Music as a Tool of Diagnosis

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Abstract

As psychiatric disorders become more well known, it has become evident that rates of misdiagnosis and prevalence of psychiatric disorders among the human race have only increased, yet there remains a void of consistent and concrete means of diagnosis. Upon analyzing the tools used to study the brain, the effects of music on the brain, functional neuroimaging of psychiatric disorders, and the potential for a combination of music and functional imaging, it is clear that there is a solid foundation on which we may build the theory that music may be used as a diagnostic tool in medicine. Eventually, it may be found that music can be used with vital sign changes to diagnose psychiatric disorders to provide more accessible healthcare.

Keywords

Music psychophysiology, psychiatric disorders, diagnosis, affordable healthcare, music therapy

Introduction

The topic of music psychology is vast and well explored, yet there remains much to be discovered. Many subtopics of the science of music can be researched, but the fastest growing area seems to be in that of music psychophysiology, which studies how the brain and body react to music. Currently, scientists can use MRI's, PET, EEG's, and CT scans in conjunction with monitoring vitals and qualitative data to determine how people react to certain types of music and how psychological disorders play a role in the body's reaction. Studies frequently include playing lyrical and non-lyrical pieces for people while simultaneously studying the concrete data i.e. brain scans (Krumhansl, 1997; Fang et al., 2015; Stewart et al., 2006). Doctors and psychologists are particularly interested in the topic of music therapy, as it seems to have a large effect on patients with mental health disorders such as depression or anxiety (Schulze and Roepke, 2014; Erkkila et al., 2008). New technology is allowing us to see inside the brain with more detail and accuracy, giving us the ability to pinpoint exactly which regions of the brain are affected by music. This then allows us to differentiate between neurotypical people and people with disorders. There are many independent studies lending to the consistency of music physiology and from the literature it is likely that there is a correlation of areas of the brain affected by music and psychiatric disorders, which allows me to connect multiple disciplines into one central idea: using music in conjunction with other tools to diagnose psychological disorders more accurately and affordably than the conventional methods. As it stands, there is enough current information to build a strong foundation to build upon the idea that we can use music as a more accurate tool of diagnosis than is currently available.

Psychiatric Disorders and Diagnosis

Psychiatric disorders are often referred to as "silent disabilities" because they are rarely visible and often go undiagnosed, while their effects can severely interfere with day to day activities. In order to be diagnosed, one must first recognize their own symptoms before seeking the advice of a medical professional who often uses subjective criteria to diagnose the psychiatric disorder. This informal and inconsistent method of diagnosis presents a serious issue; the literature suggests that misdiagnosis rates of psychiatric disorders in children are extremely high (Merten et al., 2017) and often lead to improper treatment of the actual disorder. Merten et al. (2017) found that, on average, ADHD is over diagnosed, bipolar disorder is underdiagnosed, and major depression disorder is both over and underdiagnosed, depending on methods. This is mainly due to the fact that there are very few concrete tests doctors can use to accurately diagnose disorders without spending immense amounts of money. The problem of misdiagnosis presents the issue that patients are often mistreated or lacking the support they need, causing secondary issues down the road.

Many studies have found a correlation of activation of certain brain regions and changes in basic vital signs when stimulated with music (Krumhansl, 1997; Warren, 2008; Nizamie and Tikka, 2014; Grecius et al., 2007; Fang et al., 2015). In addition, functional imaging has provided us with consistent findings on the impact certain psychiatric disorders have on regions of the brain (Nizamie and Tikka, 2014; Schulze and Roepke, 2014; Frangou, 2014; Spoormaker et al., 2014; Grecius et al., 2007; Stewart et al., 2006; Tagaments et al., 2014). The findings of these studies show a correlation of regions of the brain while stimulated with music and regions of the brain affected by psychiatric disorders, implying that it may be possible to use music as a more accurate tool of diagnosis in conjunction with a variety of tools and thus bring better treatment to those affected by psychiatric disorders.

