Article

A neuroscience-based rationale for patient-preferred live music as a receptive music therapy intervention for adult medical patients: A literature review

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ABSTRACT

Although patient-preferred live music (PPLM) is a frequently utilised receptive music therapy intervention, a neurological rationale for this treatment does not yet exist. The current paper reviews existing literature and proposes several potential neurologic rationales for PPLM as a receptive music therapy intervention for neurotypical adult patient populations. Additionally, the authors discuss gaps in the current research and make suggestions for further inquiries. The term 'patient-preferred live music' is parsed into four separate components: music, familiarity/preference, choice/autonomy, and live performance. The authors searched relevant neuroscience and music therapy literature to find research concerning each of these components. Results indicated extensive neuroscience research regarding the brain's neurologic response to music, mostly pertaining to the reward system and the process of dopamine release. Additionally, the authors found evidence to suggest that exposure to familiar stimuli and the act of making a choice may both be neurologically reinforcing. Research regarding the mirror neuron system may be a vital entry point from which to begin investigating the live and social aspects of PPLM. Further music-specific and neuroscience research is required to confirm these hypotheses. While various researchers have investigated individual components of PPLM, there is a lack of basic music therapy and neuroscience research regarding the paradigm as a whole. Further investigation is warranted.

KEYWORDS

patient-preferred live music, neurologic, neuroscience, music therapy, brain

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INTRODUCTION

In their systematic review of patient-preferred live music with adult medical inpatients, Silverman, Letwin and Nuehring operationally defined patient-preferred live music (PPLM) as "a receptive music therapy experience involving music selected and preferred by the patient that is performed live by a qualified music therapist" (Silverman, Letwin & Nuehring 2016: 2). The researchers analysed eight PPLM-based studies meeting inclusion criteria and noted results were consistently positive in support of the use of PPLM. The researchers found evidence to support PPLM, when delivered by a qualified music therapist, as an applicable intervention for affective states including pain and nausea as well as physiological measures for adult cancer and transplant patients. However, with an understanding that there is no existing neuroscience-based literature that supports the PPLM model as a whole, the present paper aims to: 1) dissect the term 'patient-preferred live music' and provide potential neurologic explanations for the effectiveness of each of its components; 2) highlight limitations of current literature; and 3) suggest directions for future research. As music therapy becomes an increasingly relevant field, researchers, clinicians, and consumers must pursue a neurologic rationale for specific interventions, seeking to answer *why* certain practices are successful in an effort to use them most effectively. Vital to this understanding is an awareness of *how* music therapy interventions may function to affect neural change and alter behaviours, cognitions, and affective states.

MUSIC AS A NEUROLOGIC REWARD IN PPLM

At the basis of understanding the effectiveness of PPLM is a simple – yet incredibly complex – inquiry: how does the human brain respond to music? Several researchers have investigated the activation of the neurologic reward system in response to music listening, focusing much of their research on the release of dopamine. Central to this process are the Nucleus Accumbens (NAc) and the Ventral Tegmental Area (VTA) (Berridge & Robinson 2003; Blood & Zatorre 2001; Kelley & Berridge 2002; Koelsch 2014; Menon & Levitin 2005). Dopaminergic neurons, located in the VTA, are projected through the mesolimbic pathway, eventually arriving in the medial forebrain bundle and supplying structures of the limbic system and the NAc (Siegel & Sapru 2015).

Blood and Zatorre (2001) conducted a positron emission tomography (PET) study and identified a correlation between VTA activation and intensity of pleasurable responses to participant-selected music. In PET scans, the researchers observed increases in cerebral blood flow in the ventral striatum, left dorsomedial midbrain, right thalamus, and anterior cingulate cortex, all areas associated with reward, emotion, and arousal. In this study, the researchers did not explicitly state whether the musical selections presented were live or recorded, though contextual cues may be used to infer that the music was pre-recorded. This highlights the importance of reporting guidelines to increase transparency in music-based interventions (Robb, Burns & Carpenter 2011). The authors of these guidelines advised that when recorded music is utilised, the researcher should "specify placement of playback equipment and the use of headphones vs. speakers," in addition to describing "who determined/controlled volume," and the "decibel level of music delivered and/or use of volume controls to limit decibels" (Robb, Burns & Carpenter 2011: 4). Implementation of these reporting guidelines can provide valuable information for clinicians and investigators when attempting to use and generalise research.

