Project Number: FB: 0100

CREATIVITY AND FLOW IN MUSIC

An Interactive Qualifying Project Report

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by

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Abstract

The relation of where creativity occurs, in accordance with the brain, remains largely unknown. To analyze this concept, the form of creativity that was selected was music, in particular jazz improvisation. After much practice, during improvisation, the musician experiences a phenomenon called flow, where the performer "loses themself" in the performance. Creativity is amplified, as the performer is one with the music. Methods for musicians in reaching such a condition were investigated, such as meditation and sleep. These techniques were found to not be applicable, in a reasonable manner, to facilitate musicians in entering the state of flow.

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1. Introduction

Many musicians have expressed the state of mind of flow in the midst of their performance. After rehearsal for his Grammy Awards performance in 2007, John Frusciante, former guitarist of the popular rock band, Red Hot Chili Peppers, was interviewed. One of the questions asked referred to what occurs in his mind during the process of performing and the effortlessness that he exhibits while playing guitar. Frusciante's response was: "Nothing. The idea there is to shut your mind off. Music comes thru you when you're not thinking, when you just learn to surrender to the current of music. It's not about thinking anything or planning anything. You just learn to shut your mind off gradually through years and years of practice".[1]

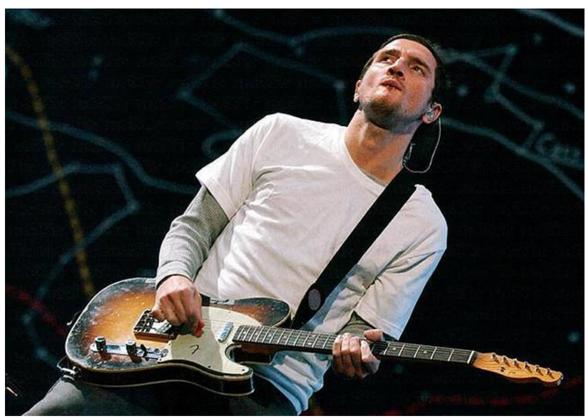

Figure 1: John Frusciante[2]

In this process, it is said to be a release of all distractions and outside interference, a complete focus on the music. It guides the performer to conduct the most natural piece of expression because they become one with the piece. As a listener, it is possible for anyone to channel this stimulation. The participators of meditation are also believed to enter a similar condition of concentration in

[1] "Red Hot Chili Peppers Grammy Rehearsal / John Frusciante Interview." YouTube. Video file, 31:04. Posted April 3, 2013. Accessed April 27, 2013. http://www.youtube.com/watch?v=Yd6TcxcMvSQ.

[2] *John Frusciante.* Photograph. flickr. February 12, 2008. Accessed April 27, 2013. http://www.flickr.com/photos/dragao/2260166093/in/set-72157605557619270.

their practice. The goal of this project is to investigate the correlation between the brain activity of flow with musicians and listeners, to that of a meditator's serene state of mind. A musician's education can be looked at as expressionless, due to the unintentional procedure of restriction. If there exists a relationship between the two, meditation should and can be used to facilitate the process of entering flow and spur creativity. The concept of sleep will also be investigated. Due to the creativity that occurs during dreaming, the state of flow can display strong resemblance. Most significantly, this study will explore the neurological aspects that pertain to flow.

2. Background

2.1 Creativity and Flow

Creativity is a universal element of human behavior, although the neural aspects of it remain largely unknown. It is often described as "occurring in an altered state of mind beyond conscious awareness or control".[3] Mihaly Csikszentmihalyi describes the importance of creativity and explains how humans can become more creative in his book, "Creativity: Flow and the Psychology of Discovery and Invention". He expresses that creativity is assisted by a "genetic predisposition" for a given domain. This implies that some people are born with certain talents depending on their genes to excel, such as a person being born with a perfect pitch doing well in music. Being superior at their corresponding domain, such as art or music, creative people become increasingly interested, become more knowledgeable, and thus are in a better position to innovate in their field with less difficulty.[4] Although the measure of how talented someone is can't be evaluated by their performance as a child or if there even allowed access to their domain depending

[3] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679

[4] Csikszentmihalyi, Mihaly. "Creativity: Flow & the Psychology of Discovery & Invention." Last modified May 9, 1997. Microsoft Word. : 2-3.

on their upbringing and mentors/teachers (luck) to display their talent, an early interest and determination in their domain is essential to creativity.[5] The creative process for the subjects mentioned is characterized by sustained concentration and losing oneself in their craft, called a flow experience. Focus and concentration are vital to attain flow.[6] The elements that exemplify a flow experience, as distinguished by Csikszentmihalyi are:[7]

- Clear goals every step of the way
- Immediate feedback to one's actions
- Balance between challenges and skills – Task difficulty and ability of person must be equal. If not, anxiety or boredom will occur.[8]
- Action and awareness are merged – Involuntary action transpires with minimal or no attention.[9]
- Distractions are excluded from consciousness
- No worry of failure
- Self-consciousness disappears – Removal of internal thoughts and social phobias. Replaced with pleasant thoughts. [10]

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[5] Csikszentmihalyi, Mihaly. "Creativity: Flow & the Psychology of Discovery & Invention." Last modified May 9, 1997. Microsoft Word. : 3.

[6] Ibid., 6.

[7] Ibid., 6.

[8] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 301.

[9] Ibid., 301.

[10]Ibid., 301.

- Sense of time becomes distorted – Time becomes faster or slower than conceivable.[11]
- The activity becomes autotelic – Task is seen as “intrinsically rewarding”, and completing the work is comparable to executing a goal.[12]

Combined with long periods of time of focus and concentration during flow, creative people have an abundant amount of enthusiasm and innovation. Most significantly, though, Csikszentmihalyi explains that the energy harnessed by creative individuals during these experiences is “internally generated” and the focus that is produced outweighs any advantage one might have from their genetics.[13] Distractions hinder flow and it may take hours to re-attain the serenity of mind that is necessary to complete the task. If the work is more ambitious, it will take longer to achieve a flow experience, while getting distracted becomes easier.[14] Also, for their work to triumph, it is important for creative individuals to follow the pace of action with taking time off to reflect.[15]

Örjan de Manzano et al explores the concept of flow experience by analyzing the flow-inducing task of playing a piano in his article, “The Psychophysiology of Flow During Piano Playing”. Manzano et al describes flow as “what motivates people to devote more time to certain activities than would be expected based solely on associated external rewards”.[16] The universal element among humans who experience flow is the “intrinsically rewarding experience” that one

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[11] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 301.

[12] Ibid., 301.

[13] Csikszentmihalyi, Mihaly. "Creativity: Flow & the Psychology of Discovery & Invention." Last modified May 9, 1997. Microsoft Word. : 3

[14] Ibid., 6.

[15] Ibid., 3.

[16] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 301.

feels when engulfed in such an activity, which leads to additional, desired practice.[17] The state of flow is complemented with an emotional state distinguished by medium to high levels of valence and arousal. The flow experience, in fact, depends on the emotional state.[18] The emotional state is directly associated with the characteristics of a flow experience, as described by Csikszentmihalyi. For example, pleasant emotions reduce the self-conscious awareness characteristic. Attention is a human trait that is essential for maintaining and executing goals, and is essential to the flow experience. The contradiction, in relevance to flow, though, is how concentration has to be effortless, yet still considerably focused. Manzano et al hypothesizes that this could be due because a task that requires a substantial amount of attention may be experienced with less effort in a state of positive affect.[19] Expertise, while not vital for flow, has shown to maintain attention, reduce distractions, and increase many, if not all facets of flow. In relation to the challenge-skill characteristic of a flow experience, the task difficulty and skill of the performer must be equal. If the task is fixed, a certain skill level of the performer may be necessary if the task is too challenging or too simple. Contrarily, if it is variable, a high skill level (expertise), in pair with a task of great challenge, promotes probability of flow.[20] Based on the following information, Manzano et al defines flow as "the subjective experience of an interaction between positive valence and high attention during performance of a nontrivial task whose difficulty is on par with the skill level of the subject, which is facilitated by a certain level of expertise".[21] A musical instrument, such as a

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[17] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 301.

[18] Ibid., 302 .

[19] Ibid., 302.

[20] Ibid., 302.

[21] Ibid., 302.

piano, is well suitable for conducting an experiment to explore flow. Playing a piano is considered a flow-inducing task, not just because it contains all requirements for producing a high level of flow, but because it creates a state of mind of high valence/arousal and high concentration, which enhances the experience.[22] The experiment that Manzano et al conducted was choosing a group of experts of twenty-one professional classical pianists. The task was for each individual to select a piece of music that they were comfortable with and could play well, which would correspond to a three to seven minute performance. The design of the experiment was intentional, in that its purpose was for the performer to select a piece of music that would increase the probability of a high level of flow. After each trial, flow was measured using self-reports and physiological measures acquired during each trial.[23] The results of this experiment, when skill and task were constant, were that the two components that generated the largest variance were Concentration and Autotelic. These two dimensions are disputably most associated with attention and emotional state.[24]

2.2 Brain Activity During Music Improvisation

As previously mentioned, the neural aspects of creativity remain largely unknown. However, regions of the brain can be analyzed that are active/inactive during a creative process, and therefore a correlation can be made of their functions to that of the dimensions of flow. The creative process that will be examined is music improvisation. Musical improvisation is an act of spontaneous creativity that is not prepared by the musician during a performance, but instead an

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[22] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 304.

[23] Ibid., 304.

[24] Ibid., 309.

impulsive phenomenon of “ad-lib” that is pure expression of the musical framework that the performer is subjected to. It is also the cornerstone for jazz music, whose structure is dependent upon improvisation, and many other forms of music.

Charles Limb and Allen Braun discuss this topic in their article, “Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation”. For their experiment they selected six professional jazz musicians that were evaluated with functional MR brain scans, while playing a piano keyboard in a fMRI setting. Two paradigms were constructed that were opposing extremes of musical complexity for testing the subjects. Scale was comparatively low in musical complexity, while Jazz was high. For each paradigm, there was a control condition and an improvisational condition.[25] The control conditions dealt with either repeatedly playing quarter notes in a one-octave C major scale (ScaleCtrl) or playing the composition with the supplement of the audio recording of a pre-recorded jazz quartet (JazzCtrl). The improvisation conditions concern either improvising a melody utilizing quarter notes in a C major scale within the same octave (ScaleImprov) or improvising using the chord structure of the composition and supplement of the audio recording of a pre-recorded jazz quartet (JazzImprov).[26]

The neural results of the following conditions displayed that spontaneous improvisation led to the activation of the medial prefrontal cortex (mPFC) and deactivations of the dorsolateral prefrontal cortex (DLPFC) and amygdala. The control conditions exhibited the reciprocal outcomes in the majority of neural regions tested.[27]

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[25] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 2.

[26] Ibid., 2.

[27] Ibid., 3.

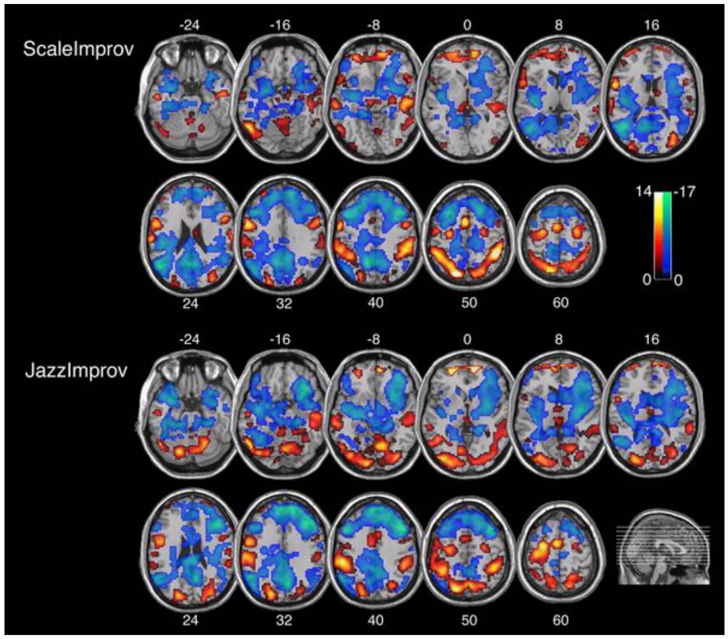

Figure 2: Axial slice renderings of mean activations (red/yellow scale bar) and deactivations (blue/green scale bar) associated with improvisation during Scale and Jazz paradigms[28]

The function of each region will benefit correlating the following results of a flow-inducing task, such as playing a piano (music improvisation), to where flow and creativity occurs in the brain. The mPFC region concerns the "neural instantiation of self, organizing internally motivated, self-generated, and stimulus-independent behaviors".[29] The DLPFC plays a role in "effortful problem-solving, conscious self-monitoring, and focused attention", or goal-directed behavior.[30] Limb and Braun suggest that deactivation of the DLPFC may be connected to "defocused, free-floating attention" that allows for "spontaneous unplanned associations, and sudden insights or

[28] *Axial slice renderings of mean activations (red/yellow scale bar) and deactivations (blue/green scale bar) associated with improvisation during Scale and Jazz paradigms*. Image. Not Totally Rad. March 4, 2008. http://lh5.ggpht.com/thesamurairadiologist/R8zuRqgS7zI/AAAAAAAAAMk/pSPB-UTitho/s800/Axial-Brains-journal.pone.0001679.g002.png.