Music and the Brain

It has been long known that music is capable of producing extreme emotions, calming effects, and physiological changes such as goosebumps or the natural urge to dance. However, it is only within the past twenty years that we have been able to visualize and quantify those changes. In multiple studies, Krumhansl (1997) explains that music does in fact invoke emotions, which are quantifiable by the observed changes in heart rate, respiratory rate, vascular output, electrodermal changes, and cardiac activity. In addition, different types of music can induce different responses; for example, sad music tends to correlate to blood pressure and temperature, whereas happy music correlates to increased respiration rate. These changes are an important distinction of how music emotion is different than the everyday emotion humans experience, as music is one of the only stimuli that produces such great changes. From Krumhansl's (1997) study, we can deduce that music does in fact yield significant changes in the body of a healthy individual and in turn produces changes in the brain that must correlate to the change in vital signs.

Until MRI's were widely available, scientists did not have accurate ways to analyze the brain while a patient was still alive. Instead, they used volumetric differences in the hippocampus post mortem, which lacked the ability to tell differences in the brain other than pure volume (Spoormaker et al., 2014). Upon the introduction of magnetic resonance imaging (MRI), functional MRI's (fMRI) were quickly introduced and allowed scientist to study how the brain reacted to different stimuli (Warren, 2008). Warren (2008) studied specifically how music is a form of language and thus produces brain activity in similar ways that language does. It was found that music is specifically processed in the primary auditory cortex of the brain, which includes the limbic system in the brain (Warren, 2008). These findings were significant as the limbic system – which is made of the amygdala, hippocampus, thalamus, hypothalamus, basal ganglia, and cingulate gyrus – is also connected to various psychiatric disorders (Nizamie and Tikka, 2014; Schulze and Roepke, 2014; Frangou, 2014; Spoormaker et al., 2014; Greicius et al., 2007; Stewart et al., 2006; Tagaments et al., 2014) and is responsible for controlling emotion and behavior, as well as regulating aggressive behavior in response to stimuli. Additionally, Warren (2008) found that certain components of music, such as pitch, timbre, and tempo, are processed in different areas of the brain, as shown by Figure 1 below.

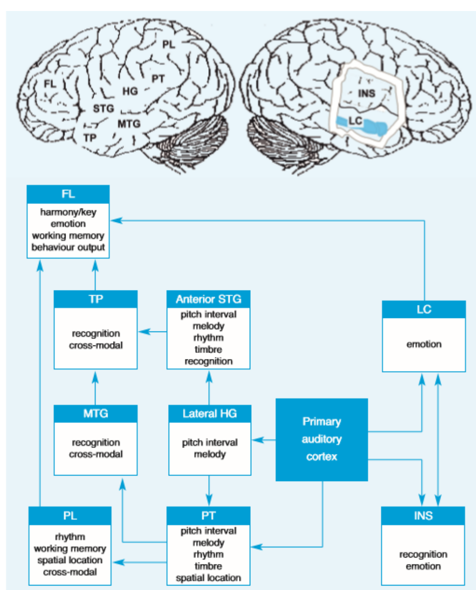

Figure 1: A scheme for organization of the musical brain based on evidence from the study of normal and damaged brains. (FL= frontal lobe, HG = Heschl's gyrus, INS = insula, LC = limbic circuit, MTG = middle temporal gyrus, PL = parietal lobe, PT = planum temporale, STG = superior temporal gyrus, TP = temporal pole). Warren, J. (2008) Music and the Brain

Fang et al. (2015) also correlated music to language and found that both music and speech involve perception, action, learning, memory, and emotion. They led a data-driven analysis in which participants underwent a natural stimulus functional MRI (N-fMRI) while music and speech were used as stimuli. It was found that music and speech produced almost the same results, with distribution of activity as shown in Table 1 (Fang et al., 2015).

