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Music Composition Using a Real-Time MRI Biofeedback System

Interactive Qualifying Project Report completed in partial fulfillment

of the Bachelor of Science degree at

Worcester Polytechnic Institute, Worcester, MA

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Date: July 6th 2011

Submitted to:

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Acknowledgement

The author of this paper would like to thank the following individuals:

- Frederick Bianchi of Worcester Polytechnic Institute for his assistance, guidance and advising in this project.
- Karl Helmer of Medical School in Harvard University for providing help and guidance in this study.

Abstract

The goal of this project was to describe a real time music composition through an fMRI based-biofeedback system that monitors the activity in the medial prefrontal cortex (MPFC) of the brain. Based on creativity and neuroscience research, it is suggested that increased MPFC activity is closely associated with creativity in jazz improvisation.[51]

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I. *Introduction*

There have been studies in the area of music processing based upon neurological and electrical activity of the brain using functional Magnetic Resonance Imaging, Electroencephalograph, Positron Emission Tomography, and Magnetoencyphalograph. Different methodologies with different detecting devices have been used to explore the relationship between musical actions and specific locations in the brain.

The goal of this project is to achieve real time music composition through an fMRI based-biofeedback system that monitors the activity in the medial prefrontal cortex (MPFC) of the brain. Based on creativity and neuroscience research, it is suggested that increased MPFC activity is closely associated with creativity in jazz improvisation.[51]

Prior to developing the biofeedback music composition system, a study is needed to test the hypothesis that an enjoyable passive listening experience may also result in increased activity in the MPFC. If a subject exhibits increased MPFC activity while passively listening to music it may suggest a heightened state of involvement similar to the active state of creative involvement. If an enjoyable listening experience results in similar brain activity as creative involvement, then it may be plausible to construct a biofeedback composition system that aims to monitor and optimize activity in the MPFC through the real time manipulation of aural input.

II. *Literature Background*

There are different ways for looking at the activity in the brain. This includes MRI images for the interior component of the brain or by EEG that detects electrical signals (brain waves) that exists during different states of thinking and activity. These electrical waves originate from specific areas in the brain and are detected from different locations at the cerebral cortex (outermost tissue to the cerebrum of the mammalian brain).

FIGURE (1): The cerebrum of the brain. (Source: http://healthnhealthy.com)

II.I. ***Music and the Brain***

What is the secret of music's strange power?

Music surrounds us and it couldn't be any other way. An exhilarating orchestral crescendo can bring tears to the eyes and send shivers down the spine. Background swells add emotive punch to movies and TV shows. Organists at ballgames can bring a cheering crowd to their feet, and parents croon soothingly to infants [15].

Music and the brain is the science that studies the neural mechanisms that underlie musical behaviors in humans and animals. These behaviors include music listening, performing, composing, reading, writing, and ancillary activities. It also is increasingly concerned with the brain's basis for musical aesthetics and musical emotion. Scientists working in this field may have training in cognitive neuroscience, neurology, neuroanatomy, psychology, music theory, computer science, and other allied fields [16]. The brain reacts in various ways to sound and music. For example, when unpleasant melodies are played the posterior cingulate cortex activates which indicates a sense of conflict or emotional pain [17].

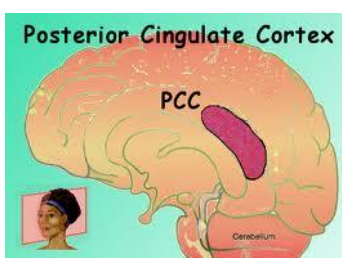


FIGURE (2): Posterior Cingulate Cortex (Source: neuro.questionsthatmatter.info)

Furthermore, the right hemisphere has also been found to be correlated with emotion, which can activate areas in the cingluate in times of emotional pain, specifically social rejection (Eisenberger). This evidence, along with observations, has led many musical theorists, philosophers and neuroscientists to link emotion with musical organization. This seems almost obvious because the tones in music seem like a characterization of the tones in human speech, which have emotional content. The vowels in the phonemes of a song are elongated for a dramatic effect, and it seems as though musical tones are simply exaggerations of the normal verbal tonality [16].

Cognitive musicology is a branch of Cognitive Science concerned with computationally modeling musical knowledge with the goal of understanding both music and cognition. [18] More broadly, it can be considered the set of all phenomena surrounding computational modeling of musical thought and action. [19]

Cognitive musicology can be differentiated from the better known field of Music Cognition by a difference in methodological emphasis. Cognitive musicology uses computer modeling to study music-related knowledge representation and has roots in Artificial Intelligence and Cognitive Science. The use of computer models provides an exacting, interactive medium in which to formulate and test theories [20]

This interdisciplinary field investigates topics such as the parallels between language and music in the brain. Biologically inspired models of computation are often included in research, such as neural networks and evolutionary programs. [21] This field seeks to model how musical knowledge is represented, stored, perceived, performed, and generated. By using a well-structured computer environment, the systematic structures of these cognitive phenomena can be investigated. [22]

II.II. ***Biofeedback, Brain Waves and EEG***

Biofeedback is the process of becoming aware of various physiological functions using instruments that provide information on the activity of those same systems, with a goal of being able to manipulate them at will.[23][24] Processes that can be controlled include brainwaves, muscle tone, skin conductance, heart rate and pain perception.[25]

There are many kinds of biofeedback sensors (instruments) with different operating concepts: Electromyograph, Thermometer, Electrodermograph, Electroencephalograph, Photoplethysmograph, Electrocardiograph, fMRI and etc. But the ones that are most directly related to the current study of brain activity, creativity and music enjoyment are the EEG and fMRI.

