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A Systematic Review on the Neural Effects of Music on Emotion Regulation: Implications for Music Therapy Practice

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Background: *Emotion regulation (ER) is an internal process through which a person maintains a comfortable state of arousal by modulating one or more aspects of emotion. The neural correlates underlying ER suggest an interplay between cognitive control areas and areas involved in emotional reactivity. Although some studies have suggested that music may be a useful tool in ER, few studies have examined the links between music perception/production and the neural mechanisms that underlie ER and resulting implications for clinical music therapy treatment. Objectives of this systematic review were to explore and synthesize what is known about how music and music experiences impact neural structures implicated in ER, and to consider clinical implications of these findings for structuring music stimuli to facilitate ER.*

Methods: *A comprehensive electronic database search resulted in 50 studies that met predetermined inclusion and exclusion criteria. Pertinent data related to the objective were extracted and study outcomes were analyzed and compared for trends and common findings.*

Results: *Results indicated there are certain music characteristics and experiences that produce desired and undesired neural activation patterns implicated in ER. Desired activation patterns occurred when listening to preferred and familiar music, when singing, and (in musicians) when improvising; undesired activation patterns arose when introducing complexity, dissonance, and unexpected musical events. Furthermore,*

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the connection between music-influenced changes in attention and its link to ER was explored.

Conclusions: *Implications for music therapy practice are discussed and preliminary guidelines for how to use music to facilitate ER are shared.*

Keywords: *music; emotion regulation; neuroscience, amygdala*

Self-regulation is a complex process of self-directed change. It is the ability to implement processes and actions that allow one to effectively control and manage multiple levels of experiences: cognitive, emotional, behavioral, and physiological (Bandura, 1991; Blaustein & Kinniburgh, 2010; Karoly, 1993; Larsen, 2000; Smith-Donal, Raver, Hayes, & Richardson, 2007). Self-regulation is considered a central developmental milestone in early childhood (Liebermann, Giesbrecht, & Müller, 2007) that has lifelong implications for one's emotional, cognitive, social, and mental health. An essential component of self-regulation is emotion regulation (ER) (Diamond & Aspinwall, 2003; Geva & Feldman, 2008) and the development of ER is considered an early marker for the development of appropriate self-regulation (Cole, Dennis, Smith-Simon, & Cohen, 2009).

There has been a significant increase in the past 25 years in exploring the neural correlates underlying a phenomenon; ER is no exception. In addition, there has been increased interest in the music neurosciences and in studying the neural correlates underlying music perception and cognition. Although it has long been considered that music influences emotions, there has been little attention given to understanding how music affects emotion regulation. For the music therapist, an understanding of this phenomenon has therapeutic implications for a variety of clinical populations that find it a challenge to control and manage their emotional experiences. Thus, the major goal of this review was to explore what is known about how music and music experiences impact neural structures implicated in emotion regulation, and to consider possible clinical implications of these findings.

Emotion Regulation

Emotion regulation is an internal process through which a person is able to maintain a comfortable state of arousal by modulating one or more aspects of emotion (Blaustein & Kinniburgh, 2010; Diamond & Aspinwall, 2003; McRae et al., 2010). It involves using strategies and processes designed to create a new emotional response or change a current one (Gyurak, Gross, & Etkin, 2011; McRae et al., 2010; Ochsner & Gross, 2005) that can be explicit (e.g., effortful or conscious) or implicit (e.g., automatic or unconscious) (Diamond & Aspinwall, 2003; Gyurak et al., 2011). Generally, successful emotion regulation strategies either alter the way an individual attends to a situation, interprets the meaning of a situation (McRae et al., 2010), or changes the situation itself (Diamond & Aspinwall, 2003). Difficulties with emotion regulation can have a life-long impact on an individual's mental health and well-being (Saxena, Dubey, & Pandey, 2011). Many researchers consider appropriate emotion regulation to be a marker of mental health as it allows a person flexibility in how he or she responds and reacts to situations and moments of distress (Cole et al., 2009; Gyurak et al., 2011; McRae et al., 2010). There are many disorders and syndromes in which difficulties with emotion regulation can be a challenge, including Attention Deficit/Hyperactivity disorder, Autism and Asperger syndrome (Masao, 2004), Post-Traumatic Stress Disorder (PTSD), and trauma (Ehring & Quack, 2010).

The neural correlates underlying emotion regulation suggest an interplay between frontal lobe areas involved in cognitive control and areas involved in emotional reactivity (Gyurak et al., 2011). More specifically, cognitive control areas include the lateral prefrontal cortex (Gyurak et al., 2011; McRae et al., 2010; Ochsner & Gross, 2005), the orbitofrontal cortex (Masao, 2004; Ochsner & Gross, 2005; Rempel-Clower, 2007; Schore, 2001), and the anterior cingulate cortex (Gyurak et al., 2011; McRae et al., 2010; Ochsner & Gross, 2005). The amygdala is the primary structure implicated in emotional reactivity (Gyurak et al., 2011; Masao, 2004; McRae et al., 2010; Ochsner & Gross, 2005). In general, emotion regulation is characterized by increased activation in the cognitive control and monitoring areas—the anterior cingulate cortex, orbitofrontal cortex, and lateral prefrontal cortex—which leads to decreased activation in the amygdala (Gyurak et al., 2011; Ochsner & Gross, 2005; McRae et al., 2010; Rempel-Clower, 2007).

Music and Emotion Regulation

Music has long been thought to influence emotions and emotion control. In his seminal book *The Anthropology of Music*, Merriam (1964) wrote about music's role as a producer of emotions. It has also been noted that music can evoke emotions in listeners (Sloboda & Juslin, 2010) and may be an effective mood induction technique (Thaut & Wheeler, 2010). However, mood induction is different than emotion regulation; moods are affective states lower in intensity than emotions (Juslin & Sloboda, 2010). Furthermore, evoking emotions is a general concept whereas emotion regulation is geared towards the specific goal of maintaining a comfortable state of arousal (Blaustein & Kinniburgh, 2010; Diamond & Aspinwall, 2003; McRae et al., 2010). More recent research has focused on the neural basis underlying music-evoked emotions, finding that music does indeed impact neural areas implicated in emotion processing (Blood & Zatorre, 2001; Koelsch, 2010; Trainor & Schmidt, 2003). However, much in the literature is from the music neuroscience field and focuses on the neural mechanisms underlying music listening, playing, or improvisation. There is little that explores the connection between music processing and clinical treatment; as such, there is little in the way of clinical implications relevant to the music therapy clinician. Therefore, the purpose of this exploratory review was to synthesize findings from studies that reported on the effect of music and music-based experiences on neural structures implicated in ER, and to create preliminary clinical considerations based on this synthesis.

