Module II

Early neurodevelopment

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e-EarlyCare-T

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Early neurodevelopment

1.1. Brain Development: Basic Premises

The development and maturation of the brain is characterized by being long-lasting and occurring heterochronously. However, as brain structures develop, functions begin to express themselves in observable behaviors. Thus, the structures that develop more quickly manifest their functions, before those functions that develop more slowly. Kolb and Whishaw, 2003., Coll, 2011).

In the first months of life, the cerebral cortex undergoes a significant proliferation of synapses (neuronal communication) that will result in the formation of synaptogenesis followed by a period of synaptic pruning (elimination of synapses, often due to lack of use).

1.1. Brain Development: Basic Premises

Another element involved in brain development is the process of myelination of the axons of neurons covered with a kind of "insulator" formed of white matter that allows an adequate transmission of the signal.

In this developing brain, the amount of myelin in a brain area will indicate the use made of that area inducing the development of a certain cortical area associated with a subsequent cognitive process.

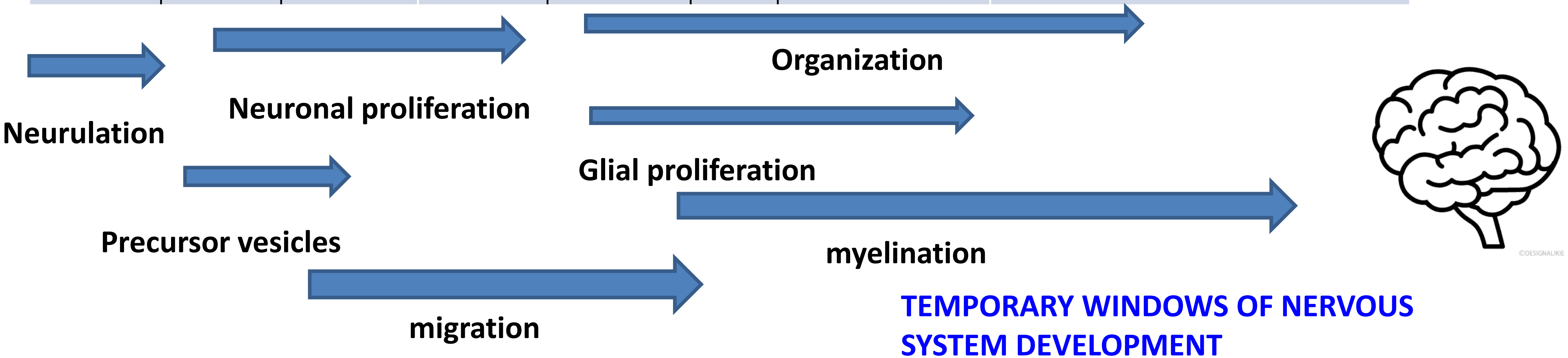
As with synaptogenesis processes and synaptic pruning processes, myelination also has different rates of formation depending on which areas of the brain are developing.

Therefore, we would be talking, not only about how many neurons or synaptic connections exist, but also about how is the structure of the white matter (axons and myelin), the dendrites, as well as the neurochemical circuits that shape brain functioning. Sebastián Gallés, (2012).

Early Neurodevelopment: Some Features of Brain Development	
Postnatal growth of the human brain	Brain mass quadruples between birth and adulthood. -Notable increase in the number and complexity of neurons -Firm increase in the density of synaptic connections in various regions of the cerebral cortex. - Increase in the myelination process which will allow an improvement in the speed of information transmission between neurons.
Loss or "synaptic pruning" of synaptic connections	It involves selective loss in brain development (synaptic density). Pattern of initial increase and subsequent decrease or "pruning" of synaptic density that appears at different ages according to various cortical regions. Overproduction of synaptic connections and subsequent "pruning" related to the special plasticity of the infant brain.
Brain plasticity	Fundamental property of the development of the cerebral cortex. The process of differentiation and specialization of the different areas of the cortex is strongly influenced by the neuronal activity itself, in addition to the inherent factors related to the automatic "ignition". Different cortical zones can serve as the basis for various representations, depending on the input they receive, there does not seem to be, totally predetermined functional areas.

