well-documented. Studies show that children with musical training are better than their untrained peers in terms of pitch and rhythm discrimination, melody recognition and *motor-sequence learning*.[22]

Far transfer effects have been harder to find but these generally appear once a child has trained for at least two years. These include general gains in IQ along with improvements in spatial, verbal and mathematical performance.[23, 24]

Musicians whose training started early in life are better at detecting speech sounds in random noise.[25] This benefit appears after as little as two years of group music training.[26] In addition, music training also benefits reading and verbal memory such as the ability to remember spoken words,[27] and *phonological skills* such as rhyming.[28, 29]

Children between the ages of five and seven, who are better at clapping in time to a rhythm, show neurophysiological responses that correlate with better literacy skills. This set of skills includes the ability to process information more quickly, to better distinguish speech sounds, read words, spell, and use grammar accurately.[31]

Musicians' brains become more efficient

It's an oversimplification to say that the power of music-making lies in its ability to activate large swaths of the brain. In fact, with training, professional musicians tend to activate fewer of the brain's motor regions than amateurs when they play their instruments.

Brain activation in musicians is finely tuned to the task at hand, leaving them with more cognitive resources to devote elsewhere.[30] This fine-tuning in the brain is mirrored in the behavioral changes that accompany training. With greater expertise, professional musicians use less of their body to play than amateurs.

In fact, music teachers are always looking for ways to simplify movements and take out unnecessary effort. In this way, musicians become more and more capable of executing complex movements with no wasted muscle or brain power.

Music training improves listening skills by tapping into the plasticity of the *auditory cortex* and related regions. With better listening skills, children are better at detecting speech sounds so that they can communicate more effectively.

Music education, however, does not just indiscriminately "turn up the volume" of sound processing. When compared with non-musicians, trained musicians are more attuned to meaningful sound, parsing it from noise more effectively.

program or a group musical training program. Scientists found that when they first enrolled, the students were matched in terms of their neural responses to speech and other auditory measures. Yet those who underwent musical training showed greater enhancement in *phonological* processing and the accompanying *neuroplasticity*.[34]

Phonological processing is the skill that allows kids to recognize and work with the sounds of spoken language. It's key in learning to read.

Kids between the ages of five and seven who are better at clapping in time to a rhythm show neurophysiological responses that correlate with better literacy skills.

For example, musicians pay more attention to the upper note of a musical chord, which is often more meaningful, musically-speaking. This ability transfers to other areas of life, since they also pay more attention to the parts of a baby's cry that signal emotion.[32]

Musicians are also more effective at separating speech from noise: their training leads to a selective enhancement of meaningful sound in their auditory processing.[33]

Although many studies focus on neurodevelopmental gains in babies and children, high school is not too late to see measurable brain benefits from a music program, benefits that extend beyond social and emotional factors.

In 2015, there was a longitudinal study of teenagers enrolled in either a Junior Reserve Officers Training Corps (JROTC)

For Albert Einstein, music training likely improved his IQ, his ability to process information from the outside world, as well as his listening, speaking and reading skills. It probably taught him perseverance and the rewards that come with learning to do something hard.

Sadly, children raised in noisy urban environments learn to tune out sound early, which can lead to difficulties in speech and language processing, including reading ability.[35] The brains of at-risk children have been found to be 'noisier' in terms of how they respond to sound. Music making has been shown to offset this liability by increasing the salience of speech sounds – ramping up that signal in the brain.[36]

Public school music programs can surely help. (See "YOLA at HOLA" below for an inspiring case study.)

CASE STUDY: YOLA at HOLA proves music programs benefit underprivileged kids

Decades ago, Venezuelan educator José Antonio Abreu saw the power of music to create social change.

> "Music has to be recognized as an agent of social development in the highest sense, because it transmits the highest values — solidarity, harmony, mutual compassion. And it has the ability to unite an entire community and express sublime feelings."

To harness this power, he launched the transformative *El Sistema* movement, which is now credited with rescuing thousands of Venezuelan children from extreme poverty, drug abuse, and crime.

Graduates include the star conductor of the Los Angeles Philharmonic, Gustavo Dudamel.

> "Music saved my life and has saved the lives of thousands of at-risk children in Venezuela," says Dudamel. "Like food, like health care, like education, music has to be a right for every citizen."

Under his leadership, the Philharmonic's Youth Orchestra Los Angeles (YOLA) program was launched to provide a free community-based music education program inspired by the success of *El Sistema*. The program provides students from underserved neighborhoods in L.A. with free instruments, intensive music training, and academic support.

One such neighborhood is the Rampart District, the country's second most densely populated neighborhood, with an average household income of $27,000. This is where YOLA at the Heart of Los Angeles, was born and soon dubbed YOLA at HOLA for short.

Partnering with the Brain and Creativity Institute at the University of Southern California, YOLA at HOLA began a five-year study in 2012 to track how the program impacts students' brain development, cognitive and social development, overall well-being, and success. Twenty-five kids ages six-to-seven from the program were compared with kids who participated in either a sports training program or no after-school enrichment program.

All the children were tested before any training with structural and functional Magnetic Resonance Imaging (MRI), *Electroencephalography (EEG)*, and a comprehensive battery of psychological and social tests. These tests gave the scientists the opportunity to look at the brains of the kids along with the development of their mental abilities, social and emotional skills.

The children went back for testing once a year for five years. When the study began, the kids were no different from each other on any of the brain measures, psychological, or social and emotional tests. But just two years in, scientists began to see differences.

Children in the music program were better at pitch perception and production, what we call musically-relevant skills, which is not surprising. They showed more mature auditory pathways, meaning that they were better at processing all kinds of sounds, and they showed measurable changes in the auditory regions of the brain.

They also had more connectivity between their right and left hemispheres, similar to professional musicians who have a bigger *corpus callosum* and more *white matter*. Just like bigger leg muscles give a sprinter an edge, better connections between the hemispheres give kids an edge at integrating information or being creative.

Scientists also found that cognitive and *executive function* skills, like holding multiple ideas in mind at the same time, were better in the musically-trained children.

With functional imaging, the researchers discovered that the kids in YOLA at HOLA showed more activation in the frontal regions of the brain, which are critical for high-level thinking, decision-making, and other tasks that require focus.

The scientists weren't the only ones to notice a difference – parents of kids in the music program also reported that their kids were less aggressive and hyperactive, and more emotionally-stable over time. These observations were not made by parents of kids in the control group.

The test results from YOLA at HOLA show that the ability to reap brain benefits from music training is not limited to privileged children. Children from all socioeconomic backgrounds can make demonstrable gains if they're given the chance to engage in music-making.

To learn more, visit: www.laphil.com/learn/yola.

With contributions from Assal Habibi, Assistant Research Professor of Psychology at University of Southern California and Elsje Kibler-Vermass, Vice President of Education, at the Los Angeles Philharmonic

Sources:

Habibi, A. et al. (2014). An equal start: absence of group differences in cognitive, social, and neural measures prior to music or sports training in children. Front. Hum. Neurosci. 8, 690.

Habibi, A., et al. (2016). Neural correlates of accelerated auditory processing in children engaged in music training. Dev. Cogn. Neurosci. 21, 1–14.

Habibi, A., … and Damasio, H. (2017). Childhood Music Training Induces Change in Micro and Macroscopic Brain Structure; Results from a Longitudinal Study. Cerebral Cortex, 1-12.

Habibi, A., Damasio, A., Ilari, A., Sachs, M., and Damasio, H. (2018). Music Training and Child Development – A Longitudinal Study. Annals of the New York Academy of Sciences.

Ilari, B. S., Keller, P., Damasio, H. and Habibi, A. (2016). The Development of Musical Skills of Underprivileged Children Over the Course of 1 Year: A Study in the Context of an El Sistema-Inspired Program. Front. Psychol. 7, 62.

