International Journal of Healthcare Sciences ISSN 2348-5728 (Online)
Vol. 10, Issue 1, pp: (263-271), Month: April 2022 - September 2022, Available at: www.researchpublish.com

Understanding Neuroplasticity and the Brain's Potential for Change

Rachel Yun

DOI: https://doi.org/10.5281/zenodo.7043253

Published Date: 02-September-2022

Abstract: **Neuroplasticity is a relatively new concept about the brain's ability to rewire itself in certain areas. The general idea was developed in the 20th century, and it has become an intriguing field of study due to the superhuman-like feats of the brain that allows people with missing parts of the brain, impaired neurological functions, and certain mental disorders to live with more function. Neuroplasticity occurs in both animals and humans, as both react similarly to the environment, and results can be compared to reach a deeper understanding about how stress, which is a consequence of internal and external pressures, affects neuroplasticity. Other external stimuli, however, such as music, can improve the rate of neuroplasticity in people or undo damage in the nervous system. On the other hand, neuroplasticity does also have its downsides, which must be carefully avoided to prevent any issues related to mentality. In other words, while neuroplasticity can cure people of disorders, it may also be the exact reason why it developed in the first place. This curious phenomenon explores the true capabilities of the brain. This paper will describe the effect neuroplasticity has on people and the ways people can affect their rates of neuroplasticity.**

Keywords: **neuroplasticity, neuroscience, growth mindset, fixed mindset, nervous system, depression, mental disorder, brain, digital media, gene expression.**

I. INTRODUCTION

Neuroplasticity allows the brain to operate despite missing an entire sensory organ in the nervous system, a third of the brain, a half of the brain, or nearly the entire brain. Only a madman would not explore such an incredible yet relatively unknown ability of the brain. Neuroplasticity occurs at the cellular level, such as rewiring synapses or strengthening the connections between neurons, or a broader, larger-scale movement of entire, complex functions of the brain. There are factors that hinder neuroplasticity and enhance the negative sides of neuroplasticity, such as stress or mental disorders such as depression. Neuroplasticity can affect the level of addiction one suffers from, whether the source of addiction is drugs, video games, or another addictive substance. However, adding stimuli that will result in an enriched environment, such as music, will cause neuroplasticity to improve the absorbance and organization of new information, memory, and motor skills. In this way, neuroplasticity seems a bit like a double-edged sword: capable of hurting, but when carefully wielded and polished, it becomes extremely beneficial to have on your side.

II. WHAT IS NEUROPLASTICITY?

For a great number of decades, the brain was considered limited; brain cells, researchers believed, could not be created again once they died[1]. Aging was widely accepted as the reason brain cells died over time, though further research showed that this is not the case[1]. Neuroplasticity as a term was first used by Jerzy Konorski, a Polish neuroscientist, in 1948[1]. Konoski's "neuroplasticity" described visible, obvious changes in neuron structure[1]. However, even earlier than Konoski, in the beginning of the 1900s, Santiago Ramón y Cajal, a Spanish neuroscientist commonly known as "the father of neuroscience," confirmed that a person's brain was able to change after reaching adulthood[1]. His term for this process was "neuronal plasticity," in contrast to "neuroplasticity."

In the 1960s, around the time the word "neuroplasticity" became more common, scientists discovered that, after experiencing a shocking or traumatic event, neurons were capable of reorganizing, changing, and fixing themselves[1]. Stress from traumatic events was found to change the functions as well as the physical structure of the brain[1]. Several decades later, in the late 1990s, research uncovered a possibility that stress, along with aging, could be another factor that is killing brain cells[1]. The view that the brain is an unchanging organ is shifting, and the concept of neuroplasticity has come to light.

Neuroplasticity is a relatively new idea about the brain regarding its ability to, simply put, adapt to changes in the environment[1]. Depending on people's personal experiences, paths among the neurons spring to life and slip away. All memories, including memories of locations, people, and events, have underlying plasticity[2]. When something new is learned, this new part is another aspect of life that the brain had not previously encountered, and as a result, connections are created[1]. Opening these connections happens daily for the large majority of people, and it can be encouraged or stimulated within the right circumstances[1].

Neuroplasticity often takes place within the reward- and/or stress-related sections of the brain, as previously mentioned[2].The reason behind this is that it is advantageous for one's survival because people are more easily able to recall memories that increase their chances of escaping or avoiding danger altogether[2].

