Chapter 10

What Is Music for Neuroplasticity?

Combined Value on Infant Development and Inclusion

Efthymios Papatzikis
https://orcid.org/0000-0003-1801-6986
Oslo Metropolitan University, Norway

Hadas Rishony
Hebrew University of Jerusalem, Israel

ABSTRACT

Neuroplasticity has been increasingly discussed in phylo-ontogenetic terms the last few years, with a rising number of studies and scientific publications demonstrating its importance in the whole life span learning, development, and well-being domains. This chapter, focusing specifically on the neuroplastic changes happening in the infant brain when provoked from music, attempts to discuss the basic features and principals permeating this connection, bringing to the fore their combined value in terms of enriched development and extended social inclusion. The chapter content offers a steppingstone to both academics and practitioners alike, upon which they can update, 'rephrase', and specialize their knowledge in the particular interdisciplinary topic, while further reflecting towards the more sensitive and special in education and development practice contexts.

INTRODUCTION

From our point of view, inclusion means giving every human being an equal opportunity to express himself, be seen, and fulfil his potential regardless of race, sex, age, or disability. In this chapter, we will discuss neuroplasticity and the abilities of the developing brain to react and communicate through music. We will also suggest possible advantages of inclusive musical activities and the importance of their establishment at a young age for all participants, whether they are neurotypical or dealing with

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cognitive or emotional disabilities. We believe that various inclusive learning environments enable to clear a path to the hearts of many people from different backgrounds and, therefore, create new communication channels for those whose voice is not often heard.

BACKGROUND

What is Neuroplasticity?

The brain is a unique organ that demonstrates widespread variability within and across populations, with certain differences being described in structural and functional terms. These differences in the brain are seen to account for variability in behaviour, with anatomical differences observed to lead to difference in empathy, time perception, sensitivity to pain, cognitive capacity, and moral values among others (Gu & Kanai, 2014). Such differences can exist from birth and across the lifespan. One area in brain differences that has gained interest in recent years is the study of neuroplasticity. Neuroplasticity refers to the dynamic physiological changes that occur in the brain resulting from the organism's interaction with the environment. Plasticity of the brain can be best defined as "the brain's ability to create adaptive changes in morphological and network neuronal structure and function of the nervous system, which includes changes in neuronal connectivity, neurogenesis and neurochemical changes" (Sasmita, Kuruvilla & Ling, 2018).

Neuroplasticity has enabled adaptation of organisms and provided an evolutionary advantage (Anderson & Finlay, 2014). Neuroplasticity develops from a delicate interplay between genotype and environment and helps adjust the functioning of neural networks while maintaining homeostasis on changing environments (Butz, Wörgötter & van Ooyen, 2009). Since this process occurs throughout the whole life of an organism in response to external environment, it is also referred as experience dependent or activity induced neuroplasticity (Hamaide, De Groof & Van der Linden, 2016). Study of this extraordinary capacity has helped us throw light on the age-old nature-nurture debate through showing the extent to which the environment influences the biology of an organism.

The concept of neuroplasticity was first introduced by William James, who framed it as the "possession of a structure weak enough to yield to an influence, but strong enough not to yield all at once" (James et al., 1890). Later, Cajal improved the concept suggesting in his cerebral gymnastics hypothesis that the capacity of the brain could be augmented by increasing the number of connections between neurons (DeFelipe, 2006). Another aspect of neuroplasticity was later introduced by Hebb (1949) proposing that cortical neural connections change with experience. For example, if a person loses their vision at a young age, then cortical remapping will take place for the other sensory modalities (Ortiz-Terán et al., 2016). Hebbian plasticity can best be summarized by the notion suggesting that 'cells that fire together will wire together' and is a process that takes place naturally during development of the nervous system as well as in subsequent learning (Fauth & Tetzlaff, 2016).