Menon and Levitin (2005) completed an investigation similar to that of Blood and Zatorre (2001), citing the importance of studying this process with advanced and more accurate fMRI technology. In this study, the researchers reported utilising digitised sound files in the "music" and "non-music" conditions. The music condition contained short excerpts from songs in the classical music canon, while the control condition utilised "scrambled" version of the same songs which the researchers manipulated to maintain pitch and loudness while removing any sense of musical continuity or predictability. The researchers found evidence suggesting that passive music listening stimulates a network of structures in the mesolimbic system involved in reward processing. Structures including the NAc, VTA, hypothalamus and insula work in tandem to regulate the brain's response to rewarding stimuli. The researchers found a positive correlation between NAc reaction to music and release of dopamine in the VTA. This study reaffirms the findings of Blood and Zatorre (2001), this time utilising the high resolution of the fMRI to measure and observe the activation of the Nucleus Accumbens. Menon and Levitin (2005) further suggested that passive music listening may provide an effective way to explore the neural mechanisms of anhedonia in patients with mental health disorders, as well as potential dysfunctional responses in the NAc, VTA, insula, hypothalamus, and orbitofrontal cortex, all of which are implicated in processing affect.

Dopamine release, in addition to immediately affecting reinforcement pathways and reward processes, has meaningful implications for cortical development. Researchers have demonstrated that a combination of dopamine release in the VTA and sensory stimulation results in cortical remapping, an influential component in reward processing and reinforcement learning (Bao et al. 2001; Chanda & Levitin,2013). As noted by Stegemöller (2014), it is generally accepted that dopamine plays an integral role in neuroplasticity. She suggests, "music therapists may be providing an enhanced learning environment for non-music tasks/behaviours through music-stimulated dopaminergic mediated neuroplasticity mechanisms" (p. 217). Additionally, Altenmüller and Schlaug (2015) highlighted the importance of the neurotransmitter *serotonin* in brain plasticity. While dopamine triggers feelings of pleasure resultant from unexpected or novel stimuli, serotonin triggers feelings of satisfaction from expected stimuli, both vital processes in reinforcement learning.

Music listening is not the only activity that works to stimulate the mesolimbic reward pathway. Researchers demonstrated that increases in dopamine levels in the VTA and NAc also occur in response to primary rewards like food or water and even act as a reinforcing effect for some addictive drugs (Berridge & Robinson 2003; Kelley & Berridge 2002). The same structures activated by music are likely to be activated in response to other euphoria-inducing stimuli, including eating, drinking, sexual behaviour, and using certain drugs of abuse. These selective circuits, including structures such as the NAc, VTA, periaqueductal gray, brainstem, and parts of the hypothalamus, may provide positive reinforcement associated with these rewarding activities (Blood & Zatorre 2001; Siegel & Sapru 2015). As early as 1980, Goldstein found that the music-activated neurologic pleasure response could be blocked by the opioid agonising drug naloxone. Goldstein's finding suggests that the pathway mediating musical reward response could be the same conduit that reinforces opioid use. Although there is a dearth of contemporary research specific to the relationship between musical reward and opioid-activated pathways, musical activation of reward circuitry may have meaningful implications in the treatment of drug addictions.

