AN ANALYTICAL REVIEW ON COGNITIVE TRAINING FOR BEHAVIORAL IMPROVEMENT, BRAIN REWIRING AND MEMORIZATION DURING ADOLESCENCE PERIOD USING NEURAL PLASTICITY

Abstract

Projection of neural connectivity occurs after some critical synaptic alteration during adolescence period. However, the adolescent brain is yet to be relied on pre-frontal cortex. On the other hand, hormonal changes, emotions, impulsive behaviors affect the brain maturity harshly which ultimately resists the development of brain. Hence, the adolescent brain needs to be rewired during such crucial impulsive age. Memories are associated with brain-rewiring; hence its potentiality needs to be retrieved efficiently for memory preservation. Till date, there is no reliability of diagnosis or medication to improve the potentiality of brain. Therefore, Neural Plasticity is the most approachable way to reorganize the neural pattern and boost up brain rewiring. This article is intended towards analyzing the hormonal and psychological attributes of brain during adolescence period and implicating neural plasticity as a cognitive training process to facilitate synaptic activities in neurons. For a holistic neuro-anatomical improvement, neural plasticity is served as the driving force to rewire brain functionality. It brings an immense change in neural pattern, there by triggers the synaptic activities. Although an inflicted fluctuate in plasticity level may impair the growth of rewiring, adolescent brain can regain its plasticity no sooner. Instead of any pharmacy dependent technique, brain stimulation can be followed on the basis of cognitive trainings for the overall development of adolescents.

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I. INTRODUCTION

Adolescence period is the most sensitive phase of life, ambiguous for its dramatic neural and psychological changes. It encompasses with vigorous puberty hormones that effecting emotional, behavioral and experiential independency between the ages of 12 years to 19 years which influence neural transition. The complex neural transition initiates from the genetic blueprint and synaptic synchronization of neurons where memories reside(Blakemore & Mills, 2014). Although, development of human neural schema and its functionality begins from pre-natal phase; the neural system tends to stabilize slowly with biological development of body and it varies from one individual to another(Stiles, 2000). The reorganization of neuron alters utmost psychologically as we tend to reach adolescence period; but doesn't cease the process of stabilization.

During adolescence period, brain deals with sensitive phases such as self-consciousness, social isolation, interpersonal violence, peer pressure and other puberty issues (Dunn et al., 2017). This can be a root cause of dramatic variation in physiological, mental and psychological health. Undoubtedly, the alteration in neural connectivity occurs due to hormones and environmental stimuli of that individual. The experience from the internal and external surroundings plays an important role in brain development (see Table 1.1). The ability of thinking, learning, cognition and memorizing occurs in the anterior-posterior lobes of brain and the mechanism is unstoppable. Meanwhile, specific neural windows are adaptive for new cognitions and experiences. Primarily, environmental stimuli exert profound consequences on neural connectivity. Brain continuously gathers visual, auditory experiences from observation and learning. Later on, all the experiences are stored as explicit memories and short-term memories in the hippocampus and prefrontal cortex respectively (Cooper, Vargha-Khadem, Gadian, & Maguire, 2011; Kiuru et al., 2022).But, keeping those experiences and cognition as a long term memory is still hard to achieve. Therefore, reorganization of those memories critically demands for Neural Plasticity (NP) as a subtractive interconnection of neurons. Figure 1 explains the summery of Plasticity in a flow diagram.

The outcome of neuro-anatomical alteration in cortical brain influences the frequent behavioral changes in adolescents (Crews, He, & Hodge, 2007; Galván, 2010; Spierer, Chavan, & Manuel, 2013) gives rise to plasticity or neurologically termed as "Neural Plasticity" (NP).

Adolescence Regulatory Parameters	**Dominated Hormones**	**Affected Brain regions**	**Impact on Brain development**	**Ref.**
Hormones	Testosterone	Frontal lobe	New cell growth, Increase in grey matter volume, Improve decision making skills	(Farrell, Gruene, & Shansky, 2015; Hyer, Phillips, & Neigh, 2018)
	Progesterone	Hypothalamus	Increase the chance of altering cognition, emotions	(Bayer, Schultz, Gamer, & Sommer, 2014)
	Estrogen	Hypothalamus, Frontal lobe	Act as a neuro-protector	(Behl, 2002)

	DHEA and androgens	Hypothalamus	Decrease oxidative stress , Increase synaptic plasticity	(Nguyen, 2018)
	TSH	Hypothalamus	It serves mood changes	(Naicker, Abbai, & Naidoo, 2019)
	Sex steroids	Cerebral Grey matter	Development of secondary sexual characteristics	(Ponti, Farinetti, Marraudino, Panzica, & Gotti, 2018)
Social Behavior	**Dominant factors**	**Non-dominant factors**	**Affected Brain regions**	**Impact on Brain development**
	Education	Life satisfaction	Orbital pre-frontal cortex,	Protect the brain from accelerated aging
	Sexual orientation	Gender differentiation	Amygdala	Helps in sensory and cognitive development
	Health literacy	Cognitive function starting at late life	superior temporal cortex	Organize their thoughts, reflect on their understanding and find gaps in their reasoning.
	Exposure to drugs and alcohol	Abuse of other substances	hypothalamic–pituitary–adrenal axis	It can cause sleep deprivation, changes in brain architecture, increase anxiety, alter mood, and decrease memory and cognitive flexibility.
	Negative Mood (Depression, Anxiety, Stress)	-	Pre-frontal cortex	It can elevate the level of "stress hormone" know as cortisol, which can impair cognitive development.
	Physical activities and Diet Patterns	-	Frontal Cortex	It can reverse cognitive declination, create new neurons
	Social connection and Isolation	Social and cultural norms	Medial-Prefrontal Cortex	It affects the neural activities especially during the activations in ventral visual cortex—areas associated with perceptual processing

