The Musical Brain

How the Human Mind Understands Music

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Cultures throughout history have each had various forms of musical expression. This consistancy reflects a natural human affinity to music. The scientific study of our relationship to music is rooted in analysis of the brain. An ever expanding area of modern research, the effects of music on our brains are being found to be increasingly complex. Music has the ability to activate many different areas of the brain. In particular, it is seen to have its strongest effects on those areas involved in internal imagery, auditory perception, and motor functions.

Musical Imagery

Music is widespread and prevalent in daily life, and influences even those who don't actively seek it. In his book, *Musicophilia*, Oliver Sacks, Professor of Neurology at New York University, states: "This barrage of music puts a certain strain on our exquisitely sensitive auditory systems, which cannot be overloaded without dire consequences." One of these consequences, he explains, is the "brainworm"—a repeating loop of music in the brain that can recur from a couple of minutes to a few days. Brainworms are generally 15 to 20 second long stretches of music. Sacks finds that these brainworms behave similarly to a tic or seizure because music enters a part of the brain that causes it to play repeatedly. He compares these brainworms to well-known examples of sensory overstimulation. One example would be the feeling people get of rocking back and forth after having been on a boat for a prolonged period. Sacks states that the human mind is attracted to repetition, and the brainworm is a manifestation of that affinity (1).

Musical imagery is the internal music we hear in our minds. Imagery can be the involuntary playing of brainworms to the conscious recall of melodies. A study by Kraemer et al. found that individuals imagining music were found to activate their auditory cortex. Subjects were played both familiar and unfamiliar songs with short gaps of two to five seconds while their brain activity was scanned using functional magnetic resonance. The silent gaps in songs familiar to the listener were found to activate the auditory association areas of the brain more than unfamiliar songs. When subjects listened to familiar songs with no lyrics, activity was also recorded in the primary auditory cortex. Even though the subjects had no instruction or warning of the pauses in music, they only reported hearing gaps in unfamiliar songs. This suggests that participants unconsciously filled the gaps in familiar songs (2).

The accuracy with which a musical segment is remembered is also a notable characteristic of musical imagery. This is quite different from visual memory, which is comparatively unreliable. Each individual builds his visual world around interpretations of the outside environment. As such, visual memory can be altered by the mind. However, the musical characteristics of a piece, including "its tempo, its rhythm, its melodic countours, even its timbre and pitch—tend to be preserved with remarkable accuracy" (1). According to Robert Zatorre, a Professor of Neurology at McGill University, "the phenomenology of this effect suggests that musical imagery

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Figure 1: Studies show that musicians who are reading music show activity in the auditory cortex of their brains that is comparble to if they would if they were actually playing music.

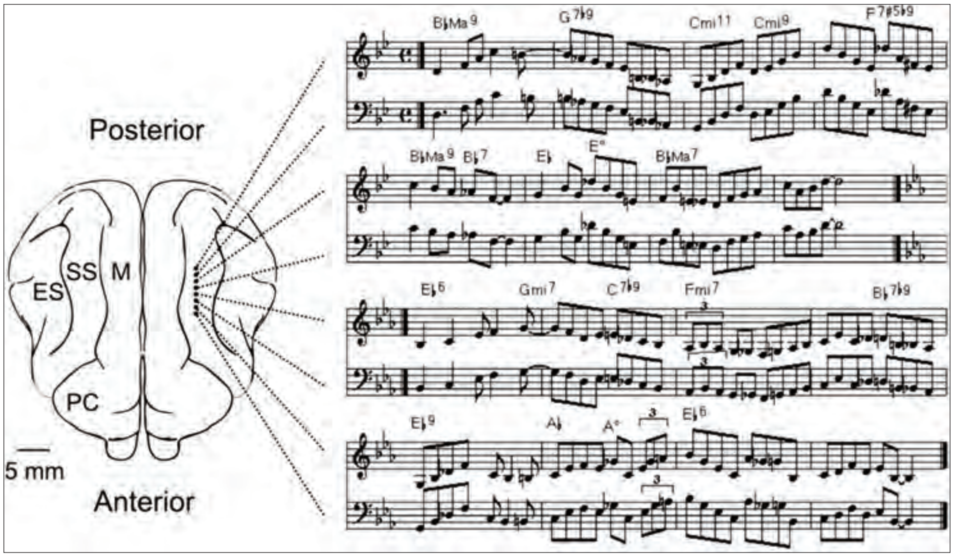

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Figure 2: We do not possess a music "center" that processes all musical input. Our brains are programmed to comprehend and enjoy music from a variety of regions that vary from individual to individual.

retains many of the properties of real perception…but that it is not confusable with real hearing" (3). A specialist in musical effects on the brain, Zatorre studied this characteristic of musical imagery by assessing the speed of musical processing (4). Zatorre asked subjects to judge a pitch change in two syllables of a well-known song. Not only did the subjects show that they had an internal representation of pitch structure by responding correctly, but the time that elapsed before they responded was a near-linear function of the time between two syllables in the music played (4). This experiment suggests that musical imagery takes place in something close to real time.