In addition to the wide body of research regarding dopamine release in response to music listening, some researchers have suggested a relationship between music listening and changes in autonomic response. It has long been hypothesised that regulatory functions including heart rate and respiration, which are largely mediated by the hypothalamus, may respond to pleasurable music listening (Blood & Zatorre 2001; Goldstein 1980; Krumhansl 1997). In their fMRI study, Menon and Levitin (2005) observed increased activation in the hypothalamus in response to pleasant music. The authors cited high correlations not only between NAc and VTA responses, but also between NAc and hypothalamic responses. They further suggested a "tight link" (p. 182) connecting the affective and cognitive systems, proposing meaningful implications for understanding human emotional and physical responses to music. Koelsch (2014) confirmed this notion in his meta-analysis of studies on music-evoked emotions, citing numerous researchers who observed increased activity in the hippocampal region in response to music listening. These findings aligned with another study by Koelsch and colleagues (2006), wherein the researchers found that a network of limbic and paralimbic structures (including the amygdala, hippocampus, parahipocampal gyrus, and temporal poles) responded to musical stimuli containing emotional valence, both pleasant and unpleasant. Based on their findings, the researchers suggested the effectiveness of music to regulate neuronal activity in this network of structures, in both an inhibitory and excitatory capacity.

FAMILIARITY AND PREFERENCE IN PPLM

Patient preference is a vital component of PPLM. Although there is evidence to support the use of familiar music in music therapy, neuroscience research about the relationship is scarce. Stegemöller (2014) advocates the use of preferred music when attempting to increase dopamine release in the listener's reward centre. Mitchell, MacDonald and Brodie (2006) found that patient-preferred music resulted in a "significantly greater feeling of control over a painful experience" (p. 348) and greater negative effect on mood disturbances than other distraction conditions during an autologous stem cell transplantation procedure. In an initial meta-analysis of music in medical and dental settings, Standley (1986) suggested the use of music therapy interventions utilising patient-selected or preferred music to act as an *audioanalgesic*. The author found evidence to suggest that music, especially when used in conjunction with other medical anaesthetics or analgesics, may be effective in reducing pain, anxiety and stress in a wide variety of patient populations. The researcher also noted the potential of patient-preferred receptive music to enhance chemical effects, thus reducing the amount, duration or side effects of medication administration, and possibly even shortening the length of hospitalisation. A majority of the studies included in Standley's meta-analysis utilised recorded music listening, and patient diagnoses ranged from neonatal care to cancer and dental procedures. Dependent variables included a variety of physiological measures including pulse rate, stress hormone levels, muscle relaxation and blood pressure, as well as affective states such as pain and anxiety perception. Several of the studies analysed by Standley noted the inverse effect of music on the amount of analgesic medication requested or administered.

Additionally, O'Kelly et al. (2013) found that for healthy control participants, live performance of preferred music resulted in the greatest positive effect on EEG amplitude when compared with improvised live music entrained to respiration, digital recording of disliked music, and white noise. It is important to note, however, that for healthy control data reported in this study, participants were instructed to keep their eyes closed, potentially minimising any effect of the live/social components of the musical stimulus and limiting the investigation to the patient preference aspect. Furthermore, the researchers found significantly increased EEG amplitude associated with preferred music for the experimental group of patients in vegetative and minimally conscious states, as well as increased blink rate in response to preferred music within the group of patients in a vegetative state. Although this research adds to the growing rationale for further study of PPLM, it cannot necessarily be generalised to the larger population, most of whom do not fall into the same clinical context.

It is possible that the familiarity of patient-selected music makes it especially stringent in the therapeutic setting, even if the music therapy consumer is not conscious of this preference. In an early study, Wilson and Zajonc (1980) found that participants reliably discriminated between familiar and unfamiliar stimuli, even if the stimuli themselves were not consciously recognised. That is, if participants heard stimuli that they had been exposed to in the past, even if not conscious of their recognition, they still reported preference for familiar over new stimuli. Relatedly, Redish (2013) described the brain's memory storage system in terms of "pattern completion" (p. 259), wherein the brain's content-addressable memory system uses existing neural connections to retrieve large amounts of information with just partial content. With minimal information about the stimulus itself and with relatively little cognitive processing required, participants may feel and react more positively toward stimuli they have heard before than that which is unfamiliar. This seemingly subconscious preference for familiar stimuli over unfamiliar may contribute to the impact of PPLM in the therapeutic setting.