Ilari, B., Perez., P., Wood., A., and Habibi, A. (2019). The role of community-based music and sports programs on parental views of children's social skills and personality. International Journal of Community Music 12(1) 33-56.

Sachs, M., Kaplan, J., Damasio, A., and Habibi, A. (2017). Increased engagement of the cognitive control network associated with music training in children during an fMRI Stroop task. PLOS One 12(10), e0187254.

Enhancing performance across the board

What about skills that are somewhat further removed from simple auditory processing, like *working memory*, vocabulary and acquiring a second language?

These skills can also be enhanced with music training.[37] Studies have shown that children with musical training performed better than their untrained peers on the *Wechsler Intelligence Scale for Children (WISC-III)*,[38] a popular IQ test for kids ages six to 16.

They also showed enhanced verbal memory.[39] What's more, both children and adults with music ability showed enhanced second-language learning.[40] Still, as each of these skills rely on hearing, it's not surprising that music training can show transfer.

But what about *executive function*, attention and other non-language functions?

While it might not be quite as straightforward, music students practice skills that are in fact similar to those that help individuals succeed in many different walks of life.

Focusing attention, translating thoughts into actions, learning a complex symbolic notation system, integrating information across domains: These are all skills that musicians practise and build up. Furthermore, these skills are useful in many high-demand jobs that will continue to be in high demand in the future.

In one study, primary school children were exposed to either music training or enhanced natural science lessons. After 18 months, the music students outperformed their science-trained counterparts on measures of *working memory*.[41] This result included the *central executive*, which is considered a core cognitive function affecting performance in a number of different domains, from creative writing to math.

The improvement in *working memory* might help explain why practicing a musical instrument can lead to better performance on general intelligence tests like the *Raven's Progressive Matrices*.[42]

> Music lessons in childhood correlate with better academic performance and higher IQ scores, even when controlling for family income and parental education.

Children with musical training also show enhanced nonverbal reasoning skills.[43]

In fact, taking music lessons in childhood from six to 11 years of age has been shown to correlate with better overall academic performance and higher IQ scores even when controlling for family income and parental education.[44]

What about skills even less likely to show transfer, such as spatial reasoning or math?

Here too, we can see some benefits of music training, although not all measures of spatial tasks have demonstrated clear enhancements and some of the benefits taper off with time (for meta-analyses, see Hetland, 2000 and Vaughn, 2000).[45, 46]

One promising study of six school districts in Maryland found that middle-school students enrolled in instrumental or choral music programs scored higher on algebra tests with a particularly compelling benefit for Black students.[47]

These benefits also extend to high school students. In a study of students in British Columbia, researchers found that participating in a music program was associated with higher academic achievement, and that the better grades a Grade 11 student received in music, the higher their GPA in Grade 12.[48]

One of the arguments against adding music classes to an already packed curriculum is that it takes time away from core curriculum lessons. Yet researchers have long known this fear is baseless. As the study from British Columbia demonstrates, spending time in music programs does not impede academic excellence. Making music benefits performance across the board.

These findings have been replicated in elementary schools. A recent study showed that increasing the amount of classroom time for music did not affect language and reading skills, even though these lessons were cut short to make time for music.[49]

Because parents with means are more likely to provide music lessons for their children than families who are disadvantaged, it can be hard to disentangle socioeconomic status from the effects of music training. Yet a recent study did just that, showing that access to a musical instrument is a driver of academic achievement regardless of a family's financial situation.[50]

There is no lack of evidence proving that the benefits of music training reach far beyond the domain of music-making. Children perform better on IQ tests and enjoy enhanced abilities in other domains, such as mathematics, the ability to focus, make decisions, and hold multiple ideas in their minds at one time.[51]

Importantly, these benefits transfer, regardless of the student's socioeconomic status.

Improving social skills

Benefits proven from infancy through adolescence

Practicing a musical instrument can involve many hours alone in a practice room. Yet few musicians are motivated solely by the reward of making music. Music-making is an inherently social activity. Much of the benefit of school music programs comes from the social aspects of making music in a group.

In infancy, participatory group music-making helps babies recognize and return social gestures.[52] By age four, joint drumming can tame preschoolers by encouraging them to cooperate spontaneously.[53]

Even in early childhood, music lessons can help kids parse emotions in speech prosody (rhythm and tone),[54] and perceive and recognize emotions in human voices. These skills provide the building blocks for social interaction later on.[55]

In the study mentioned on p. 16 that shows increased classroom music time did not affect language and reading skills even though those lessons were cut short, teachers reported more social cohesion in the classroom, greater self-reliance in the students, and more positive attitudes.[56]

These effects were amplified in the kids who had the most to gain: Those with low ability who seemed the least interested in academics showed the biggest improvements.

In a U.S. study, adolescents who participated in performing arts programs were less likely to engage in risky behaviors, particularly related to alcohol use, compared with peers who were primarily involved in athletics.[57] These same students were also more likely to report liking high school, had a higher GPA in Grade 12, and were more likely to be attending college full-time at age 21.

In the U.K., high school students reported that playing in an ensemble helped them gain confidence — in part because ensemble music-making underscores the importance of every player, especially in small groups.[58] Feeling as though their contribution was important helped foster a sense of belonging to the group. It also taught them the value of compromise, exchanging supportive comments, and working effectively as part of a team.

> Adolescents in performing arts programs were less likely to engage in risky behaviors compared with peers who were primarily involved in athletics.

Flexibility of group size, the give and take, the thrill of performance, the feeling of joint accomplishment, and the acquisition of a skill that can be shared with others throughout life — it's hard to beat the social benefits of music education.

Building character

Helps foster a growth mindset

A child's belief about her abilities can have a profound influence on her motivation and ultimate academic achievement.[59]

In her seminal work on the topic, Stanford professor Carol Dweck describes two mindsets that form around the following beliefs:

- students with a **fixed mindset** believe that intelligence is an immutable trait
- students with a **growth mindset** believe their intellectual abilities can be developed.[60]

Mindsets are influenced by the environment in which a student learns as well as the type of praise they receive. Children praised for achievement rather than effort are more likely to develop a fixed rather than growth mindset and vice versa.[61, 62]

While a mindset might seem like a small thing, Dweck and her colleagues have shown that the construct can affect many different aspects of a child's behavior that multiply to have an outsize influence on achievement.[63]

Children with a fixed mindset tend to avoid taking risks. They often work on skills that they have already mastered rather than ones that still need work. Over time, they lose motivation and are less likely to persevere in the face of obstacles. They tend to see effort as a sign of weakness and to envy the success of others.

In contrast, kids with a growth mindset seek out challenging learning environments because they see difficult tasks as a path to mastery. They show greater perseverance and react to criticism with less emotion-related processing and more memory-related processing. This behavior leads to better performance on retests after correction. Ultimately, this behavior leads to better grades[64] and more successful careers.

Piano lessons have been shown to increase self-esteem in kids from low-income families.

Sadly, socioeconomic status can influence mindset, with kids from low-income homes being less likely to endorse a growth mindset. But those who find their way to a growth mindset can mitigate some of the effects of poverty.

In a study of all 10th graders in Chile, researchers found that students whose family income fell in the lowest 10th percentile but who espoused a growth mindset performed as well academically as students who had a fixed mindset but whose family income was in the 80th percentile.[65] This demonstrates the powerful effect that mindset can have in terms of helping kids overcome the obstacles that poverty sets in their path to success.

School music programs are a great way to change mindsets and ensure that students see how effort can lead to achievement. Indeed, piano lessons have been shown to increase self-esteem in kids from low-income families.[66]

Skill-learning happens in stages. Quick gains in performance happen at first and eventually slow down or stall altogether.[67]

To punch through a plateau and see improvements in performance once again, the learner needs to change their mental representation or how they are performing the task. This process requires trial and error, reaching out to experts, and taking risks. All these factors drive the person towards a growth mindset.

