PSYCHOPHYSIOLOGICAL FACTORS OF SUCCESSFUL MASTERING OF A FOREIGN LANGUAGE BY STUDENTS

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Abstract— In the work, new data on the features of autonomic, motor and cognitive factors of the success of mastering the English language by international students are obtained. Evidence has been obtained in favour of the fact that in primary school students the success factor is the severity of the functional activity of the left hemisphere, and in senior courses a similarity of the functional activity of both regions is necessary. It is shown that the high activity of the autonomic nervous system and a moderate amount of stress reactions are a physiological factor in the success of the process of mastering the English language. It was revealed that the amplitude-time characteristics of the gaze movement when working with texts in the native and English languages differ in people with different successes in learning English. Based on the results of a study of the psychophysiological correlates of the success of the effect of language acquisition, it is possible to build an expert decision support system for assessing the level of language training.

Index Terms— Articulation, Coherence, Integrity, Foreign Language, Psychophysiological Factors, Successful Mastery, Students.

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1 INTRODUCTION

The studies of psychophysiological mechanisms ensuring the success of mastering a foreign language is an urgent problem of modern cognitive science [1-4]. In this problem, neurophysiological, psycholinguistic, anthropological and other aspects are distinguished. However, the features of the functional state related to the optimal modes of the implementation of linguistic functions are still poorly studied. Of most considerable interest in this regard is the English language, which has become the universal language of international communication.It can be assumed that the basis of individual success in mastering the English language is the totality of all "physical, physiological, and more broadly, biological properties of the individual". Therefore, to search for psychophysiological signs that serve as indicators (markers) of the success of mastering a foreign language, comprehensive research is necessary taking into account the ontogenetic aspect: from the search for optimal functional states for the successful mastering of a foreign language and ending with the psychophysiological markers of language competence.
Based on the definition of cognitive experience within the framework of the model of the psychological structure of intelligence, we can designate the psychophysiological factors for the success of mastering the English language as certain physiological states that provide optimal storage, ordering and transformation of available and incoming information in a

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foreign language, thereby facilitating the reproduction of the cognizing subject in the psyche sustainable, regular aspects of his environment.

2 A COMPREHENSIVE PSYCHOPHYSIOLOGICAL APPROACH TO THE STUDY OF THE PROCESS OF MASTERING A FOREIGN LANGUAGE

Within the framework of the method, it is assumed that different modules process information signals and overlapping neural structures [5] participate in different information processing cycles.After entering the brain, sensory information is transmitted from the primary associative region to the posterior associative or prefrontal cortex, where it is enriched with an emotional assessment of the significance of the situation, is converted, and only then sent to the higher cortical representation of the motor system. The amygdala (amygdala) provides an adequate assessment of the biological significance of the signals. By integrating recent sensory information with that stored in memory, a particular emotional state is formed. Physiological confirmation of this is the fact that the neural cycles of Yakovlev and Peipez, which are responsible, respectively, for the mechanisms of emotions and memory, include, first of all, amygdala, temporal and frontal lobes of the cortex, cingulate (cingular) gyrus and hippocampus. These cycles, called the limbic system, are in close interaction with the autonomic nervous system, the highest centre of which is the hypothalamus [6]. The result is the interaction of neural networks, which form the emotional and vegetative components of perception.Thus, it is possible to outline the brain structures that ensure the formation of perception with all four essential components: cognitive, emotional, motor and autonomic. A connection is known between different modules of processing an information signal; overlapping neural structures participate in different cycles of information processing (Fig. 1).
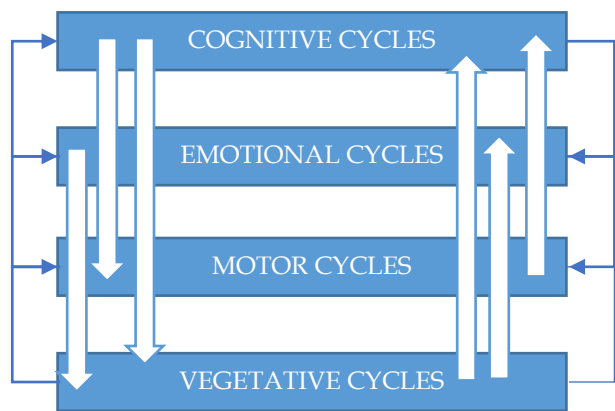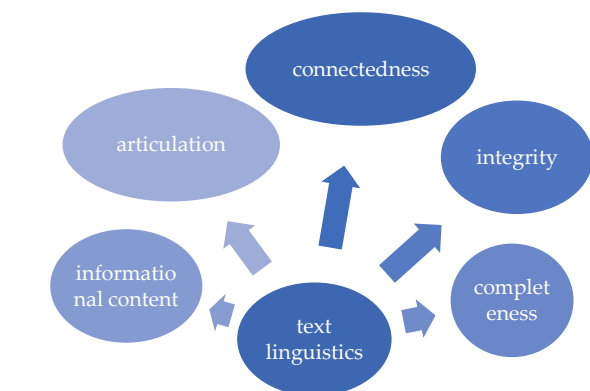
Fig. 1. Cycles are processing an information signal [6].

