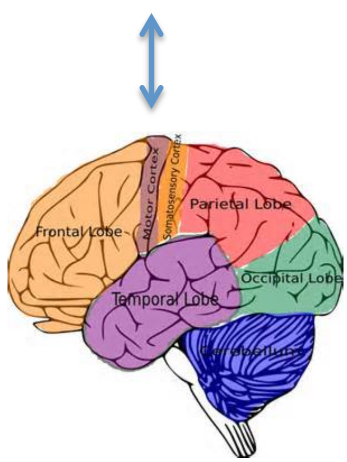
CAPSTONE



So you think you can dance or not?

February 16, 2015

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INTRODUCTION:

Music has been present in ancestral populations before the dispersal of humans around the world so it has been in existence for at least 50,000 years. According to the Merriam-Webster Dictionary, Music is the science or art of ordering tones or sounds in succession, in combination, and in temporal relationships to produce a composition with unity and continuity. It is also a universal language because every known human culture has music that also plays an important role in their social and habitual activities. This phenomenon has a variety of functions, branches and responses. Different kinds of music produce different types of responses as follows: lullabies make babies sleep; dirges sooth the bereaved and classical music calms the mind etc. However, the specific response to music that is being concentrated on in this paper is the rhythmical motion response known as dancing. People have speculated that music has its origins set in Africa from simple rhythmical movements like toe tapping and hand clapping, which is also required in music, as rhythm cannot exist alone. Music and rhythm have been with humans for centuries, developing and evolving along with them. Its influence on human behavior and mood can reach levels whose limits are still unknown, especially in relation to perception, where the entire nervous system is involved. Thus, physiology and psychology become strongly connected areas. Unlike other sensory motor activities, dancing requires precise timing of several hierarchically organized actions, implemented through diverse effectors based on the individual's experience in dance training and creativity in relation to the specific beats of a musical piece. As one listens to music, it affects intricate sets of complex brain processing systems, like sensory-motor processing and functions related to memory, cognition and emotion or mood fluctuations. Thoughts and emotions are often connected through music and, therefore, formulate questions surrounding the ‘‘Theory of Mind’’ (the ability to empathize with others on an emotional state and understand their intentions). However, little is understood about how listening to music affects the brain. That is why this research paper serves to elaborate on the relationship between rhythmical motion response and brain activity. Music activates a wide range of brain areas. There is no single music center within the brain, because different aspects of music activate different regions of the brain. The fascination arises from how the brain regions break down the various components of a musical piece to provide an output of specific rhythmical patterns of motion. This is referred to as bottom-up and top-down processing in psychology. Much interest falls on how tempo and rhythm, two of the many aspects of music, can elicit movement coordinated with the music, such as, toe tapping, swaying and dancing. These responses of motion can also be associated with activity in motor areas of the brain. This paper serves to understand if there can be a difference in the brain activity of a professional dancer and an unprofessional dancer. First of all, a general comparison is done with music and dance to show how they are related and why dance is associated with music often. Secondly, the relationship between brain activity and music will be discussed and then the relationship between Dance and brain activity are broken down into three subtopics: timing, rhythm and spatial organization in order to explain why people dance and how dance can be a sequentially planned series of movement. To conclude the research, music, dance and brain activity are related altogether to different brain regions to understand why dance occurs and how its subsequent movements occur. Listening to music requires at least three basic motor control functions: timing, sequencing and spatial organisation of movement. These functions mediate complex behaviours, which are controlled and interpreted by several cortical regions, sub cortical regions, motor areas and most importantly, mirror neurons, by converting incoming sensory information into motor instructions and actions[5, 9,11,16,18,19].

How does Dance result from music?

