Neuro-biological basis of emotional development and change in adolescence

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Abstract

In the last decades, a great development in both neurophysiologic and neuropsychological areas have been observed that offered new possibilities to support the main principles of psychoanalytic theory.
Can psychoanalytic conceptions of the psychic apparatus remain consonant with what is currently documented to function in nature?
Can the psychoanalytic theoretical model contemplate psychic function and biological structure together?
The purpose of these notes is to briefly expose the recent advances in neuroscience regarding the adolescent mind and pursue the goal of interesting the reader in the possible "metaphorical" psychodynamic union of these biological facts.
In this perspective the present study was firstly aimed at reviewing the most relevant characteristics of the adolescent brain, clarifying the development of the cerebral structures connected to emotions and impulse control. A particular focus was offered to the role of mirror neurons in the development of empathic reactions and, thus, of inter-subjectivity. A second aim of the study was to clarify the role of neuronal plasticity in the evolution of adolescent brain and in the process of change. The interpersonal contact during the psychotherapeutic process was particularly examined as an instrument that facilitate personality changes, with a particular focus on patient-therapist moments of meetings that permit to modify the implicit relational knowing.

Keywords: *adolescent brain; emotional development; mirror neurons; implicit knowledge; moments of meetings.*

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Introduction

Several researches dealing with brain development show how different types of precocious relational experience have a positive or negative impact on the evolving psychic structure.

In particular, neurosciences are currently defining structures and functions of the brain systems which process the information regarding the relationship with the *caregiver*, mediate affection and involve mechanisms of subjectivity and inter-subjectivity.

Can psychoanalytical conceptions of the psychic apparatus be consonant with what is currently proved to work in nature?

Can the theoretic psychoanalytical model include both the psychic function and the biological structure?

Nowadays, through the use of *brain imaging* it is possible to observe the brain development during adolescence and, in particular, the growth of frontal lobes which represent the discriminative element between human beings and other animal species.

Our experience of reality is based on activity patterns of neuronal groups inside the brain which give rise to functional units able to represent our experiences in different forms, as images and sounds, words and sensations, abstract ideas or perceptions. Neural activations can be assembled in different ways (autonomously or interacting with other people), influencing the nature of our experience of reality. Communications and relations between humans rely, at least partly, on sharing these representations, and the patterns of communication which are established in the course of more precocious relations directly affect the development of mind.

Elaborating the activity and the nature of neuronal connections, experiences shape the circuits they are based upon, such as processes connected to memory, emotions or self-consciousness. Understanding the impact experiences have on the mind helps us also understand how the past keeps affecting significantly the present and the decisions for the future.

Brain development: some general principles

Until the last two decades both the role of experience on the development of brain structures and to the active role of the child on his/her own brain development through the interaction with the environment were only scarcely considered (Shore, 1997).

During the foetal development neurons migrate to spawn the different regions of brain (Edelman, 1988), creating the basic cerebral structure. So, at the birth, children just have all the groups of neurons necessary for their adjustment (National Cleringhouse on Child Abuse and Neglected Information, 2001). Subsequently, and until death, the brain continues its development but changes are not as relevant and dramatic as those occurring soon after the birth are. The first brain areas achieving a complete development are the brain stem and the mid-brain, which regulate the essential autonomic functions for survival (breathing, digestion, excretion, and thermoregulation). The last structures reaching a complete development are the limbic system, which

regulates emotional responses, and the cerebral cortex, that enables the abstract thought.
During their development, cerebral structures increase their volume and plasticity. Importantly, the growth of each brain region largely depends on the environmental stimuli they receive that determine the development of new synaptic connections between neurons (LeDoux, 2002). The number and type of synaptic connections that will be formed depend only on experience.

