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ITS POWER TO LIFT MOOD AND BUILD CONNECTIONS

"OF COURSE, I COULD DIE"
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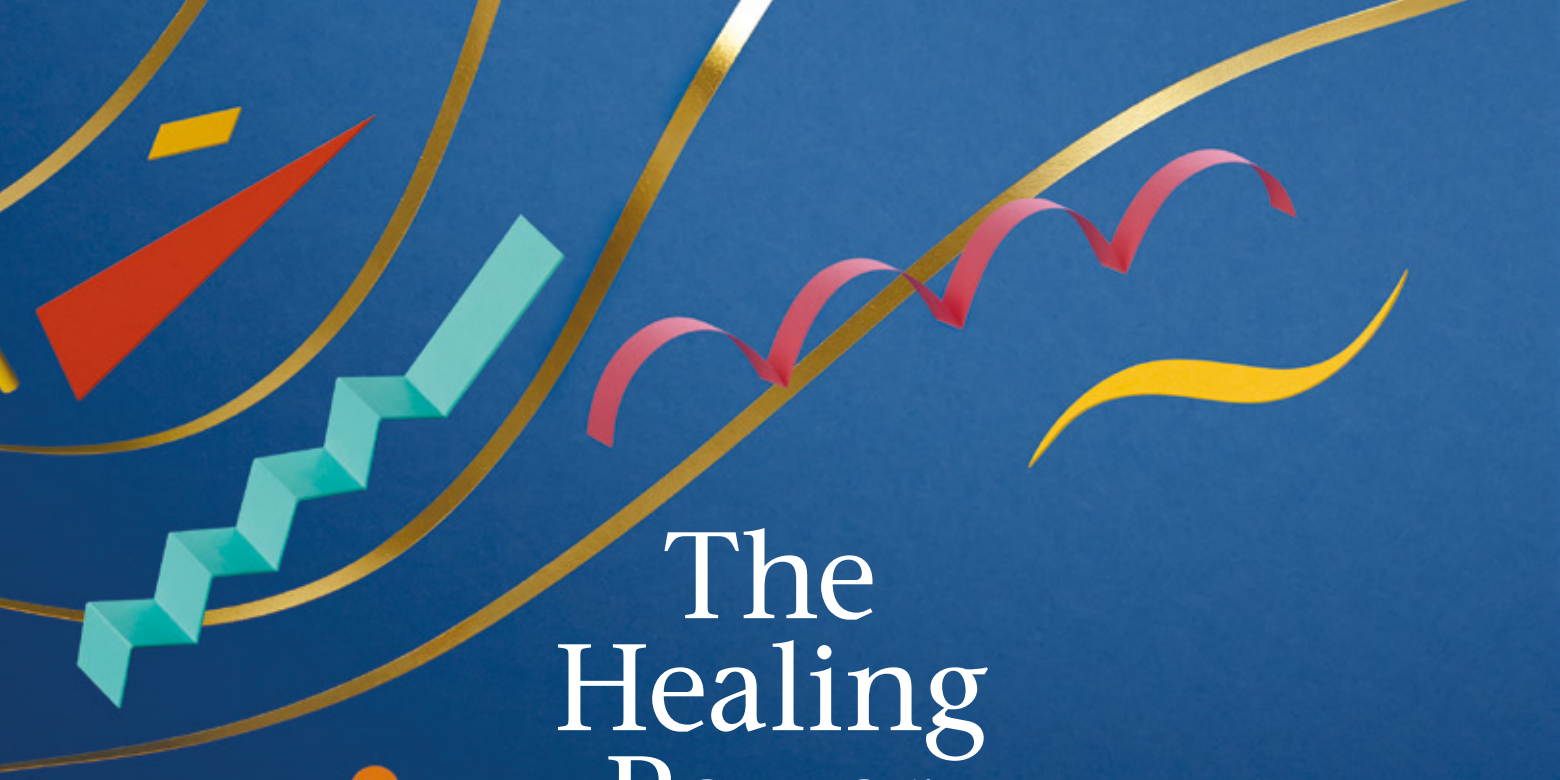
FIRST AID
FOR MENTAL HEALTH