Many experiments have been done through the 20th century to build a musical composition from a person’s electrical head signals (EEG).

Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain.[26]

The EEG is typically described in terms of (1) rhythmic activity and (2) transients. The rhythmic activity is divided into bands by frequency.

Table1: Comparison table (Brain Waves).[27]

Comparison of EEG bands				
Type	Frequency (Hz)	Location	Normally	Pathologically
Delta	up to 4	frontally in adults, posteriorly in children; high amplitude waves	▪ adults slow wave sleep ▪ in babies ▪ Has been found during some continuous attention tasks (Kirmizi-Alsan et al. 2006)	▪ subcortical lesions ▪ diffuse lesions ▪ metabolic encephalopathy hydrocephalus ▪ deep midline lesions
Theta	4 – <8	Found in locations not related to task at hand	▪ young children ▪ drowsiness or arousal in older children and adults ▪ idling ▪ Associated with inhibition of elicited responses (has been found to spike in situations where a person is actively trying to repress a response or action) (Kirmizi-Alsan et al. 2006).	▪ focal subcortical lesions ▪ metabolic encephalopathy ▪ deep midline disorders ▪ some instances of hydrocephalus
Alpha	8 – 13	posterior regions of head, both sides, higher in amplitude on dominant side. Central sites (c3-c4) at rest .	▪ relaxed/reflecting ▪ closing the eyes ▪ Also associated with inhibition control, seemingly with the purpose of timing inhibitory activity in different locations across the brain (Klimesch, Sauseng, & Hanslmayr 2007; Coan & Allen 2008).	▪ coma
Beta	>13 – 30	both sides, symmetrical distribution, most evident frontally; low amplitude waves	▪ alert/working ▪ active, busy or anxious	▪ benzodiazepines

			thinking, active concentration	
Gamma	30 – 100+	Somatosensory cortex	▪ Displays during cross-modal sensory processing (perception that combines two different senses, such as sound and sight) (Kisley & Cornwell 2006; Kanayama, Sato, & Ohira 2007; Nieuwenhuis, Yeung, & Cohen 2004) ▪ Also is shown during short term memory matching of recognized objects, sounds, or tactile sensations (Herrmann, Frund, & Lenz 2009)	▪ A decrease in gamma band activity may be associated with cognitive decline, especially when related the theta band; however, this has not been proven for use as a clinical diagnostic measurement yet (Moretti et al. 2009).
Mu	8 – 13	Sensorimotor cortex	▪ Shows rest state motor neurons (Gastaut, 1952).	▪ Mu suppression could be indicative for motor mirror neuronsworking, and deficits in Mu suppression, and thus in mirror neurons, might play a role in autism. (Oberman et al., 2005)

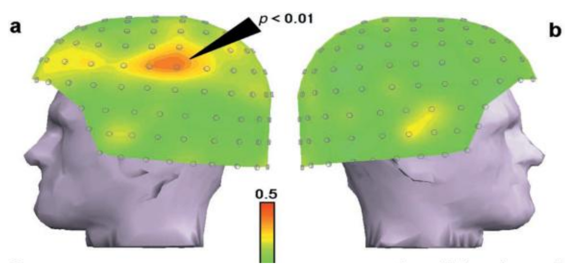
The two most important waves are the Alpha and the Beta wave. Alpha waves are one type of brain wave detected either by electroencephalography (EEG) or Magnetoencephalography (MEG) and predominantly originate from the occipital lobe during wakeful relaxation with closed eyes [2]. Beta states are the states associated with normal waking consciousness. Low amplitude beta waves with multiple and varying frequencies, 12 and 30 Hz, are often associated with active, busy, or anxious thinking and active concentration. [7]

In the mid-1960s, Alvin Lucier composed *Music for Solo Performer*. He placed electrodes on his own scalp, amplified the signals, and relayed them through loudspeakers that were "directly coupled to percussion instruments, including large gongs, cymbals, tympani, metal ashcans, cardboard boxes, bass and snare drums."[55]

In the early 1970s David Rosenboom, of California Institute of the Arts, began systematic research into the potential of using EEG to generate music [56]. Rosenboom thought that it might be possible to understand specific aspects of human's musical experience by capturing EEG signals, digging for potentially useful information to make music. Thirteen years later, Eduardo Miranda, of Plymouth University in UK, developed new techniques to enhance the EEG signal and to train the computer to identify EEG patterns associated with different cognitive musical tasks.[57]

In addition, fMRI has a great potential as a biofeedback (neuro-activity) system for music composition. Its applications have a wide range of advantages and usages, including the reading of brain states, brain–computer interfaces, communicating with locked-in patients, lie detection, and learning control over brain activation to modulate cognition or even treat disease.[52] Moreover, MRI has great advantages in detecting the neurological activity while listening to music and improvising. While EEG detects the electrical waves only on the surface of the cerebrum, fMRI gives high-resolutions images (1 mm cubical voxels) from any part of the brain. That is why fMRI is more realistic and more accurate.

