

Music of the hemispheres

Playing instruments gives brains a boost

By Rachel Ehrenberg ■ Photograph by Cary Wolinsky

Not so long ago, Mozart mania swept the nation. A small study found that students who listened to 10 minutes of a Mozart sonata performed better on a paper-folding task than their peers, and suddenly a flourishing industry sprouted. Mozart's music sang from CDs and videos marketed for children, babies and moms-to-be. The craze reached a crescendo when Georgia's governor Zell Miller included \$105,000 in his state budget to send every child born in a Georgia hospital home with a classical music tape or CD.

"No one questions that listening to music at a very early age affects the spatial, temporal reasoning that underlies math and engineering and even chess," Miller said.

Actually, a lot of researchers questioned the link between listening to

music and smarts. In the original study, the "Mozart effect" was minor and lasted only minutes. Follow-up studies found the effect specific neither to the composer nor to music. Students listening to Mozart were just more stimulated than those listening to a relaxation tape or silence. And while arousal can improve learning, research suggests, the effects can be fleeting and aren't limited to music. Assessments of the original report now tend to be dirges: In the May-June issue of *Intelligence*, researchers from the University of Vienna published a paper titled "Mozart effect-Shmozart effect."

"It's a short-lived effect and it spawned a huge industry of baby Einstein, baby Mozart CDs, all sorts of stuff," says Aniruddh Patel of the Neurosciences Institute in San Diego. "But the science behind it is pretty thin."

Yet even though listening to Mozart

won't make you smarter, a growing body of evidence suggests that playing his music will. Musical training doesn't just make you a better musician — the acquired skills seem to transfer to other areas, various studies have found. And research focused on the brain's particular relationship with music and language suggests that engaging the mind with musical training could remedy language impairments such as dyslexia.

"There really is now so much evidence showing that musical experience has a pervasive effect on how the nervous system gets molded and shaped throughout our lifetimes," says Nina Kraus, head of the Auditory Neuroscience Laboratory at Northwestern University in Evanston, Ill. "This kind of transformation comes about only with active engagement with sound. My daddy always said, 'You never get something for nothing.' You're not going to get big biceps by watching wrestlers — you've got to do it."

In the long run, musical training appears to improve a suite of verbal and nonverbal skills. Playing an instrument may add finesse to how people move their bodies. Making music makes you hear better, fine-tuning the ability to extract a signal from noise. Musical training also may improve grammar skills, the ability to grasp meaning from words and to distinguish a question from a command.



Until recently, establishing cause and effect for music's mental impact has been difficult. But long-term studies peering into brain structure and activity are now showing that musical training changes the brain in lasting ways.

The brain on beats

Playing an instrument calls upon circuitry from many areas of the brain, says Daniel Levitin, director of the music perception, cognition and expertise laboratory at McGill University in Montreal. For a long time, music was considered a creative "right brain" endeavor. That idea has now gone the way of the Macarena. Music processing is distributed throughout the brain, says Levitin, and playing an instrument, in particular, is an ensemble activity. It involves paying attention, thinking ahead, remembering, coordinating movement and interpreting constant feedback to the ears, fingers and, in some cases, lips.

"It's one of the most complicated tasks that we have," Levitin says. "Take a symphony orchestra. What you have is 80 or 100 of the most highly trained members of our society — more highly trained than astronauts or surgeons in terms of the numbers of hours and years of preparation — and they are performing the works of some of the greatest minds that ever lived. It's really extraordinary."

Music experiment



Musically trained

Not musically trained

Language experiment



Musically trained

Not musically trained

Say what? When children with musical training hear a sequence that ends with a "hanging" chord, their brains respond more strongly than do other children (shown at left, darker is more intense). These kids also show stronger responses to violations in sentence syntax (shown at right).

The breadth of the musician's task and the required cognitive effort are probably behind much of the enhancement of other skills, says neuroscientist Laurel Trainor, director of the auditory development lab at McMaster University in Hamilton, Canada. Playing an instrument "engages basically most of your brain," Trainor says. The activity appears to boost executive function, being the boss of your body and mind. Evidence suggests that with musical training comes improved memory, finer motor skills and better attention control — the ability to ignore one thing and pay attention to something else. "Our working hypothesis is that it's these control processes that are what is key for the transfer effects," Trainor says.

Some musicians are certainly musically inclined to begin with. But recent work suggests that the superior perfor-

mance demonstrated by musicians on some tasks is more about nurture than nature. Teasing out that balance has been a recent focus of Gottfried Schlaug's music and neuroimaging research at the Beth Israel Deaconess Medical Center and Harvard Medical School.

A study by Schlaug's team found that after 15 months of weekly keyboard lessons, 6-year-olds showed greater change in their brains than kids who attended a weekly music class without instrument training. Among the most changed were a part of the auditory cortex and brain regions involved in control of movements. Kids with training also did better on tests related to finger movement and discerning melodies and rhythm, Schlaug and colleagues reported last year in the *Journal of Neuroscience*.

