AFFECT REGULATION, MENTAL HEALTH DISORDERS, AND MALADAPTIVE BRAIN RESPONSES IN MUSIC LISTENING

A Correlational Study

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Affect regulation may be defined as a process by which an individual maintains or modifies his or her mood or emotional state, by conscious or automatic processes. Adequate affect regulation may play an important role in mitigating or preventing mental illness, which is a widespread, inadequately treated and inadequately understood phenomenon. Music, which is known to express and induce emotions, may be used for affect regulation in a variety of ways, both self-directed and in therapeutic contexts. The effectiveness, however, of different uses of music in affect regulation is not yet understood. Both psychological testing and neuro-imaging were used to explore the relationship between individual differences in music use, risk or presence of mood disorder, and brain responses in music listening. For 123 participants, depression, anxiety and neuroticism measures were correlated with Music in Mood Regulation (MMR) scores. Psychological and MMR scores were then correlated with levels of neural responses in regions of interest (ROIs), exposing differences in participants with higher levels of depression or anxiety, and who more frequently use music in conjunction with a discharge or diversion regulation strategy. Differences were found between males and females both in music use and in neural responses to music listening. Males used the MMR strategy Discharge more when they had higher levels of anxiety and neuroticism. Measures of ROI activation in the right amygdala, right fusiform gyrus, and the bilateral prefrontal cortex correlated either positively or negatively with higher levels of depression, anxiety, or neuroticism, as well as males and females who used Discharge and Diversion as mood regulation strategies.

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mood regulation; music; depression; anxiety; functional magnetic resonance imaging (fMRI); gender differences; correlational analysis

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CONTENTS

1 INTRODUCTION

"Music oft hath such a charm
to make bad good, and good provoke to harm."
(Shakespeare, trans 1992, Measure for Measure, 4.1.14)

The focus of this research project will be to examine the behavioral- and neuro-correlates of affect regulation achieved by music listening, with special attention to behaviors and neural responses that correlated to mood and anxiety disorders and their known risk factors. Depression, the most common mood disorder, is characterized by pervasive negative mood, anhedonia, sleep disturbance, fatigue and can include suicidal thoughts. Anxiety disorders are characterized by persistent worry or fear, mental apprehension and physical tension (DSM, 1994). Recent studies of the incidence, prevalence, and treatment of mental health disorders in the United States found that the lifetime prevalence for adults' experience of anxiety disorders is 28.8%. (Kessler, Chiu, Demler, & Walters, 2005). Of these, 36.9% were receiving treatment, but only 12.7% were considered to be receiving "minimally adequate treatment" (Wang, Demler, & Kessler, 2002). In the same studies, mood disorders lifetime prevalence was 20.8% among the US adult population, with 4.3% of the adult population, experiencing symptoms that could be classified as "severe," the highest percent of any class of mental health disorder (Kessler, Chiu, Demler, & Walters, 2005). Only 50.9% of individuals with a mood disorder were receiving treatment, and just 19.6% were considered to be receiving "minimally adequate treatment" (Wang, Demler, & Kessler, 2002). Current pharmacological treatment options, notably the commonly used benzodiazepines for anxiety and SSRI for depression, are far from perfect in their efficacy (Kirsch et al., 2008). The prevalence of mood disorders worldwide is second only to anxiety disorders in a majority of countries with a shown 12-month prevalence of diagnosis being up to 9.6%, which is likely an underestimate due to inadequacies in systematic diagnosis and low self-reporting rates (Kessler et al., 2005). Though the etiology of mood disorders is clearly complex, multifaceted, and subject to individual differences, the need for a better understanding of vulnerability factors and potential treatment options is clear and demands interdisciplinary study (Beevers, 2011). Anxiety and depression can also appear in the same individual, a phenomenon known as comorbidity. Comorbidity is common between mood disorders and anxiety disorders, with up

to 60% of individuals diagnosed with depression also experiencing generalized anxiety disorder (GAD) (Kessler, et al., 2005).

Certain personality traits have been linked to higher incidence of depression and anxiety, notably neuroticism as measured by the Big Five Personality Test (Hayes & Joseph, 2003), which indicates an increased likelihood to experience negative mood. Studies have linked factors ranging from experience of emotional or physical trauma (Heim et al., 2008; Heim et al., 2004), genetic factors (Caspi et al., 2003), and nutrient deficiency (Bodnar et al 2005) to increased vulnerability to depression, suggesting a complex and multifaceted etiology affected by individual difference and the interaction between multiple factors. Among these factors, which have begun to receive more attention in recent years, are the differences in the ability of individuals to effectively regulate their emotions and mood states (Fernandez-Berrocal et al., 2006; Gross & Thompson, 2007; Joormann, & Gotlib, 2010). Mood regulation may also play an important role in anxiety disorders (Barlow et al., 2004; Amstadler, 2008). While many studies of such regulatory mechanisms have focused on adaptive and maladaptive behaviors and cognitive strategies, other research has found specific areas of brain activation associated with emotion regulation and its subsets (Ochsner & Gross, 2005; Koenigs & Graffman, 2009). Improvement in the understanding of neuroanatomical differences between the brains of healthy individuals and those with depression, a disorder which is still clinically diagnosed through behavioral and cognitive measures, also point insistently to the relevance of examining behavioral- and neuro-correlates together (Seminowicz et al., 2004).

Literature dealing with human emotion is often mired in poorly defined terms that must be disentangled (Juslin & Västfjäll, 2008). For the purposes of this study, *emotion* is defined as an affective response to a stimuli which may include psychological, cognitive and physiological aspects and with a duration between several minutes and hours; *mood* is defined as a less-intense affective state with a duration between hours and days, and which is not necessarily in response to a specific emotional stimuli; *affect* will be used, after the model provided by Juslin and Västfjäll (2008), as an umbrella term encompassing both emotion and mood. *Stimuli* in these cases can refer both to an external physical stimuli such as music, images or social interactions but also to internal objects such as memories, imagery or conscious thoughts.

The above definition opens a vast range of stimuli that might be used to study affect regulation. In deciding which of these stimuli to study, music is an immediately appealing choice due to its ubiquity (Hargreaves & North, 1999) and documented ability to communicate emotions to as well as produce emotions in its listeners (Juslin, 2003; Juslin, 2013). Though music is currently being used in the treatment of mood disorders in the form of music therapy, with some evidence for its efficacy, there is a paucity of well-controlled studies to explain the mechanism by which positive effects may take place (Maratos, Gold, Wang, & Crawford, 2008). It has also been shown that individuals use music for mood regulation in a variety of ways (Saarikallio & Erkkilä, 2007), but these also importune further investigation, as there is not yet much data on their relative effectiveness.

The relationship between music consumption and mental health may of course go both ways. Rising concerns in the 1990's about adolescent mental health, suicide risks and violence lead to rampant public speculation about the contribution of popular genres such as heavy metal and rap to this degeneracy as well as a smattering of actual scientific studies with mixed and sometimes ambiguous results (Jones, 1997; Scheel & Westefeld, 1999; Lacourse et al, 2001). Researchers are also only beginning to examine the curious phenomenon that many individuals choose to listen to sad music for pleasure, sometimes even when negative affect is experienced as a result, a fact that poses a serious problem for theories that music is adaptive as a purely hedonistic activity (Garrido & Schubert, 2011; Vuoskoski & Eerola, 2012). In his own defence, the famous heavy metal musician Marilyn Manson wrote that humans have needed no inspiration from the arts to commit violence against one another since prehistoric times (Manson, 1999). However insightful this speculation may be (or alternatively, however dubious the assertion that music emerged in human history after homicidal violence), it remains that there is still insufficient research to fully explain potential relationships between music consumption and mental health, be they positive or negative. And given the prevalence of mental illness and of music in contemporary society, a potential relationship between these two is worth investigation. Correlations between preferences for particular genres or certain patterns of listening and increased or decreased risk of mood disorder could have implications for neural and psychological models of emotional processing, clinical music therapy, general clinical treatment of mood disorders. Identification of such correlations is of course a

necessary precursor to further experimental study to establish causality and to test resulting treatment methods.

1.1 Research Questions

The aim of this study will be to explore whether any correlation can be established between individuals' use of music in affect regulation, their brain responses to music, and their risk of experiencing a mood disorder. While not specific to music therapy, the topic will be approached from the perspective of potential clinical applications. As client-preferred music is generally stressed as having the greatest benefit to music therapists in training (Borczon, 2004), it would be imperative for an effective therapist to have an understanding of whether the clients' music listening patterns and preferences can become maladaptive, failing to assist in and even hindering their treatment. To that end, the following research questions will be addressed:

1) How does an individuals' use of music for affect regulation relate to his or her mental health?

2) What are the neuro-correlates of individual differences in affective response to music?

3) Can maladaptive affective responses to music be observed in the brain and, if so, can they be correlated to risk for mental illness?

4) If some instances of music in affect regulation are maladaptive, is this best modeled in terms of behavior, neural responses, or both?

This research will examine these questions using data gathered by Elvira Brattico and colleagues as part of the Tunteet music and emotions research project.

The literature review will examine past and current research to music processing and consumption, mood disorders and risk factors for mood disorders, and affect regulation. Behavioral, cognitive, and neuroscientific studies are all included in an effort to highlight potential parallels as well as potential incompatibilities among these areas. The aim of this literature review is to clarify the need for more intentional research and theory arising from a synergy between these related, but sometimes disconnected, areas of study.

2 LITERATURE REVIEW

2.1 Music and affective responses

Though the adaptive evolutionary function of music is still a topic of much debate (Hauser & McDermott, 2003), the fact that one of its current functions is to communicate, elicit and even modulate mood and emotions in human listeners has been shown by empirical research (Hargreaves & North, 1999; Saarikallio & Erkkilä, 2007), making it a potentially useful vehicle for increasing understanding of human emotions in general. The attempt to explain and understand human emotions is not new by any stretch of the imagination, nor is it the exclusive domain of the sciences. Indeed, scientific inquiry may not represent a first choice for many curious wonderers; each of the arts had offered its own account, rife in long-developed complexity with representation and reflection of human emotion, while the empirical scientific method was still struggling to a moderately influential level in Western culture. Still, empiricism, and particularly the experimental variety, is the epistemological winner of our own time. Furthermore, though the arts have already provided the tuned mind with a good deal of practice in recursion, the inherent difficulty of the eye seeing itself requires an element of external observation to explain the emotional relationship between man and his creative expression.

The relationship between the arts and human emotional health may seem a new concept, even erring to the side of trendiness, but a link between creative genius and insanity was speculated by Aristotle, and fell again into vogue in the nineteenth century (Galton 1892). In the advent of the scientific method, studies of varying reliability found higher prevalence of mental illness among artists, writers and musicians (Waddell, 1998). In spite of these findings, it still stands to note that, in terms of pragmatic approaches to increasing understanding of and treatment of mental health disorders, they are applicable to only a minority of individuals. Far more practical (though perhaps far less romantic) a subject lies in the experience of the audience, the reader of poetry, viewer of a painting and listener of music. The latter is

arguably the most common of all of these; studies have shown that music is present in between 37-41% of waking life (Rentfrow & Gosling, 2003).

In discussing the development of music therapy in the treatment of psychiatric disorders, Michael Thaut defines music as "an aesthetic sensory-based language consisting of spectrally and temporally high complex auditory patterns that perceptually engages cognitive, emotional and motor functions in the brain" (Thaut, 2005a). The function of music as an emotional stimulus is considered by many to be one of its most essential traits, though the mechanism by which music may express or induce emotion is an area of continued research (Juslin & Laukka, 2004; Sloboda & Väsftjäll, 2008, Brattico & Pearce, 2013). The 19th century musicologist Christian Schubart famously suggested that each of 25 major and minor keys or tonal centers possessed inherent affective characteristics: E major expressed the purest joy, while B minor was associated with patient acceptance and F minor with severe depression (Schubart, 1806). This model gave way in the advent of modern methodology to attempts at a more empirical grasp of the relationship between music and human emotion. Perhaps the most frequently cited for the development of such theories is the Gestalt-influenced Leonard Meyer, whose model of melodic expectation (1956) maintains its relevance in the study of both expression and induction of emotions in music (Sloboda, 1991). Studies of perceived emotional content in music performance have shown that listeners are sensitive to and able to judge emotional content in music that is culturally unfamiliar, based on psychophysical cues (Balkwill & Thompson 1999), and that performers use acoustic cues such as articulation, speed and timbre to successfully relay specific emotions to listeners (Juslin, 2003). Juslin and Laukka (2004) reviewed the literature and found that the more than 100 studies have shown that listeners report predictable emotional responses to various music stimuli. However, it stands to note that the relationship between perceived emotional content and induced emotion in music listeners is not completely clear (Gabrielsson, 2002) and that induced emotion is arguably more difficult to measure than perceived emotion (Juslin & Laukka, 2004). It is unsurprising, then, that defining the neural correlates of music-induced emotion in the brain is currently among the chief research interests in the field of music neuroscience (Levitin, 2009).

One of the more comprehensive, if complex, models of how music induces emotions has been provided by Juslin & Västfjäll (2008), who reviewed the literature and argued brilliantly for

the need for a clearer model of musical affect induction and tease out previously muddled terms. Their model differentiates between six distinct but not mutually exclusive mechanisms by which music may change affect: brain stem reflexes responding to music as sound, evaluative conditioning, emotional contagion, visual imagery, episodic memory and musical expectancy. Of these, they posit evaluative conditioning and emotional contagion to be most likely to produce basic emotions such as sadness or fear, while visual imagery and episodic can induce a broad range of emotions, and brainstem reflexed and musical expectancy are related more to arousal and aesthetic pleasure. These differencing mechanisms are modeled to take place in discreet brain areas, with the amygdala, basal ganglia and inferior right frontal regions among those linked to the induction of basic emotions (Juslin & Väsfjäll, 2008). Along with basic emotions, aesthetic emotional responses are becoming an area of interest in music cognition. Brattico and Pearce (2013) point out that, while most music research has focused on basic emotions, aesthetic experiences and judgments are distinct from basic emotional responses in terms of neural processes, and important to study in order to gain a complete understanding of music listener experiences. The development of musical preference can be understood as an interaction between aesthetic experiences and judgments and induced basic emotions, with familiarity and attention also playing key roles (Brattico & Pearce, 2013).