A study done at MIT designed a Magnetoencephalography experiment, to compare the motor activation in pianists and non-pianists while listening to piano pieces. The study found a statistically significant increase of activity above the region of the contralateral motor cortex (CLMC). That means when the pianists were listening to well-trained piano performance, they exhibit involuntary motor activity involving the primary CLMC [8]. They tested the participant's brain activity with MEG to find the difference in motor activation between the pianists and the non-pianists. The study suggested that the mere perception of well-trained piano music can involuntarily evoke motor cortex activity in pianists without actual movement. It is shown from the difference plot clearly that a focus of activity above the left central sulcus between the two groups, whereas other areas exhibit little differential activation [8].



FIGURE(3): The plots (a–b) show the relative differences of the MEG derivatives between pianists and non-pianists group averages [8].

The results showed that listening to well-trained piano performance can involuntarily evoke motor cortex activity in pianists without actual movement. They did not detect any activity arising from other constituents of the motor system that are known for their contribution to motor programming (like SMA or PMC). However, some sort of motor programming must have taken place because M1 activity was detected before the onset of the notes, and the finger dissociation indicated that the subjects knew with which finger the next note would normally be played. They speculated that due to the high level of skill of the subjects, the motor programming processes were highly automated and required little recruitment in the motor neurons.

Emotions, induced by music, might activate similar frontal brain regions compared to emotions elicited by other stimuli. Schmidt and Trainor (2001) discovered that valence (i.e. positive vs. negative) of musical segments was distinguished by patterns of frontal EEG activity [28]. Joyful and happy musical segments were associated with increases in left frontal EEG activity whereas fearful and sad musical segments were associated with increases in right frontal EEG activity. Additionally, the intensity of emotions was differentiated by the pattern of overall frontal EEG activity [28].

II.III. ***HISTORY OF MUSIC COMPOSITION: BRAIN ACTIVITY BASED***

Scientists used the technology of EEG biofeedback to produce music through different interfaces. This includes connecting the output of EEG directly to acoustic musical instruments, analyzing the power spectrum of the EEG waves for various applications, connecting to an analog or digital synthesizer, or manipulating the signal through software.[55],[56][57].

The use of electrical signals emanating from living organisms (bioelectric signals) to create music is not new. While a complete history of bioelectric music experiments is beyond the scope of this paper, some background is appropriate. The history of bioelectric music experiments can be traced back to 1934 with the translation of the human electroencephalogram (EEG) into audio signals (Adrian and Matthews 1934); these experiments went largely unnoticed until the late 1960s. In the decades that followed, the efforts of many composers and artists (Lucier 1976; Arcadiou 1986; Rosenboom 1976, 1989; Knapp and Lusted 1990) established work in this arena as meritorious. These systems may produce some interesting musical results, but they will tend to be stylistically limited, and due to their reliance on ill-structured methods of acquisition and analysis they tell us very little about the underlying processes of musical cognition [9]. Lucier, who started his work on “Music for Solo Performer” in 1956, uses EEG electrodes attached to the performer's scalp to detect bursts of alpha waves generated when the performer achieves a meditative, non-visual brain state. These alpha waves are amplified and the resulting electrical signal is used to vibrate percussion instruments distributed around the performance space [58].

An interesting patented (music from neurological activity) study, by Knispel, relates to a method and apparatus for translating an ongoing EEG signal into a musical feedback signal and applying the musical feedback signal to the human brain, or any other brain, to induce controllable physiological and psychological responses. A signal processor converts an ongoing EEG signal from a selected position on the scalp into electrical signals that music synthesizers convert into music. The brain receives the musical feedback after it is delayed by a period of time that is calculated so that the music reinforces specific or desired EEG activity at a particular area of the brain determined by the site of the recording electrode. In addition, the music is engineered to have psycho-acoustical and musical properties (resonant frequencies and emotionally acceptable for extended listening) that induce the brain to preferentially produce a particular type of EEG activity. The physiological response of the brain to the feedback music actively drives the ongoing EEG activity into resonance with the music to form a real time physiological feedback loop. The musical qualities and encoded physiological information of the feedback signal selectively reinforce biologically produced brain wave activity. The type of brain wave activity that is reinforced, together with the musical program in which it is encoded, can be used to promote emotional states without additional stimuli such as the presence of a therapist. For example, alpha activity can be enhanced so as to induce relaxation solely by musically reinforcing the alpha activity that is sensed by an electrode located on the scalp at the positions on the scalp known as CZ or P3 in the nomenclature of clinical neurology. [12]

II.IV. ***MRI AND THE MUSIC***

A new approach of fMRI was introduced recently for studying the internal organs, tissues and blood flow. A relatively new technology, Magnetic resonance imaging was first developed at the University of Aberdeen, UK. The first MR image was published in 1973[29][30] and the first cross-sectional image of a living mouse was published in January 1974 [31]. The concept of studying brain activity as it relates to music listening, improvising and rehearsing ... etc by the fMRI is relatively new.