Characteristics of the adolescent brain

Giedd's researches (1999), have shown how the process of brain growth happens continuously in numerous crucial areas of the adolescents' cerebral cortex, among which the parietal lobes, regions connected to the logical and spatial reasoning, and the temporal lobes, connected to language. Adolescent brain maturation is also affected by heredity, environment, and sex hormones (estrogen, progesterone, and testosterone), which play a crucial role in myelination (Giedd, 2013).
The most important datum revealed by Giedd is that frontal lobes keep on developing. Their development reaches the highest peak more or less at the age of eleven for girls and twelve for boys. After reaching larger dimensions than adults reach, grey matter starts to regress quickly. In particular, scanning the children's brain repeatedly, Giedd found that the frontal lobes are probably developed and finished only after the age of twenty years. Giedd's researches have also revealed that neural connections don't decrease constantly from the pre-pubertal age. On the contrary, the brain frontal lobe quickly increases during puberty. Giedd claims that if the adolescent brain is still engaged in deep changes, an important question to address may be what kind of experience is necessary for a brain in full development. What can we expect from adolescents since that wonderful inhibitory mechanism, their prefrontal cortex, is not completely formed? The adolescents' "in progress" condition of this structure could contribute to give sense to their impulsive and uninhibited behaviours.
Greenough (1986) developed a system to determine what is the kind of experience that affects the brain synapses in the adolescence. Some synaptic changes seem to be induced by the genes. It is what he calls experience-expectant. It is a change that should occur or it is expected it occurs in every individual of a given species in a normal environment, such as the development of sight, hearing and some components of language. If it is exposed to common images and sounds, a normal brain modulates the exuberant excess of synapses, creating properly interconnected neural networks. This way, it manages to respond to fundamental stimuli such as love calls or language. If it is not exposed to similar essential experiences, such as the mother's voice or the shape of a tree it may not manage to respond properly to stimuli. There is another kind of experience-expectant changes. It is the synaptic growth depending above all on the kind of experience an individual makes, on the kind of development that makes a brain unique and allows it to adapt wherever it is.
Giedd showed that, as the frontal lobes, also the cerebellum continues to change during adolescence. This is the last brain structure to develop, and in many cases its re-organization (an initial growth followed by pruning the brain connections) finished after the frontal lobes.
In general, the adolescent brain growth implies an overproduction, an excess of nerve

branches and brain synapses, as well as a regress on a large scale of these branches. It may mean that adolescence is a "critical" period in which the environment or the adolescent's activities can "direct" the scheme of brain growth. If the synaptic exuberance really occurs before puberty, as Giedd suggests, how does it affect the adolescent's development and behaviour? Using rigorous laboratory experiments, neuroscientists began to identify the effects of the pruning process in the development of adolescent mind. These studies clarified that it is connected to the harmonization of important cerebral functions, among which the control of inhibitory mechanisms and working memory. One of the most relevant changes occurs in the frontal and prefrontal cortex (Giedd & Thompson, 2000). In these zones, there occur the impulses control, the emotions regulation, the knowledge of the consequences of one's actions and the decisional, logical and rational processes. These so called executive functions reach a full development only at the beginning of the adult age. Finally, there is the most recent point: the development of new neurons. One of the main dogmas of neurosciences was shaken some years ago by reports according to which the adult brain, also including the adolescent's, keeps producing a regular flow of new neurons at least in the hippocampus and maybe in other areas.

Regarding the "adolescent mental confusion", a recent study (McGivern, 2002) showed that when children their ability to quickly recognize other people's emotions nosedives. What's more, this ability does not return to normal until they are around 18 years old.

For a few years the reactions speeds remain slow. It normalizes at the age of eighteen. This discovery could reflect the «relative inefficiency of the frontal neural circuits» of the adolescent brain during the process of remodelling, suddenly growing and pruning the synapses. As shown by Yurgelun-Todd's studies (2006), adolescents mainly use amygdale to recognize emotions instead of the frontal cortex like young adults. This suggests that adolescents are prepared to provide instinctive behavioural response to emotional stimuli, whereas when they grow up they are able to modulate the response or even inhibit it in case of necessity as a function of social context in which they are.

Moreover, Llinas (2000) clarified that adolescent brain constantly monitors its inner state, scanning itself and looking at the emotional contents created inside on and on. In a certain way the brain constantly dreams and sometimes it is disturbed by external events. The brain, continues the Author, is a closed world inside, a subsystem that constantly reworks its contents, as it happens in the psychological experience of the dream, where contents are a subjective and interpreted reflex of a series of really happened external facts.

