EDITORIAL

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What is neuroplasticity? Why it is important?: Types and its basic mechanisms

Nöroplastisite nedir? Neden Önemlidir?: Türleri ve temel mekanizmaları.

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ABSTRACT

The human brain is interconnected in a plastic manner to form functional brain networks. This dynamic and flexible neuronal reorganization process is essential for an efficient regeneration process in the central nervous system, especially when it comes to memory, learning, and posttraumatic conditions. Here, we tried to define basic principles and the mechanisms underlying neuroplasticity process in the brain which serve as an important template for future studies on neurorehabilitation in neurodegenerative diseases, such as stroke, Alzheimer's Disease and traumatic brain injury.

Keywords: Activity-dependent plasticity; Developmental plasticity; Post-lesional plasticity; Long-term Potentiation; Learning; Memory

ÖZ

İnsan beyni, işlevsel beyin ağları oluşturmak için plastik bir şekilde birbirine bağlıdır. Bu dinamik ve esnek nöronal yeniden düzenleme süreci, özellikle hafıza, öğrenme ve travma sonrası durumlar söz konusu olduğunda, merkezi sinir sisteminde verimli bir yenilenme süreci için gereklidir. Bu yazıda, inme, Alzheimer Hastalığı ve travmatik beyin hasarı gibi nörodejeneratif hastalıklarda nörorehabilitasyon üzerine gelecekteki çalışmalar için önemli bir şablon görevi gören beyindeki nöroplastisite sürecinin altında yatan temel prensipleri ve mekanizmaları tanımlamaya çalıştık.

Anahtar Kelimeler: Aktiviteye bağlı plastisite; Gelişimsel esneklik; Lezyon sonrası plastisite; Uzun Vadeli Potansiyasyon; Öğrenme; Hafıza

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Introduction

Several hundred million nerve cells in the human brain are interconnected in a convergent and divergent manner to form functional brain networks [1]. However, even in adults, these networks are not rigidly organized but show a dynamic reorganization process. This is especially important in the regeneration/reorganization process during the learning process or after brain trauma which is called neuroplasticity [2].

Basics

Contrary to the traditional concept inferring that CNS neurons are post-mitotic cells and exert no division and axonal growth, studies in the last decade focusing mainly on brain trauma patients have suggested that the human nervous system has a unique growth regeneration potential [3].

These findings opened a new window suggesting a dynamically organized nervous system. Today, this paradigm shift away from the statically organized nervous system is a fundamental principle of how the CNS responds to trauma and the learning process. For instance, the neuroplasticity process plays a pivotal role in functional improvements in neurorehabilitation, which say that rehabilitation might optimize functional recovery through modulating the neuroplasticity [4]. In addition to learning and trauma processes, neuroplasticity also plays an essential role during neurodevelopment by modulating the convergent organization of nerve cells in the embryonic period, which are then fine-tuned under environmental influence stimuli until the early adolescence period. This "vulnerable phase" is critical in the context of many neuropsychiatric diseases, such as early childhood traumas [5]. The second form of neuroplasticity is activity-dependent plasticity, which is related to hippocampal reorganization during the learning and memory process [6]. Here, the hippocampus plays a critical role in regulating the neuronal network and shaping the general framework of neurocognitive processes. Another activity-dependent neuroplasticity process depends on the sensorimotor cortex, which shows a rapid cortical reorganization process during motor learning. For example, in violin players, finger movements training leads to a dynamic cortical reorganization that can not be explained with the classical model of somatotopia, suggesting that the classical map-like representation of the body surface is dynamically overlapping [7]. The third form of neuroplasticity is evident when the neuroplasticity process is functionally effective beyond the traditional limits ("cross-modal plasticity"). This phenomenon is not restricted to one sensory modality but also use stimuli from other modalities to become functionally effective beyond the classical rehabilitation limits [8]. The most impressive example for cross-modal plasticity is the visual cortex's potential in overtaking the processing of tactile stimuli in blind people [9].

In contrast to trans-modal plasticity, post-lesional plasticity is observed after peripheral or central nervous system injury [10]. Hence, this process is classified in another category and includes a maladaptive neuroplasticity process: The failure to use the injured parts of the body can lead to significant deterioration in function, which is related to the dysregulation in the size of the cortical representations (phantom phenomena) [11]. However, the good news is that this period is open to applying novel neurorehabilitation and training paradigms so that the cortical representation can be increased and neurological function improved [10].

Mechanisms

As mentioned above, the central part of neuroplasticity is synaptic regulation. This includes the reversal of the strengthening and weakening of other synaptic connections, essential for a flexible neuronal reorganization. This process's electrophysiological correlates are called LTP (longer-lasting potentiation) [12] and long-term depression (LTD) [13], which describes strengthening and weakening of synaptic connections, respectively. Shortly, these mechanisms are mainly responsible for very rapid (minutes, hours) and long-lasting neuroplasticity processes (over weeks and months) [14], requiring the expression of genes and new synthesis of proteins and neurotrophins, such as BDNF [15] for permanent structural changes in the synapses and specific brain areas.

Summary

The human brain is plastic. In other words, it is not statically but dynamically organized. This astonishing potential of the brain is not only active during the development (development plasticity) where it adapts its function and structure to the environment but also during motor training and cognitive learning, which lead to a divergent reorganization process (activity-dependent neuroplasticity). Also, after peripheral or central nervous system injuries, there is a functional and structural reorganization (post-lesional plasticity) of neuronal networks. Specific mechanisms of neuroplasticity include short-term synaptic and long-term structural changes in the CNS. These flexible plasticity periods enable us to apply modern neurological rehabilitation strategies to optimize neuroplasticity and improve neurological function.

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