2.2 Affect regulation, music, and mood disorders

As a cultural and aesthetic phenomenon, music does not only simply appear passively in an individual's environment to be responded to in one way or another. Music may be sought out intentionally for a variety of reasons, one interesting one of which (for this discussion) is the desire to influence the listener's affective state.

Affect regulation may be defined as a process by which an individual maintains or modifies his internal affective state, and for the purposes of this paper will be supposed to include both emotion and mood states. Affective regulation strategies may be automatic or controlled, and include cognitive and behavioral strategies of diversion or engagement (Parkinson & Totterdell 1999). Thayer, Newman, and McClain (1994) gathered data on mood regulation strategies, including music listening, and found that strategies could be grouped as belonging to self-control, analysis-reflection or affiliative-communicative categories, and that while

social interaction was the most frequently used method, physical exercise was the most effective. The ability of an individual to effectively regulate affect is important to many functions of daily living, including the ability to attend to work, healthy adaptation within social relationships, and having a healthy inner life (Gross, Richards & John, 2006).

Larsen (2000) presented a model of the regulatory mechanism as comparable to an indoor thermostat, measuring current affect in comparison to a desired set point, and adjusting to attempt to reach this individualized set point. Larsen's model also reflects the growth in understanding of individual differences, defining six points of possible individual variance in mood regulation, including beliefs about optimal state, attention given to current state, and affective reactivity. Erber and Erber (2000) however, providing commentary on this model, criticized the supposition that the "thermostat" is always set to "happy," (that is, that increased happiness is the invariable goal of mood regulation) and suggested instead that goals of overall stability and socially appropriate behavior may lead an individual to sometimes desire to adjust his own affective state downwards. In clinical settings, for example, a therapist may wish to help a client with depression regulate his affective state upwards, but a client experiencing a manic state, such as appear in bipolar disorders, would certainly benefit more from downward affect regulation.

Gross and Thompson (2007), in attempting to model the mechanisms by which affect regulation takes place, note the difficulty in distinguishing between affect and affect regulation both in modeling and in empirical observation of neural processes. They espouse a "situation-attention-appraise-response sequence" model, further specifying that a situation may be external or internal (Gross & Thompson, 2007, p. 6-7). Resulting strategies of affect regulation can be grouped into four distinct yet overlapping categories: coping, emotion regulation, mood regulation and psychological defenses, with emotion and mood regulation being differentiated exactly as emotion and mood are differentiated; that is, by duration, intensity and the presence or lack of a focus "object" (p. 12). Like others, Gross and Thompson include attentional diversion, cognitive appraisal and rumination as possible regulation strategies.

In 1994, Thayer found it surprising that music so often appeared as a regulation strategy for his participants (p. 192), but given the previously discussed prevalence of music listening in

everyday life, the function of music as at the very least a vehicle of diversion may be less unexpected to the modern researcher. But since, as has already been shown, music is capable of inducing specific emotions in its listeners, one must consider the possibility that music's function in affect regulation can be much more than diversionary. Chen et al. (2007) found that, while participants induced into a negative mood initially opted to listen to sad music, towards the end of the eight allotted minutes these participants' choices tended to shift towards more joyful music selections, suggesting that music selection may be congruent with affective state. This, however, does not necessarily clarify whether the music in this case was intended to repair affect.

To examine how adolescents might use music for mood regulation, Saarikallio (2007) performed in-depth interviews with a focus group of adolescents and developed a model of the strategies by which music may be used for mood regulation. This led to her development of the Music in Mood Regulation scale, an individual self-report measurement tool that defines 8 categories of music mood regulation strategy and provides both an overall score of how much music is used in mood regulation and scores corresponding to how much each type of use is employed (Saarikallio, 2008). The MMR defines these strategies as: Entertainment, Revival, Strong Sensation, Diversion, Discharge, Mental Work and Solace. Each strategy is defined by a typical mood prior to music use, typical musical activity, social aspects, and typical changes in mood follow the music use. Further study found that emotional agreement with heard music was associated with high overall MMR score and higher scores in Discharge and Solace (Saarikallio, Nieminen, & Brattico, 2012). Discharge, in particular, is associated with negative mood states. It is defined by a typical mood prior to music use of anger, sadness or depression, listening to aggressive or sad music, and with an outcome of the music having expressed the negative feeling. Solace, while similar, has an outcome of the listener feeling comfort (Saarikallio, 2007, p. 96). The MMR does not, however, specifically provide information on the relatively efficacy, adaptiveness or maladaptiveness of the behaviors it measures, which could be a subject of great interest for mental health professionals, and particularly for music therapists.

This question of efficacy may begin to be addressed by examining research related to non-music affect regulation strategies. Various cognitive patterns and behavioral patterns have been correlated to increased or decreased risk of both mood and anxiety disorders in

individuals. Troy, Wilhelm, Shallcross, and Mauss, (2010) found that higher cognitive reappraisal ability (CRA), the ability of an individual to consciously change his or her assessment of an emotion-inducing stimuli as being less negative than initially experienced, decreased subjects' risk for experiencing depressive symptoms after stressful events. Klenk, Strauman, and Higgins (2011) proposed a model in which repeated failure of psychological mood regulatory mechanisms promote both depression and anxiety in individuals. McRae and colleagues (2008) found cognitive reappraisal similarly effective for male and female subjects, but that brain responses during cognitive reappraisal tasks differed by gender. While women showed greater increases in prefrontal areas and ventral striatal areas, associated with reappraisal and reward respectively, men showed greater decreases in amygdala response, suggesting that emotion regulation may be a more automatic process for males (McRae et al., 2008).

Hayes and Joseph (2003) found a correlation between high score in the personality trait neuroticism, defined as a tendency to experience negative emotions, and increased risk of depression. In the dimension of approach and avoidance tendencies, both have been shown to have functionality in coping with stress (Roth & Cohen, 1986), but avoidance tendency has been correlated with depression (Matsudaira & Kitamura, 2006). Rumination, in psychology, can be defined as cognitive processes involving the engagement in repetitive focus on situations, frequently the negative aspects of a situation. Unlike cognitive reappraisal, rumination does not involve attempts to change the conscious understanding of a situation. It has been frequently correlated with increased risk of depression and anxiety (Arnone et al., 2009; Papadakis et al., 2006). Moulds Kandris, Starr, and Wong (2007) explored the relationship between rumination and its subtypes, avoidance and its cognitive and behavioral subtypes, and depression by means of multiple surveys, examining the relationship of depression and anxiety to 'brooding' and 'reflecting' rumination, as well as to avoidance behaviors. Results showed that rumination and behavioral avoidance were correlated, but this relationship did not hold true for rumination and cognitive avoidance when anxiety was removed as factor.

One of the difficulties in assessing current literature on correlations between music listening and mental disorders is the myriad of theoretical frameworks that can be employed in such research. Miranda, Gaudreau, Debrosse, Morizot and Kirmayer (2012) reviewed literature

relating music listening and psychopathology, and defined no less than seven models by which previous research has explored this relationship, with music acting as a (1) risk factor, (2) compensatory factor, (3) common cause, (4) mediator, (5) moderator, (6) protective factor, or (7) a precipitating factor. Some of these models are self-explanatory; the first, for which Miranda and colleagues found inconsistent support, espouses hypotheses in which listening to a certain type of music, such as metal, increases an individuals' risk of experiencing mental illness, while the second, for which firmer evidence exists, examines the opposite phenomenon of music listening decreasing risk of mental illness. In the third model, a non-musical risk factor, such as neuroticism, may predispose an individual to develop maladaptive listening habits as well as symptoms of mental illnesses such as depression. In the other four models, music acts either in concert with or opposition to other independent variables in predicting mental illness. None of these models, according to Miranda and colleagues, either completely explains or completely fails to explain a relationship between music listening and mental illness, a conclusion that points to the need for further research and more complex model development.

One recent area of inquiry in music cognition research, which suggests a tantalizing parallel between cognitive rumination and music listening, is the phenomenon that individuals may choose to listen to sad music for enjoyment. Garrido and Schubert (2011) suggest ruminative tendency and absorption, defined as the extent to which an individual experiences the same emotions as are expressed by a stimulus, may explain a preference for sad music in some individuals. A combination of strong absorption and music empathy will lead to preference for sad music for aesthetic enjoyment; music empathy on its own will lead to avoidance of sad music; and high absorption with attentional bias towards negative affect, common to depressive rumination, will lead to preference for sad music though it may prolong or increase negative mood. Further study associates absorption and rumination as individual traits with listening to sad music in a way that does not repair negative mood (Garrido & Schubert 2012).

Research is needed to establish whether there are correlations between music listening strategies, such as those defined by the MMR, and diagnosis of mood disorders. The similarity between Discharge and rumination make it a particularly interesting category in terms of this potential. In Discharge, the listener's mood is expressed rather than changed as

an outcome of music use; while this does not *necessarily* imply a relationship to Garrido and Schubert's model of musical empathy and absorption, there is certainly room for this model within the range of possible mechanisms at work when Discharge is employed as a mood regulation strategy. As Diversion indicates using music to distract from negative emotions, it could also be construed as an opposite to rumination, such that a lower score in using Diversion as a mood regulation strategy may indicate increased risk of depression.

Joorman and D'Avanzato (2009) reviewed the literature and found that, while certain regulation strategies, including rumination, have been correlated to increased risk of depression, few studies have been done to understand the relationship between individual differences, affect regulation and risks for mood disorder. Given the gender differences shown by McRae and colleagues (2008) in neuro-correlates to regulation strategies, and the importance of brain imaging studies for understanding how music might induce emotions, a complete understanding of individual differences in affect regulation using music must therefore take brain responses to music listening into serious consideration.

2.3 Brain responses in mood disorders and mood regulation

The neural mechanisms by which individuals experience affective states, and changes therein, is a matter for continuing research (Davidson et al., 2002), and from a clinical perspective must be examined when considering music in light of its role in mood disorders (Thaut, 2005b). Traditionally, the "emotional brain" in humans is associated with structures that appeared early in human evolution relative to the cortex. The *mammalian brain*, which represents a layer above the slightly more famous *reptilian brain*, is comprised primarily of the limbic system, which is densely connected with yet distinct from the cortex and is usually considered to include the hypothalamus, the anterior cingulate cortex (ACC), the thalamus, and the amygdala. The amygdala, broadly associated with fear responses, is a collection of nuclei including the *basolateral complex,* which is involved in emotional arousal in humans (Baars & Gage, 2010). That affect can be affected by exposure to external stimuli, including images of faces expressing different emotions, has been shown in multiple studies (Schneider, Gur, Gur, & Muenz,1994; Ramel et al., 2007; Dyck et al., 2009). Recent developments in research technology have allowed for increased understanding as to the neural mechanisms by which emotional stimuli is processed and mood induction or regulation may occur. The ACC

has been shown to be broadly implicated in cognitive and emotional responses (Bush et al., 2000). Philips (2003) and others posited two separate but related neural systems for emotional processing: a ventral system responsible for stimulus identification and automatic emotional responses, and a dorsal system responsible for emotional regulation. Further research has shown that the medial prefrontal cortex (mPFC) along with the amygdala is active in the processing of emotional stimuli (Phan et al., 2006).

Vuilleumeir and colleagues (2005) showed images of faces expressing fear, faces with no expression, or a house with varying degrees of attention and awareness to the participant. They found that fearful faces activated the left amygdala regardless of whether the participant was aware of the fearful face, while conscious perception increased activation of cortical areas including the prefrontal cortex. This suggests that emotional stimuli need not be attended to consciously in order to produce a response from the limbic system. The usefulness of this ability from an evolutionary perspective is fairly easy to surmise; automatic responses to fearful stimuli have clear survival benefits. Similarly, however, its maladaptiveness to modern environments is also possible to imagine. A highly responsive limbic system may, for example, at one point have been a benefit to survival, but high responsiveness to, for example, exposure to sad or aggressive music in a modern environment may have more negative effects in the listener.

The relationship between the neural mechanism of mood state and those of pervasive mood disorders is not yet clearly understood and likely not linear (Drevets, 2008). Frodl and colleagues (2003) found increased amygdala volume in individuals experiencing a first depressive episode, but no difference in size of amygdala between chronically depressed individuals and healthy controls. Caetano et al. (2004), however, showed decreased size in the amygdala and hippocampus in individuals with depression compared to healthy controls. Holmes and colleagues (2012), however, showed that an imbalance in size between the amygdala and the medial prefrontal circuitry is related to negative affect and decreased social functioning in the general population, which may be linked to genetic risk factors for depression. Previous research has shown repeatedly that individuals with mood disorders, and particularly with major depression, experience different responses on both perceptual and neuromechanical levels from normally functioning peers. This is most often observed in terms of amygdala activation (Leppänen, 2006; Raes, Hermans, Williams, & Mark, 2006; Peluso et

al., 2009, Bourke, Douglas, & Porter, 2010;). Similar research has also shown the importance of the fusiform gyrus in emotional processing of visual pictures, and difference between healthy and depressed participants in fusiform gyrus activation in response to images of happy or sad faces (Surguladze et al., 2005). This is often described as an attentional bias towards negative emotions in individuals with mood disorders. It may, however, be just as accurate to describe this phenomenon by stating that individuals with depression experience a failure in an automatic mechanism of attentional bias *away from* negative emotion in stimuli when compared to typically functioning participants (Viviani, Lo, Sim, Beschoner, Stingl & Horn, 2010). Furthermore, depressed individuals tend to experience longer activation of the amygdala in response to negative stimuli, suggesting a tendency for individuals with mood disorders to experience longer negative mood states than healthy peers (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002).

In the above research, the stimuli employed were visual—either pictures or movies, so research cannot yet comment upon whether the same neural differences can be seen between depressed and non-depressed individuals when listening to music, but they certainly suggest that differences would exist. Maladaptive neural responses to music listening may be similar to those describe in previous research, including increased responsiveness of the amygdala to music expressive of sadness or anger.

