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MUSIC, BRAIN PLASTICITY AND THE RESILIENCE: THE PILLARS OF NEW RECEPTIVE THERAPY

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SUMMARY

This paper describes a new type of receptive music therapy which aims to build the patients' psychological resilience by increasing the levels of dopamine, serotonin and oxytocin in order to increase standard psychopharmacological treatment efficiency. Previous research concerning the musically induced production of the two neurotransmitters and a hormone is discussed and reviewed. Based upon the existent studies concerning the influence of music on dopamine, serotonin and oxytocin induction, a new design of specific music features for this purpose is proposed and elaborated upon. The music features are numerically described using Music Information Retrieval software in order to objectivise the otherwise intuitively chosen music elements such as event density (number of notes started in one second of time), tempo, harmonic rhythm (number of harmonies changes in one second), dynamics, key changes and roughness coefficient (level of sensory dissonance). Finally, the new concept of resilience enhancing therapy is proposed and defined using the music features described above.

Key words: *music therapy – resilience – neuroplasticity – dopamine – oxytocin - serotonin*

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INTRODUCTION

Music, as an art form, has only recently come to be analysed from a scientific perspective: the effects of its elementary features have been studied by observing the processes through which music is perceived, created, responded to, and incorporated into everyday life (Tan 2010). Modern music psychology is mainly empirical; it interprets data collected through interaction with and observation of human participants. Its uses have had a practical relevance in numerous areas of musical and non-musical research: composition, education, therapy, music perception, psychoacoustics and computational modelling. The advancements in sound technology (Music Information Retrieval Software or MIRToolBox) have enabled us to extract the numerical data depicting the usually traditionally analysed basic elements of music such as tempo, dynamics, rhythm, harmony and melody. Having numerical data enabled the researchers to perform statistical analysis and empirically analyse the effect of particular music features on human behaviour and perception.

Psychological resilience has likewise only recently become the subject of research. Defined as an individual's ability to successfully adapt to life challenges in the face of highly adverse conditions, resilience can be developed and sustained. There are several factors that develop and sustain the resilience (Helmreich 2017): active coping (problem solving skills and planning), self-efficacy, optimism or positive attributional style, social support, cognitive flexibility (acceptance of negative situations and emotions), religiosity or spirituality or religious coping. These factors can be achieved and supported by regular psychotherapy practices, such as cognitive-behavioural therapy (Abbott 2009, Songprakun 2012), acceptance and commitment therapy (Ryan 2014), mindfulness-based therapy (Geschwind 2011), attention and interpretation therapy (Loprinzi 2011, Sood 2014), problem-solving therapy (Bekki 2013, Sahler 2013), as well as stress inoculation (Farchi 2010). Currently, no empirically validated theoretical framework exists that outlines the mode of action of resilience interventions (Bengel 2012, Leppin 2014). However, music therapy has shown to be able to provide a good basis for resilience interventions.

The ability to developed and sustain psychological resilience in adult individuals is enabled by the brain's capacity to adjust and transform throughout the lifespan, called neuroplasticity. In the following paragraph we will discuss how music in particular affects brain plasticity and what are the possible benefits of this interaction.

MUSIC, NEUROPLASTICITY AND BRAIN DEVELOPMENT

Neuroplasticity, the ability of brain to change and grow during the individual's life in response to different experiences, is allowing us to adapt to various environmental stresses and conditions, enabling the development of psychological resilience in the adult age (Graham 2013). Neuroplasticity is happening on different levels within the brain: synapses may strengthen or weaken, the proportion of gray matter can change over time, or brain activity associated with a specific function can transfer to a different region. The formerly held view, that the brain is a physiologically static organ, has been replaced by neuroplasticity that explores how and in which ways does brain change through a person's life. The changes in neural pathways can be a consequence of various factors: changes in behaviour, environmental and neural processes, changes resulting in bodily injury and learning of new skills.