Table 1: Distribution of brain activity due to music stimuli. Fang et al. (2015)

Lobe	Canonical Distribution	Percentage
Left frontal	23.74%	27.66%
Right frontal	24.02%	28.37%
Left Parietal	11.17%	7.09%
Right Parietal	5.87%	4.96%
Left temporal	3.91%	1.42%
Right temporal	6.98%	3.55%
Left occipital	11.73%	12.06%
Right occipital	12.57%	14.89%

It has also been found that music is mainly processed in the non-dominant side of the brain, and contains the element of prosody, or poetic rhythm and tone (Mula and Trimble, 2009). Patients who presented with right-sided brain lesions lacked the ability to process prosody in music, which helped lend to Mula and Trimble's conclusion that mood disorders and music are processed in the same area of the brain (Mula and Trimble, 2009). It was also mentioned that many famous composers and musicians were known to have significant psychiatric disorders, such as major depression, schizophrenia, and bipolar disorder (Mula and Trimble, 2009). The correlation between music, emotion, and psychiatric disorders is very consistent, which supports the hypothesis that music may be used as a diagnostic tool in conjunction with the proper tools.

While fMRI proves to be a consistent and reliable tool for studying the brain, electroencephalogram (EEG) is another way to determine the exact locations of the brain that processes music (Nizamie and Tikka, 2014). It was discovered that the acoustic circuit involves the auditory nerve, brainstem, medial geniculate, body of the thalamus, and auditory cortex (Nizamie and Tikka, 2014). Not only do these areas of the brain strongly correlate to the limbic system, but that after undergoing music therapy, schizophrenia patients showed significant changes in the frontal EEG after undergoing music therapy sessions (Nizamie and Tikka, 2014), which is strong evidence that music does in fact have a noteworthy effect on the brains of both healthy and unhealth individuals.

Certainly, if music can affect the brain in many different areas, there must be additional processes that are affected as well. In fact, music involves cortical systems extending well beyond auditory cortices and affects not only heart rate and respiratory rate, but capnography as well (Stewart et al., 2006). Capnography is the measure of carbon dioxide output and can often relate to the mental state of a patient, such as sleepiness, alertness, and calmness. This connection may lead to the ability to monitor carbon dioxide output along with music stimuli to diagnose certain psychiatric conditions, making the diagnosis more accurate and affordable than the conventional methods.

Psychiatric Disorders and the Brain

While there is very little research connecting the effects of music on specific psychiatric disorders, there is a fair amount of documented functional imaging of disorders and the areas of the brain they effect. In order to ensure that music would affect the brain during an fMRI, Stewart et al. (2006) found that certain musical listening disorders did in fact show significant differences in activation with music stimuli. Stewart et al. (2006) also found that Alzheimer's produced increased perfusion in the left temporal lobe and angular gyrus, and that musical hallucinations often occurred in patients with depression, schizophrenia, obsessive-compulsive disorder, and alcoholism. This review will not focus on Alzheimer's or alcoholism, but the research done by Stewart is worth mentioning as it is one of the only studies connecting music and psychiatric disorders during functional imaging.

Personality disorders are a common issue in today's society but is frequently misdiagnosed, with only approximately 71.7% of diagnoses remaining constant upon a second evaluation by a psychiatrist (Merten et al., 2017). There are many types of personality disorders, but the most common are bipolar disorder, antisocial personality disorder, and narcissitic personality disorder. Bipolar disorder (BD) happens to be the most common of the three, and upon using manual tracing methods with fMRI, BD shows affective and behavioral disregulation , impariments of prosody and interpersonal connections, and disturbed relatedness, as well as smaller grey matter volume in the amygdala and hippocampus (Schulze and Roepke, 2014; Frangou et al., 2014). These findings are significant in relation to this review because the amygdala and hippocampus are both involved in processing music, and the impairments in prosody shown could relate to how a person with BD would react to music. Antisocial personality disorder (APD) and narcissistic personality disorder (NPD) both showed lower activation of the amygdala with orbitofrontal and ventromedial implications (Shulze and Roepke, 2014). The subtle differences between BD and NPD is key in looking for potential diagnostic abilities, as BD focuses on a smaller grey matter of the amygdala, while NPD focuses on lower activation, as shown by Figure 2.