Even though the idea may seem quite simple, neuroplasticity is complex and filled with unknowns. Generally, there are two perspectives regarding neuroplasticity[1]. Some neuroscientists view neuroplasticity as an individual process that refers to all and any change in neuron structure or behaviors, while others believe neuroplasticity is more carefully defined as an "umbrella term" for an extensive collection of various changes and adaptations the brain makes[1]. Acceptance of the first perspective would result in a single overall theory with several main principles, and there would be one inclusive framework of neuroplasticity that could neatly define it[1]. Acceptance of the second perspective, in contrast, would require different frameworks and methods of organization to correctly categorize and comprehend each phenomenon[1]. Neuroplasticity is a "young field," and new discoveries are still being made, so neither perspective has been adopted as part of the definition of neuroplasticity[1].

There are two branches of neuroplasticity: structural neuroplasticity and functional neuroplasticity. Structural neuroplasticity describes the change in strength of connections between neurons or synapses instead of actual rewiring of the bonds[1]. On the other hand, functional neuroplasticity indicates the "permanent changes in synapses due to learning and development" [1]. Learning and development does not include quick and simple memorization of new facts; rather, learning a language or learning how to play an instrument will open new pathways and take better advantage of neuroplasticity[1].

In current times, most of the focus is on structural neuroplasticity since in the neuroscience field, functions have already been discovered to be "rerouted, relearned, and re-established," while alterations of the form and structure of the brain have many undiscovered parts, making it even more interesting and filled with possibilities[1].

III. CASE STUDIES

A. Neuroplasticity Case Study 1: Cheryl Schiltz

From one perspective, neuroplasticity may seem like a superpower, or a thing of fiction. Neuroplasticity allows people to function, even when it seems all hope is lost. With treatment or simply because of interactions with the environment, the brain will learn to overcome obstacles and change. It is what rescues people from severe mental fatigue in cases similar to that of Cheryl Schiltz.

Cheryl Schiltz is a woman who is perpetually exhausted by the imbalance of her senses[3]. When she stands up without support, her body wobbles back and forth, as if she is standing on a shaky tightrope. Even though her feet are grounded, her weight is being shifted everywhere at once, and inevitably, she falls. Even after she falls, she occasionally describes the resulting feeling as losing "the sense of the feeling of the floor…and an imaginary trapdoor opens up and swallows me" [3].

For five years, Cheryl has suffered due to the absence of her vestibular apparatus, which is a sensory organ that controls her balance systems[3]. The continuous feeling of falling has drained her completely, and Cheryl is filled with fear of the future, of falling, of growing old[3]. Being constantly on high alert has taken away her mental strength for other tasks, such as retaining her memory, calculating, or reasoning[3]. Because the link between her vestibular apparatus and her visual system is damaged, she is unable to track objects or people with her eyes[3]. Despite the damage, her vision is one of the only tools she can use to somewhat keep her balance. Once the lights turn off, she falls immediately[3]. Any kind of movement, such as a person reaching towards her, or pattern, such as zigzags on the floor, will aggravate her unbalanced state[3].

Paul Bach-y-Rita, one of the first scientists to attempt to extensively understand neuroplasticity, is able to help her. A creation of his includes an accelerometer, or sensor, in a construction hat and a tongue display, which is a piece of plastic with electrodes on it, meant to be placed on the tongue, that receives signals from the accelerometer[3]. A feeling of champagne bubbles accompanies movement of the head and body; if one leans forwards, bubbles will explode on the tip of the tongue, whereas if one leans backwards, the bubbles will swirl to the back of the tongue[3]. Eventually, a person using this device will forget that the signals are on their tongue and start to correlate the signals will their movements[3]. Simply, the signals are changing from their usual path to the sensory cortex to a new pathway that leads into the area that handles balance[3].

Although Cheryl Schiltz had close to no natural sensors, with this treatment, she was able to recover. After around twenty minutes of standing still with no support, she was able to walk and move without anything attached to her[3]. Bach-y-Rita and his team biophysicist, Yuri Danilov, increased the amount of time she was being treated, and eventually, she was able to build up her residual effect[3]. Cheryl has now completely recovered after four months of move about with no supports or treatments[3]. She no longer believes she has the disability.

B. Neuroplasticity Case Study 2: Boy, Age 6

In another case, a six-year-old boy tragically had around a third of his brain removed completely due to suffering from severe seizures[4]. These seizures did not respond to medication, and the parts of the brain that were removed were in the right side, including the occipital cortex and much of the temporal lobe[4]. These are vital for retaining basic sight and recognizing faces, objects, and words[4]. Face-blindness is thought to be a common result of extensive damage to right side pathways[4].