The role of neuro-scientific study of emotions for the psychoanalytic theorization

What are the great contributions of neurosciences and their resonance for psychoanalysis? Neurosciences posited emotions at the centre of the psychic life and the mechanisms of cerebral functioning. Affection and emotion have become the crucial point of intersection between neuroscience studies and psychoanalytic theorization. The studies on the neural basis of emotions (LeDoux, 2002; Damasio, 1994; Panksepp, 2005; Watt, 1998) on one hand, and the recent psychoanalytic focus on

the attachment system, on alexithymia and on the emotional experience of meeting (Stern, 1998; Fonagy, 2002) suggest dialogue and propose points of convergence between these two different research areas.

In this vein, Damasio (1994) introduced the concept of somatic marker as a central element of the emotional learning that records and keeps track of the emotional reactions to certain situations. According to him, the processes we conceive as mental are representations of the body in the brain. More specifically, the essence of what we are mirrors the patterns of interconnectivity between brain neurons, and all the brain does consist in the synaptic transmission between neurons and in retrieving the information codified by a former synaptic transmission. Like Damasio (1994), LeDoux (2002) points out the human prerogative to have feelings, which activates high cortical circuits, and on the defence reactions coming along with emotions.

The core of Panksepp's point (2005) is the description of a series of prototypical emotional states, emotional networks, preordained circuits, common to all mammals, which are responsible for the fundamental emotional affections.

According to Pankseep, the "sense" of emotions, peculiar of our world of affections and mood, is organized in a very different way from sensorial modalities directed towards the outside.

Emotions reflect those changes of our body that are communicated to the somatic monitoring structures of our brain, not only through specific channels of information processing, but also through less sophisticated mechanisms of chemical transport of the blood and cerebrospinal fluid circulation stream.

Human feelings, in conclusion, seem to reflect old cerebral functions. The apparent psychic power of these functions appears to decrease with the high cortico-cognitive growth, especially among the most intellectualized and autistic members of our species. Maybe, for many people the emotional arousal becomes part of their dynamic unconscious because they have learnt to rely on their own cognitive resources (Panksepp, 2005).

Lieberman et al. (2007) observed, in persons subject to fRMI, that the verbalization of their own emotions and sensations sets up cerebral changes. In particular, the amygdale arousal decreases and the prefrontal region of the right brain is activated. Lieberman et al. (2007) write: "The same way one presses on the brake as soon as the yellow light is on, so one puts a brake to one's own emotive responses translating emotions in words".

The role of mirror neurons and incarnate simulation for the emotional development

What percentage does a developing adolescent brain change with experience, and how? Is it all predestined by the tiny strand of DNA or the destiny of the synapses and the adolescent's behaviour can be really modulated by significant and long-lasting interactions such as the psychotherapeutic experience?

By longitudinal studies on twins, Giedd (1999) showed that developing cerebral regions are susceptible to changes due to external stimuli. Some researches appear to show that «the least heritable» part of the brain, the one that shows the main differences between identical twins as they were interacting with the surrounding environment, is the cerebellum. In fact, it seems that this is the last cerebral structure to develop and in many cases it

finishes its restructuring project after the frontal lobes.

Mentalizing, i.e. having a theory of mind, implies the ability to recognize that the other's mind is different from ours (Dennett, 1978; Fonagy & Target 1993-2000; Fonagy 2001; Fonagy et al. 2002). This also implies the ability to infer what occurs in someone else's mind through their facial expression, the tone of voice and other non-verbal communications. In substance, it is the ability to understand one's own and the others' behaviours in terms of mental states such as beliefs, sensations and motivations (Fonagy & Target 1997). By a constant work of tuning, the adolescent looks for a new way to communicate with themselves and with others, through the developmental ability to experiment and express emotions.