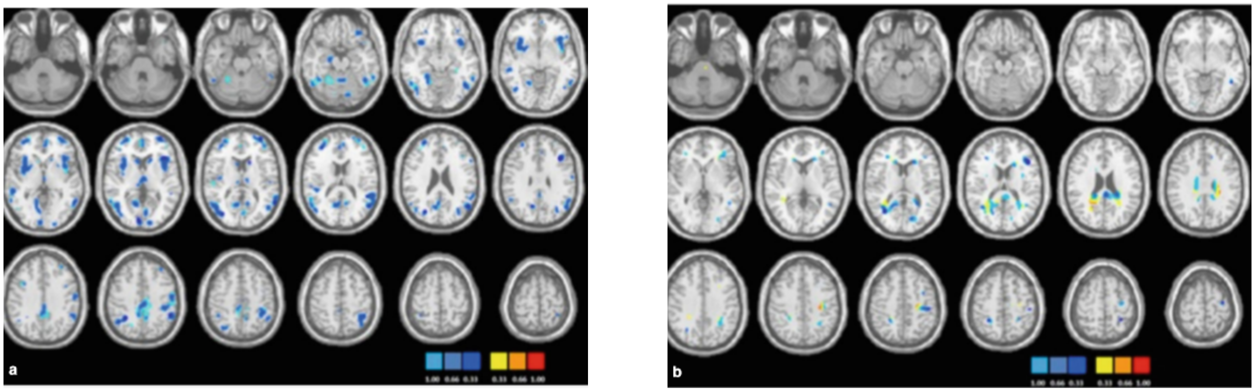

Figure 2: Discrimination maps for grey matter (a) and white matter (b) classification between patients with bipolar disorder and healthy individuals. Frangou et al. (2014)

Anxiety disorders are extremely common, especially in adolescents. The term “anxiety” is a blanket term that covers many specific types, namely post-traumatic stress disorder (PTSD), panic disorder, and generalized anxiety disorder. Even though generalized anxiety disorder is most commonly diagnosed, PTSD has received the most funding for research as it affects more adults and is especially prevalent in our military and medical field. fMRI is the preferred method for studying anxiety disorders as it allows scientists to see the activity in the brain when fear is used as a stimulus (Fang et al., 2015; Spoormaker et al., 2014). While hyperactivity in the amygdala is a general feature of most anxiety disorders, PTSD has shown significant hyperactivity in the amygdala as well as the anterior hippocampus and parahippocampal gyrus, which is very unique to PTSD (Spoormaker et al., 2014). Panic disorder specifically causes increased midbrain activity and changes in capnography (both hypo- and hypercapnia), along with differences in heart rate and blood pressure (Spoormaker et al., 2014), implying that it is necessary to use more tools than just functional imagery. Generalized anxiety shows increased activity in the amygdala, pallidum, and hippocampal complex specifically during social stimuli (Spoormaker et al., 2014). The most common feature across all anxiety disorders discussed is increase in activity in the amygdala and insula, which is analogous to fear conditioning in healthy humans. The unique features of each depend on stimuli and vital signs, making it clear that these variables are important to keep in mind when studying music’s effect on psychiatric disorders.

Major depression disorder (MDD) is another common psychiatric disorder, though it is frequently misdiagnosed and research suggests that antidepressants are a less effective treatment than music therapy (Nizamie and Tikka, 2014). The subgenual cingulate, thalamus, and orbitofrontal cortex were all activated at a much higher rate than healthy individuals (Greicius et al., 2007). In addition, the entorhinal cortex (EC) showed extreme asymmetry between the orbital and medial prefrontal cortex (OMPFC) and the amygdala when subjects were asked to classify happy faces during fMRI’s, specifically involving left-sided differences involving top-down connections (Almeida et al., 2009). One of the most unique features of major depression in functional imaging is the asymmetry in the EC, but it should be noted that Almeida et al. (2009) were only able to replicate the results with female participants and while providing the specific stimulus of classifying happy faces. As common as MDD is, there is little research on the functional imaging of MDD, especially using music or language as a stimulus. The most consistent unique feature seems to be increased activation of the thalamus and orbitofrontal cortex, as illustrated by Figure 3 (Greicius et al., 2007).