After the boy's surgery, researchers monitored him for three years, anxiously watching for signs of failing to function normally[4]. To their surprise, the boy's brain preserved the ability to recognize, though five years later, the boy became unable to see out of the left half of his vision[4]. This remarkable recovery was due to the left half of the brain taking over the tasks that the right side had carried out in the past, as the brain scans showed[4].

As the boy continued his normal activities, he became completely seizure-free and as a cherry on top, his IQ increased from 116 to 118, comparing his intelligence from before his surgery to after, respectively[4].

C. Neuroplasticity Case Study 3: Michelle Mack

Although the removal of a third of the brain seems drastic, Michelle Mack's story is even more extreme: she was born with only half a brain[3]. Her left hemisphere of the brain, the section that controls the right side of the body, as well as skills in logic such as in science or math, never actually developed[3]. A possibility for this result may be that while Michelle was still a fetus, her left carotid artery became blocked, stopping the flow of blood to the left hemisphere[3].

Although half her brain is missing, Michelle functions fairly normally; in fact, even a professional neurologist may not be able to tell, without a brain scan, that something as major as an entire hemisphere is missing[3]. Michelle Mack works at a part-time job, reads, watches movies, understands the news and sports, and votes in elections[3]. This is extremely extraordinary because all the operations that would normally be carried out by the left side of her brain, such as speech and language, were transferred over to her right[3].

However, it is clear from close observation that signs of her missing hemisphere show. Her right wrist is bent and slightly twisted, but still useable; similarly, a brace supports her right leg so that she can walk[3]. Because vision and movement of the right side of the body is controlled by the left hemisphere, Michelle is lacking in those aspects. Although she cannot see very clearly in her right side of vision, she is able to make up for this through extremely keen hearing[3]. By blocking out sound with her hands, she is careful to avoid sensory overload when a traffic horn blares or organ pipes ring at her church[3]. Michelle's sense of touch is also more sensitive than most, and her mother assists her in cutting off tags or other material that could cause distress due to overload of her senses[3].

In some respects, Michelle excels. When tested by asking to find similarities and differences between two different objects, such as a chair and a horse, she answered correctly and quickly, much faster than the average person[3]. She also has a phenomenal photographic memory, and, as of 2007, she can remember details of every single day back to the fall of 1984[3]. She can calculate arithmetic easily and immediately; at least, up to algebra, where more abstract concepts are introduced[3]. Though Michelle has a knack for details, she struggles to comprehend abstract concepts, such as proverbs, metaphors, and abstract thought. When a story has an implicit moral, she has difficulties stating what it is[3]. She also finds proverbs or sayings perplexing, and she has to think about what the proverb means, especially if it is one she has never heard of before[3].

Jordan Grafman is the research scientist who theorizes what could have happened inside Michelle's brain[3]. He has identified four different types of neuroplasticity: "map expansion," "sensory reassignment," "compensatory masquerade," and "mirror region takeover" [3]. "Map expansion" is a type of neuroplasticity and adaptation that happens at the edges of the brain and at the boundaries of brain areas[3]. "Sensory reassignment" is when one of the senses are blocked, such as sight, and another sense takes over and gives input to compensate for the missing sense[3]. "Compensatory masquerade" is also called "alternative strategies," and it refers to the fact that the brain knows of multiple ways to approach a task[3]. For example, a person with problems absorbing academic material through reading could perform much better with audio tapes instead. The fourth and final type of neuroplasticity, "mirror region takeover," relates most closely to the type that Michelle's brain went through. It describes how, when one hemisphere fails to carry out its tasks, the mirrored region in the brain will take on, to the best of its ability, the functions of its opposite side[3].

Michelle's brain was likely able to carry out this process of neuroplasticity because the damage to her brain was done at a very early age[3]. When a baby is first born, their hemisphere will be quite similar[3]. According to Grafman, the basic main functions are specialized as the infants grow, and if a million people's brains are compared, specific functions should not be located in exactly the same place because each person will have different life experiences that shape the brain in different ways[3].

D. Neuroplasticity Case Study 4: R222

A rat, surprisingly, was able to demonstrate the extent to which neuroplasticity can be applied. R222 is a rat in professor of psychology Craig Ferris's laboratory that had a brain that suffered from the effects of hydrocephalu[5]. Hydrocephalus was a condition in which the brain condensed, collapsed, and filled with fluid[5]. For a person or animal with this condition to have even a slim chance of survival, all their processes would have to be relocated by the brain to areas that were not submerged in fluid[5].