In the processes of developmental changes, new emotional patterns regulate the new connections that are created during adolescence, as well as continuous emotive signals regulate the connections with new experiences. From the first years individuals, during their lifelong development acquire a sense of continuity through an individualized and lasting pattern of affective monitoring. Since emotions and affections in adolescence are connected to specific relational experiences happened in the past, their new arousal in similar circumstances is facilitated. This proposes the idea of emotional patterns of the self in relation to others (Bucci, 1997). Another fundamental aspect is that the self is connected to the repeated experiences made with other significant individuals. They are interiorized during the first years of life. This line of thought is linked to that of some psychoanalytic theorists who point out the importance of emotive representations, structured in the first years of life, regarding the self and the others (Stern, 1985; Kernberg, 1990). It is important to remember that any conception of affective nucleus has to be referred to multiple interactive processes, not to a single generic process.

The adolescent's condition is to put to the test–subjectivate their salience, i.e. the ability to recognize an important situation and take action, carry out acts of passage. The acts of passage imply an intentional movement of the subject towards the object. Every intentional relation can be seen as a relation between subject and object. The intentional movement of the adolescent towards the object implies per se the ability to recognize and understand the other's movement. He/she is engaged in a reorganization of the affection rooted in the processes of mirroring and imitation. Mirroring mainly consists in the fact that the plain observation of another person's actions induces an arousal of the motor cortex that is somatotopic with respect to the part of the body watched doing the action, even without any movement by the subject observing. Mirror neurons have the characteristic to respond both when the subject does something specific and when that something specific is seen to be done by someone else. In other words, mirror neurons are not activated only to imitate the watched movement but also to understand the complexity and the aim of the entire motor sequence: they are able to read the other's intentions. As Gallese and colleagues state: "In our brain there are neural mechanisms (mirror mechanisms) allowing us to understand the meaning of others' actions and emotions replicating them to our internal (simulating them) without any explicit reflexive mediation. The novelty of our approach consists in giving for the first time a neurophysiological description of the exponential dimension of the understanding of others' actions and emotions" (Gallese et al., 2004). In this vein, Meltzoff's

researches (2002) have shown that just few hours from their birth babies are able to reproduce mouth and face movements of the adults who are looking at them. The child's body perfectly simulates the adult's, not as a given reflex arc but through visual information turned into motor information, with a mechanism that has been called active intermodal mapping (Meltzoff & Moore, 1998). It defines a supramodal actual space (Meltzoff, 2002) not linked to a single interaction mode, be it visual, auditory or motor.

This intersubjective mode, which keeps on expanding in the course of life, could underlie the maternal mirroring (Winnicott, 1967) and the concept of affective attunement (Stern, 1985). Recent studies seem to clarify a more articulated mechanism that implies the role of mirroring even of logically related neurons. Besides classically described mirror neuron firing both during the performance and during the observation of a certain motor act, there are also neurons activated by the visual stimulus of a certain motor act downloading during the performance not of the same motor act but of another one functionally related to the one observed (Iacobini et al., 2005). Besides giving a functional role to these logically related mirror neurons, the results of these studies also allow to speculate that they can be part of the neuronal chain which codifies the intensions of others' actions. The traditional way to see the understanding of intention is that the description of an action and the interpretation of why that action is performed largely depend on different mechanisms. According to this hypothesis, it is possible to come to a direct experiential understanding of others' actions, modelling the behaviour of others as an intentional action on the basis of a motor equivalence between what the others do and what the observer does. The mirror neurons system is likely the neural correlate of this mechanism that we can describe in functional terms as incarnate simulation. With the incarnate simulation we do not simply witness an action, emotion or sensation; rather the observer's mind creates inner representations of body states related to those same actions, emotions and sensations, "as if" he/she were performing a similar action or trying a similar emotion or sensation.

When another person's facial expression was observed, and this perception leads us to identify a particular affective state in the other, his/her emotion is reconstructed, experienced and directly understood through an incarnate simulation that produces a body state shared by the observer. This body state involves the activation of viscero-motor neurovegetative mechanisms, as showed by several fMRI studies focused on the facial muscles involved in the expression of the observed emotion (Dimberg, 1982; Dimberg & Thunberg, 1998; Dimberg et al., 2000; Lundqvist & Dimberg 1995). It is therefore the activation of a neural mechanism shared by the observer and the observed that allows the direct experiential understanding of a given basic emotion.