The physiological connections musical imagery has to the brain is also notable (4). Zatorre examined this aspect of musical imagery by studying individuals with cortical excision in the superior temporal gyrus, an area in the temporal lobe that contains the auditory cortices. In patients with damage to the right cerebral hemisphere, both musical perception and imagery were affected and their performance on pitch judgment for both heard and imagined music was worse than the performances of those without damage to this area (4). However, patients with lesions on the left side were able to complete the tasks at a level comparable to that of the control group (4). By observing the dysfunctional pitch judgment in patients with damage to the right hemispheric superior temporal gyrus, Zatorre was able to connect that neural area with both musical imagery and perception.

Zatore built on these conclusions by conducting neuroimaging studies on functional subjects. Individuals were scanned while being asked to perform the same type of pitch judgment. Activity was observed in the superior temporal gyri on both sides of the brain as subjects listened to and imagined the tunes, suggesting that sensory areas in the brain might be responsible for musical imagery. In another neuroimaging experiment, listeners were asked to continue a familiar musical excerpt in their minds after hearing only the first few notes. In this study, activity was recorded in the superior temporal gyrus of the right hemisphere as the patient imagined the music. Since the music chosen for the experiment was instrumental and left out verbal associations, Zatorre concluded that mechanisms in the right-hemisphere involve melodic processing (3).

A Kinetic Melody

Of all mammals, close interaction between the motor and auditory systems in the brain is only seen in humans. Humans are able to anticipate and synchronize musical beats as well as to understand and internalize rhythmic patterns. Even when there is not a pattern present, such as in the sounds of a clock ticking at constant intervals, the brain can create its own pattern. The motor cortex and subcortical motor systems in the basal ganglia and cerebellum are not only activated when we move to music, but also through the acts of listening to, or imagining music. This connection between music and sensorimotor movement extends even to human rhythmic patterns of walking and dancing. According to Sacks, "keeping time, physically and mentally, depends on interactions between the auditory and the dorsal premotor cortex – and it is only in the human brain that a functional connection between the two cortical areas exists" (1).

Neuroimaging studies have been especially insightful in studying this connection (4). In one investigation, non-musicians were taught how to play an easy song on a keyboard. After learning the song, activity was found in both the auditory cortex and premotor areas of subjects when the piece was played (4). This was not the case when the subjects listened to a melody they had not learned (4). In other experiments, activity in the supplementary motor area (SMA) and premotor areas was reported in both non-musicians when they imagined hearing musical excerpts and musicians when they imagined performing a piece. This strongly suggests that musical imagery contains both motor and auditory elements (4). For example, trained musicians are able to induce motor imagery while listening to or imagining a piece they have rehearsed many times. There have also been findings of activity in the premotor cortices and SMA even when listeners have not rehearsed motor associations with a musical piece or set of rhythms. This suggests that these areas play a role in unconscious rhythm tracking. (4)

Music Therapy

Since music is able to recruit and connect numerous parts of the brain, music therapy has succeeded over many other conventional forms of therapy. In particular, they are found to work well in helping treat aphasia, Parkinsonism, and dementia (1). In the cases of many of Sacks' patients, individuals in the advanced stages of these disorders retained much of their ability to respond to music (1).

The localized speech area of the brain is the premotor zone in the brain's dominant frontal lobe. Damage to this area can cause aphasia. Though many patients with damage to the premotor zone can barely speak or struggle to form fluid sentences, some still retain the ability to sing the words of songs. Therefore, it is possible for some patients to become reacquainted with speech when it is inserted into music. The right hemisphere, which usually has only very basic speech capabilities, can be transformed by music to produce speech.