Table 1: Various Physical and Physiological Factors That Impacts On Brain Growth And Development

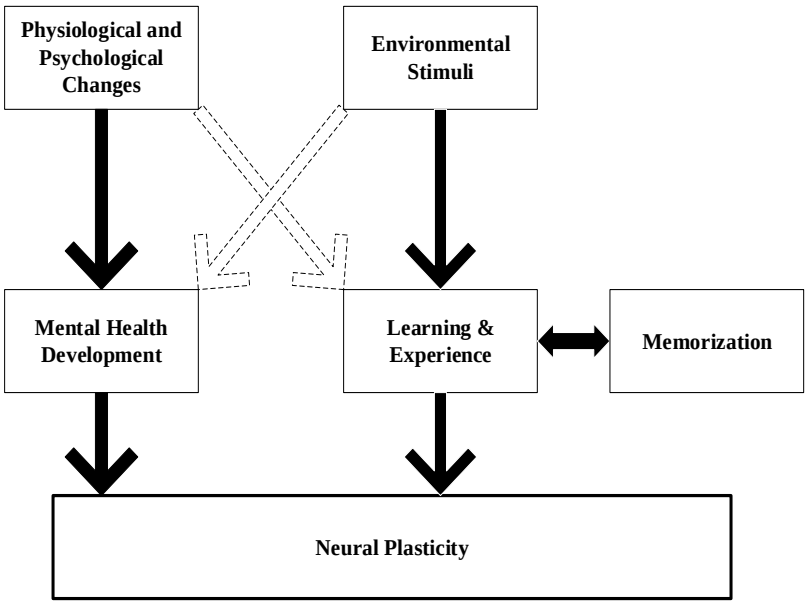

Figure 1: Effect of Internal and External Stimuli on NP

Although the concept was discovered 100 years ago by William James, in his book entitled "Principle of psychology(James, Burkhardt, Bowers, & Skrupskelis, 1890)" where he recognized that human brain is capable of reorganizing memory and cognition. But, concept of NP was highlighted to discuss about brain mapping by Hubel and Wiesel in 1967 (V. J. Li, Chorghay, & Ruthazer, 2023) where they emphasize inherent stimuli and period of experience for the cognitive development of cortical brain. NP is active in specified brain regions such as inferior parietal cortex and prefrontal cortex exposing highest synapses which is responsible for neuro-anatomical reorganization of synaptic network (Chokron, Perez, & Peyrin, 2016) related to independent aspects. However during brain juries(Wang et al., 2019), the cognitive re-organization of prefrontal cortex is different from other fore-brain regions affecting cognitive flexibility, prospective memory, impulsive inhibition and behavior. Every teenager experiences physical and psychological changes activated by hormonal systems to cope of with all kinds of physical, mental and social situations (Giedd et al., 2006; Kaimara, Oikonomou, & Deliyannis, 2021; Kuriakose & Lahiri, 2015). Physical changes are mediated by synaptic nervous system whereas psychological changes are slower and more responsive towards protracted parameters. Figure 2 and 3 shows a comparative graph of both physical and psychological parameters between adolescents and adults accordingly.

Secondary sexual characteristics of adolescents are initiated at the age of 13 years where genital hormones are responsible for organizational and behavioral changes(Cameron, 2004). However, sex-oriented functional changes can only be observed during adulthood concluding the fact that organizational chances are constant where as functional changes are inconsistent. Growth hormones are responsible for neurogenesis and synaptogenesis during neural development(Döring et al., 2021; Herting & Sowell, 2017).

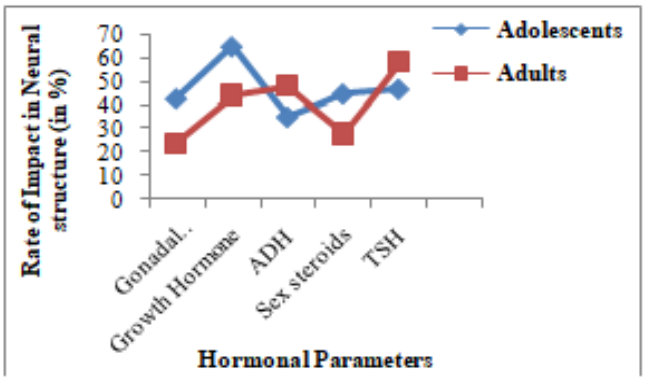

Figure 2: Impact of Hormonal Parameters in Neural Structure

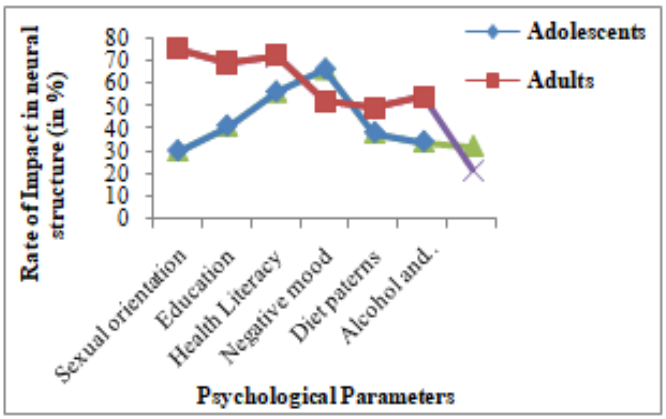

Figure 3: Impact of Psychological Parameter in Neural Structure

Additionally, the hormone is involved in other brain functions such as learning and memory. It has drawn special attention when researches are made on preservation of neural integrity after any brain injury while there is excessive secretion of growth hormones(Garcia-Estrada, Del Rio, Luquin, Soriano, & Garcia-Segura, 1993). Among the physical hormones, the puberty is majorly affected by Gonadal hormones such as testosterone in male, estrogen and progesterone in female. These hormones acts as biological markers for the development of cognitive functions such as experiencing task, decision making skill, learning and episodic memory. Moreover, the acquisitions of complex cognitive and behavioral skills are thought to be enhanced by plasticity. This enhancement relies on the maturation of frontal cortex and parietal lobe of brain followed by observed gains in cognitive functions.