There is increasing evidence showing that large areas of neuronal systems which although take up energy sources while lying dormant, have high plastic potential and could be helpful in adapting to stress, trauma or disease and can have effects of inducing extraordinary creativity and intellectual capacities in humans such as in the case of savants (Ovsepian, 2019). Neuroplasticity is extensively studied within neurological and neurodegenerative disorders which affect memory, cognition, and motoric functions

(Sasmita, Kuruvilla & Ling, 2018) in order to facilitate neurorehabilitation and, there is a rising call to use engineered neuroplasticity to induce quicker and more effective changes (Moritz, 2018).

The views regarding neuroplasticity have evolved from the critical period viewpoint where the brain was thought to be highly susceptible to change and modifications only during an early stage of development, to accepting change across the lifespan (Lillard & Erisir, 2011). The role played by critical periods, plasticity inhibitors and neuromodular systems on brain plasticity, as well as how these factors interact with age, sex, and sensory experience to produce these changes in the brain is now studied (Voss et al., 2017).

Neuroplasticity, viewed as sensitivity to sensory information, can lead to what can be termed as positive and negative effects on the brain. Here, we define positive as change that is beneficial or related to a difference in skill, learning or ability such as the brain's response to music training (Merrett, Peretz & Wilson, 2013); rehabilitative effects of music therapy on brain after injury or neurodegenerative diseases (Stegemoller, 2014); improved attention and memory performance due to exercise induced neuroplasticity (Hötting & Röder, 2013; El-Saves et al., 2018) as well as the changes in the brain indicating the influence of training on social behaviour and empathy (Davidson & McEwen, 2012). Negative neuroplastic effects are defined as a change that is associated with negative consequences such as changes in the brain due to stress or depression (Fuchs & Flügge, 2014; Kraus et al., 2017).

When an individual learns a skill, there is both reorganization of functional brain networks as well as structural changes such as increased grey matter (GM) volume (Dayan & Cohen, 2011). These neuroplastic effects were initially studied through studying the consequences of long-term learning processes (Voss et al., 2017). However, more sophisticated imaging techniques have enabled the study even on short-term neural adaptations (Tavor et al., 2019). Short-term cortical representation changes in the brain lead to certain modalities becoming more linked to certain functions than other, for a temporary period. In the long run however, this does lead to structural changes in the brain, affecting the introcortical and subcortical networks once proficiency in the skill has been reached. For example, Tavor and colleagues (2019) demonstrated using diffusion Magnetic Resonance Imaging (MRI) that learning of motor sequences, such as finger movements, can lead to changes in the cerebellum and motor areas on learning sequential motor activities. This means that learning induced plasticity is domain specific at least in the short-term.

The concept of plasticity, unlike localizationism, does not see the brain as merely the sum of different parts but has the distinctive feature of being able to build or adapt to various demands in an interconnected systemic manner using its history and experience (von Bernhardi, Bernhardi & Eugenín, 2017). The flexibility that such a mechanism provides must essentially be diverse in its nature which means that studying plasticity could refer to different levels of evaluation. One way to look at and divide neuroplasticity approach is to look at it through different temporal periods. The capacity for the brain to change has been seen not only during the lifetime of an individual, but on a larger scale through adaptive changes in organisms over the course of evolution. This is what is referred to as ontogenetic and phylogenetic neuroplasticity, respectively.

Phylogenetic and Ontogenetic Neuroplasticity

Simply put, phylogenetic are these adaptions which happen on a larger evolutionary scale of the human species while ontogenetic are these adaptations happening on a smaller scale such as throughout the human life span (Reybrouck, 2013). Phylogenesis and ontogenesis may seem like different concepts when considered in the context of 'representation and coding of information'. In regard to the phylogenetic point of view, it can be assumed that there exists a circuitry for perceptual information pick up. From an ontogeny point of view, it can be said that there are learned mechanisms for information processing and sense-making.