Music training is a great example of how a complex skill is developed through effortful, mindful and informed practice. It helps students adopt a growth mindset and build grit, determination and self-confidence.

"Music has a power of forming the character and should therefore be introduced into the education of the young."
— Aristotle

Motivating people, even through difficult periods

With the social aspects of music-making and the gratification from creating sound that brings joy, students learn to stay motivated even during difficult periods when learning involves struggle and effort.

Music, whether it involves passive listening or active participation, has the power to strongly engage our brain's reward circuitry.[68] This characteristic has lead some authors to say it is addictive.

Although the label "addictive" is an exaggeration, many adolescents spend copious leisure hours listening to music. Add to this the fact that the neurochemical and electrophysiological signatures of music's effect on the brain overlap significantly with those of activities such as eating and gambling and we can see why people make the correlation.

The strong motivational power of group music-making in particular largely underlies what might be the biggest benefit of music education: ensuring that students come to school and graduate. (See the "Harmony Project case study" below.)

CASE STUDY: Harmony Project encourages youth to stay in school

While earning her doctorate in Public Health at UCLA, Margaret Martin had a habit of visiting the nearby farmers' market.

One morning, she watched as a group of Los Angeles gang members, sporting all the usual gang regalia, stopped in front of a tiny kid playing Brahms on the violin. They listened for five minutes and then, without discussing it, each of the gang members pulled out a few dollars and laid them in the child's violin case.

Margaret was struck by how these gang members clearly appreciated what the kid was doing. Some might even have wished they could be playing music instead of engaging in their gang activities. But no one had given them the chance.

After she finished her doctorate in 2001, Margaret decided to work towards giving kids in gang-run communities that chance. She founded the Harmony Project, starting with 36 high-needs students and a $9,000 check from the Rotary Club.

Since then, the project has grown to include more than a dozen youth orchestras and bands in L.A. and seven other cities like Tulsa, O.K., Kansas City, M.O. and Hudson, N.Y.

In these communities, the normal high-school dropout rate is about 50 percent.

Yet in 2016, 100 percent of the students in the Harmony Project graduated from high school. All but one were accepted into colleges. In the 2017/18 academic year, the Harmony Project enrolled another 5,767 students to continue these positive results.

The Harmony Project isn't just a successful community program; it's also fertile ground for research into the impact of music education on the brain.

Led by Nina Kraus at Northwestern University, the collaboration between researchers and the project leaders demonstrated that children who stuck with the program for at least two years had stronger neural signals in response to speech sounds compared with students in music appreciation classes[1] or no classes at all.[2] They also found that music making in the Harmony Project seemed to counter the poverty achievement gap in terms of reading ability.[3]

Making music matters: simply listening isn't enough to cause measurable brain changes.

Although music is a powerful tool for *neuroplasticity*, the nervous system is resilient to change. It takes prolonged exposure and effort to reshape the brain. Active engagement is the key to turning on *neuroplasticity* in children and adults alike.

Sources:

1 Kraus, N., Slater, J., Thompson, E. C., Hornickel, J., Strait, D. L., Nicol, T., and White-Schwoch, T. (2014). Music enrichment programs improve the neural encoding of speech in at-risk children. Journal of Neuroscience, 34(36), 11913-11918.

2 Kraus, N., Slater, J., Thompson, E. C., Hornickel, J., Strait, D. L., Nicol, T., and White-Schwoch, T. (2014). Auditory learning through active engagement with sound: biological impact of community music lessons in at-risk children. Frontiers in neuroscience, 8, 351.

3 Slater J, Strait DL, Skoe E, O'Connell S, Thompson EC, Kraus N (2014) Longitudinal effects of group music instruction on literacy skills in low-income children. PLoS One. 9(11): e113383.

Boosting creativity

Enhancements to *working memory* have a direct link to creativity

Creativity is often listed by employers as the number one trait that they search for in employees. Members of the general public often say creativity is the thing they admire most in others.

Yet creativity scores have been plummeting in children over the last two decades[69] just as music and other arts programs have been cut back.

This trend is wrong-headed: music training helps develop the very skills that lead to creativity in adults.

For example, musicians outperform non-musicians on tests of *working memory*,[70] a type of memory that has been shown to be important for creativity because it allows a person to hold and manipulate multiple ideas at the same time.

Working memory helps people find connections where they are not obvious — connections like Albert Einstein visualized with his Theory of Relativity.

Furthermore, when scientists observed brain activity in musicians as they engaged in a *working memory* task, they found that music training leads to faster updating of information in *working memory* in both auditory and visual domains.

Similar improvements in *working memory* performance have been observed in kids ages seven and eight, who participated in an extended music education program over the course of 18 months, compared with peers who spent that time in a natural science lesson.[71]

> There is ample evidence that music instruction and practice lead to measurable gains in creativity.

Enhanced *working memory* has been shown to directly impact creativity because it allows individuals to maintain focus for longer periods of time. They also generate more ideas and improvisations and recombine elements in creative ways,[72] as seen in a study of semi-professional cellists.

The cellists had better *working memory* capacity compared with non-musicians and those cellists with a high *working memory* capacity showed the most creative improvisations.

It's simply not true that creativity cannot be trained. There is ample evidence that instruction and practice lead to measurable gains in creativity. This finding is especially apparent in musical improvisation where studies have shown that practice, with a bit of guidance, can boost creativity.

These studies also show increased connectivity between brain regions like the premotor and prefrontal cortices at the front of the brain,[73] more engagement in regions towards the back of the brain, and less reliance on the *executive function* of the *prefrontal cortex*. All this allows the sensory and association areas of the brain to lead the way during improvisation.

When first learning to improvise, students often display rule-based thinking, which is reflected in greater activation of the prefrontal cortex or *executive function*. But with training, they also learn to trust their gut, quiet their prefrontal cortex and let the back of the brain take over.

This flexibility is a key to creativity since many different cognitive processes and brain circuits are involved and there is no single route to a creative idea.

Creativity is a combination of domain-specific skills and general thinking styles such as generating new ideas or finding remote associations.

Motivation also plays a big role, tied to the social context in which the person is working. Paradoxically, external rewards like money or prizes can decrease creativity by diminishing intrinsic motivation, the sense that the creative process itself is the reward.

Music training affects each of these factors by teaching children how to develop complex skills in a specific domain and to develop creative cognition more generally, as in the example of increasing their *working memory* capacity.

This learning sets them on a path to develop a growth mindset, which helps them find intrinsic motivation in the creative process. It also ensures that they have the foundational skills to be creative.

"I found that the best engineers, the bright ones, the really creative artists that can create an entirely new product category at Apple, they ALWAYS had a strong music background."
— Steve Wozniak, Co-Founder of Apple

Benefiting the whole community

It's not just for the children

Music programs in schools do not just benefit the kids who participate in them — they also engage the larger community. Performances provide a space for neighbors to gather and interact, which is becoming increasingly rare as traditional institutions like churches and community groups decline in the U.S.

Children who participate in music programs have been shown to talk more with parents and teachers, and their parents are more likely to talk to other parents, fostering a sense of community second only to sports programs.[74]

School music programs have an incredibly positive effect on their surrounding communities.

Delivering a strong return on investment

If it's about money, then we need to invest in music education

Keeping kids in school, especially through high school, provides a major economic advantage.

According to the California Dropout Research Project, economic losses from juvenile crime in California add up to more than $8.9 billion annually.[75] An estimated $1.1 billion is directly associated with high school dropout rates.

The report found that every student who graduates in California adds $115,300 in value to the federal government and $53,600 to state and local governments — after deducting the cost of educating that student.