Functional MRI (fMRI) measures signal changes in the brain that are due to changing neural activity. The brain is scanned at low resolution but at a rapid rate (typically once every 2–3 seconds). Increases in neural activity cause changes in the MR signal via T^*_2 changes;[32] this mechanism is referred to as the BOLD (blood-oxygen-level dependent) effect.

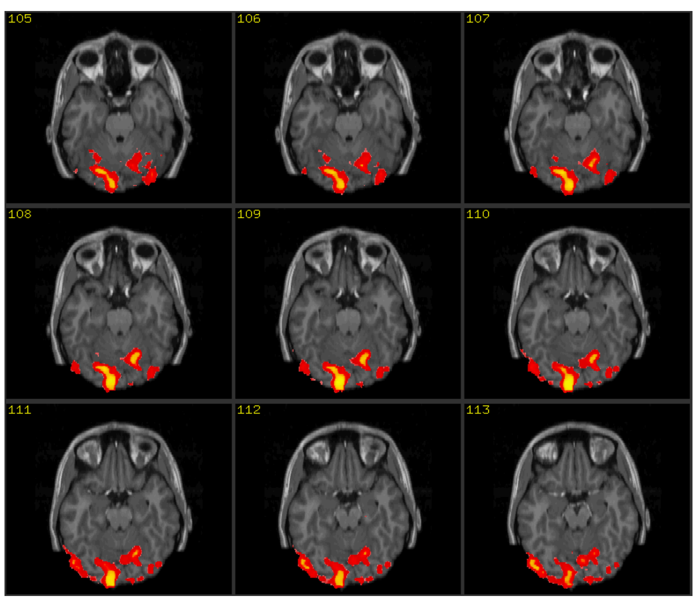


FIGURE (4): Images from fMRI (Source: csulb.edu).

Increased neural activity causes an increased demand for oxygen, and the vascular system actually overcompensates for this, increasing the amount of oxygenated hemoglobin relative to deoxygenated hemoglobin. Because deoxygenated hemoglobin attenuates the MR signal, the vascular response leads to a signal increase that is related to the neural activity. The precise nature of the relationship between neural activity and the BOLD signal is a subject of current research. While BOLD signal is the most common method employed for neuroscience studies in human subjects, the flexible nature of MR imaging provides means to sensitize the signal to other aspects of the blood supply. Alternative techniques employ arterial spin labeling (ASL) or weight the MRI signal by cerebral blood flow (CBF) and cerebral blood volume (CBV). The CBV method requires injection of a class of MRI contrast agents that are now in human clinical trials. Because this method has been shown to be far more sensitive than the BOLD technique in preclinical studies, it may potentially expand the role of fMRI in clinical applications. The CBF method provides more quantitative information than the BOLD signal, albeit at a significant loss of detection sensitivity [33].

Like any technique, fMRI has advantages and disadvantages, and in order to be useful, the experiments that employ it must be carefully designed and conducted to maximize its strengths and minimize its weaknesses.

Some of the advantages of fMRI:[33]

- It can noninvasively record brain signals without risks of radiation inherent in other scanning methods, such as CT or PET scans.

- It has high spatial resolution. 2–3 mm is typical but resolution can be as good as 1mm.
- It can record signal from all regions of the brain, unlike EEG/MEG which are biased towards the cortical surface.
- fMRI is widely used and standard data-analysis approaches have been developed which allow researchers to compare results across labs.
- fMRI produces compelling images of brain "activation."

Here is also some of its (fMRI) disadvantages:[33]

- The images produced must be interpreted carefully, since correlation does not imply causality, and brain processes are complex and often non-localized.
- Statistical methods must be used carefully because they can produce false positives. One team of researchers studying reactions to pictures of human emotional expressions reported a few activated voxels in the brain of a dead salmon when no correction for multiple comparisons was applied, illustrating the need for rigorous statistical analyses [34].
- The BOLD signal is only an indirect measure of neural activity, and is therefore susceptible to influence by non-neural changes in the body. This also means that it is difficult to interpret positive and negative BOLD responses [35].

- BOLD signals are most strongly associated with the input to a given area rather than with the output. It is therefore possible (although unlikely) that a BOLD signal could be present in a given area even if there is no single unit activity [36].

- fMRI has poor temporal resolution. The BOLD response peaks approximately 5 seconds after neuronal firing begins in an area. This means that it is hard to distinguish BOLD responses to different events which occur within a short time window. Careful experimental design can reduce this problem. Also, some research groups are attempting to combine fMRI signals that have relatively high spatial resolution with signals recorded with other techniques, electroencephalography (EEG) or magnetoencephalography (MEG), which have higher temporal resolution but worse spatial resolution.

- fMRI has often been used to show activation localized to specific regions, thus minimizing the distributed nature of processing in neural networks. Several recent multivariate statistical techniques work around this issue by characterizing interactions between "active" regions found via traditional univariate techniques.