On the other hand, psychological parameters of teenagers are partially affecting the development of brain. Positive and negative mood swings are the resultant of some puberty hormonal shift during adolescence period. This is the beginning of adolescence, the social and mental conflicts often draw a line between adults and teenagers. All these physical and psychological parameters are responsible for regulating neurogenesis, promoting neural proliferation and activate neuro-protection.

Apart from the earlier generalized discoveries in neurogenesis, NP underscores predominately in cognitive learning accomplishing the competencies. As learning process

tends to ignite by age, plasticity has implemented through various methods such as auditory-visual training programme, When behavioral consequences and practical challenges of life are outlined with the neural architecture, neuroimaging techniques have associated with NP to describe all shapes of emerging brain (Galván, 2010). However, many studies have shed light on the role of synaptic activities gleaned as an executive function to refine the prefrontal cortex connectivity, simultaneously highlighting vulnerabilities during adolescent periods (Selemon, 2013). As the brain starts to mature during this phase, neural connectivity depends more on plasticity for the enhancement of memory (Hahn, Heib, Schabus, Hoedlmoser, & Helfrich, 2020). But, this process is a way long to initiate brain maturation in adolescents when it calls for a simple stimulus-response learning task. Reinforcement learning often tends to speed up in adolescents when working memory subtle due to the early puberty hormones (Master et al., 2020). Observing many such issues, NP should be preferred as a presumptive option for indisputable initiation of brain rewiring as well as memory enhancement. The inter-relation between Learning, memory and NP is depicted in a single flow diagram in figure 3.

This review article aims to analyze the schematic framework of NP dependent on internal and external sources implicated for cognitive learning, brain rewiring, memory synthesize, behavioral improvement etc. Many literatures of recent years are referenced manifesting the development of NP to amend synaptic activities through neurons. To extend this, we have discussed briefly about brain rewiring and existence of memory in adolescents. Then, we have reviewed various aspects of NP as a fillip up and evaluate the gap between excessive and deficiency of NP during the intervention. Finally, regaining of plasticity has recuperated by numerous techniques such as neural replacement, synaptic modeling, and metaplasticity along with many pharmacological approaches.

II. A BLUE-PRINT OF BEHAVIORAL DEVELOPMENT

During the life-span of a human, he or she may have undergoes through multiple changes in their behaviors in terms of their basic skills, learning and acquiring process, memorization schemes etc. All these analytical approaches play a key role in the overall cognitive and emotional development, educational and skill acquisition, mental health ontogenesis, accessional experience(Harper, 2005). Behavioral development is the outcome of all these analytical approaches which is highly dependent on biological and environmental stimuli and differs from person to person (Khanna & Kendall, 2015).

The socio-emotional and behavioral development of an adolescent has interplay a huge impact on their physical and mental health, learning and behaviors. The inter-relation between NP and behaviors is a blooming research in behavioral science(Hayes, Barnes-Holmes, & Wilson, 2012). As the primary function of brain is to develop behavior in a child, but the behavior is inconsistent at that time. Later on, plasticity can change their behavior from minute to minute which is commonly known as “mood swings” can be short term as well as long term (Ghalambor, Angeloni, & Carroll, 2010). Short term behavioral changes are relevant for next few minutes such as someone choice in a food menu. In that scenario, single neuron is responsible for the synaptic change at different time scales and underlies brief memories. In contrast, long term behavioral changes are associated with a network of active neurons and responsible for multi-synaptic changes. However, both the ways have a

significant impact on someone's behavioral growth/reduction(Henrich, Glombiewski, & Scholten, 2023; Ohno et al., 2011).

Behavior is correlated with three different principle of plasticity such as experience-dependent, experience-independent, and experience-expectant (Frankenhuis & Nettle, 2020; Kolb & Gibb, 2014; Kolb, Harker, & Gibb, 2017).

1. **Experience-Expectant Plasticity**: It mostly occurs during development. For different brain systems to develop they require specific types of experience. It starts with the visual dominance found in pre-frontal.

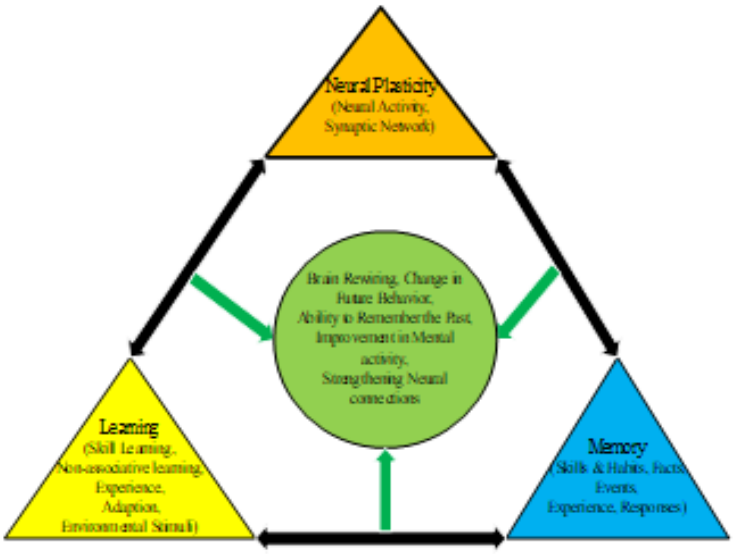

Figure 4: Inter-Relationship Between Learning, Memory and NP Cortex, and then the Binocular Vision Provides Mechanism to Store Every Events and Facts as Memory.