What is so remarkable about this rat is that it sees, breathes, hears feels, and moves normally, to the point where R222 is indistinguishable from the other rats if not for the brain scans[5]. The brain scan itself shows what looks like a blank space where the brain should be–in other words, the rat virtually looks as if it has no brain. However, Ferris clarifies that the rat's brain is not nonexistent; rather, it is more like a flat disk that had been shoved out of the way[5].

R222's life could be seen as a miracle because it has been living for two years, as of January 2020, which, converted into human age, is over 70 years[5]. The researchers in Ferris's lab ran multiple tests to observe to which extent R222 behaved the same as other rats[5]. The first puzzle tested R222's reaction to new surroundings; normal rats and R222 were each placed into Plexiglas boxes with different objects and space[5]. A maze was used to test memory and spatial learning skills, and physical behaviors were measured by closely watching how the rats crossed a balance beam[5].

R222 behaved similarly to other rats in all except one of these tests[5]. In the new environment test, while the other rats energetically moved about seemed to be intrigued, R222 stayed in place[5]. However, its reaction is not uncommon. Staying still in unexplored surroundings is a typical response in more anxious animals[5]. In the end, the tests and puzzles only confirmed that R222 functioned completely normally and with the naked eye, it was not possible to detect that something was exactly wrong with R222[5].

This is a very curious discovery. Parts of the brain that are vital for survival, such as the hippocampus, an area of the brain that controls memory, were distorted to the point where it could not be recognized from just the brain scans[5]. Only when Ferris and his team traced the chemicals in the brain were they able to recognize it[5]. Ferris describes that "the lower part of the brain stem had everything collapsed in it" [5]. The more they uncovered details about R222, the more evident it became that R222 could never have been alive if the brain had not undergone neuroplasticity.

If what was left of R222's brain had not taken over the roles of all the missing parts of the brain, surviving for two years would be impossible. However, R222 was likely born with this condition[5]. Similarly, to Michelle Mack, although both she and R222 were missing large portions of their brain, the remaining parts of their brains would have started to take on roles that were normally not controlled by that part of the brain.

R222's condition is, in fact, an extreme case, but neurologists have also found that possessing an IQ of up to about 126 and a brain mostly made fluid are not mutually exclusive[5]. Neuroplasticity is the brain's way of ensuring that people kept living. In R222's case, it extends to animals as well, showing that neuroplasticity does not occur only in people, though people may have more complex minds and emotions.

IV. DEPRESSION, ANTIDEPRESSANTS, AND NEUROPLASTICITY

Depression is often defined as a "state of chemical imbalance," and antidepressants are seen as a "cure" for this imbalance[6]. This is a generally simplistic view because depression is a mental disorder, unlike a sickness that makes one physically unwell. Depression can cause the "loss of dendritic spines, shrinkage of the dendritic tree and loss of synapses in the hippocampus and prefrontal cortex" [6]. Glia, a kind of cell in the central nervous system that are not neurons, may also decrease[6]. In cases of very severe depression or extreme circumstances, apoptosis, or cell death, may also occur[6]. Antidepressants protect against and occasionally reverse these effects, but the "stress-induced neurohistological changes" cannot be completely repaired[6]. The antidepressant treatments can also restore some functional neuroplasticity, and therefore also enhancing adaptation, learning, and memory[6].

The neuroplasticity hypothesis of antidepressant action claims that there are changes in the hippocampus, prefrontal cortex, amygdala, and other areas that explain features of depression[6]. It suggests that the definition of depression should no longer be "a chemical state of imbalance" and instead a "disorder of the hardwiring of the brain" [6].

There are several defining claims of the neuroplasticity hypothesis. One is that the effect of stress can be an explanation for the neurobiology of depression[6]. Stress "triggers and maintains" depression, so learning how to handle stress has therapeutic results. As a result, discovering exactly what impacts stress has on the brain can be a clue to the mysterious origins of depression in the brain[6]. Another assumption made by the hypothesis is that animals that model stress, depression, and anxiety are valid models to deepen understand of the neurobiological effects of stress, depression, and anxiety in people[6]. There are many similarities in animals and humans of the shifts in the endocrine system, learning, and memory, as well as "changes in the histology of certain parts of the brain, [and general] changes in behavior" [6]. Therefore, stress-induced alterations due to depression as well as adjustments after antidepressant treatment in animals can serve as valid comparisons to changes in people[6].

As observed in animal models, stress harms neuroplasticity in specific parts of the brain and enhances neuroplasticity in other parts. It is observed that in animals, antidepressant drugs reverse many behavioral effects of stress[6]. These revisions are along a time course that is parallel to the time course of the action of antidepressants in humans[6]. Therefore, it is also assumed in the neuroplasticity hypothesis that "antidepressant drugs reverse depression in humans by reversing the neurohistological effects of stress" [6].