If we include societal gains in the form of higher earnings, lower Medicaid/Medicare expenditures, and so on, the net gain for inducing a potential high school dropout to graduate is estimated at close to half a million dollars.*

When music classes are strategically scheduled, teenagers in high school are more likely to show up.

> If one at-risk student graduates as a result of participating in a music program, the net societal gain would pay for 10 years of a music teacher's salary.

In 2013, the effectiveness of an enhanced music program in Nashville public schools was studied. Researchers found that students who participated for up to a year showed significantly higher attendance and graduation rates, higher GPAs and other test scores, and fewer discipline reports compared with their nonparticipating peers.[76] The children described the music program as a motivator for attendance and said they felt happier, less stressed, and more accomplished.

*The California Dropout research project assessed the net gain for inducing a potential high school dropout to graduate was $392,000 in 2006 dollars. Adjusted for inflation, this figure is $489,978 or close to half a million dollars today.

Another compelling case is the Harmony Project (see p. 21) founded in Los Angeles to bring music education to high-crime, underserved neighborhoods. In areas where the high school dropout rate is 50 percent, 97 percent of high school seniors who participated in the project for at least three years graduated and went to college.

Music programs pay for themselves because they improve school attendance and graduation rates. By decreasing delinquency and detention rates, music can be a path out of the poverty-to-prison pipeline.

According to the 2016 Berklee College of Music survey *Music Careers in Dollars and Cents*, the median salary range for school music teachers between Kindergarten and Grade 12 is $43,580 to $48,690.

The average cost of jailing a federal inmate is $31,978 a year, according to the Federal Register, though this cost varies dramatically by state. For example, the *Los Angeles Times* reported that housing a prisoner in California costs $75,560 a year.

Keeping one child out of prison by engaging them in a music program would be a better deal for taxpayers than laying off the teacher who can provide it. If one at-risk student graduates as a result of participating in a music program, the net societal gain would pay for 10 years of a music teacher's salary.

The data speak for themselves: music education programs provide a compelling return on investment.

Conclusions

Music is a tool that has shaped human development through millenia. At a time when creativity and innovation are critical to the U.S. economy, music programs are the best investment in education that governments can make.

From infancy through adolescence, music training enhances brain development and improves everything from language and literacy to reasoning and creativity. Music-making increases connectivity in the brain, giving kids an edge when it comes to integrating information and coordinating thinking and behavior. Children with music training also gain a boost in *working memory* and *executive function* — both of which are necessary for critical thinking, decision-making, and other tasks that require focus.

In fact, studies have shown that children with music training performed better than their untrained peers on the *Wechsler Intelligence Scale for Children (WISC-III)*, a popular IQ test for kids aged six to 16.

Detractors argue that time invested in music education takes away from core subjects like reading and math. On the contrary, researchers have found that taking part in a music program is associated with higher academic achievement across the board. Not only that, teachers report more social cohesion in the classroom and greater self-reliance among students.

These effects are amplified in the kids with the most to gain: Those with low ability who seemed the least interested in academics have shown the biggest improvements.

Participation in the performing arts is an effective way to help kids develop confidence. Researchers have proven a correlation between student participation in the performing arts, higher GPAs, and college attendance rates.

The dollars invested in music programs yield a compelling return, as proven by programs such as the Los Angeles Harmony Project. In an area where the high school dropout rate is 50 percent, 97 percent of the high school seniors who took part in the program for at least three years graduated and went on to college.

The net societal gain for every single child who stays in school and graduates — instead of going to jail — can fund a music teacher's salary for 10 years. Isn't this a more positive investment than spending money on prisons?

It's time to give every child in America the chance to reap the benefits of a high-quality music education. It's their birthright.

Call to Action

We hope you've enjoyed this white paper, learned some brain science, and now understand the logic behind our conviction that every child should have access to music education. Please send this paper to anyone who could play a role in convincing the government, school boards, and community decision-makers to restore and expand funding for music programs.

About the Author

Neuroscientist/ Opera Singer/Science Communicator

Indre Viskontas is a **sought-after brain science communicator** across all media. **Combining a passion for music with scientific curiosity**, she is affectionately known as Dr. Dre by students at the San Francisco Conservatory of Music where she is **pioneering the application of neuroscience to music training** at the University of San Francisco where she teaches neuroscience. She holds a Bachelor of Science in Psychology from the University of Toronto, a Master of Music in Voice Performance from the San Francisco Conservatory of Music, and a Doctor of Philosophy in Cognitive Neuroscience from UCLA.

As a scientist, Dr. Viskontas has **published more than 50 original papers** and chapters related to the neural basis of memory and creativity. Her dissertation was recognized as the best in her class at UCLA and her scientific work has been featured in **Oliver Sacks' book *Musicophilia,*** as well as leading journals and magazines: ***Nature: Science Careers*** and ***Discover Magazine***. In the popular media, Dr. Viskontas **co-hosted** the docuseries ***Miracle Detectives*** on the **Oprah Winfrey Network** and has **appeared on *The Oprah Winfrey Show*** as well as on the *Discovery Channel*, the *History Channel* and the *Travel Channel*. In 2017, she co-hosted the web series *Science in Progress* for Tested.com and VRV. She is also the host of the **popular science podcast *Inquiring Minds***, which has been downloaded more than **8 million times** and her new podcast, ***Cadence: what music tells us about the mind*** was a finalist for the 2018 *Science Media Awards*.

Her **24-lecture course *Essential Scientific Concepts*** by The Great Courses sold more than 20,000 copies in its first year and her **second online course**, ***Brain Myths Exploded: Lessons from Neuroscience*** was released in early 2017 and **hit #1 on the nonfiction bestseller list at Audible.com.** Her third course, ***How Digital Technology Shapes Us*** will be released in late 2020, and she is currently working on her fourth, entitled ***The Creative Brain.*** She is also the **Creative Director at Pasadena Opera**, where she directed *The Man Who Mistook his Wife for a Hat*, a chamber opera based on the famous case study written by Oliver Sacks, and most recently, *Proving Up*, by Missy Mazzoli and Royce Vavrek.

Her **first book**, ***How Music Can Make You Better***, was published by Chronicle Books in 2019. More at www.indreviskontas.com.

Acknowledgements

The San Francisco Conservatory of Music gratefully acknowledges the contributions of the following individuals, whose work and conversations at our 2018 Symposium created the foundation of this document: Katherine Damkohler, Lisa Delan, Robert Duke, Judy Evans, Gordon Getty, Assal Habibi, Lee Koonce, Anna Potengowski, Kathy Schick, Robert Slevc, Dalouge Smith, Nicholas Toth, Rhys Williams and Michael Winger. Additional edits and helpful comments were provided by Nina Kraus and Heidi Moss Erickson. We would also like to thank the Getty Foundation for its generous support of this effort.

Glossary

Arcuate fasciculus: A pathway of axons (neuron endings) connecting the temporal and frontal lobes — specifically Wernicke's area, which is important for language comprehension, and Broca's area, which is vital for speech production.

Auditory cortex: The region of the brain that processes sound.

Axon: The projection from a neuron (nerve ending) that conducts electrical information and can transmit a signal by releasing neurotransmitters: chemicals that are exchanged between neurons.

Bimanual coordination: Using both hands at the same time to accomplish a coordinated motor act, like driving a car with a gearshift, playing the piano, or conducting an orchestra.

Broca's area: A part of the frontal lobe that is important for speech production.

Corpus callosum: A fiber tract or axon pathway that joins the left and right cerebral hemispheres.

Cortex: The outermost layer of the brain made up of gray matter, where cell bodies and dendrites reside.

Cortical representation of fingers: In the cortex, both sensory and motor information coming from and going out to the body is represented in specific regions and arranged topographically. Body parts that are near each other (fingers and hand) are represented in regions close together.

Dendrites: The parts of the neuron that receive information from other neurons.