[29] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 4.

[30] Ibid., 4.

realizations".[31] Furthermore, creative instinct may function when "an attenuated DLPFC no longer regulates the contents of consciousness, allowing unfiltered, unconscious, or random thoughts and sensations to emerge".[32] In summary, based on the following results, musical creativity may stem from triggering intentional, self-generated behavior (mPFC) with disconnection of self-monitoring and goal-directed behavior (DLPFC). Concerning the amygdala, deactivation may be credited to the positive emotional valence that one experiences during improvisation.

Sara Bengtsson and Mihaly Csikszentmihalyi executed a similar experiment in their article, "Cortical Regions Involved in the Generation of Musical Structures during Improvisation in Pianists". They, too, used fMRI to analyze brain activity during music performance using a piano keyboard. The only significant difference between their approach compared to that of Limb and Braun were the subjects that were chosen. Limb and Braun selected six professional jazz musicians, while Bengtsson and Csikszentmihalyi chose eleven professional Swedish concert pianists. Three paradigms were produced for their research: Improvise, Reproduce, and FreeImp. The Improvise model involved the musician improvising on a given visually presented melody, with the awareness of having to memorize what they just performed. Reproduce concerned the musician playing the performance they memorized in Improvise. FreeImp dealt with the musician improvising, similar to the Improvise paradigm, but with no concern of memorizing their performance.

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[31] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 2.

[32] Ibid., 4.

The results of these experiments displayed that DLPFC activity increased, notably with higher activity being seen in FreeImp than in Improvise.[33] From the information given, it can be seen that this article contradicts the Limb and Braun article in relation to the results according to the DLPFC. The authors suggest that the main function of the DLPFC in improvisations is to "maintain and execute an overall plan for the improvisation through top-down influences on the activity".[34] Possibly, a reason for the contrast in results between the two experiments, according to the DLPFC, may be associated to the type of musician being analyzed, as this is the only noteworthy difference between the two settings.

2.3 Methods of Measurement

Scientists have conducted various research studies on the effects of meditation on the brain by studying the change in brain activity with the use of tools such as Electroencephalograms (EEG), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), and Functional Magnetic Resonance Imaging (fMRI).

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[33] Bengtsson, Sara L., Mihaly Csikszentmihalyi, and Fredrik Ullen. "Cortical Regions Involved in the Generation of Musical Structures during Improvisation in Pianists." *Journal of Cognitive Neuroscience* 19, no. 5 (May 2007): 830-42.

[34] Ibid., 839.

2.3.1 MRI / fMRI

Figure 3: Image of an fMRI Scanner[35]

MRI and fMRI are both employed to image the brain or other body parts. MRI functions by utilizing a magnet, along with radio waves, to create an image. The patient is to lie down in a cylindrical shaped machine while radio waves are sent to the patient.[36] Due to the magnetic field created by the magnet, the protons inside the patient's body are aligned with the magnetic field.[37] The sent radio waves disturb the aligned protons and causes the protons to be displaced temporarily, in which they will then return to their original alignment.[38] The action of moving protons as they realign causes radio waves to be emitted, which are captured to construct an image.[39] fMRI can be used to measure brain activity by detecting changes in oxygen and blood

[35] Picture of a Siemens fMRI Scanner. Image. SingularityHUB. April 24, 2009. http://singularityhub.com/wp-content/uploads/2009/04/fmri_machine_scanner.jpg.

[36] "What is fMRI?" Bayor College of Medicine. Last modified April 7, 2005. http://www.bcm.edu/news/packages/trust-fmri.cfm.

[37] Ibid.

[38] Ibid.

[39] Ibid.

flow.[40] It functions very similarly to MRI, except that it considers the facet that blood consists of iron, as well as the aspect that the amount of blood in an area correlates with activity.[41] For example, a more active brain area would exhibit more blood in the area. The iron, similarly to the protons, would cause distortions in the magnetic field, which would result in emission of radio waves to the receiver: “A large amount of freshly oxygenated blood pours into any activated brain structure, reducing the amount of oxygen-free (deoxy) hemoglobin. This causes a small change in the magnetic field, and thus the MRI signal, in the active region”.[42] The main advantage of using MRI or fMRI is that it is non-invasive and does not involve the use of radioactive material.[43] The disadvantages are that due to the magnetic field, metallic objects or pacemakers, or other similar devices, would be regarded as dangerous for the patient.[44] Other disadvantages are that due to fact that the patient must lie down in the cylindrical shaped machine, the patient may feel uncomfortable or claustrophobic. The noise generated by the machine may be distracting to the patient. As a result, the patients are required to wear earplugs.[45] Thus, the use of MRI or fMRI may affect results in which a completely relaxed or concentrated state is required for the subjects.

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[40] Devlin, Hannah. "What is Functional Magnetic Resonance Imaging (fMRI)?" Edited by John M. Grohol. PsychCentral. Last modified July 6, 2012. http://psychcentral.com/lib/2007/what-is-functional-magnetic-resonance-imaging-fmri/.

[41] "What is fMRI?" Bayor College of Medicine. Last modified April 7, 2005. http://www.bcm.edu/news/packages/trust-fmri.cfm.

[43] Weissman, Daniel. "What is fMRI?" Attention and Cognitive Control Laboratory. http://www.lsa.umich.edu/psych/danielweissmanlab/whatisfmri.htm.

[44] Ibid.

[45] Ibid.

2.3.2 EEG

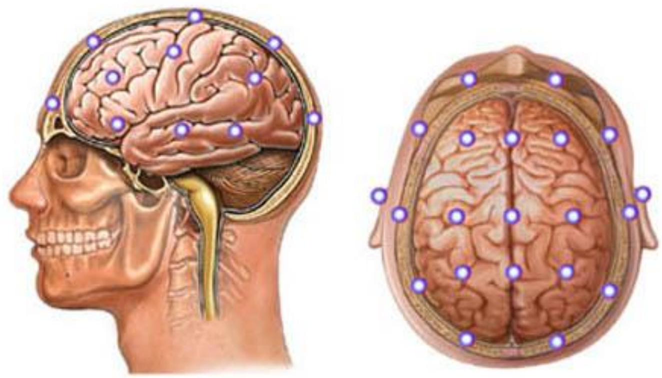

Figure 4: Image depicting the various locations for the EEG Probes[46]

EEG is a test that measures the electrical activity of one's brain by using sensors, such as electrodes.[47] The test measures for brain waves, which are categorized as Alpha, Beta, Delta, and Theta.[48] The Alpha waves are only present when the patient is awake with his or her eyes closed. These waves are not present if one's eyes are opened or are in a concentrative state.[49] Beta waves are usually found when the patient is alert or have taken medication, such as benzodiazepines.[50] Both Delta and Theta waves are usually found in young children or when the patient is asleep.[51]

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[46] Image of brain with locations for EEG probes depicted. Beth Israel Deaconess Medical Center. http://www.bidmc.org/CentersandDepartments/Departments/Medicine/Divisions/CardiovascularMedicine/DiseasesandConditions/Arrhythmias/LongQTSyndrome/~/media/Images/CentersandDepartments/Medicine/CardiovascularMedicine/Diagnosis/Sensor%20Placement%20for%20EEG.ashx.

[47] "Electroencephalogram (EEG)." WebMD. Last modified July 26, 2010. http://www.webmd.com/epilepsy/electroencephalogram-eeg-21508.

[48] Ibid.

[49] Ibid.

[50] Ibid.

[51] Ibid.

Together, these brain waves can be analyzed to determine the status of a patient to detect possible abnormality of the brain. Since the EEG test uses brain waves, the accuracy of the test is not as accurate as the MRI or fMRI tests. The major advantage of the EEG test is that it is safe, such that it only measures electrical activity and does not send any electrical current to the patient.[52] A risk associated with the EEG test is that the patient may need to take medication that would increase risks for seizure during the test, but such medication would only apply to tests that are designed to specifically study seizures.[53] In summary, the EEG test is generally a safe method, but is perhaps not as accurate as the MRI and fMRI tests.

2.3.3 PET

Figure 5: Image of a Positron Emission Tomography Machine[54]

PET utilizes radioactive substance to measure activity of tissues and organs of a patient, in which the radioactive substance used depends on which tissue/organs are being examined.[55] The

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[52] "Electroencephalogram (EEG)." WebMD. Last modified July 26, 2010. http://www.webmd.com/epilepsy/electroencephalogram-eeg-21508.

[53] Vrocher, Diamond, III, and Mark J. Lowell. "Electroencephalography (EEG)." emedicinehealth. http://www.emedicinehealth.com/electroencephalography_eeg/page2_em.htm#eeg_risks.

[54] Image of Positron Emission Tomography Machine. Tokyo Clinic. http://www.tokyo-cl.com/english/images/equipment3.jpg.

[55] "Positron emission tomography (PET) scan." MayoClinic. http://www.mayoclinic.com/health/pet-scan/MY00238.

patient is injected with a radioactive substance known as a tracer, which is usually a form of glucose.[56] The areas that are more active will have more radioactive substance, since higher activity correlates with higher chemical activity.[57] The radioactive material emits positrons, which a machine can record to construct an image. The more radioactive substance there exists in an area, the brighter the image.[58] Risks of the PET test is that the patient may find it difficult to remain lying still, causes anxiety due to the PET scanner, and could possibly lead to cell damage due to the use of radioactive material, although this risk is low.[59] Due to the fact that the patient may have difficulty remaining still, as well as possible anxiety, the test may not be accurate for tests requiring absolute concentration.

2.4 The Brain

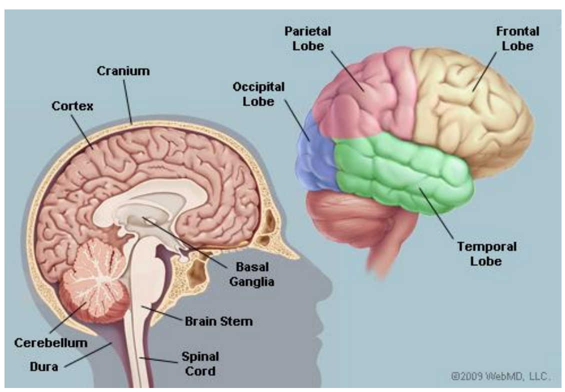

Figure 6: Portions of Brain

The most complex organ without a doubt is the brain. The human brain is separated into many portions, as depicted by Figure 6 from WebMD. Notice that the brain has been categorized

[56] "Positron Emission Tomography (PET)." WebMD. Last modified July 28, 2011. http://www.webmd.com/a-to-z-guides/positron-emission-tomography.

[57] "Positron emission tomography (PET) scan." MayoClinic. http://www.mayoclinic.com/health/pet-scan/MY00238.

[58] Ibid.