V. THE EFFECT OF MUSIC ON NEUROPLASTICITY

Because of how it evokes emotion and causes people to act in different ways, the effect of music on the brain is undeniable. Practicing and performing music are series of actions that require wide networks in the brain, and in order to play even just one song or piece, instant associations between motor sequences and auditory signals at the moment are crucial[7].

A musician's brain is incredibly interesting in the context of neuroplasticity because musical training has continuously been connected to changes in the brain[7]. The longer the duration of the training is, the more changes may surface[7]. Musicians must combine a multitude of skills including but not limited to "auditory perception, kinaesthetic control, visual perception and pattern recognition," and they also hone the ability to commit long pieces to memory[7]. Even if a song is not memorized, musicians translate what they visually observe into movements of their fingers, mouths, or feet.

The demands of instrumental practice bring about two levels of adaptation in musicians: macrostructural and microstructural[7]. Macrostructural adaptation refers to the anatomical, or visible, distinctions in the brain between professional musicians, amateur musicians, and non-musical people, and microstructural adaptation describes very fine modifications of strength in the synapses which can be observed in distributed cortical networks[7]. Microstructural changes are quite subtle, and these functional variances occur after increased experience or more advanced practice has taken place[7].

Different instruments may produce slightly varying results in the brain. For instance, instruments that require the movement of two hands, such as the piano, will further develop the cortical functionality in symmetric areas of the brain that include motor, auditory and visuospatial processing[7]. However, musical training with instruments involving less bimanual action, such as the violin, will yield less thorough development as compared to the piano[7]. Figure 1 shows the variety of mechanisms that occur inside the brain when an instrument is played. According to multiple studies, there are "differences in the size of the primary motor cortex size, the cerebellum, the planum temporale, the corpus callosum, Heschl's gyrus and the arcuate fasciculus"[7]. The size of these areas of the brain correlates with the varying ability of the musicians to identify and process auditory changes[7].

The improved connectivity between the synapses that occur as an outcome of microstructural adaptation "further acts as a basis for learning and memory through alterations at the level of neural circuits" [7]. These alterations consist of changes in the strength or number of synaptic links, as well as adjustments in the roles or quantity of postsynaptic receptors that are involved in the release of transmitters and the formation of new synapses[7].

These modifications in the structure of the brain, however small, make a significant difference. The improved strength of the synapses could have an effect so that absorbance of new knowledge and memorization is easier; neuroplasticity could change specific parts of brain circuits that were already active[7]. Skills in distinguishing sounds may also develop more in the musically suited areas of the brain first, then slowly spread into other domains that control different functions, such as speech, emotion, and general hearing[7].

Even though the external environment may not require any specific part of the brain to be activated, the brain continues to process information and further reinforce recent learning, as well as preparing often-used areas of the brain[7]. Improving and triggering "this pattern of increased resting state connectivity" is predicted to be a result of musical training[7]. However, there is no definitive research to show clear differences between musicians and non-musicians regarding the connectivity of the brain at rest, or in other words, when the body is in a "task-free condition" [7].

Music can also be a form a therapy for the elderly recovering from "neurological impairments, such as neurodevelopmental disorders and acquired brain injuries" [7]. Even if a person is not actively involved in music by playing an instrument, singing, etc., listening to music benefits the "working memory, attention, semantic processing, target detection and motor function"[7]. For instance, consider Parkinson's disease. Parkinson's disease is a neurological disorder that causes sporadic shaking, overall stiffness of the body, and struggles in coordination and balance[12]. A common effect of Parkinson's disease is suddenly feeling as if one's feet are frozen to the ground. However, music has been used to correlate a certain movement or an action to a particular song, and this assists people in recovering from this "freezing of gait"[8]. Neurological surgeries have been unable to make as much progress in the rewiring of the brain circuits as music has[8].

The Hebbian theory of neuroplasticity applies to this situation; for two neurons to forge a new connection, they must simultaneously fire action potentials[8]. Because music interacts with a wide variety of areas in the brain, it can activate memories, emotions, and actions through listening, reading, playing, and moving to music[8]. Neuroplasticity is facilitated through the power of music.

Music sets up an "enriched environment" in the brain that can boost the brain's function to memorize, process, and organize new information. By pairing music with "movement, vocalization, breathing, and heart rate," music therapists can help the synchronous firing of neurons in their patients' brains, helping them function more easily in society, although an explicit cure for their neurological condition may not exist[8].

