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The Experience of Music Perception: A Review of Physiological, Neural, and Psychological Responses

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ABSTRACT

Music allows artists to express and connect themselves with broad and diverse audiences. Certain musical choices can greatly impact the amount of influence the artists' message has on an audience. To best share messages through a musical work, it can be beneficial for an artist to understand the biological processes with which the audience may experience the perception of music. The physiological, psychological, and neural responses represent the bodily effects of music and are thus informative to study in relation to the individual experience of a musical work on an individual. This paper will review the biological view of music and create a narrative to show how physiology, psychology, and neurology can be applied to influence a social or individual atmosphere toward an artist's desired message. After synthesizing the biological effects of musical feature changes (such as tempo, rhythm, volume, pleasantness, structure, music type, emotions, and audience type) this paper will make three conclusions relating to the intersection of physiology, neurology, and psychology. First, the ability to prefer or expect a musical change or feature can have a large emotional impact. Second, the arguably most important musical emotion of empathy can likely be created through rhythmic features of tempo and synchronization. Third, peak musical experiences are emotionally arousing and largely influenced by musical structure and audience setting.

Introduction

Music is a form of influential artistic expression and connection. A multitude of research in the 20th century and earlier has focused on a sociocultural view of music, exploring how music can be a powerful societal influence (see e.g., Honigsheim, 1989; Merriam, 1955; Siegmeister, 1938). Indeed, throughout history, music has been used to cultivate connections among groups and to express different ideas and emotions (see e.g. Hayes, 2005; Wilson, 2013). While people can express themselves in many ways, music in particular has been shown to have numerous positive benefits influencing key aspects of health, such as stress relief and mood regulation (MacDonald, 2013). Further, music increases our social wellbeing by stimulating our thoughts and emotions to help us connect with others (Wilson, 2013). Aside from connecting with broad and diverse audiences, participating in music creation can be extremely beneficial. Choral singers have been shown to receive many additional psychological benefits when performing for the general public (Judd, 2014). Similarly, older individuals belonging to musical groups were able to connect with their peers and community on a more emotional level, allowing for additional social, emotional, and cognitive benefits across their lifespan (Hallam, 2012). This is of particular importance given how much loneliness pervades old age (Pinquart & Sorensen, 2001). Studying music allows us to understand and encourage these benefits for broader groups of people.

The impact music has on individuals is not limited to performers/artists (used as a blanket term for composer, songwriter, melodist, etc.). Viewing a musical work brings about different effects within the body, with many biological features (e.g. skin conductance: Richard, 2004; heart rate: Dainow, 1977; piloerection: Craig, 2005) relating to the connectivity/understanding audience members may have toward the intended message of the performer/artist.

Oftentimes the placement of music in a larger artistic work - or the changes of musical beats, tempo, volume, etc… - can greatly affect the physiological, neural, and psychological impact on an audience member (e.g. Bhoria, 2012; Dillmon, 2007). Larger works involving an array of musical selections can include anything from a theatrical musical, a classical opera, any type of dance routine, a symphony, a musical ballad from a pop singer, or as simple as a playlist arranging music in a specific order.

All of these types of works are examples of opportunities for making various artistic choices. Features related to the creation of music can greatly impact the amount of influence the artists' message has on an audience. Artists make hundreds of complex artistic decisions in creating their work. While the methods by which artists choose the order and/or the content of their music will not be discussed in this paper, the effects of such musical choices will be reviewed (e.g. altering tempo, volume, style, biological and physiological responses to music). Often, the effect an artist has on an audience is very much implicit within the created work itself. An artist may inadvertently exploit the biological effects of music to make the audience feel sad at a certain moment.

To best share messages through a musical work, it can be beneficial for an artist to understand the biological processes with which the audience may experience the perception of music. These biological reactions to music represent the internal bodily effects of music, and thus are necessary to study in relation to the individual experience of a musical work on an individual. Taken together, these biological reactions represent the influence music has on an audience. Recently, new technology has allowed for more of a biological/neural assessment of music's influence (e.g. Bigliassi et al., 2019; Nieminen et al., 2011; Peretz, 2006). This paper will summarize the biological view of music and create a narrative to show how biological factors of physiology, neurology, and psychology can be applied to influence a social or individual atmosphere toward an artist's desired message.

Physiological Responses to Music

The first area of biological responses that will be reviewed in this paper are physiological reactions to music. Responses to a stimulus are often accompanied by automatic neural and physical bodily responses (Craig, 2005). These responses can range anywhere from perspiration, to change in heart rate, to eye pupil dilation, with many recent research studies focusing on using these physiological responses to better quantify the impact that music has on its listeners (e.g. Craig, 2005; Dainow, 1977; Richard, 2004). Some physiological responses are easier to measure, and therefore used more frequently when demonstrating bodily impact. Namely, skin conductance, because of its connection to emotion, attention and stress, is an often-used indirect measure of sympathetic autonomic activity (e.g. Khalfa et al., 2002). The physiological responses of chills, heartbeat, and skin conductance are reviewed next as demonstrated through music.

Chills

A response many audience members feel when listening to music is the experience of 'goosebumps' or 'chills'. The subjective feeling of chills of music listeners has been shown to be associated with the piloerection (standing hairs on skin) and the galvanic skin response (electrical resistance of skin) (Craig, 2005). The perception of chills, as described through self-report in response to musical stimuli, is helpful for the study of emotional responses to music alongside their relationship with physiological skin responses.