Using Perlovsky's (2007) "knowledge instinct" as a framework, Koelsch (2015) explained how possessing an understanding of the structure of a musical piece may result in feelings of pleasure or reward. A familiar song fulfils a person's inherent desire to understand, and thus they experience it as rewarding. Koelsch continues by hypothesising that this would potentially activate the dopaminergic reward pathway, although he noted that this has not yet been empirically supported. The familiar structure of a preferred song might lead to an increased dopaminergic response, thus making the song more rewarding to the listener.

Although outside the scope of this paper, it should be noted that the process of auditory stimulation itself and the expectedness of familiar music may have important implications for the motor system. Thaut (2015) describes how the auditory system is extensively connected with motor centres in the brain at cortical and subcortical levels. The author explains how firing of auditory neurons, upon rhythmic and musical stimulation, entrains motor neuron firing. As a result, the motor system is primed "toward a state of readiness to move" (p. 258). Although constituting older research, other investigators utilising EEG demonstrated the priming and activation of muscle groups in response to rhythmic and musical stimuli via reticulospinal pathways (Paltsev & Elner 1967; Rossignol & Jones 1976). This relationship between familiar musical stimuli and neurologic response, though it may be supported from a behavioural standpoint, has yet to be studied empirically in terms of dopamine release in the mesolimbic pathway. Further study through a neuroscience lens may result in a deeper understanding of this process.

CHOICE AND AUTONOMY IN PPLM

In their review of PPLM for adult medical patients, Silverman, Letwin and Nuehring (2016) noted the sense of autonomy that is afforded a patient who receives PPLM. First, the patient has the opportunity to initially accept or decline music therapy services. For a patient in a medical setting who likely has few opportunities for choice, the act of making this initial decision may be empowering in itself. Moreover, the authors claimed that by choosing preferred music and having the opportunity to manipulate certain features of the music therapy session, patients may perceive themselves as in control of their environment. This, too, would likely induce feelings of empowerment and autonomy. Similarly, psychological researchers have long suggested the positive influence of choice on behavioural performances such as learning and memory tasks (Iyengar & Lepper 1999; Perlmuter, Monty & Kimble 1971; Setogawa, Mizuhiki, Matsumoto, Akizawa & Shidara 2014). In a recent study, Setogawa et al. (2014) suggested self-choice was critical in that when a participant chooses a task rather than being instructed to complete it, that task's value might be enhanced. This enhanced value could actually function to improve the participant's performance on a memory or learning task.

In a classic study, Perlmuter, Monty and Kimble (1971: 49) reported that participants' performance was less disrupted when being "forced" to learn two competing sets of materials (A-B, followed by A-C) than when they were able to choose the first set of material and forced to learn the second. That is, when an opportunity for choice was given, then taken away, their performance on the task was more negatively affected. The researchers continued by suggesting that people who "have the opportunity to choose their own responses…may learn faster than subjects who do not exercise choice" (Perlmuter, Monty & Kimble 1971: 52). Iyengar and Lepper (1999) found that Anglo-American students performed better on anagram tasks when given the choice of which puzzle to complete than when they were not given a choice. When told their mother or the experimenter chose the puzzle, the students performed significantly worse on the task. In contrast, Asian-American participants actually performed better when told the task was chosen for them by their mother. Motivation in response to self-choice may in fact be a cultural phenomenon. It is possible that socio-cultural factors play a vital role in the understanding of and reaction to perceived autonomy. Future research concerning this factor is warranted.