The Healing Power of Music

New therapies are using rhythm, beat and melody to help patients with brain disorders recover language, hearing, motion and emotion

By William Forde Thompson and Gottfried Schlaug

ILLUSTRATIONS BY CHRISSIE MACDONALD

One day when Laurel was 11, she began to feel dizzy while playing with her twin sister and some friends in a park on Cape Cod. She sat down, and one of her friends asked her if she was okay. And then Laurel's memory went blank. A sudden blockage in a key blood vessel leading to the brain had caused a massive stroke. Blood could no longer reach regions crucial for language and communication, resulting in permanent damage. Laurel was still able to understand language, but she struggled to vocalize even a single word, and what she managed to say was often garbled or not what she had intended.

Except when she *sang*.

Through a type of treatment called melodic intonation therapy, Laurel learned to draw on undamaged brain regions that moderate the rhythmic and tonal aspects of language, bypassing the speech pathways on the left side of her brain that were destroyed. In other words, she found her way back to language through music.

The therapeutic program that helped Laurel—like the others we focus on in our work as scientists and clinicians—is one of a new class of music-based treatments based directly on the biology of neurological impairment and recovery. These treatments aim to restore functions lost to injury or neurological disorders by enlisting healthy areas of the brain and sometimes even by reviving dysfunctional circuitry. As evidence accumulates about the effectiveness of these techniques, clinicians and therapists from a variety of fields have begun to incorporate them into their practices, most notably music therapists, who are at the intersection of music and health and important mediators of these interventions, as well as speech therapists and physical therapists. And among the beneficiaries are people diagnosed with stroke, autism, tinnitus, Parkinson's disease and dementia.

As scientists learn more about the effect of music on cognitive and motor functions and mental states, they can tailor these therapies for each disorder, targeting specific brain injuries or dysfunctions. In Laurel's case, the treatments were designed to trigger, over time, the development of alternative neural pathways in healthy parts of the brain that would compensate for the lost pathways in the damaged language centers. But the ultimate aim was to help her recapture as much as she could of the world that had collapsed around her that day in the park.

Music as Medicine

Across cultures and throughout history, music listening and music making have played a role in treating disorders of the mind and body. Egyptian frescoes from the fourth millennium B.C. appear to depict the use of music to enhance fertility in women. Shamans in the highland tropical forests of Peru use chanting as their primary tool for healing, and the Ashanti people of Ghana accompany healing ceremonies with drumming.

Much of the power of music-based treatment lies in its ability to meld numerous subtle benefits in a single, engaging package [*see boxes beginning on this page*]. Music is perhaps unrivaled by any other form of human expression in the range of its defining characteristics, from its melody and rhythm to its emotional and social nature. The treatments that take advantage of these attributes are rewarding, motivating, accessible and inexpensive, and basically free of side effects, too. The attractive quality of music also encourages patients to continue therapy over many weeks and months, improving the chance of lasting gains.

The view that music can be useful in treating neurological impairment gained some scientific heft in a landmark study published in 2008. Psychologist Teppo Särkämö of the University of Helsinki and his team recruited 60 patients who had suffered a stroke in the middle cerebral artery of one hemisphere. They split the patients into three groups: the first participated

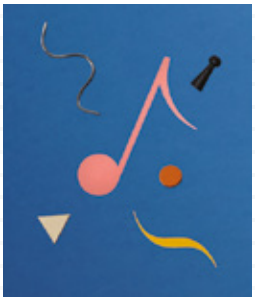
MUSICAL ATTRIBUTES

Music is a uniquely effective tool for treating neurological impairment because it recruits nearly every region of the brain. Imaging studies show that both listening to and making music spur activity and foster connections across a wide swath of brain regions typically involved in emotion, reward, cognition, sensation and movement. Here are seven ways music might work to benefit our mind and brain: ⇨

FAST FACTS

MUSICAL PRESCRIPTIONS

1. Music can be a powerful tool in the treatment of brain disorders and acquired injuries, helping patients recover language and motor skills.
2. New music-based therapies can trigger neuroplasticity—fostering local connections and long-range pathways that compensate for impairments in damaged regions of the brain.
3. The greatest benefits from therapy—cognitive, emotional and social—come from effortful engagement with music.