Since pathological affect can been seen in the brain, the mechanism by which affective states are changed in the brain is also an area of interest. Neuroimaging studies lend support to the existence of distinct regulation processes. Ochsner and Gross (2005) reviewed neuro-imaging studies related to cognitively-controlled affect regulation and found that different control strategies, such as distraction or cognitive reappraisal, activate close but distinct parts of the lateral and medial PFC. When dividing regulation processes according to whether emotion is sought to be increased or decreased, Ochsner and Gross found that the right lateral PFC, along with the orbitofrontal cortex (OFC), became more activated when the strategy involved decreasing an undesirable emotion. The researchers also suggest that another useful division of distinct affect regulation processes is between those which recruit only ventral systems and those with recruit both ventral and dorsal systems (Ochsner & Gross, 2005), in agreement with the previously discussed model provided by Philips (2003). Koenigs and Grafman (2009) further explored ventral and dorsal substrates of the PFC in relation to depression by

reviewing neuro-imaging, lesion and brain-stimulation studies, and found that the dorso-lateral PFC and ventral-medial PFC appear to play reverse roles depending on whether individuals studies were healthy or depressed. In individuals with depression, the vmPFC, richly connected to the amygdala and hippocampus associated with emotional responses, was hyperactive while the dlPFC, associated with cognitive responses was hypoactive. The researchers suggest that the vmPFC may play a key role in the generation of negative emotion, but also may be important for self-awareness and self-reflection (Koenigs and Grafman 2009).

Fabiansson, Denson, Moulds, Grisham, & Schira (2012) draw on distinctions made by previous researchers in types of rumination, particularly 'analytical rumination' compared to 'angry rumination'. Twenty-one participants underwent neuro-imaging while being instructed to think of an anger-inducing event from the last year, about which they filled out a mood questionnaire, and were instructed to think of the event in different ways to reflect reappraisal, analytical rumination, and angry rumination Results showed that emotional regulation strategies differ in terms of extant functional connections between neural regions. One other notable finding of this study is that, during analytical and angry rumination, but not during reappraisal, inferior frontal gyrus activation was positively correlated to amygdala and thalamus activation (Fabiansson et al 2012).

A summary of possible brain areas of interest in emotion regulation in music listening is presented in Table 1:

Table 1: Brain areas implicated in emotion regulation by previous research

Areas of Interest	Brodmann Area	Literature
Ventral-medial Prefrontal Cortex (vmPFC)	BA10, BA11, BA25	(Philips, 2003; Ochsner & Gross, 2007; Koenigs and Grafman 2009)
Lateral Prefrontal Cortex (lPFC)	BA9, BA46, BA44, BA47	(Philips, 2003; Ochsner & Gross, 2007; Koenigs and Grafman 2009, Fabiansson et al 2012)
Anterior Cingulate Cortex (ACC)	BA24, BA32, BA33	(Bush et al. 2000; (Sloboda & Väsfjäll, 2008).
Fusiform Gyrus	BA19, BA20, BA37	(Surguladze et al, 2005)

Amygdala (L/R)	Subcortical, medial temporal lobes	(Frodl et al., 2003; Sloboda & Väsfjäll, 2008; Koelsch, 2010)
Basal ganglia	Subcortical, telencephalon	(Sloboda & Väsfjäll, 2008)

In defining expected 'maladaptive' responses to music listening, it seems probable that the listed areas will be active during music listening, and that the differences between individuals with depression and healthy individuals in music listening will be similar to those reported above. These responses that literature has previously associated with depression may be considered maladaptive in music listening. However, since music listening has been shown induce pleasure (Blood and Zatorre 2001), it may be further added that the failure of neural mechanisms associated with pleasure to respond to music listening may also be considered maladaptive. In sum, a maladaptive brain response to music is here defined as the one that is associated with increased negative or decreased positive emotional experience when compared to normal listening responses.

2.4 Current aims

In affect regulation, music differs from previously studied stimuli, such as faces expressing various emotions, in that many individuals will seek out music consciously as a means of mood regulation or mood reinforcement (Chen et al., 2007; Saarikallio et al., 2012). Thus, its ecological validity as a stimulus merit more thorough study of the neural correlates of emotional information processing and mood induction in healthy individuals and those vulnerable to or experiencing mood disorders. The neural correlates of processing music as an emotional stimulus have not yet been thoroughly examined. Koelsch (2010; 2014) reviewed the literature on the neural correlates of musical emotion and found that limbic and paralimbic structures are considered by many researchers to be of high significance in the processing of emotional content in music, and that this processing is strongly affected by cross modal stimulus processing. As with non-musical stimulus studies, the amygdala, hippocampus and parahippocampal structures have been shown to play an important role in processing of emotional content in music (Koelsch, 2010).

From current research, it is reasonable to suspect that a correlation may be found between the individuals' tendency to listen to sad music without repairing their mood (i.e., using Discharge as a listening strategy) and their likelihood of experiencing a mood disorder, as revealed by psychological testing and by abnormal brain responses, such as increased amygdala activation. Increased understanding of the parameters of such a correlation could have implications in clinical settings, where self-regulation skills may be emphasized. This may be particularly true of music therapy, where client preference often drives a therapists' choice of music. In cases of mood disorder where music may be used as a medium for rumination, or similarly may increase negative mood through maladaptive neural responses as is seen with other emotionally focused stimuli, a client's preferred sad music would likely not a suitable choice for a therapeutic context. However, the mechanisms by which emotional processing and mood induction take place in the brain are not well understood, and the relationship between individuals' use of affect regulation and what could constitute maladaptive use also requires further research.

The first aim of the current study, therefore, is to test whether there will indeed be correlations between Discharge use and depression or its risk factors (i.e. anxiety and neuroticism). This study will also examine whether, during music listening, there are correlations between depression or its risk factors (i.e. anxiety and neuroticism) and maladaptive patterns of neural activation, or between any MMR scores and maladaptive patterns of neural activation.

3 METHODOLOGY

This study uses data that has been collected at Aalto University by Elvira Brattico and others in conjunction with the Tunteet Project, which is designed to explore neural activity related to emotional responses in music listening. This study employed extensive psychological testing of subjects, as well as collection of fMRI data for a subset of these subjects.

Preprocessing and statistical analysis for psychological and brain data will first be done separately. The importance of delaying attempts at correlating brain and behavioral data prior to separate statistical analysis is highlighted by Vu and colleagues (2009), who published a meta-analysis of studies combining neuroimaging techniques and behavioral or psychological measures. They found that correlations between fMRI data and such psychological measures are often reported to be statistically higher than should be possible according to measure of reliability, due to significant clusters being defined by correlation to behavioral measures. Their results emphasize the importance of completing independent analysis of fMRI data prior to correlating this data to behavioral measures. Meaningful correlations between functionally defined ROIs and behavioral measures can thus be calculated between percent signal changes for each ROI per participant and each participants' behavioral test scores (Vu et al, 2009).

3.1 Psychological Testing

3.1.1 Participants

A total of 123 participants (68 females), between the ages of 18 and 55 completed psychological testing. Participants' mean age was 28.8 (SD = 8.89 years). The majority of these participants were non-musicians (N = 68), while others were identified as amateur musicians (N = 38) or professional musicians (N = 20). Participants were recruited from the student and staff of Aalto University and Helsinki University.

3.1.2 Measurement Tools

Participants completed the MMR in addition to an extensive range of psychological tests related to emotion, mental health and personality. The tests which were used in the current study are displayed in Table 2.

Table 2: Psychological Tests

Test	Purpose
Music in Mood Regulation (MMR)	Defining music-related mood regulation behaviors
The Hospital Anxiety Scale (HADS-A)	Level of anxiety from none/low to high
Montgomery-Åsbert Depression Scale MADRS	Level of depression, from none/low to high
NEO-Psychological Personality Inventory (NEO-PPI)	Level of neuroticism
Big Five Questionnaire (BFQ)	Level of neuroticism

The BFQ assesses the traits defined by the Five Factor Theory of Personality: openness, conscientiousness, extraversion, agreeableness and neuroticism. The participants rank their level of agreement from 1-5 with statements related to each domain, such as "I'm fascinated by novelties" or "I'm an active and vigorous person" (Caprara et al., 1993). The NEO-PPI further divides these traits into sub-facets, with both anxiety and depression falling under the category of neuroticism (McCrae, Costa & Martin, 2005). The MADRS is a diagnostic test, the scoring of which allows clinicians to rank depression level based on the participants' score between 0 and 60 points. Müller, Szegedi, Wetzel, and Benkert (2000) correlated the MADRS to the Hamilton Depression Rating Scale in order to distinguish four levels of depression: none/recovered (1-8), mild (9-17), moderate (18-34), severe (>35) (Müller et al., 2000). Previous studies have used the MADRS as a continuous measure (Raison et al., 2007). The Hospital Depression and Anxiety Scale is also a self-report measure designed to indicate the severity of depression and anxiety symptoms, and possible or probable cases of clinical disorders (Zigmond & Snaith, 1983) with demonstrated validity (Bjelland, Dahl, Haug, & Neckelmann, 2002). However, it should be noted that, in this study, the HADS test was translated into Finnish from Swedish, resulting in some discrepancies in meaning, identified by native Finnish speakers. Because of this, only the HADS-A, measuring anxiety, was used for this study.

Additionally, the Helsinki Online Music Questionnaire (Gold et al., 2013) was used to assess the musical abilities of participants. This was considered necessary to control for individual differences in musical ability and experience in participants' neural reactions to music listening, as well as potential differences in use of music for mood regulation. Previous studies have shown differences between the brains of musicians and non-musicians (e.g., Gaser & Schalug, 2003).

Although each of these tests is subject to the limits of all self-report measures, chiefly the ease with which a participant may exaggerate or understate his own symptoms, these tests are well established as measures to determine the personality traits and mental healthiness of the participants.

3.2 FMRI Measures

3.2.1 FMRI Data Collection Overview

FMRI uses the Blood-oxygen-level dependent (BOLD) signal contrast to measure the degree of activation in discrete brain areas over time. The BOLD signal arises from the difference in magnetization between oxygen-rich and oxygen-poor blood. Changes in cerebral blood flow to particular brain regions as a result of neuronal activation result in changes in oxygenation of the area result in changes increase magnetization, which in turn causes an increase in the MRI signal. This allows for collection of spatially detailed information. Temporal information, however, is somewhat obscured by physiological factors such as the speed of blood flow to an activated area, as the BOLD signal takes about 5 seconds to reach a maximum for a given activation, and the length of time it takes the BOLD signal to return to baseline after such an activation, as the BOLD does not return to baseline for 15-20 seconds after peak activation. Images of BOLD signal activation at a given time point are taken at regular intervals (every two seconds in the current study) to create a time series of three-dimensional images, stored and analyzed as data matrixes containing activation information for each voxel at each point in time.

3.2.2 Participants

A subset of 60 subjects participated in the fMRI session and of them four were excluded from the analysis due to technical issues, excessive movements during scanning, neuroradiological abnormalities as diagnosed by a doctor. The remaining 56 (33 female) participants between the ages of 20 and 53 (mean age 28.5 years, SD = 8 years) were measured using fMRI to assess brain responses to emotionally valenced music stimuli. 29 of these participants were identified as non-musicians, while the remaining participants were either amateur musicians (N = 22) or semi-professional or professional musicians (N = 5).

3.2.3 Stimulus

Music stimulus of 30 excerpts (10 each representing happiness, sadness, and fear) was derived from the Soundtracks dataset for music and emotion developed at the University of Jyväskylä by Eerola and Vuoskoski (2011). Soundtrack music is considered an appropriate stimulus for emotion perception because it is composed with the utilitarian purpose of inducing and expression appropriate emotions in the context of a film, and it is less likely to be overtly familiar to listeners, thus reducing the possibility of variation in response due to associated episodic memories. The dataset includes 360 excerpts that have been experimentally shown to accurately express five discrete emotions: happiness, sadness, anger, tenderness and fear. These discrete categories have also been validated in a dimensional model of music and emotion. Note, however, that the excerpts have been experimentally validated in terms of *perception* (the listener can identify correctly which discrete emotion is being expressed by the music) rather than *induced emotion* (the listener experiences discrete emotions as a response to the stimuli).

For the current experiment, 81 excerpts were chosen from the happy, sad and fearful categories, which were highly ranked by participants as expressing these emotions in the Eerola (2011) study. Fear, it should be noted, was found by Eerola and Vuoskoski (2011) to be similar to and even difficult to distinguish from anger in terms of listeners' perceptions. Excerpts were reduced to 4 seconds each with 500ms fade-in and fade-out. Excerpts were normalized to match each other for loudness. 10 participants who did not undergo fMRI measurement rated the resulting excerpts. Ten excerpts judged most representative of each happiness, sadness, and fear were chosen.

3.2.4 Design and Procedure

Design plays an important role in fMRI research, determining the level of detail of the information gained as well as whether analysis will involve subtractive or interactive principals (Amaro & Barker, 2006).

The paradigm chosen for this study is a 2 x 3 factorial design, such that each subject was presented with music stimuli from each of the three emotional categories (happy, sad and fear). Participants were instructed either to attend to the number of instruments they heard in each excerpt, or to the emotion they felt was being expressed by the excerpt, such that the emotional content of each excerpt was processed either implicitly or explicitly. The design is clarified in Table 3.

Table 3: fMRI Study Design

Happy-Implicit (HI)	Sad-Implicit (SI)	Fear-Implicit (FI)
Happy-Explicit (HE)	Sad-Explicit (SE)	Fear-Explicit (FE)

FMRI data was collected at the Advanced Magnetic Imaging (AMI) Center at Aalto University, using a 3 T MAGNETOM Skyra whole-body scanner (Siemens Healthcare, Erlangen, Germany), collecting brain images at two second intervals. To control for usual mood states, subjects were given the POMS, which measures the immediate mood state of participants in terms of six factors: tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, vigor-activity, and confusion-bewilderment (McNair, Lorr, & Droppleman, 1999). Is should be noted that, though depression and anxiety are both measured by the POMS, the test measures the current affective state of the participant which do not necessarily indicate a diagnosis of depression or anxiety as pervasive disorders.