Many studies have shown that music training in particular has an effect on brain development; research has shown structural and functional differences in the brains of adult instrumental musicians compared to those of non-musicians, with intensity and duration of instrumental training and practice being important predictors of the differences (Schlaug et al. 2005). Schlaug has also studied the effect of music training on the developing brains of children aged 5 to 11 and found that in 5 to 7 year olds (14 months after the beginning of training), cognitive and brain effects from instrumental music training can already be found, mainly in domains such as fine motor and melodic discrimination. In 9 to 11 year olds with an average of four years of musical training, the observed effects become more pronounced, as well as the new transfer effects begin to emerge, namely those in closely related motor and auditory domains. Thus, their research has demonstrated that music training in children results in long-term enhancement of visual-spatial, verbal, and mathematical performance, although the underlying neural bases of such enhancements is still unknown, as are the contributions of factors such as the intensity and duration of instrumental training, extracurricular activities, attention, motivation, or instructional methods.

Most recent studies in neuroplasticity show that adult brains can also be shaped by music. Researchers (Dehaene 1997, Dehaene et al. 1998, Pinel et al. 2004, Piazza et al. 2007) have come to a conclusion that music making can enhance the function and structure of many brain areas in adults, proving that training-induced plasticity is not restricted to the developing brain. Studies show that music making in particular leads to structural and functional changes in the vicinity of the intraparietal sulcus (IPS) which is the region for neural representation of all types of numerical representation and operations and also involved in the meaning of symbols and the mental manipulation of symbolic representation. Thus, we can see that music making can lead to not only the changes in primary and secondary motor and auditory regions of the brain but also in multi-modal integration regions in the frontal and parietal regions (Wan & Schlaug 2010).

Even more relevant is the effect of music listening on the brain plasticity in adults.

Research has shown that daily music listening can improve auditory and verbal memory, attention, and mood as well as induce structural gray matter changes in the early post-stroke stage (Sarkamo et al. 2012). Further research on stroke patients has been done by Sarakamo et al. (2014) that confirmed these results: Voxel-based morphometry (VBM) analysis was performed on the 6-month post-stroke stage structural magnetic resonance imaging data of the patients who either listened to their favourite music (MG- music group), verbal material (ABG-audio book group) or did not receive any listening material (CG- control group) during the 6- month recovery period. All groups showed significant gray matter volume increases. However, there was a specific network of frontal areas and limbic areas in patients with left hemisphere damage in which the gray matter increases were larger in the MG than in the ABG and in the CG. The study thus showed that music listening after stroke enhances behavioural recovery and induces neuroanatomical changes in the brain.

Finally, Stegemoller (2014) has pointed out three principles of neuroplasticity that explain why music therapy in particular is effective in encouraging changes in behaviour. The first one is the fact that music affects the release of neurotransmitters such as dopamine and serotonin which are responsible for the reward system in the brain and for the induction of feelings of happiness. Since the stimulation of dopaminergic neurons has been shown to result in cortical remapping (Bao et al. 2001) it is well accepted that dopamine plays a vital role in neuroplasticity. This shall be discussed in more detail further along. The second principle is based on the Hebbian theory that states that ‘neurons that fire together, wire together’, meaning that neurons that fire together within less than tens of milliseconds, will make a new connection or strengthen an existing one. Musical rhythm is a feature in music that can be entrained or synchronised to a diverse palate of non-musical behaviours inducing synchrony in the neural networks underlying the behaviours. In other words, by pairing music with movement, vocalization, breathing, and heart rate, therapists might be able to elicit simultaneous firing of neurons in areas that control the described behaviours. The third principle mentioned by Stegemoller states that continuous listening to noise can negatively affect brain plasticity; it increases stress, which consequently impairs both cognition and memory (Amemiya et al. 2010). Long term exposure to music however, leads to improvements in learning, presumably due to changes in the hippocampus in animal models (Kim et al. 2006). This is probably due to the fact that the acoustic signal of song is more consonant than that of speech (Stegelmoller 2008). Music therapists, as professional musicians, are thus in advantage in their ability to optimize the level of noise in the vocal and instrumental sounds.