2. **Experience-Independent Plasticity:** It is designed to produce a rough structure during brain development. A large number of neurons are produced and then a strong neural connection has built in response of both internal and external stimuli. Simultaneously, the neurons are fired during the connectivity where strong connections get efficient potentiation and weak connections die automatically. For example, having a dream during deep sleep where we experience lots of events but hardly can recall the entire dream in a sequence after wake up.

3. **Experience-Dependent Plasticity:** It modifies the neural structure where the neurons are already fired during any synaptic activity. This kind of plasticity is observed while teenagers face decision making problems, intense environmental manipulation etc. Basically, all the synaptic changes during this plasticity are experience dependent. Additionally, early learning has a significant impact on ongoing as well as post occurring plasticity. Although, genetics has already wired a child's brain by birth, exert a powerful impact on behavior of a teenager.

Three principles are describes in brief to demonstrate a correlation between learning and behavior. They are: classical conditioning (Bouton, 2018), operant conditioning (Bąbel, 2020), and observational learning (Goubert, Vlaeyen, Crombez, & Craig, 2011).

- **Classical Conditioning:** It is driven from Pavlov's classical experiment on making an association between a stimulus and a response. For example, an infant might quickly begin to associate the sight of a baby bottle with being fed.
- **Operant Conditioning:** When you reward a behavior, chances are that same behavior is likely to occur again in the future. When a behavior is punished, it becomes less likely that it will occur again in the future. This concept signifies operant conditioning. For example, when a child is rewarded for cleaning their room, they become more likely to repeat the same behavior later on.
- **Observational Learning:** It depends on admiration of the individual towards parents, siblings, friends, any popular celebrity or character. Various learning sources such as video games, smart phones, television, and internet can manipulate their psychology either in a positive or negative direction gradually.

Other sensitive factors enriched with loving, friendly, comfortable, responsive circumstances from family and society plays a crucial role for a child's behavior. And, this kind of behavior may carry forward towards adolescence period also. However, the behavior can dramatically change as such nurturing environment can't be consistent for a prolonged time. The common reason behind this inconsistency is peer pressure. A child's behavior is highly impacted by another child's behavior. This peer relationship can again affect either positively or negatively on child's behavior and psychology. Additionally, the culture that a child lives in adds yet another element to this already complex mix. Even within the same culture, variations in things like social status, income, and educational background can have an impact on how kids are raised. Therefore, it is summarized in this section as behavioral development is thought to result from the interplay among genetic inheritance, congenital characteristics, cultural contexts, and parental practices as they directly impact the individual.

III. THE STATE-OF-ART OF BRAIN REWIRING

The dynamic reorganization of brain is perpetually adaptive for skillful learning and acquiring experience from the circumstances. Brain accommodates to impulsive synaptic changes while activating the neurons from dendrites extensions and alters its mode of functionality. Meanwhile, the alteration in brain functionality provides fruitful scope to rewire the brain. Earlier, it was a myth that brain rewires itself according to the neuro-anatomical development and eventually becomes static for adults. Although, the brain reaches its $3/4^{th}$ of maturity by the age of 2, the prefrontal cortex (PC) still has to wait up to 25 years for its complete maturation (Ramnani & Owen, 2004). The immaturity of PC reflects physically, hormonally and intellectually during adolescence period. But the reorganization of brain never stops and rewires itself whenever the neurons tend to reconnect among themselves.

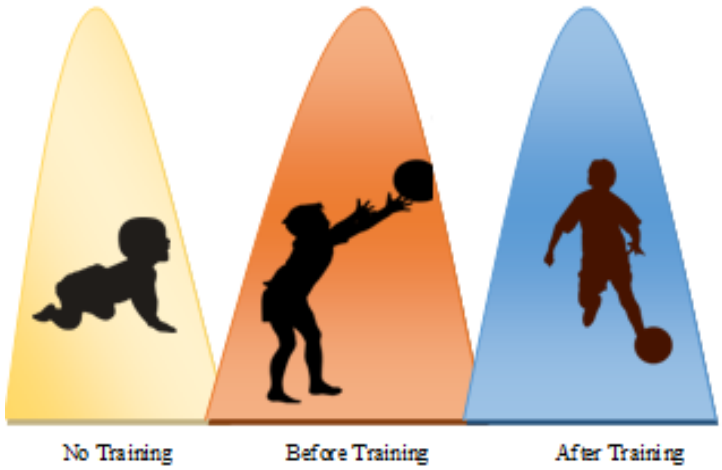

Figure 5: Usefulness of Training for Learning a Skill

Modern cognitive science observed that we have to put some extra effort to rewire the brain to its full efficiency. Initiation of brain rewiring appears in sub-cortical regions, but it is accustomed with PC involving an effortful learning-experience pathway. However, it is influenced by brain mapping as an experiential outcome. This process of lasts till we die, and not only restricted to the early stages of life. From a report given by Carnegie Mellon's Center for Cognitive Brain Imaging (CCBI), learning new skills influences the brain to rewire itself in younger generation (Just, 2013). The age between 5 to 12 years is perfect period for physical and mental training as children in this age group are adaptive to express their interest, capable of receive any new skill and active in memorization as shown in figure 4. Millions of neurons producing synapses are activated which promotes the structural and functional brain development. However, most of the unused synapses are died off due to synaptic pruning (Selemon, 2013).