Description of the Condition

For the purposes of this review, ER was defined as an internal process through which a person is able to maintain a comfortable state of arousal by modulating one or more aspects of emotion (Blaustein & Kinniburgh, 2010; Diamond & Aspinwall, 2003; McRae et al., 2010). It is characterized by the involvement of the amygdala (Gyurak et al., 2011; Masao, 2004; McRae et al., 2010; Ochsner & Gross, 2005), the anterior cingulate cortex (Gyurak et al., 2011; McRae et al., 2010; Ochsner & Gross, 2005), the orbitofrontal cortex (Masao, 2004; Ochsner & Gross, 2005; Rempel-Clower, 2007; Schore, 2001), and the lateral prefrontal cortex (Gyurak et al., 2011; McRae et al., 2010; Ochsner & Gross, 2005). There are cases where "emotion regulation" has the same meaning as "affect regulation" (Schore, 2001), although there are times when affect regulation refers to a set of intervention techniques (Verheugt-Pleiter, 2008); the latter did not fit the intent of this review.

Description of the Stimulus

For the purposes of this review, "music" referred to any acoustic stimulation provided by a complex, organized sound. As long as the study fit other criteria for this review, "music" also included musical properties, such as rhythm, musical interval, harmony, and pitch, and music experiences, such as listening to music, playing an instrument, improvising, or composing. The literature lists "music" most often, with occasional references to terms such as "acoustic stimulation," "music therapy," and "complex musical sound stimuli." Research using rhythm that was associated with circadian rhythm, cardiac rhythm, respiratory rhythm, dietary rhythm, and other nonmusical references to rhythm were excluded.

Objectives

1. To explore and synthesize results examining the effects of music on neural structures implicated in emotion regulation.
2. To create preliminary clinical considerations for structuring the music stimulus when facilitating emotion regulation.

Methods

Search Strategies

The search and analysis processes used in this review were consistent with those outlined by Cooper (1998) and Khan, Kunz, Kleijnen, and Antes (2011). Studies considered for this review were published through April 2012 and identified through a comprehensive search in the following electronic databases: MEDLINE, PsycINFO, CINAHL, SIGLE, National Institute for Health Research, Current Controlled Trials, ClinicalTrials.gov, and CAIRSS for Music. Electronic databases were searched using the following keyword phrases: "music and amygdala," "music and orbitofrontal cortex," "music and anterior cingulate," and "music and prefrontal." Search results generated from the "music and prefrontal" keyword phrase were scanned and included for consideration if they included the words "dorsolateral," "ventrolateral," or "lateral."

Article Inclusion Criteria

1. The article was a primary research study.

2. Participants were typically-developing humans, with no restrictions as to age, gender, ethnicity, or type of setting.
3. Music was the primary stimulus, regardless of how it was implemented (e.g., singing, listening, improvising, etc.), the genre of music, or the music instrument(s) incorporated.
4. Study results reported on the impact of music on one or more of the following neural structures: amygdala, anterior cingulate cortex, orbitofrontal cortex, and lateral prefrontal cortex.
5. Articles were published in English.
6. Articles were published in peer-reviewed journals.

Article Exclusion Criteria

1. The article was a review study or theoretical paper.
2. Participants had a disorder, brain damage (such as lesions and excisions), or a syndrome.
3. The study of rhythm was associated with circadian rhythm, cardiac rhythm, respiratory rhythm, dietary rhythm, and other nonmusical references to rhythm.

Data Collection and Analysis Process

The author and two research assistants independently extracted pertinent information from the included studies related to the first objective. This included, as applicable, information about participant characteristics (i.e., number of participants, sex distribution, average age, age range, and musical ability), study design (i.e., primary research question, neural measurement tool utilized, and other behavioral and neuropsychological tools utilized), characteristics of the music and/or music experience utilized (i.e., type of music experience, music characteristic studied, music instrument used, and genre of musical stimulus), and study outcomes (i.e., general outcomes of the study and neural structure-specific outcomes). Pertinent data related to the objective were extracted and study outcomes were analyzed and compared for trends and common findings. Differences in data extracted were discussed and results agreed upon for data analysis. Initial interrater reliability among the three coders was 75.5%. When controlled for typographical errors and updates to the coding sheet that occurred as a result of discussing differences in data extracted, final inter-rater reliability was 83.6%.

Results of the Search

The comprehensive electronic database search resulted in 319 articles that were evaluated for inclusion according to the inclusion and exclusion criteria listed above. Of those initial studies, 103 met the criteria. Forty-four (44) studies were duplicates, which led to the inclusion of 59 unique studies. During the coding process, an additional nine studies were excluded for the following reasons: the neural structures were not activated as a result of music stimulation (Dehaene-Lambertz et al., 2010; Schulze, Zysset, Mueller, Friederici, & Koelsch, 2011; Sluming et al., 2002), music was not used as the intervention (Blasi et al., 2011; Haslinger et al., 2004; Milton, Solodkin, Hluštik, & Small, 2007), the study was a dissertation (Chapin, 2010), the study offered preliminary data that was reported in a second study (Zarate & Zatorre, 2005), and the study did not report information clearly enough for data extraction (Bodner, Muftuler, Nalciogly, & Shaw, 2001). Thus, this review included 50 research studies.

Results

Characteristics of Included Studies

Participant characteristics. There were a total of 811 participants in the studies (*M* = 25.1 years; *SD* = 6.2 years, range: 12–60 years), 757 adults and 54 adolescents. Over half of the participants were male (54.7%) and the rest were female (45.3%). Studies used an average of 16 participants (range: 6–49 participants). Almost half of the studies used musicians as participants or a combination of musicians and nonmusicians (44.4%) and the remainder either used nonmusicians or authors were not specific in the reporting (Table 1).

Characteristics of study design. Frequency information, related to study design characteristics of the included studies, is reported in Table 1. The two most common neural measurement tools used were functional Magnetic Resonance Imaging (fMRI) (65.5%) and Positron Emission Tomography (PET) (18.2%). Other techniques used included electroencephalography (EEG), event-related potentials (ERPs), magnetoencephalography (MEG), and a brain oxygen measurement tool called an OT system. Studies included in this review incorporated a variety of musical experiences. The majority of studies (69.6%) used listening to recorded music as the experience, followed by singing, instrument playing, and improvisation. The most common musical instrument used, when specified, was piano (41.7%) followed by voice (18.3%), and the most common musical genre used, when specified, was tonal, Western instrumental music (43.1%), followed by popular or current music, jazz or improvisation, and nonwestern music. Almost half of the time (49.1%) researchers were not investigating a particular musical element (i.e., rhythm, pitch, harmony, etc.). If they did, harmony was investigated the most frequently (21.8%), followed by rhythm, melody, pitch, timbre, and pitch interval.

Synthesis of Results

A summary of pertinent characteristics and outcome measures of individual studies is reported in Table 2 and a synthesis of the main findings is reported in Table 3. Anterior cingulate cortex activation was reported and/or described the most frequently (32.9%), followed by lateral prefrontal cortex activation, amygdala activation, and orbitofrontal cortex activation (Table 1). Results will be presented in a bottom-up fashion, from the deepest neural structure, the amygdala, to the most superficial area, the prefrontal cortex.