The behavioral tip of a deep relationship between music perception and movement generation comes from tapping of the feet and the fingers. This effortless induction of movement elicited by musical rhythm has evolved into the complex combination of specific patterns of body movements known as dancing. Dancing is a universal practice that can be used for anything like mourning, celebration or preservation of cultural heritage depending on the timbre of the music, but in general the rhythmical movement of the body is instinctive. It is a natural response to music because of its emotional and psychological affiliation to music. The cognitive connection to music evolved from an older skill, the ability to gather emotion from motion. When pairing a particular emotion to a melody, the same combination of spatiotemporal features (having to do with a certain speed, rhythm and smoothness) is chosen. Music invokes motor representations of emotions by recruiting the insula, which is a neural relay between the limbic and motor systems. The philosopher, Leonard Meyer argued that music sets up sonic patterns and regularities that compel us to make unconscious predictions about what comes next and some interpret this through dance if not mentally. This relates to the fact that human beings posses the ability to formulate sequential series of movements with accuracy and creativity. The practices we have cultivated in ourselves, is not only an ability to deliver specific patterns, but also the ability to make new ones. This creative act comes from thinking as well as making movements that are learned. Sensory awareness aids in receiving new impulses to movement that arise in the heat of the moment, in response to the moment or as an expression of whatever is happening. Furthermore, musical accompaniments aid in improving timing, rhythm and coordination when dancing.[8, 9,11,13]

Music and Brain activity

Music affects multiple regions of the brain and not just a specific part and that is what makes it unique. Daniel Levitin of McGill University and his colleagues conducted an experiment where the processing and integration of music that are common across people were studied in order to recognize the brain regions involved. The study was done on male and female participants who listened to either a musical piece by the late-Baroque composer, William Boyce or listened to the two different control conditions lacking the qualities and structure of music. An fMRI scan was used to monitor brain activity by detecting associated changes in blood flow. The experiment helped discover that a distinct set of brain regions showed activities that were common across the participants who listened to music only and not the control sounds. During the presentation of music, activities were shown within the auditory areas of the thalamus, the temporal cortex of the right hemisphere and both sides of the right parietal cortex. Another discovery was the presence of activity in the areas of the cortex associated with the planning of movement, known as the premotor cortex. All these activities happened in the right hemisphere because it is the hemisphere known for artistic abilities and creativity. These interesting observations were found in non-musicians so they could not have been imagining how the music would be played especially since they lacked the level of training equal to that of a musician. This study showed that activity within the auditory cortex and higher cortical areas like the right frontal cortex and the right parietal cortex, tracked the aspects of musical structure over time similarly in all individuals despite the level of musical training. This has shown that the brain does not solely show patterns of activity while listening to music; it also shows a specific pattern of activity within the brain that is unique to music[5].

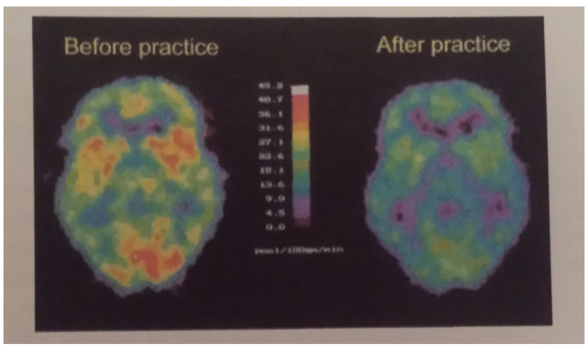

Fig.1 Listening to music is not just hearing a series of sound. Recent research has shown that distinct brain circuits are involved when you listen to music. This image compares the brain activity when listening to music and when there is no music to listen to[5].

Levitin uses modern techniques of neuroscience to study the making and listening of music and how it affects various brain region activities. His discoveries were as follows: Within the main auditory centers of the brain, in the thalamus and the temporal cortex, there are different areas that play a critical role in the early stages of processing music. Music consists of different pitches (how high or high low a tone is) and they are represented by different regions of the brain, arranged in an orderly and predictable fashion going from high to low like the keys of a piano keyboard. Different areas of the temporal cortex other than where the pitch is produced also represent different sounds. These areas are the sulcus or fissure that runs lengthwise along the middle of the temporal lobe.[5, 19]

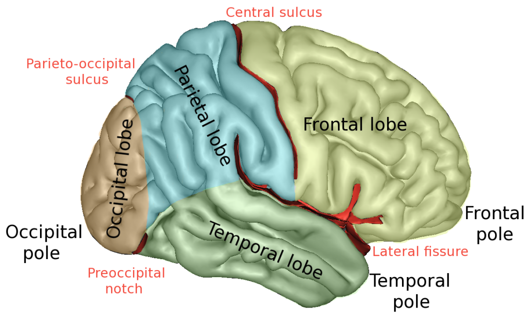

Fig 2. The four lobes of the brain that identify the sulci (fissures) [3].