1.2. Development of the nervous system (embryonic period- fetal period- postnatal period)

Embryonic development		Fetal development					Postnatal stage Birth-adulthood
1st month	2nd month	3rd month	4th month	5ºmont h	6º mon th	3rd trimester	Postnatal stage Birth-adulthood



TEMPORARY WINDOWS OF NERVOUS SYSTEM DEVELOPMENT

1.2 Prenatal and postnatal development

The complexity of the brain and the embryology of the brain involves brain regionalization, neural migration and the formation of synapses by neural cells during the embryonic and **perinatal periods.**

The nervous system is formed as a function of three sheets (Gastrulation)

Synaptogenesis (summative process, synapses increase)

Apoptosis (regressive processes, the synapses that are used to us die)

Neurodevelopmental disorders

- Description of the processes where the beginnings of developmental alterations occur, specifically in neuronal positioning and in the migration process, directly linked to the acquisition of neurological, psychiatric, cognitive and affective diseases.

Early development

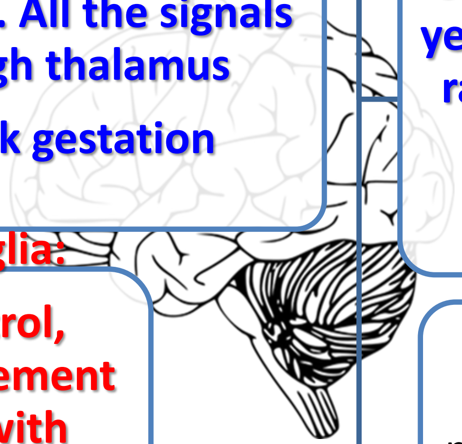
1. Brain stem:
Sleep-wakefulness
Heart-respiratory rhythm
Vital functions

2. Thalamus: relay station with the brain. All the signals pass through thalamus

16-37 week gestation

3. Basal ganglia:

Posture control, voluntary movement (afferences with trunk) substantia nigra, frontal lobe. (60 days and 65 first synapses)



4. Hippocampus
Memory store

5. Cerebellum: until the second year of life the cerebellum grows rapidly to reach adult size. (6-9 years)

6. Primary areas motor/sensory: maturation of the motor cortex, (development of spontaneous reflex movements)

7. Secondary motor and sensory areas

8. Tertiary and posterior areas of the cerebral cortex

9. Prefrontal cortex

Anatomical neurodevelopment

1.2.2 Cognitive functional neurodevelopment:

The development of the main cognitive functions depends on the maturation of the brain circuits that support it. Knowing the evolution and normal development of cognitive functions will be fundamental to identify and interpret possible alterations in this development.

The study from neuropsychology focuses on the study of the main cognitive processes that will be established as the nervous system develops. (Enseñat, Roig and García, 2015).

Cognitive functional neurodevelopment:

Visual perception

Memory

Executive functions

1.2.2 Cognitive functional neurodevelopment

1.2.2.1. Visual perception

During the first year of life, the visual system undergoes important functional changes (both for oculomotor regulation and for visual acuity) showing functional changes that become dependent on subcortical structures at first, and then move to the progressive domain of processing at the level of the cerebral cortex.

There are two ways in charge of processing movement, shape of objects, places and faces.
(Ventral and dorsal routes).
The ventral pathway is responsible for the processing of the shape. The first way to develop, so it is going to be processed are going to be faces, objects and places.
The dorsal pathway is responsible for processing the movement. The integrated response to movement is earlier than the integrated processing of the form. Movement processing, however, will take longer to reach maturity and appears to be more susceptible to being altered (Enseñat et al., 2015).

1.2.2 Cognitive functional neurodevelopment

1.2.2.1. Visual perception

One of the most studied visual processes in the infant stage has been the recognition of faces.

Already at the age of 5 years or perhaps earlier, maturity is reached in the perception of faces, partly due to genetic mechanisms and innate contributions.

Therefore, it could be considered that in childhood the adult mechanisms used in the perception of faces are already present.

This would include phenomena associated with the recognition of individuality and the learning of new faces, global processing, as well as the acceptance of the absence of certain traits, but managing to recognize that previously coded face. (Enseñat et al., 2015).

It should not be forgotten that the maturation of other cognitive processes will also contribute to improving the recognition of faces beyond early childhood.

The recognition of faces will improve if we join the development of the recognition of emotional expression, related to changes in the connections between neuroanatomical structures such as the fusiform gyrus and the structures of the limbic system (amygdala, hippocampus).

1.2.2 Cognitive functional neurodevelopment

1.2.2.2. Memory

The age at which mnesic maturity is reached will depend on several factors.

On the one hand, it will be mediated by **the development of coding strategies** dependent on the maturation of the prefrontal cortex, and by the development of the mnesic process itself associated with the maturation of the medial temporal lobe.

