The Effect of Music on Autism Spectrum Disorder and Music Therapy

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Abstract:

Whether we notice it or not, different types of music have different effects on us and our brains. Do you ever wonder why you prefer a specific song and why it makes you feel good? The reason for this is that certain parts of your brain, such as the cerebellum or amygdala, are important for processing music, and listening to music releases neurotransmitters, such as dopamine, which makes you feel good. Now imagine if your brain worked differently than everyone else's, such as those with Autism Spectrum Disorder (ASD). How would it integrate music now? Those with Autism Spectrum Disorder integrate information and perceive emotions differently. This suggests that people with Autism Spectrum Disorder might integrate music stimuli differently as well. Additionally, the way that they integrate music differently can also be used to help them in the form of music therapy. In this research paper, we will explore what Autism Spectrum Disorder is, how music is normally integrated compared to how it's integrated in a brain with Autism Spectrum Disorder, and what music therapy and its benefits are.

Introduction:

In the United States, 1 in 36 children are born with Autism Spectrum Disorder (ASD). ASD is a neurodevelopmental disorder, and individuals with it often experience difficulties in social communication and have restricted or repetitive behaviors. However, the cause of ASD is not completely understood. Risk factors for developing ASD include genetic components such as shared genetics, genetic mutations, or heritability. Shared genetic risk factors are frequently identified in families with twins. Identical twins are found to both have ASD in 50-80%of studies, while fraternal twins both have it up to 30 percent [1]. Furthermore, rare de novo mutations – genetic mutations that arise spontaneously – are common risk factors for ASD. When diagnosing ASD, researchers often look for copy number variants (CNV), which are mutations that occur as microduplications or microdeletions in genomes. More specifically, they look for rare de novo CNVs since people with ASD tend to have an elevated rate of them. It is also possible for a child to develop ASD as a result of pregnancy complications including exposure to medications or toxic materials, and prematurity [1]. Future factors such as the age of the parents at the time of conception are associated with ASD. For instance, older fathers end up contributing to more de novo mutations [1].

These genetic and environmental factors play a major part in an individual's brain development, especially for those with ASD. The regions of the brain that are most affected or disrupted by ASD include the prefrontal cortex, temporal lobe, amygdala, etc. (Figure 1). These regions are all important for social cognition, language, and the regulation of their emotions, respectively. These are important to every human's day to day functions. Compared to

individuals with ASD, neurotypical people experience more activity in these regions. However, the temporal lobe is a brain region where there is generally more activity for a brain with ASD.

