Malleability of Intelligence

Authored by
mohammad looti

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Malleability of intelligence describes the processes by which human intelligence may be augmented through changes in neuroplasticity. These changes may come as a result of genetics, pharmacological factors, psychological factors, behavior, or environmental conditions. In general, the majority of plasticity as it relates to intelligence occurs at either the onset of development, during the critical period, or during old age. Malleable intelligence may refer to changes in cognitive skills, memory, reasoning, or muscle memory related motor skills.

Charles Spearman, who coined the general intelligence factor "g", described intelligence as one's ability to adapt to his environment with a set of useful skills including reasoning and understanding patterns and relationships. He believed individuals highly developed in one intellectual ability tended to be highly developed at other intellectual abilities. A more intelligent individual was thought to be able to more easily "accommodate" experiences into existing cognitive structures to develop structures more compatible with environmental stimuli.

In general, intelligence is thought to be attributed to both genetic and environmental factors, but the extent to which each plays a key role is highly disputed. Studies of identical and non-identical twins raised separately and together show a strong correlation between child IQ and socio-economic level of the parents. Children raised in lower class families tend to score lower on intelligence tests when compared to children raised in both middle and upper class families. However, there is no difference in intelligence scores between children raised in middle versus upper class families. The IQs of a large enough population are calculated so that they conform to a normal distribution.

Definitions

Intelligence: a very general capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience.
Critical period: a restricted developmental period during which the nervous system is particularly sensitive to the effects of experience.

Neuroscience basis

The biological basis of intelligence is founded in the degree of connectivity of neurons in the brain and the varying amounts of white and grey matter. Studies show that intelligence is positively correlated with total cerebral volume. In particular, the volume of the cortical grey matter in the prefrontal region plays a large part in both brain volume and intelligence. While it is true that the number of neurons in the brain actually decreases throughout development, as neural connections grow and the pathways become more efficient, the supporting structures in the brain increase. This increase in supporting tissues, which include myelination, blood vessels, and glial cells, leads to an increase in overall brain size. When brain circumference and IQ were compared in 9 year olds, a positive correlation was found between the two. An increase of 2.87 IQ points occurred for each standard deviation increase in brain circumference.

Importance of critical period

The brain grows rapidly for the first five years of human development. At age five, the human brain is 90% of its total size. Then the brain finishes growing gradually until age twenty. From start to finish, the brain increases in size by over 300% from birth. The critical period, defined as the beginning years of brain development, is essential to intellectual development, as the brain optimizes the overproduction of synapses present at birth. During the critical period, the neuronal pathways are refined based on which synapses are active and receiving transmission. It is a "use it or lose it" phenomenon. The more cortical thinning that occurs, the higher the IQ.

On a chemical level, BDNF activates the nucleus basalis, a part of the brain that focuses attention and remains activated throughout the critical period. BDNF also consolidates connections between neurons that fire together in order to wire them together and provide more reliable firing in the future. At the end of the critical period, BDNF deactivates the nucleus basalis. One of the problems in autism is that BDNF is released prematurely, causing all connections to be reinforced. BDNF then prematurely ends the critical period and seals in place these undifferentiated connections of brain maps. Merzenich and Kilgard tested the effectiveness of the nucleus basalis to control the critical period by electrically stimulating the nucleus basalis of rats and exposing the rats to a continual frequency of 9 Hz. Merzenich discovered that the brain map for the 9 Hz frequency had been massively expanded. This research raises further questions on the ability to turn on/off the nucleus basalis and thus the critical period through electrical or pharmacological means.

Neural plasticity

Neural plasticity refers to any change in the structure of the neural network that forms the central nervous system. Neural plasticity is the neuronal basis for changes in how the mind works, includig learning, the formation of memory, and changes in intelligence. One well-studied form of plasticity is Long-Term Potentiation (LTP). It refers to a change in neural connectivity as a result of high activation on both sides of a synaptic cleft. This change in neural connectivity allows information to be more easily processed, as the neural connection associated with that information becomes stronger through LTP. Other forms of plasticity involve the growth of new neurons, the growth of new connections between neurons, and the selective elimination of such connection, called "dendritic pruning".

Genetic factors of intelligence

Humans have varying degrees of neuroplasticity due to their genetic makeups, which affects their ability to adapt to conditions in their environments and effectively learn from experiences. The degree to which intelligence can be linked to genetic heritability increases with age. A study of Dutch twins concludes that intelligence of a 5 year old is 26% heritability, while the intelligence of a 12 year old is 64% based on heritability. Structurally, genetic influences explain 77-88% of the variance in the thickness of the mid-sagittal area of the corpus callosum, the volume of the caudate nucleus, and the volumes of the parietal and temporal lobes.

Pharmacological influence

Numerous pharmacological developments have been made to help organize neural circuitry for patients with learning disorders. The cholinergic and glutamatergic systems in the brain serve an important role in learning, memory, and the developmental organization of neuronal circuitry. These systems help to capitalize on the critical period and organize synaptic transmission. Autism and other learning disabilities have been targeted with drugs focusing on cholinergic and glutamatergic transmission. These drugs increase the amount of acetylcholine present in the brain by increasing the production of acetylcholine precursors, as well as inhibiting acetylcholine degradation by cholinesterases. By focusing on heightening the activity of this system, the brain's responsiveness to activity-dependent plasticity is improved. Specifically, glutamatergic drugs may reduce the threshold for LTP, promote more normal dendritic spine morphology, and retain a greater number of useful synaptic connections. Cholinergic drugs may reconnect the basal forebrain with the cortex and hippocampus, connections that are often disrupted in patients with learning disorders.