Music is Physical

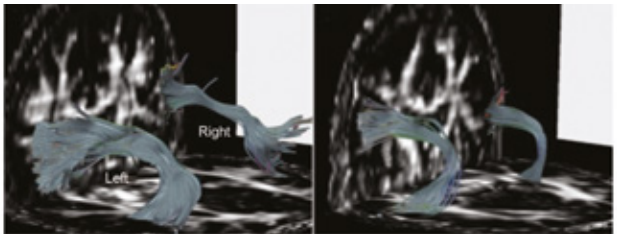
Music encourages people to move with the beat. The more salient the beat, the more sweeping and emphatic the body movements. Physical exercise can help improve circulation, brain health, and fine and gross motor function.

in daily sessions of music listening, the second listened to audiobooks every day and the third received no auditory treatment. Researchers observed the patients over two months. Those in the group that listened to music exhibited the greatest recovery in verbal memory and attention. And because listening to music appears to improve memory, the hope now is that active music making—singing, moving and synchronizing to a beat—might help restore additional skills, including speech and motor functions in stroke patients.

The Singing Cure

The variety of music-based treatment that Laurel received springs from a remarkable observation about people who have had a stroke. When a stroke affects areas of the brain that control speech, it can leave patients with a condition known as nonfluent aphasia, or an inability to speak fluently. And yet, as therapists over the years have noted, people with nonfluent aphasia can sometimes sing words they cannot otherwise say.

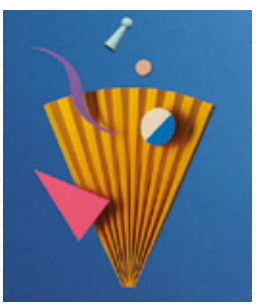
In the 1970s neurologist Martin Albert and speech pathologists Robert Sparks and Nancy Helm (now Helm-Estabrooks), then at a Veterans Administration hospital in Boston, recognized the therapeutic implications of this ability and developed a treatment called melodic intonation therapy in which singing is a central element. During a typical session, patients will sing words and short phrases set to a simple melody while tapping out each syllable with their left hand. The melody usually involves two notes, perhaps separated by a minor third (such as the first two notes of "Greensleeves"). For example, patients might sing the phrase "How are you?" in a simple up-and-down pattern, with the



Images show the arcuate fasciculus, an auditory-motor tract, in each hemisphere of a healthy musician (*left*) and a healthy nonmusician, both in their early 60s, demonstrating the brain-enhancing benefits of lifelong music making.

stressed syllable ("are") assigned a higher pitch than the others. As the treatment progresses, the phrases get longer and the frequency of the vocalizations increases, perhaps from one syllable per second to two.

Each element of the treatment contributes to fluency by recruiting undamaged areas of the brain. The slow changes in the pitch of the voice engage areas associated with perception in the right hemisphere, which integrates sensory information over a longer interval than the left hemisphere does; as a consequence, it is particularly sensitive to slowly modulated sounds. The rhythmic tapping with the left hand, in turn, invokes a network in the right hemisphere that controls movements associated with the vocal apparatus. Benefits are often evident after even a single treatment session. But when performed intensively over months, melodic intonation therapy also produces long-term gains that appear to arise from changes in neural circuitry—the creation of alternative pathways or the strengthening of rudimentary ones in the brain. In effect,



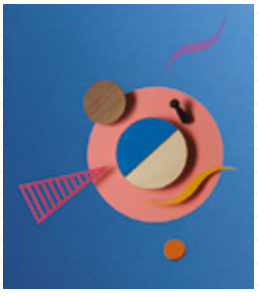
Music is Emotional

Music induces emotional states by initiating changes in the distribution of neurochemicals that can induce positive moods and heightened arousal, which may in turn increase the rate of change in the brain, speeding rehabilitation.