3.3 Analysis

3.3.1 Psychological Measures

Correlation of psychological test scores was done using SPSS version 20 (SPSS Inc., Chicago, Illinois, U.S.A.), running on Mac OS X 10.8.5. Because tests results included differing scales *z*-scores were obtained prior to performing any statistical analysis.

3.3.2 FMRI Preprocessing

Before it can be analyzed, fMRI data requires preprocessing to correct for spatial discrepancies within and between participants, which are created by slight movements of the participants while they are in the scanner and by anatomical differences in size and shape of participants' brains respectively. Statistical Parametric Mapping (SPM), a voxel-based, widely used software packaged designed to assist in the analysis of brain imaging data and run using MATLAB (The MathWorks, Inc) as a platform, was used for preprocessing and analysis of data.

For the current study, images for each participant were first realigned such that each voxel for each image was aligned with itself in reference to the first image. This was done using rigid body transformation, which allows for six parameters of possible motion. Following this, each participant's functional images were aligned with their anatomical images, and normalized to a standardized template, developed at the Montreal Neurological Institute (MNI), such that each participant's images corresponded in size and shape and thus can be navigated within a predefined coordinate system.

It is important to note that these seemingly straightforward processes are subject to disagreement among researchers in light of methodological and theoretical differences. Normalization of brain data, for example, is intended to bring similarly functional brain areas between participants into the closest possible alignment, but this is complicated both by the lack of a single anatomical standard, the MNI template being an alternative to the Talairach template, which has been defined from extensive analysis of a single subject, and both templates being statistically imperfect (Brett et al, 2002). To further reduce the problem of individual differences and increase statistical power, spatial smoothing was employed using a

Gaussian filter with an FWHM of 6 x 6 x 6. Spatial smoothing is the application of a filter that removes some high frequency information (that is, small scale changes in the data), essentially "blurring" the images. This processes increases the signal-to-noise ratio and decreases the likelihood of artifacts, as well as further correcting for individual anatomical differences.

3.3.3 SPM and GLM

SPM can be thought of as the computational incarnation of the statistical methodology originally developed by Friston et al (1990, 1991) for analysis of Positron Emission Tomography (PET). This methodology applies statistical processes and methods of assessment to the spatial domain, using classical inference to identify regionally specific responses to experimental stimuli as activated clusters of voxels, in light of probabilities defined from Gaussian Random Field (GRF) theory. Put as simply as possible, GRF theory states that, in a given vector containing purely random data, that vector can be said to *k*-variate and to be normally distributed if all linear combinations of the vector's *k* components has a normal distribution, allow for the assumption that neighboring voxels are not necessarily independent of each other. For practical purposes, this provides a model of data that can be said to fulfill a null hypothesis, as it allows for the prediction of the number of voxel clusters that would appear above a given activation threshold by chance alone, indicating that the data has not been significantly affected by experimental manipulation. Conversely, a greater number of voxel clusters appearing above a threshold than would be predicted by GRF theory provides support for rejecting a null hypothesis. The Family-wise error (FWE) is the chance of getting a Type I error anywhere in the entire image, and must be calculated in situations where many statistical tests are done at once, as a traditional alpha level of $p < 0.05$ would tend to produce 5,000 false positives per 100,000 voxels tested A FWE of 0.05 means that there is a 5% chance of getting a Type I or false positive anywhere in the whole image. FWE may be calculated using the Bonferroni correction, using the formula [$P^{FWE} = 1- (1-a)^n$], although this result tends to be quite conservative. FWE may also employ GRF, which mathematically corrects the topology of thresholded images. GFR-based correction has the

advantage of accounting for smoothness within the data. GRF-based correction also employs RESEL, or RESolution Element, which is a virtual voxel size derived from smoothness parameters. For a given volume in the data at a given time, a decrease in RESEL value corresponds to a decrease in the corrected p-value—that is, the significance increases, since a greater degree of smoothness results in a milder problem of multiple testing (Poldrack, Mumford & Nichols, 2011).

SPM analysis also applies the General Linear Model (GLM) to make classical inference about data. The GLM is given by the formula [Y = XB + U], where Y is the matrix of neural responses, expressed by a linear combination of an X design matrix and a B matrix of estimated parameters, and a U error matrix. The design matrix, in the current study, refers to the combinations of emotion and processing type, leading to six conditions, along with the covariate of gender.

The design matrix image for the current study is displayed in Figure 1:

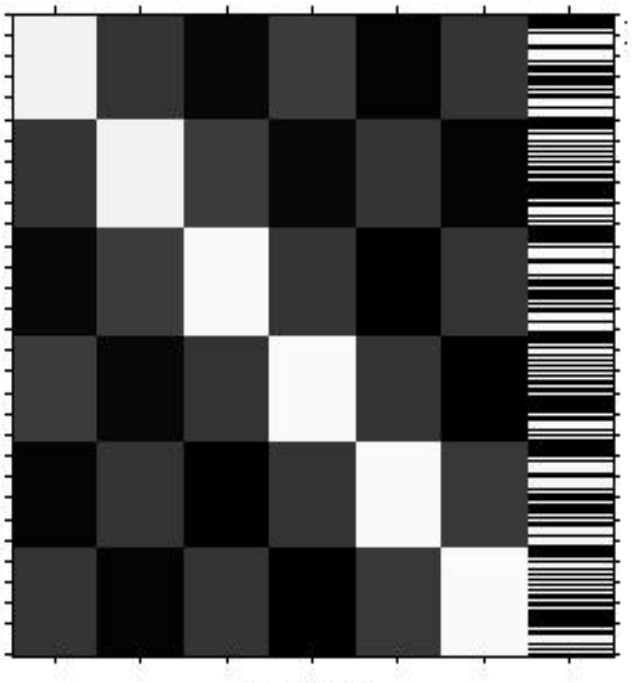

Figure 1: Design Matrix

After GLM design has been specified in to the SPM software interface, SPM generates an output of a beta estimate for each condition, corresponding to the average amplitude of the BOLD response estimated at each voxel. Following this, T contrasts are used to compare voxel activation for conditions relative to each other. T contrasts are used to answer the question of whether a participant experienced different brain activation in one condition compared to another. A T contrast can be defined by a vector in which conditions are assigned numbered weights, with conditions that are not being contrasted assigned a weight of zero while the two contrasted conditions are assigned 1 or -1. For example, for a vector representing each condition [HI, HE, SI, SE, FI, FE], a T contrast vector of [1 1 -1 -1 0 0] could be employed to compare BOLD responses obtained from happy music stimuli and from sad music stimuli.

F contrasts denoting the overall effect of one variable, in this case music type and processing type, can also be calculated from factorial designs, and are known as the main effects. The main effect of processing type, for example, is calculated by subtracting all explicit from all implicit, [(HI + SI + FI) - (HE + SE + FE)].

3.3.4 ROI Definition and Analysis

Once an activation threshold has been established for the whole brain, a commonly approach to fMRI analysis involves the extraction of signal from specific brain regions, known as regions of interest (ROIs) (Poldrack, 2007). ROI analysis can be particularly beneficial in complex factorial designs, as activation patterns may be more evident in particular regions than across the whole brain. ROI analysis also can be used to decrease the likelihood of making a Type I error, by limiting further statistical testing to specific functionally or anatomically defined regions (Poldrack, 2007). Another benefit of ROI analysis is that it arguably implies a greater or at least simpler connection between the gathered data and the mental processes to be explored; voxels, after all, are a purely practical construct, conduit of information on brain activation but not inherent to it (Nieto-Castanon et al, 2003).

Despite these pleasingly simple and intuitive benefits, however, many aspects of ROI analysis are still under debate. One area of contest is how best to define ROIs in a given study. In 2002, Brett and colleagues published an extensive review of the difficulties involved with

defining and labeling ROIs, noting that coordinate systems such as those derived from MNI and Talairach atlases cause some difficulties in anatomical generalization, especially to non-human subjects, while both gross and fine anatomical labels are subject to difficulties involving individual difference. Rather than defining ROIs according to pre-existing knowledge about brain anatomy, some researchers choose to define ROIs functionally based on the voxel activations above their determined threshold. Functional ROIs can be defined at an individual or group level, with the former reaping the benefits of more certain detection of a given effect, and the latter increasing the likelihood that an effect can be generalized. In 2003, Swallow and colleagues collected two separate functional data sets from eleven participants in order to explore the viability of using group-defined functional ROIs compared to atlas-defined, and found that group-defined ROIs were less reliable across the two tests than atlas-defined ROIs. This finding, however, is applicable to what the researchers define as a typical sample size of about ten subjects. The present study having a significantly larger sample of 56, group voxel activation was used to define ROIs. While this may result in loss of information on individual differences in activation, it also increased the generalizability of the results.

Using the MarsBaR Toolbox (Brett et al, 2002), a set of scripts which runs in MATLAB in concert with the SPM Toolbox, ROIs were extracted from brain data for each T contrast and main effect using the Monte Carlo simulation to determine 26 as the lower limit for the number of significantly activated voxels that could be considered an ROI. MarsBaR was then used to calculated the percent in signal change between ROIs according to the defined T and F contrasts. ROI signal value was averaged over the four seconds of stimulus presentation to obtain activation level for each stimulus.

Using SPSS version 20 (SPSS Inc., Chicago, Illinois, U.S.A.), ANOVA and post-hoc tests were preformed to clarify which conditions differed significantly from others in relevant ROIs. SPSS was then used to correlated ROI activations to psychological test scores. Although many correlational tests were performed, a correction such as a Bonferroni correction was considered too conservative in this case, as it would increase the risk of type II errors. The possibility of type I errors resulting from this analysis must be kept in mind, as with any statistical study (Perneger, 1998)

4 RESULTS

This current study aimed to explore correlations between participants' use of music in affect regulation, risk factors for experiencing depression including neuroticism and anxiety, and maladaptive brain responses to music listening. Correlations were explored between psychological measure and fMRI measures separately first, and then analyzed together.

4.1 Behavioral Measures

MADRS (depression), HADS-A (anxiety) and Neuroticism as measured by the BFQ results revealed a statistically normal, psychologically healthy sample. As participants with mood disorders were not specifically sought for this study, this is the expected result. Only three participants scored above 20 on the MADRS, and could thus be considered severely depressed.

Results of the MADRS, HADS-A, the MMR and Neuroticism were correlated to each in all 123 subjects. As expected based on previous literature, MADRS scores were significantly positively correlated with HADS-A scores, $r = .53$, $p = .0001$, and with Neuroticism scores, $r = .54$, $p = .0001$. MMR Discharge scores were weakly but significantly correlated with HADS-A scores, $r = .24$ $p = .007$, and similarly correlated with Neuroticism scores, $r = .2$, $p = .02$. No other MMR areas were significantly correlated with other psychological test scores. Full results can be viewed in Table 4.

Table 4: Correlations coefficients for all subjects

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. MADRS	-									
2. HADSA	.52**	-								
3. Neuroticism	.54**	.64**	-							
4. Discharge	.114	.24*	.2*	-						
5. Diversion	-.009	.06	.01	.33*	-					

6. Entertainment	-.04	-.01	.008	.12	.23*	-				
7. Revival	-.07	-.13	-.15	.15	.55**	.35*	-			
8. Strong Sensation	-.01	.02	-.16	.37*	.53**	.16	.38*	-		
9. Solace	.12	.12	.14	.46*	.71*	.23*	.41*	.46*	-	
10. Mental Work	-.01	.05	-.005	.49*	.64**	.13	.38*	.57*	.69**	-

* Correlation is significant, p = < .05 ** Correlation is significant, p = <.01

Because previous literature has suggested that gender differences exist in affect regulation between males and females (Thayer, Rossy, Ruiz-Padial, & Johnsen, 2003; McRae, Ochsner, Mauss, Gabrieli, & Gross 2008), correlations were also determined for male and female participants separately. First, independent sample t-tests were done to determine any difference between females and males in MADRS, HADS-A, Neuroticism and MMR scores. As expected from previous literature (Costa, Terracciano, & McCrae 2001)., for Neuroticism scores there was a significant difference between females and males, with females (M = 19.13, SD = 7.20) having a higher mean score than males (M = 15.43, SD = 7.84), $t(119) = -2.69$, $p = .008$. There were no significant differences in MADRS scores between females (M = 5.31, SD = 3.78 and males (M = 5.55 SD = 4.77), $t(119) = .280$, $p = .7$. There were no significant differences in HADS-A scores between females (M = 5.18, SD = 2.70) and males (M = 4.35, SD = 2.68), $t(119) = -1.675$, $p = .09$. There were no significant differences in MMR Discharge scores between females (M = 2.63, SD + 1.07) and males (M = 2.40, SD = 1.06), $t(119) = -1.18$, $p = 2.40$. There was, however, a significant difference in MMR Diversion scores between females (M = 3.22, SD = .962), and males (M = 2.88, SD = .780), $t(119) = -2.07$, $p = .040$.

There were no significant correlations for female participants between MMR scores and other psychological scores. For male participants, positive correlations were found between HADS-A and MMR Discharge, $r = .36$, $p = .007$ (Figure 2), as well as between Neuroticism and MMR Discharge, $r = .321$, $p = .02$. HADS-A scores (Figure 3). Neither Neuroticism nor HADS-A retained a significant correlation with Discharge when the other variable was controlled for using partial correlations.