Neuroscientific research regarding exactly why the action of making a choice may be neurologically rewarding is scarce. Redish (2013) identified the importance of the nucleus accumbens (NAc) in both the deliberative decision-making and reward systems. This particular brain structure is vital in the processing of both evaluation of choices and reward. The NAc receives information from the hippocampus about past experiences and potential future outcomes and uses this information to evaluate the options presented. According to Redish, the NAc includes cells that "respond to reward consumption, as well as other cells that respond to cues that predict rewards, and other cells that seem to represent the expected value of an outcome" (Redish 2013: 81). Only further neuroscience research can determine if the NAc or other brain structures perceive decision-making as a reinforcing experience, and if this is in fact dependent on cultural background, as suggested by Iyengar and Lepper (1999).

LIVE AND SOCIAL ASPECTS OF PPLM

Several music therapy researchers found results indicating patient preference for live music over recorded music in receptive music therapy interventions (Bailey 1983; Cassileth, Vickers & Magill 2003; Silverman, Letwin & Nuehring 2016; Standley 1986). In Bailey's (1983) study of 50 hospitalised patients with cancer, subjects who experienced live singing and guitar playing reported significantly less anxiety and greater vigour than the control group that heard tape-recorded performances. In Standley's (1986) meta-analysis, the researcher suggested the significance of using live music, rather than pre-recorded music, to improve patient physiological and affective states, citing the importance of music therapists' ability to manipulate musical elements in response to patient state. Both the live component of PPLM and the social reinforcement of receiving a face-to-face music therapy intervention may be vital to its effectiveness. Koelsch (2015) explains the importance of social contact as a basic human need and potential for music as a conduit for social cognition, including "figuring out intentions, emotions, desires, and beliefs of other individuals" (p. 198). This aligns with Cassileth, Vickers and Magill's (2003) finding that live music therapy more effectively reduced pain and had a greater impact on mood when compared to a non-structured recorded music listening condition. The social aspects of a live musical interaction may play a major factor in the effectiveness of PPLM for improving mood states, when compared with recorded music listening.

The growing base of neuroscience research involving the mirror neuron system may have a profound influence on the developing neurologic rationale for PPLM. This system consists of a set of visuomotor neurons in the ventral premotor cortex that are activated in response to both performed and observed actions (Rizzolatti & Craighero 2004). Mirror neurons were initially discovered in the monkey ventral premotor cortex, but there is substantial evidence to suggest the presence of analogous neuronal structures in the fronto-parietal regions of the human brain (di Pellegrino et al. 1992; Gallese, et al. 1996; Molenberghs, Cunnington & Mattingley 2012; Rizzolatti et al. 2001; Rizzolatti 2005). Mirror neurons appear to be implicated in both processing and comprehending human motor actions. Furthermore, they may be related to higher-level processes such as imitation, language and empathy (Molenberghs, Cunnington & Mattingley 2012; Rizzolati 2005; Wan, Demaine, Zipse, Norton & Schlaug 2010). Koelsch, Fritz, Cramon, Müller and Friederici (2006) found that music listening activated motor areas implicated in the creation of vocal sounds. In their fMRI study, the researchers observed activation in the brain areas representing vocal production, even when participants were simply listening to music they perceived as pleasant.

Although there is limited empirical research on the topic, the salience of PPLM may be attributed to a process referred to as *emotional resonance* or *emotional contagion* (Juslin & Västfjäll 2008; Koelsch 2015). Acknowledging the lack of research on this particular subject, Koelsch (2015) theoretically discusses several different aspects of this process, wherein an individual perceives an emotion, be it a sound, a gesture or a facial expression, and mirrors or mimics the same emotion either internally, externally or both. The author explains the example of people listening to music that they perceive to be joyful. The listeners then embody 'joyful' music by smiling, singing along or moving with the music. In turn, this motor feedback actually evokes a feeling of joy. The author also discusses this process at the neuronal level, describing the process of sounds modulating arousal via the limbic pathway. Additionally, the author discusses the human mechanoreceptors, Pacinian corpuscles, which may become stimulated by musical sounds and thus lead to affective change.