FROM "MUSIC MAKING AS A TOOL FOR PROMOTING BRAIN PLASTICITY ACROSS THE LIFE SPAN," BY CATHERINE Y. WAN AND GOTTFRIED SCHLAUG, IN *NEUROSCIENTIST*, VOL. 16, NO. 5; OCTOBER 2010

for patients with severe aphasia, singing trains structures and connections in the brain's right hemisphere to assume permanent responsibility for a task usually handled mostly by the left.

This theory has gained support in the past two decades from studies of stroke patients with nonfluent aphasia conducted by researchers around the world. In a study published in September 2014 by one of us (Schlaug) and his group at the Beth Israel Deaconess Medical Center and Harvard Medical School, 11 patients received melodic intonation therapy; nine received no treatment. The patients who received therapy were able to string together more than twice as many appropriate words per minute in response to a question. That same group also showed structural changes, assessed through MRI, in a right-hemisphere network associated with vocalization. The laboratory is now conducting studies to compare the benefits of melodic intonation therapy with other forms of therapy for patients with aphasia.



Music is
Engaging

Musical treatments are engrossing and rewarding, so patients are highly motivated to participate with enthusiasm, focus and dedication.

Because melodic intonation therapy seemed to work by engaging the right hemisphere, researchers then surmised that electrical or magnetic stimulation of the region might boost the therapy's power. In two recent studies that we conducted with our collaborators—one in 2011 at Beth Israel Deaconess and Harvard and the other in 2014 at the ARC Center of Excellence in Cognition and Its Disorders in Sydney, Australia—researchers stimulated an area in the right hemisphere called the inferior frontal gyrus, which helps to connect sounds with the oral, facial and vocal movements that produce them. For many participants, combining melodic intonation therapy with noninvasive brain stimulation yielded improvements in speech fluency after only a few sessions.

The benefits of melodic intonation therapy were dramatic for Laurel (who was part of a study led by Schlaug). The stroke had destroyed much of her left hemisphere, including a region crucial for language production known as Broca's area. When she began therapy in 2008, she could not string together more than two or three words, and her speech was often ungrammatical, leaving her frustrated whenever she tried to communicate. Her treatment plan was intensive—an hour and a half a day for up to five days a week, with 75 sessions in all. By the end of the 15-week treatment period, she could speak in sentences of five to eight words, sometimes more. Over the next several years she treated herself at home using the techniques she learned during the sessions. Today, eight years after her stroke, Laurel spends some of her time as a motivational speaker, giving hope and support to fellow stroke survivors. Her speech is not quite perfect but remarkable nonetheless for someone whose stroke damaged so much of her left brain. Evaluation of the long-term benefits of combination therapy is next on researchers' agenda.

When performed intensively over months, melodic
appear to arise from changes in neural circuitry—the

Music and Motion

Music making can also help stroke survivors living with impaired motor skills. In a study published in 2007 neuropsychologist and music educator Sabine Schneider and neurologist Eckard Altenmueller, both then at the Hannover University of Music, Drama and Media in Germany, asked patients to use their movement-impaired hand to play melodies on the piano or tap out a rhythm on pitch-producing drum pads. Patients who engaged in this intervention, called music-supported training, showed greater improvement in the timing, preci-

THE AUTHORS

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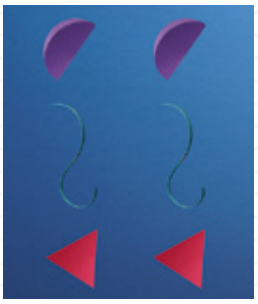


Music permits Synchronization

Music helps listeners synchronize rhythm (by tapping along) and melody (by singing along), addressing problems of timing, initiation and coordination in people with stroke, Parkinson's disease, and other brain disorders involving sensory and motor systems.

sion and smoothness of fine motor skills than did patients who relied on conventional therapy. The researchers postulated that the gains resulted from an increase in connections between neurons of the sensorimotor and auditory regions.

Rhythm is the key to treatment of people with Parkinson's, which affects roughly one in 100 older than 60. Parkinson's arises from degeneration of cells in the midbrain that feed dopamine to the basal ganglia, an area involved in the initiation and smoothness of movements. The dopamine shortage in the region results in motor problems ranging from tremors and stiffness to difficulties in timing the movements associated with walking, facial expressions and speech.

