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ANALYSIS OF AGE-RELATED CHANGES IN THE CORTICAL THICKNESS OF THE HUMAN CEREBRAL AND CEREBELLAR CORTEX IN AREAS ASSOCIATED WITH FACE RECOGNITION

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Tatiana Tsekhmistrenko[1,2]✉, Aslan Mazloev[1], Nicolas Chernykh[3], Valentina Vasilyeva[2], Dmitry Obukhov[4], Sami Omar[1]

[1] *Peoples Friendship University of Russia (RUDN University), Moscow*
[2] *Institute of Developmental Physiology, Russian Academy of Education, Moscow*
[3] *Public Health Center #62, Moscow Department of Health, Moscow*
[4] *St. Petersburg State University, St. Petersburg, Russia*

✉ *tsekhmistrenko_ta@pfur.ru*

ABSTRACT — Aims. Perception and recognition of faces is supported by a network of nerve centers in the human brain that have different maturation periods in postnatal ontogenesis. In this article, we analyze the relationship between changes in the thickness of the cortex in facial recognition centers in children from birth to 12 years old.
Methods. Histological material was obtained from the left cerebral hemispheres and bilaterally from the cerebellum of 62 boys who died from injuries without brain damage. The material was grouped at annual intervals. Measurements of the cortical thickness were carried out in field 37a in the fusiform face area on the medial surface of the occipital lobe, in field 10 on the lateral surface of the frontal pole, as well as in the lateral right and left parts of the posterior quadrangular lobule (H VI) of cerebellum. Morphometry was performed on virtual images of sagittal paraffin sections, stained with Nissl cresyl violet. The mean, standard error and confidence interval were calculated for the indicators of different age groups.
Results. The most significant increase in cortical thickness in fields 37a and 10 occurs during the first year of life, at 2–3 and 6 years. Increases in cortical thickness in the lobule H VI of the on the right cerebellum are observed at 1, 2, and 7 years, on the left during the first two years of life. Evaluation of the relationship between age-related changes in cortical thickness using Spearman's rank correlation analysis showed that the strongest, direct and significant two-way relationship is between the indicators in the pairs field 37a & field 10 and field 10 & H VI on the right, a moderate significant relationship in the pair field 37a & H VI on the left.
Conclusions. It is assumed that age-related changes in the cortical thickness in the centers of face recognition and their relationship reflect the stages of the formation of the facial processing in children.

KEYWORDS — cerebral cortex, cerebellar cortex, cortical thickness, facial recognition centers, children, postnatal ontogenesis.

INTRODUCTION

Recognizing facial features, understanding and interpreting facial expressions allows you to obtain a large amount of socially significant information. This function is gradually formed in children until adolescence [5]. The analysis of invariant facial features associated with facial identity is supported by a network of nerve centers, among which several areas of the cerebral cortex and cerebellum play a particularly important role [6].

Postnatal changes in the cortical thickness make it possible to trace the rates and timing of structural transformations of the cortical centers involved in face recognition. The most interesting is the fusiform face area (FFA), damage to which can cause prosopagnosia (face recognition impairment) [9]. The dorsolateral prefrontal cortex is involved in cognitive operations related to the renewal of working memory, recognition and storage of facial features [8]. The oculomotor area of the cerebellar cortex in the region of the posterior quadrangular lobule (H VI) is also included in the facial recognition neural network [1, 10]. In the system of neural networks that carry out face processing, specialized cortical centers of different levels functionally interact due to the variety of anatomical connections.

It was important to understand how the changes are interconnected in the cortical thickness in different centers of face recognition in the process of age development in children. The aim of this work was to study quantitative changes in cortical thickness in the areas of the brain and cerebellum involved in facial processing in children of different ages and to assess the closeness of the relationship between these changes.

METHODS

The material consisted of the left cerebral hemispheres and cerebellum of boys aged from birth to 12 years (62 cases) who died from injuries without brain damage. The collection of sectional material was authorized by the ethical commission of the Institute of Developmental Physiology of the Russian Academy of Education.

The brain was fixed in 10% neutral formalin. Fragments of tissue were excised in field 37a of the lateral occipitotemporal gyrus, where the fusiform face area is located [4], and also in field 10 of the prefrontal cortex on the inferolateral surface of the frontal lobe. The cerebellar cortex was examined in the posterior quadrangular lobule on the right (HVI_R) and left (HVI_L) in the lateral regions of the hemisphere of cerebellum. The histological material was grouped at annual intervals.

Cortical thickness was measured on sagittal paraffin sections stained with Nissl cresyl violet using programs Image Tools (NIH, USA) and Image-Expert™ Gauge (NEXSYS, Russia). The number of measurements for each section was at least 10, for each preparation at least 40, for each age at least 120. Statistical analysis of the obtained quantitative data was performed using the SigmaPlot software package (SYSTAT Software, USA). For indicators of different age groups, we calculated the mean, standard error and confidence interval, while checking compliance with the normal distribution of values in the compared samples, analyzed the probability distribution of quantitative data [7]. We also determined the significance of differences between the average values of different age groups using a two-sample t-criterion (Student's t-test) at P≥95% (p<0.05).

To evaluate the relationship between age-related changes in cortical thickness in the compared cortical zones, we calculated Spearman's rank correlation coefficient (Rs) and its statistical significance using the Student's table of critical values.

RESULTS

By the time of birth, the cortical thickness in field 37a in the fusiform face area averaged 1477 ± 28 μm, in field 10 of the prefrontal cortex 1611 ± 82 μm. In newborns, there were no statistically significant differences in the mean group parameters of cortical thickness between field 37a and field 10 of the neocortex in the left hemisphere. In the cerebellum of newborns, the cortical thickness averaged 295 ± 11 μm in the posterior quadrangular lobule on the right (HVIR), and 244 ± 11 μm in the same lobule on the left (HVIL). The cortical thickness in the posterior quadrangular lobule on the right was significantly greater than on the left (p <0,01).