[59] "Positron Emission Tomography (PET)." WebMD. Last modified July 28, 2011. http://www.webmd.com/a-to-z-guides/positron-emission-tomography.

into many sections, as well as 4 general divisions, which are known as lobes. According to WebMD, the four lobes are associated with specific functionalities:[60]

- “The frontal lobes are responsible for problem solving and judgment and motor function.”
- “The parietal lobes manage sensation, handwriting, and body position”.
- “The temporal lobes are involved with memory and hearing”.
- “The occipital lobes contain the brain’s visual processing system”.

WebMD mentions that the cortex of the brain is associated with thinking and voluntary movements.[61] Several researchers refer to the cortex as “grey matter”.[62] The human brain has also been separated into areas known as Brodmann Areas.[63] The Brodmann Area system assigns numerical numbers to the many brain regions to more easily refer to them.[64]

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[60] WebMD. Image Depicting the Brain, Separated into Various Sections. Image. WebMD. 2009. http://img.webmd.com/dtmcms/live/webmd/consumer_assets/site_images/articles/image_article_collections/anatomy_pages/brain2.jpg.

[61] WebMD. "Brain and Nervous System Health Center." WebMD. Last modified 2009. http://www.webmd.com/brain/picture-of-the-brain.

[62] "Human Brain Structure." NewsMedical. http://www.news-medical.net/health/Human-Brain-Structure.aspx.

[63] University of Michigan. "The Human Brain." University of Michigan. http://www.umich.edu/~cogneuro/jpg/Brodmann.html.

[64] Ibid.

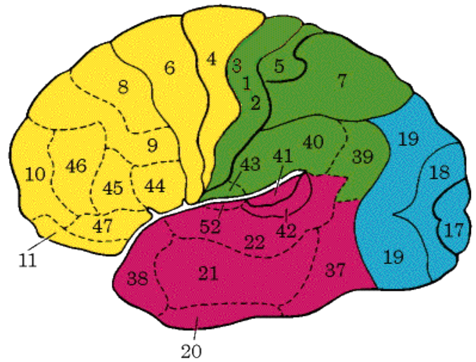

Figure 7: Brodmann Area Map[65]

Figure 7 shows the Brodmann Area Map, where the yellow sections make up the frontal lobe, the green sections make up the parietal lobe, the pink/purple areas make up the temporal lobe, and the blue sections make up the occipital lobe.[66] The brain areas of concern for this paper are the frontal lobes, as well as the cortex.

2.5 Brain Areas

2.5.1 Dorsolateral Prefrontal Cortex

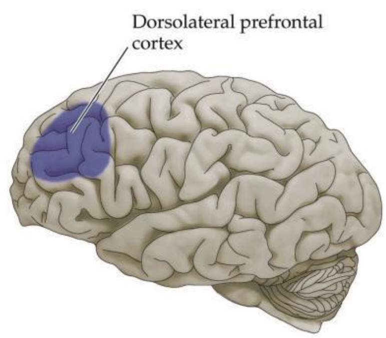

Figure 8: Image showing the location of the Dorsolateral Prefrontal Cortex[67]

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[65] University of Michigan. *Sagittal View*. Image. University of Michigan. http://www.umich.edu/~cogneuro/jpg/Brod_hemi2.gif.

[66] University of Michigan. "The Human Brain." University of Michigan. http://www.umich.edu/~cogneuro/jpg/Brodmann.html.

[67] Picture of the brain indicating the location of the Dorsolateral Prefrontal Cortex. Image. Quora. http://qph.cf.quoracdn.net/main-qimg-38fdc7bb0971c0922881586d94b14b97.

One of the brain areas within the frontal lobes and cortex is the Dorsolateral Prefrontal Cortex (DLPFC). As shown in Figure 8, the Dorsolateral Prefrontal Cortex (DLPFC) is an area located in the front of the brain. According to Bradley Voytek, the DLPFC is strongly linked with processing information to and from the sensory regions of the brain.[68] The sensory areas refer to the basic forms of sense, such as visual, auditory, touch, smell, and taste.

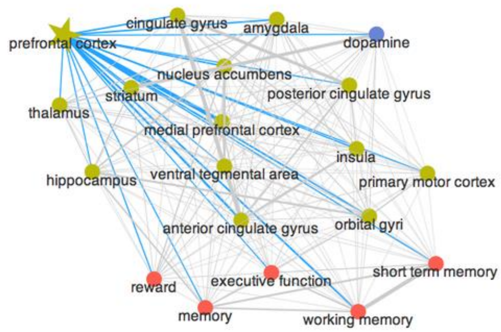

Figure 9: Image showing the connections and associations of the prefrontal cortex to other brain areas and functions[69]

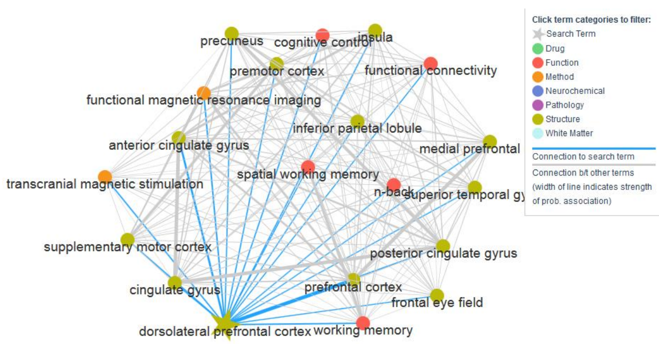

Figure 10: Image generated by BrainSCANr that shows the connections and associations of the DLPFC with other brain areas and functions[70]

[68] Voytek, Bradley. "Neuroanatomy: What are the Primary Functions of the Dorsolateral Prefrontal Cortex?" Quora. http://www.quora.com/Neuroanatomy/What-are-the-primary-functions-of-the-dorsolateral-prefrontal-cortex#%29.

[69] Voytek, Bradley. Image showing associations of the Dorsolateral Prefrontal Cortex with other areas and functions of the brain. Photograph. Quora. http://qph.is.quoracdn.net/main-qimg-07991ec87d57289d5f90cad8d0c5c748.

[70] Voytek, Bradley, and Jessica Bloger Voytek. Image showing associations of the DLPFC and other brain areas and functions. BrainScanr.

As seen in Figure 9, the prefrontal cortex, in general, is connected with various other brain areas including the amygdala, memory related areas, and executive function. Figure 10 shows the associations of the DLPFC. Notice that the DLPFC is linked with the working memory, among many other associations.

The DLPFC is related to logic and reasoning. This is evident through the various studies that have been conducted. The DLPFC has been linked with decision-making, as shown in a study conducted by Marios G. Philiastides et al.[71] The authors define decision-making as: "Perceptual decision making is the process of choosing one option or course of action from a set of alternatives based on information gathered from sensory systems".[72] The key concept from this definition is that the chosen option is based on gathered information, which relates decision making to logic and reasoning. Decision-making consists of an analytical aspect, where the person compares each possible answer to another in order to determine the best choice. The study investigated the required amount of evidence each subject needed to reach a decision, as well as the time required to reach such a decision. The authors conducted this study by comparing the outcome of the subjects who's DLPFC was disrupted in one trial, in relation to undisrupted DLPFC in another trial. The results displayed that the accuracy decreased, while the reaction time increased, after the DLPFC was disrupted.[73] The findings also exhibited that the rate of gathering evidence has reduced for subjects with disrupted DLPFC compared to undisrupted DLPFC.[74] Along with the

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http://www.brainscanr.com/Search?term_a=dorsolateral+prefrontal+cortex.

[71] Philiastides, Marios G, Ryszard Auksztulewicz, Hauke R Heekeren, and Felix Blankenburg. 2011. Causal role of dorsolateral prefrontal cortex in human perceptual decision making. *Current Biology* 21 (11) (6/7): 980-3.

[72] Ibid, 980.

[73] Ibid, 981.

[74] Ibid, 982.

reduction in evidence gathering, the authors also mention that the time necessary to reach a decision remained the same, indicating that the disruption of the DLPFC only affected the information gathering process.[75] Since the time required to reach a decision remained the same, the disruption of the DLPFC caused less information to be processed. This demonstrates that the DLPFC is indeed, in some way, associated with the gathering of information, which is related to the process of decision-making. Therefore, a disrupted or inactive DLPFC would somehow cause issues for decision making, and therefore activities associated with logic and reasoning.

Robert S. Blumenfeld and Charan Ranganath have conducted a study showing connections between the DLPFC and the working memory brain areas by using fMRI to monitor the DLPFC.[76] The study consisted of subjects who proceed through two types of tests, one for "rehearsal", and another for "reordering".[77] Rehearsal pertains to memorization of the word by simply repeating the given sets of words, while reordering relates to the reorganization of words into the correct category.[78] The aspect of organization is also associated with the concept of logic and reasoning. In order to organize something, one must first analyze the object, in order to determine which category would best fit the object. Memorization involves temporarily "holding" on to the given information. Accordingly, the rehearsal aspect is to hold on to the information, then to replay it. Unlike organization, the memorization does have an analytical aspect. The results displayed that

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[75] Philiastides, Marios G, Ryszard Auksztulewicz, Hauke R Heekeren, and Felix Blankenburg. 2011. Causal role of dorsolateral prefrontal cortex in human perceptual decision making. *Current Biology* 21 (11) (6/7): 980-3.

[76] Blumenfeld, Robert S., and Charan Ranganath. 2006. Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organization. *The Journal of Neuroscience* 26 (3) (January 18): 916-25.

[77] Ibid, 916.

[78] Ibid, 916 – 917.

the activity of the DLPFC have increased much more significantly during the reorder test than the rehearsal test.[79] The authors explain that the results from the study indicate that the DLPFC is associated with organization of the working memory.[80] Since the DLPFC showed much more significant activity during the reorganization trial, the results indicate the role of the DLPFC is more related with the organizational aspect, rather than storing or memorization. Therefore, the DLPFC is utilized for organization, which plays a role in the concept of logic and reasoning skills.

The DLPFC has been shown to be associated with the concept of self-evaluation in a study conducted by Taylor W. Schmitz, Tisha N. Kawahara-Baccus, and Sterling C. Johnson.[81] The subjects of the study participated in three trials: "self-evaluation, significant other evaluation, and semantic positively evaluation".[82] These three trials differentiate evaluation into three categories. During the self-evaluation trial, the subject is to determine whether or not the presented adjective matches oneself. Similarly, the significant other-evaluation pertains to determining whether or not the adjective matches a close friend or family member.[83] Lastly, during the semantic positively evaluation trial (control), the subject simply determines whether or not the given adjective is a positive word or not.[84] The concept of self-evaluation is to analyze oneself, where one may ask themself whether or not he is doing something correctly. When one is in deep concentration, it

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[79] Blumenfeld, Robert S., and Charan Ranganath. 2006. Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organization. *The Journal of Neuroscience* 26 (3) (January 18): 919.

[80] Ibid, 923.

[81] Schmitz, T. W., T. N. Kawahara-Baccus, and S. C. Johnson. 2004. Metacognitive evaluation, self-relevance, and the right prefrontal cortex. *Neuroimage* 22 (2): 941-7.

[82] Ibid, 942.

[83] Ibid, 942.

[84] Ibid, 942.

would seem logical for the self-evaluation to be turned off. The results of the study demonstrated that during both the self and other-evaluation, when compared to the semantic positively evaluation, various brain areas depicted activity, such as the medial prefrontal cortex, medial orbital cortex, and the thalamus, which showed activation.[85] Although the self and other evaluations displayed similar brain activation when compared to the control, the authors also compared the results of the two evaluations to each other. The results found that for the self-evaluation, there was significant DLPFC activation, especially the right DLPFC.[86] The authors state that since the results from this study indicate that the right DLPFC showed significant activation during the self-evaluation, compared to the other-evaluation, then the right prefrontal cortex of the brain is associated with the evaluation of oneself.[87]

2.5.2 Working Memory

Pascale Michelon describes: "Working memory is the ability to keep information current in mind for a short period, while using this information for the task at hand".[88] Therefore, the working memory is associated with memorization, such that information is stored in a temporary area. This indicates that the working memory behaves as a short term memory, and that the stored information is utilized shortly after it is stored. Therefore, the working memory may play an important role in tasks that demand quick actions. Alan Baddeley has categorized the working memory as a brain system made up of three portions, the "central executive", "phonological loop",

[85] Schmitz, T. W., T. N. Kawahara-Baccus, and S. C. Johnson. 2004. Metacognitive evaluation, self-relevance, and the right prefrontal cortex. *Neuroimage* 22 (2): 944.