Music with a strong beat can allay some of these symptoms by providing an audible rhythmic sequence that people can use to initiate and time their movements. Treatments include so-called rhythmic entrainment, which involves playing a stimulus like a metronome. In neurologist Oliver Sacks's 1973 book *Awakenings*, musical rhythm sometimes released individuals from their immobility, letting them dance or sing out unexpectedly.

The use of rhythm in motor therapy gained momentum in the 1990s, when musician, music therapist and neuroscientist Michael Thaut of Colorado State University and other researchers around the world demonstrated a technique called rhythmic auditory stimulation, or RAS, for people who had trouble walking, such as stroke and Parkinson's patients. A therapist will first ask patients to walk at a comfortable speed and then to an audible rhythm. Tempos that pushed patients slightly past their comfort zone yielded the greatest improvements in velocity, cadence and stride length.

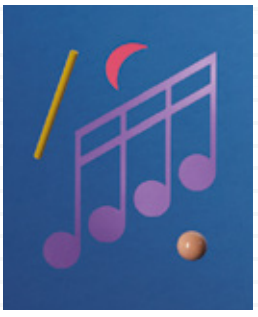
Despite these encouraging outcomes, the neural mechanisms that trigger improvements have been difficult to pin down. Imaging work suggests that during rhythmic auditory stimulation, neural control of motor behavior is rerouted around the basal ganglia; instead the brain stem serves as a relay station that sends auditory input to motor networks in the cerebellum, which governs coordination, and to other cortical regions that could help synchronize sound and motion.

Recovered Memory

Fewer neurological disorders inspire greater fear than dementia, one of the most common diseases of the elderly. According to some estimates, 44 million people worldwide are living with dementia, a number expected to reach 135 million by 2050. Alzheimer's disease, a neurodegenerative condition, accounts for more than 60 percent of the cases; multiple strokes can also cause so-called vascular dementia.

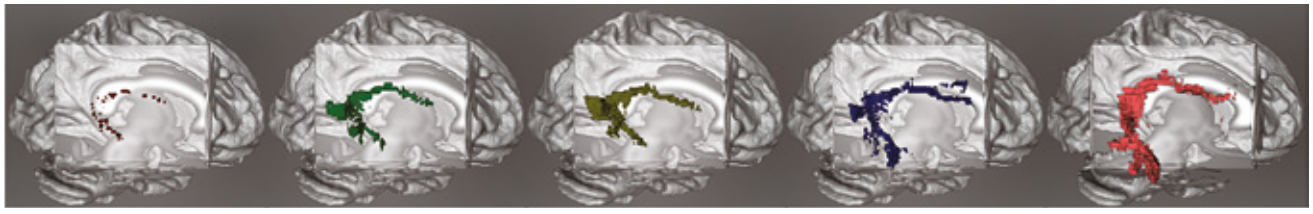
Music may be ideally suited to stimulating memory in people with dementia, helping them maintain a sense of self. Be-

intonation therapy produces long-term gains that creation of alternative pathways in the brain.



Music is Social

Musical activities can be collective experiences. Social isolation is a common consequence of many neurological disorders, and social support through music making helps in recovery, rehabilitation and coping.



The sequence above shows how, over time, melodic intonation therapy built up connections between the hearing and speaking regions in Laurel's healthy right brain.

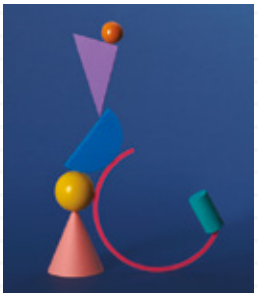
cause music activates neural areas and pathways in several parts of the brain, the odds are greater that memories associated with music will survive disease. Music also stimulates normal emotional responses even in the face of general cognitive decline. In a 2009 study psychologist Lise Gagnon of the University of Sherbrooke in Quebec and her colleagues asked 12 individuals with Alzheimer's and 12 without it to judge the emotional connotations of various pieces of music. The Alzheimer's participants were just as accurate as the others despite

ceive will vary, from receptive (listening) to active (dancing, singing, clapping). Music that the patient selects is most effective because the choice represents a connection to memory and self. The benefits vary, too, and tend to be short-term. But when the treatment does work, it reduces the feelings of agitation that lead to wandering and vocal outbursts and encourages cooperation