Recent perspectives focus not on studying either phylogenetic or ontogenetic alone but look to integrate the two. It is hoped that studying the development of the brain, and other nervous system structures, may provide unique mechanistic insights that inform our understanding of adult cognitive function (Hannan, 2007). More recent research has shown that these two, instead of being opposites, are in fact linked. Phylogenetic adaption has helped in providing the abilities for ontogeny adaptions to take place. Such studies have been conducted in studying the mechanism of empathy (Gonzalez-Liencres et al., 2013), Alzheimer's (Zhuravin et al., 2018), sleep (Corner & van der Togt, 2012), consciousness (Mashour & Alkire, 2013), and music (Reybrouck & Brattico, 2015).

In fact, studying neuroplasticity in the context of music can help provide insights into integrating the phylogenetic and ontogenetic approaches. Musical training and even listening have been seen to create significant structural and functional changes in the brain. Music is a function that is seen in all cultures, thus hinting at phylogenetic significance while also showing ontogenetic differences across lifespan in various domains. Music is truly universal in that it transgresses not only the boundaries of culture but also species. It is present in recorded histories of all time periods as well as pervasive among all cultures (Trehub, 2003). On top of this, the animal world is filled with songbirds, gibbons and whales which create music in some form (Miller, 2000). However, music is not just universal across cultures but also appears to be universal in terms of individuals - everyone has the capacity to be musical. This capacity is likely to be realized to different degrees and in different ways in different cultural and social environments (Cross, 2006).

MAIN FOCUS OF THE CHAPTER

Neuroplasticity and Music

For a long time, music was considered only as an aesthetically pleasurable experience (Brattico & Pearce, 2013). According to Darwin, all animals perceive and appreciate rhythm and melody because they have a comparable nervous system (Darwin, 1871). However, there are differing explanations for the utility and function of music. While some see music as nothing other than an evolutionary 'cheesecake' – pleasant but non-essential (Pinker, 1997) – there is growing evidence showing that music may have played a vital role in shaping essential evolutionary functions. The underlying neurological mechanism of music has been linked with essential adaptive functions such as emotional communication, social bonding, mate selection and language (Snowdon, Zimmermann & Altenmüller, 2015). It has also been hypothesized that while the early roots of music may have been an affective signalling system common to many living mammals, it became more specific for humans, inducing aesthetic emotions and facilitating auditory learning, promotion of social cohesion, and psychological and physiological well-being (Altenmüller, Kopiez & Grewe, 2013).

Our emotional evaluation of music has been shown to depend on the dynamic interplay of multiple hierarchically organized brain mechanisms (Juslin, Barradas & Eerola, 2015, Papatzikis, Svec & Tsakmakidou, 2019). These mechanisms are instantiated in distributed brain networks, including basal forebrain regions that encode biological drives and rewards, limbic regions that represent and evaluate emotional states, temporo-parietal cortical areas that represent structural harmonic and rhythmic properties of music, mesial temporal structures that support episodic memory and prefrontal areas that mediate psychological expectancy and social cognition processes. Music can thus be a biologically sanctioned mechanism for transforming private, emotional mental states efficiently into public social signals (Clark, Downey & Warren, 2014).

Music and its mechanism in the brain has also been found to be biologically grounded in the phylogenetically ancient neural machinery of reward and memory (Zatorre & Salimpoor, 2013). Findings that dopamine is the primary neurotransmitter implicated in neuroplasticity (Yamasaki & Takeuchi, 2017) point out common neural networks involved in learning reinforcement and reward (Morita, Morishima & Sakai, 2013). This connection could explain why music therapy has been found to be effective for neurorehabilitation. Music training also appears to be linked to the development and regulation of cognitive and behavioural skills such as communication, language, verbal intelligence, reading, and inhibition (Moreno & Bidelman, 2014; Papatzikis & Papatziki, 2017). In related studies, children showed a positive association between pitch perception and reading abilities (Anvari et al., 2002), and years of musical training predicted increased verbal recall (Jakobson, Cuddy & Kilgour, 2003) and reading skills (Butzlaff, 2000). Additionally, musically trained children showed superior auditory, finger tapping, and vocabulary skills when compared to their musically untrained counterparts (Schlaug et al., 2005). Structural differences between musicians and non-musicians reported larger anterior corpus callosum in musicians' depth of the central sulcus – often used as a marker of primary motor cortex size – for both hemispheres, although more pronounced on the right hemisphere for musicians compared to non-musicians. Playing music depends on a strong coupling of perception and action mediated by sensory, motor, and multimodal integration regions distributed throughout the brain, and this is why structural brain differences have been reported in musicians who play different instruments (Schlaug, 2015).