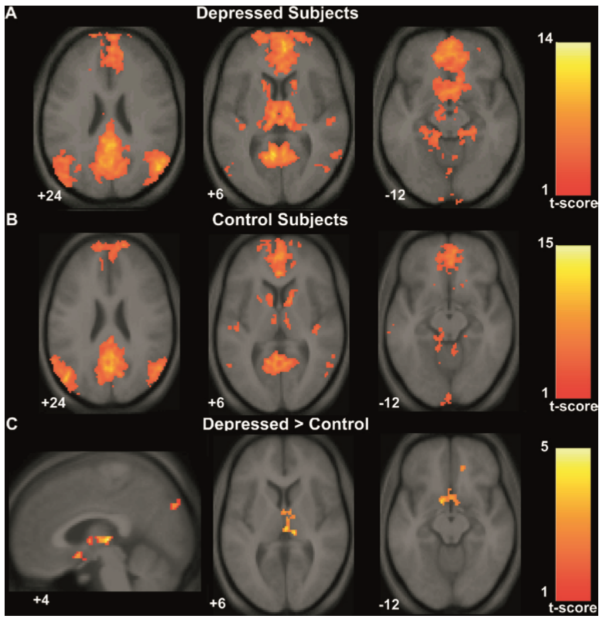

Figure 3: Functional MRI differences between healthy and depressed individuals. Greicius et al. (2007)

Schizophrenia is often considered one of the most extreme psychiatric disorders, as it produces symptoms that severely interfere with the lives of patients and there is no cure. Upon analyzing fMRIs of patients with schizophrenia stimulated by a word monitoring task, Tagaments et al. (2014) found that the cuneus, lingual gyrus, medial superior frontal gyrus, ilateral middle superior/middle temporal gyrus, posterior visual areas, medial superior frontal gyrus, left middle/superior frontal cortex, and right precentral cortex all showed differences when compared to healthy individuals. Schizophrenia is the most complicated with regards to the number of regions activated, but can be easily identifiable when compared to other psychiatric disorders' fMRIs as one would see incredible differences in nearly all regions of the brain. Though Tagaments et al.'s (2014) research was speech based, my hypothesis is that using music as stimuli would produce similar results, as many have concluded that music is a form of communication (Stewart et al., 2006; Fang et al., 2015; Warren, 2008). Schizophrenia is not well studied at this point and requires much more research in order to include it in disorders that music would be able to diagnose.

Conclusion

In summary, all psychiatric disorders discussed present with differences in the amygdala, insula, orbitofrontal regions, lingual gyrus, or cingulate gyrus, which are all regions connected to the processing of music in healthy individuals as well. There are unique differences for each disorder, which lends to the hypothesis that music may be a reliable stimulus that produces unique results when studying functional imaging of the brain. While there is a significant amount of research that has been done studying music and the brain in healthy individuals and functional imaging of some psychiatric disorders, research in the field of music psychophysiology is hardly complete. There is enough information to build a foundation for future research, but more research is needed to create consistent findings in the functional imaging of some disorders, such as in schizophrenia, depression, and others not mentioned in this review. In addition, there is yet to be information on how certain psychological disorders correlate directly to music as a stimulus. While some researchers site a correlation between music and vital sign changes (Krumhansl, 1997; Spoormaker et al., 2014), more research is also required to correlate vital signs and music as a stimulus in healthy individuals. Possible future research methods could include functional imaging of patients with psychiatric disorders listening to music, testing different types of music, monitoring vitals during musical listening with psychiatric patients, and testing the effectiveness and accuracy of using music to diagnose psychiatric illnesses.

Based on the information given by the current research, it can be concluded that psychiatric disorders would show differences in the brain when stimulated with music and it may be hypothesized that one could use music in conjunction with fMRI to diagnose the aforementioned psychiatric disorders. If researchers are able to find a correlation between vitals, music, and specific disorders while listening to music that is both unique to the disorder and reliable, affordable healthcare, diagnosis, and treatment of psychiatric disorders may be brought to the community and change the means, accuracy, and costs of mental health issue diagnosis and treatment.

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