This will result in an increase in general knowledge that will necessarily improve the ability to memorize. As Enseñat et al., (2015) explain, another factor that influences is the development of basic cognitive functions such as processing speed, attention, working memory capacity and the effect of complex functions such as the ability to solve problems or metamemory (Enseñat, 2015, Ofen, 2012).

Episodic memory is considered to develop throughout childhood, but it is unclear whether maturity is reached at a certain age or, conversely, continues to develop throughout development into adolescence.

1.2.2 Cognitive functional neurodevelopment

1.2.2.2. Episodic memory

With regard to the development of **coding strategies,** in those cases in which the tasks involve greater complexity and force the use of certain strategies to obtain a free memory or greater involvement of a temporal order, they will have a later development. (Frontal lobe vs occipital lobe).

If we consider the role of the temporal medial lobe for memory processes and the few structural changes of this region from childhood, it could be considered that the processes involved in memory most related to the medial temporal lobe, such as associative memory, would be those that would mature earlier. (Ofen, 2012, Enseñat et al., 2015).

In its entirety, the evolution of episodic memory emerges from the development of a brain network that includes at a minimum, the hippocampus and the prefrontal cortex.

The role of the parietal lobe in the development of episodic memory is not so clear and it is suggested that it can function as a mediator by the involvement of attentional processes.

1.2.2 Cognitive functional neurodevelopment

1.2.2.2. Procedural memory

About procedural memory, necessary for complex thinking, we know that, from an early age, children already acquire procedural skills that will later serve them in learning new skills.

The age of acquisition will depend on the skill required, the times that what is memorized is repeated and the requirement of other cognitive functions to be able to carry it out.

It is considered that the learning of procedures first goes through a more external phase, in which cognitive resources (short-term memory) are needed so that it can progressively convert this type of procedural memory into an implicit and automated memory in which this procedure guided by external data is diminished.

However, it seems difficult to explain through this approach, all procedural learning in children in whom the mechanisms of explicit learning and cognitive control have not yet been developed..

1.2.2 Cognitive functional neurodevelopment

1.2.2.2. Working memory

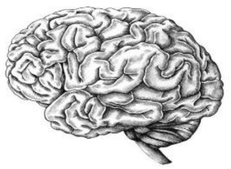
It is the ability to maintain and manipulate for a short period of time the information necessary to guide a certain behavior.

In general, it is considered that this capacity experiences a significant increase at age 11, as well as between 15 and 19 years, reaching maximum levels in adulthood.

Its correct development has been related to the maturation of cortical areas such as the **superior frontal cortex,** the **intraparietal cortex,** as well as their connections.

The development of different types of memory provides the basis for the acquisition of the adult's own skills and knowledge. Knowledge of the milestones that are reached during childhood not only provides useful information for evaluation, but also because of the important implications for education.

Keeping in mind that the episodic memory of children is basically associative (at least until primary education) is fundamental to consider it necessary to instruct them in the use of specific strategies for the improvement of memory performance in the classroom. Enseñat et al. (2015)



1.2.2 Cognitive functional neurodevelopment

1.2.2.3. Language

The acquisition of language, as well as the acquisition of other cognitive functions, will depend to a large extent on the level of environmental stimulation and the correct brain maturation (Enseñat et al., 2015).

The proper development of language systems depends on interaction with other functional networks responsible for skill, e.g. motor or visuospatial, memory, attention, acoustic discrimination capacity, and social and emotional skills.

It is important to note that not all aspects of language are acquired in the same time windows. We know, for example, that the critical period for learning phonemes will occur during the first year of life. Shortly after birth, babies are already able to discriminate the phonetic contrasts of different languages, even those that contrast not present in their native language. (Enseñat et al., 2015).

1.2.2 Cognitive functional neurodevelopment

1.2.2.3. Language

Exposure to a linguistic context during the first year of life will allow the specialization of this skill, achieving better capacity for the phonological contrasts of the languages present in their day to day. (Linguistic period).

During the following months, the child learns an average of 10 words per month until exceeding the figure of 50 words, later, about 18 months the explosion of that vocabulary is evident and the child is already able to learn an average of 30 words per month. (Enseñat et al., 2015).

Around the second year of life, between 18 and 36 months of life, syntactic learning begins.

The child is already able to perform and combine words into simple grammatical structures (sentences with two words) and later, around the age of five, children will increase the complexity of these grammatical structures that they use to add the use of negative questions and phrases.

From the age of five, children already begin to experiment with the uses of language, so that communication strategies and keys already appear that allow them to follow a conversation with another person, clarify misunderstandings of a discourse, increase their level of understanding as well as narrative production (Enseñat et al., 2015).