But why has music been discussed in terms of phylo-ontogenetic neuroplasticity in recent years? It can principally be contrived to be because of two reasons. The first one is that it can be experienced without the need of a functional acoustic apparatus. Most other aesthetical-creative activities necessitate a sensory organ such as eyes for visual art. However, for music, an individual can still get an aesthetical experience through vibrations without being able to use their ears and still induce neuroplastic changes in their brain. This is evidenced by foetuses being able to respond to music as well as deaf individuals (Chorna et al., 2019). The second reason why it has come into focus is music's challenging learning profile. This challenging learning profile – practically summarised through bimanual instrument training for example – seems to provide a link between microscopic and macroscopic, cortical, and subcortical changes.

At a microscopic level, a short-term cortical change happens in the callosal fibre, of which composition and size would change to an extent. At the same level, bimanual training causes an increase in cortical functionality for the symmetric areas involved in the motor and auditory mechanisms, while in the long term – macroscopic level – it leads to a permanent change in the size of the corpus callosum, which in turn leads to a change in the intro-cortical and subcortical networks (Burunat et al., 2015; Lee et al., 2003; Schlaug et al., 1995).

Neuroplasticity and Infant Development

Neuroplasticity constitutes an essential part of the human developmental process, mainly since it enables the brain to perceive and process multiple types of information simultaneously. During the first five years of life, the brain constantly encounters environmental stimuli and rapidly forms and reforms neural pathways accordingly (Asby, 2018). This ongoing ability to reorganize itself repeatedly may explain why early childhood is considered the optimal period for learning and acquiring new skills. In order to get a better understanding of this process, we will be focusing on one of the most critical underlying mechanisms of this ability to create new efficient neural pathways – the Programmed Cell Death mechanism (Costandi, 2016).

Extensive cell death is not an unusual feature in the developing human brain, and it also can be found among all organisms. The human brain contains between 80 to 120 billion neurons; however, it does not need to use them all to develop properly. According to the neurotrophic hypothesis (Costandi, 2016) the brain intentionally produces more neurons than it needs aiming to eliminate those not in need. All neurons compete for a limited supply of a small target-derived protein called nerve growth factor (NFG). NFG has been found to promote neural survival and differentiation, and therefore plays an essential role in this process of neural elimination; neurons that receive a signal survive and undergo maturation, while those who do not – die. This process is called Programmed Cell Death. Its purpose is to regulate the size of neuronal populations to enable the remaining neurons to gain proficiency in accordance with brain necessities. The entire process occurs under genetic control – it requires unique cell death genes that function as “executors”. Once a neuron does not get the neurotrophic signal (NFG), cell death genes switch on, and the suicide program is activated (Costandi, 2016).

However, this process is not governed by genetics alone. The formation of neural pathways depends highly on environmental stimuli exposure during the early postnatal period (Costandi, 2016). The infants’ neuroplastic brain responds to external stimuli, enabling them to build the neural infrastructure necessary for acquiring vital life skills. One of the best examples of this interactional relationship would be the developmental process of the human auditory system. The auditory system already develops early in gestation so that during the third trimester, the fetus’s brain can react to sound. By the 23rd and 25th weeks of pregnancy, essential structures of the auditory system are already in place, and by the 26th and 30th weeks fetus can detect and respond to sound stimuli (McMahon, Wintermark & Lahav, 2012). During that time, the hair cells – specialized cells in receiving and translating environmental sounds found in the cochlea – become fine-tuned to specific frequency bands by the influence of external (e.g., music, voices) and internal (e.g., heartbeat, digestion, respiration) sounds. The hair cells convert these acoustic signals into electrical stimuli and then forward them to the brain through the auditory nerve. The uterus has a critical role in protecting these delicate, newly developed hair cells from harmful high pitch sounds throughout this process. Therefore, it can be seen as an ideal place for this process of auditory maturation (Vandormael et al., 2019).