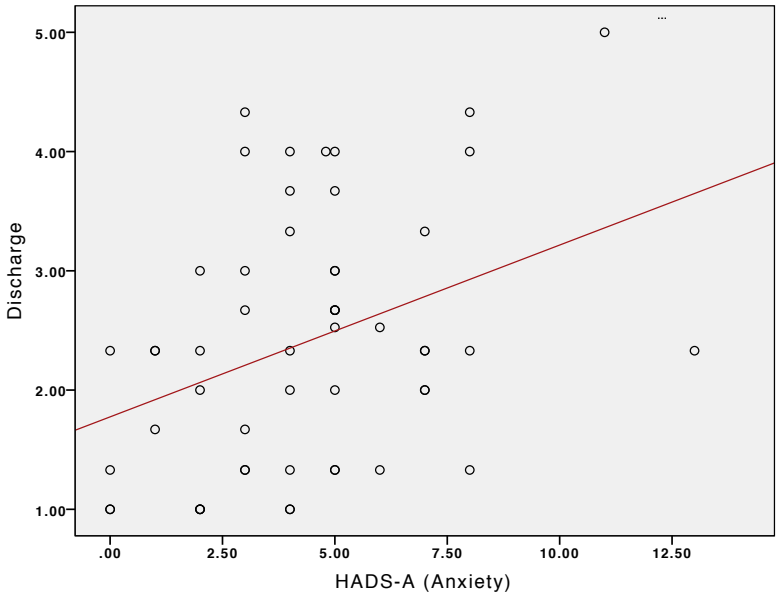

Figure 1: Males Discharge and Anxiety

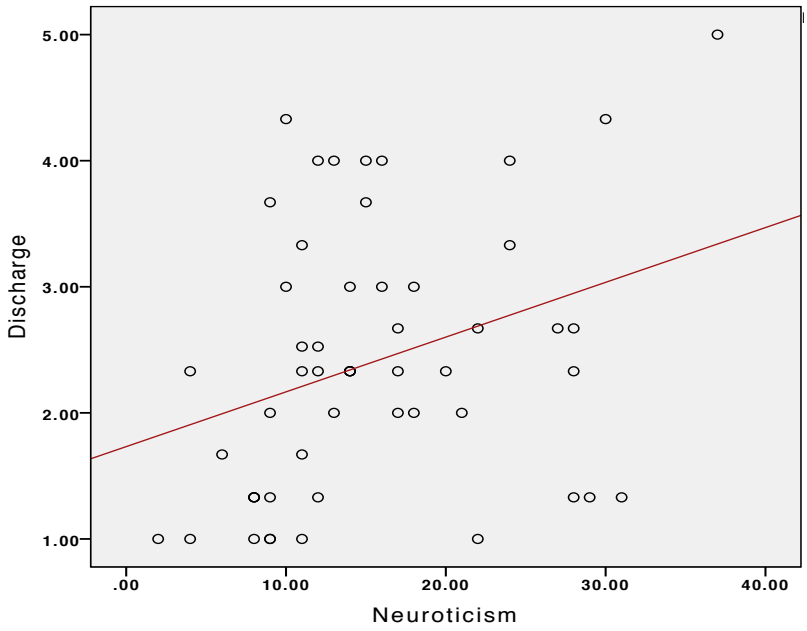

Figure 2: Males Discharge and Neuroticism

Although previous literature has shown differences between musicians and non-musicians in music consumption, no significant correlations were found for amateur or professional musicians between MMR scores and other psychological test scores.

There were no significant correlations found between total MMR score for each participant and HADS-A, MADRS or Neuroticism scores.

4.2 FMRI Measures

Functional ROIs were defined using F and T contrasts. For the main effect of music emotion, significant 26 clusters, including 55 sub-regions, were identified. These ranged in size from 26 voxels to 4797 voxels. For the main effect of processing type, 36 significant clusters were identified, including 70 sub-regions, with clusters ranging in size from 27 to 2401 voxels.
The main clusters identified as significant for the main effect of music emotion are displayed in Table 5. For a table including clusters and sub-regions, please see Appendix 1.

Table 5: ROIs identified for Main Effect of Emotion

Hemisphere	Region	BA	Cluster size	MNI Coordinates
R	Superior Temporal Gyrus	BA 22	4797	56 -2 -4
R	Medial Frontal Gyrus	BA 11	312	2 46 -16
R	Parahippocampal Gyrus	Amygdala	54	20 -6 -20
R	Superior Parietal Lobule	BA 7	284	42 -62 50
R	Middle Frontal Gyrus	BA 6	63	26 -4 54
R	Caudate	Caudate Tail	73	34 -46 10
R	Anterior Cingulate	BA 32	81	14 30 22
R	Cerebellar Tonsil	*	27	16 -40 -42
R	Caudate	Caudate Body	87	20 20 16
R	Subcallosal Gyrus	BA 47	49	16 18 -12
R	Precentral Gyrus	BA 6	50	54 -2 48
L	Superior Temporal Gyrus	BA 22	4347	-50 -10 -2
L	Parahippocampal Gyrus	BA 34	120	-18 -10 -20
L	Caudate	Caudate Head	206	-12 14 -6
L	Medial Frontal Gyrus	BA 8	236	-6 18 54
L	Posterior Cingulate	BA 30	183	0 -54 18
L	Middle Frontal Gyrus	BA 10	49	-30 46 8
L	Sub-Gyral	Hippocampus	34	-32 -44 0
L	Superior Parietal Lobule	BA 7	28	-34 -50 50
L	Precentral Gyrus	BA 6	28	-50 -4 46
L	Paracentral Lobule	BA 5	29	-18 -34 54
L	Inferior Frontal Gyrus	BA 47	57	-50 42 -14
L	Postcentral Gyrus	BA 3	101	-42 -30 56
L	Middle Frontal Gyrus	BA 46	53	-44 38 22
L	Medial Frontal Gyrus	BA 10	57	-8 64 20
L	Culmen	*	26	-6 -48 2

The ROIs identified using the main effect of processing type (explicit or implicit) are displayed in Table 5. For a table including all sub-regions of clusters, please see table in Appendix 1.

Table 6: Main effect of Processing Type

Hemisphere	Region	BA	Cluster size	MNI Coordinates
R	Inferior Occipital Gyrus	BA 19	2104	44 -78 -8
R	Middle Frontal Gyrus	BA 46	839	48 38 20
R	Culmen	*	111	30 -64 -32
R	Inferior Parietal Lobule	BA 40	1162	48 -42 54
R	Caudate	Caudate Head	227	10 10 2
R	Superior Frontal Gyrus	BA 9	1693	14 62 36
R	Middle Frontal Gyrus	BA 6	377	32 12 58
R	Fusiform Gyrus	BA 20	58	42 -14 -32
R	Uvula	*	94	10 -82 -48
R	Insula	BA 13	112	44 -4 14
R	Middle Temporal Gyrus	BA 37	107	58 -56 -16
R	Inferior Parietal Lobule	BA 40	52	48 -30 26
R	Thalamus	Medial Dorsal Nucleus	27	6 -12 10
R	Middle Frontal Gyrus	BA 6	26	50 8 50
R	Parahippocampal Gyrus	BA 30	31	6 -40 4
R	Cuneus	BA 19	47	16 -94 32
R	Superior Temporal Gyrus	BA 39	35	52 -64 20
L	Inferior Occipital Gyrus	BA 19	2401	-40 -80 -12
L	Inferior Frontal Gyrus	BA 9	212	-44 8 30
L	Inferior Temporal Gyrus	BA 37	240	-60 -56 -16
L	Precuneus	BA 19	44	-38 -84 34
L	Inferior Parietal Lobule	BA 40	271	-50 -34 36
L	Cingulate Gyrus	BA 32	155	-4 20 44
L	Superior Frontal Gyrus	BA 6	76	-26 4 58
L	Uvula	*	69	-32 -62 -34
L	Middle Frontal Gyrus	BA 6	51	-54 8 48
L	Middle Frontal Gyrus	BA 46	122	-48 36 28
L	Superior Parietal Lobule	BA 7	122	-26 -66 46
L	Posterior Cingulate	BA 29	26	-4 -44 8
L	Thalamus	Anterior Nucleus	72	-8 -4 14
L	Lentiform Nucleus	*	52	-10 4 -2
L	Inferior Semi-Lunar Lobule	*	45	-8 -78 -50
L	Cingulate Gyrus	BA 24	27	-2 -16 42
L	Medial Frontal Gyrus	BA 6	27	-8 -4 66
L	Precentral Gyrus	BA 4	37	-26 -26 64
L	Inferior Frontal Gyrus	BA 47	34	-28 16 -20

For each condition (HE, HI, SE, SI, FE, FI), a number representing the percent of signal change for each ROI, for each subject, was extracted using the MarsBaR Toolbox.

To decrease the likelihood of obtaining a Type I error, only ROIs that have been shown in previous literature to be related to mood disorder and mood regulation were selected for further analysis and for correlations with psychological data for this study (see Table 1). The areas included in analysis were the left parahippocampal gyrus (BA34), the right medial frontal gyrus (BA11), the right amygdala, the right ACC (BA32), the left inferior frontal gyrus (BA47), the left cingulate gyrus (BA32), the right fusiform gyrus (BA20), and the lateral prefrontal gyrus (BA9). It should be note that for this ROI, significantly activated for the main effect of processing type, the main cluster identified is in the right hemisphere. However, sub-regions of the same cluster are identified as existing in the left hemisphere (see Appendix 1), thus the region is bilateral.

According to the above results, ROIs identified using emotion as a main effect could differ significantly from each other between any two emotions or all three. Because of this, further analysis was needed to better understand these ROIs, using ANOVA to show the differences between ROIs and post-hoc testing to determine between which listening conditions (HI, HE, SI, SE, or FI, FE) the differences between these ROIs were significant. One-way within-subjects ANOVA was performed to determine whether the selected ROIs differ from each other according to each of the six conditions.

As expected, there was a significant effect of listening condition (HI, HE, SI, SE or FI, FE) on ROI percent signal change score at the $p < .05$ level for BA 34 [$F(3,330) = 3.36$, $p = .004$], for BA11 [$F(5,330) = 2.73$, $p = .02$] and for BA47 [$F(5,330) = 2.65$, $p = .02$]. There was a significant effect of condition on ROI percent signal change and the $p = .01$ level for BA9 [$F(5,330) = 14.1$, $p = .001$], for the left cingulate gyrus BA32 [$F(5,330) = 15.2$, $p = .001$] for BA20 [$F(5,330) = 7.41$, $p = .001$] and for the right ACC [$F(5,330) = 9.20$, $p = .001$]. The effect of listening condition was not quite significant for the right amygdala [$F(5,330) = 2.15$, $p = .06$]. The differences in activations are visualized by gender in Figure 4 and Figure 5.

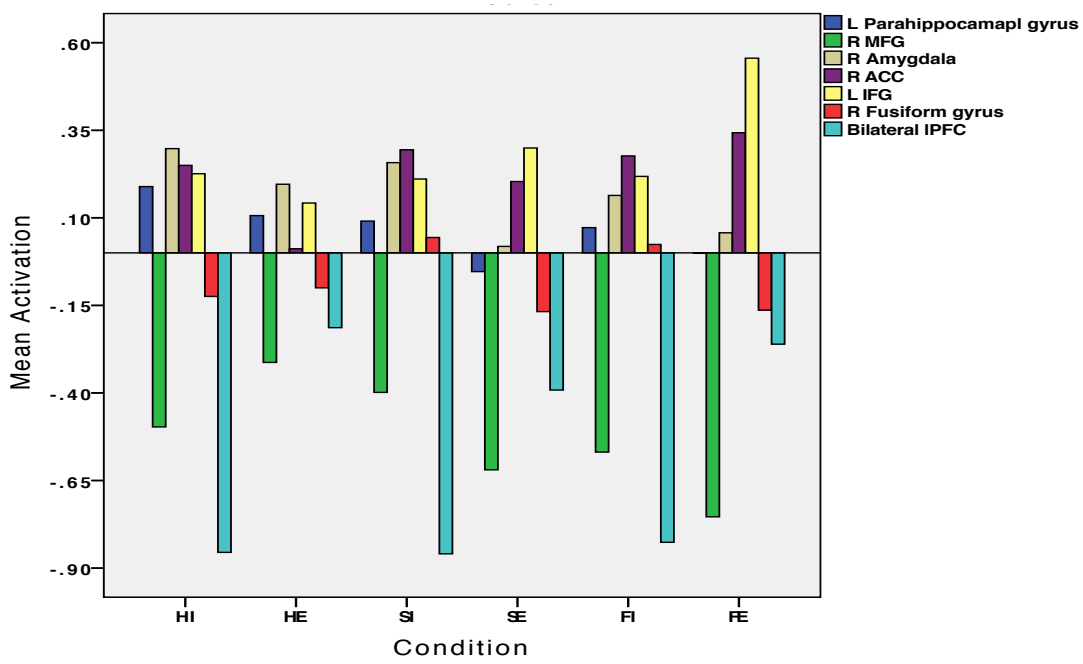

Figure 4: ROI Activation in Females by condition

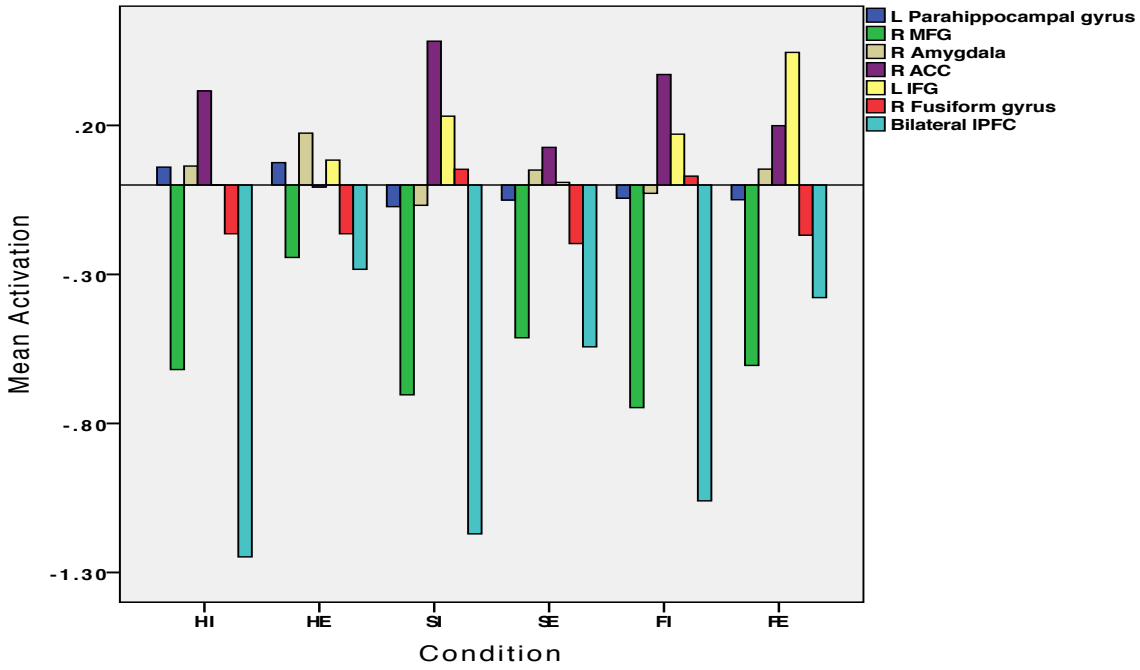

Figure 5: ROI Activation in Males by Condition

Because equal variances could not be assumed in all cases, a Games-Howell post-hoc test was used to show which of the six listening conditions differed from each other in the ROIs. Post-hoc tests revealed that for BA34, mean score for HI (M = .136 SD = .290) differed significantly from mean score for SE (M = -.052, SD = .304). For BA11, means were