Amygdala. Multiple studies reported that the amygdala was activated when listening to minor, dissonant, negative, or unpleasant music (Koelsch, Fritz, Cramon, Müller, & Friederici, 2006; Lerner, Papo, Zhdanov, Belozersky, & Hendler, 2009; Pallesen et al., 2005). Amygdala activation occurred during an unexpected event (e.g., hearing an irregular chord) and its activity could be modulated by a single chord change (Koelsch, Fritz, & Schlaug, 2008). One study reported that the amygdala was activated during music listening regardless of consonance or dissonance (Ball et al., 2007). Amygdala activation increased when listening to music with eyes closed (Lerner et al., 2009) and was activated more strongly when music was paired with visual stimuli as compared to no visual stimuli (Baumgartner, Lutz, Schmidt, & Jäncke, 2006; Eldar, Ganor, Admon, Bleich, & Hendler, 2007). One study noted a lateralization effect, reporting that the right amygdala was activated more strongly during an audiovisual condition than the left amygdala, and its activity increased with exposure over time (Dyck et al., 2011). The right amygdala in

Table 1
Frequency of Participant and Study Characteristics

Category	Number	Relative frequency
Music training of participants		
1. Nonmusicians only	15	30%
1. Musicians only	13	26%
1. Not specified	13	26%
1. Both musicians and nonmusicians	9	18%
Neural measurement tools used		
1. fMRI	36	65.5%
1. PET	10	18.2%
1. Electroencephalography (EEG)	5	9.1%
1. Event-related potentials (ERP)	2	3.6%
1. Magnetoencephalography (MEG)	1	1.8%
1. Event-related potentials (ERP)	1	1.8%
Type of music experience		
1. Music listening (recorded music)	39	69.6%
1. Singing	8	14.3%
1. Instrument playing	5	8.9%
1. Improvisation	4	7.1%
Music instrument(s) utilized		
1. Piano	25	41.7%
1. Voice	11	18.3%
1. Instrumental (orchestral)	8	13.3%
1. Instrumental (electronic)	5	8.3%
1. Not specified	4	6.7%
1. Instrumental (accompaniment)	3	5.0%
1. Instrumental (solo)	2	3.3%
1. Instrumental (nonwestern)	1	1.7%
1. Other	1	1.7%
Genre of music		
1. Western tonal instrumental music	22	43.1%
1. Not specified	13	25.5%
1. Popular/current music	6	11.8%
1. Jazz/improvisation	4	7.8%
1. Nonwestern music	3	5.9%
1. Western tonal vocal music	2	3.9%
1. Other	1	2.0%
Music element studied		
1. Not specified	27	49.1%
1. Harmony	12	21.8%
1. Other	6	10.9%
1. Rhythm	3	5.5%
1. Melody	2	3.6%

TABLE 1
Continued

Category	Number	Relative frequency
1. Pitch	2	3.6%
1. Timbre	2	3.6%
1. Interval	1	1.8%
Neural structure reported on		
1. Anterior cingulate cortex (ACC)	24	32.9%
1. Lateral prefrontal cortex (lateral PFC)	21	28.7%
1. Amygdala	12	16.4%
1. Orbitofrontal (OFC)	9	12.3%

Note. Some studies incorporated multiple types of neural measurement tools, music experiences, music instruments, music genres, studied multiple music elements, and reported on multiple neural structures. These numbers are reflected in the reported frequencies.

particular was recruited during “sad” music (Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007), is implicated in early neural responses to chord violations (James, Britz, Vuilleumier, Hauert, & Michel, 2008), and exhibited chord-dependent responses (Pallesen, Brattico, Bailey, Korvenoja, & Gjedde, 2009). The left amygdala had consistently similar activation patterns, with increased activation reported when listening to music rated with a higher negative emotional valence (Dyck et al., 2011). The amygdala was deactivated during music improvisation (Limb & Braun, 2008) and when listening to pleasant music (Blood & Zatorre, 2001; Koelsch et al., 2006). A long-term habituation effect was noted, perhaps due to the amygdala’s role in evaluating salience (Mutshuler et al., 2010). To summarize, amygdala activation and deactivation patterns changed based on the type of music experience, the characteristics of the music stimulus, and perceived valence of the music.

Anterior cingulate cortex (ACC). The ACC was activated during voluntary pitch correction (Zarate, Wood, & Zatorre, 2010), discrimination tasks (Brown & Martinez, 2007), when listening to chord violations (James et al., 2008), and when monitoring performance errors (Ruiz, Jabusch, & Altenmüller, 2009). In addition, listening to familiar music activated the ACC (Janata, 2009) as did, in musicians, listening to dissonant chords (Foss, Altschuler, & James, 2007). ACC activation increased during both singing (Perry et al., 1999) and music listening tasks (Menon &

TABLE 2
Summary of Study Characteristics and Outcomes

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Ball et al. (2007)	fMRI and anatomical map study analyzing response of amygdala sub-regions to pleasant/unpleasant auditory stimuli	14	Nonmusicians	Music listening (recorded)	Harmony, tempo	Amygdala	(1) Reported lateralization and regional activation differences in amygdala to affective auditory stimuli; (2) No response difference to pleasant and unpleasant auditory stimuli
Baumgartner et al. (2006)	fMRI study exploring neural mechanisms implicated when music enhances pictures	9	Not specified	Music listening (recorded)	Not specified	Amygdala, dlPFC	(1) Congruent emotional music and visual stimuli can increase activity in visual processing areas and ventral emotion processing system; (2) Structural and functional dissociation between combined music/picture and picture alone; (3) More prefrontal activation with picture alone
Bengtsson et al. (2007)	fMRI study exploring neural mechanisms underlying improvisation	11	Musicians	Improvisation	Melody	dlPFC	(1) Frontal and temporal association areas activated when professional musicians improvised; (2) dlPFC implicated in creative aspect of behavior when adapted to satisfy a result

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Berkowitz & Ansari (2008)	fMRI study exploring neural mechanisms underlying improvisation	12	Musicians	Improvisation, instrument play	Rhythm, melody	ACC	Music improvisation activated networks thought to be involved in generation of novel motor sequences, including ACC
Berns & Moore (2012)	fMRI study exploring ability to predict popularity of music	27	Not specified	Music listening (recorded)	Not specified	OFC	(1) Liking a song not predictive of sales, but activation of reward-related neural structures significantly correlated with the number of units sold; (2) Neural responses to music do not predict number of purchases, but may predict cultural popularity
Berns et al. (2010)	fMRI study investigating neural mechanisms associated with social influence	27	Not specified	Music listening (recorded)	Not specified	ACC	Outlines mechanisms underlying effect of popularity ratings on consumer decisions and association of anxiety with mismatch of personal preference and popularity, including increased ACC activation