Understanding how the auditory system develops can make one wonder whether and how the brain can tune to its sound and language environment at an early stage of infancy or before birth. Although, preliminary results show that music can be processed somewhat faster than language at the level of the brainstem in the very beginning of life (Papatzikis et al., 2021), several studies have indicated that infants can perceive auditory information regarding the prosodic properties of their native language well at the level of the neocortex. For instance, it has been found that neonates, only a few hours after their birth, could discriminate between different prosodic patterns (Saito, Kondo& Ayoma, 2007). Another study conducted on neonates right after birth showed more robust responses in left temporal areas when a stimulus containing sentences in the mother language was presented, compared to the same stimulus played backwards (Peña et al., 2003). The preference for forward speech over backward was also found among 3- and 4-month-old infants (Dehaene-Lambertz et al., 2002; Minagawa-kawai et al., 2011). Considering these studies, it seems reasonable to conclude that the brain can process music and prosodic properties of environmental sounds and more specifically its native language, even before birth. How the brain responds to external auditory stimuli and adapt demonstrates its neuroplasticity in infancy.

Another realm in which the neuroplastic nature of the developing brain is manifested is emotional regulation. During the first five years of life, children need a caregiver to help them soothe extreme emotional reactions to uncomfortable stimuli (Asby, 2018). Either the presence or absence of this caregiver can potentially impact the formation of neural pathways in the child's brain. Some studies have shown structural changes in the brain due to the absence or presence of a supporting caregiver in early childhood. For instance, it was found that maternal support in early childhood can predict the volume of the hippocampus in later childhood (Francis & Meany, 1999). Furthermore, an association has been found between childhood poverty and the volume of the hippocampus and more minor levels of white matter and cortical gray matter (Luby et al, 2012). In some cases of abuse and neglect in early childhood, damaged neural pathways were found to be a breeding ground for mental issues later in life (Cattane et al., 2017). However, the neuroplastic nature of the brain in early childhood can help repair these damages by reforming harmful neural pathways. Therefore, early intervention is crucial since the critical period of neuroplasticity occurs during the first five years of life (Asby, 2018).

Music, Musicality and Development

As defined by Steven Mithen, 'musicality' is the human ability to communicate using variations in pitch, timbre, rhythm, and dynamics by a combination of voice, body, and material culture (Mithen, 2009). Mithen claimed that musicality was essential to the lives of pre-linguistic hominins since it enabled a form of affective communication. He assumed that the ability of our ancestors to communicate their emotions through vocalizations, rhythm, and body gestures used to be adaptive since it made them successful members of a social group and therefore increased their chances to survive. Due to its importance, musicality continued to evolve and became more sophisticated by physical evolutionary changes. It was not until a very late stage in human evolution that musicality as a primary form of communication was pushed aside by spoken languages, which developed due to the need for transmission of information. Nevertheless, it remained a form of emotional communication among humans and eventually became music as we know it today (Mithen, 2009).