VI. GENE EXPRESSION IN NEUROPLASTICITY

Long-term neuroplasticity in the brain has great significance to learning and maintenance of memory, as well as the development and eventual treatment of psychiatric disorders[2]. Molecular and cellular mechanisms play a part in different types of plasticity, and long-term neuroplasticity does rely on gene expression changes[2]. Long term potentiation (LTP) and long-term depression (LTD) are the most defined cellular mechanisms in plasticity[2]. They are both used to describe lasting changes in the "efficiency of synaptic transmission that occur in response to repeated stimulation" [2]. LTP and LTD also contribute to the development of every type of memory formation in the brain[2].

An indication that LTP was a gene-related part of neuroplasticity was when LTP did not seem to persist when animals were injected with protein synthesis inhibitors[2]. This lack of action showed that LTP formation in the hippocampus depended on new gene expression[2]. The protein synthesis inhibitors also have major effects on "memory formation, reactivation, and reconsolidation," which allowed researchers to conclude that new protein expression was necessary for each of these functions[2].

For a long time, scientists believed that protein synthesis was only required for the later stages of LTP or LTD[2]. However, in 2006, a study by Fonseca demonstrated that early stages of LTP can also depend on protein synthesis, given that there are elevated levels of synaptic activity[2].

Transcriptional and post-transcriptional changes are clearly vital to the development of neuroplasticity, though the specific mechanisms themselves are complex and not perfectly understood[2]. Furthermore, the transcriptional target genes involved in long-term plasticity have not all been identified[2]. Research in the regulation of transcription factors, chromatin structure, and mRNA processes will further deepen the understanding of the facilitation of long-term changes in the brain[2]. The study of MicroRNA (miRNA) is especially important because its exact role in plasticity will also provide scientists with ideas to improve a technique that is used to “knock down” the expression of genes in separate brain regions in adult animals[2]. The purpose of this technique is to analyze the functions of these specific genes in long-term changes[2].

Research of gene expression in neuroplasticity will pave the way for more specialized or even completely new treatments for memory disorders, drug addiction, and depression, as well as other conditions[2].). If the understanding of these molecular and cellular mechanisms is enhanced, it may eventually be possible to specifically develop a particular area of the brain or block parts of neuroplasticity with undesirable effects[2].

VII. DOWNSIDES OF NEUROPLASTICITY

As technology develops, younger generations are inevitably exposed to digital media. One possibility, some say, of this exposure is that “technologies are infantilizing the brain into the state of small children who are attracted by buzzing noises and bright lights”[9]. In this society, digital media plays a prominent role. Therefore, a primary concern is that the younger generations are becoming “unempathetic, passive, intellectually shallow and uncritical, desensitized, depressed, and attention deficient”[10].

There are two different debates regarding the effect digital media has on teenagers and children. One side argues that technologies are strengthening cognitive abilities, such as multitasking, which becomes a crucial skill to “live successfully in the accelerated space–time compression of our postmodern world” [10].

Some believe that younger generations that grow up side-by-side with quickly evolving forms of digital media make more progress in developing skills that allow them to “parallel-process” and show a clear advantage of processing information more quickly[10]. However, during certain periods of a person’s life, their brain becomes more vulnerable to forming pathways and networks between synapses in the brain based on input from their social and environmental situations[10]. One of these periods include adolescence, which is why the extensive absorption of digital media is intensely discussed[10].

Depending on what kind of content they consume, adolescents could become very different. For instance, at the University of Michigan, a study revealed that after a walk in a natural environment, compared to a walk in a hectic urban setting, the ability of students to learn improved[10]. The conclusion drawn from this study was that an overload of information from the environment, demonstrated by the urban setting, fatigued the brain and hurt the learning process[10]. This urban setting could be compared to multitasking; the “constant bombardment of digital stimuli” would easily tire the brain and prevent it from getting any rest in between different activities[10]. The lack of rest for the brain impairs people’s ability to organize long-term memory and information learned[10].

One, and possibly the only, downside to neuroplasticity is that the connections in the brain can be rewritten. Ironically, this is also one of its biggest advantages. though digital media may increase the level of multitasking, this does not necessarily mean that the same quality of work will be produced[10]. Generally, errors in performed tasks increase, and the time taken to complete each of those tasks increase significantly[10]. Consumers of a large quantity of media also have a reduced ability to “filter irrelevant information and to manifest ‘‘breadth-biased’’ rather than selective and focused cognitive control[10].