The positive response to music opens the way to engage in activities with other people, acquiring

significant impairments in different areas of judgment. Other research suggests that taking part in musical activities throughout life keeps the mind young and may even decrease the risk of developing dementia [see "Everyone Can Gain from Making Music," on page 40]; the continuous engagement of the parts of the brain that integrate senses and motion with the systems for emotions and rewards might prevent loss of neurons and synapses.

The type of therapy that individual dementia patients re-



Music is Persuasive

Music can make associated media such as lyrics and films seem more compelling. When patients believe in their treatment, their attitude tends to remain positive.

and interaction with others. Music therapy can also help patients with dementia sleep better and can enhance their emotional well-being.

These emotional and social benefits are clear in the case of June, an 89-year-old woman from New Hampshire. June has severe, irreversible dementia and is cared for at home by her daughter (who described her mother's circumstances to a clinician in Thompson's lab). Throughout the day, June is mainly nonresponsive and sits with her head hanging low. She cannot talk or walk, and she is incontinent. Yet when her daughter sings to her, June comes alive. She bangs her hands on her legs, smiles widely and begins to laugh. June especially loves Christmas songs and may even blurt out a word or two. When listening to music, she can bang her leg in time with the beat.

Music on the Spectrum

Perhaps the most fascinating interplay between music and the brain lies in the case files of people with autism spectrum disorder, a neurodevelopmental syndrome that occurs in 1 to 2 percent of children, most of whom are boys. Hallmarks of autism include impaired social interactions, repetitive behaviors and difficulties in communication. Indeed, up to 30 percent of people with autism cannot make the sounds of speech at all; many have limited vocabulary of any kind, including gesture.

One of the peculiarities of the neurobiology of autism is the overdevelopment of short-range brain connections. As an

COURTESY OF GOTTFRIED SCHLAUG

Music is Personal

Neurological impairment can make people feel that they have lost touch with themselves. The personal nature of music can evoke memories and help individuals maintain a sense of identity.

ing drums while singing or speaking words and phrases. In a proof-of-principle study, six completely nonverbal children took part in 40 sessions of this training over eight weeks. By the end, all were able to produce some speech sounds, and some were even able to voice meaningful and appropriate words during tasks that the therapy sessions had not covered. Most important, the children were still able to demonstrate their new skills eight weeks after the training sessions ended.

Quiet, Please

Music-based treatments can also train the brain to tune out the phantom strains of tinnitus—the experience of noise or ringing in the ear in the absence of sound that affects roughly 20 percent of adults. Age-related hearing loss, exposure to loud sounds and circulatory system disorders can all bring on the condition, with symptoms ranging from buzzing or hissing in the ears to a continuous tone with a definable pitch. The sensation can cause serious distress and interfere with the ability to concentrate on other sounds and activities. There is no cure.

The past decade has seen a surge in understanding of the neurological basis of the disorder. In one view, cochlear damage (most likely caused by exposure to loud sounds) reduces the transmission of particular sound frequencies to the brain. To compensate for the loss, neuronal activity in the central au-

treatments that can help children with autism social, language and motor skills as they do.

apparent consequence, children with autism tend to focus intensely on the fine details of sensory experience, such as the varying textures of different fabrics or the precise sound qualities emitted by appliances such as a refrigerator or an air conditioner. And this fascination with sound may account for the many anecdotal reports of children with autism who thoroughly enjoy making and learning music. A disproportionate number of children with autism spectrum disorder are musical savants, with extraordinary abilities in specialized areas, such as absolute pitch.

The positive response to music opens the way to treatments that can help children with autism engage in activities with other people, acquiring social, language and motor skills as they do. Music also activates areas of the brain that relate to social ways of thinking. When we listen to music, we often get a sense of the emotional states of the people who created it and those who are playing it. By encouraging children with autism to imagine these emotions, therapists can help them learn to think about other people and what they might be feeling.