Today, there are generally accepted ideas about the presence of dynamic properties of functional interhemispheric asymmetry (FIMA) [7].Heart rate variability (HRV) is a generally accepted term for describing changes in the instantaneous heart rate and PP intervals [8]. HRV analysis is "a method for assessing the state of the mechanisms of regulation of physiological functions in humans and animals, in particular, the overall activity of regulatory mechanisms, neurohumoral regulation of the heart, and the relationship between the sympathetic and parasympathetic parts of the autonomic nervous system".Reading is a complex task, and understanding its cognitive specificity is an urgent problem. In the information approach, the text is considered as a way of encoding information based on the rules of a particular language [9]. In linguistic forms, cognitive images that have developed in the process of collective experience are fixed and reflected.The objectives of the study affect the position from which the text is considered (object or subject). It consists of some units that are interconnected. In the linguistics of the text, researchers identified such characteristics as coherence, integrity, completeness, information content, articulation (Fig. 2).

Fig. 2. Characteristics of Text Linguistics

Obtaining information that is necessary and sufficient to reconstruct the images encoded in the text is provided during the reading process. Studying the features of eye movement when reading texts makes it possible to obtain information about the features of processing verbal information by a person based on individual models that are created and improved in the process of language acquisition.As objective determinants of the complexity of working with text, consider the features of syntax and semantics that affect the perception and understanding of the text: the frequency of words and phrases, word length, lexical uniqueness of phrases, etc. To calculate the objective complexity of a text, the equation is usually used [10]:

$$RE\_eng = 206.835 - 0.846 * wl - 1.015 * sl \qquad (1)$$

where wl is the number of characters per 100 words (that is, it is a measure of the length of words), sl is the number of words in the sentence (that is, it is a measure of the length of the sentence).

RE (for English) often falls into the framework from 0 to 100, where 0 indicates the high complexity of the text, and 100 - its simplicity.

Although this model does not take into account the most critical aspects related to the complexity of the structure of sentences and vocabulary, it is important to note one undoubted advantage: this model allows you to evaluate the objective complexity of a text in any language.

3   EXPERIMENT AND EVALUATION

The total number of subjects participating in the study was 114. Table 1 shows the sample structure.

TABLE 1

THE STRUCTURE OF THE SAMPLE

Assessed Factors	English language learning phase	Age	Experiment No. series	N	
Evaluation of FIMA as a factor of readiness for successful mastery of the English language	Students of 1-2 courses	16-17	ES 1	41	
	Students of 2-3 courses	17-19	ES 2	49	
	Masters	18 and older	ES 3	20	
Assessment of the vegetative support of the process of mastering the English language	Students of 1-2 courses	16-17	ES 4	43	
	Students of 2-3 courses	17-19	ES 5	51	
	Masters	18 and older	ES 6	18	
Assessment of eye movement when working with texts as a reflection of the success of mastering a foreign language	Students of 1-2 courses	16-17	ES 7	42	
	Students of 2-3 courses	17-19	ES 8	50	
	Masters	18 and older	ES 9	19	

For testing students, the TYE Adult Learners Cambridge English test methodology [11] was used.

Each participant is invited to choose the correct answers to 25 questions. The list of items includes 25 points with four possible solutions: 5 points for each level of knowledge of English - Elementary level, Pre-Intermediate level, Intermediate level, Upper-Intermediate level and Advanced level. When analyzing the forms with the answers of the subjects, first of all, the number of correct answers to the items of the Elementary level was calculated, then Pre-Intermediate, then Intermediate, Upper-Intermediate and Advanced. Table 2 shows the conditions for assigning a level to subjects depending on the number of correctly resolved points of different difficulty levels.

TABLE 2

ENGLISH LANGUAGE ASSIGNMENT ALGORITHM

Correctly solved tasks					Assigned Level
Elementary	Pre-Intermediate	Intermediate	Upper-Intermediate	Advanced	
3-5	1-2	–	–	–	Elementary
4-5	3-5	0-1	–	–	Pre-Intermediate
5	4-5	4-5	0-1	0-1	Intermediate
5	5	4-5	4-5	0-3	Upper-Intermediate
5	5	5	4-5	3-5	Advanced

Statistical processing.