Electroencephalogram (EEG): A tool used to measure electrical activity in the brain. Usually, electrodes placed on the scalp can track the actions of many neurons at once.

Electrophysiology: The measurement of electrical activity in the brain.

Emotional regulation: The ability to control emotional reactions in socially-appropriate ways.

Executive function or central executive: A set of skills necessary for cognitive control — choosing, executing, and adjusting behaviors in the pursuit of a goal. Skills include directing attention, inhibiting inappropriate impulses, holding information in the mind, manipulating information, flexible thinking, problem solving, and decision-making.

Frontal lobe: One of the four major sections of the cerebral cortex located at the front of the brain behind the forehead. In terms of evolution, this is the newest part of the brain, which develops last in humans. It plays a fundamental role in working memory with functions that include planning and controlling voluntary actions, making decisions, navigating social interactions, suppressing impulses, predicting consequences, and working toward a goal.

Functional neuroanatomy: Defines what parts of the brain are involved in different tasks or functions.

Gray matter: The part of the brain that contains cell bodies of neurons and their support cells as well as dendrites, the part of the neuron that receives information from other neurons.

Heschl's gyrus: The first structures in the cortex to process incoming auditory information.

Inferior frontal gyrus: A part of the frontal lobe. In most people, the left inferior frontal gyrus is vital for language production or speech.

Mismatch negativity (MMN): A type of brain wave signal that scientists see when a person experiences something unexpected, such as hearing a wrong note in a familiar melody.

Motor-sequence learning: Learning a particular pattern of motor behavior like tapping out a specific rhythm.

Myelination: The process by which axons, or the output ends of neurons, can speed up electrical conduction. During myelination, an insulating fatty sheath covers much of the axon, leaving small gaps so that the electrical signal can jump from gap to gap rather than being regenerated along the entire axon.

Neural activity: Electrochemical activity that can be measured by scientists and is the primary way by which the brain functions.

Neuroanatomy: The organization of the brain.

Neurophysiology: The study of the electrochemical changes in the brain.

Neuroplasticity: How the brain changes with experience. There are multiple ways in which these changes can happen:

- at the level of the synapse by strengthening or weakening connections between neurons
- at the regional level by making more connections between brain regions
- by changing what a brain region does.

Neurons: A special cell that transmits nerve impulses, a nerve cell.

Omega sign: A hook-like structure seen in the part of the brain that controls the left hand in string players and some other musicians.

Phonological processing or skills: The ability to understand the sound structure of words. For example, knowing where a syllable or word begins and ends, which words rhyme, and eventually to associate sounds with letters.

Pre-attentive: Sensory information that our brain is processing before we are aware of it.

Prefrontal cortex: The front part of the frontal lobe, which is important for executive functions like determining the consequences of actions, distinguishing good from bad, suppressing urges that would be socially-inappropriate, and working toward a goal.

Premotor cortex: A region of the brain just in front of the motor cortex, involved in planning movement, understanding the actions of others, and using abstract rules to perform tasks.

Primary auditory cortex: See Heschl's gyrus or auditory cortex.

Raven's Progressive Matrices: A non-verbal test of abstract reasoning and fluid intelligence.

Sensory representations: Where and how information from the environment is processed by the brain.

Structural neuroanatomy: The regional organization of the brain.

Synapse: The gap between neurons in which cells communicate with each other by sending and receiving electrical and/or chemical messages.

Temporal lobe: The part of the cerebral cortex lying just behind the ears that plays a major role in auditory information processing, long-term memory, and categorization.

Wechsler Intelligence Scale for Children (WISC-III): A popular intelligent test for children aged 6-16 that gives a full-scale IQ value, based on five subtests: Verbal Comprehension, Visual Spatial Index, Fluid Reasoning, Working Memory, and Processing Speed.

White matter: Made up of the projections from neurons — their axons — white matter contains the fibres that connect cells and brain regions, allowing them to communicate with each across the brain

Working memory: When you are keeping something in mind, you're using working memory: a set of cognitive processes with a limited capacity that enable us to hold and manipulate information in consciousness, like remembering a number long enough to enter it into your phone.

References

To stay current on information about the impact of music training on the brain, check out https://www.brainvolts.northwestern.edu/music/, highlighting the prolific work of Dr. Nina Kraus.

Anvari, S. H., Trainor, L. J., Woodside, J., and Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. Journal of experimental child psychology, 83(2), 111-130.

Arain, M., Haque, M., Johal, L., Mathur, P., Nel, W., Rais, A., ... and Sharma, S. (2013). Maturation of the adolescent brain. Neuropsychiatric disease and treatment, 9, 449.

Besson, M., Chobert, J., and Marie, C. (2011). Transfer of training between music and speech: common processing, attention, and memory. Front. Psychol. 2:94. doi: 10.3389/fpsyg.2011.00094

Belfield, C. R., and Levin, H. M. (2009). High school dropouts and the economic losses from juvenile crime in California. California Dropout Research Project Report, 16, 1-55.

Blood, A. J., and Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. Proceedings of the National Academy of Sciences, 98(20), 11818-11823.

Bonacina, S., Krizman, J., White-Schwoch, T., and Kraus, N. (2018). Clapping in time parallels literacy and calls upon overlapping neural mechanisms in early readers. Annals of the New York Academy of Sciences. 1423 (1), 338-348.

Broh, B. A. (2002). Linking extracurricular programming to academic achievement: Who benefits and why? Sociology of education, 69-95.

Burunat, I., Brattico, E., Puoliväli, T., Ristaniemi, T., Sams, M., and Toiviainen, P. (2015). Action in perception: prominent visuo-motor functional symmetry in musicians during music listening. PloS one, 10(9), e0138238.

Chan, A. S., Ho, Y. C., and Cheung, M. C. (1998). Music training improves verbal memory. Nature, 396(6707), 128.

Claro, S., Paunesku, D., and Dweck, C. S. (2016). Growth mindset tempers the effects of poverty on academic achievement. Proceedings of the National Academy of Sciences, 113(31), 8664-8668.

Coffey, E. B., Mogilever, N. B., and Zatorre, R. J. (2017). Speech-in-noise perception in musicians: A review. Hearing research, 352, 49-69.

Costa-Giomi, E. (1999) The effects of three years of piano instruction on children's cognitive development. Journal of Research in Music Education, 47(5), 198-212.

Costa-Giomi, E. (2005). Does music instruction improve fine motor abilities?. Annals of the New York Academy of Sciences, 1060(1), 262-264.

De Dreu, C. K., Nijstad, B. A., Baas, M., Wolsink, I., and Roskes, M. (2012). Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. Personality and Social Psychology Bulletin, 38(5), 656-669.

Dolgin, K. G., and Adelson, E. H. (1990). Age changes in the ability to interpret affect in sung and instrumentally-presented melodies. Psychology of Music, 18(1), 87-98.

Dweck, C. S. (2008). Mindset: The new psychology of success. Random House Digital, Inc..

Eason, B. J., and Johnson, C. M. (2013). Prelude: Music Makes Us baseline research report. Metropolitan Nashville Public Schools.

Eccles, J. S., and Barber, B. L. (1999). Student council, volunteering, basketball, or marching band: What kind of extracurricular involvement matters? Journal of adolescent research, 14(1), 10-43.

Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B., and Taub, E. (1995). Increased cortical representation of the fingers of the left hand in string players. Science, 270(5234), 305-307.

Evans, G. W., and Maxwell, L. (1997). Chronic noise exposure and reading deficits: The mediating effects of language acquisition. Environment and behavior, 29(5), 638-656.

Forgeard, M., Winner, E., Norton, A., and Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. PloS one, 3(10), e3566.

Gaser C, Schlaug G. (2003) Brain structures differ between musicians and non-musicians. J Neurosci. 23: 9240–5.