Recently the Music and Neuroimaging Laboratory at Beth Israel Deaconess and Harvard (which Schlaug directs) developed a new technique called auditory-motor mapping training, or AMMT, for children whose autism has left them unable to speak. The treatments have two main components: intonation of words and phrases (changing the melodic pitch of one's voice) and tapping alternately with each hand on pitch-produc-

FURTHER READING

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- **Listening to Tailor-Made Notched Music Reduces Tinnitus Loudness and Tinnitus-Related Auditory Cortex Activity.** Hidehiko Okamota et al. in *Proceedings of the National Academy of Sciences USA,* Vol. 107, No. 3, pages 1207–1210; January 19, 2010.
- **Auditory-Motor Mapping Training as an Intervention to Facilitate Speech Output in Non-Verbal Children with Autism: A Proof of Concept Study.** Catherine Y. Wan et al. in *PLOS ONE,* Vol. 6, No. 9, Article No. e25505; September 29, 2011.
- **Music, Health, and Wellbeing.** Edited by Raymond MacDonald, Gunter Kreutz and Laura Mitchell. Oxford University Press, 2012.
- **Music, Thought, and Feeling: Understanding the Psychology of Music.** Second edition. William Forde Thompson. Oxford University Press, 2014.

ditory system changes, creating neural "noise," perhaps by throwing off the balance between inhibition and excitation in the auditory cortex, leading to the perception of sounds that are not there. Also at play might be dysfunctional feedback to auditory brain regions from the limbic system, which is thought to serve as a noise-cancellation apparatus that identifies and inhibits irrelevant signals.

Music treatment seeks to counteract this dysfunction by inducing changes in the neural circuitry. For those with tonal tinnitus, one treatment involves listening to "notched music," generated by digitally removing the frequency band that matches the tinnitus frequency. The notching—pioneered and proved effective by neurophysiologist Christo Pantev and his group at the University of Münster in Germany—might help reverse the imbalance in the auditory cortex, strenghtening the inhibition of the frequency band that might be the source

Everyone Can Gain from Making Music

The perks of learning to play an instrument last for decades

By Julia Calderone

REGINE MAHAUX *Alamy*

Think back to your elementary school music class. You absorbed commands from a baton-wielding conductor while deciphering inky notes on a page. You kept tempo with the rest of the band while your contorted fingers sped from key to key. There is no doubt that musical training is a challenge for the brain. And in the past decade an abundance of studies have found that this effort confers cognitive benefits on all who study music, from toddlers to retirees.

Researchers became interested in the effects of music on the brain when a provocative study in the early 1990s claimed that simply listening to a Mozart sonata could make you brainier—so dubbed the "Mozart effect." The finding was never confirmed. Various studies followed that showed listening to music has transient effects on cognitive functions such as spatial ability, speed of processing and creative problem solving—but such effects last only about 10 minutes once the music is switched off. Experts continue to debate whether frequently engaging with music has longer-term effects on cognition. In recent years new techniques to measure the brain's response to auditory cues in real time have given researchers valuable data to address the issue. "We can see how these ingredients of sound are processed by the brain," says Nina Kraus, an auditory neuroscientist at the Northwestern University School of Communication. Today some evidence suggests that musical training may enhance a suite of cognitive functions, including listening, linguistics, focus and memory, along with spatial, motor and mathematical skills.

Better Reading through Music?

Young children are ripe subjects for research in this field because their brains are primed to develop language skills, which music seems to enhance. Many studies suggest that children who are musically trained have stronger cognitive abilities, including better vocabulary, reading skills and sound perception. Yet these studies leave unanswered the important question of correlation: Are musicians better at certain tasks because of musical practice alone? Or are they drawn to music because they have these skills already or because they come from advantaged backgrounds?

Kraus and her colleagues have conducted a number of studies to tackle this question. In one experiment published last September, they gathered 44 children aged six to nine from disadvantaged schools in Los Angeles and asked them to participate in musical instruction for two hours a week. One group practiced for one year; the other practiced for two. After administering a battery of neurophysiological tests that recorded their brain activity, Kraus's team found that those who participated in the music program for two years, independent of their age, were markedly better at processing speech syllables—such as differentiating between the sounds [ba] and [ga]—than those who had only one year of training.