Bannister and Erola (2021) further categorized chills into their emotional associations with music. 'Vigilance chills' are accompanied by feelings of awe and characterized by increased tonic skin conductance levels and decreased skin temperature, while 'social chills' are linked to experiences of being 'moved' and characterized by less pronounced increases in skin conductance and skin temperature (Bannister & Erola, 2021). These two types of chills can be predictably elicited through stimulus manipulations that emphasize either structural or social aspects of music. Regardless

of the type of chill sensation, an artist is able to trigger what individuals associate as a 'chill' and the different physiological reactions that accompany it. When musical stimulus is paired with extra-musical information (information provided before listening) or visual accompaniment emphasizing structural developments in the music, emotional experiences are more strongly characterized as 'awe', whereas information or visual accompaniment emphasizing narrative and social components results in stronger states of being 'moved' (Bannister & Erola, 2021). So, an artist is able to create either of the two 'chill' effects through different methods depending on the structural or social elements of the musical work they want to emphasize. How the information or visual accompaniment surrounding music can affect the physiological responses of an audience member, and therefore, influence the social atmosphere that an artist can use to point an audience toward a desired feeling is an important development.

The context in which an audience member is listening or watching music has an influence on the physiological response of chills as well. In a study where participants in a social setting pressed a button every time they experienced chills when listening to music, it was found that chills were reported more when listening alone than in a group (Egermann et al., 2011). This finding was theorized to be caused by one of four possible reasons: lack of social feedback, possibility of social loafing, evolutionary function of chills, and a lack of concentration in the group setting (Egermann et al., 2011). The study identified the role of attention as being the most important factor. This may be interpreted as it being harder to experience chills socially in a larger audience due to less individualized concentration on the music. Thus, in these social conditions, it may be useful for artists to draw in the attention of the audience directly before a large musical shift to achieve the most impactful chills.

Heartbeat and Respiration

Beyond the physiological responses seen in chills, listening to music can affect other common bodily responses like heart and respiration rate (e.g. Dainow, 1977; Koelsch & Jäncke, 2015). Heart rate and respiration rates are seen as some of the most connected body responses with musical pulse, possibly due to their essential function as rate-controlling constants of the brain (Dainow, 1977; McLaughin, 1970). Early research on heart rate is somewhat inconclusive as to whether or not stimulative music causes an increase in heart rate and sedative music causes a decrease in heart rate, or if any music causes an increase in heart rate (Dainow, 1977). However, modern research has found that both heart rate and respiratory rate are higher in response to exciting music compared with tranquilizing music (Koelsch & Jancke, 2015). Similarly, heart and respiration rate have been found to be higher during pleasant than unpleasant sounding music (Koelsch & Jancke, 2015). These findings on two basic functions of the human body in relation to musical activity represent how fundamental aspects of the human body can be altered by a change in musical tempo or musical pleasantness.

Skin Conductance

A highly studied physiological response, skin conductance, offers researchers an easy way to measure emotional state, arousal, and stress (e.g. Storm et al., 2002). Skin conductance is therefore an excellent measure for bodily responses to music (e.g., Khalfa et al., 2002). In fact, music can be seen as an auditory structural feature because the sympathetic nervous system, as shown from skin conductance, is activated when compared with silence (Carpentier & Potter, 2007). As explained earlier, as the tempo of a song increases, the sympathetic nervous system (e.g. heart rate and respiration rate) increases as well. Additionally, Carpentier and Potter (2007) use skin conductance to point out an important distinction between different types of music. They found that as rock and roll music increases tempo, skin conductance decreases, and as classical music increases tempo, skin conductance increases (Carpentier & Potter, 2007). The distinction between tempo increases in different types of music brings up important ways in which an artist can alter the physiological effects of music based on which type of music is being played.

Skin conductance has allowed some theorists to posit evidence for the emotivist thesis, which suggests that emotional responses to music are of the same nature as emotions elicited by non-aesthetic stimuli (Lundqvist et al.,

2009; Richard, 2002). Skin conductance was shown to be more significantly increased by an emotionally powerful piece of music than an emotionally powerful film scene - consistent with participants' subjective rating of each as the music having significantly greater emotional impact than the film scene. (Richard, 2002).

Supporting the emotivist thesis is very important for the research of emotion from music because it demonstrates that the physiological effects are increasing as the participants are reporting their emotions increasing, showing that the emotions are internalized on a bodily- response level. Humans may not just be recognizing the emotional intention of the artist, but also perceiving those emotions directly within the body (Lundqvist et al., 2009), given the study of physiological effects of music, most prominently that of skin conductance.

Skin Temperature

Similar to skin conductance, skin temperature has also been shown to relate to musical emotions, although it is a less frequently studied physiological metric (Pérez-Guarner et al., 2019). Music judged by subjects to produce arousing, negative emotions terminated temperature increases and perpetuated temperature decreases, whereas music judged to produce calm, positive emotions terminated temperature decreases and perpetuated temperature increases (McFarland, 1985), suggesting possible links between emotional perceptions of music and skin temperature fluctuations.

However, recent evidence suggests skin temperature might not be an accurate method for differentiating between negative emotions broadly, including physiological stress (Pérez-Guarner et al., 2019). While emotional responses will be discussed later in the psychological section of this paper, it is important to note here that skin temperature, although not widely used, is still a physiological response to music. This measure may not be robust or consistently used to assess emotionality and music, but may be useful to consider in further research, possibly alongside skin conductance, in order to better understand what may be validly assessed with skin temperature.