One of the most popular forms of digital media is video games, and studies have shown that levels of dopamine in the body correlates with the amount of time spent playing[10]. Therefore, due to constant play, dopamine is constantly and regularly provided. Among “computer game addicts,” studies show a dramatic reduction in their overall levels of dopamine, which indicates that the functions of the brain have changed; these people now are physically dependent on the stimuli to increase their dopamine to normal levels[10]. The lowered levels of dopamine will inevitably lead to withdrawals, and withdrawals will lead to “dopamine-seeking behaviours, not unlike drugs, alcohol, gambling, or shopping” [10]. The consumption of digital media becomes an addiction.

During adolescence, the prefrontal cortex undergoes the most significant changes[10]. It is associated with different parts of behavioral control, including “decision-making, working memory and multitasking, and also with social cognitive skills including empathy, perspective taking, and emotional recognition” [10]. The period of “vulnerabilities and opportunities” is the developmental period in which the prefrontal cortex is altered[10]. The adolescent becomes vulnerable to factors that may change the previously stated capacities. Factors that have shown to influence the capacities are digital media and the Internet.

Neuroplasticity in the teenage brain is a source of risk because of the wide possibility of results, ranging from mental illness to behavior issues[10]. In adolescent development, there is an “imbalance between the affective/motivational system and the cognitive/regulatory system" as well as increased specialization of areas of the brain that have to do with "cognition, executive function, and emotional processing" [10]. When the affective/motivational systems and cognitive/regulatory systems are not balanced, teenagers are hypothesized to be more prone to making questionable and risky choices[10]. While neuroplasticity may seem like an untapped resource full of potential, this is not the case in some situations. The most advantageous component of neuroplasticity (the ability of the brain to be altered through external stimuli) can also be harmful if people do not control their environment to a certain degree.

VIII. THE GROWTH MINDSET APPROACH

A growth mindset is a relatively new concept, and it refers to a mindset in which one believes that "one's innate skills, talents, and abilities can be developed and/or improved with determination"[1]. This idea mirrors neuroplasticity because neuroplasticity is defined as the physical ability of the brain to rewire synapses, form new connections, and develop areas of the brain, even if one is far past the developmental period of childhood and adolescence. A growth mindset is a way of thinking that celebrates the effort and the process undertaken to achieve a certain result, rather than only considering the result. The main idea behind growth mindset--"that [one] can get smarter, better, or more skilled at something through sustained effort" -- overlaps with the hopeful message that neuroplasticity presents[1].

The idea of the growth mindset is most often used with students and inside classrooms. Angela Lee Duckworth, a seventh-grade math teacher in New York City, noticed that, among her students, high IQs were not necessarily correlated with top grades[11]. Occasionally, some students with the highest IQs in the classroom would not have the best grades, and other students with low IQs would outperform all other students[11]. Duckworth decided to return to graduate school to study the students' motivations, or lack of motivation, to succeed academically[11]. The "key to success" that she discovered was grit[11]. She defines grit as not simply "resilience in the face of failure, but also having deep commitments that you remain loyal to over many years" [11]. Grit increases as people age, because the appreciation of effort also increases as people face more difficult tasks throughout the course of their life[11].

A fixed mindset is the opposite of a growth mindset. Students with a fixed mindset believe, consciously or subconsciously, that their intelligence is measurable and limited. They see a certain level of intelligence as a permanent characteristic they are born with, not something they can develop as time passes[11]. This mindset is harmful to students because instead of, for instance, attempting to improve test grades, they may decide that this is the best they could do. Eventually, this mindset could also cause low self-esteem if the students do not believe that they are in control of their own grades, and instead believe that the test was too difficult for their level of intelligence. The expectations of parents could also exacerbate the problem. Carol Dweck, the psychologist credited with defining the growth mindset and discovering distinctions between the growth and fixed mindset, also noted that a common reassurance tactic parents use when their child is struggling in school is reminding them how smart they are[11]. She advises against this, however, because it "confirms the fixed mindset and makes kids all the more certain that they don't want to try something difficult--something that could lose them their parents' high regard" [11].

A growth mindset shows that by simply thinking that one can make progress, one will make progress. By celebrating the effort, rather than the result, it gives hope to students that may not always be at their best. This is similar to the message that neuroplasticity provides to people struggling due to brain injury, deficiency, or illness: your current state is not permanent.