Psychological factors

Psychological factors and preconceived notions about intelligence can be as influential on intelligence as genetic makeup. Children with early chronic stress show impaired corticolimbic connectivity in development. Early chronic stress is defined as inconsistent or inadequate care-giving and disruption to early rearing environment. These children showed decreased cognitive function, especially in fluid cognition, or the ability to effectively utilize working memory. The lack of connectivity between the limbic system and the prefrontal cortex can be blamed for this deficiency.

In addition to stress, perceptions of intelligence can also play a negative role in cognitive development. A study at Columbia University showed entity theorists, or people with a belief in fixed intelligence, showed less improvement on cognitive testing after receiving initial feedback than incremental theorists, or people with a belief in malleable intelligence. Entity theorists focus on performance goals and proving their intelligence, which makes them vulnerable to negative feedback and failure. This is in contrast to incremental theorists, who focus on learning goals and rebound well from occasional failure or feedback. Incremental theorists focus on challenging tasks to expand intelligence instead of working to prove their own intelligence. Thus, a variety of psychological factors can inhibit one's propensity to expand his intelligence.

Behavioral factors

In the study of malleable intelligence, behavioral factors are often the most intriguing because these are factors humans can seek to control. There are numerous behavioral factors that affect intellectual development and neural plasticity. The key is plasticity, which is caused by experience-driven electrical activation of neurons. This experience-driven activation causes axons to sprout new branches and develop new presynaptic terminals. These new branches often lead to greater mental processing in different areas. For instance, use of the popular Fast ForWord learning system has been shown to increase visually-based IQ. As a result, participants' verbal reading scores also improved. Thus, mental processing generally improved due to an improvement in temporal processing of the visual field. Other programs similar to Fast ForWord have boasted similar results, but recent studies show that the cognitive processing improvements gained from these programs diminish after instruction has ended. In the end, the program intervention may help expedite the neural development of children with less neural plasticity, but after the intervention is removed, children with greater neural plasticity not involved in the program will eventually meet and surpass the program participants.

Taking advantage of the critical period

As previously discussed, the critical period is a time of neural pruning and great intellectual development. The time scale for humans to learn language without an accent begins in infancy and ends around 8 years old. Languages learned after 8 years old will be spoken with an accent and will not be processed in the same part of the brain as the native language. Similarly, a study was conducted in which children were exposed to Zulu before the age of 2. The children could discriminate non-native contrasts that adults had difficulty perceiving. Thus, the critical period prepares children to process numerous types of stimulus input that the adult brain cannot process.

Another example of the critical period playing an important role in development is with eyesight and cataracts. Infants born with cataracts will become blind if the surgery to remove the cataract is not done during the critical period. After the critical period, the brain map for eyesight will have rewired itself, and the child will be blind. Similarly, rats reared in the dark will maintain the critical period for eyesight until placed in a lit environment, when the vision is corrected. However, the extension of the critical period does not last infinitely. Eventually, without light input, the rats will go blind as their visual cortex is overcome by other neural connections via plasticity.

In regards to cognitive processing, individuals who are considered "genius" often began exploring their fields well before maturity. One obvious example is Albert Einstein, who began studying the universe at age 5 and learned advanced math at age 12. The ability of these geniuses to understand their field is due largely in part to their interest at a young age, during the ongoing critical period. Interestingly, another factor that has a strong correlation with intelligence is breast feeding of infants. Even after normalizing for mother's intelligence, age, education, socio-economic status, and mood fluctuations during pregnancy, breast fed infants show greater scores on cognitive functioning tests, which persisted throughout development.

Executive attention and intelligence

One study conducted by Rosario Rueda and colleagues investigated the effects of an educational intervention in executive attention in children 4 and 6 years old . Executive attention refers to the self-regulation of cognition and emotion. The training focused on developing the child's ability to track moving objects, anticipate events, memorize stimuli over brief periods of time, and inhibit learned responses. This training improved intelligence in the 4-year old but not the 6-year old group. The training had no effect on a test of executive attention, the "Attention Network Test".

Environmental factors

Environment plays a significant role in intellectual development, especially the environment present during the critical period. Marion Diamond from the University of California, Berkeley, discovered dendritic spines from infants reared in enriched environments were both longer and more highly branched than dendritic spines in the brains of infants raised in deprived environments. However, a fully enriched environment does not greatly differ from an enriched environment in terms of cognitive development. In other words, multicolored mobiles or Mozart CDs have little consequences on brain wiring. An enriched environment is similar to vitamins, a minimum dose is necessary, but taking extra won't help.

Other environmental factors, like disease, play a significant role in intellectual development. A study from Norway by Eriksen et al. concluded that infants born just after the Hong Kong Flu pandemic during July-October 1970 scored lower on cognitive tests than others born in 1970 when normalized for parental education, paternal age, and premature percentages. Maternal flu can cause both transient breathing and eating difficulties, both of which have long term effects on the intellectual development of the developing fetus.