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Music and the Brain

By Paul McKay

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Sex. Chocolate. Caffeine. Champagne. Cocaine.

If none of the above turn your cranial crank, it's also likely that Mozart or Alanis Morissette won't send shivers down your spine. And that your pulse rate should be checked by a doctor -- because the human survival instinct is hard-wired to the same brain circuits that process intense pleasure.

A team of researchers at the Montreal Neurological Institute, using the world's most advanced brain-mapping machines, have found that the same neural clusters that process the seductive pleasures of sex, chocolate and even hard drugs also fire up for music.

There is also persuasive evidence that the brain tends to prune these neural circuits for maximum pleasure the way a gardener cuts unproductive branches to make a rose bush bloom. Music, it seems, may make the brain bloom best because it literally electrifies, at lightning speed, a web of nerve paths in both hemispheres of our cerebral cortex that connect the neural clusters processing musical pitch, rhythm, harmony, melody, short term memory, long term memory, and emotions. Now, for the first time, neuroscientists mapping the musical mind at McGill University have confirmed that those music circuits also comprise the inch-worm shaped clusters that process exquisite pleasures, including illicit ones. But unlike other addictions, it leaves no hangover, drug habits, clogged arteries, or sexual diseases.

Sound too good to be true? If it is, billions of brain cells, a $6-million MRI imaging machine, and a leading cognitive neuroscientist are all wrong.

Robert Zatorre and his colleagues at McGill University have been heading studies into the effects of music on the human brain for more than two decades. Deep in the bowels of an old stone building on the McGill campus, they scan human brains the way a geologist scans mineral maps, except they are tracing, in real time, the topography of human brains while circuits and clusters of neurons fire.

They and their international colleagues have used sophisticated PET and MRI scanners to peer inside brains to detect where pitch, melody, harmony and rhythm are processed. The answer, it turns out, changes with the complexity and composition of the music. There are distinct clusters of cortex that seem to be responsible for each component of music, such as rhythm or harmony. Yet even the simplest song heard or sung by a child sends showers of neural sparks across both sides of the brain, linking each element of music to respective cranial regions. Music also lights up the lobes where memory is stored, the clusters where logic and speech are processed, the brain stem where sounds relayed by the ear are filtered, and the cerebral throne of emotion.

The brain even processes harmonic and dissonant music in different neural circuits.

For a landmark study published last year, Zatorre's McGill team created an experiment with remarkable results. Ten students, each with advanced musical training, were asked to select a favorite piece of music. Among the selections were Samuel Barber's Adagio for Strings and Rachmaninoff's Piano Concerto No. 3 in D minor.

Each of the subjects was played an excerpt from their favored music while they were scanned for brain neuron firing, cranial blood flow, heart rate, EMG, respiration and skin temperature. All 10 subjects were also played an excerpt from another student's selection, a calibrated patch of ordinary noises, and a passage of silence.

Sure enough, chills tingled down the students spines as they heard their favorite music selections. Their other vital signs spiked upwards during 77 per cent of the scans. But the real discovery came as the computer-linked scanner/cameras took split-second snapshots through the multiple folds and mounds of grey matter: Blood flowed to areas where neurons fired in galaxies of electro-chemical energy bursts, but away from areas where brain neurons were relatively dormant.

During the moments of musical euphoria, their cranial blood streamed to the parts of the brain which previous, independent studies had isolated as the places where sex, chocolate, champagne or cocaine can produce ecstasy. In effect, 10 different cortex clusters burst into neural fireworks, creating the familiar spine-tingling chills of pleasure. Equally intriguing, the blood flowed away from brain cells associated with depression and fear.

"We have shown that music recruits neural systems of reward and emotion similar to those known to respond specifically to biologically relevant stimuli, such as food and sex, and those artificially activated by drugs of abuse," Zatorre concluded in his published paper. "This is quite remarkable, because music is neither strictly necessary for biological survival or reproduction, nor is it a pharmacological substance."