Summary

All the physiological elements combined create a better picture of the bodily effects of music as a whole. As described above, different changes in musical emotion, musical tempo, musical type, musical pleasantness, musical structure, all have an effect on the body (Carpentier & Potter, 2007; Craig, 2005; Dainow, 1977; Khalfa et al., 2002; McFarland, 1985). Although they are all related, different physiological responses are generally used to study different types of changes in music (e.g., Bannister & Erola, 2021; Carpentier & Potter, 2007).

Skin conductance and skin temperature are generally used to prove the perception of emotion and how emotional changes in music can affect temperature fluctuations (Khalfa et al., 2002; Rickard, 2002; Storm et al., 2002). The relationship between emotion and physiology will be discussed more in depth later.

When paired with heart rate and respiration rate, skin conductance can be used to show the significant effects of tempo on the body (Dainow, 1977; McLaughin, 1970; Khalfa et al., 2002). Stimulative music generally causes an increase in heart rate and respiration rate while sedative music causes a decrease in heart rate and respiration rate (Koelsch & Jancke, 2015), but if rock and roll music tempo increases, skin conductance decreases whereas when classical music increases tempo, skin conductance increases (Carpentier & Potter, 2007). In addition to the type of music, musical pleasantness can increase or decrease these physiological features (Koelsch & Jancke, 2015).

The structure of music can also affect bodily reactions through the experience of chills, made up of the galvanic skin response and piloerection (Craig, 2005). Chills have two distinct ways to be triggered depending on whether a musical work is paired with (i) information or visual accompaniment emphasizing structural developments in the music or (ii) information or visual accompaniment emphasizing narrative and social components in the music (Bannister & Erola, 2021). Chills are generally experienced in the same place in a musical work (Craig, 2005; Madsen et al., 1993), but can be affected by the context within which a musical piece is listened. If the musical work is consumed in a group setting, the artist may seek to draw in the attention of the audience before emphasizing any structural

elements of the piece due to a possible lack of concentration in a group setting that can diminish the experience of chills (Egermann et al., 2011).

The combination of musical structure, musical emotion, musical tempo, musical type, and musical pleasantness are all important factors that can influence an audience member's physical reaction to a musical work, and thus, affect an artist's attempt to highlight a desired message.

Neural Responses to Music

Another area of biological interest in response to music takes the form of neural research. The nervous system in the brain can be used to expose another layer of the body's physical response (e.g. Badenoch, 2022; Bigliassi, 2019; Morgan et al., 2015). Electroencephalography (EEG) recordings are normally used to record changes in temporal brain waves in relation to the body's current state (e.g. Biasiucci et al., 2019; Klass & Brenner, 1995; Petersén & Eeg-Olofsson,1971). An EEG can be very useful in examining the changing neural activity in the temporal lobes. Its ability to measure indirect responses with great precision in ways people cannot directly self-report allows for the creation of very beneficial associations between neural waves and music responses.

Generally, the main brain waves studied in this field are alpha and beta waves (e.g. Bohria, 2012; Bigliassi, 2019; Hurless, 2013). Alpha waves are associated with more calm or relaxed thoughts, while beta waves are more commonly associated with active thinking or more focused concentration (Baumeister et al., 2008; Bhoria et al., 2012). Each wave can independently explore information about an individual. For example, in a study (conducted by Bigliassi et al., 2019) attempting to show that music has positive psychological effects during physical activity, a portable EEG was used to record beta waves in the frontal-central areas of the brain. An up-regulation of high-frequency beta waves were assessed when participants engaged in physical activities and listening to music, as compared to listening to a podcast more passively. So, because an increase in beta waves is linked with more dissociative thoughts, the participants could shift their focus from the exercise by dissociating with the music (Bigliassi et al., 2019).

Music Preference

Alpha and beta waves detected by an EEG in the frontal hemisphere of the brain also have been posited to contain sufficient information to discriminate an individual's preference of music (Pan et al., 2013). A study conducted by Hurless et al. (2013) concluded that listening to a preferred genre of music produces greater alpha wave amplitudes than listening to an unpreferred genre (Hurless et al., 2013). This was hypothesized as related to the function of alpha waves (Hurless et al., 2013). When participants listened to their preferred genre, they are more likely to be relaxed and therefore apply less attention while listening, resulting in increased alpha wave amplitude (Hurless et al., 2013). Recently, because of this stress relief function, an EEG feedback system was designed, proposed by Chang et al., (2017) that can recommend preferred music to obtain music stress relief from those with high stress (Chang et al., 2017). This design not only presents real-world applications of genre preference of music because of its stress-relieving capabilities, but also demonstrates how an artist can utilize the genre preference of an audience to create relieving situations in their musical work.

Tempo and Volume Changes

In addition to genre preference, neural waves can also reflect tempo and volume changes of a musical work (Bhoria et al., 2012; Hurless et al., 2013). Artificially modified tempo of preselected songs affects beta wave activation, the amplitude of which tends to increase with tempo (Hurless et al., 2013). It can be reasonable to assume that more upbeat music would relate to increases in neural arousal due to the association of beta waves with wakefulness. Similarly, beta wave activation was related to identification of disturbed states (unrelaxed and anxious) caused by volume

changes (Bhoria et al., 2012). Low power of beta waves obtained during music with lower volume indicated a relaxed state; whereas higher volume (e.g., 100 decibels or greater) caused beta wave power to increase, indicating a disturbed and tense situation (Bhoria et al., 2012).

It is important to note that there are limited findings on neural relation to volume preference and should be studied more to determine whether having greater tolerance for loud volume has an effect on the amplitude of brain waves. Both tempo and volume changes have an effect on the biological function of the brain (Bhoria et al., 2012; Hurless et al., 2013) and therefore the state of mind of the audience. It is important for an artist to take these into consideration when making dramatic tempo and volume changes in a musical work.

