PHYSIOLOGY

Reactivity of the Right and Left Hemispheres in 3.5-5-Year-Old Children with Different Attention Efficiency

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Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 150, No. 10, pp. 364-367, October, 2010
Original article submitted January 26, 2010.

Here we present the analysis of age-specific and individual characteristics of sensory systems of the right and left hemispheres in preschool children. We studied the role of visual, auditory, and cutaneous sensory zones of the right and left hemispheres in 3.5-5-year-old children in the structure of functional systems realizing attention processes with different efficiency. Sensorimotor parameters reflecting the structure of functional systems at the perceptive level were identified. These data are helpful for diagnostics of the causes of low efficiency of cognition abilities.

Key Words: *reactivity of sensory zones; cognitive abilities*

Despite intensive development of age-specific physiology, individual peculiarities of perceptive capacity of the brain remain poorly understood [2,4,5]. At the same time, pedagogical and psychological practice aimed at correction of brain ontogeny requires more detailed study of the mechanisms realizing cognitive capacities, because understanding of the mechanisms underlying disturbances in these mechanisms at the early stages of human ontogeny will help to improve the efficiency of methods of correction and compensation [3,6]. In light of this, the study of reactivity of the sensorimotor cortex in preschool children can be very helpful, because psychological correction performed before the age of 7 years is most effective due to high plasticity of the brain and excess of synapses at early stages of ontogeny [5].

Here we studied the role of visual, auditory, and cutaneous sensory zones of the right and left hemispheres in 3.5-5-year-old children in the structure of functional systems realizing attention processes with different efficiency.

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MATERIALS AND METHODS

We examined children of younger and middle groups of kindergarten No. 91 (Kursk): 32 boys at the age of 3.5 years; 42 boys and 44 girls at the age of 4 years; 45 boys and 46 girls at the age of 5 years.

Cognitive capacities were evaluated using Bourdon correction test.

The children with adequate behavior, well-developed speech, and high efficiency of attention processes comprised group 1 (norm). Group 2 included children with attention efficiency below the average values. This distribution of the examinees to the experimental groups was coordinated with kindergarten teachers, speech therapist, and psychologist.

The main empirical method used in the study was measuring the time of right- and left-hemispheric reac-

tions to visual, auditory, and cutaneous stimuli realized in two stages [3].

The first stage consisted of three consecutive cycles including measuring the time of right- and left-hemispheric reactions to visual, auditory, and cutaneous stimuli presented in pairs (background). Stage 2 (mental load) consisted in recording of the reaction time (RT) in intervals between the diagnostics of the efficiency of attention processes.

On the basis of the parameters of right- and left-hemispheric reactions to visual, auditory, and cutaneous stimuli at the stages "background" and "mental load", sensorimotor parameters reflecting the structure of functional systems at the perceptive level were calculated:

1) averaged RT of the right and left hemisphere to visual, auditory, and cutaneous stimuli;
2) character and magnitude of changes in RT to mental load;
3) intrahemispheric ratio of activities of sensory zones;
4) parameters of interhemispheric asymmetry of visual, auditory, and cutaneous sensory zones.

The significance of differences between the groups was evaluated using Student's *t* test [1].

RESULTS

High reactivity of sensory zones of the cutaneous analyzer in both hemispheres and its predominant activation in response to mental load were noted in 3.5-year-old children, which attested to an important role of this analyzer in cognitive processes. In the group of 3.5-year-old children with high attention efficiency, left-hemispheric reactions predominated at the background state (Table 1), while right-hemispheric reactions predominated after mental load (Table 2).

In 3.5-year-old boys of group 1, the rate of right- and left-hemispheric reaction was 646.4±23.1 and 709.5±22.1 msec, respectively, while in group 2 the corresponding values were 819.5±26.6 and 797.7±20.5 msec.

In 4-year-old boys of group 1, the rate of right- and left-hemispheric reaction was 500.3±21.6 and 553.2±21.5 msec, respectively, while in group 2 the corresponding values were 580.4±23.8 and 699.5±29.7 msec (Table 1). It should be noted that the reactions to visual and cutaneous stimuli were more intense in boys of this age. Left-hemispheric reactions prevailed in the beginning of the experiments, while right-hemispheric reaction appreciably predominated after mental loads due to, first, considerable acceleration of right-hemispheric reactions to light and cutaneous stimuli in boys of group 1, and, second, due to pronounced inhibition of left-hemispheric reaction to auditory stimuli in group 2 boys. During mental activity, generalized

TABLE 1. Parameters of Right- and Left-Hemispheric Reactions in 3.5-5-Year-Old Children before Mental Load (*M*±*m*)