3.3.4 Executive functions (FE):

They are a set of cognitive functions that allow you to maintain a coherent and organized plan towards a certain end.

These functions include the ability to plan and organize information, flexibility and planning, as well as the ability to control impulses. (Roselli, 2002).

The most critical regions for the emergence of executive functions are located in the prefrontal cortex, in the most anterior part of the frontal lobe, in front of the motor areas.

The prefrontal cortex and the connections that this region establishes with other brain areas undergo changes not only throughout childhood, but also, in a very accentuated way, during adolescence. Coll, 2011.

FEs include so-called cold executive functions as well as hot executive functions.

The first refer to the ability to plan, organize, set goals, monitor behavior, solve problems, inhibition, working memory and cognitive flexibility.

The latter include empathic capacity, emotional regulation, theory of mind and decision-making capacity with an affective component, skills necessary to be able to regulate our behavior with a purpose. (Enseñat et al., 2015)

3.3.4 Executive functions (FE):

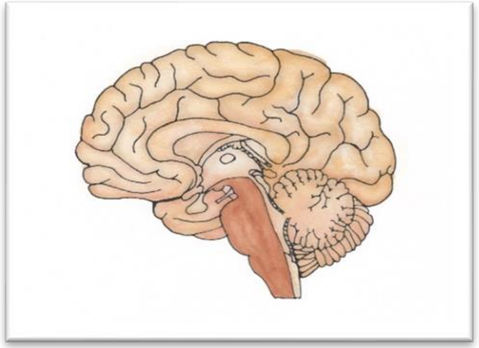
The development of the prefrontal lobe begins in the prenatal period, showing metabolic and structural changes during childhood and adolescence, but does not reach its evolutionary maturity until the thirties, when myelination is terminated.

There is an early maturation of attentional control and some working memory capacity, while other more complex skills such as planning and organization are acquired during adolescence and adulthood.

Attentional control (selective attention, response inhibition, self-regulation, and self-monitoring) is the first element of executive function to mature.

Evidence regarding goal setting (planning, goal setting, and problem solving) during the age of the infant stage is scarce.

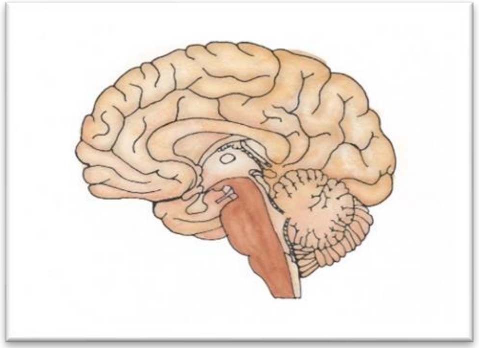
By age 5, children can already set goals and plans.



3.3.4 Executive functions (FE):

In relation to the ability to make decisions with an affective component, we know that children from 3 to 6 years old are based exclusively on immediate rewards.

Until adolescence, it is when you begin to make decisions in an effective way. This ability has been linked to late maturation of ventromedial and orbitofrontal prefrontal areas and appears to be independent of the improvement in inhibitory control and working memory that will occur at the same stage of development. (Anderson et al., 2008. Enseñat et al., 2015).



3.4 Brain plasticity in a child's brain development

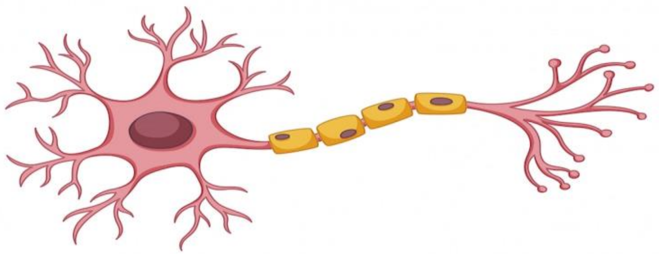
The CNS has a remarkable ability to modify its function and, to some extent, modify its anatomical structure in response to activity, environmental stimuli or the damage it may suffer.

Plasticity is a constant process, which can be observed in different areas: synaptic, structural and organization of neuronal maps. (Medina et al., 2004).

We can affirm that changes in behavior that are described (according to circumstances) such as learning, memory, habits, maturation, recovery and others, are associated with corresponding changes in the nervous system.

The concept of 'neural plasticity' refers, under normal circumstances, to the ability of the nervous system to model its structure and function according to experience, which gives rise to learning processes.

And in circumstances of pathological loss, to their ability to try to update the potentialities of the individual genetic program through remodeling phenomena.