[86] Ibid, 945.

[87] Ibid, 945.

[88] Michelon, Pascale. "What is Working Memory? Can it be Trained?" SharpBrains. Last modified November 16, 2010. http://www.sharpbrains.com/blog/2010/11/16/what-is-working-memory-can-it-be-trained/.

and a “visuospatial sketch pad”.[89] The key idea is that the working memory is not a specific brain area, but a network of the brain, or system.

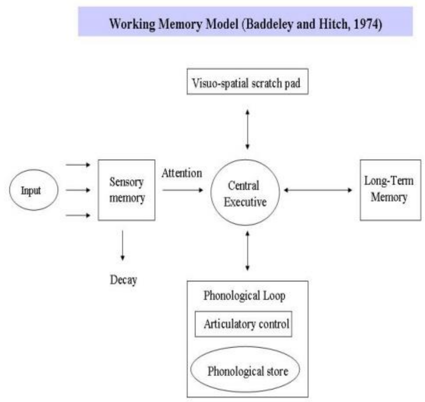

Figure 11: Baddeley’s and Hitch’s Model for the Working Memory[90]

Figure 11 depicts the system of working memory proposed by Alan Baddeley and Graham Hitch. The “central executive” is thought to be associated with the control and utilization of “phonological loop” and “visuospatial sketch pad”.[91] As seen in the figure, information is processed by the central executive, and then is able to either send or receive information to the phonological loop or visuospatial sketch pad. The phonological loop is associated with the auditory information, while the visuospatial sketch pad is relates to visual information.[92] According to Baddeley, the phonological loop contains two parts, the “phonological store” and the “articulatory control process”.[93] The “phonological store” can be visualized as a storage area that maintains

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[89] Baddeley, Alan. 1992. Working memory. *Science* 255 (5044) (Jan 31, 1992): 556, http://search.proquest.com/docview/213552179?accountid=29120.

[90] Alan Baddeley's and Graham Hitch's model of the working memory. Image. SimplyPsychology. 2012. http://www.simplypsychology.org/Working%20Memory2.jpg.

[91] McLeod, Saul. "Working Memory." SimplyPsychology. Last modified 2008. http://www.simplypsychology.org/working%20memory.html.

[92] Ibid.

[93] Baddeley, Alan. 1992. Working memory. *Science* 255 (5044) (Jan 31, 1992): 558, http://search.proquest.com/docview/213552179?accountid=29120.

auditory information, such as sounds and voice, for 1 to 2 seconds, while the "articulatory control process" can be seen as the sub-vocalization, which is one's "inner speech".[94] The inner speech refers to when one reads or speaks to oneself mentally, without articulating any sound. Baddeley also explains that information is stored and maintained through the process of sub-vocalization and "sub-vocal repetition".[95] Since sub-vocalization is associated with the processing of auditory information, perhaps by improving sub-vocalization skills, one can improve auditory related tasks.

Jan W. de Fockert et al conducted a study that connects the working memory to the act of maintaining visual attention.[96] The study consisted of presenting a low load and a high load for working memory to the subjects, while visual stimulus was also presented as distractors.[97] The low load pertains to less content for the subject to remember, while high load relates to more content that is to be remembered. The working memory should then be less activated in low load scenarios compared to high load. The distractive visual stimulus was to present names, along with a picture of a person's face, which may or may not match. The subject is then to remember the presented content prior to the distractive stimulus, as well as indicate whether the name was of a famous person or politician.[98] The results of the study demonstrated that the reaction times of the subjects, during the indication of the presented name, were higher for the high load trials compared to the low load.[99] The higher reaction time would relate to the tendency to be distracted. The authors

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94 Baddeley, Alan. 1992. Working memory. *Science* 255 (5044) (Jan 31, 1992): 558, http://search.proquest.com/docview/213552179?accountid=29120.

95 Ibid.

96 de Fockert, Jan W., Geraint Rees, Christopher D. Frith, and Nilli Lavie. 2001. The role of working memory in visual selective attention. *Science* 291 (5509) (March 02): 1803-6.

97 Ibid, 1804.

98 Ibid, 1804.

99 Ibid, 1804.

explain that this implies that when the working memory is occupied with a high load of content to process, the subjects would be more affected by the distractions.[100] Therefore, the study shows that if the working memory is over loaded, one may not be able to maintain attention due to being more prone to distractions. Since the study displays a connection between the working memory and attention, perhaps the training of the working memory can improve attention. The training of the working memory may increase its capacity, which would then lead to the ability to handle larger loads of information.

Engle et al also conducted a study that shows the correlation between the working memory and attention, but with the auditory aspect.[101] The subjects were presented with two different audio recordings, simultaneously, in which the subject was to repeat the words that they hear in one ear, while ignoring the audio presented in the other ear; the ignored audio consists of the subject's name.[102] The subject was to indicate how many times they had heard their name in the audio.[103] The hearing of one's name from the audio to be ignored shows that the subject was distracted. This is due to the fact that since the audio was to be ignored, the subject is to focus their attention entirely on the other audio recording and completely block off the ignored audio. The results displayed that much more of subjects with low working memory capacity indicated that they had heard their names, compared to subjects with high working memory capacity.[104] The outcome indicates that people with high working memory capacity are less prone to distraction.

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[100] de Fockert, Jan W., Geraint Rees, Christopher D. Frith, and Nilli Lavie. 2001. The role of working memory in visual selective attention. *Science* 291 (5509) (March 02): 1805.

[101] Engle, Randall W. 2002. Working memory capacity as executive attention. *Current Directions in Psychological Science* 11 (1) (February 01): 19-23.

[102] Ibid, 22.

[103] Ibid, 22.

[104] Ibid, 22.

Engle et al have also conducted a study where subjects were presented a list of 10 words, in which they were to remember and then perform a task right after.[105] The results demonstrated that the subjects with a higher capacity for working memory tend to remember more of the presented words than those with lower capacity.[106] This indicates that people with a high working memory capacity have a larger storage for information. From the various studies conducted by Engle, the results together indicate that people with high working memory capacity are able to maintain more information, as well as being able to maintain attention more effectively, than those with low working memory capacity.

2.5.3 Amygdala

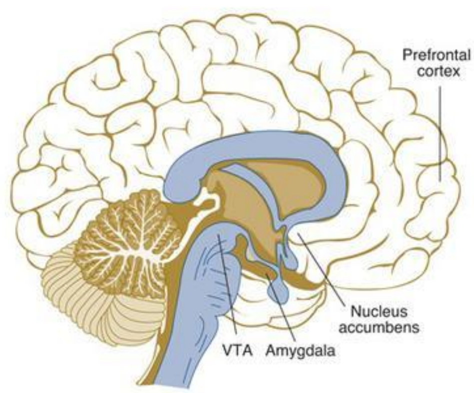

Figure 12: Image showing the location of the amygdala of a human brain[107]

According to Anthony Wright, the Amygdala is associated with emotion and motivation.[108] Ralph Adolphs et al have conducted a study which investigates the correlation between the

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[105] Engle, Randall W. 2002. Working memory capacity as executive attention. *Current Directions in Psychological Science* 11 (1) (February 01): 20.

[106] Ibid., 20.

[107] Picture of the brain showing the location of the amygdala. Image. Dictionary.com. http://img.dictionary.com/amygdala-323349-400-326.jpg.

[108] Wright, Anthony. "Limbic System: Amygdala." Neuroscience Online. http://neuroscience.uth.tmc.edu/s4/chapter06.html.

amygdala and facial recognition.[109] The authors would ask the subjects to rate the approachability and trustworthiness of the faces they see. Facial recognition pertains to understanding how the person feels, based on his facial expression. The results indicated that all the subjects would rate the faces more positively, and that when rating negative faces, their ratings were much more different than the controls.[110] This shows that the amygdala is required for the analysis of emotions. Without the amygdala, one would make inaccurate judgments. The authors also noted that the subject with the most severe amygdala damage made the most mistakes.[111] This indicates that the degree of damage on the amygdala is inversely correlated with the accuracy of the analysis.

Adolphs et al further investigated the relationship between the amygdala and social judgment by having the subjects determine the approachability and trustworthiness of a person, based on adjectives or background information. The outcome displayed that all three subjects with amygdala damage performed normally.[112] The authors explain that the reason was that since the verbal description was sufficient, the amygdala was not needed to determine the approachability or trustworthiness.[113] This shows that the amygdala is utilized for the analysis of emotional information. Since the verbal description was enough, the amygdala was not necessary to process the data. For the visual trials, the amygdala was required because the subjects were to analyze their

[109] Adolphs, R., D. Tranel, and A. R. Damasio. 1998. The human amygdala in social judgment. Nature-London-: 470-3.

[110] Ibid., 471.

[111] Ibid, 471.

[112] Ibid, 472.

[113] Ibid, 472.

visual perceptions, in order to reach an adjective that would determine whether or not the person is approachable or trustworthy.

A study conducted by Elizabeth A. Phelps et al has linked the amygdala to fear.[114] The study involves the utilization of fMRI to monitor the brain activity, where the subjects were connected to electrodes. The subjects were told that when they see one of the two colored squares, they may receive an uncomfortable, but un-painful shock. They were also told that they would not receive a shock for the other colored square or for the word "rest".[115] Although the subjects were told that they may receive a shock, no actual shocks were given.[116] The results of the study showed significant increases in activity for the left amygdala and a moderate increase in the right amygdala.[117] This result demonstrates that the amygdala would activate when the subject is in an emotional state, which in this case is fear. The study also indicated that the amygdala activity tended to decrease during the safe state.[118] The safe state would be associated with being calm. Therefore, the deactivation implies that the amygdala was not required due to the lack of emotional stimulus.

A study conducted by Stefan Koelsch et al, investigated the effects of pleasant and unpleasant music on the brain emotionally.[119] Their results showed that the amygdala tends to activate when the subject listens to unpleasant music, and deactivates when listening to pleasant

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[114] Phelps, E. A., K. J. O'Connor, J. C. Gatenby, J. C. Gore, C. Grillon, and M. Davis. 2001. Activation of the left amygdala to a cognitive representation of fear. *Nature Neuroscience* 4 (4): 437-41.

[115] Ibid., 437.

[116] Ibid, 438.

[117] Ibid, 438.

[118] Ibid, 439.

[119] Koelsch, Stefan, Thomas Fritz, D. Yves v. Cramon, Karsten Müller, and Angela D. Friederici. 2006. Investigating emotion with music: An fMRI study. *Human Brain Mapping* 27 (3): 239-50.

music.[120] This result shows that in terms of emotion, the amygdala is specifically associated with unpleasant emotions. Pleasant emotions would correspond to calmness, happiness, and joy, while unpleasant emotions would relate to fear and anger. The various studies of the amygdala that were mentioned previously also support this notion. Notice that although the study conducted by Adolphs et al [121] related amygdala to emotion, the method that was utilized only included unpleasant emotion. Their study asked the subjects to determine the trustworthiness and approachability of a person.[122] The process of determining trustworthiness and approachability is similar to determining how unpleasant the person is or how afraid the subject is of the person. Similarly, the study conducted by Phelps et al[123] also used methods that only include unpleasant emotion. Their study revolved around the concept of fear, which also is an unpleasant emotion. Wright also mentions that the removal of the amygdala have been shown to induce tameness in animals and calmness in humans.[124] If the state of being calm is considered as a pleasant emotion, then the result indicate that the removal of the amygdala leads to a more pleasant emotional experience. In both the studies conducted by Adolphs et al and Phelps et al, the amygdala displayed activations. Therefore, based on these results, the amygdala is specifically associated with unpleasant emotions, where the amygdala would activate when one experiences emotions, such as fear, and deactivate when one experiences pleasant emotions, such as happiness.

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[120] Koelsch, Stefan, Thomas Fritz, D. Yves v. Cramon, Karsten Müller, and Angela D. Friederici. 2006. Investigating emotion with music: An fMRI study. *Human Brain Mapping* 27 (3): 239-50.