George, E. M., and Coch, D. (2011). Music training and working memory: an ERP study. Neuropsychologia, 49(5), 1083-1094.

Gerry, D., Unrau, A., and Trainor, L. J. (2012). Active music classes in infancy enhance musical, communicative and social development. Developmental science, 15(3), 398-407.

Giedd, J. N. (2004). Structural magnetic resonance imaging of the adolescent brain. Annals of the New York Academy of Sciences, 1021(1), 77-85.

Gouzouasis, P., Guhn, M., and Kishor, N. (2007). The predictive relationship between achievement and participation in music and achievement in core grade 12 academic subjects. Music Education Research, 9(1), 81-92.

Gunderson, E. A., Sorhagen, N. S., Gripshover, S. J., Dweck, C. S., Goldin-Meadow, S., and Levine, S. C. (2018). Parent praise to toddlers predicts fourth grade academic achievement via children's incremental mindsets. Developmental psychology, 54(3), 397.

Halwani, G. F., Loui, P., Rueber, T., and Schlaug, G. (2011). Effects of practice and experience on the arcuate fasciculus: comparing singers, instrumentalists, and non-musicians. Frontiers in psychology, 2, 156.

Kirschner, S., and Tomasello, M. (2009). Joint drumming: social context facilitates synchronization in preschool children. J. Exp. Child Psychol. 102, 299–314.

Kokotsaki, D., and Hallam, S. (2007) Higher education music students' perceptions of the benefits of participative music-making, Music Education Research, 9:1, 93-109, DOI: 10.1080/14613800601127577

Kraus, N., and Chandrasekaran, B. (2010). Music training for the development of auditory skills. Nature reviews neuroscience, 11(8), 599.

Krings, T., Töpper, R., Foltys, H., Erberich, S., Sparing, R., Willmes, K., and Thron, A. (2000). Cortical activation patterns during complex motor tasks in piano players and control subjects. A functional magnetic resonance imaging study. Neuroscience letters, 278(3), 189-193.

Lee DJ, Chen Y, Schlaug G. (2003) Corpus callosum: musician and gender effects. NeuroReport. 14:205–9.

Lima, C. F., and Castro, S. L. (2011). Speaking to the trained ear: musical expertise enhances the recognition of emotions in speech prosody. Emotion 11, 1021–1031.

Mangels, J., Butterfiels, B., Lamb, J., Good, C., and Dweck, C. S. (2006). Why Do Beliefs about Intelligence Influence Learning Success? A Social Cognitive Neuroscience Model. Social Cognitive and Affective Neuroscience, 1, 75-86.

Moritz, C., Yampolsky, S., Papadelis, G., Thomson, J., and Wolf, M. (2013). Links between early rhythm skills, musical training, and phonological awareness. Reading and Writing, 26(5), 739-769.

Mueller CM, Dweck CS (1998) Praise for intelligence can undermine children's motivation and performance. J Pers Soc Psychol 75(1):33–52.

Münte, T. F., Altenmüller, E., and Jäncke, L. (2002). The musician's brain as a model of neuroplasticity. Nature Reviews Neuroscience, 3(6), 473.

Oztürk AH, Tascioglu B, Aktekin M, Kurtoglu Z, Erden I. (2002) Morphometric comparison of the human corpus callosum in professional musicians and non-musicians by using in vivo magnetic resonance imaging. J Neuroradiol. 29:29–34

Partanen, E., Kujala, T., Tervaniemi, M., and Huotilainen, M. (2013). Prenatal music exposure induces long-term neural effects. PloS one, 8(10), e78946.

Heathcote, A., Brown, S., and Mewhort, D. J. K. (2000). The power law repealed: The case for an exponential law of practice. Psychonomic bulletin & review, 7(2), 185-207.

Helmrich, B. H. (2010). Window of opportunity? Adolescence, music, and algebra. Journal of Adolescent Research, 25(4), 557-577.

Hetland, L. (2000). Learning to make music enhances spatial reasoning. J. Aesthet. Educ. 34, 179–238.

Kim, K. H. (2011). The creativity crisis: The decrease in creative thinking scores on the Torrance Tests of Creative Thinking. Creativity Research Journal, 23(4), 285-295.

Pascual-Leone, A., Nguyet, D., Cohen, L. G., Brasil-Neto, J. P., Cammarota, A., and Hallett, M. (1995). Modulation of muscle responses evoked by transcranial magnetic stimulation during the acquisition of new fine motor skills. Journal of Neurophysiology, 74(3), 1037-1045.

Picton, T. W., Alain, C., Otten, L., Ritter, W., and Achim, A. (2000). Mismatch negativity: different water in the same river. Audiology and Neurotology, 5(3-4), 111-139.

Pinho, A. L., de Manzano, Ö., Fransson, P., Eriksson, H., and Ullén, F. (2014). Connecting to create: expertise in musical improvisation is associated with increased functional connectivity between premotor and prefrontal areas. Journal of Neuroscience, 34(18), 6156-6163.

Roden, I., Grube, D., Bongard, S., and Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. Psychology of Music, 42(2), 284-298.

Romero C, Master A, Paunesku D, Dweck CS, Gross JJ (2014) Academic and emotional functioning in middle school: The role of implicit theories. Emotion, 14(2): 227–234.

Salimpoor, V. N., van den Bosch, I., Kovacevic, N., McIntosh, A. R., Dagher, A., and Zatorre, R. J. (2013). Interactions between the nucleus accumbens and auditory cortices predict music reward value. Science, 340(6129), 216-219.

Schellenberg, E. G. (2004). Music lessons enhance IQ. Psychological science, 15(8), 511-514.

Schellenberg, E. (2006). Long-termpositive associations between music lessons and IQ. J. Educ. Psychol. 98, 457–468.

Schlaug, G. (2001). The brain of musicians. Annals of the New York Academy of Sciences, 930(1), 281-299.

Schlaug, G., Jäncke, L., Huang, Y., Staiger, J. F., and Steinmetz, H. (1995). Increased corpus callosum size in musicians. Neuropsychologia, 33(8), 1047-1055.

Schlaug, G., Norton, A., Overy, K., and Winner, E. (2005). Effects of music training on the child's brain and cognitive development. Ann. N.Y. Acad. Sci. 1060, 219–230.

Slater, J., Skoe, E., Strait, D. L., O'Connell, S., Thompson, E., and Kraus, N. (2015). Music training improves speech-in-noise perception: Longitudinal evidence from a community-based music program. Behavioural brain research, 291, 244-252.

Slevc, L. R., and Miyake, A. (2006). Individual differences in second-language proficiency: does musical ability matter? Psychol. Sci. 17, 675–681.

Spychiger, M., Patry, J. Lauper, G., Zimmerman, E., and Weber, E. (1993). 'Does more music teaching lead to a better social climate'. In R. Olechowski and G. Svik (eds) Experimental research in teaching and learning. (Bern, Peter Lang).

Steele, C. J., Bailey, J. A., Zatorre, R. J., and Penhune, V. B. (2013). Early musical training and white-matter plasticity in the corpus callosum: evidence for a sensitive period. Journal of Neuroscience, 33(3), 1282-1290.

Stipek D, Gralinski JH (1996) Children's beliefs about intelligence and school performance. J Educ Psychol 88(3):397–407.

Strait, D. L., Kraus, N., Skoe, E., and Ashley, R. (2009). Musical experience promotes subcortical efficiency in processing emotional vocal sounds. Annals of the New York Academy of Sciences, 1169(1), 209-213.

Thompson, W. F., Schellenberg, E. G., and Husain, G. (2004). Decoding speech prosody: Do music lessons help? Emotion, 4(1), 46.

Tierney, A. T., Krizman, J., and Kraus, N. (2015). Music training alters the course of adolescent auditory development. Proceedings of the National Academy of Sciences, 112(32), 10062-10067.