This theory by Mithen provides a possible explanation for the important role music plays in human lives. It is not by chance, therefore, that music constitutes a significant part of all human cultures, or that our brains respond profoundly to musical stimulation since the very beginning of our lives (Papatzikis & Papatziki, 2016; Papatzikis, Svec & Tsakmakidou, 2019). A growing body of literature has shed light on the early development of sound and music perception. For instance, high-intensity music to fetuses has been shown to cause heart rate accelerations and motor responses. Moreover, low-intensity music has been shown to cause the opposite physical effects (Chorna et al., 2019; Lecanuet, 1996). Another study has shown entrainment of preterm infants and term-born neonates to live-sung lullabies. Infants synchronized their sucking, respiration, tongue movements, and vocalizations according to the sung musical contours (Provasi et al., 2014). Furthermore, newborn infants exposed to music before birth, but having minimal to no exposure after birth, showed physiological responses to basic rhythm and pitch patterns already in the first days of life (Chorna et al., 2019; Hepper 1991, 1996). In addition to the studies presented above, neurophysiological findings have also supported this line of thought. In one study, researchers have exposed fetuses to a simple recorded lullaby five times a week, starting from the 29th week of gestation until birth. Compared to controls, fetuses in the exposure group have shown significantly stronger ERP (i.e., event-related potential) responses at birth and several months later (Partanen et al., 2013). These findings support a sustained fetal musical memory, which lasts throughout early infancy.

All in all, it seems as if fetal auditory sensitivity constitutes the foundation to the acquisition of an essential emotional communicative skill set. Infants can recognize their mother's voice even while in utero, and their auditory cortex is more adaptive to maternal sounds than environmental noise (Webb et al., 2014). This phenomenon may come from a fundamental innate survival mechanism, in which the infant must recognize the mother in order to communicate their needs to her. During infancy, mothers and other caregivers communicate with their infants using a unique form called infant-directed speech. It is characterized by exaggerated prosodic traits and therefore communicates emotions effectively, and that way helps establish the bond between a caregiver and an infant. Due to its prominent prosodic features, many researchers consider infant-directed speech a musical form of speech (Maloch & Treverten, 2018; Mithen, 2009; Fernald, 1991). Moreover, several studies have shown that infants prefer infant-directed speech, play songs, and lullabies over a standard adult-directed form of speech (Tsang & Trainor, 2020; Masataka, 1999) – a preference that may continue beyond infancy (Papatzikis & Papatziki, 2016).

This preference infants show to songs is far from being coincidental. Singing is a cross-cultural way for adults to practice affect regulation with their infants. Since infants have limited emotional self-regulation skills at their disposal, they need their caregivers' help to learn how to soothe themselves (Trehub et al., 2015). There are two primary kinds of songs sung by caregivers to their infants – play songs and lullabies. Despite cultural differences, a few similarities have been found between lullabies worldwide; they will usually present features such as slow tempo, frequent repetitions, limited pitch range, few dynamic changes, and a high degree of continuity (Chorna et al., 2019). These similarities result from the function of lullabies as sleep enhancers. Unlike lullabies, play songs tend to be more vigorous and stimulating. However, in both kinds, the infants' musical experience is multimodal – while hearing the music, they feel contact, comfort, and movement, which eventually help them to calm down (Trehub et al., 2015).

SOLUTIONS AND RECOMENDATIONS

Music and Inclusion through the Prism of Neuroplasticity

Inclusion means giving every human being an equal opportunity to express themselves, be seen, and fulfil their potential regardless of race, sex, age, or disability. By understanding therefore at a deeper level neuroplasticity and the abilities of the developing brain to react and communicate through music, possible inclusive learning environments may occur, enabling a path to the hearts of many people from different backgrounds and, therefore, create new communication channels for those whose voice is not often heard. The advantages of inclusive musical activities and the importance of their establishment at a young age for all participants, whether they are neurotypical or dealing with cognitive or emotional disabilities, can be therefore manifested by the neuroplastic nature of the developing brain. The early development of the auditory system and its ability to process external sounds may indicate its importance for the human capacity to communicate; it allows the establishment of communicative infrastructure upon which an infant develops the ability to interact with her surroundings and survive. Considering this, early exposure to musical stimulation, whether by listening or participating in group musical activities, can be highly beneficial for children with disabilities, special needs or being at risk. Due to the deep-rooted influence music has on our brains, a window can be opened to inclusive educational activities using music's advantages to facilitate social communication between children with and without disabilities. Since all humans are innately wired to react to music, inclusive musical activities have the potential to make all participants feel equal, enhance their sense of capability, and increase their self-esteem.

