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Neuroplasticity Beyond Childhood: Evidence, Influences, & Limitations

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ABSTRACT

This paper explores neuroplasticity in adults, focusing on scientific evidence that shows the adult brain can continue to change and adapt. It explains how neuroplasticity supports learning and cognitive function and may help protect against certain diseases. The paper also examines strategies to enhance neuroplasticity, while reviewing studies with negative results, thus offering a balanced perspective. In addition, the roles of social engagement and stress are discussed to show how the environment factors influence neuroplasticity. Finally, it reviews the modern advances as well as the current limitations in our understanding of the topic.

Keywords: *Adult Neuroplasticity, Physical Exercise and Brain Health, Social Engagement and Stress, Enhancing Neuroplasticity, Environmental Influence on Neuroplasticity.*

INTRODUCTION

Santiago Ramón y Cajal, the father of modern neuroscience, describes neuroplasticity as "nonpathological changes in the structure of adult brains" (Fuchs and Flügge 1). In simpler words, Neuroplasticity is the ability of the brain to change and adapt itself by forming new neuronal connections, strengthening old ones, and reorganizing itself in response to injury, experiences, or learning.

For a long time, it was thought that the adult human brain was incapable of neuroplasticity and change. Researchers believed that the brain was only malleable until a certain age, and once you pass that, your brain will stay the same and not change.

Take this experiment, for example.

In 1963, Wiesel and Hubel (1963a) conducted an experiment where they took a young kitten and covered one of its eyes, and they reported a loss of cells in the deprived eye of the kitten, specifically in the lateral geniculate nucleus (LGN). The same test, Adult-onset monocular deprivation, was conducted in an adult cat, and they found that this had no effect on their LGN size. Similarly, "early visual deprivation resulted in a profound effect in the striate cortex such that nearly all of the recorded cells responded only to inputs conveyed by the non-deprived eye," (Mowery and Garraghty 2). This basically means that when the eye was covered in the kitten, there was a big effect in the striate cortex (the part of the brain that processes vision) such that almost all the cells only responded to inputs from the non-deprived eye, and didn't respond to the covered eye. However, when this test was done, no such effect was taking place when the deprivation began in adulthood. This research showed that early childhood is a very sensitive time for brain development, and most change happens at this age (Fuchs and Flügge 1).

Despite this previous belief, new research has shown that the adult brain is, in fact, susceptible to change. There are numerous examples of adult neural plasticity, which we will discuss in the next few pages.

EVIDENCE OF NEUROPLASTICITY IN ADULTS

In a study conducted by Maguire et. al (2000), it was found that experience shapes the brains of humans. In their research, they found that London taxi drivers, with their detailed knowledge of the complex street plans, had an enlarged posterior hippocampus. The size of the hippocampi directly correlated with the number of years spent driving a taxi in the complex streets of London, which suggests that the "observed difference was indeed a result of experience, rather than a pre-existing brain characteristic that predisposed people to become taxi drivers" (Valkanova et al. 892).

The first longitudinal study in this area investigated visuo-motor learning. In their study, Draganski et al. (2004) discovered that learning to juggle over a span of three months was associated with an increase in the volume of gray matter in the visual motion areas bilaterally. This increase still persisted 3 months later, but it was reduced compared to when they first started learning. Driemeyer et al. (2008) used the same design to investigate the temporal aspect of this increase and found that it can be after as little as a week of starting training. They also showed "that neither performance nor exercise alone could explain these changes and concluded that to induce structural changes learning of a new task itself is more important than continuous training of an already-learned task" (Valkanova et al. 892). In a study conducted by a different group on the same topic, they attempted to replicate the earlier juggling study. After six weeks of learning how to juggle and training, Scholz et al. (2009) found that again, that there was an increase in GMV (gray matter volume), however, this time it was in different regions of the brain, mainly the medial occipital and parietal cortex; however, this increase was sustained after up to 4 weeks without practice. Other motor training experiments that have been proven to increase GMV in certain parts of the brain are 40 hours of golf practice over 150 days (Bezzola et al., 2011) and 5 hours over 7 days of practicing a visuo-motor task involving optical rotation (Landi et al., 2011). (Valkanova et al. 892).

Another study shows a change in GMV after a very short amount of time. In a study conducted by Kwok et al. (2011), they found an increase in GMV in the left visual cortex after just *2* hours of learning color names, while Bueti et al. (2012) found an increase in GMV in the right cerebellar hemisphere after a mere one hour of temporal discrimination training. These studies show that it is possible for gray matter to increase in the brain in a short amount of time, although these last two studies did not use any control group to measure alongside, which makes interpretation of the results more difficult.