By the time teenage has arrived, the pressure of self recognition, understanding the intentions and emotions of others unfold neural interaction strategically. The role of neural interaction during adolescence period has put an unconventional impact to rewire the "Social brain". Understanding the social dogma quicken brain rewiring and cultivates its functionality minutely (Arden, 2010). In addition to that, infestation of immense synapses strengthens the brain which is completely dominated by synaptic pruning. The end process of pruning predominate myelin over grey matter in PC lobe to reconstruct the brain extensively. Existence of numerous emotions such as thoughts, beliefs, experiences, skills and decision-making abilities may be last for lifetime or may be lost forever in teenagers. Synaptic pruning selects the neural interactions for those emotions to rewire the brain efficiently; simultaneously eradicating unused neural connections (Lieberman, McGuirt, Tang, & Sulzer, 2019).

A rewired brain unfolds the sections where planning, hypothesis, insights and mood regulation resides. The freedom to explore such sections is exquisitely demands for social flexibility. Although brain rewiring is a legacy of neurogenesis, an akin rivet slants towards different sensory and motor functions, Gonad hormones, age, sex, nutrition, stimulants and social key factors (O'Connor & Cryan, 2014). Despite of recognizing the emotions like cry, laugh, anger, fear and so forth that developing the brain roots biologically; the adolescent

brain may also discover the existence of some complex emotions to deal with such as embracement, guilt, aggression, confusion etc. All of these key issues can affect the way of brain rewiring (Mills, Goddings, Clasen, Giedd, & Blakemore, 2014; Ordaz, Foran, Velanova, & Luna, 2013). Placing all cells together and engages the brain in its right way is not an easy job to do. The myth about genes regulating our emotions, behavior and experience has shuttered. Recently, Neuroscience has witnessed that prevision and potentiality of learning based experience change the neural interaction. To acknowledge this legitimacy, our mind should be stress free, tamed and calm before learning something new. Therefore, teenagers should lay out their brain for an upright training to exaggerate brain rewiring.

IV. EXISTENCE OF MEMORY

The unstoppable process of acquiring information, storing it and later retrieving them when needed over time is what we called as "Memory" (Ebbinghaus, 2013). It resides in the hippocampus, amygdale, cerebellum and prefrontal cortex cerebrated with neuro-anatomy. This biological process is not eternal; it may be lost to recall its evolution either in the pre-natal phase of life or when the living body is brain dead. In aid to that, subsistence of memories can highly affected by several brain diseases, stress, lack up sleep, indulgent life style and the list goes on. However, formation of memory starts from an unpredictable node and hit the infancy queerly (Manthiou, Kang, Hyun, & Fu, 2018).

Life after birth up to first 3 years is completely volatile; hence the memories are also improbable. This phenomenon is known as infantile amnesia (Josselyn & Frankland, 2012; Kartikeswar, Parikh, Pandya, & Pandit, 2020), hence it has never triggered back to flashback. After the age of 3, the child starts to learn and remember language, people, quotidian automatically and those memories are stores as implicit memories. Contradictorily, children are well acquainted with their mother's voice since their birth which proves the existence of declarative memory developed in toddlers. As the child jump into a tough school life; episodic and semantic memories have already built up (Otten & Rugg, 2002). By the time; daily routines such as wearing shoes, organizing books in the bag, riding bicycle etc. are also started to pile up as procedural memories in cerebellum. This memory is continues to germinate as per the child's neuro-anatomical development. At the door step to adolescence period; working memory, long-term and short-term memory are bloomed at the hippocampus. Let's explain it with an example as shown in figure 5. The visualize frame of tree comes to mind of a child when someone utters the word "Tree". The child starts observing each of the features and when every time he/she looks towards the tree, there is a recall and rehearsal of arranging the features together and frame a tree in mind. As the child grows, there is no need to repeat the features every time. The image is created in a fraction of second taking all the features together which is enough to describe how a tree looks like. To expand this process, memory serves as an alpha factor which exercises the learning, events, skill and other symbiotic entities from past as well as present. It treats the past events as references, working on present while storing experiences and reusing those experiences in future(Hitchcock et al., 2020).

Memory and disremembering co-exist in mind since childhood, but there are vigorous ways to overcome the bad habit of forgetting. Visual memory is always in prior to recall the information in an agile mind of a child. However, it fades away as the child tends to

learn from the real world (Olesen, Macoveanu, Tegnér, & Klingberg, 2007). To overcome this problem, different Mnemonics are implicated to increase the recalling ability by storing each memory segments as a cyclorama. Memory palaces have proved to be the best ever discovered mnemonics devices of all the time to keep the memories as files and import them when needed. Since ancient times, adequate nourishment impacts cognition, hence parents put their children on a Mediterranean diet with ample of omega-3, fatty acid, Docosahexaenoic acid (DHA), vitamin B6 complex and a few amount of epi-catechin usually found in tea, coffee and berries. However, bellyful nutrition is not enough during childhood to memorize uncountable numbers of iterative and non-iterative information (Lynch, 2002). Therefore, chunking helps in clubbing our memories in a bunch and leaves it to retrieve later. Cognitive training has turned up to change the most usual way of memory development in triggering working memory for the repetition of multiple tasks as well as by incrementing the information quantity.