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Blood & Zatorre (2001)	PET scan exploring neural mechanisms activated with pleasant emotional responses to music	10	Musicians	Music listening (recorded)	Not specified	Amygdala, OFC, ACC	(1) Listening to preferred music recruits neural systems associated with reward and emotion similar to those known to respond to biologically-relevant stimuli; (2) Heart rate and respiration increased while listening to music that elicited chills.
Brown & Martinez (2006)	fMRI study exploring neural mechanisms underlying melody and harmony discrimination	11	Musicians	Music listening (recorded)	Harmony, Melody	ACC, dlPFC	(1) Discrimination processing involves domain-specific sensorimotor area and domain-general working memory and error detection areas; (2) Similar activation patterns between melody/harmony processing and between perception/production of music, including dlPFC and ACC
Brown et al. (2004)	PET study exploring neural mechanisms underlying pleasant feelings	10	Nonmusicians	Music listening (recorded)	Not specified	ACC	(1) Spontaneous activation of limbic and paralimbic areas during task-free, passive listening to unfamiliar but liked music; (2) Stronger left-hemisphere activation with music-elicited positive emotions

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Brown et al. (2006)	PET study exploring neural mechanisms underlying melodic and speech generation	10	Musicians	Music listening (recorded), Singing	Melody	ACC	(1) Significant overlap in structures activated during melodic improvisation and sentence generation, including ACC; (2) Some lateralization differences, such as stronger left-hemisphere activation with sentence generation
Callan et al. (2006)	fMRI study investigating the neural differences between perceiving and producing song and speech	16	Nonmusicians	Music listening (recorded), singing	Not specified	OFC	Diffuse, bilateral network of overlapping neural processes underlie perception and production of speech and song, supporting relationship between them
Coen et al. (2009)	fMRI study exploring effect of negative emotional stimuli on neural processing	12	Not specified	Music listening (recorded)	Not specified	ACC, dlPFC	(1) Evidence of right hemisphere dominance when processing negative emotions; (2) Right insula and right ACC seem integral to awareness of emotion; (3) Sadness perception increased when listening to sad music but did not affect pain perception

TABLE 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
de Manzano & Ullen (2012)	fMRI study exploring neural mechanisms underlying response generation	18	Musicians	Improvisation, instrument play	Not specified	ACC, dlPFC	(1) Significant overlap in activation during improvisation and sight-reading, suggesting these regions fulfill generic functions in free generation regardless of goal; (2) Higher activity during pseudo-generation task in attention, working memory, and executive control areas
Dyck et al. (2011)	fMRI study exploring amygdala response when presented with visual v. audiovisual input	30	Not specified	Music listening (recorded)	Not specified	Amygdala	(1) Amygdala may be implicated in emotion regulation, not just emotion perception; (2) Reported left-lateralized cognitive/intentional control of mood and right-lateralized automatic induction of emotion; (3) Reported stronger activation with audiovisual input
Eldar et al. (2007)	fMRI study exploring limbic responses to music when paired/not paired in a real-world context	12	Not specified	Music listening (recorded)	Not specified	Amygdala, LPFC	(1) Brain may have preferential response to emotional stimuli when associated with a concrete context; (2) Music can elicit greater emotional effect when paired with a concrete visual stimuli v. when presented on its own

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Flores-Gutiérrez et al. (2007)	fMRI and EEG study exploring neural activity associated with pleasant/unpleasant emotional states	19	Nonmusicians	Music listening (recorded)	Not specified	OFC	(1) Music-elicited emotions require cognitive-sensory integration and have widespread activation of cognitive, language, and emotion processing areas; (2) Different structures involved in processing positive and negative musical emotions with left side activated for pleasant emotions and right for unpleasant
Ford et al. (2011)	fMRI study investigating neural mechanisms underlying autobiographical memories associated with music	16	Not specified	Music listening (recorded)	Not specified	ACC, LPFC	(1) Different neural structures and networks recruited for different types of autobiographical memory; (2) Supports use of music as an autobiographical retrieval cue for memories that are positive, emotionally charged, and subject to reliving as it activated areas related to emotion processing and memory retrieval (e.g., VPFC and ACC)

TABLE 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Foss et al. (2007)	fMRI study exploring neural mechanisms implicated in Pythagorean ratio rules	13	Both musicians and nonmusicians	Music listening (recorded)	Interval	ACC	(1) Neural activation of dissonant intervals significantly greater than consonant intervals; (2) Activation patterns to dissonance different in musicians (left-lateralized) v. nonmusicians (right-lateralized), suggesting stronger activation in musicians' language processing areas
Fujisawa & Cook (2011)	fMRI study exploring neural networks activated when listening to different Western harmonies	12	Nonmusicians	Music listening (recorded)	Harmony	3OFC, dlPFC	(1) Reported activation patterns when processing harmonies; (2) OFC significantly activated during chord changes; (3) Moving from a tension chord to a favored chord elicits a strong brain response.
Green et al. (2008)	fMRI study exploring neural responses to musical modes	21	Nonmusicians	Music listening (recorded)	Harmony	ACC	(1) Found differential activation of certain structures when listening to minor v. major music, which may be due to dissonance or overall quality of sadness; (2) Minor melodies activated more limbic areas than major melodies

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Hugdahl et al. (1999)	PET scan exploring activation patterns associated with dichotic listening	12	Not specified	Music listening (recorded)	Timbre	dlPFC	(1) Asymmetry effects when presenting different stimuli in each ear, with greater left hemisphere activation for speech and greater right hemisphere activation for music; (2) Stronger activation for processing speech v. music, perhaps because auditory cortex specialized for phonological processing; (3) dlPFC may play a role in detecting complex timbre
James et al. (2008)	ERP imaging study investigating neural differences musical training has in harmonic processing	26	Both musicians and nonmusicians	Music listening (recorded)	Harmony	rt. Amygdala	(1) Rapid, right-lateralized neural responses to chord violations for musicians v. nonmusicians, suggesting that music training enhances right hemispheric dominance; (2) Amygdala activated when detecting harmonic incongruencies

TABLE 2
Continued

Author	Description of study	Study characteristics				Outcomes	
		N	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Janata (2009)	fMRI study investigating neural mechanisms underlying autobiographical memories associated with music and MPFC activation	13	Not specified	Music listening (recorded)	Not specified	vlPFC	(1) mPFC associated with processing music and memories, with a generalized activation increase based on familiarity and autobiographical salience of music; (2) Results demonstrate extended autobiographical memory network that includes mPFC and lateral prefrontal and posterior cortices
Jeffries et al. (2003)	PET study investigating brain networks activated during singing and speaking	20	Nonmusicians	Singing	Not specified	dlPFC	(1) Left hemisphere more activated when producing speech and right when producing music; (2) Singing words did not activate "mirror-image" structures in right hemisphere, suggesting multiple neural networks may be involved in different aspects of singing