[121] Adolphs, R., D. Tranel, and A. R. Damasio. 1998. The human amygdala in social judgment. Nature-London-: 470-3.

[122] Ibid., 472.

[123] Phelps, E. A., K. J. O'Connor, J. C. Gatenby, J. C. Gore, C. Grillon, and M. Davis. 2001. Activation of the left amygdala to a cognitive representation of fear. *Nature Neuroscience* 4 (4): 437-41.

[124] Adolphs, R., D. Tranel, and A. R. Damasio. 1998. The human amygdala in social judgment. Nature-London-: 470-3.

2.5.4 Medial Prefrontal Cortex

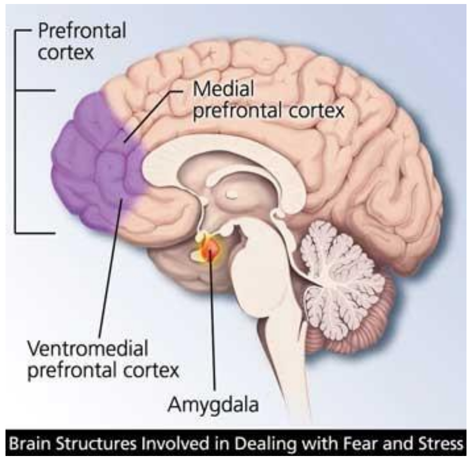

Figure 13: Medial Prefrontal Cortex[125]

The medial prefrontal cortex (mPFC) is another area of the brain, which is shown in Figure 13. Notice that it is within the prefrontal cortex region. A study conducted by Gui Xue et al have associated the mPFC to the aspects of risks and rewards.[126] Their study utilized a computerized gambling simulation where there are two options, a risky and a safe option.[127] The idea is for the subject to choose either the risky or safe options, during the gain (subject gains money) or loss (subject loses money) trials of the game.[128] The safe option consists of only one option, where the subject can win (or lose) $1, during the respective trials. For example, during the gain phase, the subject's choices are associated to gaining money. Similarly, during the loss trial, the subject's

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[125] *Brain Structures Involved in Dealing with Fear and Stress*. Photograph. The Female Brain's Reaction to Stress. December 6, 2010. http://3.bp.blogspot.com/_4ify7vDXrDs/TP1Njm7u7mI/AAAAAAAAGw8/Q4VedNlNUP0/s400/amygdala_and_medial_prefrontal_cortex_vmpfc.jpeg.

[126] Xue, Gui, Zhonglin Lu, Irwin P. Levin, Joshua A. Weller, Xiangrui Li, and Antoine Bechara. 2009. Functional dissociations of risk and reward processing in the medial prefrontal cortex. *Cerebral Cortex* 19 (5) (May 01): 1019-27.

[127] Ibid., 1019 – 27.

[128] Ibid., 1020.

choices are associated with losing money. Therefore, the goal is for the subject to maximize his or her earnings during the gain trial, while minimizing the losses during the loss trial.[129] The risky option presents the subject three possible scenarios, where he or she may be able to win (or lose), but the values are greater than $1.[130] The outcome of this study indicated that the dorsal mPFC exhibited activation when the subject made a risky choice, compared to a safe choice.[131] Therefore, this study shows that the dorsal medial prefrontal cortex is specifically associated with risk or uncertainty.

2.6 Meditation

Meditation consists of a variety of different techniques, such as Yoga and Zen meditation. According to Antoine Lutz et al, in "Attention Regulation and Monitoring in Meditation", the many forms of meditation can be categorized into two main sections, "Focused Attention (FA)" and "Open Monitoring (OM)" meditation.[132] They explain that the goal of FA meditation is to completely concentrate on a single object, and to practice the ability to sustain this concentration: "One style, Focused Attention (FA) meditation, entails the voluntary focusing of attention on a chosen object".[133] OM meditation is associated with the focusing aspect, but not on any explicit or specific object: "The other style, Open Monitoring (OM) meditation, involves non-reactive

[129] Xue, Gui, Zhonglin Lu, Irwin P. Levin, Joshua A. Weller, Xiangrui Li, and Antoine Bechara. 2009. Functional dissociations of risk and reward processing in the medial prefrontal cortex. *Cerebral Cortex* 19 (5) (May 01): 1019-1020.

[130] Ibid, 1020.

[131] Ibid, 1022.

[132] Lutz, Antoine, Heleen A. Slagter, John D. Dunne, and Richard J. Davidson. 2008. "Attention Regulation and Monitoring in Meditation." *Trends in Cognitive Sciences* 12 (4): 163-169. doi:10.1016/j.tics.2008.01.005. ,1

[133] Ibid., 1.

monitoring of the content of experience from moment to moment".[134] The idea is to practice the aspect of being able to concentrate on any object or event in the surrounding, but being flexible enough such that this attention can jump from one to another. Therefore, both forms of meditation still revolve around the concept of focus and high concentration, but differ in the end goal of where the focus is invested.

Many studies have been conducted by researchers to investigate the effects of meditation on the brain. Various studies used either fMRI or MRI to investigate the brain activity of experienced meditators. Others have also measured the density of grey matter of the brain to determine the impact of meditation over a long period of time. A higher thickness of grey matter would correlate to a more activated area.[135] The controls of the various studies were either a group of novice meditators or experienced meditators in a resting state. At first thought, a state of meditation may be thought to be equivalent to a state of rest, however this assumption is incorrect. There is a difference between a meditative state and a restful state. In a meditative state, one is focused and aims to sustain concentration, while in a restful state, the person does not sustain any concentration or focus on any particular object.

K. A. Brefczynski-Lewis et al in "Neural Correlates of Attentional Expertise in Long-Term Meditation Practitioners" compared the brain activity of expert meditators to that of novices with the use of fMRI.[136] The study separated meditators into groups of novices and experts by the factor

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[134] Lutz, Antoine, Heleen A. Slagter, John D. Dunne, and Richard J. Davidson. 2008. "Attention Regulation and Monitoring in Meditation." *Trends in Cognitive Sciences* 12 (4): 163-169. doi:10.1016/j.tics.2008.01.005. ,1

[135] Lazar, Sara W., Catherine E. Kerr, Rachel H. Wasserman, Jeremy R. Gray, Douglas N. Greve, Michael T. Treadway, Metta McGarvey, Brian T. Quinn, Jeffery A. Dusek, and Herbert Benson. 2005. Meditation experience is associated with increased cortical thickness. *Neuroreport* 16 (17): 1893 -7.

[136] Brefczynski-Lewis, J. A., A. Lutz, H. S. Schaefer, D. B. Levinson, and R. J. Davidson. 2007. "Neural Correlates of Attentional Expertise in Long-Term Meditation Practitioners." *Proceedings of the National Academy of Sciences of the United States of America* 104 (27): pp. 11483-8. http://www.jstor.org/stable/25436140.

of time spent in meditation. Brefczynski-Lewis et al claims that their research demonstrate that the amount of time spent on meditation, in hours, correlates in an “inverse u-shaped curve” to brain activity in the regions pertaining to attention.[137] The “inverse u-shaped” correlation implies that as more time is spent on meditation, the brain activity first increases, but then significantly decreases. Their tests were conducted in a manner such that the brain activity during meditation was compared to the brain activity occurred while the meditators were resting. They split the expert meditators into two groups, one with more time spent on meditation and one with less.[138] Their study show that the group with more time spent resulted in a less active brain, when seen as a function of time.[139] They indicate that the expert meditators did in fact show activation in the DLPFC, but in both cases, the activity would decrease right after the spike of activation.[140] The expert meditators, who have spent more time in practicing meditation, depicted a faster decrease of activation of the DLPFC after an initial spike of activation than the expert meditators with less experience.[141] This result displays that the meditators with more time have less brain activity, since the brain quickly returned to initial state. The meditators with less time lasted much longer, indicating that the brain is active for a much longer period of time. These results show that meditation does in effect increase activity of the DLPFC, but the activity would attenuate faster for meditators with more experience. Less brain activity for the expert meditators compared to the

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[137] Brefczynski-Lewis, J. A., A. Lutz, H. S. Schaefer, D. B. Levinson, and R. J. Davidson. 2007. "Neural Correlates of Attentional Expertise in Long-Term Meditation Practitioners." *Proceedings of the National Academy of Sciences of the United States of America* 104 (27): pp. 11483.

[138] Ibid, 11484.

[139] Ibid, 11484.

[140] Ibid, 11484.

[141] Ibid, 11484.

novice meditators in various brain areas, including the DLPFC and the amygdala were also found.[142] This indicates that meditation may also decrease the DLPFC activity, since expert meditators showed less DLPFC activity than novice meditators. The decrease in amygdala activity may be due to the calm state that is associated with concentration and focus in meditation. These results together, demonstrate that the effects of meditation on the DLPFC are mixed, where it changes accordingly with experience. Initially, meditation will cause increases in DLPFC activity, such as for novices, however after a certain amount of experience has been accumulated, DLPFC activity would decrease, such as for experts.

E. Baron Short et al also investigated the DLPFC brain activity of meditators during a session of meditation.[143] The study compared the meditative state to a control state, where the meditators were occupied with a task of determining the color or presented shapes.[144] The concept behind the control state is to ensure that the meditators were not meditating; the authors were concerned that if the meditators were told to rest, they may enter a meditative state.[145] The results demonstrated that the activity of the DLPFC for less experienced meditators was larger during meditation, but was only evident when meditation was conducted first, rather than control.[146] The outcome also indicated that the DLPFC activity would increase as a function of time, regardless

[142] Brefczynski-Lewis, J. A., A. Lutz, H. S. Schaefer, D. B. Levinson, and R. J. Davidson. 2007. "Neural Correlates of Attentional Expertise in Long-Term Meditation Practitioners." *Proceedings of the National Academy of Sciences of the United States of America* 104 (27): pp. 11486.

[143] Short, E. B. 2010. "Regional Brain Activation during Meditation shows Time and Practice Effects: An Exploratory FMRI Study." *Evidence-Based Complementary and Alternative Medicine* 7 (1): 121.

[144] Ibid., 122.

[145] Ibid., 122.

[146] Ibid., 124.

of whether control or meditation was conducted first.[147] Therefore, meditation causes an increase in DLPFC activity for less experienced meditators. For the DLPFC with more experienced meditators, activity was larger during meditation, when meditation was conducted first. Activity increased as a function of time in the trial when control was conducted first.[148] For expert meditators, the correlation between meditation and the DLPFC is mixed. As indicated from the results, the DLPFC activity would be different depending on whether the control or meditation trials were conducted first. Regardless, in both trials, the DLPFC displays increase in activity. Overall, the results from the study indicate that the DLPFC would lead to an increase in DLPFC activity for either novice or expert meditators.

Wendy Hasenkamp et al have investigated the brain activity for FA meditation, where they specifically looked into the activity during the multiple stages that a meditator would experience during a session of meditation.[149] The authors describe that FA meditation consists of four states, which they call: Focus, Shift, Mind Wandering (MW), and Aware.[150] These four states pertain to the FA meditation method, in which the meditator's goal is to sustain attention onto a certain object, such as one's own breath. During the meditation process, the meditator may lose attention. The meditator must become aware that he or she has lost focus and must return to the focused state once again. The results indicated that there was noticeable DLPFC activity during the Shift state,

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[147] Short, E. B. 2010. "Regional Brain Activation during Meditation shows Time and Practice Effects: An Exploratory FMRI Study." *Evidence-Based Complementary and Alternative Medicine* 7 (1): 124.

[148] Ibid., 124.

[149] Hasenkamp, Wendy, Christine D. Wilson-Mendenhall, Erica Duncan, and Lawrence W. Barsalou. 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59 (1) (1/2): 750-60.

[150] Ibid., 751.

as well as the Focus state.[151] This result indicates that during FA mediation, the DLPFC is used specifically when the meditator is in the process of fixating his or her focus. Therefore, after the meditator has become aware that attention was lost, the DLPFC is utilized to refocus and maintain attention. During the MW state, activity in various brain areas were found, including the medial prefrontal cortex (medial PFC).[152] This finding indicates that the medial PFC may be associated with unfocused states, where the meditator has lost concentration and attention.