All these methodologies mature the memorizing abilities throughout entire childhood, but brainstorming and cognitive performances tends to drop off in the crucial period of adolescence. Besides that adolescent brain is intensified in memorizing plenty number of stuffs, some peculiar teenager attributes can sluggish its performance. As mentioned in (Paulus, Putman, Dugosh, Dzindolet, & Coskun, 2002), disturbances in memory such as unable to recall recent information, often mislay things around, forgetting names, events whenever required not only affect their routine life and mental stability but also lead to depression. Many neurologists and psychologists have failed to go underneath the root cause of memory deficiency. However, slow learning activities, lack of

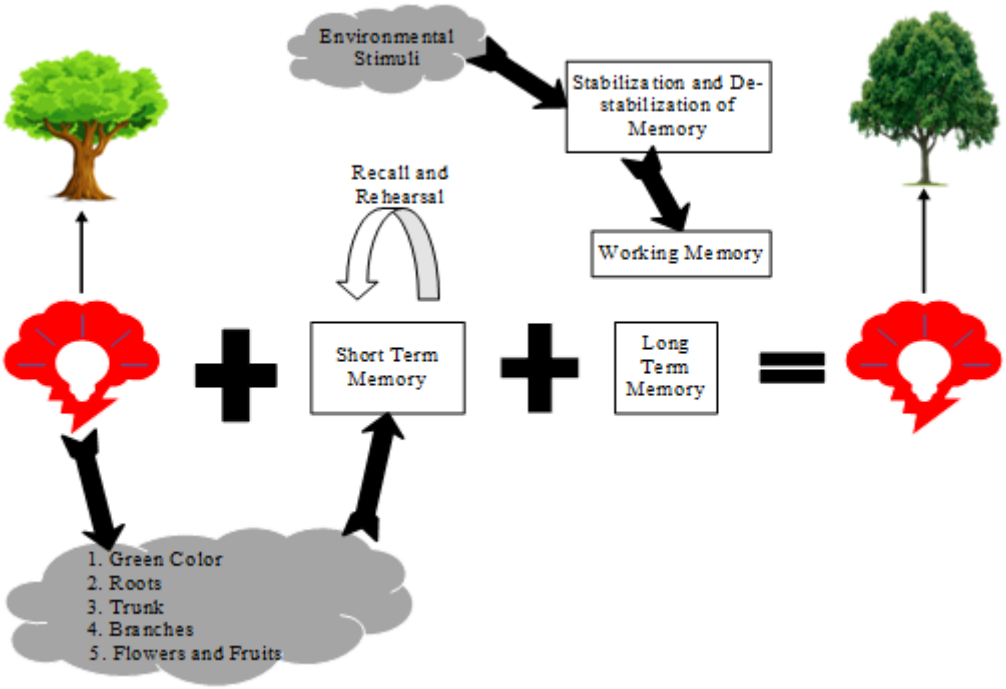

Figure 6: Example of Memory Formation and Storage by Visual Dominance

creativity, lack of concentration, excessive drug addiction, peer pressure, stress, anxiety, outdistance from society are some of the possible reasons behind memory loss in teens. Adding to that, some medical history of brain injuries, neuro-degeneration, seizures, and endocrine dysfunctions can cause either sub-accurate or chronic memory loss (Stramaccia, Meyer, Rischer, Fawcett, & Benoit, 2020).

Life with such memory deficiency becomes chaotic when brain gets over-stimulated by puberty hormones. Memory is affected the most when the mind deals with thousands of emotions, planning, strategies, ambitions and social stigma. Moreover, sleeping pattern overpowers memory in such a way that a deprived adolescent experiences lack of concentration compared to a rested teenager. To check the memory density and concentration, a preliminary skill test has conducted based on tricky mental math questions, puzzle solving, basic information regarding dates and events. Such delicate issues need a medical practitioner to keep an eye on their sleeping pattern as well as diagnose possibilities of any pre-term or post-term seizures, brain injuries, anxiety issues etc(Shipstead, Redick, & Engle, 2012). However, medical science doesn't provide any facilities to diagnose or cure memory deficiency. Hence, we need to train our brain in a way that would reactivate all the dozy neurons automatically.

V. NEURAL PLASTICITY AS AN ADDED FILLIP

Originally, Neuropsychology recounted that development of brain depends on plasticity. During this development, brain is subjected to reorganize neural patterns and synchronize its functionality depending on the external and internal stimuli. The occurrence of NP begins at pre-natal stage of life where the immature brain prepares itself for functioning which is the most sensitive period for vigorous studies. The memories developed during this stage may be responsible for maternal recognition. During the occurrence of synaptogenesis, most of the events are carried forward if something new is learned and memorized. In case of brain injury, it adapts to repair the damaged neurons and compensate learning process from remaining lobes of brain (Johnston et al., 2009).