HOW DOES IT MAKE YOUR BRAIN SHARPER ?

Neuroplasticity is not just about repairing the brain after injury, but also about making the brain function more efficiently and intelligently. When you challenge yourself by practicing a new skill, such as learning a musical instrument, studying a new language, or solving complex puzzles, your brain undergoes both functional and structural changes. These activities strengthen existing neural pathways and create new ones, which increases what scientists call cognitive reserve. Cognitive reserve acts like a buffer that makes your brain more adaptable and efficient, allowing you to think more quickly and flexibly when faced with challenges. Over time, as you continue to expose your brain to new learning opportunities, tasks that once required effort begin to feel automatic because your neural circuits become more efficient. According to Lövdén et al. (2010), training and challenging the brain through different kinds of learning leads to structural changes in regions associated with memory and reasoning (PubMed). These changes explain why adults who engage in regular mental training are able to process information more quickly, recall memories more easily, and improve their problem-solving skills. Stern (2012) also emphasizes that lifelong mental activity builds a stronger cognitive reserve, which essentially helps the brain “rewire” itself to stay sharp for longer periods of time and to handle new and unexpected demands more effectively. In short, neuroplasticity allows the adult brain to not only learn but to keep upgrading itself, leading to long-term benefits in intelligence and mental sharpness.

DISEASE PREVENTION

Another major aspect of neuroplasticity is its ability to protect the brain from disease and help it heal after damage. Stroke recovery is one of the clearest examples: when a part of the brain is damaged, other regions can sometimes reorganize to take over the lost functions, which allows patients to regain skills like speech or movement over time. This process relies on the brain’s plasticity mechanisms, such as forming new synapses and strengthening alternative pathways. Research has shown that stroke patients with higher cognitive reserve often experience better recovery outcomes because their brains are more flexible and capable of reorganizing (Rosenich et al.) Similarly, in neurodegenerative diseases like Alzheimer’s, lifelong learning and mentally engaging activities are associated with a slower progression of symptoms. Stern (2012) explains that individuals with greater cognitive reserve can tolerate more brain pathology before showing clinical symptoms, essentially delaying the onset of memory loss and cognitive decline (PubMed).

This protective effect of neuroplasticity is why therapies aimed at stimulating the brain are becoming increasingly important. Approaches like mindfulness, physical exercise, cognitive training, and even non-invasive brain stimulation are being studied for their ability to trigger plastic changes in neural networks. For example, recent studies on cognitive stimulation therapy in Alzheimer’s patients found improvements in both cognitive performance and functional connectivity in memory-related brain regions (Frontiers). These findings highlight the role of neuroplasticity not only as a mechanism for recovery after injury but also as a defense system that helps preserve brain function throughout life. Overall, neuroplasticity plays a dual role: it sharpens the mind through continued learning and protects it from decline by allowing the brain to reorganize and adapt in the face of disease.

ENHANCING NEUROPLASTICITY

While learning and mental exercise are key for building neuroplasticity, lifestyle factors like diet and sleep play an equally important role in keeping the brain healthy and adaptable. Getting enough quality sleep helps consolidate memories and strengthens the neural connections formed during the day. During deep sleep, the brain clears out toxins and reorganizes information, which directly supports plasticity and learning. According to Walker (2017), sleep is one of the most powerful tools for brain optimization, as it not only restores energy but also enhances memory formation and emotional regulation (Walker, Why We Sleep). Similarly, a proper diet provides the nutrients needed for neurons to grow, communicate, and repair. Diets rich in omega-3 fatty acids, antioxidants, and vitamins—like those found in fish, nuts, fruits, and vegetables—have been shown to promote the production of brain-derived neurotrophic factor (BDNF), a protein essential for forming new neural connections. Gómez-Pinilla (2008) explains that “food is a powerful environmental factor that modulates brain plasticity,” linking nutrition directly to learning and mental health (Chen and Goodwill 3). On the other hand, poor sleep and unhealthy eating habits can reduce BDNF levels and increase inflammation, which can slow down neuroplastic processes. This means that maintaining a balanced diet and getting consistent, restful sleep work together to keep the brain flexible, resilient, and ready to learn.