Age/groups	Right-hemispheric reaction				Left-hemispheric reaction			
	visual	cutaneous	auditory	right hemisphere	visual	cutaneous	auditory	left hemisphere
3.5-year-old boys group 1 (*N*=15)	732.3±25.9	630.4±26.2	654.1±21.6	672.3±26.2	743.4±26.5	691.5±28.4	699.3±24.5	711.3±23.2
group 2 (*N*=17)	802.6±27.8	786.7±24.7*	868.7±29.7*	819.3±24.1*	864.4±25.7*	774.4±22.1	754.9±22.6	797.8±21.1
4-year-old boys group 1 (*N*=20)	585.2±24.8	656.9±25.7	578.05±29.30	606.3±27.7	646.9±23.8	602.3±25.9	569.2±23.1	605.6±21.8
group 2 (*N*=22)	716.7±28.1*	820.6±28.2*	723.5±23.1*	753.7±22.8*	760.4±22.7*	670.9±28.2	630.9±26.1	686.1±21.1
4-year-old girls group 1 (*N*=21)	658.7±24.1	884.5±28.8	806.5±22.9	783.1±21.3	889.9±21.1	723.90±26.09	620.4±24.1	744.7±29.7
group 2 (*N*=23)	950.5±29.2*	950.8±27.1	798.3±29.2	900.0±25.8	780.7±28.1	843.80±22.09	850.6±22.7*	825.0±25.7
5-year-old boys group 1 (*N*=21)	570.1±24.1	567.2±27.7	558.2±21.1	565.5±29.7	605.6±27.7	647.7±23.2	508.3±26.2	587.8±27.7
group 2 (*N*=24)	743.5±21.2*	938.5±25.1*	908.9±24.7*	863.8±27.2*	779.8±27.9*	763.2±26.8*	819.2±29.2*	787.4±22.7*
5-year-old girls group 1 (*N*=22)	426.2±21.8	492.01±27.80	466.4±25.8	461.2±24.2	432.3±26.7	464.1±22.7	442.9±23.3	446.1±28.1
group 2 (*N*=24)	856.2±23.7*	897.6±29.8*	1067.8±26.8*	1025.6±22.3*	898.6±21.8*	934.2±27.7*	1029.9±23.2*	978.5±21.1*

Note. Here and in Table 2: *$p<0.05$ compared to group 1.

TABLE 2. Parameters of Right- and Left-Hemispheric Reactions in 3.5-5-Year-Old Children after Mental Load (*M*±*m*)

Age/groups		Efficiency of attention	Right-hemispheric reaction				Left-hemispheric reaction			
			visual	cutaneous	auditory	right hemisphere	visual	cutaneous	auditory	left hemisphere
3.5-year-old boys	group 1 (*N*=15)	22.4±1.4	585.1±27.8	581.3±28.1	772.4±23.6	646.4±23.1	761.4±24.7	700.5±24.8	666.2±25.1	709.5±22.1
	group 2 (*N*=17)	18.1±1.2	802.05±25.70*	786.2±24.1*	868.4±23.8	819.5±26.6*	864.1±27.8	774.3±25.7	754.3±28.6	797.1±20.5
4-year-old boys	group 1 (*N*=20)	39.02±3.70	417.2±23.8	579.01±28.70	503.05±29.70	500.3±21.6	562.5±25.8	540.05±28.60	558.4±22.6	553.2±21.5
	group 2 (*N*=22)	30.4±2.3	535.1±29.4*	624.4±26.5	588.7±21.6	580.4±23.8	737.7±26.6*	630.8±29.1	728.2±22.7*	699.5±29.7*
4-year-old girls	group 1 (*N*=21)	47.3±3.2	549.9±28.1	592.6±22.1	537.9±28.5	560.1±29.1	641.4±22.6	633.8±27.7	554.4±20.7	611.1±26.6
	group 2 (*N*=23)	41.3±2.9	746.3±25.7*	776.9±25.7*	698.8±24.8*	740.6±27.2*	706.1±25.8	781.6±23.1*	737.7±22.5*	741.5±28.6*
5-year-old boys	group 1 (*N*=21)	54.5±3.4	514.7±23.5	494.6±21.2	495.4±21.8	501.7±29.6	554.4±24.6	544.7±25.7	445.2±26.6	515.4±21.8
	group 2 (*N*=24)	50.1±2.8	642.4±24.1*	868.5±28.4*	689.4±22.8*	798.6±29.1*	837.2±23.7*	919.7±21.3*	674.5±23.1*	810.3±28.7*
5-year-old girls	group 1 (*N*=22)	55.4±5.05	387.5±29.7	443.05±24.80	451.01±21.70	427.05±22.10	393.4±24.7	449.5±25.1	362.3±24.5	401.6±29.6
	group 2 (*N*=24)	51.01±4.40	754.2±22.1*	847.3±21.5*	866.4±29.6*	852.4±26.6*	762.4±20.9*	809.7±23.6*	877.6±27.6*	851.4±27.7*

activation of sensory zones in both hemispheres was observed with the following intrahemispheric activity gradient for the sensory zones: $RT_{VIS}<RT_{CUT}<RT_{AUD}$.