Trainor, L. J., Austin, C. M., and Desjardins, R. N. (2000). Is infant-directed speech prosody a result of the vocal expression of emotion?. Psychological science, 11(3), 188-195.

Vaughn, K. (2000). Music and mathematics: modest support for the oft-claimed relationship. J. Aesthet. Educ. 34, 149–166.

Young, L. N., Cordes, S., and Winner, E. (2013). Arts involvement predicts academic achievement only when the child has a musical instrument. Educ. Psychol. 1–13.

Wan, C. Y., and Schlaug, G. (2010). Music-making as a tool for promoting brain plasticity across the life span. The Neuroscientist, 16(5), 566-577.

Zhao, T. C., and Kuhl, P. K. (2016). Musical intervention enhances infants' neural processing of temporal structure in music and speech. Proceedings of the National Academy of Sciences, 113(19), 5212-5217.

Endnotes

1 Partanen, E., Kujala, T., Tervaniemi, M., Huotilainen, M. (2013). Prenatal music exposure induces long-term neural effects. PLoS ONE 8(10), e78946.

2 Lordier, L., Meskaldji, D. E., Grouiller, F., Pittet, M. P., Vollenweider, A., Vasung, L., Borradori-Tolsa, C., Lazeyras, F., Grandjean, D., Van De Ville, D., and Hüppi, P. S. (2019). Music in premature infants enhances high-level cognitive brain networks. Proceedings of the National Academy of Sciences of the United States of America 116(24), 12103–12108.

3 Zhao, T. C., and Kuhl, P. K. (2016). Musical intervention enhances infants' neural processing of temporal structure in music and speech. Proceedings of the National Academy of Sciences, 113(19), 5212-5217.

4 Gerry, D., Unrau, A., and Trainor, L. J. (2012). Active music classes in infancy enhance musical, communicative and social development. Developmental science, 15(3), 398-407.

5 Trainor, L. J., Austin, C. M., and Desjardins, R. N. (2000). Is infant-directed speech prosody a result of the vocal expression of emotion?. Psychological science, 11(3), 188-195.

6 Dolgin, K. G., and Adelson, E. H. (1990). Age changes in the ability to interpret affect in sung and instrumentally-presented melodies. Psychology of Music, 18(1), 87-98.

7 Giedd, J. N. (2004). Structural magnetic resonance imaging of the adolescent brain. Annals of the New York Academy of Sciences, 1021(1), 77-85.

8 Arain, M., Haque, M., Johal, L., Mathur, P., Nel, W., Rais, A., ... and Sharma, S. (2013). Maturation of the adolescent brain. Neuropsychiatric disease and treatment, 9, 449.

9 Steele, C. J., Bailey, J. A., Zatorre, R. J., and Penhune, V. B. (2013). Early musical training and white-matter plasticity in the corpus callosum: evidence for a sensitive period. Journal of Neuroscience, 33(3), 1282-1290.

10 Schlaug, G. (2001). The brain of musicians. Annals of the New York Academy of Sciences, 930(1), 281-299.

11 Münte, T. F., Altenmüller, E., and Jäncke, L. (2002). The musician's brain as a model of neuroplasticity. Nature Reviews Neuroscience, 3(6), 473.

12 Pascual-Leone, A., Nguyet, D., Cohen, L. G., Brasil-Neto, J. P., Cammarota, A., and Hallett, M. (1995). Modulation of muscle responses evoked by transcranial magnetic stimulation during the acquisition of new fine motor skills. Journal of neurophysiology, 74(3), 1037-1045.

13 Costa-Giomi, E. (2005). Does music instruction improve fine motor abilities?. Annals of the New York Academy of Sciences, 1060(1), 262-264.

14 Gaser C, Schlaug G. (2003) Brain structures differ between musicians and non-musicians. J Neurosci. 23: 9240–5.

15 Rüsseler, J., Altenmüller, E., Nager, W., and Kohlmetz, C (2001). Event-related brain potentials to sound omissions differ in musicians and non-musicians. Neuroscience Letters. 308(1), 33-6.

16 Ibid.

17 Burunat, I., Brattico, E., Puoliväli, T., Ristaniemi, T., Sams, M., and Toiviainen, P. (2015). Action in perception: prominent visuo-motor functional symmetry in musicians during music listening. PloS one, 10(9), e0138238.

18 Schlaug, G., Jäncke, L., Huang, Y., Staiger, J. F., and Steinmetz, H. (1995). Increased corpus callosum size in musicians. Neuropsychologia, 33(8), 1047-1055.

19 Halwani, G. F., Loui, P., Rueber, T., and Schlaug, G. (2011). Effects of practice and experience on the arcuate fasciculus: comparing singers, instrumentalists, and non-musicians. Frontiers in psychology, 2, 156.

20 Wan, C. Y., and Schlaug, G. (2010). Music-making as a tool for promoting brain plasticity across the life span. The Neuroscientist, 16(5), 566-577.

21 Blood, A. J., and Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. Proceedings of the National Academy of Sciences, 98(20), 11818-11823.

22 Forgeard, M., Winner, E., Norton, A., and Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. PloS one, 3(10), e3566.

23 Ibid.

24 Schellenberg, E. G. (2004). Music lessons enhance IQ. Psychological science, 15(8), 511-514.

25 Coffey, E. B., Mogilever, N. B., and Zatorre, R. J. (2017). Speech-in-noise perception in musicians: A review. Hearing research, 352, 49-69.

26 Slater, J., Skoe, E., Strait, D. L., O'Connell, S., Thompson, E., and Kraus, N. (2015). Music training improves speech-in-noise perception: Longitudinal evidence from a community-based music program. Behavioural brain research, 291, 244-252.

27 Chan, A. S., Ho, Y. C., and Cheung, M. C. (1998). Music training improves verbal memory. Nature, 396(6707), 128.

28 Anvari, S. H., Trainor, L. J., Woodside, J., and Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. Journal of experimental child psychology, 83(2), 111-130.

29 Moritz, C., Yampolsky, S., Papadelis, G., Thomson, J., and Wolf, M. (2013). Links between early rhythm skills, musical training, and phonological awareness. Reading and Writing, 26(5), 739-769.

30 Krings, T., Töpper, R., Foltys, H., Erberich, S., Sparing, R., Willmes, K., and Thron, A. (2000). Cortical activation patterns during complex motor tasks in piano players and control subjects. A functional magnetic resonance imaging study. Neuroscience letters, 278(3), 189-193.

31 Bonacina, S., Krizman, J., White-Schwoch, T., and Kraus, N. (2018). Clapping in time parallels literacy and calls upon overlapping neural mechanisms in early readers. Annals of the New York Academy of Sciences.

32 Strait, D. L., Kraus, N., Skoe, E., and Ashley, R. (2009). Musical experience promotes subcortical efficiency in processing emotional vocal sounds. Annals of the New York Academy of Sciences, 1169(1), 209-213.

33 Kraus, N., and Chandrasekaran, B. (2010). Music training for the development of auditory skills. Nature reviews neuroscience, 11(8), 599.

34 Tierney, A. T., Krizman, J., and Kraus, N. (2015). Music training alters the course of adolescent auditory development. Proceedings of the National Academy of Sciences, 112(32), 10062-10067.

35 Evans, G. W., and Maxwell, L. (1997). Chronic noise exposure and reading deficits: The mediating effects of language acquisition. Environment and behavior, 29(5), 638-656.

36 Krizman, E., Kraus, J., and Kraus, N. (2013). The impoverished brain: disparities in maternal education affect the neural response to sound. Journal of Neuroscience 33(44),17221–17231.