Antonietta Manna et al in "Neural Correlates of Focused Attention and Cognitive Monitoring in Meditation investigated the brain activity of FA and OM meditators by comparing the brain activity of meditators during the meditative state to a resting state, with the use of fMRI.[153] The study made multiple comparisons, FA vs Rest, OM vs Rest, and FA vs OM, with both experts and novices. The results of the comparison between FA meditation of experts and rest demonstrated that there was lower brain activity in multiple areas, including the medial frontal

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[151] Hasenkamp, Wendy, Christine D. Wilson-Mendenhall, Erica Duncan, and Lawrence W. Barsalou. 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59 (1) (1/2): 754.

[152] Ibid., 754.

[153] Manna, Antonietta, Antonino Raffone, Mauro Gianni Perrucci, Davide Nardo, Antonio Ferretti, Armando Tartaro, Alessandro Londei, Cosimo Del Gratta, Marta Olivetti Belardinelli, and Gian Luca Romani. 2010. "Neural Correlates of Focused Attention and Cognitive Monitoring in Meditation." *Brain Research Bulletin* 82 (1–2): 46-56. doi:10.1016/j.brainresbull.2010.03.001.

[153] Hasenkamp, Wendy, Christine D. Wilson-Mendenhall, Erica Duncan, and Lawrence W. Barsalou. 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59 (1) (1/2): 751.

[153] Ibid, 754.

[153] Ibid., 754.

[153] Manna, Antonietta, Antonino Raffone, Mauro Gianni Perrucci, Davide Nardo, Antonio Ferretti, Armando Tartaro, Alessandro Londei, Cosimo Del Gratta, Marta Olivetti Belardinelli, and Gian Luca Romani. 2010. "Neural Correlates of Focused Attention and Cognitive Monitoring in Meditation." *Brain Research Bulletin* 82 (1–2): 46-56. doi:10.1016/j.brainresbull.2010.03.001.

gyrus and the DLPFC.[154] Notice that from this study, the outcome indicated a deactivation, rather than activation, for the DLPFC. For OM meditation, the results showed that there were higher brain activity in areas, such as the medial anterior prefrontal cortex (medial aPFC) when compared to rest state.[155] The increase pertaining to the medial aPFC, during OM mediation, may be due to the wandering aspect when the meditator is shifting attention from one object to another. This finding displays some similarity to the study conducted by Hasenkamp et al, where they found activation of the medial PFC, when the subject was in the process of Shift, or refocus of attention.[156] The results also showed that when OM was compared to FA meditation, there were various regions of the brain that displayed increased activity, such as the DLPFC and the medial frontal areas.[157] The authors indicated that the reason for these large increases in activity is simply due to the decreased activity during FA meditation.[158] For the novice group cases, the results displayed increased activity for the DLPFC and medial frontal areas, during FA mediation, compared to rest. During OM mediation, multiple activations occurred in areas, including the right medial aPFC compared to rest state.[159] Therefore, for novice mediators an increase in DLPFC was

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[154] Manna, Antonietta, Antonino Raffone, Mauro Gianni Perrucci, Davide Nardo, Antonio Ferretti, Armando Tartaro, Alessandro Londei, Cosimo Del Gratta, Marta Olivetti Belardinelli, and Gian Luca Romani. 2010. "Neural Correlates of Focused Attention and Cognitive Monitoring in Meditation." *Brain Research Bulletin* 82 (1–2): 48.

[155] Ibid., 48.

[156] Hasenkamp, Wendy, Christine D. Wilson-Mendenhall, Erica Duncan, and Lawrence W. Barsalou. 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59 (1) (1/2): 754.

[157] Manna, Antonietta, Antonino Raffone, Mauro Gianni Perrucci, Davide Nardo, Antonio Ferretti, Armando Tartaro, Alessandro Londei, Cosimo Del Gratta, Marta Olivetti Belardinelli, and Gian Luca Romani. 2010. "Neural Correlates of Focused Attention and Cognitive Monitoring in Meditation." *Brain Research Bulletin* 82 (1–2): 48.

[158] Ibid., 48.

[159] Ibid., 48.

found in this study, as opposed to the decrease in DLPFC for experts. The overall results from this study also show that meditation has a mixed association with the DLPFC, with experience as a variable.

Various studies have investigated the correlation between the grey matter thickness of the human brain and meditation. Frequently activated areas of the brain are thicker than other areas.[160] Sara W. Lazar et al explained that their study showed that the thickness of the frontal brain regions of the 40 – 50 year old meditators were similar to those of 20 – 30 year olds.[161] The authors also mention that the thickness of the frontal regions of the brain tend to thin as one ages.[162] Therefore, the outcome indicates that meditation may lead to a more activated PFC, therefore a thicker PFC. Britta K. Hölzel et al investigated the correlation between meditation and the concentration of grey matter density.[163] A more concentrated grey matter density would mean that the brain area has been more active.[164] Their results did not demonstrate any significant concentration of grey matter of the DLPFC for meditators.[165] Therefore, the outcome indicated that perhaps meditation does not lead to a more active DLPFC. The correlation between meditation and the grey matter density of the DLPFC is also mixed. It must be mentioned that the method of measuring brain activity through grey matter density may not be as accurate as using fMRI. The reason is due to the methods

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[160] Lazar, Sara W., Catherine E. Kerr, Rachel H. Wasserman, Jeremy R. Gray, Douglas N. Greve, Michael T. Treadway, Metta McGarvey, Brian T. Quinn, Jeffery A. Dusek, and Herbert Benson. 2005. Meditation experience is associated with increased cortical thickness. *Neuroreport* 16 (17): 1893 - 1897.

[161] Ibid., 1896.

[162] Ibid, 1896.

[163] Hölzel, Britta K., Ulrich Ott, Tim Gard, Hannes Hempel, Martin Weygandt, Katrin Morgen, and Dieter Vaitl. 2008. "Investigation of Mindfulness Meditation Practitioners with Voxel-Based Morphometry." *Social Cognitive and Affective Neuroscience* 3 (1): 56.

[164] Ibid, 56.

[165] Ibid, 58.

of testing, where the grey matter density measurement measures for thickness and density, while fMRI directly measures the brain activity.

2.7 Sleep / Executive Function

As can be assumed, the closest form to flow is sleep. The ability to fall asleep is a universal element among all humans, where one must concentrate, but lose enough focus, to enter the sleep state. Thus, sleep can be analyzed, in terms of brain activity involved during the actual act of falling asleep and dreaming. Insight in this area allows for comparisons to be made in relation to flow. Also, sleep deprivation can be investigated to examine if it is harmful for flow and creativity.

Amir Muzur et al explores these themes in his article, "The prefrontal cortex in sleep".[166] Muzur et al explains that the executive functions, located in the prefrontal cortex, are lost in sleep. The executive functions relate to the elements most closely related to the DLPFC. This involves focused attention, self-conscious awareness, planning, and decision-making. In particular, the relationship between self-conscious awareness is significantly different from waking consciousness to that in sleep, specifically in dreaming. This mainly concerns the aspect of seeing yourself as separate when dreaming. He explains that the concept of sleep is divided into two conditions: non-rapid eye movement (NREM) and rapid eye movement (REM). NREM describes the state of actual sleep, while REM relates to dreaming. Executive functions are considerably impaired in NREM, while being weak in REM. NREM is characterized by deactivation in both the DLPFC and MPFC. REM is depicted as remained deactivation in DLPFC, however it involves a re-activation in MPFC.[167] The following information can explain that when one is dreaming,

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[166] Muzur, Amir, Edward F. Pace-Schott, and J. Allan Hobson. "The prefrontal cortex in sleep." *TRENDS in Cognitive Sciences* 6, no. 11 (November 2002): 475-80.

[167] Ibid., 475 – 480.

there involves illogical thinking, with minimal to no control of self, which entails low attention span, self-monitoring, and decision-making, because the DLPFC is deactivated. The MPFC involves self-generated, internally motivated behavior, so this might imply that it is responsible for creating the dream. Braun explains the disengagement of the executive functions in his article, “Regional cerebral blood flow throughout the wake cycle”. He says, “REM sleep may constitute a state of generalized brain activity with the specific exclusion of executive functions which normally participate in the highest order analysis and integration of neural information”.[168]

Sleep deprivation is defined by the condition of not receiving an adequate amount of sleep. It can be lead to inability to focus or function in a daily routine. Muzur et al describes that the executive functions are strained with extended durations of wakefulness. The prefrontal cortex lags behind most sections of the brain to function upon consciousness following sleep. This suggests that with prolonged periods of sleeplessness, this lag will continue to grow and the sleep recovery time necessary for the prefrontal cortex to operate efficiently will expand.[169]

From this analysis, it can be concluded that REM sleep (dreaming) is most closely related to flow and improvisation, as seen in the Limb and Braun article, in that the DLPFC is de-activated and the MPFC is activated. However, there is no practice for someone to dream to achieve flow. It is human instinct to fall asleep. Once asleep, our consciousness is uncontrollable. We fall asleep, possibly have a dream, and wake up the next day. Therefore, these findings only relate dreaming and flow as being the most closely connected because of their respective content of brain activity. There is no method for sleep to better supplement flow. Concerning sleep deprivation, it would

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[168] Braun, A. R. "Regional cerebral blood flow throughout the sleep-wake cycle." *Brain* 120 (1997): 1173-97.

[169] Muzur, Amir, Edward F. Pace-Schott, and J. Allan Hobson. "The prefrontal cortex in sleep." *TRENDS in Cognitive Sciences* 6, no. 11 (November 2002): 475-80.

actually be more beneficial to experience less sleep to achieve flow, as you want the prefrontal cortex to lag, in order to reach flow. However, this is an illogical method to attain flow because of what it would require the musician to endure.

3. Discussion

The elements outlined by Csikszentmihalyi[170] for the state of flow, generally revolve around the concept of high concentration and focus on the task at hand. He described that creativity was "internally generated" stemming, most importantly, from the passion and enthusiasm that one has with their respective creative craft.[171] This fervor outweighs any advantage one might have concerning education or genetics, during the flow experience. Manzano et al expresses this process as an "intrinsically rewarding experience" for the individual.[172] Specifically, this experience relates to the phenomenon of what inspires creative people to engulf themselves in their craft when no external rewards exist. Conversely, the rewarding experience is defined by the enjoyment and delight that the creative individual feels during the creative process.

Manzano et al explains that attention is vital for the flow experience, though it has to be forced, yet effortless. This may seem like a contradiction because it seems unfeasible to be focused, without exertion, when concentrating on something. However, he describes that when one is in a state of positive affect, tasks that generally contain a significant amount of concentration are experienced as effortless. Expertise in one's craft is explained to be a considerable supplement to flow. This sustains attention, reduces distractions, and increases several, if not all, elements of

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[170] Csikszentmihalyi, Mihaly. "Creativity: Flow & the Psychology of Discovery & Invention." Last modified May 9, 1997. Microsoft Word. : 2-3

[171] Ibid., 3.

[172] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 301

flow. The relationship between task difficulty and skill is also noteworthy to experience flow. Ability should be balanced at the same level to the complexity of the task. If this does not occur, the concentration involved during the performance will be lost if, for instance, the task is too simple for an expert, or vice versa.[173]

Meditation usually comes to mind when the term “high concentration” is brought up. The reason for this is due to the fact that the end goal of meditation is to enter a state of focus and attention. As indicated by Lutz, meditation can be categorized into either Focused Attention (FA) or Open Mindedness (OM) meditation. FA relates to concentrating attention on one object and OM relates to concentrating on multiple objects, one by one.[174] In fact, Ed Sarath explains that the reason why meditation is included in the Jazz major curriculum at the University Of Michigan School Of Music is to promote creativity, as well as other various qualities.[175] Although meditation may seem as a logical method to help facilitate the entering into the state of flow, the results of various studies of meditation shows otherwise.