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Jerde et al. (2011)	PET study exploring structures underlying working memory for rhythm and melody	10	Nonmusicians	Music listening (recorded)	Rhythm, Melody	ACC	Rhythm and melody seem to have unique neural processing networks in early stages of processing and in higher cognitive processing of working memory
Kleber et al. (2007)	fMRI study exploring neural networks involved in singing and imagined singing	16	Musicians	Singing	Not specified	ACC, vlPFC, Amygdala	(1) Broad range of activation in xcpartly overlapping cortical and subcortical areas when overtly and imagining singing; (2) Imagined singing activated areas involved in working memory; (3) Emotion processing areas showed enhanced activation during imagined singing
Kleber et al. (2010)	fMRI study exploring effect of vocal motor skills training on functional somatosensory activation	49	Both musicians and nonmusicians	Singing	Not specified	dlPFC	(1) Music training associated with increased activation in diffuse motor, sensory, frontal, parietal, subcortical, and cerebellar structures; (2) Vocal skills training correlated with increased activity in kinesthetic motor control, sensorimotor guidance, and implicit motor memory areas

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Knösche et al. (2005)	EEG and MEG study exploring neural-based perception of musical phrase structure	12	Musicians	Music listening (recorded)	Melody	ACC, OFC	Timing and topography for processing musical phrases similar to those used to process prosodic phrase boundaries in speech
Koelsch et al. (2006)	fMRI study exploring neural mechanisms involved in processing pleasant v. unpleasant music	11	Nonmusicians	Music listening (recorded)	Not specified	Amygdala	(1) Different structures and networks activated when processing unpleasant v. pleasant music; (2) Activations increased over time during presentation of music, indicating time effect of emotion processing
Koelsch et al. (2008)	fMRI study investigating neural networks involved in perceived emotional valence chords	20	Both musicians and nonmusicians	Music listening (recorded)	Harmony	Amygdala	(1) Music-syntactical errors activated structures related to emotional processing, including amygdala; (2) Irregular chords were judged more unpleasant compared to "regular" chord ending

TABLE 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Lee et al. (2011)	fMRI study exploring brain regions implication in discrimination melodic contour	12	Nonmusicians	Music listening (recorded)	Melody	ACC	(1) Reported on 3 distinct cortical areas, including ACC, whose activity seemed to discriminate different contours; (2) Descending and ascending parts of the contour alter brain activation patterns
Lerner et al. (2009)	fMRI study exploring differences in neutral networks activated when listening to music with eyes open v. closed	15	Nonmusicians	Music listening (recorded)	Not specified	Amygdala	(1) Greater activation of amygdala when listening to emotional music with eyes closed and when listening to negative music; (2) Findings support system-based model of perceived emotionality with amygdala having central role in mediating effects of context-based processing by recruiting “low” (e.g., visceral) and “high” (e.g., cognitive) neural operations

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Limb & Braun (2008)	fMRI study exploring neural networks involved in music improvisation	6	Musicians	Improvisation, instrument Play	Not specified	OFC, dlPFC, Amygdala	(1) Spontaneous improvisation characterized by widespread deactivation of lPFC and focal activation of mPFC, regardless of complexity, indicating cognitive dissociations in the creative process; (2) Improvisation caused activation of cortical sensorimotor areas and deactivation of limbic structures
Menon & Levitin (2005)	fMRI study exploring neural networks activated when having an emotional reaction to music	13	Nonmusicians	Music listening (recorded)	Not specified	OFC, ACC	(1) Listening to music strongly modulates activity in mesolimbic reward-processing network, including the ACC, and structures involved in regulating autonomic and physiological responses to emotional stimuli; (2) Music listening may connect affective and autonomic processing systems

TABLE 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Mitters-chiffthaler et al. (2007)	fMRI study exploring neural differences when listening to happy v. sad music	16	Not specified	Music listening (recorded)	Not specified	ACC, Amygdala	(1) Different neural networks activated when listening to happy/sad/neutral music; (2) Music-elicited emotion processing may integrate ventral and dorsal striatum (for reward experience and movement), ACC (for attention), and medial temporal lobes (for emotion appraisal and processing); (3) Reported an order effect in activation patterns when listening to happy music first v. sad music
Mizuno & Sugishita (2007)	fMRI study investigating neural correlates to processing mode-induced emotional responses	18	Musicians	Music listening (recorded)	Harmony	ACC	(1) Certain structures and networks were activated when listening to triads with a tonal structure than those without; (2) ACC activated during minor and major mode conditions

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Mutshuler et al. (2010)	fMRI study exploring changes in brain activity when habituated to an affective musical stimuli	19	Nonmusicians	Music listening (recorded)	Harmony, tempo	vlPFC, Amygdala	(1) Reported amygdala-cortical networks implicated in habituation effects of emotional experiences; (2) Different time scales of habituation coexist with perception of music
Nakamura et al. (1999)	PET and EEG study exploring neural networks activated when listening to music	8	Not specified	Music listening (recorded)	Not specified	ACC	Passive music listening caused increase activation in posterior two-thirds of scalp, suggesting an interaction between music processing and cognitive processes
Ohnishi et al. (2001)	fMRI study exploring differences in activation patterns in musicians v. nonmusicians during music perception	28	Both musicians and nonmusicians	Music listening (recorded)	Not specified	dlPFC	Reported left hemisphere dominance when listening to music for musicians, right hemisphere dominance for nonmusicians, and significant difference in degree of activation in certain areas in musicians, including left dlPFC

TABLE 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Pallesen et al. (2009)	fMRI study investigating changes in brain activation when cognitively and emotionally processing affective stimuli	10	Nonmusicians	Music listening (recorded)	Harmony	rt. Amygdala	(1) Noted differences in activation patterns during music listening with and without working memory task; (2) In some regions, the greater the working memory task the larger the decrease; (3) Task-related decreases may be further affected by emotional impact of music
Pallesen et al. (2005)	fMRI study exploring neural networks involved in processing emotional responses to chords in musicians and nonmusicians	21	Both musicians and nonmusicians	Music listening (recorded)	Harmony	Amygdala	(1) Neural processing in emotion-related brain areas can be activated by single chords; (2) Emotion processing was enhanced in absence of cognitive requirements; (3) Musicians and nonmusicians do not differ in neural processing of single chords

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Pallesen et al. (2010)	fMRI study exploring differences between musicians and nonmusicians in working memory of musical sound task	21	Both musicians and nonmusicians	Music listening (recorded)	Harmony	ACC, LPFC	(1) Musicians performed better on cognitive tasks; (2) Musicians had increased activation in areas implicated in attention and cognitive control, especially in right hemisphere; (3) Relationship between task performance and magnitude of response more positive in musicians
Perry et al. (1999)	PET scan investigating neural activation patterns associated with singing	13	Nonmusicians	Music listening (recorded), Singing	Not specified	ACC	(1) Reported on a complex, distributed network of cortical activation patterns during singing production; (2) Simple, chant-like singing activates similar networks as speech with some hemispheric differences in motor and auditory regions
Ruiz et al. (2009)	EEG study exploring neural correlates associated with executive control during piano playing	19	Musicians	Instrument Play	Not specified	ACC	(1) Error monitoring networks, generated by ACC, processes errors 70 ms prior to them; (2) Reported on different contributions of auditory and somatosensory information to error monitoring; (3) Auditory information modulated error processing post-execution