- The BOLD response can be affected by a variety of factors, including: drugs/substances;[37] age, brain pathology;[38] local differences in neurovascular coupling;[39] attention;[40] amount of carbon dioxide in the blood;[41] etc.

Nowadays the brain activity detection – Neurological signals- can be done by a continuous (real time) fMRI. The main advantages to fMRI as a technique to image brain activity related to a specific task or sensory process include 1) the signal does not require injections of radioactive isotopes, 2) the total scan time required can be very short, i.e., on the order of 1.5 to 2.0 min per run (depending on the paradigm), and 3) the in-plane resolution of the functional image is generally about 1.5 x 1.5 mm although resolutions less than 1 mm are possible. Due to the ability to image the entire 3-dimensional volume of brain, fMRI is capable of isolating many simultaneous and coordinated brain events. This "multi-level" view of brain activity can include "executive" functions and high level cognitive tasks simultaneously with the primary and secondary input such as vision and audition as well as cerebellar contributions [60].

For these reasons, Functional imaging provides insights into neural processing that are complementary to insights of other studies in neurophysiology.

Researchers from Johns Hopkins University's Peabody Institute used MRI to study spontaneity and creativity on jazz musicians. They found that a region of the brain known as the dorsolateral prefrontal cortex, a broad portion of the front of the brain that extends to the sides, showed a slowdown in activity during improvisation. This area has been linked to planned actions and self-censoring, such as carefully deciding what words you might say at a job interview. Shutting down this area, dorsolateral prefrontal cortex, could lead to lowered inhibitions and self-generated behaviors (such as improvisation) occur here in the absence of the context typically provided by the lateral prefrontal regions according to researcher Limb [51]. Deactivation of this DLPFC may be associated with defocused, free-floating attention that permits spontaneous unplanned associations, and sudden insights or realizations [59].

The researchers also saw increased activity in the medial prefrontal cortex, which sits in the center of the brain's frontal lobe. This area has been linked with self-expression and activities that convey individuality, such as telling a story about yourself [51].

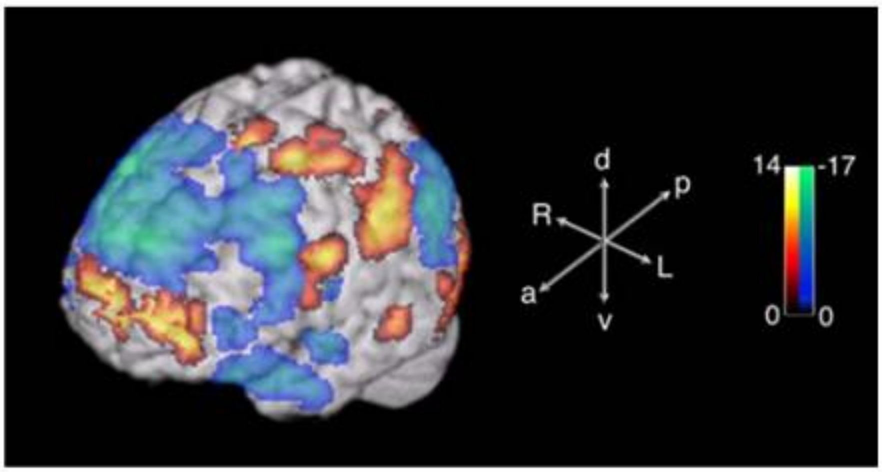


Figure 5 Three-dimensional surface projection of activations and deactivations associated with improvisation during the Jazz paradigm. Medial prefrontal cortex activation, dorsolateral prefrontal cortex deactivation, and sensorimotor activation can be seen. The scale bar shows the range of t-scores; the axes demonstrate anatomic orientation. Abbreviations: a, anterior; p, posterior; d, dorsal; v, ventral; R, right; L, left.

Source: [51]

II.V. ***Meditation***

WHAT is mediation and HOW is meditation related to the current study?

Meditation refers to any of a family of practices in which the practitioner trains his or her mind or self-induces a mode of consciousness in order to realize some benefit [42][43][44]. A review of scientific studies identified relaxation, concentration, an altered state of awareness, a suspension of logical thought and the maintenance of a self-observing attitude as the behavioral components of meditation;[46] it is accompanied by a host of biochemical and physical changes in the body that alter metabolism, heart rate, respiration, blood pressure and brain activation.[47][48] Meditation has been used in clinical settings as a method of stress and pain reduction. Meditation has also been studied specifically for its effects on stress.[49][50]

Meditation is the key for opening the doors of mysteries to your mind. In that state man abstracts himself: in that state man withdraws himself from all outside objects; in that subjective mood he is immersed in the ocean of spiritual life and can unfold the secrets of things-in-themselves.[45]

Meditation is related to our study in several perspectives:

- During meditation, practitioners try to control their minds and go in a state where they have an internal concentration (tracking) within their bodies. On the other hand, in our experiment the musicians have to concentrate on a piece of music when they are listening (tracking).