To assess the differences between physiological indicators and grades for the success of mastering the English language between groups of subjects (with an abnormal distribution and sample size less than 30), the non-parametric U Mann-Whitney test was used; To divide the sample into groups with different success rates in the lesson and practical English class, K-means clustering was used. To assess the influence of the factor of success in an English lesson, the factor of the orientation of the university training on psychophysiological indicators, we used one-factor and multivariate analysis of variance, a posteriori analysis according to the Fisher criterion. To assess the relationship between the variables, the Spearman rank correlation criterion was used.

Study Designs.

The overall design of the study of the physiological factors of success in mastering the English language involved monitoring functional hemisphere asymmetry before and after the lesson (test) and/or heart rate variability before, during and after the lesson (test) in English, as well as fixing success (Fig. 3)
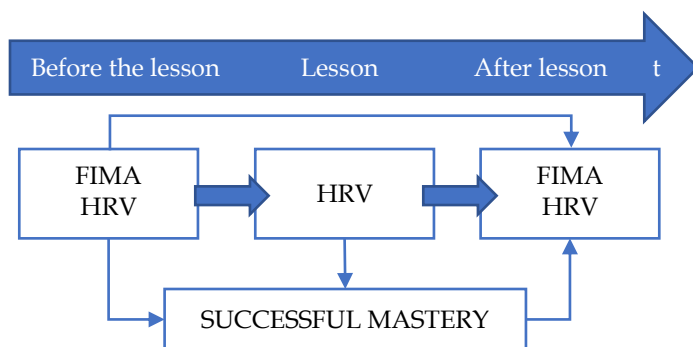

Fig. 3 The overall design of the study of physiological factors in the success of the process of mastering the English language

The overall design of the study of biological indicators (biomarkers) of the success of the English language learning outcome included assessing the English language learning outcomes through testing, measuring the gaze trajectory when working with texts in the native language and English (Fig. 4).
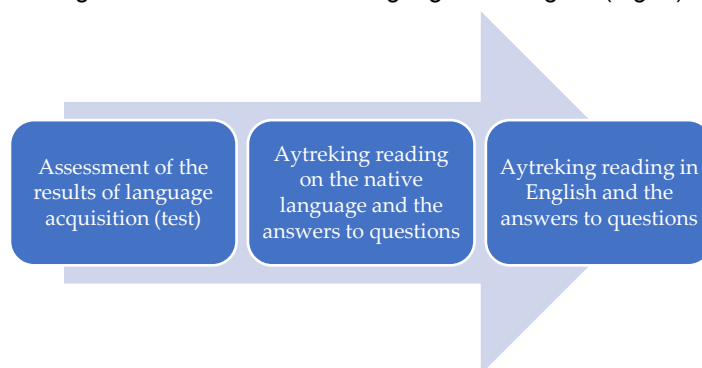

Fig. 4. The overall design of the study of biomarkers of the success of the result of mastering the English language

Based on the situational model of understanding the text, a model of the reading process was formulated (Fig. 5). At the input - the text (in native and English), then the information is processed through a model of working with text in a specific language; then there is an understanding of the text. By measuring the parameters of gaze movements, it is possible to evaluate the effectiveness of the text model by analyzing saccade dynamics and fixations.
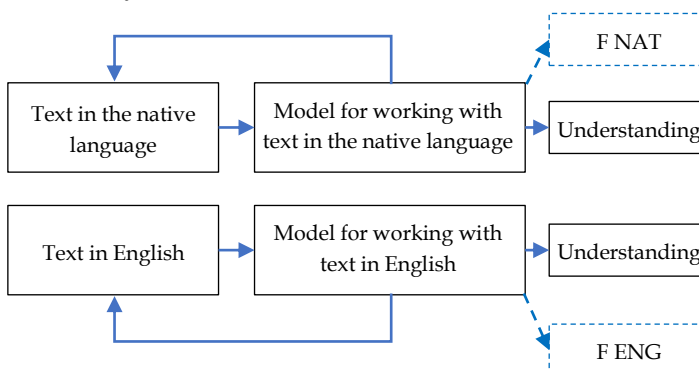

Fig. 5. Reading comprehension model

In the course of processing the research results, the difference

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in the parameters of the gaze movement was calculated when working with texts in Russian (native) and English (foreign) language (ΔF = F nat - F eng). This coefficient was informative for classifying the subjects according to the level of success of the result of mastering the English language. It is essential that in the framework of the thesis, for the first time, the level of mastering a foreign language is assessed by the degree of similarity of motor displays when working with texts in the native and English languages.