MUSIC THERAPY, RESILIENCE AND MENTAL HEALTH

Music therapy has been known to increase psychological resilience in children and adolescents coping with adversity and difficult life situations ranging from problematic family life to cancer treatment. Its potential lies in the ability to provide socio-cultural and aesthetic experience while fostering a therapeutic outcome (Robb et al. 2014, Pasiali 2011). The role of the music therapist is thus to point out the strengths that each client possesses and to engage in a process of increasing each person's capacity for sociocultural adaptation and for gaining control in their lives (Garred 2006).

Guided Imagery and Music (GIM) therapy (Bonny 1995), a receptive method which engages patients in music listening in a state of deep relaxation, is able to reach the inner resources of each patient by:

- enhancing their capacity for adaptation to social demands and the capacity to gain control over their lives,
- increasing a positive self-concept and confidence,
- developing their ability to cope with strong impulses and feelings (Bruscia & Grocke 2002).

Since the most recent findings in psychological resilience (Helmreich et al. 2017) point out those 3 factors as 'well-evidenced and modifiable' in enhancing resilience, it is expected that after engaging with music therapy (GIM) for a period of time, the patients will show an increase in psychological resilience.

In order to enhance the effects of standard GIM therapy on the psychological resilience of patients, a new type of therapy was developed called 'Resilience enhancing music therapy' which patients can practice themselves, without or with little help of a therapist. Another novelty of the 'Resilience enhancing music therapy' is that the music used is not intuitively chosen, but rather selected on the basis of empirically validated assumptions of the influence of music on the neural pathways in the brain. This approach enables us to directly affect the synaptic network responsible for the brains capacity for neuroplasticity. This new type of therapy will focus on determining the exact types of music that evoke the above- mentioned feelings by choosing pieces which features induce the increase in the release of dopamine, oxytocin and serotonin. These two neurotransmitters and a hormone are capable of affecting the emotions linked to prosocial behaviours (Thompson 2007) arousal (Schultz 2015) and feelings of happiness and well-being (Fessler 2001), which are all factors in enhancement of the psychological resilience in patients.

MUSIC AND DOPAMINE

Dopamine, a neurotransmitter that plays an important role in motor control, arousal, motivation, and reinforcement, also acts as a 'global reward signal': the initial phasic dopamine response to a rewarding stimulus encodes information about the value and the context of a reward (Schultz 2015). In addition to this, dopamine also functions as a 'reward prediction error' signal; it is a subject to the degree to which the value of a reward is unexpected (Schultz 2015). Thus, rewards that are expected still do not produce a second phasic dopamine response in dopaminergic cells, whereas rewards that are unexpected, or greater than expected, will. The omission of the expected award will consequently cause a drop in dopamine release. In music, a similar reward system has been described by Meyer (1956) and Narmour (1989), called the implication-realisation model. This model describes music as a complex texture of mutually intervening patterns which cause in a listener a certain expectation of their resolution. However, the most intriguing part of every music piece is the subversion of these expectations: moments where the music patterns break down and the course of the melody becomes unpredictable. The longer we are denied a pattern we expect, the greater the emotional release when the patterns returns. Numerous analyses have been conducted to confirm this theory, the most recent one focusing on the impact of music on the dopamine release in listeners. Salimpoor et al. (2011) made an important step in revealing the underpinnings of pleasurable feeling that occurs while listening to music. They combined the temporal specificity of functional magnetic resonance imaging (fMRI) with the neurochemical specificity of PET to explore the temporal dynamics of any dopaminergic activity: they wanted to examine whether the dopamine release was associated with the experience of the award or its anticipation. They used individuals that experience 'chills to instrumental music', because music 'chills' are a well-established marker of peak emotional responses to music (Blood 2001). The findings suggest that the favourite parts of listeners' music (the ones that cause 'chills') were preceded by a prolonged increase of activity in the caudate. They called this the 'anticipatory phase' and argued that the purpose of this activity was to help predict the arrival of their favourite part. This phase was set off by temporal cues signalling that a potentially pleasurable auditory sequence is coming and could trigger expectations of euphoric emotional states creating a sense of wanting. The peak emotional response evoked by hearing the desired sequence on the other hand, would represent the 'consummatory' or liking phase; the expectations are fulfilled. The 'consummatory phase' was marked by the increased activity in the nucleus accumbens (NAc). The research thus revealed that each of these phases involved dopamine release, but in different subcircuits of the striatum. The activity of nucleus accumbens during the 'consummatory phase' when listening to music was also confirmed by Levitin and Menon (2005): Their results show that the responses in the NAc and the ventral tagmental area, which is the origin of dopaminergic cell bodies, were strongly correlated pointing to an association between dopamine release and NAc response to pleasurable music.