Physical exercise is another powerful way to enhance neuroplasticity and overall brain function. When you move your body, especially through aerobic activities like running, cycling, or swimming, your brain releases chemicals that promote the growth and connection of neurons. Exercise increases the production of brain-derived neurotrophic factor (BDNF), often called “fertilizer for the brain,” because it helps neurons grow stronger and form new synapses. According to Cotman, Berchtold, and Christie (2007), physical activity enhances learning and memory by stimulating neurogenesis in the hippocampus, a brain region responsible for storing and retrieving information (Lövden et al. 2). Regular exercise also improves blood flow to the brain, which provides oxygen and nutrients necessary for cell repair and growth. In addition, exercise helps regulate mood and reduce stress hormones, both of which play a role in maintaining healthy brain function. Studies have shown that even moderate activity—like brisk walking several times a week—can increase brain volume in areas related to memory and executive function (Erickson et al., 2011) (Lövden et al. 4). Overall, physical exercise acts as one of the most effective natural ways to enhance neuroplasticity, improving not only physical health but also mental sharpness, emotional well-being, and long-term brain resilience.

NEGATIVE STUDIES

While we can see many positive changes in GMV when looking at these studies, it is important to note that there are also a few negative studies that show either no change or even a decrease. For instance, in a study conducted by (Tang et al., 2010), no change in gray matter volume was discovered after 11 hours of integrative body-mind training, as well as after 1 hour and 40 minutes of motor training on a sequential pinch force task (Valkanova et al. 900). There are also two other studies that show a change in function.

After two weeks of training on a motor adaptation, which is just a test used to find out how people adjust their movements in response to changes in their environment or body, "there were fMRI changes in brain activity but not structural changes" (Valkanova et al. 900). Furthermore, Mozolic et al. (2010) found that although a training program reduces cross-modal distraction in older adults resulted in a greater increase of CBF (cerebral blood flow) than in a control group, it did not lead to a significant alteration in GMV. In both of the studies, the changes in function were associated with increased performance, which suggests that they may precede structural changes and are therefore a more sensitive marker for experience-dependent plasticity; however, methodological limitations can't be overlooked.

A possible explanation for these negatives is related to the type of intervention. For example, Fields (2013) argued that the task used in the study by Thomas et al. (2009), i.e. "learning to operate a joystick when the direction of the controls is reversed, was less challenging than many of the tasks used in studies reporting positive findings, and therefore improving on this task might not require structural remodeling of the brain." Also, this task was more ecologically valid, which makes it likely that the participants had encountered similar tasks in their day-to-day life. Secondly, the negative studies always had a relatively short duration and/or intensity of the interventions, ranging from one hour and forty minutes over 5 days (Gryga et al., 2012) to 11 hours (30 minutes per day over 30 days; Tang et al., 2010).

Although, on the contrary, a study of mirror reading had two weeks of fifteen minutes a day practice only, and the authors (Ilg et al., 2008) still found an increase in GMV. It is possible that the duration and intensity of training that is required to create structural changes in the brain depends on the task and the region of the brain it involves (Valkanova et al. 900).

SOCIAL ENGAGEMENT AND STRESS

Social engagement is a very important part of an adult's daily life and can have a profound effect on learning, as these experiences shape brain structure and functions based on prior expectations, beliefs, and attitudes. The regulation of social behaviours has been shown to start adult neurogenesis (Gomazkov, 2018), while positive social engagement is extremely important for keeping cognitive function when you are older, later in life (Park et al., 2014). In addition to that, social interaction can also promote physical and mental well-being. For example, 'positive social interventions that promote wellbeing, such as cognitive therapy and meditation, have been shown to change structural and functional properties of the brain, providing support for the social environment's influence on neuroplasticity' (Davidson & McEwen, 2012). As the relationship between learning and wellbeing is bidirectional (Jenkins & Mostafa, 2015; Yu, Shek, & Zhu, 2018), social adult learning may indeed also promote wellbeing, which in turn may preserve cognitive function and continued participation in new learning opportunities over the lifespan.

The complexity of social relationships and demands for time, such as work and family responsibilities in adulthood, differ substantially from childhood and adolescence. Therefore, an important consideration in the field of neuroplasticity and learning is the influence of chronic and negative stress. There is still much unknown about the field of neuroplasticity and stress, as it is still in its infancy; however, emerging evidence has begun to untangle its complex relationship to learning and neuroplastic changes to the brain. "It has been proven that a certain amount of stress (often mimicked through the administration of cortisol hormone) during learning could increase attention and memory encoding; however, negative stress, which is usually chronic or perceived, can reduce the quality and the nature of learning and memory" (Vogel & Schwabe, 2016). "Specifically, stress may impact the retrieval of memories and cognitive flexibility, making it difficult to unlearn prior information to allow for new neural connections to be formed (Vogel & Schwabe, 2016)" (Chen and Goodwill 10). The behavioural data which shows the negative effects of stress on chronic learning and memory has been supported by mechanistic models in animals, "demonstrating that chronic and negative stress can impact the structure of the hippocampus, amygdala, and pre-frontal cortices, areas involved in social recognition, fear response, memory, and higher order cognition (Davidson & McEwen, 2012)" (Chen and Goodwill 10). For example, in college students, chronic stress altered the functional connectivity of subregions in the hippocampus (Chen et al., 2019), which may explain the observed negative consequences in memory performance.