The most frequently used technique to measure NP level is functional MRI (fMRI) which figures out the changes of blood flow in cerebral cortex and indentifies the functional brain regions to when subjected to a given task in both active and resting state (Johnston et al., 2009). University of Miami experimented about the induced NP by intermittent theta burst simulation (ITBS), a non-invasive technique to study the impact of plasticity on aging. Amplitude of highly emerging brain waves is validated initially through transcranial magnetic stimulation (TMS). However, the potentiality of the synapses can be modulated by using long- term potentiation (LTP) and long- term depression (LTD). But all these techniques are prone to clinical trials and only meant for the treatment of neurological and psychological defects in children and hence, such argumentative proposals are failed to alter the synaptic sites in adolescents. The time and frequency domain analysis of NP was carried out by STDP, but was also conk out due to onetime generation of single brain signal stipulated with *in vitro* only. Later, all the neural alteration subjected to paired associative simulation (PAS) was meticulously shifted towards the study of NP. Some research have used paired associative stimulation (PAS) technique to measure the amount of motor cortex to increase the amplitude of motor potentials in teens and failed due to the raid cortical changes occur in children. Displaying the morphological structure of brain alterations in a

three dimensional image are exhibited by enlarging the synapses or by increasing the terminal density. But, such neuroimaging techniques through positron emission tomography (PET), magnetic resonance or cranial ultrasound are spurious to depict the morphologic attributes of brain. Hence, a scrupulous attention is needed when the child reaches to the most sensitive period of life.

NP is segregated in two forms where Structural plasticity alters the neuro-anatomical structure and synaptic plasticity which alters the neuro-chemical composition of body. During the beginning period of neurogenesis, NP was circumscribed as the alteration in brain connectivity depending on external and internal stimuli. No sooner, the definition was modified when a cognitive neural transition occurs due to some critical synaptic alteration. Later on, the theory was ramified when our aptitude, behavior and strategies to do any task and decision making ability have build up at growing stage of life. A special attention should be given to all the adolescents as it is the shadow of one's personality that reflects from behavior. The more a teen brain learns, it becomes difficult to self-rewire the brain due to synaptic pruning. As pruning can't be avoided at the striking age of puberty, the process of rewiring often faces some difficulty to maintain itself in late 20's. Hence, NP is one the more trial & tested technique to get rid of pruning and stabilizes the synaptic alterations.

By the age of 5, a child's brain is open to all the positive and negative thoughts. Hence, the foundation of NP needs to be authorized at such early stage. NP helps in strengthening brain connectivity and expanding the dendrite forks and there by detecting relationships between diverse sources of information, learning something new or more specifically being curious to learn, reviewing every minute events in wider picture, and understanding the global implications of specific issues, capable of taking right decisions at right time and so on. In special cases of brain injury or disorder, the learning skill helps in recovering the lost neural interconnections more quickly. NP encourages our capacity of learning, cognition and memory in response with external and internal surroundings. It is associated with the structural and functional changes in prefrontal cortex (Huttenlocher, 2009).

Alteration of brain connectivity is highly dependent on the capability of learning, memory and adaption. A proficient intervention of plasticity synthesizes an adolescent brain during skillful learning and multi-tasking. As cognition is the pure reflection of learning something new, a child's brain should be trained accordingly to be more flexible regarding accessing and retrieving information. During the intervention, the synapses fluctuates more as we respond to outer stimuli. Specific neural tracts associated with synaptic networks for cognitive intervention. The interventions promise for deep brain stimulation, cognitive training and neuro-pharmacology processing. Dynamic modification of neural networks leads to memory formation and brain rewiring under the framework of synaptogenesis, neurogenesis, synaptic synchronization and fluctuation. As synaptic strengthening is one of the consolidated features of memory, memory retrieve are stringently dependent on type of synaptic alterations.

VI. ADEQUACY OF PLASTICITY FOR ADOLESCENTS

How much plasticity is sufficient to rewire the adolescent brain is the prior concern for researchers. When plasticity takes place, number of neurons and synapses raise

accordingly. As we proceed towards adulthood, the synaptic synchronization between neurons has reduced to half of its number, which is technically termed as synaptic pruning. If a cognitive training is alimented to a group of children, then a better results would expected from adolescents as compared to adolescents and adults. While the quality of plasticity is increased in adolescents, major hormonal and neuro-anatomical transition occurs which impacts the cognitive process profoundly (Dunning et al., 2019). When adolescents practice their cognitive skills, the working memory or short-term memory capacity enhances and simultaneously all the synaptic activities synchronize with the increased neural tissues (Buschkuehl, Jaeggi, & Jonides, 2012).

Since a few years, psycho-stimulant medications such as Amphetamine, Rivastigmine, Citalopram are clinically tested to induce the potentiality of NP by altering the neural interconnection and strengthening the synaptic sites (C.-s. R. Li & Sinha, 2008). But, no pills are guaranteed for a sharp brain to store unlimited information. Besides that, a mild overdose of pills can impair the biological stimuli leading to a maladaptive orientation. Recently, non- pharmacological agents such as music, quality of sleep, meditation, brain mapping, brain stimulation etc are introduced to enhance cognitive connections. Despite of being universally accepted, it is not taken too seriously to implement in real life. They seem to be more efficacious compared to currently available drugs. Adjuvant therapies using flavonoids are encountered as a standard treatment to enhance neuro stimulations and repair the impaired brain functions (Bayat, Farshchi, Yousefian, Mahmoudi, & Yazdian-Robati, 2021). The common hallmark of nerve tissue damage is increased by oxidative stress and inflammation. Thus, the studies on flavonoids with strong antioxidant and anti-inflammatory properties as a potential application in neuro intervention have been carried out for a long time. However, recent results have revealed another important property of these compounds in CNS therapy. Flavonoids are inhibited with antioxidants and anti-inflammatory properties to actuate neuro protective activity, and promote synaptogenesis and neurogenesis (Harborne, Marby, & Marby, 2013).