Moments of meeting and psychotherapeutic change

Freud (1912) stated that the analyst "must turn his own unconscious like a receptive organ towards the transmitting unconscious", recognizing the role of unconscious communication between analyst and patient even if he was not able to explain how this communication could occur (Freud, 1921a, 1921b, 1925, 1932). So, how does the unconscious communication happen? A possible explanation may lie in the incarnate simulation: patient and analyst could unconsciously catch, in a constant and

reciprocal way, the other's subtle stimuli activating shared neural pattern. Otherness is also substantiated by the different neural circuits that come into play and/or by their different level of activation when we are the ones who perform or experience emotions and sensations compared to when the others do it.

Many changes that occur during the analytical process have to do not only or mainly with internalization and insight and therefore with the interpretation (related to the declarative memory), but rather with the unconscious elaboration that develops in significant moments of meetings between the therapist and the patient. These are moments of human authentic spontaneous and direct meeting everyone of us well remembers in the course of our analysis (Stern, 2005). The declarative knowledge is gained or obtained by verbal interpretations that change the adolescent's intra-psychic understanding in the context of the psychoanalytical relation and transference, whereas the implicit relational knowledge is carried out through inter-subjective interactive processes that change the relational field in the context of the shared implicit relation. As the interpretation is the therapeutic action that rearranges the patient's conscious declarative knowledge, the moments of meetings represent the event that reorganizes the implicit relational knowledge between the patient and the analyst. Of course, a moment of meeting implies a condition of learning identification (Guillaumin, 1976), an availability to emotive and cognitive reappraisal, and a specific emotional harmony. These conditions describe what occurs in the domain of the shared implicit relationship, i.e. a new specific dyadic state of the participants is being created. Transference and countertransference are just the background frame of a moment of meeting. What is at stake is the personality of the two interacting people relatively stripped of any role-induction (Stern, 1998). The analytical work with the adolescent suggests with particular emphasis the value of such moments of meeting. This form of inter-subjective meeting allows the adolescent and the analyst to experiment again disturbing emotive styles and attitudes (i.e. some unconscious categories of affect). Such an involvement represents the deepest and sometimes more painful way we know to experience our self in the presence of another person. Over time, during the psychotherapy process, a new relational model is proposed and the neural networks related to the old representations of the object and the self are weaken gradually, while new associative links are formed and strengthened with the exposure and interaction between analyst and patient. As Gabbard specifies: "Therefore, the old neural networks don't disappear but are relatively weakened while the new neural networks containing new object relations of the therapy will be reinforced" (Gabbard, 2008).

Discussion

The expansion of psychological knowledge on human development enables us to recognize the crucial role played by empathy, responsiveness, visual exchanges, affective attunement, environmental response contingency and the value to be agents of one's own change. These different and complex relational processes move from the original emotional experiences of reflection and resonance, biologically oriented. These experiences revive the intersubjective exchange, favour the growing awareness of the importance of the other (possible mirroring and exchange source) and contribute to the making of stable

representations of such an awareness. Knowing that some brain areas activate, as it has been observed in some experiments related to the theory of mind, does not help the psychotherapist when they have to address a person suffering from a borderline personality organization. Notwithstanding, the theory of mind is helpful to fully consider how the mind is neither more nor less the brain activity. Coming to a confident belief to have a mind of their own and a subjective inner world is to recognize others have inner worlds different from ours.

The analytical work tends to make the subject gradually aware of the fantasy nature of scenarios he/she imagines and to release him from his/her wrong belief to catch the overall reality from such a narrow view. Weakening the constraints of recurrent fantasies, the psychoanalytic process should allow the subject to look at reality from new points of view, opening the mind to the others. Registration, that is just a translation of direct experience, occurs through mechanisms of brain plasticity. In particular, this transcription offers a mobility space, which is the potentiality to transform the processes of reality construction, being active agents of our own development. The neural plasticity is therefore condition of the development flexibility. Plasticity is, ultimately, what allows the subject, through appropriate relational experiences, to relieve from the constraints of imagined scenarios.

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