How can this be achieved? One of the underlying physiological mechanisms of human ability to benefit from music is the capability of our bodies to synchronize to rhythmic patterns heard around us. The human body comprises various rhythms, such as the heart, the respiratory system, the digestive system, etc. That is the reason why when we hear an external beat, whether as an abstract or an organized sound (i.e., music) our bodies will recognize it as something familiar and try to sync up with it. This process is called entrainment, and it enables music to affect physiological indices such as heartbeat, pulse rate, and blood pressure (Papatzikis & Papatziki, 2016) and reduce stress, anxiety, and depression levels (Sarrazin, 2014). That way, music can be a helpful tool to practice emotional regulation for all children, especially those who deal with autism or other behavioral and mental health issues. Whether it is lingual delay and sensory overload in autistic children, or a hardship coming from a severe lack of emotional support resulting from neglect or abuse, the outcome can be anger attacks, inability to read emotional signals, and adversity to communicate. The power of music to enhance emotional regulation can be significant when it comes to dealing with such issues.

Other than individual listening, the main contribution of music in cases of emotional regulation for children with disabilities, special needs or being at risk, would be in the form of group activity. Several studies have demonstrated the potential advantages of musical group activities. For example, it has been found that musical group activities require communication with other people and rely on fundamental communicative mechanisms, such as imitation and sound and movement synchronization. Therefore, it can increase empathy between participants and contribute to a sense of social cohesion (Rabinovich et al., 2013). In general, studies show that participating in activities that require synchronization, such as music and dance, can elicit emotions that are typical for social bonding, especially trust and interpersonal cohesion (Chanda & Levitin, 2013). Creating music in a group requires a joint effort of all participants to be present in the moment, mainly since this kind of activity entails physical involvement and paying attention to their surroundings. While taking part in a musical group activity, the participants depend on each other for reaching a common goal. Therefore, they need to communicate by using eye contact, body movements, and facial expressions. That way, if one of them shows any signs of distress, his partners can cheer him up, inducing serenity by relaxing gestures, or getting affected by his emotions and sync up to them. One way or another, the shared musical activity contributes to a sense of intimacy and unity among its participants (Archer- Capuzzo, 2008).

Furthermore, it seems that interpersonal cohesion can be increased based on the accuracy levels of the synchronization. It has been found that as long as the synchronization is more accurate, more endorphins are being released among participants, causing an increase in attachment and social cohesion (Bamford, 2018). Moreover, a connection was found between music and oxytocin release, a crucial neurotransmitter in creating social bonds (Harvey, 2020; Freeman, 2000). A few studies support this connection by demonstrating a significant increase in salivary oxytocin levels resulting from group musical activities, such as drumming sessions and choral singing (Yuhi et al., 2017; Kreutz, 2014). In addition, Oxytocin release has a critical role in emotional regulation, mainly since it helps moderate amygdala activity; it reduces fear and anxiety and increases sustained feelings of trust (Ishak, Kahloon, & Fakhry, 2011). Therefore, one can assume that joint musical activities may aid individuals who deal with difficulties in emotional regulation caused by an overactivation of the amygdala, which can be a primary symptom among people who deal with various neurologic and neuropsychiatric disorders. However, this assumption requires more profound further investigation.