Thus, when studying the features of eye movement when working with texts as a reflection of the success of learning English, we found that biomarkers of high competence in the English language are: the absence of an increase in fixation time, a decrease in saccade amplitude and pupil diameter when working with English text compared to Russian. Summarizing all the above, we can distinguish integrative psychophysiological factors for the successful development of the English language (table 3).

TABLE 3

INTEGRATIVE PSYCHOPHYSIOLOGICAL FACTORS FOR THE SUCCESSFUL DEVELOPMENT OF THE ENGLISH LANGUAGE

Information processing cycle	Module	Success factors
Cognitive	Functional state of the brain	left hemisphere asymmetry profile at the school stage and low stability of the left hemisphere at all stages of development
Vegetative	Heart rate variability	high activity of the autonomic nervous system
Motor	Eye movements when working with texts	identical characteristics of saccades and fixations when working with texts in the native and English languages

Thus, the cognitive module assumes a left-hemisphere asymmetry profile, low values of the Δt_stab ("stability") indicator of the left hemisphere. The vegetative module suggests a high activity of the autonomic nervous system as a whole. Motor - the same characteristics of saccades and fixations when working with texts in Russian and English. It is essential to evaluate the relationship between different psychophysiological modules that ensure the success of mastering the English language. It turned out that a vital factor for the willingness to successfully master the English language at the school stage is the simultaneous functional dominance of the left hemisphere and a more pronounced activation of the sympathetic regulation contour compared to the parasympathetic (LH / HF> 2.5). With this set of attributes, 83% of students show high scores in the English lesson (Fig.

77). Therefore, only the functional dominance of the left hemisphere is an insufficient biomarker of the optimal functional state of the student for mastering the English language: significant activation of the sympathetic nervous system is also essential.

Attention should be paid to the dynamics of functional interhemispheric asymmetry and activation of the sympathetic nervous system from the beginning to the end of the lesson:

1) It turned out that half of the students who have initially left hemisphere, but had insufficient activation of the sympathetic nervous system, and, as a result, were unsuccessful in the lesson, had a significant increase in the sympathovagal balance index by the end of the lesson.

2) All students who initially had a rather high level of activation of the sympathetic nervous system, but were right-hemispheric, and, as a result, were unsuccessful in the lesson, by the end of the lesson there was an inversion of interhemispheric asymmetry. At the same time, the sympathovagal balance index remained high.

3) Half of the students who initially had insufficient activation of the sympathetic nervous system had right-hemispheric and unsuccessful in the lesson, by the end of the lesson there was an inversion of interhemispheric asymmetry, as well as an increase in the sympathovagal balance index.

Based on these results, it can be assumed that only at the end of the lesson did all these groups of schoolchildren form an optimal functional state for mastering the English language. In this case, the second English lesson would be more effective for them than the first. To identify the mechanisms underlying
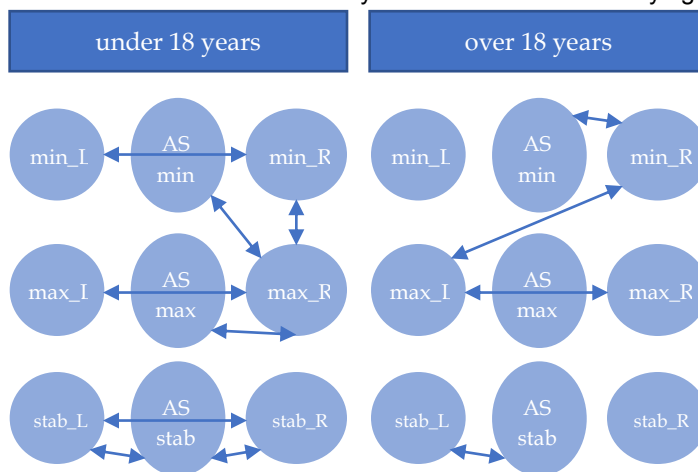
our results, we carried out a correlation analysis of the relationship of indicators within different methods for different age groups (Fig. 6-8).