The Tempo and rhythm of a musical piece involve the basal ganglia and the cerebellum. These have been discovered to be areas of movement and coordination and it re-enforces the idea of music influencing a rhythmical response of motion. In 2001, neuroscientists Anne Blood and Robert Zatorre at McGill University in Montreal, used magnetic resonance imaging (MRI) scans to show that people listening to pleasurable music have activated the limbic and paralimbic regions of the brain, which are connected to euphoric reward responses, like those we experience from sex, good food and addictive drugs. Those rewards come from the gush of a neurotransmitter called dopamine within the nucleus accumben, which is also associated with motivation and reward. Motivation, reward and pleasure are all forms of emotion and this is why the amygdala is also a region of the brain activated by music because it is the region associated with emotion. Another aspect of music that involves brain activity is the recollection of melodies and expectations about rhythm and harmony, which involve the frontal and prefrontal cortices.[2, 3, 19]

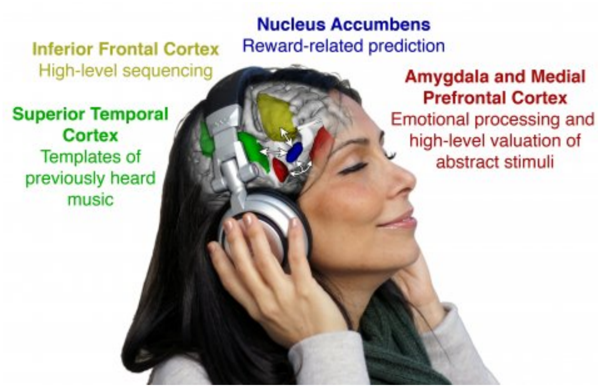

Fig.3 Region of the brain relating to emotions such as pleasure, reward and motivation that are activated by music[7]

How does Dance result from brain activity?
Timing:

Timing movement have been linked to several cortical and sub-cortical regions, including the cerebellum, basal ganglia and supplementary motor area (SMA) thanks to functional neuroimaging studies, as well as studies of brain-damaged patients. It has been proposed that the basal ganglia and possibly the SMA may be more important for interval timing at longer timescales (1 second and above), whereas the cerebellum may be more important for controlling motor timing at shorter timescales (millisecond). More neuroimaging studies have shown the cerebellar activity in relation to movement timing and that patients with cerebellar lesions have an impaired ability in completing perceptual and motor timing tasks. Although some studies have failed to support a direct contribution of the cerebellum to timing, current theories of cerebellar function suggest it may have a role in feed forward control or error correction, which would be relevant for timing. Several researchers have proposed that the cerebellum deals with predictive models of movement that would include movement timing, whereas others suggest that it is most important for online error correction based on feedback, which would also contribute to optimization of timing. Another region that has been suggested to be directly involved in movement timing is the basal ganglia. Observing patients with Parkinson's disease, who have damage in the basal ganglia system, has proven this because they show impaired movement timing. Furthermore, the basal ganglia have also been proven to be the region that is active in tasks that require timed finger tapping and control of specific motor parameters, such as force, which contribute to accurate timing.[14, 19]