In Parkinson patients, the basal ganglia are damaged, thereby preventing initiation of movement, speech, or even thoughts. Parkinsonism is thus a movement disorder and patients consequently are unable to exercise full command over their body's movements. However, studies finds that many Parksinson patients who can ordinarily barely initiate actions on their own, are capable of dancing and singing with the aid of musical cues (1). This effect was observed again when patients were asked to walk with another person in a rhythmic tempo (1). When the other person stopped walking, the subject would lose the ability to continue walking. An important aspect of musical therapy is finding the proper kind of music that the patient will respond to. Sacks thus states that: "If music is present, its tempo and speed take precedence over the Parkinsonism, and allow Parkinson patients to return, while the music lasts, to their own rate of moving, that which was natural for them before their illness. Music resists all attempts at hurrying or slowing, and imposes its own tempo" (1). In fact, some patients were able to accomplish this solely through initiating musical imagery with an outward suggestion of a musical composition (1).

Even in patients with varying stages of dementia—a degenerative loss of affect memory, language, and critical thinking functions—responses and connections to music have been observed. Sacks remarks: "Musical perception, musical sensibility, musical emotion, and musical memory can survive long after other forms of memory have disappeared. Music of the right kind can serve to orient and anchor a patient when almost nothing else can" (1) The aim of musical therapy is to use old tunes, in hopes of evoking emotions, memories, and responses from the patient. Once dementia becomes more advanced, this form of musical memory may not be as successful, but the auditory-motor relationship of rhythm can still remain in the form of movement and dancing. If music therapy takes place in a group setting, the previously detached patients are able to bond with the therapist and members of the group through the synchronization of familiar music in communal singing and dancing, according to Sacks (1). Music thus provides a form of stimulation for dormant patients and helps them to step briefly outside their diseases (1).

Conclusion

The neural effects of music, familiar and unfamiliar, voluntary and involuntary, are universal in the human population. Regardless of musical ability, humans are united through similar neural responses to the playing, singing, and imagining of music. Music is an intrinsic part of our neural function and its recruitment of numerous parts of the brain makes its presence pervasive in our lives.

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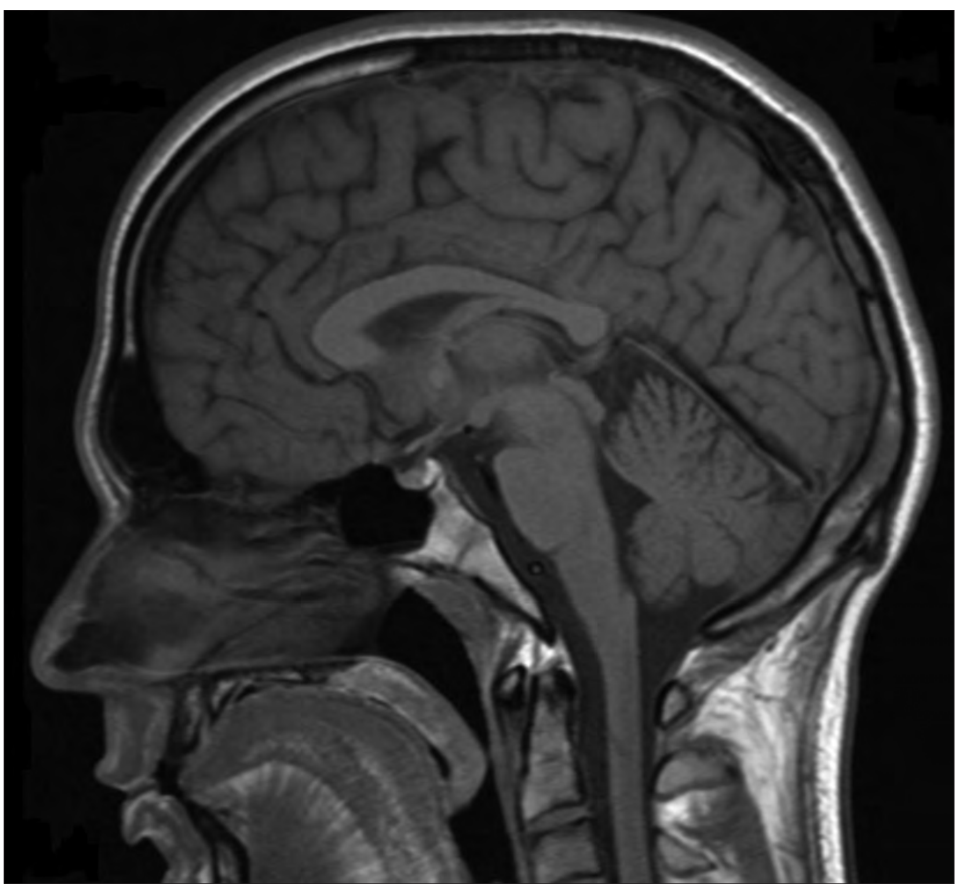

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Figure 3: MRI scan of the side of the head.