Summary

The neurological responses to music are generally studied using an EEG to report on the changes in alpha and beta brain waves in relationship to musical tempo, musical volume, and musical preference (e.g. Bohria, 2012; Bigliassi, 2019; Hurless, 2013). Alpha waves are associated with more calm or relaxed thoughts and studied with music in relation to stress responses; Beta waves are associated with active thinking or more focused concentration and studied with music in relation to a shift in focus (Baumeister et al., 2008; Bhoria et al., 2012).

As musical tempo is increased, heightened beta wave activity has shown a neural arousal resulting in wakefulness (Bhoria et al., 2012; Hurless et al., 2013). As musical volume is increased, heightened beta wave activity has been used to indicate a distributed and tense situation (Bhoria et al., 2012). So, both tempo and volume changes can result in a more anxious or relaxed audience member.

Musical preference has been associated with an increase in alpha waves due to the stress reduction of listening to preferred music (Hurless et al., 2013). So, an artist can utilize the genre preference of an audience to create relieving situations in their musical work. Although in a group it would likely be difficult to assume an entire audience's musical preference, an artist may be able to utilize this finding by altering the type of music in a work, then shifting back to the original style to create a sense of relief for the audience.

Brain waves, through their relationship with musical tempo, volume, and preference, can be utilized by an artist to alter the state of an audience member toward a desired message.

In the same way that neuroscientific research can be used to predict genre, tempo, and volume, it can also be used to effectively 'pre-determine' the emotion of an individual (e.g. Juslin, 2001; Koelsch, 2005). In fact, neural findings have located neural regions that heavily involve emotion including the involvement of limbic and paralimbic cerebral structures (e.g., amygdala, hippocampus) during the processing of music with either pleasant or unpleasant emotional valence (Koelsch, 2005). Given the vast amount of research on music emotion, these sources will be further discussed in the following section on psychological responses to music.

Psychological Responses to Music

The final area of possible biological effects from music reviewed here is psychological responses. There are many types of psychological responses that can influence an individual (e.g. Clarke et al., 2015; Lundqvist et al., 2009; Madsen et al., 1993), but to maintain focus of the paper, I will review specific aspects including the effect music has on (i) empathy, (ii) aesthetic experiences, and (iii) emotion in general. Several of these psychological effects, particularly emotion because of its great influence on perception (Barrett et al., 2007; Cacioppo & Gardner, 1999), include the use of physiological or neural research to support its conclusions. So, although this section will focus on the psychological effects, neural relationships and bodily effects will be referenced to better understand the holistic picture of musical experiences and audience responses.

Empathy

Empathy development is a highly studied psychological phenomenon (Duan & Hill, 1996) and is generally defined as the ability to understand another person's personal experience by placing oneself emotionally in another's mindset (Hietolahti-Ansten & Kalliopuska, 1990). In this paper, empathy will be viewed as an interpersonal process that can be developed and inherited over a lifetime or throughout a specific event (such as listening to a musical work) (Duan & Hill, 1996) measured, for the most part, through self-reports (e.g. Batson, 1987; Hogan, 1969; Miu & Balteş, 2012).

Empathy has been shown to be increased by an active interest in music in both children (Hietolahti-Ansten & Kalliopuska, 1990) and adults (Clarke et al., 2015; Parsons et al., 2014). For children, the ability to be receptive to impressions at a young age, like the ability to be receptive to others' feeling as in empathy, has been shown to increase self-esteem and improve inner self-control (Hietolahti-Ansten & Kalliopuska, 1990). A study on adult sensitivity to infant distress found that parents with musical training had a much greater ability to empathize with their child (Parsons et al., 2014).

Empathy can be cultivated from almost all types of music (Clarke et al., 2015) and has enormous benefits for the understanding of another group or ideology (Cikara et al., 2011). Because empathy can help people relate to others ideas, it can have a great indirect benefit when relating to experiences portrayed in music. Listening to music, even in very passive circumstances, can promote positive unconscious attitudes towards individuals originating from different cultural backgrounds (Clarke et al., 2015). So, an artist can use empathy to more readily facilitate an audience's understanding of an idea or message illustrated in a musical work.

There are many features in music that may lead to enhanced empathy, including but not limited to the synchronization or entrainment of musical events (Clarke et al. citing Jones & Boltz, 1989), mimetic resonance by interpreting music in more broadly animated ways through mirror neurons, and the stylistic familiarity with the music (Clarke et al., 2015). Mirror neurons have shown to be related to both theory of mind (the ability to understand and take into account another individual's mental state) and to the motor response of music (Gallese and Goldman, 1998; Iacoboni et al., 2005), further explaining the relationship between an individual's empathetic understanding and their physiological motor responses. Since both empathy and physiology seem to be related to mirror neurons, it becomes even more crucial that those are stimulated in a musical work that wishes to fully engage its audience. The mimetic resonance of a song (or the ability to reproduce reality in a song) can be highly utilized to stimulate such mirror neurons and thus cultivate empathy.

Synchronization may be considered a pathway for music to increase empathy given how a music performer must align with another to adjust and coordinate with the pulse of a song (Rabinowitch, 2015). This may possibly reinforce a capacity and willingness to adapt to another person's emotional situation, and to thus experience empathy towards that person (Rabinowitch, 2015). An audience member may feel these same effects depending upon their participation and engagement with the music creation. Affecting certain features of a musical work, such as the synchronization of musical pulses, can have a significant impact on the amount an audience member can sympathize with the desired message of a musical work.