significantly different between HE (M = -.284 SD = .673) and FE (M = -.692, SD = .292). For BA47, means were significantly different between HE (M = 118, SD = .677) and FE (M = .510, SD = .751) conditions. For the right ACC (BA32), means differed significantly between HI (M = .276, SD = .383) and HE (M = -.384 SD = .673) conditions, HE (M = -.384, SD = .673) and SI (M = .371, SD = .301), FI (M = .315, SD = .346) and FE (M = .283, SD = .284) conditions, and SI (M = .371, SD = .301) and SE (M = .171, SD = 267). For the left cingulate cortex (BA32), means differed significantly between HI (M =.790, SD =.6) and HE (M =.156, SD =.526) SE (M =.420, SD =.420), conditions, HE and SI (M = .853 SD = .461) and FI (M =, .538 SD =.437) and FE (M = .538, SD =.437) conditions, SI and SE and FE conditions, SE and FI conditions, FE and HE conditions. For BA9, there was a significant effect of processing type on scores $t(334) = -8.22$, $p < .001$, with implicit processing (M = -.975, SD = .672) yielding greater negative signal change than explicit processing (M = -.335, SD = .752). For R BA20, there was a significant effect of processing type on scores $t(334) = 4.63$, $p < .001$, with explicit (M = -.157, SD - .266) yielding lesser changes in signal than implicit (M = -.022, SD = .267). For R ACC (BA32), there was a significant effect of processing type, $t(334) = 7.51$, $p < .001$, with implicit processing showing greater signal increases (M = .797, SD = .55) than explicit (M = .371, SD = .487).

4.3 Correlations Between Behavioral and fMRI Data

For ROIs identified using the main effect of emotion, ROI percent signal changes for each condition were correlated with psychological scores for each subjects. Because of the overarching importance of the amygdala to this study, as well as for practical purposes, the results of these correlations, and correlations with other brain areas scores, and displayed separately in Table 7 and Table 8. For practical purposes, only ROIs and conditions with at least one significant correlation to psychological test scores have been included in Table 8, due to the large number of cortical areas and conditions tested.

It should be noted that ROI variable, such as ‘R Amygdala HI’ and ‘R Amygdala HE’ represent activation levels in the same ROI during different listening conditions. As shown by the ANOVA results, different listening conditions resulted in significantly different activation levels in some, but not all cases. Since activation levels in the same ROI during different

listening conditions are not *necessarily* significantly different from each other, it is anticipated that these variables may be highly correlated as they are measuring very similar activations. Thus the correlations higher than .80 represent collinearity between activation in the same ROI. Collinearity relates to potential adverse effects of strongly correlated variables in statistical testing. In this case, collinearity is expected and not considered relevant to the other results as they are not of interest to the research question (Mandel, 1982; Belsley, 1991; Pedhazur, 1997). This is represented in the table below with the correlations that are not of interest to the current study appearing in light gray.

Table 7: Psychological Scores and Amygdala signal change[1]

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
1. MADRS	-									
2. HADS	.61**	-								
3. Neuroticism	.53**	.61**	-							
4. Diversion	.14	.18	.07	-						
5. Discharge	.37**	.33*	.27*	.43**	-					
6. R Amygdala HI	.04	.18	.28*	.16	.10	-				
7. R Amygdala HE	-.36**	-.17	-.22	.13	.00	.31*	-			
8. R Amygdala SI	.04	.23	.31*	.24	.15	.84**	.30*	-		
9. R Amygdala SE	-.32**	-.63	-.19	.11	-.08	.37**	.84**	.27*	-	
10. R Amygdala FI	.08	.29*	.31*	.20	.16	.82**	.39**	.80**	.42**	-
11. R Amygdala FE	-.41**	-.18	-.21	.11	-.11	.39**	.81**	.35**	.01**	.45**

* Correlation is significant, p = < .05, ** Correlation is significant, p = <.01

[1] Correlations that are not of interested to the current study are represented in light gray.

Table 8: Psychological scores and cortical area signal changes[1]

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
1. MADRS	-									
2. HADS	.61**	-								
3. Neuroticism	.53**	.61**	-							

4. Diversion	.14	-.18	.07	-						
5. Discharge	.37**	.32*	.27*	.43**	-					
6. R BA11 HI	-.23	-.28*	-.11	-.06	.-.06	-				
7. R ACC HE	.01	.13	.05	-.13	.01	-.08	-			
8. BA 9 HI	-.24	-.30*	-.20	.06	.01	.07	-.14	-		
9. BA 9 SI	-.32*	-.16	-.25	.15	-.11	.32*	.04	.27*	-	
10. BA 9 FE	-.27*	-.41	-.01	.15	-.12	.31*	-.07	.26*	.34	-
11. R BA 20 HI	-.27*	-.18	-.24	-.16	-.25	-.01	.002	.13	.81*	.35*
12. R BA 20 HE	-.33*	-.25	-.26*	-.11	-.24	.06	-.01	.06	.23	.26*
13. R BA 20 FI	-.08	.01	.08	-.28*	-.26	.007	.02	.36*	.15	.11
14. R BA 20 FE	-.18	-.02	.06	-.29*	-.24	-.17	.03	-.11	.19	.16

.* Correlation is significant, p = < .05, ** Correlation is significant, p = <.01

[1] Correlations that are not of interested to the current study are represented in light gray.

Because psychological test scores indicated differences between males and females in mood regulation strategies, correlations were also run with males and females separated into different groups. For ROIs identified using the main effect of emotion, the results are displayed in Table 9 (females) and Table 10 (Males). Only correlations with at least one significant result are shown in the tables, for practical reasons.

Table 9: Females: ROIs identified by emotion, correlated with psychological scores[1]

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**
1. MADRS	-						
2. HADS	.59**	-					
3. Neuroticism	.47**	.43*	-				
4. R BA11 HI	-.22	-.35*	-.10	-			
5. R BA11 SI	.079	-.37*	.16	.83**	-		
6. R Amygdala HE	-.35*	.02	-.09	-.002	-.001	-	
7. R Amygdala FE	-.47**	.02	-.10	.29	.21	.71**	-

* Correlation is significant, p = < .05 ** Correlation is significant, p = <.01
[1] Correlations that are not of interested to the current study are represented in light gray.

Table 10: Males: ROIs identified by emotion, correlated with psychological scores[1]

	1.	2.	3.	4.	6.	7.	8.	9.
1. MADRS	-							
2. HADS	.67*	-						
3. Neuroticism	.61**	.83	-					
4. R ACC SE	-.26	-.42*	-.30	-				
5. R Amygdala HE	-.37	-.45*	-.39	-.32	-			
6. R Amygdala FE	-.35	-.48**	-.33	.53**	.92*	-		
7. R Amygdala SE	-.38	-.52**	-.40	.78**	.89**	.83**	-	
8. L BA47 HI	.23	-.46*	.35	-.40	-.10*	.16	-.19	-

* Correlation is significant, p = < .05 ** Correlation is significant, p = <.01
[1] Correlations that are not of interested to the current study are represented in light gray.

For ROIs identified using the main effect of processing type, ROIs with significant correlations are displayed in Table 11 (females) and Table 12 (males). Again, only those ROIs with at least one significant correlation are displayed in the following tables, for practical reasons.

Table 12: Females: ROIs identified by processing type, correlated with psychological scores[1]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. HADS-A	-									
2. Discharge	.25	-								
3. Diversion	.06	.41	-							
4. R ACC HI	-.36*	-.07	-.18	-						
5. R ACC HE	-.36*	-.04	.05	.24	-					
6. R BA20 HE	-.03	-.33	-.36*	-.10	.-.23	-				

7. BA9 HI	-.21	.08	.38*	.05	-.09	.04	-			
8. BA9 HE	-.22	.35*	.34	.19	.52*	-.66**	.07	-		
9. BA9 SI	-.09	.18	.38*	-.03	-.15	.12	.80**	.08	-	
10. BA9 SE	-.16	.40*	.30	.14	.32	-.45	.25	-.77*	.34	-
11. BA9 FI	-.12	.21	.41*	-.04	-.03	.03	.84**	.14	.81**	.35*

* Correlation is significant, p = < .05, ** Correlation is significant, p = <.01

[1] Correlations that are not of interested to the current study are represented in light gray.

Table 13: Males: ROIs identified by processing type, correlated with psychological scores[1]

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**
1. MADRS	-								
2. Neuroticism	.61**	-							
3. Discharge	.50**	.50*	-						
4. Diversion	.60**	.47*	.50*	-					
5. R BA20 HI	-.40	-.43*	-.60**	-.45**	-				
6. R BA20 SI	-.43*	-.27	-.57**	-.56**	.13	-			
7. R BA20 FI	-.29*	-.39	-.60*	-.48*	.82*	.84*	-		
8. BA9 HI	-.25	-.09	-.51*	-.41*	.05	.13	.02	-	
9. BA9 SI	-.46**	-.43*	-.62**	-.43*	.09	.15	.06	.80**	-

* Correlation is significant, p = < .05, ** Correlation is significant, p = <.01

The results of all correlations between brain and psychological data, with participants grouped by gender, are summarized in Table 14 and Table 15, with areas listed in italic font indicating negative correlations and areas listed in bold font indicating positive correlations.

Table 14: Summary of Brain and Psychology Correlations: Females[1]

	HI	**HE**	**SI**	**SE**	**FI**	**FE**
MADRS	-	*R Amygdala*	-	-	-	*R Amygdala*

HADS	*R vmPFC (BA11)* *R ACC (BA32)*	-	*R vmPFC (BA11)*	-	-	-
Neuro.	-	-	-	-	-	-
Diver.	**lPFC (BA9)**	*R Fusiform Gyrus (BA20)*	**lPFC (BA9)**	-	**lPFC (BA9)**	
Disch.	-	**lPFC (BA9)**	-	**lPFC (BA9)**	-	-

Table 15: Summary of Brain and Psychology Correlations: Males

	HI	**HE**	**SI**	**SE**	**FI**	**FE**
MADRS	-	-	*R Fusiform Gyrus (BA20)* *lPFC (BA 9)*	-	*R Fusiform Gyrus (BA20) (M)*	-
HADS	*lPFC (BA9) L (BA47)*	*R Amygdala*	-	*R Amygdala R ACC (BA32)*	-	*R Amygdala (M)*
Neuro.	*R Fusiform Gyrus (BA20)*		*lPFC (BA 9)*			
Diver.	*R Fusiform Gyrus (BA20) lPFC (BA9)*	-	*R Fusiform Gyrus (BA20) lPFC (BA9)*	-	*R Fusiform Gyrus (BA20)*	-
Disch.	*R Fusiform Gyrus (BA20) lPFC (BA9)*	-	*R Fusiform Gyrus (BA20) lPFC (BA9)*	-	*R Fusiform Gyrus (BA20)*	-

[1] Areas listed in bold text indicate positive correlations, while areas listed in italics indicated negative correlations.

These results indicate that the right ACC (BA32), the right amygdala, BA9 (lPFC) and right BA20 (the fusiform gyrus) are the correlated within the most conditions to psychological health scores. Only the cortical areas right BA9 and right BA20 were correlated with MMR scores.

5 DISCUSSION

The current study examined the relationship between levels of depression, anxiety and neuroticism and how individuals use music as a means of affect regulation. It also examined the relationship of levels of depression, anxiety and neuroticism to brain responses to musical emotions. 123 participants were measured for levels of depression, anxiety and neuroticism as well as given the Music in Mood Regulation questionnaire (Saarikallio, 2008). A subset of 56 participants listened to music stimuli and performed tasks of either identifying emotion or counting instruments. Stimuli were drawn from the film music database established by Eerola and Vuoskoski (2011) while undergoing fMRI measurement. Data was analyzed using SPM and MarsBaR software (Friston et al., 1990, 1991; Brett et al, 2002), running on MATLAB (The MathWorks, Inc). Correlation of psychological test scores was done using SPSS version 20 (SPSS Inc., Chicago, Illinois, U.S.A.). This study was aimed at answering the following research questions: 1) How does an individual's use of music for affect regulation relate to his or her risk of developing mental health disorders? 2) What are the neuro-correlates of individual differences in affective response to music? 3) Can maladaptive affective responses to music be observed in the brain and, if so, can they be correlated to risk for mental illness? 4) If some instances of music in affect regulation are maladaptive, is this best modelled in terms of behavior, neural responses, or both?

Prior to any attempt to answer the above questions, it should be noted that is difficult for the current study to show definite correlations between mental illness, musical mood regulation, and brain responses simply because the study participants were mostly mentally healthy according to the psychological measures used. Three participants met criteria for severe depression by scoring above 20 on the MADRS, a number obviously insufficient to allow for any even cautious generalization of the results to depressed populations, and only one of these also had a notably high score in MMR Discharge. Although previous literature shows that neuroticism and anxiety increase the risk of depression, there are certainly many other factors that influence an individual's mental health. The use of music as a means of affect regulation could, given the prevalence of music in everyday life, be an important factor. The results of the current study suggest that the use of music as affect regulation is subject to individual differences, including differences such as anxiety, depression and neuroticism that are also related to mental health. Furthermore, the results of this study highlight significant differences

between gender both in behavior and neural responses to music in relation to affect regulation.