Similarly, Juslin and Västfjäll (2008) outlined potential implications of the mirror neuron system in the process of emotional contagion, describing a situation in which a "voice-like" cello moves a listener to "experience the same sad emotion" (p. 565) expressed by the musical selection. De Gelder, Snyder, Greve, Gerard and Hadjikhani (2004) described a phenomenon where seeing body language expressing "fear" led to increased activity in brain areas associated with both motor processing and emotion. This connection between observed motor actions and emotional response may have meaningful implications for understanding the importance of live music in music therapy interventions. Juslin and Laukka (2003) noted that music commonly imitates emotional speech, and Juslin's (2001) Super-Expressive Voice Theory suggests that humans are particularly attuned to the voice-like characteristics of music due to the neural response to such stimuli. In the medical music therapy setting, this theory of emotional contagion might translate to the music therapist using tools such as words, facial expressions, gestures and vocal inflection to create an ideal atmosphere for the patient's emotional wellbeing.

Perhaps as a result of the mirror neuron system and the process of emotional contagion, the listener may automatically and subconsciously mirror the emotion she or he perceives in a live musical stimulus. Presumably, a live music therapy experience such as PPLM would provide an even stronger basis of emotional stimuli for the listener to perceive and mirror. However, there is scant empirical research regarding the relationship between the mirror neuron system and emotional contagion, even without the added variable of music. Given further research specific to the music therapy domain, these findings may add to the growing research base supporting the use of live music therapy interventions, as opposed to recorded music listening such as music medicine.

CONCLUSIONS

Based on the existing music therapy literature, it appears that PPLM is a preferred and effective receptive music therapy intervention for improvement of affective states in adult medical patients (Silverman, Letwin & Nuehring 2016). PPLM, however, like many other music therapy interventions, has yet to be explored from a neuroscience-guided perspective. In order for the evidence base and the music therapy field to grow, clinicians and consumers should continue pursuing neurologic explanations for the active change mechanisms of specific music therapy interventions. This paper calls attention to several potential neurologic explanations for the effectiveness of PPLM by breaking the intervention up into its individual components and reviewing the existing literature related to each of these components. However, the current research alone is not sufficient to empirically support the use of PPLM. The basic music therapy research required to rationalise the entire PPLM paradigm does not yet exist.

Though numerous researchers have explored individual aspects of PPLM, there is minimal literature regarding PPLM as a whole intervention. For instance, there is substantial evidence to support the neurologically rewarding nature of music via various dopaminergic and autonomic responses, but that alone does not necessarily justify the use PPLM (Berridge & Robinson 2003; Blood & Zatorre 2001; Kelley & Berridge 2002; Koelsch 2014; Menon & Levitin 2005; Stegemöller 2014). Similarly, some researchers have studied the patient preference aspect of PPLM without approaching the question of live versus recorded music (Blood & Zatorre 2001; Menon & Levitin 2005), while others focused on live versus recorded music without including the variable of patient preference (Bailey 1983; Standley 1986; Cassileth, Vickers & Magill 2003). Furthermore, there is extremely limited neuroscience research available regarding the perceived reward value of choice/autonomy, and music therapy researchers have yet to study this topic in relation to PPLM. The comprehensive research on this topic that does exist, including the study by O'Kelly and colleagues (2013), delves into only three of the four components of PPLM, and is so specific to a specialised clinical setting that it cannot be appropriately generalised to a neurotypical population. Lastly, these numerous facets of PPLM lack the solid neuroscience backing to connect them all.