In order to cause the described release of dopamine in both stages of the reward process, the choice of music must first establish a strong melodic, harmonic or rhythmic pattern that is suggestive enough for an average listener to cause certain expectations. Meyer has proposed three most important expectational tendencies in a melodic line in experienced listeners: (1) Pitch proximity; listeners expect the following pitch to be near the current pitch, (2) Post-skip reversal; listeners expect the large interval to be followed by a reverse in direction of a melodic line, (3) Step inertia; listeners expect a small interval to be followed by another small interval in the same direction. In terms of harmonic expectations, Aarden (2002) has established that the listeners' expectations conform to the following harmonic distribution: For both major and minor keys, the most common pitch is the fifth degree scale (dominant), followed by the first degree (tonic), followed by third (mediant). Scale degrees two and four are next most common, and degrees six and seven the least common. Finally, pulse and meter most commonly found in music are periodic, because periodic patterns are the easiest patterns for which brains are able to form expectations. Since we must assume that most patients are not classically trained musicians, their understanding of musical language will be limited to culturally well-established tonal systems and simpler melodic and rhythmic patterns as described above.

We now have to look at the ways the established expectations can be subverted. Expectations can arise from either explicit knowledge of specific music pieces or from more implicit musical schemes representing rules of how sound patterns are organized based on person-specific musical experiences and knowledge gained through years of listening to different musical sounds (Salimpoor 2013). Thus, we can see that if one was to design music that induces dopamine release, one must take into consideration the patients' individual musical taste and their listening experience. The selection of music should thus be done in two steps: Firstly, specific compositions should be selected individually for each patient based on their listening taste by using the music recommendation software such as Spotify. Then the recommended music would be additionally analysed to see which of the compositions featured the longest, what Blood termed 'anticipatory phase'. The anticipatory phase is characterised by the subversion of the created expectations in the following ways; (1) the expectations can be thwarted completely, (2) some expectations can be fulfilled and others thwarted simultaneously, (3) expectations could be thwarted so many times that the listener learns to expect the unexpected and (4) the outcome of expectations can be paradoxically both expected and unexpected (Huron 2006). The longer the 'consummatory phase' is delayed, the more pleasurable it will be once it has been reached.

It has been established that the exact music features that would induce the two mentioned phases of dopamine release differ from patient to patient. It would be helpful however to give a few examples of how music expectations are subverted in well-known music pieces, as described by Daniel Levitin (2006). In the Beatles' song 'Yesterday' the main melody lasts for seven bars, subverting one of the main rules of pop music genre; presenting the main theme in either four or eight bar phrases. Beethoven, on the other hand, in the main melody line of his 9th Symphony (mi-mi-fa so-so-fa-mi-re-do-do-re-mi-mi-re-re), subverts our expectations by starting and finishing on an unusual note: Starting on a third scale degree instead on the first, the melody climbs up, turns and goes back down. Once it reaches the first scale degree (do), it does not stay there, but climbs up and down again, hinting again at the approach to the first scale degree. The 'do' is however again not reached, but Beethoven stays on the second scale degree (re), delaying the resolution. He repeats the whole melody once again and the finally lets us hear the desired 'do'.

As we have seen, there are numerous ways of subverting the established musical expectations, and different listeners prefer different ways of thwarting their expectations. It is thus impossible to design a single music piece that is going to be equally effective in inducing the 'anticipatory phase' in all patients, but one must take an individual approach and select pieces on the basis of the patients' previous music experiences and preferences.