The results of this study indicate a weak positive correlation between participant scores in the music mood regulation strategy Discharge, and neuroticism and anxiety measures in all participants. When participants were grouped by gender, this correlation persisted for male participants but not for female participants. There were no significant differences between male and female scores in any of these measures save neuroticism, where females scored significantly higher than males as predicted by previous literature (Costa, Terracciano, & McCrae 2001). There were also significant differences between males and females on use of Diversion as a music mood regulation strategy, with females using music for Diversion more than males. According to Saarikallio (2007), adolescents described using Diversion as a regulatory tacit to prevent their minds from straying to negative or anxious thoughts (p 99). It is not clear exactly why this was seen more in females than males, but given that females tend to have higher neuroticism, as was found in this sample, females may also have more frequent need to distract themselves from negative thoughts.

Correlation of neural activation to psychological test scores also revealed differences between males and females in both limbic and cortical areas. Higher levels of depression, anxiety, or neuroticism were generally associated with decreased activation in the ROIs of interest. In females higher depression scores were associated with decreased right amygdala activation in explicit happy and explicit fear conditions, while in males high depression was associated with decreased activation in the bilateral lPFC (BA9) and right fusiform gyrus (BA20) in the negative implicit emotion conditions. For females, higher anxiety was associated with decreased vmPFC (BA11) activation under happy and sad implicit conditions, and decreased right ACC (BA32) activation in happy explicit and happy implicit conditions. For males, higher anxiety was associated with lower right amygdala activation under all explicit conditions, and with decreased bilateral lPFC (BA9) and right ACC (BA32) activation under happy explicit and sad implicit conditions respectively. Female neuroticism scores were not correlated with brain activations in any of the analyzed areas under any condition. Male neuroticism scores were associated with decreased right fusiform gyrus (BA20) and lPFC (BA9) for happy implicit and sad implicit conditions, respectively.

Correlations were also found between cortical areas and scores in Discharge and Diversion as measured by the MMR, with females showing increased activation correlated with higher Discharge and Diversion scores, and males showing decreased activation. In all three implicit listening conditions, for females there was a positive correlation between Diversion scores and activation in the bilateral lPFC , while for males there was a negative correlation between Diversion scores and bilateral lPFC activation during happy and sad implicit conditions. Higher Discharge scores were associated with increased bilateral lPFC in females for happy explicit and sad explicit conditions. For males, higher Discharge scores were associated with decreased right fusiform gyrus (BA20) scores for all implicit conditions, and with decreased bilateral lPFC under happy and sad implicit conditions.

5.1 Correlations between Discharge, Anxiety and Neuroticism

No significant correlations were found between Discharge and depression scores either in all participants or when participants were divided by gender. This could of course be, as previously mentioned, because the current group of participants is generally healthy and only a few had depression scores that reached clinical levels. Another explanation is that there is no correlation between Discharge use and depression risk. This could be because Discharge, defined as it is by the *expression* of negative emotion, might be considered an externalizing behavior, while depression is often categorized as an internalizing pathology (Miranda et al., 2012). However, since Discharge was correlated with both anxiety and neuroticism, two known risk factors for depression, it would likely be unwise to discard it entirely is a consideration of how music listening patterns relate to depression risk.

The association between Discharge scores, anxiety and neuroticism is perhaps the clearest of these results. Given that Discharge is defined as a strategy used when the listener is experiencing a negative affective state, with sad or aggressive music acting to give expression to the negative state, it seems at first intuitive that it should be correlated with neuroticism, which is defined as an increased likelihood to experience negative affect. An individual who does not frequently experience negative affect would by definition use Discharge as a strategy less frequently than other strategies. However, the MMR strategy Solace is also associated with negative affect as a prerequisite for its use, differing from Discharge in that it results in the music having comforted the listener, and in that sad or aggressive music is not specified

for use. The fact that Solace is *not* correlated with neuroticism provides important light for the interpretation of the relationship between Discharge and neuroticism. It is possible that the tendency of more neurotic individuals to experience more negative affective states renders the mood regulation strategy of Solace less effective for these individuals—that is, a neurotic person is less likely to be comforted by listening to music than a less neurotic person. Since Discharge carries the specification that sad or aggressive music is heard, while Solace does not, it may also be that a more neurotic person is more likely to choose Discharge as a strategy because he or she is more accustomed to experiencing negative emotions. To borrow Larsen's (2000) imagery, the affective thermostat of a neurotic person may be set at a lower affective level than a non-neurotic person; her thermostat is not, as Erber and Erber (2000) suggested could be the case, set always to "happy." Thus a neurotic person may desire to use music to express a negative mood, as in Discharge, rather than to attempt to repair it, as in Solace.

The correlations between neuroticism and Discharge, and anxiety and Discharge, could not be dissociated from each other in these results; neither anxiety nor neuroticism were significantly correlated with Discharge when the other was controlled for. This may simply be because neuroticism and anxiety are so strongly correlated with each other in this sample that they cannot be adequately parsed. Another explanation is that this is an example of a common cause model as defined by Miranda and colleagues (2012)—neuroticism predisposes an individual both to anxiety and to the use of Discharge. However, this correlation may also lend strength to the idea that Discharge could be an ineffective or even maladaptive affect regulation strategy. Personality factors such as neuroticism are fairly stable over the lifetime, but the experience of clinical levels of anxiety is more variable. While it is possible that individuals who experience more anxiety are more likely to use Discharge as a regulation strategy, it is also possible that anxious individuals who use Discharge are less likely to experience affect repair as a result of music listening. It may also be that neuroticism, anxiety and the use of Discharge together represent an ineffective combination wherein music use does not relieve negative affect or may even increase negative affect.

The fact that these correlations persisted for males when participants were examined by gender, but not for females, also warrants careful consideration. McRae and colleagues (2008) suggested that affect regulation might be a more automatic process for males than for females,

with males showing decreases in amygdala activity when affect was regulated using cognitive reappraisal while females showed increases prefrontal areas. Although Discharge is not particularly suggestive of cognitive reappraisal as a suitable non-musical analogue, it is worth considering that a person for whom affect repair is less conscious may be more likely to chose Discharge, which expresses rather than actively repairs negative mood. This may also be one interpretation for the result that females used Diversion as a music-based affect regulation strategy than males; if affect regulation is more conscious in females than males, a female may be more likely to actively choose to divert attention away from negative affect. As the definition of Discharge specifies aggressive or sad music in its use, gender differences in aggression are worth considering in interpreting these results as well. Knight, Guthrie, Page, & Fabes (2002) reviewed the literature and found that gender differences in aggression were related to how emotionally arousing the study context was, suggesting that males experience greater emotional arousal and greater difficulty regulating that arousal in response to aggressive-relevant stimuli. Thus, a male who choses to listen to aggressive music while in a negative affective state may indeed be prolonging the negative affective state. This may be because the male is not consciously attempting to repair his affective state, but may also be another example of Erber and Erber's (2000) hypothetical thermostat that is not set to happy, but set towards a more negative affect, that the regulatory strategy is prolonging.

Although insufficient to create a complete picture, these results show that music mood regulation strategy is likely to be an important element in the development of a more comprehensive model of the relationship between music listening and risk of mood or anxiety disorders. Listening to a certain quality or genre of music probably does not, in itself, cause one to become anxious or possibly also depressed; listening regularly to that same music in the context of a Discharge regulation strategy, for individuals who are more neurotic, might very well increase one's risk of experiencing mood or anxiety disorders The same music used by the same individual for Solace or Diversion may cause a different outcome in terms of mental illness risk than would be seen for Discharge. It may be possible to better clarify the models defined by Miranda and colleagues (2012) in relationship to each other if music listening strategies are included in analysis, including explaining inconsistencies in findings as to whether music acts more as a risk factor or a protective factor in mental illness.

5.2 Correlations between ROIs and Psychological Scores

5.2.1 The Lateral Prefrontal Cortex (BA9)

The bilateral lPFC (BA9) proved to be one of the most variable areas between gender and condition in this study. Its activation in music listening is not surprising given that previous literature has shown the lPFC to be active in the processes of emotional stimuli (Phan et al., 2005; Vuilleumeir et al., 2005). It has also been shown to be active in the suppression of negative mood (Phan et al., 2005). In this study, the bilateral lPFC decreased in activation during both implicit and explicit emotion processing, but decreased significantly more during implicit processing. Its increased activation in female participants who scored higher on Diversion use during implicit music listening tasks is again suggestive of McRae and colleagues' (2008) hypothesis that affect regulation is a less automatic process for females, thus involving greater recruitment of cortical areas than limbic areas compared to males. This is, however, partially inconsistent with findings by Mak, Hu, Zhang, Xiao, and Lee (2009) that the lPFC (specifically BA9) is associated with emotion regulation tasks in both males and females, since the increased activation here was specific to female participants. Decreases in this area may be related to down regulation—that is, the activity indicates the goal of decreased experience of an affective state, which is consistent with the goals associated with Diversion as a regulation strategy.

Vuilleumeir and colleagues (2005) found that lPFC activation increased in response to faces expressing fear when participants were more attentive to the stimulus. The overall effect that the bilateral lPFC is less activated in implicit processing is consistent with the previous study. In interpreting this result, it should be remembered that the implicit condition required participants to count the number of instruments heard in the excerpt. Although this task does not direct attention towards the emotional content of the music, it may indeed have required more attention from the participant to the music overall. The result may suggest that females who use music for Diversion attend to music differently than those who do not use Diversion, typically recruiting different brain areas, but the nature of these differences are difficult to deduce from the current data.

For females who scored higher on Discharge use, there was an increased activation of the bilareral lPFC in happy and sad explicit conditions, a result that is more obviously consistent

with Veuilleumeir and colleagues' results (2005), although this result was not found for music expressing fear. This may because fear is more easily expressed in faces than in music, but could also be attributed to the finding by Eerola and Vuoskoski (2011) that fear and anger were difficult to distinguish in music listening, thus the fear-explicit condition could have yielded more ambiguous results. Males who scored higher on Diversion and Discharge use both showed lower activation of the lPFC during implicit listening to happy and sad music, a result more consistent with Veuilleumeir's (2005) study. Males who scored higher on depression and neuroticism measures also showed decreased activation in the lPFC during implicit listening to sad music. Sad-implicit being one of the conditions in which female higher scorers in Diversion use showed an increase activation in the lPFC, this result is also suggestive of McRae and colleague's (2008) idea that affect regulation is a less automatic process in females than males.

5.2.2 Right Fusiform Gyrus (BA20): Decreases Associated with Task or Disease?

While difference in lPFC activation were more consistent in female participants, differences in activation of the right fusiform gyrus (BA20) were more apparent in male participants. Lower activation of the fusiform gyrus during implicit listening conditions, as is seen in these results, is consistent with previous literature associating the fusiform gyrus with categorization tasks, including facial recognition, word recognition and color information (Baars & Gage, 2010). Townsend and colleagues (2010) identified the fusiform gyrus as an area that was significantly more active in healthy controls than in depressed participants during a face-matching task. In the current study, decreased right fusiform gyrus activity was seen in male participants with higher depression scores in fear-implicit and sad-implicit listening conditions. It is thus difficult to judge from these results whether the decreases in fusiform gyrus activation were due only to the implicit condition or were also influenced by individual differences in depression, and a combination of the two effects is possible.

5.2.3 The ACC, vmPFC and IFG: Decreased Activation and Anxiety

Female participants with higher anxiety scores showed decreased activation in the right ACC (BA32) during happy music conditions. This finding might be explained by Phan and colleagues (2005), who found the left ACC to have increased activity during negative mood suppression; one would expect after all that hearing happy music would not require negative

mood suppression. However, abnormalities in the ACC has been linked to mood disorders. Joormann, Cooney, Henry and Gotlib (2012), who compared neural responses of females who had higher and lower risks of developing depression, and found those with lower risk to have significantly increased ACC activity compared to those with higher risk. That mean activation of the right ACC differed significantly for all subjects between happy-implicit and happy-explicit conditions adds further weight to the explanation that the presence of anxiety is significant in this case. Cullen and colleagues (2009) examined the dorsal and ventral neural connectivity between the ACC and the prefrontal brain regions, identifying decreased connectivity in these areas in adolescents with depression and comorbid anxiety compared with healthy controls, but did not find decreased connectivity between the ACC and amygdala as expected. Notably, however, Cullen and colleagues allowed participants to listen to self-selected music during resting-state scanning, and acknowledge this as an important variable that was not examined in the data. It is very possible that some of the participants in this study were using music for conscious mood regulation, which may have influenced amygdala responses during testing. Females with higher anxiety were also shown in the current study to have lower activation in the right vmPFC (BA11) during happy-implicit and sad-implicit conditions, a finding consistent with previous literature (Hakamuta et al, 2009; Ropongi et al., 2012), although it is worth considering why this effect did not also appear under fearful music conditions. Again, it is possible that the ambiguity of fear-expressing music, and overall lower brain reactivity to it, was a factor in this (Eerola & Vuoskoski, 2011).

Males with higher anxiety showed decreased left inferior frontal gyrus (BA47) activation under the happy-implicit condition. Similarly to the results found for females regarding the right vmPFC, however, it is troublesome that this effect only appeared in one condition. It is possible that this result is a false positive. However, Joorman and colleagues found the left inferior frontal gyrus to be the only region that differed significantly between depressed participants with and without somatic anxiety symptoms, with the more anxious participants showing less activation in the left inferior frontal gyrus, so it is possible that this finding at least hints at a true effect which might become more apparent in a study involving an experimental group that had clinical levels of depression and a healthy control group.