Table 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Satoh et al. (2001)	PET scan investigating differences musical mode has on neural activation patterns	9	Musicians	Music listening (recorded)	Harmony	OFC	(1) Attending to melodic line recruited areas related to selective attention and tonal-verbal associations (e.g., OFC); (2) Attending to harmony activated regions related to emotional processing and memory
Suda et al. (2008)	OT system study exploring effect of Mozart's music on spatial-reasoning ability	10	Not specified	Music listening (recorded)	Not specified	dlPFC	Exposure to Mozart's music enhanced performance on intelligence tests and revealed different activation patterns in areas implicated in spatial-temporal reasoning (e.g., dlPFC)
Thaut et al. (2009)	PET scan exploring activation patterns associated with rhythmic auditory motor synchronization	9	Not specified	Music listening (recorded)	Rhythm	dlPFC	(1) Reported on structures involved in different aspects of motor synchronization; (2) Findings suggest distinct, functional cortico-cerebellar circuits serve different aspects of rhythmic synchronization, conscious and subconscious response to temporal structure, and conscious monitoring of rhythmic pattern tracking

TABLE 2
Continued

		Study characteristics				Outcomes	
Author	Description of study	*N*	Participant musical ability	Type of experience(s)	Music characteristic	Neural structure(s)	General findings
Vogt et al. (2007)	fMRI study exploring effect of practicing on neural activation patterns	32	Both musicians and nonmusicians	Instrument Play	Not specified	dlPFC	(1) Mirror neuron system more strongly activated during observation of non-practiced items; (2) Left dlPFC selectively involved during observation and motor prep of non-practiced chords
Zarate & Zatorre (2008)	fMRI study exploring differences in audio-vocal integration in musicians v. nonmusicians	24	Both musicians and nonmusicians	Singing	Pitch	ACC	(1) Singers more accurate than non-singers in singing (with same neural networks recruited), at ignoring shifting feedback (with different neural networks), and same at compensate task (with different neural networks); (2) Authors propose two neural substrates for audio-vocal integration
Zarate et al. (2010)	fMRI study investigating neural networks involved in voluntary v. involuntary pitch regulation	9	Musicians	Singing	Pitch	ACC	(1) Singers less able to ignore minor pitch-shift differences than more noticeable ones; (2) Compensate task recruited functionally-connected neural network, including ACC; (3) Larger vocal corrections appear to be under cortical control

TABLE 3
Summary of Main Findings and Clinical Considerations

Neural structure	Summary of findings	Clinical considerations
Amygdala	Activation: • occurred when listening to minor/dissonant/negative/unpleasant music, during an unexpected event, during music listening in general • could be modulated by a single chord change • increased when listening to music with eyes closed, when pairing music and visual stimuli Deactivation: • occurred during music improvisation, when listening to pleasant music Right amygdala: • was recruited during "sad" music, implicated in early responses to chord violations, exhibits chord-dependent responses • was activated more strongly during audiovisual condition • activity increased with exposure over time Left amygdala: • activity increased when listening to music with a higher negative valence Long-term habituation effect was noted	To facilitate ER: • listen to music the client considers pleasant or happy • incorporate music improvisation • refrain from having sudden and unexpected musical events (e.g., abrupt chord changes, sudden dynamic changes, etc.,) • consider the effect of pairing music with a visual stimulus • do not listen to music with eyes closed
Anterior Cingulate Cortex (ACC)	Activation: • occurred during voluntary pitch correction and music discrimination tasks • occurred when listening to chord violations, when listening to familiar/favorable/energetic music, during overt and imagined singing • occurred when listening to dissonant chords (musicians only) • increased during singing and music listening tasks • was more pronounced in musicians compared to nonmusicians • increased in those faced with a mismatch between individual and group opinion, is correlated with song likability	To facilitate ER: • listen to music client considers familiar and preferred • engage client in active music making, such as singing or music improvisation • engage client in attending to specific musical cues, such as phrases or melodic lines

Table 3
Continued

Neural structure	Summary of findings	Clinical considerations
	• may be mode-dependent, i.e., patterns change based on modes (results mixed) • showed different patterns when perceiving ascending and descending melodic contours than when processing musical phrase boundaries • increased in ventral ACC versus dorsal ACC during music listening Right ACC: • was activated during music improvisation task Left ACC • was activated during rhythm- and melody-based working memory tasks, when listening to favorable/energetic music • was activated more strongly for rhythm	
Orbitofrontal Cortex (OFC)	Activation: • occurred when attending to a single musical component (e.g., melody), detecting phrase boundaries, processing types of chords, responding to syntactical irregularities • occurred when music listening regardless of preference/valence (results mixed) • was stronger during music listening than speech listening • related to song likability, with increased activation for non-liked songs Right OFC: • activation negatively correlated with chord instability • activation increased compared to the left OFC when processing emotionally-salient music	To facilitate ER: • listen to music client considers familiar and preferred • engage client in attending to specific musical cues, such as phrases or melodic lines • choose music that uses stable chords, i.e., refrain from too much dissonance

TABLE 3
Continued

Neural structure	Summary of findings	Clinical considerations
Lateral Prefrontal Cortex (lPFC), including Dorsolateral Prefrontal Cortex (dlPFC) and Ventrolateral Prefrontal Cortex (vlPFC)	lPFC activation: • was stronger during a music-based working memory task and in response to negative music paired with visual stimuli • correlated with song likability dlPFC activation: • occurred when observing and preparing to play non-practiced chords, when listening to Mozart music, when listening to music with eyes open but not closed • increased when synchronizing to tempo changes during a motor-rhythm synchronization task • patterns mixed for music improvisation task (sometimes caused activation, sometimes deactivation), mixed based on musical training Right dlPFC: • activated during singing and music discrimination tasks Left dlPFC: • activated during music improvisation task vlPFC activation: • occurred when listening to musical triads, during imagined singing task • may occur when processing syntactical music violations	To facilitate ER: • listen to music client considers familiar and preferred • engage client in active music making, such as singing or music improvisation • engage client in attending to specific musical cues, in music-based working memory tasks, and in music-facilitated motor movement experiences • refrain from listening to music with eyes closed

Levitin, 2005; Nakamura et al., 1999) and it was more pronounced in musicians compared to nonmusicians (Pallesen et al., 2010; Zarate & Zatorre, 2008). ACC activation was correlated with overall song likability (Berns & Moore, 2012) and increased in individuals who disliked a song, yet were sensitive to the song's popularity; the researchers attributed this ACC activation to a mismatch between individual and societal opinion (Berns, Capra, Moore, & Noussair, 2010). Reports of activation patterns based on musical modes are mixed, with studies reporting increased activation when listening to happy music or music that elicits chills (Blood & Zatorre, 2001; Mitterschiffthaler et al., 2007), when listening to music in a minor mode as compared to a major mode (Green et al., 2008), or when listening to music in either a major or minor mode (Mizuno & Sugishita, 2007). Different activation patterns were reported when listeners perceived ascending and descending melodic contours (Lee, Janata, Frost, Hanke, & Granger, 2011) and when processing musical phrase boundaries (Knösche et al., 2005). In addition, the ACC was activated during both overt and imagined singing (Kleber, Birbaumer, Veit, Trevorrow, & Lotze, 2007) and during singing improvisation (Brown, Martinez, & Parsons, 2006). The left ACC was activated during rhythm- and melody-based working memory tasks, though more strongly for rhythm (Jerde, Childs, Handy, Nagode, & Pardo, 2011) and when listening to favorable or energetic music (Brown, Martinez, & Parsons, 2004), whereas the right ACC was activated during a free generation task (de Manzano & Ullén, 2012). Finally, there was increased activity in the ventral ACC when listening to music compared to the dorsal ACC (Green et al., 2008). To summarize, ACC activation occurred when listening to preferred music, when engaged in an active music-making experience, and when attending to specific characteristics of the music stimulus.