MUSIC AND OXYTOCIN

Oxytocin, on the other hand, produces a very different effect on the emotional life of an individual. It induces feelings of bonding, maternal behaviour, prosocial behaviour, empathy and trust. However, the influence of oxytocin on social behaviour depends on the context and the traits of the individual in question. Oxytocin is thus not pro social per se, but rather regulates stress and anxiety and motivational states related to social interactions (Bartz et al. 2011).

The relationship between the oxytocin release and music listening has been examined by Nilsson (2008), who evaluated the effects of music on patients who have undergone heart surgery on postoperative day one. The patients were divided into the control group (n=20) and music group (n=20). The music played to the music group has been perceived as relaxing and described by Wolfe et al. (2002) as 'quiet', 'peaceful', 'soft', 'dreamy', 'soothing', 'serene', 'un-dramatic', 'slow speed', 'regular rhythm', 'pleasant combination of instruments' and 'low volume'. The music was played for 30 minutes through a MusicPillow (a pillow connected to the mp3 player). The volume used was between 50 and 60 dB, and the tempo was 60 to 80 bpm. Relaxation was assessed by determining serum oxytocin, heart rate, mean arterial blood pressure (MAP), arterial oxygen tension (PaO2), arterial oxygen saturation (SaO2) and subjective relaxation levels before and after the music listening. Levels of serum oxytocin in the music group have increased significantly in contrast to the control group after the administration of music, pointing to the conclusion that listening to relaxing music after open-heart surgery has some effect on the s-oxytocin and subjective relaxation levels.

Another study has been done by Grape et al. (2003) evaluating the effects of a single 30-minute singing lesson on the levels of serum oxytocin relative to a pre-lesson baseline in both professional and amateur singers. The two groups displayed an increase in the levels of oxytocin, reporting no differences between the groups. However, Chanda (2013) points out that there are confounding factors present in the described study; it confounded the music activity with social interaction between the researchers and the participants. Since oxytocin mediates social bonding and affiliation (Insel 2010) and has been suggested to underlie the role of social support on health (Uchino 2006), it is important to distinguish the music from social interaction in oxytocin studies. Similar difficulty in distinguishing social bonding from musical activity was found in the study of group singing (Keeler et al. 2015): They assessed the levels of oxytocin in singers of two different singing groups (pre-composed and improvised) before and after the performance, to assess the levels of social engagement and affiliation. The oxytocin levels increased only in response to improvised singing. There was no significant difference between improvised and pre-composed singing conditions observed. This again points out the fact that higher oxytocin levels might be attributed to the social effects of improvising with others.

Since oxytocin induces emotions that can be described as enhancing one's capacity for adaptation to social demands, it would be crucial to incorporate the oxytocin inducing music to the Resilience Inducing Music therapy. The defining features of this music used would have to be, as described in the Nilsson (2008) study, 'relaxing' and 'peaceful' to produce the already observed effect. According to MIRToolBox music information retrieval programme, the music would display the following characteristics: Event density (described as a number of note onsets per second) would be rather low and would also have to remain constant, in order to maintain the 'regular rhythm' and 'peacefulness'. Tempo would be, as in the Nilsson research, between 60 and 80 bpm. Dynamics would be piano or mezzo piano, measuring up to 60 dB. Harmonic rhythm (number of key changes within one bar of music) would also be regular, without abrupt changes, in order to maintain the soothing and serene flow of the music. The key changes would be within the scale to prevent the unexpected distant modulations. The music would also be characterized by a very low roughness coefficient (the measure of sensory dissonance), in order to keep the consonant sensory experience. If the above-mentioned conditions were met, the genre of the music would be irrelevant, and could range from early classical to completely modern pop music.