It is also important to note that those who are considered 'empathizers' generally differ in music taste with so-called 'systemizers', or individuals who are responsive to the underlying parts and organization of the music rather than emotional sensitivity (Miu & Balteş, 2012). Systemizers generally prefer energetic, forceful, and thrilling music, whereas the most appealing music to empathizers tends to be that of emotional, deep, reflective, and gentle music (Rabinowitch, 2015). This is consistent with the connectivity associated with reflective music compared with that of thrilling music. In one study, participants listening to sad music in a high-empathy condition (where they were instructed to imagine as vividly as possible how the performer feels about what is described in the music and try to internalize those emotions) experienced nostalgic emotions and decreased skin conductance levels, while participants listening to happy songs in a high-empathy condition experienced emotions related to feeling powerful, as well as increased respiration rate (Miu & Balteş, 2012). Emotions related to nostalgia and power also can be very influential to an audience member. If an artist is able to influence the tendency for audience members to empathize, then they

could potentially influence their emotional reactions as well. This study also demonstrated how an individual's empathy may affect physiological bodily reactions such as skin conductance and respiration (Miu & Balteş, 2012).

It is also interesting to note that empathizers demonstrated a high correlation of enjoyment with negative emotions in music (Garrido & Schubert, 2011). This is consistent with the imaginative flexibility that music empathizers may possess, and could be further utilized to create engagement with different musical emotions. Empathy is a unique category of psychological responses to music because of its connection to both emotional and cultural understanding. Altogether this evidence suggests empathy has a large capacity to promote important and interconnecting messages through a musical piece.

Aesthetic Experiences

Another type of psychological experience that relates to artistic expression is musical aesthetic responses, or the ability to consider the aesthetic creation, performance, composition or meanings of music broadly. Considering the aesthetics of music is a complex philosophical and psychological discussion (e.g., Kealy, 1982), but for the purposes of this paper, I consider music aesthetics to relate to the psychological notion of evoked power and a sense of feeling moved which could potentially be measured through a physiological proxy such as chills, or goosebumps (Madsen et al., 1993).

Considering the prior discussion on reviews of musical experiences and chills, it is important to note that an audience member typically spends several minutes in high concentration preceding this peak experience that produces chills, which can be disrupted by a competing overt experience such as talking (Madsen et al., 1993). Comparing the notion of aesthetic experiences to chills brings about certain similarities, such as how individualistic it is to perceive the 'beauty' or 'feeling of being moved' by an artistic piece. Both aesthetics and physiological experiences of chills are personal, yet also tend to be felt collectively at similar points of a musical work (Madsen et al., 1993). However, I express caution in labeling physiological chills as purely aesthetic experiences.

Aesthetic experiences have also been examined with novel neuroscience approaches (e.g. Nieminen et al., 2011; Brattico & Varankaitė, 2019). A study by Brattico & Varankaitė (2019) suggests that aesthetic experiences are correlated with brain activity distinct from that of basic 'happy' or 'sad' emotions (Brattico & Varankaitė, 2019). An fMRI showed that the cortical temporofrontal structures activated in response to the perception of sadness or happiness in music, whereas deep subcortical centres governing arousal and the autonomic nervous system activated in response to aesthetic evaluation (Brattico & Varankaitė, 2019). This unique interplay of neural regions in recognizing, reflecting, and labeling aesthetic qualities of music help clarify why both happy and sad music can elicit a positive aesthetic response.

Further, certain neural preferences for music perception skills in subcortical areas of the brain appear to develop at a young age, forming a basis for more culture-specific learning and aesthetic understanding later in life (Nieminen et al., 2011). This may imply certain features of aesthetic experiences are presumably universal, such as the human tendency to move in synchrony with a musical beat (Nieminen et al., 2011) as discussed previously. Musical activities inducing these positive universal aesthetic responses, specifically through enjoyment and liking of the music, empower the individual by improving mood, cognitive functions, happiness and quality of life (Brattico & Varankaitė, 2019). So, an artist can create a more impactful musical work by utilizing aesthetic experiences, no matter the type of emotion being portrayed.

Emotions

Likely the most researched part of human psychology in relation to music is the study of emotions (e.g. Garrido & Schubert, 2011; Lundqvist et al., 2009; Mohn et al., 2011). As explained early in this paper, music has been shown to evoke genuine emotional responses in listeners, rather than simply perceiving/understanding the emotions expressed by the music (Lundqvist et al., 2009; Richard, 2002). Several psychological mechanisms have been hypothesized to

explain how music induces emotions including brain stem responses, evaluative conditioning, emotional contagion, mental imagery, episodic memory, and musical expectancy (Lundqvist et al., 2009; Juslin & Västfjäll, 2006). These mechanisms may help elucidate why individuals are able to not only interpret musical emotion, but also cause an individual to feel that very emotion.

However, not every emotion is as easily distinguishable. As expected, 'happy' music induces greater feelings of happiness, whereas 'sad' music induces greater feelings of sadness (Lundqvist et al., 2009), but other musically-invoked emotions such as anger or disgust are generally harder to identify (Lundqvist et al., 2009; Mohn et al., 2011). Nevertheless, the way music is portrayed or composed can alter the emotion interpreted (Juslin, 2000), regardless of any previous musical experience, music instruction, or personality traits (Mohn et al., 2011). Mohn et al. (2011) suggests that humans have the ability to perceive six fundamental emotions (happiness, anger, disgust, surprise, sadness, and fear) in a musical segment previously unknown to the listener (Mohn et al., 2011). No gender differences were found in emotional reaction to music (Lundqvist et al., 2009). Further, a cross-cultural study found that basic emotions of happiness, sadness, and fearfulness found in western music are recognized universally (Fritz et al., 2009) suggesting that generally, most people across cultures tend to experience the same fundamental emotions in response to music.