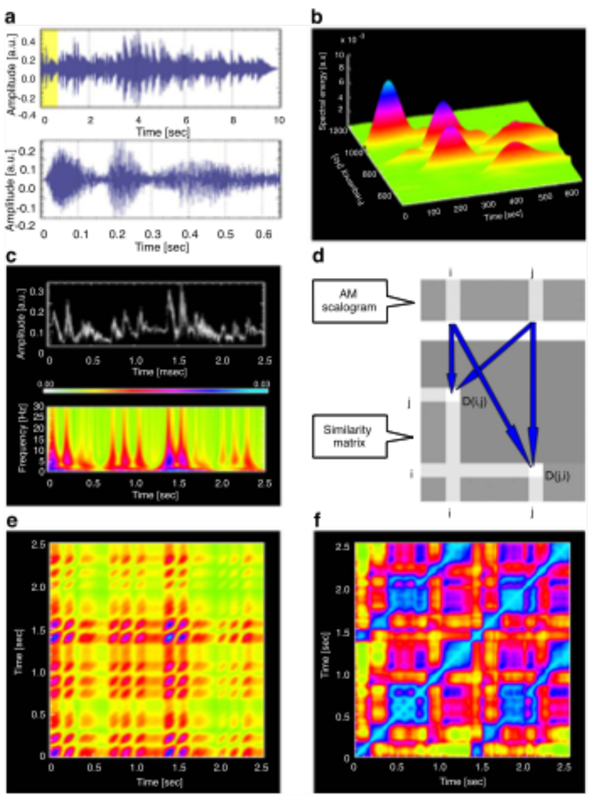

Fig.4. Different representations of the acoustical signal. (a) The acoustic signal (pressure change) of the musical motif is displayed on the upper line and an expanded copy of the yellow band of 650 ms is shown below. (b) Spectro-temporal representation of the yellow band in a. Colors relate to spectral energy. (c) The scalogram of the sound amplitude modulation of the first segment of the motif (segment A). Upper line shows the amplitude modulation (AM) as a function of time and the lower line shows the pseudo-continuous wavelet transform. (d) Schematic representation of embedding pairwise feature vectors in the similarity matrix. (e) And (f) show the rhythmogram and the self-similarity matrix of the acoustic signal, respectively. The matrices colors are proportional to the similarity measure at each pixel. In all parts of the figure where color is used to represent intensity, the level increases from green (lowest), yellow, red to blue (highest) [14]

Rhythm:

With regards to the perception and reproduction of more complex musical rhythms, studies have shown greater involvement of the dorsal premotor cortex (dPMC), lateral cerebellar hemispheres and the prefrontal cortex. It is unknown whether these changes in brain activity are directly related to the temporal complexity of the rhythms or to other parameters such as sequence complexity, or the degree to which rhythmic structure allows subjects to predict and organize their motor performance. These results indicate that, just like music, a single brain region does not control motor timing. Rather it is controlled by a network of regions that control specific parameters of movement and that depend on the timescale of the rhythmic sequence. The cerebellum is important for sequence learning and for the integration of individual movements into unified sequences, whereas the pre-SMA and SMA are involved in organizing or chunking (*The re-organization or re-grouping of movement sequences into smaller sub-sequences during performance. Chunking is thought to facilitate the smooth performance of complex movements and to improve motor memory)* of more complex movement sequences. Finally, the premotor cortex is shown to be involved in tasks that require the relatively complex sequences, and it may contribute to motor prediction. In other words, more complex sequences relate to activity from the basal ganglia, cerebellum and the dorsal premotor cortex. The left cerebral hemisphere has been concluded to be mainly involved in rhythm processing, but others have indicated that dysfunction of either the left or right hemispheres compromise tapping of rhythmic patterns from short musical pieces. A recent fMRI study has shed new light on the issue of rhythm perception, highlighting the inconsistency of stimulus material among previous studies of musical rhythm perception. The study used right-handed individuals and showed that the brain regions activated depended on the type of rhythm they were preparing to tap. Specifically, for rhythmical patterns with tones spaced evenly, the left hemisphere areas, including the left premotor area (PMA) and the right cerebellum were mostly active, whereas for rhythms with tones spaced at complex ratios, which were more difficult to memorize and tap out, a shift in areas to the right hemisphere (including the right PMA) with bilateral activation of the cerebellum were noticed. These results offered an explanation for the psychological findings showing that the accuracy of reproducing even very simple temporal patterns is strongly influenced by the rhythmic structure of the sequences. Between a dancer and a non-dancer, interpretation of rhythm is different. Psychology Prof. Richard P. Ebstein and his research associates examined DNA to show that dancers show consistent differences in two key genes from non-dancers. Using 85 dancers and advanced dancing students in Israel, the genes that coded for the serotonin transporter and arginine vasopressin receptor 1a varied. The serotonin transporter regulates the level of serotonin, which contributes to spiritual experience, among many other behavioral traits, while the vasopressin receptor modulates social communication and bonding behaviors. Both are elements involved in the age-old human social expression of dancing[6, 14, 19].