Orbitofrontal cortex (OFC). The OFC was activated when listening to preferred music (Menon & Levitin, 2005) and in a separate study was more strongly activated when listening to music as compared with listening to speech (Callan et al., 2006). OFC activation related to emotional valence were mixed, with studies reporting that listening to unpleasant or negative music activated the OFC (Flores-Gutiérrez et al., 2007) as well as listening to pleasant music (Blood & Zatorre, 2001). Several studies reported activation patterns related to attending to musical characteristics. The OFC was activated when attending to a single musical component, such as a melodic line (Satoh, Takeda, Nagata, Hatazawa, & Kuzuhara, 2001), when detecting phrase boundaries (Knösche et al., 2005), when processing types of chords (Fujisawa & Cook, 2011), and when responding to syntactical irregularities (James et al., 2008). OFC activation is reported to be related to song likability (Berns et al., 2010; Berns & Moore, 2012), with increased activation for nonliked songs (Berns & Moore, 2012). The right OFC may be implicated as a link between affective and cognitive neural systems that are engaged during music listening (Menon & Levitin, 2005). Its activation is negatively correlated with chord instability (e.g., dissonant chords) (Fujisawa & Cook, 2011) and it showed increased activation compared to the left OFC when processing emotionally-salient music (e.g., either unpleasant/negative music or pleasant music) (Blood & Zatorre, 2001; Flores-Gutiérrez et al., 2007). To summarize, OFC activation occurred when listening to preferred music, when listening to familiar music, and when attending to specific characteristics of the music stimulus.

Lateral prefrontal cortex (PFC). The majority of studies that reported on prefrontal cortex activity focused on either the dorsolateral prefrontal cortex (dlPFC) or the ventrolateral prefrontal cortex (vlPFC). Those that reported on the lateral PFC noted enhanced activity during a music-based working memory task (Pallesen et al., 2010), stronger activation in response to negative music paired with visual stimuli, but not without visual stimuli (Eldar et al., 2007), and activation that was correlated with song likability (Berns et al., 2010).

Dorsolateral prefrontal cortex (dlPFC). The dlPFC was activated during the observation and motor preparation of nonpracticed chords (Vogt et al., 2007), when listening to Mozart music (Suda, Morimoto, Obata, Koizumi, & Maki, 2008), and when listening to music with eyes open, but not closed (Lerner et al., 2009). Increased activation was noted when synchronizing to tempo changes during a motor-rhythm synchronization task (Thaut et al., 2009) and mixed results were reported when exploring dlPFC activation during a music improvisation task, which either caused activation of the dlPFC (Bengtsson, Csíkszentmihályi, & Ullén, 2007) or deactivation (Limb & Braun, 2008). The impact of music training on dlPFC activation also had mixed results, with one study noting that musicians had stronger dlPFC activation (Ohnisi et al., 2001) and another reporting that college-aged music majors had stronger dlPFC activation than laypersons, but not professional musicians (Kleber, Veit, Birbaumer, Gruzelier, & Lotze, 2010). The right dlPFC was activated during singing (Jeffries, Fritz, & Braun, 2003), and during music discrimination tasks (Brown & Martinez, 2007; Hugdahl et al., 1999). The left dlPFC was activated during a free generation task, i.e., a music improvisation task (de Manzano & Ullén, 2012).

Ventrolateral prefrontal cortex (vlPFC). The vlPFC was activated when listening to musical triads (Mutshuler et al., 2010) and it may be implicated in processing syntactical violations in music (Janata, 2009). In addition, vlPFC activation occurred during an imagined singing task, but not when overtly singing, perhaps reflecting its role in emotional recall (Kleber et al., 2007).

To summarize, lateral PFC activation occurred when listening to preferred or familiar music, when engaged in an active music-making experience, and when attending to specific characteristics of the music stimulus.

Discussion

The purpose of this exploratory review was to examine the effects of music on neural structures implicated in emotion regulation and to create preliminary clinical considerations based on this synthesis. Although the impact of music on emotion processing has long been of interest, this is the first attempt to systematically review and synthesize research specifically investigating the neural effect of music on emotion regulation. Results indicated that there are certain musical characteristics and experiences that produce desired neural activation patterns implicated in emotion regulation. From a clinical perspective, understanding this link between musical elements and the target goal—in this case, emotion regulation—helps the music therapist make informed decisions about the Therapeutic Function of Music (TFM). Hanson-Abromeit (2013) defines the TFM as “the direct relationship between the treatment goal and the explicit characteristics of the musical elements, informed by a theoretical framework and/or philosophical paradigm in the context of a client” (p. 130). In other words, having an explicit understanding of why and how music affects a desired change informs the intentional, therapeutic use of music in clinical practice. For the purposes of this study, it involves having an explicit understanding of what musical characteristics and experiences impact a person's ability to regulate his or her emotions and how.

Emotion regulation is characterized by increased activation in the cognitive control and monitoring areas—the anterior cingulate cortex (ACC), orbitofrontal cortex (OFC), and lateral prefrontal cortex (PFC)—which leads to decreased activation of the amygdala (Gyurak et al., 2011; Ochsner & Gross, 2005; McRae et al., 2010; Rempel-Clower, 2007). Overall, results indicated that there are certain music characteristics and music experiences that produce such activation patterns. For example, listening to music considered pleasant or happy activated the ACC (Blood & Zatorre, 2001; Brown et al., 2004; Mitterschiffthaler et al., 2007), the OFC (Berns & Moore, 2012; Berns et al., 2010; Berns & Moore, 2012; Blood & Zatorre, 2001; Flores-Gutiérrez et al., 2007), and decreased activation in the amygdala (Blood & Zatorre, 2001; Koelsch et al., 2006). Similar activation patterns were found when listening to music, regardless of emotional meaning for the listener (Callan et al., 2006; Menon & Levitin, 2005; Mizuno & Sugishita, 2007; Nakamura et al., 1999) and when singing (Kleber et al., 2007; Perry et al., 1999). These patterns were also reported when musically-trained individuals were improvising (Bengtsson et al., 2007; Brown et al., 2006; Limb & Braun, 2008). It should be noted, though, that one study reported deactivation in the dlPFC during improvisation, which the authors attributed to its role in providing a framework for goal-directed behaviors, a role not needed when improvising (Limb & Braun, 2008). Although it is premature to make direct clinically-based generalizations until future research is conducted, these results provide preliminary evidence supporting the use of music listening, singing, and improvisation to facilitate emotion regulation.