Physiological reactions, namely skin conductance as explained earlier, are often studied in relation to our psychological emotions (e.g., Khalfa et al., 2002; Liljeström et al., 2013; McFarland, 1985; Richard, 2002). However, skin conductance is not equivalently induced among all emotions (Khalfa et al., 2002). When four musical emotions varying in arousal were studied (fear, happiness, sadness and peacefulness), researchers found that skin conductance rate was greater with the two more stimulating emotions of 'fear' and 'happiness' when compared to the two more relaxing emotions of 'sadness' and 'peacefulness' (Khalfa et al., 2002). Physiological components are very much related to the psychological development of emotion, but can be experienced differently due to the intensity of the emotion. But even more important to note is that participant ratings of emotional clarity for each excerpt of music did not match the corresponding skin conductance level (Khalfa et al., 2002). This may imply that human cognitive labeling of emotional experiences can differ from bodily reaction. This is crucial for an artist to understand, given that physiology and meta-awareness may not always align when listening to complex music. Even if an audience member does not perceive an emotion or have the ability to recall how they felt, they may still have experienced such emotions unbeknownst to their own labeling, as evidenced through indirect measurement of physiological reactions.

Although people tend to perceive emotions similarity, this does not imply individual enjoyment is always the same. As discussed earlier in this paper, empathizers tend to enjoy negative emotion in music more than others (Garrido & Schubert, 2011), demonstrating that enjoyment can be explained, in part, by individual differences. Various personality traits may allow some to experience pleasure when listening to sad music, while others may exhibit a preference for cheerful music alone. It is important to distinguish that individual audience members have varying appreciation for different types of emotion from music. Artists should not feel deterred from utilizing negative emotion in a musical work. It is perfectly psychologically normal to enjoy negative emotion (Garrido & Schubert, 2011) and when used properly for the right type of audience, can be a very effective emphasis on a musical work's message.

In addition to enjoyment, skin conductance has been used to study emotional intensity as well (e.g. Liljeström et al., 2013). Some researchers have found that when participants were able to choose their own music, they reported significantly more intense emotions than compared to randomly selected pieces (Liljeström et al., 2013). Further, more intense emotions were also reported when listening with a close friend or partner than when listening alone, suggesting the importance of social experiences in emotion perceptions (Liljeström et al., 2013). Although allowing the audience self-choice of music is likely not a viable option for an artist, this could demonstrate how returning to familiar musical excerpts would likely exhibit more intense emotions than continually playing novel musical excerpts. Similarly, encouraging audience members to bring friends or loved ones could increase their general emotions as well and thus encourage the message of the musical work to a higher degree. However, if an individual is at a concert surrounded by friends talking to them, then they would likely get a different experience than if an individual was at a theater performance with a friend, but must be quiet. This would change the focus of the individual, even if their emotions

are increased with the presence of a friend, and likely cause a decrease in understanding and connection with the message of the musical work.

The confirmation or violation of musical expectations can also have an effect on the emotional intensity of the musical work (Koelsch, 2005). For unexpected chord structures in musical works, the orbital frontolateral cortex and the amygdala (Koelsch et al., 2005) have been shown to activate indicating the emotional significance of the stimuli (Mega et al., 1997). This is likely because the unexpected chords violate the sensory expectations of the listener, leading to an increase in perceived tension (Bigand et al., 1996) and thus generate emotional responses (Koelsch, 2005). For an artist to create a dramatic change in emotion, especially a negative one, a musical work could include unexpected musical features when illustrating a message.

If a performer is involved with the musical work, there can be other factors when eliciting emotion to an audience. For example, acoustic cues of vocal expression (such as tempo, dynamics, timing, and articulation) has been shown to be strongly linked with musical performance (Juslin & Madison, 1999). This is due to the neurological substrates underlying spontaneous vocalizations that are typically associated with providing functional information on initiating and organizing 'pre-wired' vocal expressions (Jtirgens & von Cramon, 1982; Ploog, 1986). For example, Juslin (2000) posits that singing performers can communicate emotions to listeners by using the same acoustic code as is used in vocal expression (Juslin, 2000).

For non-vocal performers, emotions can be expressed through specific memories or social learning (Juslin, 2000). Performers associate links between acoustic cues and extra-musical aspects (such as body movements) throughout their entire lives, resulting in a different utilization of acoustic cues for each performer (Juslin, 2000). So, if two instrumentalists wish to portray the emotion of fear while playing, their cues may be different but still communicate the same emotion to the audience. Artists with visual performers in their musical works should be aware that audience members interpret the visual cues of performers in addition to the musical features of the work to create a holistic emotional experience.

Summary

The psychological reactions to music are often studied in relation to emotion (e.g. Barrett et al., 2007; Cacioppo & Gardner, 1999). Several brain mechanisms are associated with how people are able to identify and feel musical emotions (Lundqvist et al., 2009; Juslin & Västfjäll, 2006) even without prior musical instruction or experience (Mohn et al., 2011). Although happiness and sadness are easier to identify (Lundqvist et al., 2009), fear and happiness tend to cause the greatest arousal in response to musical experiences (Khalfa et al., 2002). Further, the physical arousal level of an emotion does not always match up with the cognitive clarity of that emotion (Khalfa et al., 2002). An artist must be aware that an audience member might be able to feel an emotion through physiological reactions, even if they are unable to perceive it.