The existing research, although it lays an initial foundation, is insufficient to rationalise PPLM from a neurologic standpoint. Future research might examine the relationship between mirror neurons, music, and emotional contagion, as well as the specific differences in processing live versus recorded preferred music in adult neurotypical populations, and the neurologic reward processes relating to choice and autonomy. In the contemporary era of heightened accountability and evidence-based practice, basic research is warranted and may help to justify the use of PPLM and differentiate it from other non-music therapy approaches like music medicine.

REFERENCES

Altenmüller, E., & Schlaug, G. (2015). Apollo's gift: New aspects of neurologic music therapy. *Progress in Brain Research, 217,* 237-252.

Bailey, L. C. (1983). The effects of live music versus tape-recorded music on hospitalized cancer patients. *Music Therapy, 3*(1), 17-28.

Bao, S., Chan, V. T., & Merzenich, M. M. (2001). Cortical remodeling induced by activity of ventral tegmental dopamine neurons. *Nature*, *412*, 79-83.

Berridge, K. C., & Robinson, T. E. (2003). Parsing reward. *TRENDS in Neuroscience, 26*(9), 507-513.

Blood, A. J., & Zatorre, R. J. (2001). Intensely pleasurable responses to music correlated with activity in brain regions implicated in reward and emotion. *PNAS, 98*(20), 11818-11823.

Blum, K., Chen, T. J. H., Chen, A. L. H., Madigan, M., Downs, B. W., Waite, R. L., Braverman, E. R., Kerner, M., Bowirrat, A., Giordano, J., Henshaw, H., & Gold, M. S. (2010). Do dopaminergic gene polymorphisms affect mesolimbic reward activation of music listening response? Therapeutic impact on reward deficiency syndrome (RDS). *Medical Hypotheses, 74,* 513-520.

Cassileth, B. R., Vickers, A. J., & Magill, L. A. (2003). Music therapy for mood disturbance during hospitalization for autologous stem cell transplantation. *Cancer, 98*(12), 2723-2729.

Chanda, M. L., & Levitin, D. J. (2013). The neurochemistry of music. *Trends in Cognitive Sciences*, *17*(4), 179-193.

de Gelder, B., Snyder, J., Greve, D., Gerard, G., & Hadjikhani, N. (2004). Fear fosters flight: A mechanism for fear contagion when perceiving emotion expressed by a whole body. *PNAS, 101*(47), 16701-16706.

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research 91*(1), 176-180.

Gallese, V., Fadiga, L., Fogassi, L., Rizzolatti, G. (1996). Action recognition in the pre-motor cortex. *Brain. 119*(2), 593-609.

Goldstein, A. (1980). Thrills in response to music and other stimuli. *Physiological Psychology, 8,* 126-129.

Iyengar, S. S., & Lepper, M. R. (1999). Rethinking the value of choice: A cultural perspective on intrinsic motivation. *Journal of Personality and Social Psychology, 76*(3), 349-366.

Juslin, P. N., & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: Different channels, same code. *Psychological Bulletin, 129*(5), 770-814.

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences, 31,* 559-621.

Kelley, A. E., & Berridge, K. C. (2002). The neuroscience of natural rewards: Relevance to addictive drugs. *The Journal of Neuroscience, 22*(9), 3306-3311.

Koelsch, S. (2009). A neuroscientific perspective on music therapy. *Sciences and Music III – Disorders and Plasticity, 1169,* 374-384.

Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews: Neuroscience, 15,* 170-180.

Koelsch, S. (2015). Music-evoked emotions: Principles, brain correlates, and implications for therapy. *Annals of the New York Academy of Sciences, 1337,* 193-201.

Koelsch, S., Fritz, T., Cramon, D. Y. V., Müller, K., & Friederici, A. D. (2006). Investigating emotion with music: An fMRI study. *Human Brain Mapping, 27,* 239-250.

Krumhansl, C. L. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian Journal of Experimental Psychology, 51*(4), 336-352.

Kunst-Willson, W. F., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, New Series, 207*(4430), 557-558.