- An important series of neural changes have been noticed in the mPFC region of meditators, as will be shown later in the section. Interestingly, similar activation in the same region occurs while jazz musicians improvise.
- One of the aspects of the project is to determine whether that region, mPFC, is responsible for creativity. Furthermore, Alpha waves may appear to correspond to creativity. The more Alpha waves emitted, the more creative activity is occurring. It has been shown in some studies that mediation practitioner's EEG shows more Alpha waves compared to the control group.

In this context, it is shown that long-term meditation practitioners showed more activation in the prefrontal cortex during meditation than did novice mediators [3]. It was shown that the dipoles for the diffuse high-amplitude Alpha waves (in order to have a creative inspiration, your brain needs to be able to generate a big burst of Alpha brain waves [10]) are localized to both the mPFC (which is the part of the brain our study focuses on) and ACC.[11]

Previous studies have reported that meditators demonstrate better attentional functioning and lower levels of stress than do non-meditators [4,5].

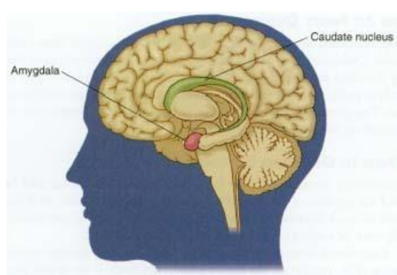
In a comparison study between meditators and non-meditators, meditators showed stronger activations in the rostral anterior cingulate cortex and the dorsal medial prefrontal cortex bilaterally, compared to controls. Greater rostral anterior cingulate cortex activation in meditators may reflect stronger processing of distracting events. The increased activation in the medial prefrontal cortex may reflect that meditators are engaged in emotional processing. [6]

III. **Hypothesis**

People perceive and respond to music in different ways. The level of musicianship of the performer and the listener as well as the manner in which a piece is performed affects the "experience" of music. An experienced and accomplished musician might hear and feel a piece of music in a totally different way than a non-musician or beginner. This is why two accounts of the same piece of music can contradict themselves. [1].

Researchers from Johns Hopkins University's Peabody Institute used MRI to study spontaneity and creativity on jazz musicians found that the dorsolateral prefrontal cortex showed a deactivation during improvisation. This area has been linked to planned actions and self-censoring, such as carefully choosing words at a job interview. Shutting down this area could lead to lowered inhibitions, Limb suggests. Those researchers also saw increased activity in the medial prefrontal cortex, which sits in the center of the brain's frontal lobe. This area has been linked with self-expression and activities that convey individuality, such as telling a story about yourself [51]. This can give us an indication that the jazz musician may be shutting off the parts of the brain that are responsible on self-monitoring. This may lead to an increased capability for creating new music and allow the musicians to focus within themselves and be in state of isolation from the surroundings. This state of mind is similar to what was proved by Britta Holzel that long-term meditation practitioners showed more activation in parts of the medial prefrontal cortex during meditation than did novice mediators, and they are more emotionally engaged 6]. While another experiment studied the cortical regions involved in the generation of musical structures during improvisation was done on non-jazz pianists who were asked to improvise. Results showed that the activated brain regions included the right dorsolateral prefrontal cortex, the presupplementary motor area, the rostral portion of the dorsal premotor cortex, and the left posterior part of the superior temporal gyrus. It is suggested that because the non-jazz pianists were not trained to improvise, as opposed to the jazz musicians, they were having scattered neurological activities in different sides of the brain. This may be due to thinking, remembering and other logical and self-censoring processes that increase the complexity load in the DLPFC. However, the increase in the DLPFC activity may be attributed to the non-jazz pianists inability to improvise.

Another interesting study found out that the amygdala—the center of the brain involved in emotion— became active as the listeners tried to put themselves in the player's position.



Figure(6): Amygdala (source: scienceblogs.com)

In the experiment, if a musician thought a piece of music was improvised and not strictly performed, he activated the same brain networks that he would if he were improvising it. This also included the activation of some motor centers associated with physical performance. Furthermore, the musicians who rated themselves in a questionnaire as more “empathetic” were better at picking out the improvisations as opposed to the strictly performed listening examples [13]. Limb suggests that jazz musicians must exhibit a sort of dissociation in the frontal lobe by which the large part of the brain controlling self-monitoring is not inhibiting self-expression of new, free-flowing ideas. This suggests that empathetic musicians try to create emotional involvement between their minds and the music, in order to predict what will be coming next. There might be a good chance that the more emotional engagement the musicians get in, the more accurate prediction occurs, as the study indicated. It is suggested that such emotional engagement might lead to betterment in the improvisational ability.

In the hypothesis, the intent is to optimize activity in the MPFC through the real time manipulation of aural input while simultaneously monitoring the MPFC. It is very plausible that in order to reach this heightened activity of mPFC, the subject must enjoy the aural input when listening, indicating a greater emotional involvement. Although the hypothesis concentrates at the whole entity of mPFC, a study found that Left medial prefrontal cortex activity was positively correlated with pleasure, and favorite music [14]. it is plausible that as more active listening and more emotional engagement occurs (in other words the more preferable and favorable music), there should be a heightened activity in the mPFC. This will be monitored by a continuous real time fMRI.