The intensity of the musical emotion is also very relevant to the creation of a musical work. More intense emotions were reported when music was self-selected and listened to with a close friend or partner (Liljeström et al., 2013). Musical expectation violations in the structure of a musical work can also lead to an increase in tension and intensity of emotions, due to the violation of sensory expectations of the listener (Bigand et al., 1996; Koelsch, 2005; Mega et al., 1997). Raising the musical emotion intensity for audience members can be very useful to help an artist emphasize a message in their musical work.

Altering the structure of a musical work can also lead to the development of an especially useful kind of emotion: empathy (Clarke et al., 2015). Empathy may be the most important emotion for an artist to develop in a musical work if they wish to connect the audience with their message because of the ability of empathy to help people relate to other ideas and promote positive unconscious feelings towards other individuals (Duan & Hill, 1996; Hietolahti-Ansten & Kalliopuska, 1990). All music has been shown to develop empathy, but certain structural elements, notably mimetic resonance and synchronization, can more readily facilitate this development (Clarke et al., 2015). Mimetic resonance (the ability to reproduce reality through sound) can stimulate mirror neurons which are directly

related to theory of mind (the ability to understand another individual's mental state) and motor neurons (physiological responses) (Gallese and Goldman, 1998; Iacoboni et al., 2005), and thus further cultivate empathy. Synchronization (aligning or adjusting with the pulse of a song) can reinforce a willingness to adapt to another person's emotional situation, and thus also cultivate empathy (Rabinowitch, 2015).

Inducing an empathetic state may lead to altered emotion preferences. Empathizers have been found to enjoy negative emotion in music more than others due to their imaginative flexibility with different musical emotions (Garrido & Schubert, 2011). Further, when listening to sad music, empathizers tend to develop an emotion of nostalgia; when listening to happy music, empathy tends to develop the emotion of power (Miu & Balteş, 2012). If an artist is able to control the empathizing tendency of audience members, they could potentially control differing emotional reactions of a musical work.

Musical structure can also create an emotional swell in a musical work consistent with chills and associated with feelings of being moved and beauty, known as an aesthetic response (Madsen et al., 1993). These responses are psychologically different from normal emotions, and involve different neural regions typically associated with governing arousal (Brattico & Varankaitė, 2019). Because of this difference, both positive and negative emotions can result in a positive aesthetic response. Like chills, an audience member must spend several minutes in high concentration preceding the peak of the musical structure (Madsen et al., 1993). The experience can be beneficial to an artist in their creation of feelings of empowerment in individuals by improving mood, cognitive functions, and happiness (Brattico & Varankaitė, 2019). So, regardless of the type of musical emotion an artist is facilitating, the musical work can become more impactful through the utilization of aesthetic experiences.

Other than the structural elements of the music, performers can also have an impact on musical emotion. If a certain performer is involved with the presentation of a musical work, cues can be used to represent emotions visually as well as auditory (Juslin, 2000). Vocal performers, due to evolutionary neurological substrates that function to initiate and organize 'pre-wired' vocal expressions, (Jtirgens & von Cramon, 1982; Ploog, 1986) can benefit by communicating emotions to listeners by using the same acoustic code (Juslin, 2000). Non-vocal performers can use individualized cues, developed through specific memories or social learning, to portray similar emotions (Juslin, 2000). These cues are yet another way to get a musical emotion across to an audience.

The musical structure can be utilized to develop a variety of musical emotions, ranging from basic emotions of happiness or sadness, to the more complex phenomena of empathy, to feelings of nostalgia and power. An artist should harness the ability to direct an audience member's emotion to influence a social or individual atmosphere toward a desired message.

General Discussion

The experience of music perception can be readily examined through its physiological, neural, and psychological components. An artist who wishes to portray a message through a musical work can utilize the biological responses of music to influence a social or group atmosphere. The changes in music that can influence these responses are musical emotion, musical tempo, musical volume, music type, musical pleasantness, musical structure, and the audience type. When the biological responses of these musical changes are studied together, important features about the perception of a musical work are exposed.

First, the ability to prefer or expect a musical change can have a large emotional impact. Neuroscience has demonstrated that listening to preferred music is associated with an increase in alpha waves, and thus a reduction of stress (Hurless et al., 2013). Further, psychological studies have shown that when participants were able to choose their own music, they reported much more intense emotions (Liljeström et al., 2013). Similarly, when musical expectations are violated in the structure of a musical work, tension and the intensity of emotions are increased (Bigand et al., 1996; Koelsch, 2005; Mega et al., 1997). Further, as musical volume is increased to a certain point, heightened beta wave activity indicates a distributed and tense situation (Bhoria et al., 2012) such that a lower or preferred volume can result in a more relaxing state. All of these preference and expectation findings from both neural and psychological

research indicate that fulfilling or violating the expectations of the audience can result in significant emotional effects. For example, an artist may be able to alter the type of music in a work, then shift back to the original style to create a sense of relief for the audience.

Second, empathy, arguably the most important musical emotion, can likely be created through rhythmic features of tempo and synchronization (Clarke et al., 2015; Rabinowitch, 2015). Empathy can help people relate to others' ideas and experiences and thus be extremely beneficial when portraying a message through a musical work. The musical element of rhythm synchronization is a way to increase empathy because of the way a music performer must align with another to adjust and coordinate with the pulse of a song (Rabinowitch, 2015). An audience member may feel these same effects depending upon their engagement with the music pulse. Tempo and rhythm, although some of the most basic features of a musical work, can have a significant impact on the body's response to music due to their connection with heart rate and respiration. Heart rate and respiration rates are seen as two of the most connected bodily responses with musical pulse, increasing and decreasing with tempo (Dainow, 1977; McLaughin, 1970). Through this physiological connection to musical tempo, rhythm synchronization isa possible avenue for development of empathy from audience members. The importance of synchronization can be seen through the art of dance and song choice, the main factor of the choice being rhythm because of its ability to express affection to people (Chen, 2015). Taking rhythm and synchronization into consideration, the emotional intensity of a musical work can be altered alongside empathic increases that allow for the message of a musical work to be better understood.