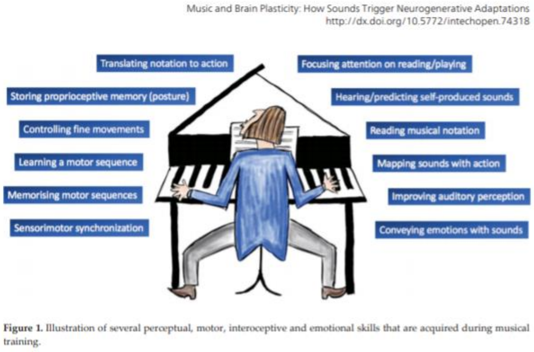

Figure 1: Demonstration of strengthened perceptual and motor skills because of increased musical activity

IX. CONCLUSION

Though there has been extensive research done on neuroplasticity, there is still much information left to uncover. Neuroplasticity can change the worlds of people, either in subtle ways or drastically and miraculously. Through musical training, one's ability to learn is enhanced, and with the growth mindset, one's motivation to learn is enhanced. In other cases, when people or animals are born without vital areas of the brain that control a myriad of functions, different parts of the brain will take over the operations, allowing the person or animal to almost live their life as if nothing is wrong. However, how gene expression contributes to neuroplasticity is not as clear. Clearer knowledge about these relations would result in more effective medical cures for mental disorders, drug addictions, and other issues in the central nervous system. Further research in this regard would remove the stigma concerning these themes. Society would benefit if a clear understanding of neuroplasticity in many different aspects can be reached.

REFERENCES

[1] Ackerman, Courtney E. "What Is Neuroplasticity? A Psychologist Explains [+14 Exercises]." *PositivePsychology.com*, 28 Apr. 2020, positivepsychology.com/neuroplasticity/.

[2] McClung, Colleen A, and Eric J Nestler. "Neuroplasticity Mediated by Altered Gene Expression." *Neuropsychophar macology*, vol. 33, no. 1, 29 Aug. 2007, pp. 3–17., doi:10.1038/sj.npp.1301544.

[3] Doidge, Norman. *The Brain That Changes Itself : Stories of Personal Triumph from the Frontiers of Brain Science*. Penguin Books, 2007.

[4] Biegler, Paul. "Boy Loses Huge Brain Section, His IQ Goes Up." *Cosmos Magazine*, 1 Aug. 2018, cosmosmagazine. com/biology/case-study-boy-loses-huge-brain-section-his-iq-goes-up.

[5] Bracci, Aria. "A Rat Had Basically No Brain. But It Could Still See, Hear, Smell, and Feel." *News Northeastern*, 22 Jan. 2020, news.northeastern.edu/2020/01/22/this-rat-that-had-no-brain-it-somehow-lived-a-normal-life/.

[6] Andrade, Chittaranjan, and Sanjay Kumarn Rao. "How Antidepressant Drugs Act: A Primer on Neuroplasticity as the Eventual Mediator of Antidepressant Efficacy." *Indian Journal of Psychiatry*, vol. 52, no. 4, 2010, p. 378., doi:10.4103/0019-5545.74318.

[7] Reybrouck, Mark, et al. "Music and Brain Plasticity: How Sounds Trigger Neurogenerative Adaptations." *Neuroplasticity - Insights of Neural Reorganization*, 6 June 2018, doi:10.5772/intechopen.74318.

[8] Stegemöller, Elizabeth. "Exploring the Mechanisms of Music Therapy." *The Scientist Magazine®*, 28 Feb. 2017, www.the-scientist.com/features/exploring-the-mechanisms-of-music-therapy-31936.

[9] Derbyshire, David. "Social Websites Harm Children's Brains: Chilling Warning to Parents from Top Neuroscientist." *Daily Mail Online*, Associated Newspapers, 24 Feb. 2009, www.dailymail.co.uk/news/article-1153583/Social-websites-harm-childrens-brains-Chilling-warning-parents-neuroscientist.html.

[10] Choudhury, Suparna, and Kelly A. Mckinney. "Digital Media, the Developing Brain and the Interpretive Plasticity of Neuroplasticity." *Transcultural Psychiatry*, vol. 50, no. 2, 18 Apr. 2013, pp. 192–215., doi:10.1177/1363461512474 623.

[11] Hochanadel, Aaron, and Dora Finamore. "Fixed And Growth Mindset In Education And How Grit Helps Students Persist In The Face Of Adversity." *Journal of International Education Research (JIER)*, vol. 11, no. 1, 2015, pp. 47–50., doi:10.19030/jier.v11i1.9099.

[12] "Parkinson's Disease." *National Institute on Aging*, U.S. Department of Health and Human Services, www.nia. nih.gov/health/parkinsons-disease#:~:text=Parkinson%27s%20disease%20is%20a%20brain,have%20difficulty%20 walking%20and%20talking.