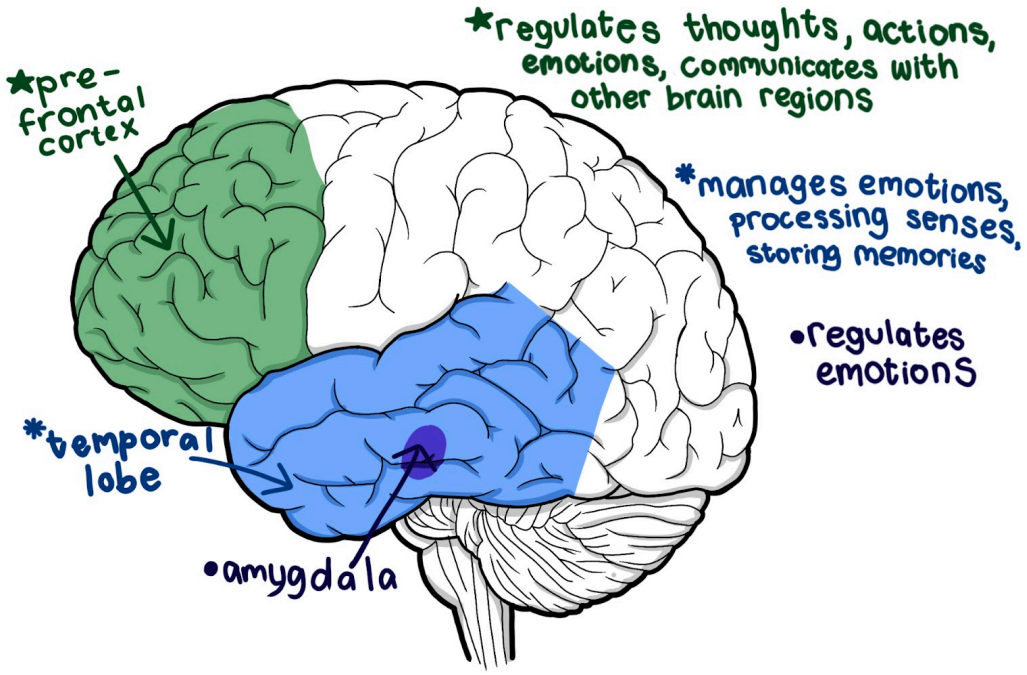

Figure 1. A diagram of a human brain with core brain regions that are often affected or disrupted in ASD.

Furthermore, a person with ASD often has distinct neural connectivity patterns which are the connections between neurons where neurons send information via neurotransmitters . The neural connectivity patterns in ASD include underconnectivity in distant brain regions and overconnectivity in neighboring brain regions [8]. On a cellular level, people with ASD tend to have an imbalance of having more excitatory neurons compared to inhibitory neurons (E/I), which are two broad classes of neurons. Excitatory neurons propagate electrical signals while inhibitory neurons slow down the action potential which are electrical impulses that send signals around the body. When action potential is slowed down, it causes less communication in neurons.

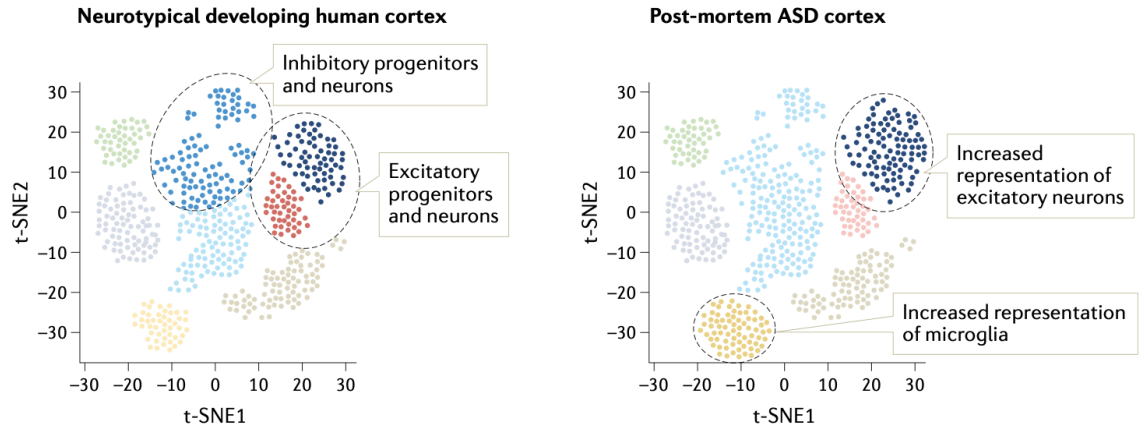

Figure 2. Taken from Willsey (2022). The analysis of single-cell gene expression data from a neurotypical developing cortex (left) compared to a post mortem ASD cortex (right). These analyses have consistently demonstrated an increased amount of excitatory neurons and microglia in ASD (Willsey, 2022).

Through analyses of single-cell gene expression data from neurotypical controls and individuals with ASD, it was identified that there is an increased representation of excitatory neurons in an individual with ASD which demonstrates an imbalance of inhibitory and excitatory neurons in an individual with ASD (Figure 2)[2]. Additionally, microglia, which are immune-expressing cells in the brain, are activated abnormally in ASD. Compared to a neurotypical brain, there tends to be an increase of microglia in ASD in the cerebral cortices area. This can cause impacts on synaptic function and in social interaction and communication. Migrogialia impacts synaptic function by detecting which synapses are strong, weak or inactive, and determining which synapses to remove while others can be kept and made stronger [9]. Therefore, too much microglia can actually contribute to neuronal damage instead.