The Dorsolateral Prefrontal Cortex (DLPFC), Medial Prefrontal Cortex (mPFC), and the Amygdala are three brain areas of concern for jazz improvisation, and therefore flow. During improvisation, the musician is considered to be in a state of flow due to the similarities between the elements listed by Csikzenmihalyi and the general concepts of improvisation. The brain activities in these areas during meditation and jazz improvisation can indicate whether or not meditation can be a feasible technique to enter a state of flow. The comparison between the brain

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[173] de Manzano , O. Theorell , T. Harmat , L. Ullen , F. (2010). The psychophysiology of flow during piano playing. Emotion, 10, 302

[174] Lutz, Antoine, Heleen A. Slagter, John D. Dunne, and Richard J. Davidson. 2008. "Attention Regulation and Monitoring in Meditation." *Trends in Cognitive Sciences* 12 (4): 163-169. doi:10.1016/j.tics.2008.01.005. ,1

[175] Sarath, Ed. 2003. Meditation in higher education: The next wave? *Innovative Higher Education* 27 (4) (06/01): 215-33, http://dx.doi.org/10.1023/A%3A1024072313202.

activity during meditation and jazz improvisation has shown some similarities, as well as major differences.

The results from various studies pertaining to DLPFC activity were generally mixed, but the majority tends to indicate significant activation of the DLPFC when subjects were in a state of meditation. Charles Limb and Allen Braun have found deactivation of the DLPFC during jazz improvisation.[176] Therefore, the activity of the DLPFC during meditation and jazz improvisation are different, indicating that meditation is different from the state of flow. Since it is different, meditation may not be utilized to enter this state. Why does the activity of the DLPFC in meditation and jazz improvisation differ when both aspects appear to be similar (i.e. high concentration)?

The deactivation of the DLPFC in improvisation can be explained by examining the functionality of the DLPFC. Studies have linked the DLPFC to decision-making, organization, and self-evaluation. Such tasks are interconnected with logic and reasoning. In logic and reasoning, decision-making is utilized to choose the best possible outcome, based on gathered information. Marios G. Philiastides et al have shown that the DLPFC is utilized to gather information.[177] The results of the study display that the accuracy of their answer, as well as the rate of gathering evidence to reach that answer, have both decreased when the DLPFC was disrupted.[178] Since a disrupted DLPFC would impede both the accuracy of the answer and rate of gathering evidence, this entails that the DLPFC must be an important component for decision-making. Robert S. Blumenfeld and Charan Ranganath have conducted a study that demonstrated that the DLPFC was

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[176] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 1 – 9.

[177] Philiastides, Marios G, Ryszard Auksztulewicz, Hauke R Heekeren, and Felix Blankenburg. 2011. Causal role of dorsolateral prefrontal cortex in human perceptual decision making. *Current Biology* 21 (11) (6/7): 982.

[178] Ibid., 981 – 982.

associated with the organization of memory.[179] Organization is the categorization of information, where analysis is involved to determine the most accurate placement. The results of the study found that the activity of the DLPFC significantly increased when the subjects were in the process of reorganizing words into their respective categories, compared to the memorization trial.[180] Memorization does not involve any analysis since it is to only remember, or to "hold" onto the information. Reorganization is a more involved process, where information must also be processed and analyzed in order to determine the most correct and accurate category. Therefore, the results of this study display that the DLPFC is more involved in the analysis of information, more so than simply holding information. Schmitz et al have also associated the DLPFC to self-evaluation, where the DLPFC is used in analysis of one's self.[181] This study found that DLPFC activation was much more significant when the subjects were to evaluate themselves, rather than evaluating others.[182]

Decision-making, organization, and self-evaluation all utilize analysis of information in order to reach a result. Since the DLPFC is in some way connected with these three activities, then the DLPFC must also be associated with logic and reasoning. Therefore, an activation of the DLPFC proves that the present action performed by a person involves a form of logic and reasoning. As indicated earlier, the study conducted by Limb and Braun demonstrated that there were significant DLPFC deactivation when the jazz musicians were in the process of

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[179] Blumenfeld, Robert S., and Charan Ranganath. 2006. Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organization. *The Journal of Neuroscience* 26 (3) (January 18): 916-25.

[180] Ibid., 919.

[181] Schmitz, T. W., T. N. Kawahara-Baccus, and S. C. Johnson. 2004. Metacognitive evaluation, self-relevance, and the right prefrontal cortex. *Neuroimage* 22 (2): 941-7.

[182] Ibid., 945.

improvisation.[183] They explained that this process can be characterized by "defocused, free-floating attention" that allows for "spontaneous unplanned associations, and sudden insights or realizations".[184] The deactivation of the DLPFC in improvisation displays that logic and reasoning was not being used when the jazz musicians were performing. Why? This is perhaps due to the association between improvisation and creativity, and the contrast between creativity with logic and reasoning. Improvisation is a creative task due to its nature, where ideas are generated freely without regulation. Logic and reasoning contrast creativity due to the necessity of analysis and regulation, where the goal is to aim for the most optimal result. For example, in decision-making, the final decision tends to be chosen as the best out of a set of possible options, based on gathered information. Due to the following analysis, activities where there exists DLPFC activity, should not be called "creative". Creativity is associated with ideas that are unanalyzed or unhampered with, where ideas freely come and go. Creative ideas are not analyzed, implying that such ideas are not processed in order to determine whether or not they are the best fit for the current scenario. These ideas are simply applied, regardless if they make sense or not, which is why they are unique.

A study conducted by Sara Bengtsson and Mihaly Csikszentmihalyi found that classical musicians, during improvisation, exhibited increased DLPFC activity.[185] Their experiments were similar to those done by Limb and Braun, however their results were strikingly different. The only difference that can be analyzed among the two were the test subjects involved. Unlike jazz musicians, classical musicians generally do not improvise in their craft. Consequently, these

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[183] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 1 – 9.

[184] Ibid., 4.

[185] Bengtsson, Sara L., Mihaly Csikszentmihalyi, and Fredrik Ullen. "Cortical Regions Involved in the Generation of Musical Structures during Improvisation in Pianists." *Journal of Cognitive Neuroscience* 19, no. 5 (May 2007): 830-42.

performers may be so inclined, after much practice, to the goal-directed behavior that characterizes classical music that they simply cannot trigger deactivation of the DLPFC during improvisation.

The amygdala has been shown to deactivate during jazz improvisation.[186] Limb and Braun explain that it may be due to the fact that the amygdala deactivates when one experiences positive feelings or arousal.[187] Such feelings include happiness, joy, or laughter. The results from a study conducted by Stefan Koelsch et al, supports the concept mentioned by Limb and Braun.[188] The study found that the subjects displayed activation of the amygdala when they were listening to unpleasant music, compared to when they were listening to pleasant music.[189] Other various studies have shown that the amygdala is associated with emotion, specifically negative or unpleasant emotion. Ralph Adolphs et al conducted a study demonstrating the association of activation of amygdala to emotion reading, which is linked to facial recognition.[190] A possible reason for activation of the amygdala may be due to the method used in the study. The subjects with amygdala damage were asked to rate how trustworthy or approachable a person is based on their faces.[191] The process of determining trustworthiness and approachability is similar to determining how unpleasant the person is or how afraid the subject is of the person. Therefore, the amygdala showed activation because the subjects were thinking about negative or unpleasant

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[186] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 3.

[187] Ibid., 5.

[188] Koelsch, Stefan, Thomas Fritz, D. Yves v. Cramon, Karsten Müller, and Angela D. Friederici. 2006. Investigating emotion with music: An fMRI study. *Human Brain Mapping* 27 (3): 239-50.

[189] Ibid 239 – 250.

[190] Adolphs, R., D. Tranel, and A. R. Damasio. 1998. The human amygdala in social judgment. Nature-London-: 470-3.

[191] Ibid., 472.

emotions during the study. Similarly, the study conducted by Elizabeth A. Phelps et al associates the amygdala to a negative emotion, specifically fear.[192] The subjects were simply told that they would receive a shock, depending on what they saw on the screen, however they were never shocked.[193] The results of this study found that when the subject anticipated the shock, amygdala activation was found.[194] On the contrary, when the subjects felt that they were safe, the amygdala showed deactivation.[195] Therefore, the correlation between the activity of the amygdala and fear indicates that the amygdala is associated with negative emotions, such as fear. These various studies indicate that the amygdala activates when a person experiences negative or unpleasant emotions. Thus, the deactivation of the amygdala in jazz improvisation during the study conducted by Limb and Braun confirms that the musicians were indeed experiencing positive emotions.

The study conducted by Limb and Braun have found activation of the medial prefrontal cortex (mPFC) during jazz improvisation.[196] Gui Xue et al conducted a study which correlates the mPFC to the aspects of risk and reward.[197] The results of the study established that, specifically, the dorsal medial prefrontal cortex (dmPFC) displayed activation when a subject made a risky

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[192] Phelps, E. A., K. J. O'Connor, J. C. Gatenby, J. C. Gore, C. Grillon, and M. Davis. 2001. Activation of the left amygdala to a cognitive representation of fear. *Nature Neuroscience* 4 (4): 437-41.

[193] Ibid., 437 – 438.

[194] Ibid., 438.

[195] Ibid., 439.

[196] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 3.

[197] Xue, Gui, Zhonglin Lu, Irwin P. Levin, Joshua A. Weller, Xiangrui Li, and Antoine Bechara. 2009. Functional dissociations of risk and reward processing in the medial prefrontal cortex. *Cerebral Cortex* 19 (5) (May 01): 1019-27.

decision.[198] Creativity can be seen as making risky decisions, since the end result for both creativity, as well as risky decisions, tend to be uncertain. As described earlier, creativity is the opposite of logic and reason. For logic and reason, the end result tends to be known, due to the presence of analysis. Limb and Braun also mention that the mPFC activation during jazz improvisation may be due to "neural instantiation of self, organizing internally motivated, self-generated, and stimulus-independent behaviors".[199] "Self-generated" behaviors can also be associated with creativity. Such behaviors verify that the created ideas are unique and novel. Thus, the activation of the mPFC in jazz improvisation may be due to the generation of unique ideas. The mPFC may have activated due to the risky decision of performing the unique idea, since the result is uncertain.

The state of flow is characterized around concepts of high concentration and strong immersion into the task at hand. Due to the common association between meditation and concentration, one usually believes that meditation can be utilized in areas that require strong focus and attention, such as entering and maintaining flow. In fact, the University of Michigan School Of Music have applied meditative experiences to their music curriculum.[200] Ed Sarath explains that meditation is included in the Jazz major curriculum at the University Of Michigan School Of Music to promote creativity, as well as other various qualities.[201] Various studies that investigate

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[198] Xue, Gui, Zhonglin Lu, Irwin P. Levin, Joshua A. Weller, Xiangrui Li, and Antoine Bechara. 2009. Functional dissociations of risk and reward processing in the medial prefrontal cortex. *Cerebral Cortex* 19 (5) (May 01): 1022.

[199] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 4.

[200] Sarath, Ed. 2003. Meditation in higher education: The next wave? *Innovative Higher Education* 27 (4) (06/01): 215-33, http://dx.doi.org/10.1023/A%3A1024072313202.

[201] Ibid., 215-233.

the brain activities of subjects during the state of meditation and musicians during improvisation show incompatibility between meditation and the state of flow.

The results from numerous studies have shown that the brain activity of the Dorsolateral Prefrontal Cortex (DLPFC) during the state of meditation have been generally mixed. Multiple studies have demonstrated that the DLPFC is in some way associated with activities relating to logic and reasoning. Therefore, if results from neurological studies show an increase in DLPFC activity, it is assumed that such activity was due to experience in activities that utilize logic and reasoning. The results from Limb and Braun's study on jazz musicians during improvisation indicated deactivation of the DLPFC.[202] Although the results pertaining to the DLPFC during meditation have been mixed, the majority of results display increased DLPFC activity. For example, a study conducted E. Baron Short et al compared brain activity between meditators during the state of meditation and an occupied state.[203] The results indicated different magnitudes of DLPFC activity depending on which trial was conducted first, trial with meditation or trial with occupation.[204] Similarly, the study conducted by Wendy Hasenkamp et al found activation of the DLPFC when the meditator is in the process of shifting attention, as well as during the focusing attention.[205] Such results indicating DLPFC activity opposes the results of DLPFC deactivation during jazz improvisation, proving that meditation cannot be used to help facilitate musicians to

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[202] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 1 – 9.