Third, peak musical experiences are very emotionally arousing and largely influenced by musical structure and audience setting. A peak experience has been defined by researchers as both a physiological reaction, known as the chill response, and a psychological reaction, known as an aesthetic response (Bannister & Erola, 2021; Brattico & Varankaitė, 2019; Craig, 2005; Madsen et al., 1993). These two responses can be branded together as aesthetic chills, which involve both brain arousal and skin responses. To create these responses, information or visual accompaniment can be paired with the music emphasizing structural or narrative components. An audience member must spend several minutes in high concentration preceding the peak of the musical structure to experience a full peak experience. So, if the musical work is consumed in a group setting, it is very important for the artist to draw in the attention of the audience before emphasizing any elements of the piece due to a possible lack of concentration or social loafing in a group setting that can diminish the experience of chills. Peak experiences are unique emotional responses to music that can cultivate feelings of empowerment and arousal due to their full body responses and thus, can be very useful to create a memorable message of a musical work.

Limitations and Future Research Suggestions

This paper is only meant to serve as a narrative about important experiences of music of perception, and has not covered every biological response to music extensively. The sources used in this paper were chosen to represent a comprehensive review of literature on the biological effects of music research. Thus, a limitation of this paper is that certain past findings may not have been included.

I recommend that the interplay between the biological elements of responses to music be studied more in relation to their social counterparts. For example, the neural relations to musical volume and stress have been well studied (Bhoria et al., 2012). However, volume preference would likely change if the social atmosphere was situated at a loud concert rather than wearing earbuds. Future study in various settings might help improve our ability to understand how music may be perceived in a variety of contexts. Similarly, if an individual is surrounded by people who enjoy a certain type of music, but are less preferentially accustomed to the genre, it is worth measuring whether their biological responses to the music would mimic those around them, or if their experience would be diminished. In sum, how would social climate affect musical preferences?

Another area of future research concern is the difference in music responses for those with or without music experience. For example, musical content in dreams for musicians was found to be almost twice as much for nonmusicians (Uga et al., 2006). This hints towards the suggestion of neural responses to music differing as a function of

experience levels, but further experimental work would need to be conducted to better draw conclusions on the meaning of such findings or relationships to physiological functioning. Also, the receptivity of unique kinds of music have been shown to be different based on musicianship (Gregory, 1994). How do differences of past music experience relate to biological responses of an audience member? Experience is a factor less identified in research studies but could have important applications in relation to the experience of music perception.

This paper focused heavily on various differences in musical experiences, but did not, for the most part, take into account cultural differences in music perception. Differences in form, timbre, pitch, rhythm, and other structural elements are all factors that change how music is produced across cultures. These interacting musical elements begin to influence human responses as early as the age of one (Morrison et al., 2009). Luckily, as discussed briefly in the psychological responses to music section, certain emotions to music can be seen across cultures (Balkwill & Thompson, 1999; Fritz et al., 2009), providing evidence for what has been described as a set of core psychological principles underlying melody formation (Krumhansl et al., 2000). Even with these possible similar responses to music, it is still important for future research to investigate these differences in more depth to expose the difference across cultures among perception and experience. While this paper aimed to keep a focused scope within signals of music perception from physiological, neural, and psychological factors, I suggest further reviews take into account a cultural perspective as well in audience responses.

Final Remarks

Human biological responses to music, although extremely prevalent in the experience of music perception, are rarely considered explicitly in the creation of a musical work. An artist does not consider whether the galvanic skin response might be fluctuating in response to a musical piece. Instead, considerations are given to the ways one creates an emotionally moving piece. Through their artistic efforts, there is still subconscious engagement in utilizing the biological effects of music.

Given my personal experience in theatre, music production, and vocalizing, I can provide personal context to how impactful certain elements of a musical work can be due to biological responses. An especially well-written musical work that illustrates this is *Les Misérables*, which I had the opportunity to perform in this past year as Jean Valjean. The song “Bring Him Home” performed in the middle of the show, demonstrates each of the main discussion points of this paper very well. Empathy is created with the audience due to the musical situation the song is placed into and the informational accompiant of narrative (Jean Valjean is praying for the safety of a boy, even if it means the cost of his own life). The rhythm is also significantly slowed down and synchronized with the character's situation of being in a resting and prayer state. A peak experience is created in the middle of the song when the song, which starts very quietly to draw the audience in, gets very loud with a cymbal crash. This almost always elicits a chill response with the audience due to the musical structure and focus of the audience because of the narrative situation in the show. Finally, musical expectations are fulfilled in this song by ending on the resolving chord of A-major, creating a relaxing and highly emotional feeling in the audience. So, through these biological responses to the music, the message is emphasized that Jean Valjean will be there to care for and protect her daughter’s lover under all circumstances.

Les Misérables is just one example of a musical work utilizing the biological response to music in order to illustrate a message. All types of musical works involve varying physiological, neural, and psychological reactions. Through the synthesis of these biological responses to music, an artist can better understand how various factors of any musical work can affect an audience member’s experience of music perception.

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