MUSIC AND SEROTONIN

Finally, serotonin is a neurotransmitter that contributes to feelings of well-being and happiness. Although the role of serotonin in mood disorders is not yet fully understood by scientists, it is thought to be implicated in cognition, mood, anxiety, psychosis and depression (Chilmonczyk 2015). Furthermore, higher serotonin levels have been linked with a lack of rejection sensitivity and a general increase in self-esteem (Fessler 2001). Music listening has been proven to affect the levels of serotonin in healthy subjects (Evers et al. 2000). They have studied the effects of pleasant and unpleasant music on the levels of the hormones prolactin and ACTH and a neurotransmitter serotonin 5-HT. There were no significant changes of prolactin and ACTH during the perception of different kinds of music, but there was an increase in serotonin levels during the perception of pleasant music as compared to the perception of unpleasant. The music used in this research was the following: For pleasant music the researchers used Johannes Brahms, Symphony No.3, op.90, third movement (Poco Allegretto), whereas the unpleasant music was represented by Krysztof Penderecki, Threnody for the victims of Hiroshima. The described features of the Brahms music are not unlike the 'pleasant' and 'relaxing' music used in the oxytocin research; the music is consonant and tonal (low roughness coefficient), in the mid pitch range, with a clear meter and simple unsyncopated rhythm (low event density). Tempo is also in the range between 60 and 80 bpm and the dynamics is around 60dB. On the other hand, Penderecki's piece is the complete opposite displaying an extremely dissonant harmonic plan, very high event density and a very high pitch range. The tempo is impossible to perceive because it changes frequently and the dynamics is quite loud with unexpected changes. It is thus easy to see how music that increases levels of serotonin corresponds to the music that induces oxytocin release, making it easy to incorporate to the Resilience Inducing Music therapy programme.

RESILIENCE ENHANCING MUSIC THERAPY

The 'Resilience enhancing music therapy', a receptive therapy method where patients listen to classical music in a state of deep relaxation would, unlike GIM therapy, focus on more than one theme throughout the programme. The patients will listen to five different compositions, one after another, each focusing on a different theme relevant for the development and sustainability of psychological resilience such as: love, power, freedom, happiness and purpose. Each of these themes would either feature music that induces the release of oxytocin and serotonin or dopamine.

In GIM, the music for the programme was chosen intuitively by the programme creator, focusing on one theme that was the title of the programme; 'Nurturing', 'Relationships', 'Imagery', 'Death- Rebirth', etc. In Resilience enhancing music therapy, the music is chosen by closely examining the extracted music features using MIRToolBox (as described above) and by tailoring the music features to specifically target the release of either dopamine or oxytocin and serotonin. The themes of love, freedom would be represented by pieces of music focusing on the oxytocin and serotonin release, whereas the themes of power, happiness and purpose would be represented by pieces focusing on the dopamine release. Additionally, the five pieces would be accompanied by a suggestive text whose function would be to suggest the described themes to the listener and encourage them to experience the themed visualisations in order to further enhance the positive self-concept and confidence and to encourage them to cope with strong impulses and feelings.

The therapy would be executed in seven initial stages, after which each patient would be given a CD containing the described pieces recorded along with a guided meditation for further listening. The seven stages will be done along with the therapist in the following manner: The first stage will introduce the complete music programme to the patients, familiarising them with the techniques of deep relaxation and the five themes explored through the compositions. This will be done in a group therapy session, where the patients will be able to experience this method first hand and talk about themes that are important to them. The next five stages will explore the five above mentioned themes (love, power, freedom, happiness and purpose), each session enabling the patients to experience the therapy method and discuss the theme explored that day. Finally, the seventh stage will focus on summarizing the experiences of the previous six stages and on distributing the CDs with the complete therapy programme recorded. The patients will be given instructions to listen to the programme every day for a period of one month and to write down their thoughts and feelings that might occur.

CONCLUSION

In conclusion, we can see that music has a potential to affect the physical processes of dopamine, serotonin and oxytocin release, which can consequently lead to positive emotional reactions, directly linked to the enhancement of psychological resilience. In contrast to other psychotherapeutic interventions designed to enhance resilience, music therapy is more immediate and direct in its approach, and more importantly, can be used by the patients on their own, without the help of the therapist. Finally, music therapy is non-invasive and natural and has not shown any side effects compared to the standard medication methods.

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