37 Besson, M., Chobert, J., and Marie, C. (2011). Transfer of training between music and speech: common processing, attention, and memory. Front. Psychol. 2:94. doi: 10.3389/fpsyg.2011.00094

38 Schlaug, G., Norton, A., Overy, K., and Winner, E. (2005). Effects of music training on the child's brain and cognitive development. Ann. N.Y. Acad. Sci. 1060, 219–230. doi: 10.1196/annals.1360.015

39 Forgeard, M., Winner, E., Norton, A., and Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. PLoS ONE 3:e3566. doi: 10.1371/journal.pone. 0003566

40 Slevc, L. R., and Miyake, A. (2006). Individual differences in second-language proficiency: does musical ability matter? Psychol. Sci. 17, 675–681.

41 Roden, I., Grube, D., Bongard, S., and Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. Psychology of Music, 42(2), 284-298.

42 Forgeard, M., Winner, E., Norton, A., and Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. PLoS ONE 3:e3566. doi: 10.1371/journal.pone. 0003566

43 Ibid.

44 Schellenberg, E. (2006). Long-term positive associations between music lessons and IQ. J. Educ. Psychol. 98, 457–468. doi: 10.1037/0022-0663.98.2.457

45 Hetland, L. (2000). Learning to make music enhances spatial reasoning. J. Aesthet. Educ. 34, 179–238. doi: 10.2307/3333643

46 Vaughn, K. (2000). Music and mathematics: modest support for the oft-claimed relationship. J. Aesthet. Educ. 34, 149–166. doi: 10.2307/3333641

47 Helmrich, B. H. (2010). Window of opportunity? Adolescence, music, and algebra. Journal of Adolescent Research, 25(4), 557-577.

48 Gouzouasis, P., Guhn, M., and Kishor, N. (2007). The predictive relationship between achievement and participation in music and achievement in core grade 12 academic subjects. Music Education Research, 9(1), 81-92.

49 Spychiger, M., Patry, J. Lauper, G., Zimmerman, E., and Weber, E. (1993). 'Does more music teaching lead to a better social climate'. In R. Olechowski and G. Svik (eds) Experimental research in teaching and learning. (Bern, Peter Lang).

50 Young, L. N., Cordes, S., and Winner, E. (2013). Arts involvement predicts academic achievement only when the child has a musical instrument. Educ. Psychol. 1–13. doi: 10.1080/01443410.2013.785477

51 For a review of two longitudinal studies on the effects of music making on communication skills, see Kraus N, White-Schwoch T (2017) Neurobiology of everyday communication: what have we learned from music. The Neuroscientist. 23(3): 287-298.

52 Gerry, D., Unrau, A., and Trainor, L. J. (2012). Active music classes in infancy enhance musical, communicative and social development. Developmental science, 15(3), 398-407.

53 Kirschner, S., and Tomasello, M. (2009). Joint drumming: social context facilitates synchronization in preschool children. J. Exp. Child Psychol. 102, 299–314. doi:10.1016/j.jecp.2008.07.005

54 Thompson, W. F., Schellenberg, E. G., and Husain, G. (2004). Decoding speech prosody: Do music lessons help?. Emotion, 4(1), 46.

55 Lima, C. F., and Castro, S. L. (2011). Speaking to the trained ear: musical expertise enhances the recognition of emotions in speech prosody. Emotion 11, 1021–1031. doi: 10.1037/a0024521

56 Gouzouasis, P., Guhn, M., and Kishor, N. (2007). The predictive relationship between achievement and participation in music and achievement in core grade 12 academic subjects. Music Education Research, 9(1), 81-92.

57 Eccles, J. S., and Barber, B. L. (1999). Student council, volunteering, basketball, or marching band: What kind of extracurricular involvement matters?. Journal of adolescent research, 14(1), 10-43.

58 Kokotsaki, D., and Hallam, S. (2007) Higher education music students' perceptions of the benefits of participative music-making, Music Education Research, 9:1, 93-109, DOI: 10.1080/14613800601127577

59 Mueller C. M., Dweck CS (1998) Praise for intelligence can undermine children's motivation and performance. J Pers Soc Psychol 75(1):33–52.
Also see: Stipek D, Gralinski JH (1996) Children's beliefs about intelligence and school performance. J Educ Psy- chol 88(3):397–407.

60 Dweck, C. S. (2008). Mindset: The new psychology of success. Random House Digital, Inc..

61 Mueller, C. M., and Dweck, C. S. (1998). Praise for Intelligence Can Undermine Children's Motivation and Performance. Journal of Personality and Social Psychology, 75, 33–52.

62 Gunderson, E. A., Sorhagen, N. S., Gripshover, S. J., Dweck, C. S., Goldin-Meadow, S., and Levine, S. C. (2018). Parent praise to toddlers predicts fourth grade academic achievement via children's incremental mindsets. Developmental psychology, 54(3), 397.

63 Claro, S., Paunesku, D., and Dweck, C. S. (2016). Growth mindset tempers the effects of poverty on academic achievement. Proceedings of the National Academy of Sciences, 113(31), 8664-8668.

64 Mangels, J., Butterfiels, B., Lamb, J., Good, C., and Dweck, C. S. (2006). Why Do Beliefs about Intelligence Influence Learning Success? A Social Cognitive Neuroscience Model. Social Cognitive and Affective Neuroscience, 1, 75-86.

65 Claro, S., Paunesku, D., and Dweck, C. S. (2016). Growth mindset tempers the effects of poverty on academic achievement. Proceedings of the National Academy of Sciences, 113(31), 8664-8668.

66 Costa-Giomi, E. (1999) 'The effects of three years of piano instruction on children's cognitive development'. Journal of Research in Music Education, 47(5), 198-212.

67 Heathcote, A., Brown, S., and Mewhort, D. J. K. (2000). The power law repealed: The case for an exponential law of practice. Psychonomic bulletin & review, 7(2), 185-207.

68 Salimpoor, V. N., van den Bosch, I., Kovacevic, N., McIntosh, A. R., Dagher, A., and Zatorre, R. J. (2013). Interactions between the nucleus accumbens and auditory cortices predict music reward value. Science, 340(6129), 216-219.

69 Kim, K. H. (2011). The creativity crisis: The decrease in creative thinking scores on the Torrance Tests of Creative Thinking. Creativity Research Journal, 23(4), 285-295.

70 George, E. M., and Coch, D. (2011). Music training and working memory: an ERP study. Neuropsychologia, 49(5), 1083-1094.

71 Roden, I., Grube, D., Bongard, S., and Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. Psychology of Music, 42(2), 284-298.

72 De Dreu, C. K., Nijstad, B. A., Baas, M., Wolsink, I., and Roskes, M. (2012). Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. Personality and Social Psychology Bulletin, 38(5), 656-669.

73 Pinho, A. L., de Manzano, Ö., Fransson, P., Eriksson, H., and Ullén, F. (2014). Connecting to create: expertise in musical improvisation is associated with increased functional connectivity between premotor and prefrontal areas. Journal of Neuroscience, 34(18), 6156-6163.

74 Broh, B. A. (2002). Linking extracurricular programming to academic achievement: Who benefits and why? Sociology of education, 69-95.

75 Belfield, C. R., and Levin, H. M. (2009). High school dropouts and the economic losses from juvenile crime in California. California Dropout Research Project Report, 16, 1-55.

76 Eason, B. J., and Johnson, C. M. (2013). Prelude: Music Makes Us baseline research report. Metropolitan Nashville Public Schools.

About the San Francisco Conservatory of Music

At the San Francisco Conservatory of Music, we give students the framework and foundation to succeed throughout their studies and careers, creating a path of lifelong learning. More than any other world-class conservatory, we focus on educating the whole person, with an interconnected curriculum that breaks down barriers between the intellectual, artistic, professional, and individual. Our faculty, facilities, and position at the heart of the San Francisco music scene have helped SFCM seize a leading role in preparing — and defining — the 21st-century musician and to harness the power of music to enrich our society.