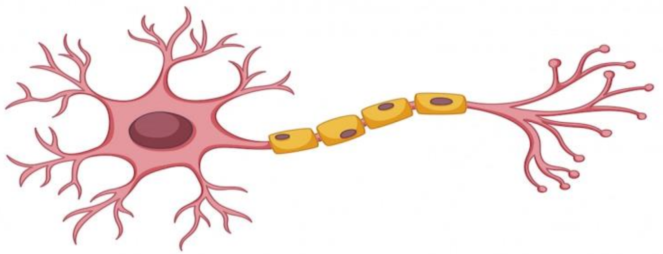


3.4 Brain plasticity in a child's brain development

This brain property can be assessed on many levels, from observable changes in behavior, brain maps, synaptic organization, physiological organization, and molecular structure.

To understand processes such as memory and habits it is necessary to understand the nature of brain plasticity.

The genomic endowment allows, therefore, a margin of adaptability when handling information and also when trying anatomofunctional compensations after suffering some pathogenic aggression. (Narbona et al., 2012).



3.4 Brain plasticity in a child's brain development

3.4.1 Types of brain plasticity:

Learning and remembering new information is linked to some kind of change in the cells of the nervous system (neurons). These changes are considered to constitute the neurological record of the information learned. As shown by Grenough and Black (1992) and Coll (2011)

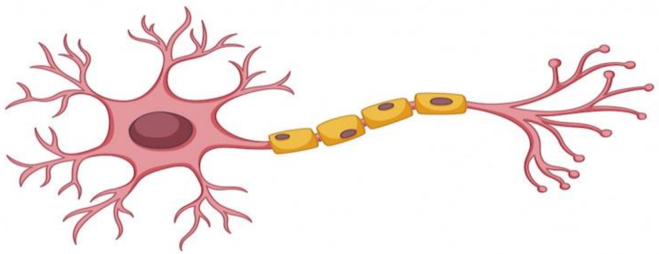
It is possible to establish, summarizing

Three main types of plasticity:

That of development,

The induced by experience during life

The one induced by damage, loss of afferences or alterations in brain activity.



3.4.1 Types of brain plasticity:

1.- Plasticity experience-expectant. (Expectant plasticity of experience)

A type of plasticity that involves synaptic changes produced by aspects of the environment that are common to all members of the species and expected at certain times of development (experiences).

Initially there is an overproduction of synapses, followed later by a neuronal loss. (Coll, 2011).

Limited to periods of maximum susceptibility during development to certain environmental variables (critical or sensitive periods).

After these critical periods, the influence that these experiences have on the brain and its connections will be much more limited.

It will determine the selection of the pattern of organization of the SN permanently and sometimes irreversibly.

This mechanism allows the genes to encode the nature of the connections to be established, already from the fetal period and then in the postnatal period where it is "anticipated" that the child will experience basic episodes, common to the entire species, such as exposure to light and sound, to preserve the previously established synaptic connections of the perceptual systems, of sight and hearing. (Siegel, 2016).

3.4.1 Types of brain plasticity:

2.-Plasticity experience-dependent. (Plasticity dependent on experience).

It reflects changes produced by information absorbed from the environment that may be unique to the particular individual, (the specific learning of vocabulary) that are experiences throughout the entire life cycle.

Such plasticity is not limited to fixed periods of time.

This type of plasticity is maximum during childhood and adolescence.

It is maintained throughout life, except for the presence of neurodegenerative diseases or neurodevelopmental disorders.

It is triggered by the detection of relevant relationships between relevant stimuli between stimuli (learning and memory) or alterations in the stimulating situation (injuries, loss of limbs).

This type of plasticity exclusively activates the genetic machinery to create synapses, whose creation depends on that set of experiences that have previously triggered the creation of these synapses.

Type of plasticity is temporary and subject to change depending on experience. (Siegel, 2016).

3.4.1 Types of brain plasticity:

3. Plasticity independent- experience:

It corresponds to changes in the number and / or function of synapses that occur as a result of the programmed expression of certain genes without external or experiential factors.

This type allows an optimal adaptation of the behavior to the changing environment.

These experiences are an endorsement of techniques that are based on sensory stimulation and learning, although this effect (increased synapses in the cortexes involved for learning) is especially noticeable in the "sensitive" or critical periods of early development, although they are also demonstrated in the adult brain. (Castaño, 2002).

Today both terms are still used, but sometimes "experience-dependent" is used exclusively to refer to both the plasticity of development and the plasticity present in the rest of life.

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Imagery

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