[203] Short, E. B. 2010. "Regional Brain Activation during Meditation shows Time and Practice Effects: An Exploratory FMRI Study." *Evidence-Based Complementary and Alternative Medicine* 7 (1): 121 - 127.

[204] Ibid., 123 - 124.

[205] Hasenkamp, Wendy, Christine D. Wilson-Mendenhall, Erica Duncan, and Lawrence W. Barsalou. 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59 (1) (1/2): 753-754.

enter the state of flow. This entails that meditation would apply more to a logical application, rather than creative. The study conducted by K. A. Brefczynski-Lewis et al found that DLPFC activity showed spikes of activity, but decreased much quickly with expertise, where experienced meditators displayed rapid reduction of DLPFC activity after the initial increase in activity.[206] This indicates that even if meditation can be utilized academically to facilitate musicians in reaching the state of flow, it would not be practical. The experienced meditators of the study had an average experience of 19,000 hours of time spent on meditation.[207] 19,000 hours of meditation is approximately 2 complete years' worth of meditation. Since the amount of time required to utilize the effects of meditation for flow is quite extensive, it is not practical for academic use.

From the results of various studies, the Amygdala has been found in some way associated with negative emotions such as fear and anger. K. A. Brefczynski-Lewis et al also found, along with less DLPFC activity in expert meditators compared to novice meditators, there also contained less amygdala activity.[208] Similarly, the study conducted by Judson A. Brewer et al indicated that Loving-Kindness meditators depicted deactivation of the amygdala.[209] The Loving-Kindness meditation focuses on acceptance, where the meditators would repeat phrases of positive moods.[210] Limb and Braun have also discovered deactivation in the amygdala of jazz musicians during

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[206] Brefczynski-Lewis, J. A., A. Lutz, H. S. Schaefer, D. B. Levinson, and R. J. Davidson. 2007. "Neural Correlates of Attentional Expertise in Long-Term Meditation Practitioners." *Proceedings of the National Academy of Sciences of the United States of America* 104 (27): pp. 11484.

[207] Ibid., 11483.

[208] Ibid., 11486.

[209] Brewer, Judson A., Patrick D. Worhunsky, Jeremy R. Gray, Yi-Yuan Tang, Jochen Weber, and Hedy Kober. 2011. Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences* 108 (50) (December 13): 20255.

[210] Ibid., 20254.

improvisation.[211] Such deactivation of the amygdala may also be related to the calm and focused state, which is a "positive" emotion. Since both, in the case of jazz improvisation and meditation, displayed deactivation of the amygdala, meditation is a possible method for musicians to reach the state of flow when seen in terms of amygdala activity. Joshua A. grant et al investigated subjects' neurological response to pain due to meditation.[212] The results from this study indicated that meditators had lower pain sensitivity, meaning that they could withstand more pain than the control group.[213] The results also presented that meditators had less amygdala activity than non-meditators.[214] Since the amygdala is associated with negative emotions, for example, pain, the reason that the meditators had less pain sensitivity may be due to the fact that meditation causes decrease in amygdala activity. In respect to jazz improvisation, the neurological results from these studies indicate that meditation can be utilized to help the musician enter a calm and focused state. However, such correlation of amygdala deactivation does not contribute to the creative aspect of flow.

The medial prefrontal cortex (mPFC) has been shown to possibly be associated with risk taking.[215] The aspect of risk taking can also be linked to creativity due to the fact that creation from creativity is unique and has not been accomplished before. Therefore, creativity is a risky decision since the end result is unknown. Limb and Braun have also found mPFC activation during jazz

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[211] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 3.

[212] Grant, Joshua A., Jérôme Courtemanche, and Pierre Rainville. 2011. A non-elaborative mental stance and decoupling of executive and pain-related cortices predicts low pain sensitivity in zen meditators. *Pain* 152 (1) (1): 150-6.

[213] Ibid., 152-154.

[214] Ibid., 150-156.

[215] Ibid.,152.

improvisation.[216] Wendy Hasenkamp et al established that mediators demonstrated activation in the mPFC when the subject's mind was wandering and unfocused.[217] Brewer et al found that meditators had less mPFC activity compared to the control subjects.[218] Antonietta Manna et al indicated that the mPFC activity correlated with the type of meditation used, Focused Attention (FA) or Open Mindedness (OM).[219] Decreased mPFC activity was found in FA meditators, while increased mPFC activity was found in OM meditators.[220] Therefore, the results of mPFC activity in meditation is mixed and is inconclusive in showing the association between meditation and jazz improvisation, or flow.

From multiple studies on meditation and brain activity of the DLPFC, amygdala, and mPFC, it can be concluded that meditation is not a practical application in facilitating musicians in entering the state of flow. As explained, the DLPFC activity during meditation tends to show activation. Such activation contrasts the deactivations of the DLPFC of jazz musicians during improvisation. This concludes that meditation leads to a state of focus that can be considered too "logical" or intense than the desired focus in the state of flow. The deactivation of the amygdala during meditation draws a parallel with the deactivation of the amygdala during jazz

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[216] Limb CJ, Braun AR (2008) Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation. PLoS ONE 3(2): e1679. doi:10.1371/journal.pone.0001679 : 3.

[217] Hasenkamp, Wendy, Christine D. Wilson-Mendenhall, Erica Duncan, and Lawrence W. Barsalou. 2012. Mind wandering and attention during focused meditation: A fine-grained temporal analysis of fluctuating cognitive states. *Neuroimage* 59 (1) (1/2): 754.

[218] Brewer, Judson A., Patrick D. Worhunsky, Jeremy R. Gray, Yi-Yuan Tang, Jochen Weber, and Hedy Kober. 2011. Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences* 108 (50) (December 13): 20255.

[219] Manna, Antonietta, Antonino Raffone, Mauro Gianni Perrucci, Davide Nardo, Antonio Ferretti, Armando Tartaro, Alessandro Londei, Cosimo Del Gratta, Marta Olivetti Belardinelli, and Gian Luca Romani. 2010. "Neural Correlates of Focused Attention and Cognitive Monitoring in Meditation." *Brain Research Bulletin* 82 (1–2): 46-56. doi:10.1016/j.brainresbull.2010.03.001.

[220] Ibid., 48.

improvisation. This indicates that meditation can be applicable for the aspect of calmness and bringing about positive emotions, but is not applicable to the creativity aspect of flow. Lastly, the mPFC activity during meditation had mixed results depending on which specific type of meditation was used. Therefore, the correlation between the mPFC activity in meditation and jazz improvisation is inconclusive. With these various results together, the application of meditation in entering the state of flow is concluded to be impractical for creativity purposes, but may be useful in calming musicians.

The concept of sleep was finally analyzed as a resemblance to flow, where strong, yet effortless, concentration is necessary to achieve it. Muzur et al explains that the executive functions, mainly the functions of the DLPFC, are lost during sleep. He described sleep in two categories: non-rapid eye movement (NREM), where actual sleep occurs, and rapid eye movement (REM), where dreaming occurs. Brain activity during NREM is distinguished by deactivation of both DLPFC and mPFC, while REM is characterized by deactivation of DLPFC, however activation of mPFC. The function of the mPFC, as discussed earlier, involves self-generated, internally motivated behavior. With the exclusion of the DLPFC, it can justified that the mPFC is responsible in producing dreams. This also explains how dreams are described to involve illogical thinking and sensing yourself as separate, without the regulation of the DLPFC.[221]

As can be seen, the state of dreaming contains the same conditions, as found by Limb and Braun, of jazz improvisation, where the DLPFC is deactivated and the mPFC is activated. The dilemma, though, is that sleep cannot act as a supplement to jazz improvisation. There is no method to practice how to dream because it is uncontrollable. It is human instinct to fall asleep, however

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[221] Muzur, Amir, Edward F. Pace-Schott, and J. Allan Hobson. "The prefrontal cortex in sleep." *TRENDS in Cognitive Sciences* 6, no. 11 (November 2002): 475-80.

what occurs during this process is unable to be anticipated. The concept of sleep deprivation was also explored to determine if it would effect improvisation. It was explained that the prefrontal cortex lags behind most areas of the brain upon consciousness, after sleep. Accordingly, the effect of sleep deprivation is that this lag will be prolonged on the basis of the amount of sleep that one doesn't receive.[222] Therefore, sleep deprivation would be a supplement to jazz improvisation, however it would be an illogical practice considering what the musician must endure. Then again, rock bands are notorious for not receiving enough sleep.

4. Conclusion

The Dorsolateral Prefrontal Cortex (DLPFC) is a section of the brain that involves problem solving, self-monitoring, and attention. The Medial Prefrontal Cortex (mPFC) is an area of the brain that relates to self-generated, internally motivated behavior. Another region of the brain, the amygdala, is associated with negative emotion. As seen in the Limb and Braun study, jazz musicians during improvisation, or flow, experience a deactivation of DLPFC, activation of mPFC, and deactivation of amygdala. However, as displayed by Bengtsson and Csikszentmihalyi, the type of musician should also be considered. Classical musicians show alternative results in brain activity than jazz musicians during improvisation. They demonstrated activation in DLPFC during improvisation, which could possibly be due to the lack of improvisation in their craft. Their brains may be so accustomed to the goal-oriented behavior of classical music that their DLPFC simply cannot deactivate during improvisation.

Application of meditation and sleep were both shown to be impractical in facilitation of musicians for entering the state of flow. From a neurological perspective, meditation appears to

[222] Muzur, Amir, Edward F. Pace-Schott, and J. Allan Hobson. "The prefrontal cortex in sleep." *TRENDS in Cognitive Sciences* 6, no. 11 (November 2002): 475-80.

oppose the elements of flow. Meditators, in large part, experienced an activation of DLPFC, with mixed results of mPFC. However, meditation can be utilized to supplement the positive emotions necessary for flow, which is characterized by deactivation of the amygdala. Sleep, in particular, dreaming, displayed the exact conditions to that of improvisation, however it cannot be implemented as a facilitator to flow because it cannot be practiced.

One possible method to supplement flow might be to train the working memory. A study conducted by Carsten K. W. De Dreu et al have found connections between creativity of improvisation and working memory capacity.[223] The working memory can be visualized as a temporary information storage area. The results from various studies conducted by Engle et al[224] indicate that people with larger working memory capacity are able to maintain more information, as well as being better in focusing attention than those with low working memory capacity. The subjects of the study conducted by De Dreu et al consisted of cellists with experience ranging from 8 to 20 years; they were first analyzed and tested to determine their working memory capacity prior to the improvisation trial.[225] The subjects during the improvisation trial were instructed to improvise a musical piece based on a given topic.[226] Each subject was critiqued by two professional cellists on the basis of creativity.[227] The results from the study demonstrated

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[223] De Dreu, Carsten K. W., Bernard A. Nijstad, Matthijs Baas, Inge Wolsink, and Marieke Roskes. 2012. Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Personality and Social Psychology Bulletin* 38 (5) (May 01): 656-69.

[224] Engle, Randall W. 2002. Working memory capacity as executive attention. *Current Directions in Psychological Science* 11 (1) (February 01): 19-23.

[225] De Dreu, Carsten K. W., Bernard A. Nijstad, Matthijs Baas, Inge Wolsink, and Marieke Roskes. 2012. Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Personality and Social Psychology Bulletin* 38 (5) (May 01): 661

[226] Ibid., 662.

[227] Ibid., 662.

that cellists with higher working memory capacity exhibited increased creativity with time during the improvisation, as opposed to cellists with low working memory capacity, who displayed decrease in creativity over time.[228] Such results indicate that working memory may be associated with creativity. Therefore, perhaps training the working memory may be a feasible method for musicians in achieving the state of flow. Due to the lack of research on the correlation between the working memory and creativity, future studies may want to investigate the neurological connections between the working memory and creative tasks, such as improvisation.

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[228] De Dreu, Carsten K. W., Bernard A. Nijstad, Matthijs Baas, Inge Wolsink, and Marieke Roskes. 2012. Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Personality and Social Psychology Bulletin* 38 (5) (May 01): 662.

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