In 4-year-old girls of group 1, the mean values of right- and left-hemispheric reaction were 560.1±29.1 and 611.1±26.6 msec, respectively, and in group 2 the corresponding values were 740.6±27.2 and 741.5±28.6 msec, *i.e.* they were inferior to boys by the velocity of reaction to all presented stimuli ($p<0.05$). Similarly as in boys, in girls left-hemispheric reactions predominated at the background stage and right-hemispheric reactions prevailed during mental load. Girls with high efficiency of attention processes demonstrated accelerated reactions to all stimuli, the reaction to light was most accelerated among the right-hemispheric reactions and reaction to sound was most accelerated among the left-hemispheric reactions ($p<0.05$).

In girls with attention capacity below the average values, RT were maximally decelerated against the background of maximum intensity of right- and left hemispheric reactions to auditory and visual stimuli, respectively, and interhemispheric asymmetry of RT values was minimum.

In 5-year-old boys of group 1, the time of right- and left-hemispheric reaction was 501.7±29.6 and 515.4±21.8 msec, respectively, while in group 2 the corresponding values were 798.6±29.1 and 810.3±28.7 msec (Table 2). In group 1, the cutaneous and auditory zones were most reactive among right-hemispheric centers, while auditory zones were most reactive among left-hemispheric centers. Children with high attention capacities demonstrated high velocity of the recorded reactions ($p<0.05$) with predominance of right-hemispheric reactions, generalized activation of right- and left-hemispheric reaction under conditions of mental load, and the following intrahemispheric gradient of sensory zones on both sides: $RT_{AUD}<RT_{CUT}<RT_{VIS}$.

Children with low attention capacity were characterized by slow reaction to all presented stimuli accompanied by activation of right-hemispheric sensory centers during testing and inhibition of some left-hemispheric centers.

Only in 5-year-old girls of group 1, RT values in all comparisons surpassed the corresponding parameters in boys (427.05±22.10 and 401.6±29.6 msec for right- and left-hemispheric reactions, respectively ($p<0.05$).

Maximum differences were noted during the analysis of intrahemispheric gradient of RT values. During mental load, the gradient for the right hemisphere in groups 1 and 2 was the follows: $RT_{VIS}< RT_{CUT}<RT_{AUD}$, the left-hemispheric gradient was different also in group 1: $RT_{AUD}<RT_{VIS}<RT_{CUT}$, while in group 2 the gradient of activity of sensory zones remained immature: $RT_{VIS}<RT_{CUT}<RT_{AUD}$.

Thus, a pronounced ontogenetic dynamics of the role of afferent structures in the formation of functional cognitive systems of different efficiency was observed in 3.5-5-year-old children.

Our experiments revealed substantial ontogenetic peculiarities in the organization of sensory systems in 3.5-5-year-old children and the dependence of cognitive processes on the development of perceptive functions.

Evaluation of the dynamics of the studied RT parameters on stimuli of different modality revealed higher reaction velocity in boys throughout the analyzed period. Sex-related differences of interhemispheric gradient of reactivity of sensory zones attested to the differences in the rate of the left hemisphere development in boys and girls [5]. Sex-related differences in the degree and pattern of interhemispheric asymmetry of RT values in boys and girls, probably, lead to the formation of different strategy of information processing starting from the early stages of ontogeny with natural succession of predominance of certain sensory centers and hemispheric reactions on the whole [4].

Presentation of mental load to preschool children is more often accompanied by activation of right-hemispheric centers. Weak activation, and even more so, inhibition of RT parameters as well as their excessive intensity in the form of generalized activation of sensory zones in both hemispheres can be considered to be unfavorable factors for attention process efficiency. The observed asynchrony of the reactivity of the studies zones is probably determined by alternation of sensitive periods in the formation of the corresponding integrative sensory mechanisms affecting the style of cognitive processes.

Comparative analysis of our data revealed differences in quantitative (RT velocity) and qualitative (inter- and intrahemispheric RT gradients) parameters in groups with different efficiency of cognitive capacities. Interhemispheric gradient of activity of sensory zones, an important marker of maturity of perceptive mechanisms in the structure of functional systems realizing attention processes in 3.5-year-old children, was characterized by accelerated reaction to cutaneous stimuli, while by the age of 4-5 years, maximum intensity of right-hemispheric reaction to visual stimuli was noted. Deviations from the revealed regularity can be associated with retarded general mental development of the child.

Thus, reactivity of sensory zones in the right and left hemispheres in 3.5-5-year-old children during the realization of cognitive processes has certain regularities of microgenesis at the psychophysiological level and deviation from these regularities can impair the efficiency and quality of attention.

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