Our brain neurons, says Zatorre, are hard-wired for music -- from cradle to grave. And the more we use 'em, the less we lose 'em.

"All normal children will spontaneously sing something like the Sesame Street song," he says in his McGill office while fielding phone calls to book precious time on an MRI machine -- which costs $400 per hour, and primarily is used to scan patients. "That's a very sophisticated neurological feat. It means their brains recognize the theme, and associate it with their favourite TV show. They will try to sing it, on their own.

They may not reproduce it very accurately, but it is recognizable. No one can teach them this, versus reading or math. Like blind children learning to walk, they just do it when they are ready. It is wired into our nervous system.

"The vast majority of people with no musical training can sing a song, and still recognize a tune when it has been altered by a different key, instrument or rhythm. That seems to be innate, something our brains are wired to do. And there is no known culture which does not have some sort of music."

The Zatorre study followed earlier McGill probes into how harmony and dissonance affect the neural clusters known to process emotions; where in the brain we select key features of voices; how people process melodies; where musical pitch and rhythm are processed; and where the mind's eye imagines and perhaps invents music.

The brain's chief task, Zatorre concludes, is to keep astonishing itself. And music may do it best.

"Music involves perception, memory, emotion, motor control, all the learning aspects. It brings together a lot of different functions in a very coherent way," says Zatorre, who is also an accomplished organist. "The brain wants patterns to assemble but it also craves diversity, so a very important part of music is surprise. And you can only be surprised if you anticipate - and don't assume a random series of notes."

"The best music plays with that tension. If it goes too far in lacking structure, it collapses into random sounds. Then your nervous system loses interest; it just becomes noise. If you go too far to the other extreme, where everything is completely predictable, soon you'll never play it again. The brain likes to be challenged."

Zatorre and Isabel Peretz, a noted neuropsychologist at the University of Montreal (see accompanying story) collaborate on complementary studies, and assembled a newly published compilation of academic reports called The Biological Foundations of Music. It summarizes much of the past decade's international research into the origins of human music, particularly neurological evidence uncovered by brain scanning technology and related experiments.

That text is augmented by continuing studies of the musical mind at universities in Montreal, Toronto, Boston, California, and Europe. Published in scientific journals and posted on university and medical school Web sites, they reveal alluring evidence that: The brains of musicians, especially those who begin dedicated practice before age 7, have larger neural clusters involving music processing such as the neural region that directs a violinist's hands -- sound perception and discrimination begins before birth, and neurons begin firing before language skills develop in infants, aided by parental cooing and lullabies.

The brain selects the most efficient neural highways to process music, closing those that create musical traffic jams and opening those that make sounds flow faster. The more these circuits are used, the more their musical range and capacity expands. Both hemispheres of the brain share music processing functions and are connected by a key neural bridge, the corpus callosum, which unites specialized regions sending complex musical data at blinding speeds. Recent studies indicate the 100 million-nerve conduit is up to 15 per cent larger in musicians trained since age eight.

Music acts as a specialized fuel to fire millions of brain nerves that otherwise remain dormant or undeveloped. As the brain burns musical fuel, it creates chemicals that produce contentment and even ecstasy. Recent studies of choir singers show elevated levels of these after performances.

"The PET and MRI scans only became available in the last two decades," says Zatorre. "They have really revolutionized the whole field of cognitive neuroscience -- the study of the brain mechanisms that allow us to perceive and think and act and reason and remember. They allow us to probe the workings of the brain in normal people. Before we had to rely exclusively on those with brain damage."

Asked to summarize what brain circuits are deployed when humans process music, Zatorre momentarily jettisons his meticulous scientific caution and flashes a grin.

"Everything from the neck up." he answers.

Paul McKay is an Ottawa Citizen reporter. More music and photos for this story, and previous stories in this series, can be seen at www.enchantedear.com.

More details about the Zatorre/McGill studies can be found at www.zlab.mcgill.ca

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