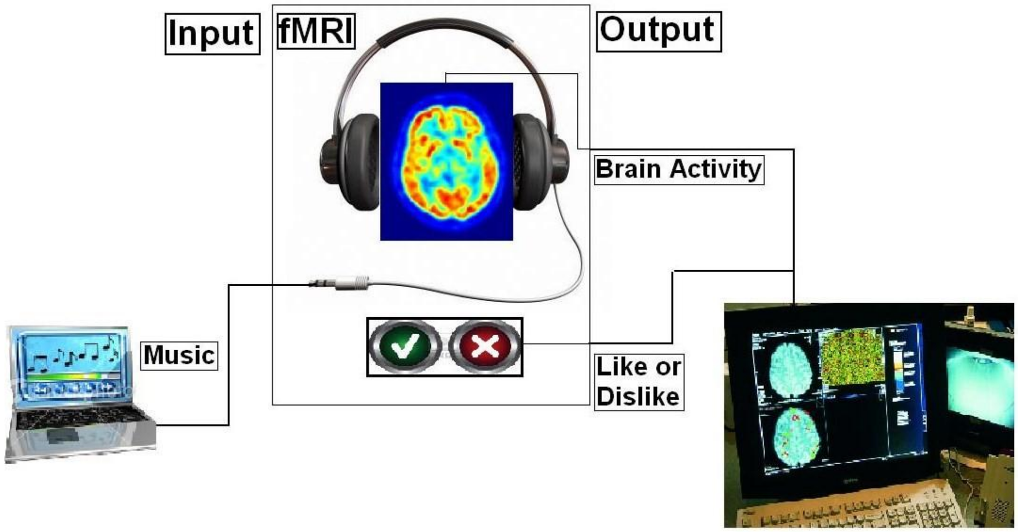
In this way, while listening to piece of music the activity in the brain, particularly in mPFC, will be an indication of whether emotional involvement is happening or not and so the aural input will alter depending on this biofeedback from the brain to keep a heightened activity state on that region, mPFC.

Ⅳ. ***Methodology***

There have been several approaches to develop brain–machine interfaces. Real Time fMRI provides a novel interface with the nervous system that offers the possibility of directly reading aspects of a person's brain activation state. It has potential applications in many contexts, particularly when a patient cannot communicate verbally. [52]

The suggested experiment will use the functional MRI and the software (E-Prime) to detect, record and analyze the activity of the brain in the medial prefrontal cortex that is timely synchronized with the decision making through a two buttons keyboard that the musician can choose either like or dislike when he/she is listening to some part of music. Both of the output data from the MRI and the keyboard will go to the analyst computer, where E-Prime will collect the data from both sources to determine how the like/dislike decision is related to the mPFC activity. In other words, whether the activity is getting lower or higher with the like/dislike recorded data or there is no relationship.

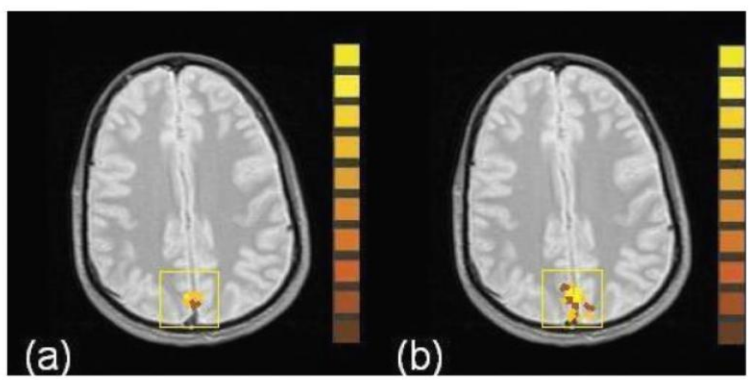
The experiment diagram is shown in the figure below:



FIGURE(7): Experiment Diagram: Two outputs could be collected when subject is listening to music.

The activation information from the mPFC can be depicted both as a scrolling line graph or as a changing image of a virtual fire, as well as the acquired data will be recorded by the E-Prime software. According to that, it is very plausible to see increased activity (more neurons firing), when listening to a favorable music, as shown in Figure 2.

Figure 8:
fMRIoxygen measures brain activation during listening to music.
a) Less favorable music.
b) More favorable music.



V. *Suggestions*

This section gives suggestions and recommendations to solve problems that might be facing the execution of this experiment.