ADVANCES AND LIMITATIONS OF OUR CURRENT UNDERSTANDING

Although neuroplasticity is now well known throughout the scientific community and is well studied, there was a time when this was not the case. At first, neuroplasticity was thought to be impossible for people once they had stopped growing. It was thought that once you have stopped growing, your brain won't be able to change and is compartmentalized, specialized, and fixed. But then, in the early 1970s, a scientist named Michael Merzenich discovered that the brain was, in fact, able to change after conducting a series of experiments on adult rats and cats. This finding forever changed the way we think of neuroplasticity and marked a significant milestone in the discoveries that have led us to our current understanding (Mowery and Garraghty 2). A new technology that has recently emerged can "establish a direct communication pathway between the brain and external devices, enabling faster and more intuitive communication and control for individuals with motor disabilities caused by stroke, spinal cord injury, limb amputation, and degenerative neurological disorders." Age is also a significant factor that significantly influences neuroplasticity. When one is young "important structural and functional changes tend to predominantly occur." (Voss et al. 2) On the other hand, when one is older, the chances of neuroplasticity occurring decrease a great deal. According to the United Nations, the population of people aged 60 is estimated to reach 25% by 2050, which reflects a trend towards global population aging (Marzola et al. 12). The capacity of the nervous system to regenerate and compensate for neuronal loss is referred to as the 'brain reserve'. The ability of your brain to fight off diseases like Alzheimer's and prevent age-related neuronal loss is weakened significantly as you get older. "On the other hand, regulation of neuroinflammation and oxidative stress, as well as maintenance of calcium homeostasis, can promote cellular resilience and neuronal circuit adaptation and ultimately increase cognitive reserve" (Marzola et al. 13). However, as the brain gets older, it does experience significant structural and functional changes, mainly in the hippocampus and cerebral cortex.

Depending on the cognitive reserve of the brain, changes and alterations in neurons and their connectivity may decrease cognitive function and increase the risk of age-related neurological disorders such as Alzheimer's and Parkinson's Disease (Marzola et al. 13).

CONCLUSION

The study of neuroplasticity in adults has transformed our understanding of the human brain, shifting it from a once-believed fixed and unchangeable organ to one that is dynamic, adaptable, and capable of lifelong growth. Early research, such as the work of Hubel and Wiesel, suggested that meaningful structural change was limited to early development.

However, decades of subsequent evidence—from London taxi drivers developing enlarged hippocampi to adults forming new gray matter after learning skills like juggling, demonstrate that experience continues to reshape the adult brain in profound ways. These structural and functional changes not only enhance cognitive abilities such as memory, attention, and problem-solving but also contribute to long-term brain health by building cognitive reserve, protecting against disease, and improving recovery after injury.

At the same time, the research shows that neuroplasticity does not operate in a vacuum. Lifestyle factors such as sleep, diet, physical exercise, and meaningful social engagement all play crucial roles in supporting or hindering the brain's ability to reorganize. Positive habits, like regular aerobic activity, nutritious eating, and mentally stimulating environments, promote neurogenesis and strengthen neural networks, while chronic stress or limited stimulation can reduce the brain's capacity to adapt. Even with strong evidence of adult neuroplasticity, studies with mixed or negative results highlight important limitations and demonstrate that not all activities, durations, or learning tasks produce measurable structural changes. These findings emphasize the need for continued research to better understand why certain forms of training transform the brain while others do not.

Despite the challenges, advances in neuroscience and technology, such as neuroimaging and brain-computer interfaces, continue to expand our knowledge of how the adult brain learns, heals, and evolves. What once seemed impossible is now accepted: adults retain a remarkable ability to grow and adapt throughout life. This understanding not only reshapes scientific perspectives but also empowers individuals, showing that learning new skills, staying socially connected, and maintaining healthy habits can meaningfully shape the brain's structure and function. Ultimately, neuroplasticity in adulthood offers a hopeful message: the brain remains capable of change, resilience, and improvement well into later life, and our choices play a powerful role in shaping that journey.

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