McClelland, J. (2013). Rapid neocortical learning of new schema-consistent information into complementary learning systems theory. *Journal of Experimental Psychology: General, 142*(4), 1190-1210.

Menon, V., & Levitin, D. J. (2005). The rewards of music listening and physiological connectivity of the mesolimbic system. *NeuroImage, 28,* 175-184.

Mitchell, L. A., MacDonald, R. A. R., & Brodie, E. E. (2006). A comparison of the effects of preferred music, arithmetic and humour on cold pressor pain. *European Journal of Pain, 10,* 343-351.

Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: A meta-analysis of 125 human MRI studies. *Neuroscience and Biobehavioral Reviews 36*(1), 341-349.

Morrison, S. J., & Demorest, S. M. (2009). Cultural constraints on music perception and cognition. *Progress in Brain Research, 178,* 67-77.

O'Kelly, J., James, L., Palaniappan, R., Taborin, J., Fachner, J., & Magee, W. L. (2013). Neurophysiological and behavioral responses to music therapy in vegetative and minimally conscious states. *Frontiers in Human Neuroscience, 7*(884), 1-15.

Paltsev, Y. I., & Elner, A. M. (1967). Change in functional state of the segmental apparatus of the spinal cord under the influence of sound stimuli and its role in voluntary movement. *Biophysics, 12,* 1219-1226.

Perlmuter, L. C., Monty, R. A., & Kimble, G. A. (1971). Effect of choice on paired-associate learning. *Journal of Experimental Psychology, 91*(1), 47-53.

Perlovsky L. I. (2007). Neural Dynamic Logic of Consciousness: The Knowledge Instinct. In L. I. Perlovsky & R. Kozma (Eds.), *Neurodynamics of Cognition and Consciousness: Understanding Complex Systems* (pp. 73-108). Berlin, Heidelberg: Springer.

Redish, A. D. (2013). *The Mind Within the Brain.* New York: Oxford University Press.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophy-siological mechaniss underlying the understanding and imitation of action. *National Review of Neuroscience, 2,* 661-670.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience, 27,* 169-192.

Rizzolatti, G. (2005). The mirror neuron system and its function in humans. *Anatomy and Embryology, 210,* 419-421.

Robb, S. L., Burns, D. S., & Carpenter, J. S. (2011). Reporting guidelines for music-based interventions. *Journal of Health Psychology, 16*(2), 342-352.

Rossignol, S., & Melvill Jones, G. (1976). Audiospinal influences in man studied by the H-reflex and its possible role in a rhythmic movement synchronized to sound. *Electro-encephalogram in Clinical Neurophysiology. 41,* 83-92.

Setogawa, T., Mizuhiki, T., Matsumoto, N., Akizawa, F., & Shidara, M. (2014). Self-choices enhance value in reward-seeking in primates. *Neuroscience Research, 80,* 45-54.

Silverman, M. J., Letwin, L., & Nuehring, L. (2016). Patient preferred live music with adult medical patients: A systematic review to determine implications for clinical practice and future research. *The Arts in Psychotherapy, 49*, 1-7.

Standley, J.M. (1986). Music research in medical/dental treatment: Meta-analysis and clinical applications. *Journal of Music Therapy, 23*(2), 56-122.

Stegemöller, E. L. (2014). Exploring a neuroplasticity model of music therapy. *Journal of Music Therapy, 51*(3), 211-227.

Thaut, M. H. (2015). The discovery of human auditory-motor entrainment and its role in the development of neurologic music therapy. *Progress in Brain Research, 217,* 253-266.

Wan, C. Y., Demaine, K., Zipse, L., Norton, A., & Schlaug, G. (2010). From music making to speaking: Engaging the mirror neuron system in autism. *Brain Research Bulletin, 82,* 161-168.

Yinger, O. S., & Gooding, L. (2014). Music therapy and music medicine for children and adolescents. *Child and Adolescent Psychiatric Clinics of North America, 23,* 535-553.

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