In addition to desired neural activation patterns for emotion regulation, there can also be undesired activation patterns. Results of this review indicated certain musical characteristics and experiences that produced increased activation patterns in the amygdala, namely listening to music that was minor, dissonant, negative, or unpleasant (Koelsch et al., 2006; Lerner et al., 2009; Mitterschiffthaler et al., 2007; Pallesen et al., 2005) and changing chords (Pallesen et al., 2009), especially in an unexpected way, as with chord violations (James et al., 2008; Koelsch et al., 2008). In addition, listening to music with eyes closed increased the amygdala's activity (Lerner et al., 2009) as did providing a more complex sensory stimulus by pairing music with a visual stimulus (Baumgartner et al., 2006; Dyck et al., 2011; Eldar et al., 2007). A primary function of the amygdala is to assess emotionally-salient sensory information. If the sensory information is determined to be unthreatening, amygdala activity decreases. The findings from this review are congruent with this primary function, as they indicate that the amygdala is processing and assessing music stimuli that is new, (e.g., chord changes), unexpected (e.g., chord violations), or complex (e.g., simultaneous aural and visual input). Thus from a clinical perspective, research also indicates characteristics of music and music experiences that should be avoided when trying to help a person regulate and shift his or her physiological and emotional state. Based on this review, these include avoiding music that is minor, dissonant, or considered unpleasant, as well as avoiding unexpected musical events (e.g., sudden dynamic changes), frequent chord changes, and listening to music with eyes closed. It should be noted that this process implies musically-facilitating a shift to a comfortable state of arousal, back to homeostasis. There may be times when it is clinically indicated to maintain or increase amygdala activation, thus maintaining or intensifying the emotional experience. This may involve the incorporation of music and music experiences that are considered unpleasant, with frequent chord changes and unexpected musical events. Future research and systematic reviews are recommended to explore and address this phenomenon.

The roles of the cognitive control and monitoring areas are more complex than that of the amygdala; therefore, their activation patterns associated with music characteristics and experiences are less straightforward. Results indicated that, for the most part, all the music experiences produced diffuse activation in those three areas. However, unlike findings related to amygdala functioning, they provided no indication of the types of music and experiences to use or avoid when facilitating emotion regulation. One possible explanation for this lack of clarity is that those structures are implicated in other tasks. For example, the ACC is thought to be involved in processing uncertainty and conflict (Brown & Martinez, 2007; Mizuno &

Sugishita, 2007; Pallesen et al., 2010), error monitoring (Ruiz et al., 2009), and response inhibition and selection (de Manzano & Ullén, 2012). Given that music is a complex stimulus, it can be hypothesized that once it has been determined that the music stimulus is not a threat—i.e., the emotion-processing aspect that results in decreasing amygdala activity—these neural structures attend to processing other aspects of the music stimulus.

Another possible explanation relates to their involvement in another emotion regulation-related process, attention. More specifically, this refers to their possible involvement in processing music-influenced changes in attention that facilitate emotion regulation. As indicated previously, a common process involved in emotion regulation is the use of strategies that can create a new emotional response or change a current one (Gyurak et al., 2011; McRae et al., 2010; Ochsner & Gross, 2005). Successful strategies either change how we interpret the meaning of a situation or alter how we attend to a situation (McRae et al., 2010). All three cognitive control areas explored in this review are thought to be implicated in networks involved in attention, a role reflected in the results of several studies included in this review (de Manzano & Ullén, 2012; Jerde et al., 2011; Knösche et al., 2005; Satoh et al., 2001). One common denominator in those studies was that the participants were instructed to focus on a specific cognitive task related to the music stimulus, such as processing the melodic phrase structure (Knösche et al., 2005) or attending to the melodic line and harmonic changes (Satoh et al., 2001). In other words, the participants were instructed to attend to the music stimulus in a different, more analytical way. From a clinical standpoint, one emotion regulation strategy these results suggest is to instruct the client to attend to a specific characteristic of the music (e.g., the melodic line, a musical cue, etc.), thus removing their focus from the emotional event. This strategy is analogous to using music to reduce pain perception, a common phenomenon reported in the medical literature (Fratianne et al., 2001; Tan, Yowler, Super, & Fratianne, 2010), and supports the use of effortful, explicit strategies when facilitating emotion regulation (Gyurak et al., 2011).

Limitations

One major limitation of this review is the lack of intervention reporting in the included studies, specifically that related to the music stimulus used. There has been a call in the literature to include clear and detailed explanations of the interventions used and why that intervention was selected (Robb, Burns, & Carpenter, 2011). However, many of the studies included in this review were not specific as to the type of music used, the names of musical pieces, the structure and characteristics of the music stimulus, whether the music was original or improvised, or the instrument(s) that were used. This lack of explicit intervention reporting is problematic for two reasons. One, it makes it difficult to understand the mechanisms underlying the neural activations, thus decreasing the reliability of the results. In other words, it makes it difficult to explore and understand what characteristics of the music stimulus are responsible for the desired activation patterns. Two, without a clear understanding of the music stimulus used, it is difficult to replicate the stimulus in future studies, as well as in clinical practice.

There are other limitations in this review that affect the generalizability of the findings. First, as the inclusion criteria stipulated that study participants be typically-developing humans, studies included in this review reflect a nonclinical population and findings may not easily generalize to clinical populations. Second, the majority of the studies utilized Western music as the stimulus (Table 1), making it unclear how these findings might generalize from a multicultural perspective. As such, the results and clinical implications of this review should be considered preliminary and should be interpreted with caution. Future research can explore the effect music has on emotion regulation in clinical populations and through a multicultural perspective. Furthermore, clearer intervention reporting is needed in future research to inform the translation of research to clinical practice.

Conclusions

This systematic review indicates that music experiences may have an impact on emotion regulation. Furthermore, the results provide preliminary guidelines for music characteristics and specific strategies that might assist in the emotion regulation process when using music as an intervention strategy. These guidelines include using music considered happy and pleasant, with predictable, consonant harmonies. In addition, the music therapy clinician should be aware of multimodal implications, such as asking a client to close his or her eyes or pairing music with a visual stimuli, as these might heighten the emotional response. Music listening, singing, and improvisation may assist in facilitating emotion regulation, as might instructing the client to attend to another task related to the music stimulus, such as focusing on noticing harmonic changes. As noted, these are preliminary guidelines and more research is needed. Future research can further explore the Therapeutic Function of Music, teasing apart the different elements of music (e.g., pitch, rhythm, harmony, melody, etc.) and studying their role, if any, on emotion regulation (Hanson-Abromeit, in press). Following that, clinical studies are needed to move this exploration from the theoretical realm to functional, clinical use. This review provides preliminary support for the use of music to facilitate emotion regulation, but studies are also needed to explore the clinical efficacy of music interventions on emotion regulation.

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