Several more studies have shown the power group musical activity has on its participants in developing empathy and affection toward their partners, emotions that underpin the ability to communicate and establish social skills. (Rabinowich et al., 2013; 2017). For instance, the results of one of the studies had indicated participants' tendency to rate their affiliation higher towards experimenter when they both tapped in synchrony (Hove & Risen, 2009). This finding is supported by another study that examined whether synchronized motion among 4-year-old children can increase their level of cooperation with an unfamiliar peer. Participants were randomly assigned to synchronous motion and control groups. Participants in the first group underwent a treatment of synchronous motion, while in other groups, they had asynchronous motion treatment or no motion at all. Then, all participants had to complete a series of different tasks. Results have shown that synchronous training caused children to enhance their level of cooperation compared with control groups; synchronization increased intentional communication between peers, which caused an increase in coordination and cooperation levels (Rabinowitch & Meltzoff, 2017). A different study, which was also conducted on children of the same age, has found that joint music-making can increase cooperation and helpful behavior (Kirschner & Tomasello, 2010). The experimental group underwent a musical activity that included common singing and dancing, while controls had a social activity with no music. In subsequent individual tasks, children in the experimental group tended to help other participants; they maintained a more robust audiovisual representation of collective intention and shared goal compared to controls.

CONCLUSION

It seems that music does not exist for pleasure alone, but it has a deeper role within the human experience. Looking at all the research work presented above, one can learn that the pleasure music evokes among humans is likely to originate from evolutionary adaptive communication mechanisms. Since the first day of life, the human brain reacts to various sonic stimulations and develops accordingly throughout time. The profound reaction of the human brain to different kinds of sound components, such as pitch, intonation, rhythm, etc., implies the importance of sound as a building block in our ability to develop future communicative life skills. This innate reaction to sound, whether in the context of non-verbal communication, language or physical entrainment, may explain why shared musical activities have the potential to evoke the psychological mechanism of interpersonal cohesion. Whether in synchronizing body movements to a constant beat during dance or percussion playing, in singing harmonies with other people, or in collective singing and dancing simultaneously to strengthen the sense of unity. These findings can enlighten the power music has to create equal and inclusive environments, considering that all humans are deeply wired to respond to it; joint musical activities can satisfy the common congenital human need to share emotions and experiences with others, regardless of any disability.

For all this, the combination of neuroplastic qualities of young-developing brains and the advantages of joint musical activities may emphasize the importance of early intervention to establish new social habits. Due to the early neuroplastic window, it would be essential to consider early intervention while combining group musical activities in inclusive educational programs. For instance, when it comes to emotional regulation, we saw that the earlier intervention will occur, the more effective it would be. Since emotional regulation is an essential communicative skill for all children, especially those with special needs, it can be critical to utilize the advantages of joint musical activities in this realm as early as possible in order to create a significant change. In addition, designing such inclusive frameworks starting from a young age can help establish a meaningful educational message saying everyone is equal and deserves to be heard.

One other potential advantage of inclusive musical activities would be the organization it requires. Children with special needs, specifically those on the autistic spectrum, often experience anxiety due to a sensory overload, leading them to sense a lack of predictability and order. One of the most effective ways to help them reduce stress and make sense of the world is by creating predictable environments built around repetitive routines. Musical activities enable to design of a suitable setting for children with special needs, mainly since it promotes a high level of organization. Predictable and well-organized social settings may aid children on the autistic spectrum or with other disabilities to function, and therefore, music, encompassing all these properties, can offer a fertile ground for improving not only their developmental prognosis, but also their sense of success and self-esteem.

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KEY TERMS AND DEFINITIONS

Auditory System: The human sensory hearing system, through which one can process various sounds within the environment.

Inclusion: The human right to get an equal opportunity to express themselves, be seen, and fulfil their potential regardless of race, sex, age, or disability.

Infant Development: Refers to children's physical, emotional, behavioural, and mental growth during the first year of their lives.

Music: An art of sound in time that expresses ideas and emotions in significant forms through the elements of rhythm, melody, harmony, and timbre.

Musicality: The human ability to communicate using variations in pitch, timbre, rhythm, and dynamics by a combination of voice, body, and material culture.

Neuroplasticity: The dynamic physiological changes in the brain resulting from the organism's interaction with the environment.

Ontogeny: The developmental events or the course of development that occur during the existence of a living organism.

Phylogeny: The history of the evolution of a species or group, especially lines of descent and relationships among broad groups of organisms.