V.I. *Noise Reduction:*

For every decision making process including moving limbs or voluntarily actions, there will be a correspondent activity in the brain. This may result in some mixing between the movement of the finger, the thinking process, and the mPFC activity that goes on when the musician decides whether they like or dislike the music. In order to get rid of some part of that noise, the following simple filtering method could be used:

First, capturing an image when the musician is doing nothing; to be called rest stage (1). Then an image when the musician is pressing on one of the buttons should be taken; that is called stage (2). After that, during doing the experiment where it is expected to see brain activity, which is due to two reasons: finger movement plus listening to the music; let us call it stage (3). In order to get rid of the noise “finger movement”, simple adding and subtraction can be made as following: add stages 1 and 3 and subtract 2; to get what we called stage (4), which is the image that we need to study. This can be illustrated by the following figure; figure3:

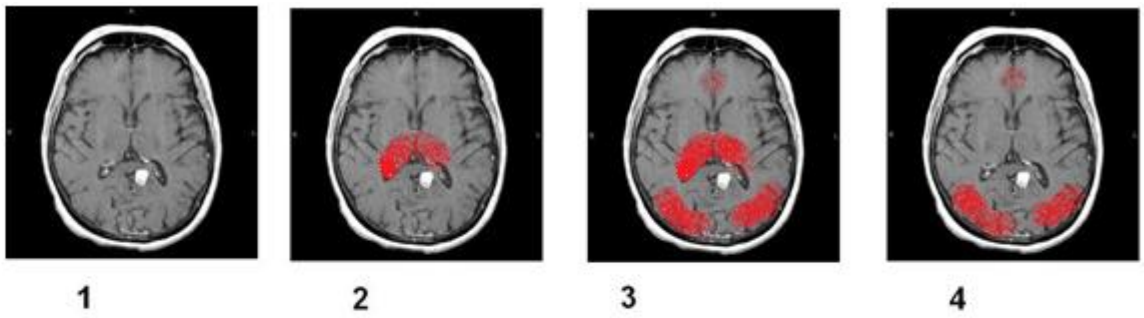


FIGURE (9): A Filter Concept to get rid of the noise resulting from pressing the like/dislike buttons. Where 1: Rest-state. 2: Pressing one buttons- state. 3: The Listening and like/dislike decision- state. 4: The resultant image from (3+1-2).

V.II. *Engaging Music Listening to Emotions*

Amygdala is involved with the emotions. This might be also true for the mPFC. The experiment could be divided into two groups: Group (A) showing the subjects pictures along with music listening that come in the same context for example: sad music comes with a picture of a break moment or a picture symbolizes loneliness, the opposite is applicable too so a picture of wedding for example with happy music and so on. Group (B) will be the control group for those not seeing pictures, but listening to the same music. After the data is being collected and comparisons are made, there might be a chance to see different activity levels, possibly higher in group (A), due to more emotional engagement.

V.III. *Quality and Speed of Imaging*

The most common technique for continuous brain activity detection is the BOLD effect, explained previously in the MRI section. Besides that, there are a lot of adjustable parameters when using the fMRI that need to be figured out, such as the magnetic field strength in Tesla, echo time (TE) in milliseconds, field of view (FOV) - spatial encoding area of the image-, flip angle (FA) -which means how much the net magnetization is rotated, due the second RF excitation, relative to the main magnetic field direction-, repetition time (TR), and the resolution measured by the voxel, three dimensional pixel, size... etc. Those parameters could be adjusted to get different sampling rate (Number of images / amount of time) with different resolution. It is recommended that a fast sampling rate of 1 to 2 images per second would work properly. Bearing in mind that a good quality for the images is important, the small changes in the blood flow in the brain - due to neuro-activation- need to be noticed.

V.IV. *Strengthening the mPFC activity by Rewarding*

Because we are dealing with an indirect detecting system that depends basically on the blood flow and not the neuro-activation itself as explained before, it is a must to think about how we could reduce the noise (e.g. increase in the blood flow due to another reason other than the brain activity), and also increase the strength of the activation in the region interest-ROI- (mPFC) in order to get a clearer image. Some information from a previous study(2001) done by Blood and Zatorre[53], could be used to strengthen the activation magnitude, where they found that some part of the medial prefrontal area and other regions in the brain are linked to rewards and motivation. That could be useful for increasing the intensity of activation by using some sort of rewarding. For example, telling the participants in advance to the experiment that the best music -that will be composed depending on the activation changes- chosen by a judge, the participant will get a certain amount of money!

V.V. ***Images Interpolation***

As we have introduced in the intro and the methodology, it is very possible that the liking/disliking decision and the imaging may occur at different times (meaning the decision could be taken place so it lags or leads the closest image). In this case, it is suggested to interpolate the images (average them), similar to what is used in mathematics. Interpolation could be done between 2 preceding images and 2 succeeding images. All of that will be done after the data from the experiment are already collected. MATLAB could be very useful in converting the image into matrices (values for pixels) and then to use its interpolation functions.

V.VI ***EEG-fMRI collaboration***

The last suggestion, which might be added to experiment, is using EEG-fMRI procedure. This new technology was first implemented in the late nineties, to reflect the brain's electrical activity, and in particular post-synaptic potentials in the cerebral cortex, whereas fMRI is capable of detecting haemodynamic changes throughout the brain through the BOLD effect. EEG-fMRI therefore allows measuring both neuronal and haemodynamic activity which comprise two important components of the neurovascular coupling mechanism [54]. It is very important to remember the correlation between the alpha wave (from EEG and corresponds to creativity) and the mPFC, which is suggested as a center for musical creativity. If our hypothesis is correct, the alpha wave emission should increase with the increase of the mPFC activity.

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