Spatial organization:

Dancing with proper rhythm requires precise spatial organization and sequential components of movements. Studies in animals and humans have established the involvement of parietal, sensory–motor and premotor cortices in the control of movements when the integration of spatial, sensory and motor information is required.

Recent neuroimaging study contrasting sequential and temporal sequence learning suggested that the dPMC might have a role in the learning of spatial trajectories. Several cortical and sub-cortical regions, including the basal ganglia, the SMA and the pre-SMA, the cerebellum, and the premotor and prefrontal cortices, have been implicated in the production and learning of motor sequences, but their specific contributions and the way they work together are not yet clear. Neurophysiological studies in animals have demonstrated an interaction between the frontal cortex and basal ganglia during the learning of movement sequences. Human neuroimaging studies have also emphasized the contribution of the basal ganglia for well-learned sequences. The prefrontal motor areas of the cerebral cortex are responsible for converting incoming sensory information into motor instructions or actions. Similarly, this region mediates other complex behaviors, including imitation or awareness of actions performed by others. This relates to an aspect of dancing known, as Choreographing. Balance is critical to choreographing and that is the major difference between a dancer and non-dancer. Due to prolonged training, dancers are not prone to dizziness because they obtain the ability to suppress signals from the balance organs in the vestibule of the inner ear linked to the cerebellum[1, 19].

Mirror Neurons

What enables human beings to effectively conduct and follow a set of preplanned movements that form dance choreography? This is a result of brain cells known as Mirror neurons that that fire when you are moving and also when you are not moving, but rather watching someone else move. They are amazing, specialized brain cells active within minutes of a child being born that allow us to understand the actions, intentions, and emotions of others through unconscious “mirroring” or imitation in our own brains. So, if you are watching someone dance, your brain’s movement control regions are activated because planning and prediction of how a dancer would move will be based on what you, as an individual would do. In humans, probably about 20% of the brain’s motor neurons are mirror neurons, and about 10% of the sensory neurons are mirror neurons, but these are only estimates. Mirror neurons are not activated solely by visual stimulus, but also by auditory stimulus. They remain activated every time we observe an action, and learning is still facilitated through its network. The ability to tap to the beat is unique to music (and probably to humans), and is a natural behavior even in people with no musical training. The listener must extract the relevant temporal information from a complex auditory stimulus, and make predictions that enable the planning and execution of sequential movements in a precisely timed manner. Since experimental evidence indicates that musical sequences are planned and executed in terms of a metrical structure[6], temporal precision is essential in musical performance, as one must be able to convey the metrical structure in order to create appropriate rhythmical movement expectations from music. Mirror neurons fire the exact same way while performing a dance routine or observing someone else do a dance routine so it does not explain the difference in brain activity of a dancer and a non-dancer, but it is essential to how people move to music and why people are able to pick up a choreography[15, 17, 19].