For most people, the transfer effects

S. JENTSCHKE AND S. KOELISCH/NEUROIMAGE 2009; PHOTO: THANKS TO THE SOUTH SHORE CONSERVATORY



Though the "Mozart effect" appears to be hype, studies do show that musical training can improve language and auditory skills.

of musical training are probably modest, says Trainor. “Otherwise, we’d expect musicians to be the most intelligent people on the planet,” she says. But musical training may strike a particularly rich chord for people with language difficulties. “There is quite a bit of evidence now that musical training does have benefits for people with dyslexia and language impairments,” Trainor says.

Peas in a syntactic pod

Evidence that the brain holds music and language in one embrace began to mount when imaging studies by Patel, Stefan Koelsch of the Freie Universität Berlin and others suggested that areas of the brain instrumental for processing language are also important for music. While

some circuitry appears to be specific to music or language, new evidence emphasizes areas of overlap. Both music and language have syntax—just as there are rules governing the construction of sentences from words, there are rules for “building” a piece of instrumental music. You don’t just randomly throw notes together. (As with language, these rules may differ across cultures.) The brain seems to tap into the same neural circuitry when processing how the building blocks of language or music fit together into a greater, hierarchical structure.

“You can have overlap in the machinery that puts the pieces together,” Patel says. “They may be different pieces, but the machinery that puts them together is shared.”

Shared processing of music’s and language’s building blocks is evidenced by the brain’s recognition of construction gone awry. Within milliseconds of hearing a sentence spoken with irregular structure, neurons fire in a specific area of the brain, researchers have learned. The brain also reacts to violations in chord structure.

Musically trained kids are better at hearing these violations than kids without training, says Sebastian Jentschke, now at University College London. Musically trained brains are also better at detecting violations in sentence structure, Koelsch and Jentschke reported in *NeuroImage* last year. The inverse relationship also holds; kids with Specific Language Impairment, marked by difficulties with grammar and complex syntax, also have trouble processing musical syntax, Koelsch, Jentschke and collaborators reported in 2008 in the *Journal of Cognitive Neuroscience*.

These studies highlight the neural intimacy of processing music and processing language. “It’s a reasonable assumption that musical training might help with kids with impairments with processing skills in the language domain,” Jentschke says.

From the top ... down

Scrutinizing brains on music suggests that training influences more than the higher-level circuitry relevant to language skills.

Playing music can also change the brain from the top down, says Kraus, influencing language processing. The highfalutin circuitry of the cerebral cortex, which plays a key role in memory, perception and consciousness, can be shaped by music and in turn can fine-tune circuitry in the lower, evolutionarily ancient “lizard brain,” changing how people hear.

“We used to think in a very hierarchical way—sound goes into your ear, up into your brain stem, then into your cortex and meaning happens,” Kraus says. “But the lizard brain is not what it used to be. We know now that the pathways that connect the cortex and feed down to the brain

Take two stanzas and call me in the morning

From poets to politicians, people have long described music as medicine for the heart and soul. Now scientists are taking a literal look at such musings, investigating music as a means to alleviate pain and enhance recovery. Though some studies are still in the early stages, your favorite soundtrack may one day accompany a prescription.

Alzheimer’s disease:

Studies have shown that individuals with Alzheimer’s have a better memory for lyrics when they are sung rather than spoken. The findings suggest that song may help these patients learn practical, everyday information.

Pain and nausea:

Cancer patients who participated in music and relaxation-imagery sessions while recovering from bone marrow transplants had less pain and nausea than patients undergoing the standard treatment alone.

Anxiety: Listening to music before glaucoma or cataract removal surgery soothed patient anxiety, lowering blood pressure levels during and after the surgery, one study found. Another study showed

that pregnant women who listen to music for 30 minutes a day report reduced levels of stress, anxiety and depression after two weeks.

Stroke: Patients who listened to music of their choosing for one to two hours a day did better on word recall tests and had fewer bouts of sadness and confusion than patients who listened to audio books or nothing at all. Research also suggests that simulating movement with music of a particular tempo may improve walking in stroke patients, and stroke patients report improved vision while listening to music.

Respiratory disease: Over eight weeks, subjects with serious lung disease who listened to music

while walking showed improved fitness, a study found. Those patients covered 24 percent more ground than a nonmusic group.

Traumatic brain injury: Some patients who underwent music therapy that involved following tempo, loudness and rhythmic pattern performed better on tests of mental flexibility, suggesting such therapy may help people with brain injuries manage switching between important tasks during daily life.

— Rachel Ehrenberg



stem ... are actually more massive than the ones going upstairs.”

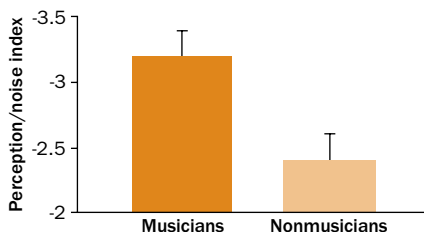
This top-down tuning may influence a person’s ability to discriminate sounds of different frequencies, the processing of pitch. Pitch is the brain’s interpretation of frequency, both in terms of absolute frequency and relative position on the musical scale. (Levitin notes that pitch is the only musical attribute that varies in the first seven notes of “Mary Had a Little Lamb.”) Pitch is crucial for conveying information: It determines whether the phrase “You are going to wash the dishes” is a question or a command. In languages such as Mandarin Chinese, saying the same syllable at a different pitch level gives the word an entirely different meaning.

