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### **Inter-hemispheric interaction in ontogeny of children’s higher mental functions and its evaluative significance for intellectual development examination**

Development of cerebral asymmetry and presence of inter-hemispheric interaction during mental activity is one of the most important characteristics of human species; it is an evolutionary acquisition that importance is equal to that of bipedalism, manual activities, ability to speak and mind. The above integral human qualities were selected through evolution due to an asymmetrical neuro-biological basis; and, at the same time, these behavioral properties themselves became cornerstone mechanisms for formation and strengthening of specific lateralized brain activities in human phylogeny and ontogeny. On the one hand, functional specialization and interaction of brain hemispheres provide mental continuity, orderliness and differentiation, and on the other, stipulate presence of degrees of freedom necessary to create new psychological integrations during ontogenetic development.

**The aim of the paper is:** to substantiate expediency of determination of cerebral asymmetry (CA) manifestations for examination of children’s intellectual development. The main objectives of the paper are:

1. to describe the concept of "inter-hemispheric interaction" from the point of view of modern psychophysiology.

2. to reveal optimal inter-hemispheric interactions for child's higher mental function formation in ontogeny.
3. to develop a new method for diagnosis of distortions in children's psychomotor and cognitive development on the base of a coefficient of cerebral asymmetry (CCA) with the tapping-test.

The concept of "**inter-hemispheric interaction**" from the point of view of modern psychophysiology embraces the next ideas:

- on *dominance* of brain hemispheres. This term usage, since the 50s of the last century, was defined proper only together with obligated indication of corresponding factors, conditions, person's age or social and cultural frame;

- on *cerebral asymmetry* that has neurobiological, psycho-physiological and psychological aspects in phylogenic and ontogenetic terms, it means *functional lateralization, specialization* of function between the left and right brain hemispheres for provision of any mental function and, more globally, provision of coherent behavioral strategies;

- on *work in pair* of the left and right brain hemispheres, on really inter-hemispheric interactions for activation of various physiological parameters or aspects of mental activities, in general, and specific mental functions or processes, in particular;

- on a *system and functions* of commissural fibers (corpus callosum), which provide pair brain work at different stages of ontogeny; i.e. on structures and mechanisms that are involved in realization of comprehensive inter-hemispheric interactions (coordination).

At the present time, much attention is paid to study of interaction of the brain hemispheres, namely: systemic and dynamic modules and levels of interaction support, ontogenetic characteristics as well as basic and pathologic phenomena that are present in health and diseases. Inter-hemispheric interaction formation in ontogeny passes a number of stages, evolutionary meaning of which comprises of gradual inclusion of commissural fibers of different levels and of different phylogenic maturity into processes that provide integrated mental activity. This

process precedes formation of cerebral asymmetry, and then runs in parallel to it according to the rules of heterochrony and asynchrony; it has its own periods and passes in accordance with the universal invariant laws of ontogenetic development. The inclusion of each successive stage involves processes of assimilation, integration of the former one, which begins to execute a subordinate role and continues to provide the basic functions in a minimized controlled form.

Recent achievements of neuropsychological science made possible to determine three main levels of inter-hemispheric interaction during ontogeny [3].

At the first level of inter-hemispheric interaction formation (2-3 year old), trans cortical connections at the brainstem level - cerebral commissures in hypothalamic- diencephalic area and of basal ganglia are principal. In the first functional unit of the brain (a power unit), inter-hemispheric interaction provides neurophysiologic, neurohumoral, sensory-vegetative and neurochemical asymmetries that underlie physical, affective and cognitive child's states; organizes sensorimotor horizontal relationships (e.g., convergence of eyes and reciprocal interactions of limbs) and vertical ones (such as opto-oral and oral-manipulative); at this stage, the ontogenetic fundamental factor - the imprinting mechanism - is "localized", namely selective brainstem activity is the base of further lateralization of hemisphere functions.

The next age period (7-8 year old) is characterized by activation inter hippocampus commissural fibers. At this stage of ontogeny, all major inter-hemispheric asymmetries of the operational level - the second level of the brain functional unit (perception, information processing and storage - the brain sensory system) - are become stable and automatic. Brain hemisphere dominance for a hand and speech are formed, right- or left hemispheric locus of control over specific psychological factors is fixed.

The final stage is the stage of priority of the trans-commissural complex, it lasts from 7 to 12-15 year old. From the neurophysiologic point of view, it is supported by formation of "Walter's waves" - a central mechanism of voluntary attention. This morphological and functional maturity of corpus callosum, which

plays a central role in phylogeny and ontogeny in the terms of frontal interaction provision, stipulates a hierarchy and consistency of inter-hemispheric interactions already achieved during previous stages of psychophysical development. Inter-hemispheric interactions organize mental process provision at the regulatory level that is most important for social integration - the third brain functional unit (programming, control and regulation of mental activities).

It must be understood that in spite of early manifestation of inter-hemispheric differences, the left brain hemisphere does not play at childhood such a leading role in speech implementation as is the case of adults. A specific feature of cerebral organization of speech functions at childhood is that the right brain hemisphere plays an important role in this process. The latest results of research of the right hemisphere role in speech functions provision have shown that it has special contribution to speech activities and does not duplicate left hemisphere activities. The functional role of the right hemisphere is characterized by provision of imaginative, holistic, extra- and paralinguistic components of speech; the right hemisphere is involved in speech perception processes as well as reproduction processes as parts of a speech functional system. The specificity of right hemisphere contribution is shown at different levels of speech implementation processes: acoustic, prosodic, lexical, grammatical, syntactic and semantic.