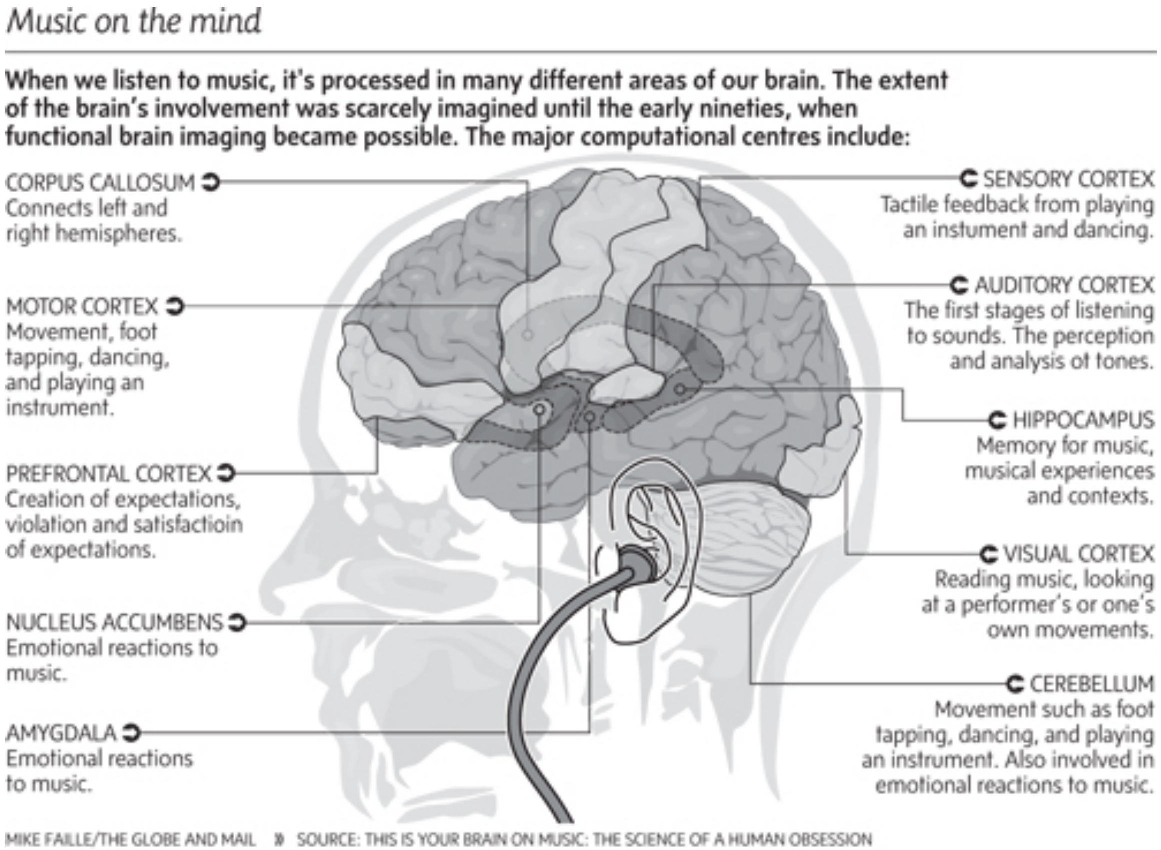

Fig 5. This image summarizes the regions of the brain that are activated by music[4]

Conclusion

It has been proven that music and dance are particularly pleasurable activators of the sensory and motor circuits known as mirror neurons. High-level control of sequence execution appears to involve the basal ganglia, PMC and SMA, whereas the cerebellum may control fine-grain correction of individual movements. In addition to that there are the limbic and paralimbic regions, the nucleus accumbens and the amygdala that are activated by the pleasure, motivation and emotional response gotten from listening to music. Taking into account that dancing is a varied activity just like music because different cultures implement different methods and styles, neuroimaging techniques have shown that there is a greater volume in the brain regions activated by music in professional dancers who exhibit more rhythmical movements than non-dancers. Mirror neurons do not explain the difference in the brain activity of dancers and non-dancers, but it is essential for movement coordination, development and learning. Varied rhythmic responses of motion come from an individual's training experience in music and dance, their brain's health condition and the condition of their muscles. From the research and brain scans done on people listening to music, we were able to deduct from them and apply it to expectation with regards to motion. However, we may be able to get more specific and accurate results in the future with the help of more advanced technology that could monitor brain activity while in motion. Due to a dancer's ability to withstand dizziness it could help facilitate a solution for people who suffer from chronic dizziness[6, 11, 19].

Fig.6 A dance choreography that is being observed and mimicked with the help of mirror neurons being fired[10].

Additional questions arose from this research such as:

- Is the orderly organization of pitch by the brain present in all humans or unique to those able to differentiate pitch?
- Would the brain regions responsible for movement planning and timing still show

activity in people incapable of moving or that have lack of coordination due to a disability if they just listened to music or imagined a dance movement to accompany the music?

- Why do some people "have rhythm" more than others? Because being able to respond with proper rhythm can be learned or innate.

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