The Effect of Music:

How Music is Normally Integrated:

Music has a much greater effect on our brains and emotions than we may realize. Music is processed in the auditory cortex in the temporal lobe[5]. When it comes to responding to music, the amygdala and cerebellum are important [5]. The cerebellum is located in the posterior, or back, of the brain and is responsible for corresponding and regulating motor activity (Figure 3). The cerebellum plays a critical role in rhythm perception, as this involves a large part of the motor system especially when it comes to the human ability to dance to music. Furthermore, the ability to keep rhythm is even measurable in newborns since they can be trained or influenced to recognize rhythms [5]. This demonstrates how even from the beginning, music has a large impact on us. By contrast, the amygdala, which is also part of the temporal lobe, is associated with experiencing emotions, fear, and motivation (Figure 3). It is responsible

for the emotions we feel when processing melodies.

Additionally, a research effort led by neuroscientist Zattore has shown that oftentimes when individuals listen to music, they experience a feeling best described as “musical chills” or “shivers” 77% of the time when listening to certain parts of songs [3]. This feeling of chills is positive and shows extreme enjoyment from the listener. Zatorre found that activity in the amygdala decreased as the feeling of chills increased through brain scans. The chills have a connection to the amygdala’s parts that correspond to fear and negative emotion as it decreases that activity [3]. This is because of how the amygdala receives inhibitory presynaptic input from cholinergic neurons intrinsic to the nucleus accumbens, which are a brain region in the amygdala. Cholinergic neurons are associated with different parts of the brain, such as the cerebral cortex and amygdala, and act in an inhibitory way. They are part of the parasympathetic nervous system which is responsible for the body’s relaxation response. Therefore, music can evoke strong reactions in a person's brain.

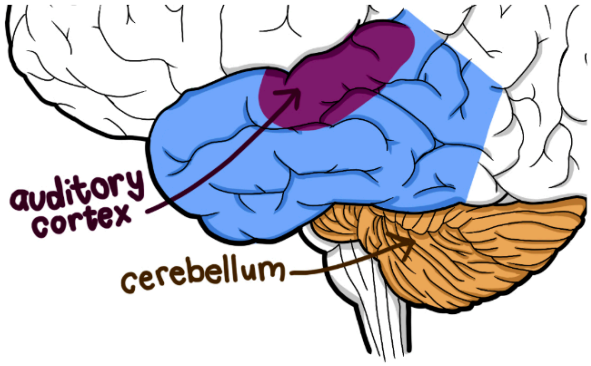

Figure 3. Brain regions that are important for processing and responding to music.

How Music is Integrated in a Brain with ASD:

In ASD, music is integrated differently as it can evoke more intense reactions. Studies have shown that music can induce strong and consistent positive or negative emotions in individuals with ASD, and even stronger than neurotypical individuals [4]. Furthermore, the neural connectivity underlying music processing includes a network of limbic and paralimbic structures, which are structures that have to do with the feelings of reward and emotion. In people with ASD, the amygdala, hippocampus, parahippocampal gyrus, and other brain regions were observed to be activated in response to music [4]. Additionally, different types of music activate different brain regions. The neurobiologist Caria and her team conducted an experiment with 22 individuals with and without ASD and gave them the stimuli of listening to music consisting of 10 happy and sad musical excerpts each. Then, 10 control stimuli to listen to which consisted of random sequences of tones with no melody or rhythm. Caria et al., identified that happy music activated a greater amount of regions for an individual with ASD when compared to other types of music, such as sad music. The experiment revealed high blood oxygenation level-dependent (BOLD) responses, which means that the functional magnetic resonance imaging (fMRI) measured high amounts of blood flow and oxygen in the brain. Increased blood flow is a way to measure activity of a brain region, because the more active the more blood it needs to keep up with the cellular demands of active neuronal cells. By looking at the BOLD, researchers found that listening to music increased activity in the prefrontal cortex for [4]. This

activity suggests a higher level of emotional processing in people with ASD which could be linked either to the feeling reward in the limbic systems or to not being able to immediately understand the sensory input of intense emotional responses. This high BOLD was also seen in the cortical and subcortical brain regions, which shows music perception and emotional processing when music is being processed. This demonstrates how although a person with ASD may have trouble expressing themself or being social, they are able to process music and feel a lot of emotion while listening to it, as the brain activity increases greatly[4].