The nature of interactions between the hemispheres is not the same at different stages of mental function development in different periods of ontogeny. Age-related reorganizations of the internal structure of mental functions lead to changes in brain mechanisms and, corresponding, to changes of inter-hemispheric interactions. Implementation of a mental function depends on adequacy of functional contributions or functional roles of the cerebral hemispheres during their conjugated activities to provide normative individual paths of mental formation in ontogeny [1].

The range of individual paths of children's mental and physical development tends to increase with age during transition from one ontogeny period to another, and thus borders of age periods become more indistinct. This is associated with the

certain regularity: alongside genetic factors, more variable social factors of individual and general environment influence on psychophysical development. In this case, a significant role has individual experiences as a leading factor of child's psychological development. According to the evolutionary genetic principle, younger, from the phylogenic point of view, mental functions have considerable individual variability. The same principle can be applied to describe formation of separate higher mental functions and different, from the phylogenic point of view, psychological functional subsystems that consistently enter into complete brain organization of appropriate higher mental functions at different stages of ontogeny. At the early stages of ontogeny (prenatal and early childhood periods), these are brain subsystems that are associated primarily with the projection areas of the cortex; and at later stages (preschool and school periods), the functional subsystems are established that are associated with frontal neocortex and phylogenetically younger brain formations.

According to the psychodynamic developmental concept, personal basic characteristics and basic structure are formed in early childhood, and remain almost unchanged throughout later life. Moreover, relationships with people around a child in the first years of life (especially with parents) are projected later, transferred to other people who are important to the person (so called transfer), thereby these relationships determine features of child's interactions in society and in family. One of the leading contemporary psychodynamic concepts for

division into periods of personal social development is the scheme of E. Erickson [4], according to which person's mental development, formation of person's "identity" can be described as a series of individual psychosocial stages of crises. At each normal critical stage, a person chooses positive or negative variants of certain personality traits that define person's further life philosophy and relationships with society. The most important concept in psychology of personality - a "self-concept" - is closely associated with types of personality and includes 3 main blocks: "Me, as I am ", "I compared with others", "I compared with We (They)". It must be emphasized that a personality type is formed to 5 - 6

years of age (and is stable later) and is characterized by a typical individual way of processing of information signals of all types. The concept of C.G. Jung on personality types that are formed in childhood, starting with the earliest stages, is close to psychoanalytic views on "core of personality" development.

4 pairs of alternative psychological typological features (TF) are examined according to Jung's psychological types or sociotypes: extraversion-introversion, rationality - irrationality, logic - ethics, intuition - sensing. A structure of individual psychological ("functional") type is a combination of psychological typological features that are formed in early ontogeny.

The method for examination of children's psychomotor and cognitive development with CCA evaluation by the "Tapping-test" was developed by us. As for the practical model [3], child's psycho-physiological examination is performed with the "Tapping - test", a child performs the test separately and sequentially by his/her right and left hands; and received information becomes the base for computer calculation, using the special formula, of the coefficient of cerebral asymmetry (CCA). If the coefficient exceeds normal values, we diagnose distortion of child's psychomotor and cognitive development.

Determination of the coefficient of cerebral asymmetry (CCA) by the "Tapping-test", which a child performs separately and sequentially by his/her right and left hands, allow us to determine function lateralization of child's brain hemispheres that reflects intensity of the inter-hemispheric interaction asymmetry and indicates presence of disorders of psychomotor and cognitive development.

In accordance with the proposed method, we performed psycho-physiological examination of 100 children of primary school age - 50 children participated in a control group (25 girls and 25 boys with normal mental and physical development) and 50 mentally retarded primary school children (25 girls and 25 boys with intellectual disabilities).

The results show that the mean CCA value of girls with impaired intelligence ( $13.97 \pm 3.26$ ) is significantly higher than the mean CCA value of the girls from the control group ( $4.46 \pm 1.45$ ). CCA of boys with delayed intellectual

development equals  $15.81 + -3.34$  , while the mean CCA of the boys without distortion in intellectual development is  $1.16 + - 1.54$ . These results demonstrate significant higher CCAs of children with delayed mental and physical development that indicates on diagnostic importance of inter-hemispheric interaction evaluation for determination of distortion of children's psychomotor and intellectual development.

### **Conclusions**

1. The "inter-hemispheric interaction" term, from the point of view of modern psycho-physiology, involves the next ideas: *functional lateralization* , *specialization* of the left and right brain hemispheres during any mental function formation, conjugate operation of the left and right brain hemispheres at activation of various physiological processes and all mental activity, in general, and specific mental functions, in particular; a system and functions of commissural links that provide brain hemisphere operation in pair at different ontogeny stages to implement comprehensive inter-hemispheric coordination.
2. Optimal inter-hemispheric interaction formation during ontogenesis plays a major role in child's higher mental function development, has its age periods and specific manifestations, in progresses on the base of the universal invariant laws of neuron genetic development at ontogeny.
3. We propose the method for examination of children psychomotor and cognitive development with CCA evaluation by the "Tapping-test". Child's psycho-physiological examination is performed with the "Tapping - test", a child performs the test separately and sequentially by his/her right and left hands; and received information becomes the base for computer calculation, using the special formula, of the coefficient of brain function lateralization (CCA). If the coefficient exceeds the normal value – 4.0, we diagnose distortion of child's psychomotor and cognitive development.

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