5.2.4 Right Amygdala Decreases with Mental Health Risk Increase

The negative correlation between right amygdala response and depression scores during explicit listening in all participants becomes even more interesting in light of the fact that this correlation seems to shift from depression to anxiety when male participants are examined alone. This decrease in right amygdala response is one of the most consistent findings of the current study in that, for all participants, the correlation exists in all three explicit listening conditions, for males alone the correlation with anxiety exists in all three explicit listening conditions, and for females alone the correlation with depression exists in two out of the three explicit listening conditions (happy-explicit and fear-explicit). This distinction almost demands that an interpretation of the results implicate this explicit condition. Previous studies have indeed shown the right amygdala is indeed less active during implicit emotion processing (Hariri, Bookheimer & Mazziota, 2000; Keightley et al., 2003). However, these results are in direct opposition to those found by Habel and colleagues (2007), who required participants either to select which of two words best described the emotion expressed by a face, or to select which of two decades was closer to the age of the person in the stimulus image, and found significantly increased right amygdala activation during the explicit condition, and they are not alone in that finding (Gorno-Tempini et al., 2001; Gur et al., 2002). The deciding factor may lie in verbal labeling; Kapler, Hariri, Mattay, McClure, and Weinberger (2001) found that passive observation of facial expressions activate the amygdala, but requiring the participants to label the observed emotion resulted in deactivation. One explanation for the findings of the current study is that this effect is simply more statistically apparent when the amygdala is already strongly activating. This suggests, albeit indirectly, that the right amygdala may play a stronger role in depression in females and anxiety in males, highlighting again the need for understanding gender differences in mental health and affect regulation. In healthy participants, previous research has shown greater functional connectivity of the right amygdala in males than in females, and that males experience great lateralization of emotional processing, in favor of the right hemisphere, than do females (Wager, Phan, Liberzon &Taylor, 2003). Depression, however, has been shown to change the volume of the left, but not the right amygdala regardless of gender (Lorenzetti, Allen, Whittle & Yücel, 2010). Again, the inconsistency of the current study with these previous findings may be due to the fact that few participants were clinically depressed or anxious, but it should also be remembered that few previous studies have used music as a stimuli, favoring images

of faces or film clips instead. Although it seems likely that emotional processing of music should be similar to emotional processing of other types of stimuli, it is possible that there are some differences. Just as further research comparing depressed or anxious participants to healthy controls is needed to clarify the findings of the current study, research comparing the emotional processing of music to the emotional processing of other types of stimuli will help to clarify whether similar patterns of amygdala lateralization should be expected in music processing as in other types.

6 CONCLUSIONS AND FURTHER RESEARCH

"Of all the problems that may confront a music psychologist,
none is perhaps more important than to explain listeners' reactions to music."
(Patrik Juslin and Daniel Västfjäll, 2008)

The chief recommendation for empiricism lies perhaps in the realization that our situation is a little better than that of Sisyphus; in the end, we are at least standing at the bottom of a new mountain. Complete understanding of listeners' reactions to music may require facing more mountains than can be summited in a lifetime, considering the complexity and variability of music itself and the complexity and variability of the human brain. Still, the current study asked questions that have been at least partially answered by its data.

Of the first question, how an individuals' use of music as a means of affect regulation might relate to his or her risk of developing a mental health disorder, we can say that a male with higher anxiety, neuroticism or both is more likely to use Discharge, using sad or aggressive music to express a negative mood. We can also say that, given that the data used included mostly healthy participants, the door open for further studies to identify more patterns of music use in individuals with mental illness. A study including participants with clinically diagnosed mood disorders compared with healthy controls may extend this knowledge to females or identify different patterns for females, and even parse listening patterns depending on diagnosis and severity of illness.

Individual differences in the neuro-correlations affective response to music were also examined. The current study suggests that both limbic and cortical areas can differ during music listening depending on such factors as gender, anxiety levels, depression levels, and patterns of music use in mood regulation. Some of the most variable areas included the bilateral lPFC (BA9), the right fusiform gyrus (BA20) and the right amygdala. Again, further experimental study using clinical and control groups could help to strengthen and clarify these results. Such study would also help to answer the third question posed by this study, whether maladaptive affective responses to music can be observed in the brain. The results of this study may indicate, indirectly, that females with higher depression and males with higher anxiety may have stronger right amygdala responses to music listening in non-attending

conditions. However, this question could be more completely answered with an experimental study involving clinically diagnosed and healthy participants.

The answers (and partial answers) to the above questions suggest that engagement with music may, in some cases, be implicated with maladaptive manifestations of affect. Because this has been a correlation study, causation can of course not be determined, but it is not so wild a speculation to imagine that individuals who employ other maladaptive coping strategies, such as rumination or avoidance, might also use music in a maladaptive way. Since the current study has shown that brain responses to music vary with individual differences of depression, anxiety and neuroticism levels, we might also suppose it possible that certain music listening patterns, such as listening to sad or aggressive music without the outcome of mood repair, might have more negative neural outcomes for such depressed, anxious or neurotic individuals than healthy individuals. Music therapists, usually advised to hold client preferred music in highest regard, may in such cases be better advised to aid clients in learning to use music for affect regulation more effectively. The results of the current study should at least stand as a reason for a therapist to exercise caution when dealing with a client prone to negative affect who also consistently prefers negatively valenced music.

Research on the relationship between music and human emotions, healthy and unhealthy, still has a long way to go. But at least we are now looking down a path more nuanced than the glorification of all music as a salve for the ill, or the demonization of a single artist, genre or quality. The demon of mental illness has always been as much a human phenomenon as music itself. The autochthonic nature of maladaptive uses of and responses to music should therefore not be a surprise; we look forward to future work having been reminded again that to study music is to study ourselves.

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8 APPENDIX 1: ALL ROIS AND SUBREGIONS

	Region	BA	Cluster size	MNI coordinates
	MAIN EFFECT OF EMOTION			
R	Superior Temporal Gyrus	BA 22	5155	56 -2 -4
R	Superior Temporal Gyrus	BA 22		52 -10 -2
R	Superior Temporal Gyrus	BA 42		62 -28 16
L	Superior Temporal Gyrus	BA 22	4644	-50 -10 -2
L	Superior Temporal Gyrus	BA 38		-52 0 -6
L	Superior Temporal Gyrus	*		-60 -22 4
L	Parahippocampal Gyrus	BA 34	209	-18 -10 -20
L	Parahippocampal Gyrus	BA 28		-22 -18 -20
R	Medial Frontal Gyrus	BA 11	528	2 46 -16
R	Medial Frontal Gyrus	BA 11		2 58 -10
R	Medial Frontal Gyrus	BA 11		2 34 -16
L	Cingulate Gyrus	BA 32	589	-6 22 38
R	Anterior Cingulate	BA 32		8 30 30
L	Cingulate Gyrus	BA 32		-4 30 32
R	Parahippocampal Gyrus	Amygdala	117	20 -6 -20
R	Parahippocampal Gyrus	BA 28		22 -14 -20
L	Middle Frontal Gyrus	BA 10	119	-32 48 8
R	Inferior Parietal Lobule	BA 40	381	40 -60 48
R	Superior Parietal Lobule	BA 7		34 -70 50
R	Inferior Parietal Lobule	BA 39		44 -68 40
L	Inferior Frontal Gyrus	BA 47	110	-50 44 -12
L	Middle Frontal Gyrus	BA 47		-50 42 -4
R	Precentral Gyrus	BA 6	103	54 -4 48
R	Posterior Cingulate	BA 30	190	2 -54 18
L	Posterior Cingulate	BA 23		-2 -60 14
R	Posterior Cingulate	BA 29		6 -58 8
L	Precentral Gyrus	BA 6	56	-50 -4 48
L	Caudate	Caudate Head	216	-12 14 -6
L	Caudate	Caudate Head		-14 20 6
L	Subcallosal Gyrus	BA 11		-12 26 -10
L	Inferior Frontal Gyrus	BA 47	60	-38 18 -6
L	Claustrum	*		-32 16 0
R	Caudate	Caudate Tail	75	34 -46 10
R	Sub-Gyral	Hippocampus		34 -40 0
	No Gray Matter found			28 -56 12
R	Cingulate Gyrus	BA 31	60	2 -32 36
R	Cingulate Gyrus	BA 31		4 -42 36
L	Inferior Parietal Lobule	BA 40	39	-36 -50 52
L	Precuneus	BA 7		-30 -50 44
L	Medial Frontal Gyrus	BA 10	131	-6 62 24
R	Medial Frontal Gyrus	BA 10		2 62 28

R	Inferior Frontal Gyrus	BA 47	52	40 20 -4
R	Insula	BA 13		44 16 2
L	Parahippocampal Gyrus	BA 35	41	-16 -28 -10
R	Middle Frontal Gyrus	BA 10	81	30 56 24
R	Superior Frontal Gyrus	BA 10		38 54 32
R	Caudate	Caudate Body	39	20 22 12
L	Cuneus	BA 18	74	-16 -100 8
L	Lingual Gyrus	BA 17		-12 -92 -2
R	Middle Occipital Gyrus	BA 18	196	24 -98 0
R	Lingual Gyrus	BA 17		20 -90 0
R	Middle Occipital Gyrus	BA 19		26 -98 12
L	Middle Frontal Gyrus	BA 46	138	-44 32 22
L	Inferior Frontal Gyrus	BA 46		-50 38 16
L	Middle Frontal Gyrus	BA 46		-52 36 26
R	Precuneus	BA 7	117	12 -60 46
R	Precuneus	BA 7		6 -72 42
R	Precuneus	BA 7		16 -66 38
L	Parahippocampal Gyrus	BA 19	26	-32 -48 0
L	Posterior Cingulate	BA 29	31	-4 -48 6
L	Postcentral Gyrus	BA 3	39	-44 -26 58
R	Middle Frontal Gyrus	BA 46	26	48 54 10
L	Inferior Temporal Gyrus	BA 37	47	-62 -54 -16
L	Inferior Temporal Gyrus	BA 37		-64 -56 -8
L	Superior Parietal Lobule	BA 7	29	-34 -66 54
R	Anterior Cingulate	BA 25		

MAIN EFFECT OF PROCESSING

L	Inferior Occipital Gyrus	BA 19	2881	-40 -80 -12
L	Fusiform Gyrus	BA 19		-36 -70 -16
L	Middle Occipital Gyrus	*		-38 -92 -6
R	Inferior Parietal Lobule	BA 40	1567	50 -42 54
R	Superior Parietal Lobule	BA 7		38 -76 42
R	Superior Parietal Lobule	BA 7		30 -60 40
R	Inferior Occipital Gyrus	BA 19	2900	44 -78 -8
R	Middle Occipital Gyrus	BA 19		32 -88 8
R	Middle Occipital Gyrus	BA 19		44 -84 2
R	Culmen	*	134	30 -64 -32
R	Culmen	*		40 -58 -34
R	Declive	*		36 -72 -30
L	Inferior Frontal Gyrus	BA 9	305	-44 8 30
L	Middle Frontal Gyrus	BA 6		-54 8 48
R	Middle Frontal Gyrus	BA 46	979	48 38 20
R	Inferior Frontal Gyrus	BA 9		52 10 36
R	Inferior Frontal Gyrus	BA 9		48 10 26
R	Caudate	Caudate Head	266	10 10 2

R	Caudate	Caudate Body		12 2 10
L	Superior Frontal Gyrus	BA 6	170	-26 4 58
L	Middle Frontal Gyrus	BA 6		-28 0 68
L	Inferior Temporal Gyrus	BA 20	266	-58 -54 -18
R	Middle Frontal Gyrus	BA 6	488	30 12 58
R	Superior Frontal Gyrus	BA 8		30 24 58
R	Middle Frontal Gyrus	BA 8		26 12 48
R	**Superior Frontal Gyrus**	**BA 9**	**2284**	**14 62 36**
L	**Superior Frontal Gyrus**	**BA 9**		**-6 60 32**
L	**Superior Frontal Gyrus**	**BA 9**		**-6 54 38**
L	Precuneus	BA 19	40	-38 -84 34
L	Cingulate Gyrus	BA 32	242	-2 20 44
R	Medial Frontal Gyrus	BA 6		6 32 40
L	Superior Frontal Gyrus	BA 6		-4 10 56
L	Postcentral Gyrus	BA 2	390	-50 -34 38
L	Inferior Parietal Lobule	BA 40		-54 -44 54
L	Inferior Parietal Lobule	BA 40		-40 -42 42
R	Insula	BA 13	204	44 -4 14
R	Superior Temporal Gyrus	BA 22		52 2 6
R	Precentral Gyrus	BA 44		44 4 12
R	Uvula	*	68	10 -82 -48
R	Pyramis	*		8 -88 -42
L	Lentiform Nucleus	Medial Globus Pallidus	53	-10 4 -4
L	Caudate	Caudate Head		-8 10 4
R	Middle Temporal Gyrus	BA 37	196	58 -56 -16
R	Inferior Temporal Gyrus	BA 37		62 -62 -8
L	Middle Frontal Gyrus	BA 46	177	-46 36 26
L	Inferior Frontal Gyrus	BA 46		-44 36 16
L	Middle Frontal Gyrus	BA 46		-44 46 10
L	Uvula	*	61	-28 -66 -32
L	Tuber	*		-36 -60 -34
R	Fusiform Gyrus	BA 20	45	42 -14 -32
R	Parahippocampal Gyrus	BA 20		40 -28 -24
L	Thalamus	*	150	-6 -6 12
L	Thalamus	Ventral Lateral Nucleus		-18 -18 18
L	Caudate	Caudate Body		-14 -10 18
R	Insula	BA 13	66	50 -24 24
L	Inferior Frontal Gyrus	BA 47	161	-44 22 -12
L	Inferior Frontal Gyrus	BA 47		-34 16 -16
L	Inferior Frontal Gyrus	BA 47		-46 30 -6
L	Precuneus	BA 7	125	-24 -82 44
L	Superior Parietal Lobule	BA 7		-28 -66 46
L	Precuneus	BA 7		-24 -72 40
L	Uvula	*	27	-32 -78 -36
R	Precuneus	BA 7	46	8 -62 52

R	Thalamus	Medial Dorsal Nucleus	46	6 -10 10
R	Superior Frontal Gyrus	BA 8	71	10 34 54
R	Superior Frontal Gyrus	BA 8		14 38 46
R	Superior Temporal Gyrus	BA 39	62	52 -64 20
L	Insula	BA 13	127	-42 -8 12
L	Claustrum	*		-32 0 12
L	Insula	BA 13		-40 2 8
L	Lentiform Nucleus	Putamen	30	-22 4 6
L	Cingulate Gyrus	BA 24	36	-4 -14 38
L	Cingulate Gyrus	BA 24		-2 -20 44
L	Cingulate Gyrus	BA 31	32	-8 -48 34
L	Medial Frontal Gyrus	BA 6	29	-4 -8 66
R	Superior Parietal Lobule	BA 7	28	14 -66 66