How Music Therapy Works and its Benefits:

Understanding the effects of music on the brain can be used for the benefit of people with ASD through music therapy. Music therapy is a form of therapy that utilizes music to address emotional, physical, social, and cognitive needs. It can be a useful intervention since it can be individualized for a person's needs or even as a group. Children with ASD tend to have less neural organization which is the organization of structural, functional, and dynamical interactions in the brain [7]. Researchers have demonstrated that a lack of neural organization in children with ASD prevents them from healthily responding to their environment [6]. Furthermore, it leads to the underlying motor deficits leading to an inability to plan, initiate, and complete a motor sequence.Music therapy can help because it has a rhythmic structure, providing clear cues for people with ASD to follow and to anticipate responses. Not only does music therapy provide a structured environment, but it is also extremely flexible since it can be changed to fit what is most needed, which helps provide accommodations for the person with ASD. This helps to encourage a more creative or even non-musical response [7].

The board-certified music therapist A. Blythe LaGasse did a study in which 17 participants with ASD were randomized so that eight followed a social skills group (SSG) while the other nine were assigned to a music therapy group (MTG) [6]. During this time, each group followed the same processes but the exercises would be specific to their type of therapy. For instance, in the Sensory Experience section, the SSG had a deep pressure regiment while the MTG also had a deep pressure regiment but with the added factor of song as they would have squeezes that went along with the rhythm of a song. Deep pressure is a form of tactile sensory input that is commonly delivered through squeezing, hugging, holding, and more [7]. Furthermore, it strengthens sensory processing in individuals with ASD, thereby exercising parts of the brain that are used in social functioning. An example of a group exercise is when each participant plays instruments with different timbres together. They will

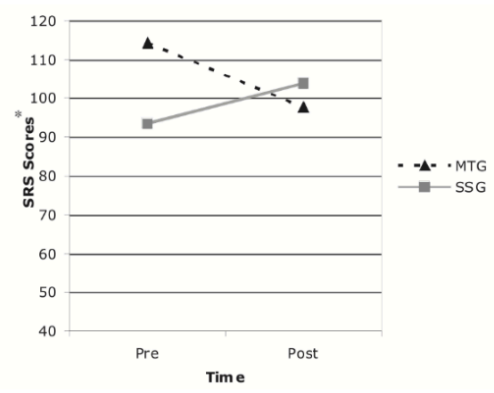

Figure 4. The interaction of the Musical Therapy Group (MTG) and the Social Skills Group (SSG) on a Social Responsiveness Scale (SRS). Lower scores means better social function (LaGasse, 2014).

have to focus on prompts to listen and take turns playing. This increases joint attention and responses to communication from others. After completing the full MTG process, they set each group's Social Responsiveness Scale (SRS) and the lower the scores correlated with better social function. The MTG had much lower scores, but the SSG scores increased [7]. Overall, with music therapy, a person with ASD can practice open social interaction better in a structured experience that is more personalized towards them to push them toward success.

Music therapy is extremely helpful as it improves social skills and joint attention in people with ASD. Studies have also shown that it specifically helps a lot in increasing eye contact and social engagement in a group setting [7]. Within the brain, music therapy helps and affects the frontal lobe, auditory and visual cortexes, the amygdala, and the frontotemporal and cortico-subcortical networks. In ASD, most of the disruptions that are seen in the brain have to do with the prefrontal cortex and this shows how music therapy helps with targeting that area. This also means that it helps and improves brain connectivity and behavior in the frontal lobe. fMRI studies have shown that music therapy increases auditory-motor and subcortical connectivity, and this increased connectivity improves the top-down processing in a person with ASD [4]. Top-down processing describes an order of processing in a hierarchy. Higher up on this hierarchy is the thinking or feeling aspect of the brain but as you go lower, it has to do more with sensing and responding. The near opposite is bottom-up processing, where the brain starts lower on the hierarchy with sensing or responding then moves up to thinking and feeling after (Figure 5). While top-down processing