During the first year of life, cortical growth in thickness in the studied cortical zones occurred with different intensities. By 12 months, in the 37a field the cortical thickness increased by 1.6 times, in the 10 field — 1.2 times, in HVI_R — 1.3 times, in HVI_L — 2.4 times compared to newborns. In children over 1-year-old, the cortical thickness increased by 1.7 times in 37a field at age 3 years and 1.8 times by 6 years compared to newborns. In the field 10, the cortical thickness increased 1.4 times by 2 years, and 1.5 times by 6 years. At the HVI_R area the cortical thickness increased by 2.3 times by 2.3 years, at age 7 years by 2.7 times, and in the HVI_L area at age 2 years by 3.1 times.

The cortical thickness in the neocortex stabilized after 6 years. By the age of 12, the cortical thickness in field 37a averaged 2660 ± 54 μm, and in field 10 2482 ± 106 μm. In the cerebellar cortex, the cortical thickness stabilized in the HVI_R after 7 years, and in the HVIL after 2 years. By the age of 12, the cerebellar cortex thickness in HVIR was 781±43 μm, and in the HVI_L region, 821±45 μm.

We used Spearman's rank correlation analysis to evaluate the relationship between the rate of cortical thickness growth in facial treatment centers in children from birth to 12 years of age. Rs correlation coefficients between mean cortical thicknesses in annual intervals and on a rank scale are shown in the table.

Table. *Correlation matrix of age-related changes in the thickness of the cerebral cortex in fields 37a, 10 and in the posterior quadrangular lobule of the cerebellum on the right (HVI_R) and on the left (HVI_L) in children from birth to 12 years*

n=13	Field 37a	Field 10	HVIR	HVIL
Field 37a	1,000 (0,00)	0,836** (0,8)	0,682* (0,57)	0,287 (0,75)
Field 10	0,836** (0,8)	1,000 (0,00)	0,88** (0,7)	0,34 (0,74)
HVIR	0,682* (0,57)	0,88** (0,7)	1,000 (0,00)	0,33 (0,74)
HVIL	0,287 (0,75)	0,34 (0,74)	0,33 (0,74)	1,000 (0,00)

Note: *n is the number of rank pairs of compared values; the top indicator is the correlation coefficient (Rs); bottom (in brackets) is t-stat (Student's t-test). Two-sided level of significance (p-value): * 0.05; ** 0.001*

It follows from the table that there is a strong and direct two-way relationship (Rs = 0.836; p = 0.001) between age-related changes in the thickness of cerebral cortex in fields 37a and 10. This indicates the conjugate development of two cortical centers in the left cerebral hemisphere including the frontal center, which controls working memory during facial processing, and the occipitotemporal visual center, for recognizing facial features.

The correlation between age-related changes in cortical thickness in field 37a and HVI_R is moderate and direct (Rs = 0.682; p = 0.05). A weak direct two-way relationship was found between changes in cortical thickness in field 37a and HVIL (Rs = 0.287; p> 0.05). Obviously, in the process of postnatal development, functional connections between FFA on the left side are maintained with the right lateral part of the oculomotor visual center in the cerebellar cortex. This relationship corresponds to a system of anatomical projection connections between the cerebral left hemisphere and cerebellum.

There was a strong and direct two-way relationship between changes in cortical thickness in field 10 and in the HVI_R lobule (Rs = 0.88; p = 0.001). A weak and direct relationship was determined between changes in cortical thickness in field 10 and in the HVI_L lobule (Rs = 0.34; p> 0.05). This means that the prefrontal field 10 of the left hemisphere, as well as field 37a of the occipital-temporal cortex, is characterized by a closer functional interaction with the visual area of the cerebellar cortex in its contralateral hemisphere in the system of distributed systemic connections in comparison with the homolateral hemisphere.

DISCUSSION

Our study showed that the most significant changes of the cortical thickness in fields 37a and 10 of the cortex in the left cerebral hemisphere, which are involved in facial processing, occur in children during the first year of life, as well as at 2–3 years and 6 years.

Our assessment of the relationship between age-related changes in cortical thickness using Spearman's rank correlation analysis allows us to conclude that the strongest two-way relationship is between the indicators in the pair field 37a of the occipitotemporal cortex & field 10 of the prefrontal cortex. The presence of a functional connection between the dorsolateral prefrontal cortex and the occipitotemporal cortex in face recognition is confirmed by physiological studies [11], which demonstrate their interaction in the implementation of a cognitive operation related to the categorization of visual stimuli during facial processing [2].

The growth of the thickness of cerebellar cortex in the lateral part of the posterior quadrangular lobule (H VI) has different durations on the right and left. The anticipatory cortical growth in the H VI lobule of the left cerebellum from birth to 2 years compared to its right hemisphere is of interest due to the participation of the left oculomotor zone of the cerebellar cortex in the classification of facial emotional expressions, that has been shown in experiments with transcranial magnetic stimulation of the left cerebellum [3]. The longer growth of the cortical thickness in lobule VI of the right cerebellum, which lasts up to 7 years, compared with the left cerebellum, may be due to the close functional interaction of right cerebellum with the left cerebral hemisphere, the role of which in the processing of the face differs from that of the right hemisphere [2].

CONCLUSIONS

We assume that age-related changes in cortical thickness in facial recognition neural networks reflect stages of improvement in facial processing in children with age. The interaction of cortical facial processing centers occurs in the system of associative connections between the occipitotemporal cortex and the prefrontal cortex, as well as in the system of forward and backward projections between the cereberal cortex and cerebellar cortex.

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