On the other hand, neural deterioration is a common symptom occurs according to the grown up age. Hence, the level of plasticity reduces gradually with teenager's naïve towards life. Traumatic brain injuries can severely interrupt the cognitive and emotional behavior followed by uncontrolled sensory-perception, impaired neuro-modulatory function. Such distorted plasticity or "negative plasticity" often restricts the teenagers participating in academic activities, socio-cultural functions and cognition grooming programs(Dietz, 2012). In aid to that, aging factor is the most unavoidable parameter which naturally declines NP despite of vigorous NP enhancer implications. Therefore, possibilities of gaining memory and rewiring the unstoppable brain can be balanced by enhancing the cognitive training. Many challenge based tasks are essential elements to trigger plasticity which merely expecting some relevancy and importance in return. Although, several studies have given hypothesis on enlarged plasticity either enhanced or impaired the cognitive learning for same intervention; but the crystallized cognition remains invariant irrespective to age or even may mutate during adulthood. As it takes time to bring a stringent structural and functional changes in plasticity, inventive brush up of task schedule must be refocused.

VII. REGAINING NEURAL PLASTICITY

An adolescent brain has the ability to regain plasticity by repairing the suppressed neurons and drive the synaptic arc efficiently. Brain extends the heterogeneity of neuronal

subtypes to drive stem cells and specifies only a few essential subtypes to regain the dysfunctional neural functionality (Johansson, 2011). However, the new neurons are integrated with the pre-exist ones near the hippocampus and too difficult for the hierarchical reorganization. An alternative approach to enhance plasticity is to replace the non-functional neurons with the activated ones under the process of neurogenesis. But this neuron replacement approach must be implemented in newborn for the effective synaptic synchronization. Indeed, the cell replacement technique may be unsafe because of its unknown potential. Hence, both the strategies demands for a successful clinical trial.

But, modern contextual learning always demands for a quick and efficient approach. Hence, an approachable pharmaceutical glutamate receptor, namely "AMPA" is meant to be delivered to the center of learning and memory that's the hippocampus region. For that, a cellular model of synaptic chaotic activities has been depicted by LTP associated with associative learning. Although neural stimulations are transmitted in synaptic activities, the AMPA receptor acts as an interceder for faster synaptic transmission which is used widely in synaptic potentiation and cognitive learning during experience-dependent NP (Malinow & Malenka, 2002). In another aspect, remodeling of NP demands for stimulus transduction to maintain the learning and memory related neural function. Hence, an epigenetic enzyme lysine-specific demethylase-1 (LSD1) or neuro LSD1 have been implicated in the neuro specific splicing variant process through an antagonistic mechanism. This transcriptional receptor co-activates the androgen and estrogen receptors which modulates emotional behavior and enhances neural maturation during memory formation. However, the single neuro LSD1 genomic structure has both positive and negative modulation depending on the transcription activities(Borrello et al., 2017).

The balance between dominated and suppressed plasticity exists by entailing the threshold of NP in metaplasticity where synapses improve their ability to regain NP within a stipulated period. Metaplasticity encountered the change which outlast for a longer bout compared to common plasticity(Farashahi et al., 2017). It can line up the learning intervention strategically despite of any reward uncertainties or explicit optimization of sources. A metaplasticity model is more precise to predict uncertainty than any optimal models considering the neural activities occur in prefrontal cortex(Iigaya, 2016). Moreover, meta-plastic models bring synaptic changes in the brain, but doesn't encroach the synaptic efficacy. Hence, metaplasticity acts as an extenuation between adaptability and precision via simulation whose results can substantially enhance synaptic efficiency. These models strengthen the adaptability-precision palliation by two meta-state frameworks (1) Reservoirs and (2) Buffers(Khorsand & Soltani, 2017). It has observed that synaptic efficiency is robust for reservoirs creating a strong synaptic activity without any evident plasticity(Wu et al., 2018). In belie, synaptic efficiency is restricted under the circumstances of buffer meta-state without any major change in plasticity. Hence, meta-plastic models are quite adaptive for plasticity transition and capable of understating any uncertainties.

VIII. CONCLUSION

Pubertal hormones, impulsive behavior, external and internal environmental stimuli and other factors may restrict synaptic potential for self-rewiring which alternatively retarding memorizing ability. A tiny frequent change in neural connectivity provides a scope for self-rewiring; however it has proved to be a myth during the grown-up age. Of course, the

inter-relation between brain rewiring and memory enhancement becomes chaotic as the adolescent brain deals with thousands of mixed emotions, stress, hormonal alterations and social hindrances. And, as we tend to adulthood, synaptic pruning starts decaying our long term memory and makes the brain a static organ to respond to obvious stimuli only. Although, basic training sessions has been conducted since decade to enlarge memory density such as meditation, audio-visualization therapy, healthy nutrients and exceptionally psychopathic drugs; still are uncertain in their full-efficiency. However, development of memory is a never-ending process and it explores the synaptic activities with exuberance of external and internal stimuli. This article suggests a cognitive training session for adolescents in which neural plasticity has implicated as an additive fill-up to boost the synaptic activities. However, measurement of NP is seemed to be necessary as we are dealing with a sensitive phase of life. Therefore, adequacy of brain stimulation, brain mapping and Adjuvant therapies can be imposed at the beginning to conciliate the brain from past neuro-anatomical injuries. Sometimes, care should be taken to avoid the negative plasticity as it may cause neural deterioration during brain maturity. Moreover, plasticity can be refined and crystallized with an amendable way by regaining the threshold of plasticity. For this, metaplasticity is to be suggested which has the ability to bridge the adaptability-precision conflict and cope of with plasticity transition efficiently. But, this is not the termination of neurogenesis. Likewise the unstoppable memory and brain rewiring; the cognitive training process should be modified time-to-time to deal with the synaptic transitions uninterruptedly.

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