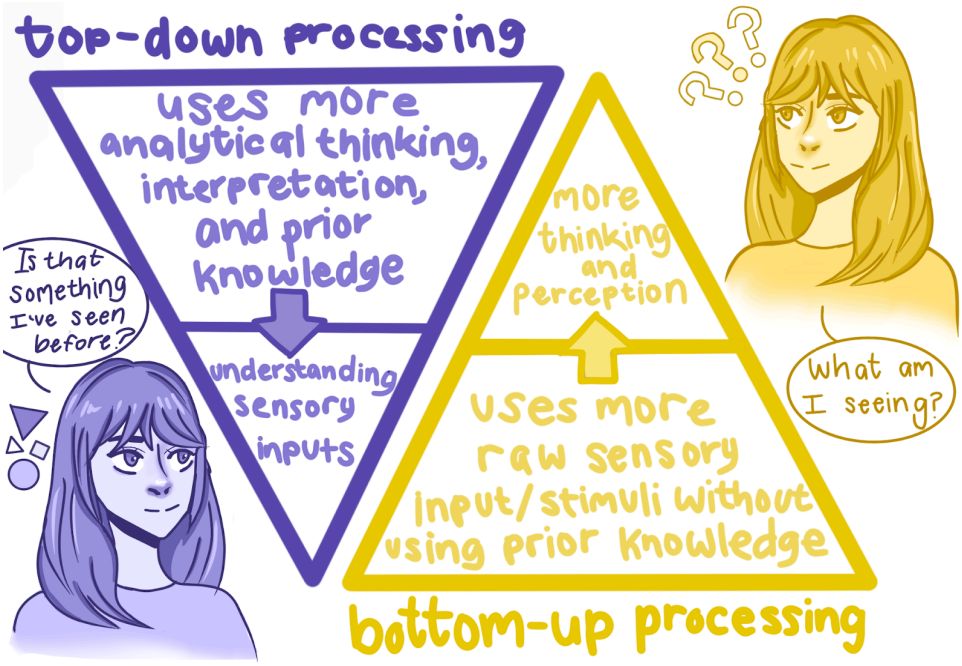

Figure 5. The difference between top-down processing (left) and bottom-up processing (right). There tends to be more bottom-up processing in an individual with ASD.

uses more prior knowledge to make inferences, bottom-up processing uses raw senses to come to conclusions without taking prior knowledge or expectations into consideration. In ASD, there is more bottom-up processing so there is an imbalance. Increasing the connectivity in the auditory-motor and subcortical complexes helps to rebalance the trade-off between top-down and bottom-up processing. This then connects to excitatory and inhibitory imbalances because of how there are more excitatory neurons in ASD similar to how bottom-up processing is more prominent. Overall, because of both of these imbalances, music therapy helps increase connectivity and more communication among neurons. At the same time, if needed, music therapy can also help reduce the connectivity between the auditory and visual cortexes. Sometimes, a person with ASD may face overconnectivity of the auditory and visual cortexes, which are both part of bottom-up processing as they are processes that are lower in the hierarchy. When this overconnectivity is reduced, it helps the overall processing to be more balanced out.

Conclusion:

Ultimately, the purpose of this paper is to demonstrate the impact and cause of having ASD, how music is normally integrated in our brain compared to how it is integrated in a person with ASD's brain, and how the impact of music can be used as music therapy to be beneficial for people with ASD. Due to the imbalance of bottom-up and top-down processing for ASD, the integration of music starts to differ a lot. The increased amount of bottom-up processing in ASD also connects to how there's underconnectivity and inhibitory neurons in distant brain regions but overconnectivity in neighboring regions. However, in a more structured environment, music can strengthen the brain and its processing, and help with behavioral responses. Furthermore, since ASD in each individual can be different, music therapy is flexible in the way that it can be used to respond to each individual's needs. It helps people with ASD identify and appropriately express their emotions. For these reasons, music therapy should be further studied and considered as a form of therapy for individuals with ASD.

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