Among people unfamiliar with Mandarin, musicians are better than nonmusicians at discriminating between Mandarin syllables, Patrick Wong, Kraus and others reported in *Nature Neuroscience* in 2007. Electrodes recording brain activity revealed that a particular pitch-related neural response, thought to originate in the brain stem, was more robust in the musicians.

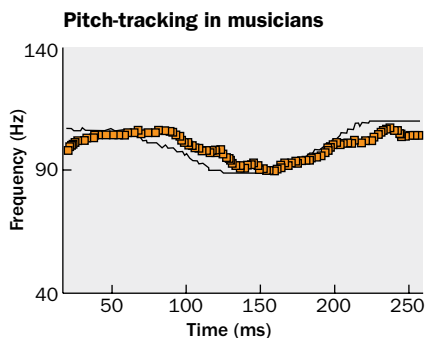
Other work on the effects of musical training suggests that it improves overall pitch processing. After six months, Portuguese third graders in a musical training group performed better on a reading task and on a pitch discrimination task than kids in a painting group, researchers reported last year in *Cerebral Cortex*. These results were also reflected in brain wave activity, says study coauthor Sylvain Moreno of the Rotman Research Institute and York University in Toronto.

Hear this Musically trained adults can hear words in background noise better than untrained peers (more negative index, better detection).

Perceiving words within noise

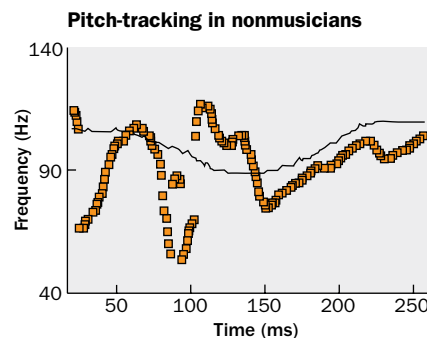


SOURCE: A. PARBERY-CLARK ET AL./EAR & HEARING 2009



SOURCE: P.C.M. WONG ET AL./NATURE NEUROSCIENCE 2007

Follow that tone The Mandarin language conveys word meanings with tone. When a musician with no knowledge of the language hears a Mandarin tone, activity in the brain stem (orange) tracks the frequency of the changing tone (black). The nonmusician’s brain is out of sync.



This training-induced, top-down tuning appears to affect hearing in general. On a task known as backward masking, in which subjects detect a sound masked by a second sound, musicians with more than 10 years of musical training outperformed nonmusical peers, Kraus’ team reports in the March *Hearing Research*. The musicians also performed better at distinguishing cartoon characters based on the pitch of their sounds.

Listening skills such as the ability to discriminate pitch or discern a signal from noise are related to some language impairments, including dyslexia, research suggests. People with dyslexia often have a hard time reading—a difficulty that is thought to result from trouble transforming the letters on a page into the sounds of language. This sound-meaning connection happens before children learn to read, says Kraus, and may be crucial for reading skills to develop.

A team that included Kraus and Jane Hornickel, also from Northwestern, looked at how the auditory brain stem responded to the sounds of different syllables for kids with a wide range of reading abilities. Kids with the weakest reading skills had a harder time distinguishing the sounds *ba*, *da* and *ga*, the team reported last year in *Proceedings of the National Academy of Sciences*.

Everyone has trouble hearing in a noisy restaurant. But children with dyslexia can have an even harder time perceiving sounds in noisy conditions. “If you’ve got a kid who is just struggling to hear what the teacher is saying, he’s got

very little extra neural resources to be thinking about ‘What does this mean?’” Kraus says.

If musicians’ responses are much less affected by background noise, she says, musicians can devote more neural resources to meaning rather than just hearing. That suggests musical skill could give children a learning benefit.

“If you have a nervous system in which the signal still comes through loud and clear in a noisy classroom, now that kid has an advantage,” Kraus says.

For a clearer picture of the relationship between musical training and learning, more studies are needed. But the accumulating research is tantalizing, and it suggests that upping the quality and quantity of musical training in schools is warranted, Kraus and Northwestern colleague Bharath Chandrasekaran write in the August *Nature Reviews Neuroscience*.

“Music has the power to transform our nervous system in substantial, enormous, unambiguous ways,” says Kraus.

Many researchers now equate musical training with learning to read. (Patel calls each of them a “transformative technology of the mind.”) Perfectly intelligent, capable people can do fine in life without cracking a book or strumming a tune. But both can make the mind sing. ■

Explore more

- Nina Kraus’ laboratory: www.soc.northwestern.edu/brainvolts/
- Daniel J. Levitin. *This Is Your Brain on Music: The Science of a Human Obsession*. Dutton, 2006.