As Kraus explains, a key element of literacy is the ability to discern meaningful differences between speech sounds—so studying music, which shares characteristics with speech such as pitch,

of the phantom sound in the first place. Another approach involves playing a series of pitches to patients and then asking them to imitate the sequence vocally. As the patients refine their accuracy, they learn to disregard irrelevant auditory signals and focus on what they want to hear. In time, the stimulus of effortful attention might help the auditory cortex return to its normal physiological state.

For any novel therapy, enthusiasm can sometimes outpace the evidence, and researchers have rightly pointed out that the new music-based treatments must prove their efficacy against the more established therapies. But of all the techniques for addressing neurological disorders, music-based therapies seem unique in their capacity to tap into emotions, to help the brain find lost memories, to let patients resume their place in the world. We are only now beginning to understand the science behind the belief in the power of music to heal. **M**

timing and timbre, may help kids read better. The authors say the study provides the first direct evidence that a community music program for at-risk youth has a biological effect on the children's developing nervous systems. Other experts urge caution when interpreting these results. "We already know that music training makes you a better listener," says psychologist Glenn Schellenberg, who researches music's effect on cognition at the University of Toronto Mississauga. Until researchers have behavioral evidence that kids who get music training become superior at reading or perceiving speech, he explains, the question of whether music can influence language development remains open.

Empathetic Multitaskers

As a musician grows up, other cognitive benefits appear, among them a better ability to multitask, according to a 2014 study by psychologist Melody Wiseheart and her colleagues at York University in Toronto. The team recruited 153 university students aged 18 to 31, about half of whom were musicians with about 12 years of formal musical training; the others were nonmusicians. The students performed multitasking exercises, such as switching between identifying how many numbers were on a screen and indicating which particular number was on the screen or tracking a moving white dot with their mouse while monitoring a flashing set of letters.

"We found that musicians were doing a lot better," Wiseheart says; they were about 30 percent more accurate than the nonmusicians when performing two tasks at once. She says that musicianship appears to enhance working memory, which underlies the ability to multitask and can boost skills both in and out of the classroom—when holding numbers in mind to compute an equation, for instance, or avoiding distractions while driving.

Playing in a band or singing in a choir provides another type of benefit important for this age group. Studies show that making music in a group improves communication, coordination, cooperation and empathy among group members. Many of these advantages of musicianship may be felt for decades, but some may not. For example, child musicians appear to have better spatial reasoning than their nonmusician peers, but adult musicians do not.

Preventing Age-Related Decline

Many areas in which child and young adult musicians outperform their nonmusician peers—such as processing speed, memory and attention—also happen to correlate with areas of cognitive decline in old age. A small but growing body of evidence suggests that lifelong musical practice makes our brains healthier as we age—especially in combating hearing loss, which affects an estimated two thirds of adults older than 70 in the U.S. A series of studies by neuroscientist Alexandra Parbery-Clark of the Swedish Medical Center in Seattle and her colleagues found that musicians aged 45 to 65 appear to lack four of the five hallmark declines of speech processing in old age—they maintained consistent and speedy brain responses to speech, for example, and the ability to understand speech in noisy settings.

In addition, studies suggest that older adult musicians tend to have stronger memory, more focused attention and faster brain processing. Although such effects are most evident in adults who have practiced their instrument at least twice a week for 20 minutes a session since childhood, researchers think that such benefits may also exist for less enthusiastic hobbyists. The act of making music appears to be key because it requires the integration of various senses, motor coordination and concentration in a way that even very attentive listening does not.

What this means is that learning to play a musical instrument is very good for you. And when that practice begins early in life, its positive effects can stretch into old age. "Biologically, our past shapes our present," Kraus says. Both she and Wiseheart hope educators and policy makers will take note of this research and keep music in classrooms. As Kraus says, "We want to improve human communication by harnessing the brain's ability to change."

Julia Calderone is a freelance science writer and former Mind *intern.*