Fig. 6 Functional Interhemispheric Asymmetry

The characteristics of the indicators of spectral analysis of HRV in schoolchildren and students who are successful in teaching and testing in the English language indicate a high power of the regulation spectrum due to an increase in the values of all its links (LF and HF).
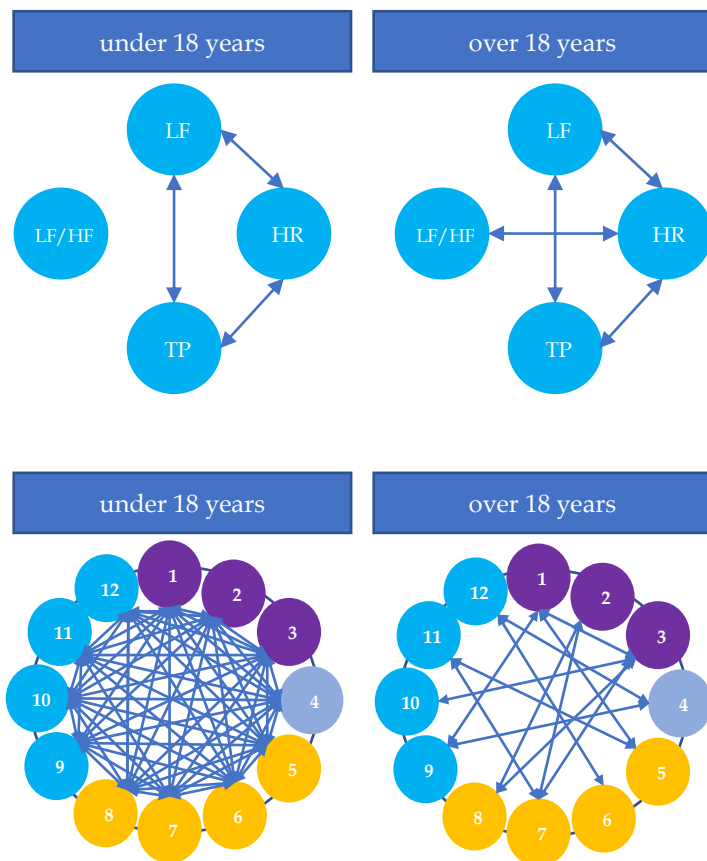
Fig. 7 Heart rate variability

Fig. 8 Indicators of activity in the classroom*

1 - Interaction with students; 2 - Interaction with the teacher; 3 - Interaction with the group; 4 - Appropriateness of utterances; 5 - Accuracy in the use of new material; 6 - The speed of application of new content; 7— Use of new structures; 8 - Use of a new dictionary; 9 - Accuracy in using old material; 10 - Speed of using old material; 11 - Use of old structures; 12 - Use of the old dictionary.

Comparison of correlation diagrams in terms of functional interhemispheric asymmetry at different stages of mastering the English language shows a reduction in intrasystem relationships with age. Such a reduction indicates a decrease in the degrees of freedom in the system of interhemispheric relations and, as a consequence, less adaptability to environmental influences. Comparison of correlation diagrams by spectral indicators of heart rhythm variability at different stages of mastering the English language shows, on the one hand, the reduction of intrasystem relationships with age, and on the other, the absence of any connection between the activity indicators of regulatory systems and the sympathovagal balance index in the pubertal period. In general, such results indicate a decrease in the degree of freedom in the neurovisceral sphere with age.Comparison of correlation diagrams in terms of activity during classes at different stages of learning the English language shows, in general, an increase in the number of intra-system connections with age. Still, the maximum number of

connections was noted in the puberty period.Similar results can be explained either by uneven maturation of different linguistic functions with age or by special psychophysiological conditions for the formation of linguistic features in the puberty.It is interesting to note that in most theories, it is precisely the puberty period that is considered as a turning point (the "critical period" when there is a change in strategies for mastering a foreign language: before puberty, a foreign language can be mastered unknowingly (implicitly), and after that only consciously, intentionally (explicitly).In the framework of the theory of functional systems, heterochronism (uneven maturation of body structures in ontogenesis) is considered as the central condition for the formation of any functional system. It can be assumed that in the puberty there is a "consolidation of the components" of the operation of linguistic functions, when its separate, separately maturing components reach the degree of maturity that is sufficient to unite them into a linguistic system. Thus, as you master the English language, there is a reduction in intra-systemic connections in physiological indicators and an increase in relationships with linguistic indicators. In general, within the framework of this study, a comprehensive psychophysiological study was conducted, which examined the holistic process of mastering a foreign language: from the search for readiness factors for a successful mastery of a foreign language, and ending with the correlates of the success of its mastery. Moreover, this process was investigated using such non-invasive methods that allowed monitoring in the context of natural educational activities. Data on markers of the optimal state for mastering the English language by Russian-speaking schoolchildren and students in the long term can be used in neural interfaces, biofeedback training to increase the effectiveness of the educational process. Thus, the thesis contains results that are promising for commercialization.

4 CONCLUSION

The article carried out a comprehensive psychophysiological study, on the basis of which the integrative psychophysiological factors of the successful development of the English language are identified (Table 3). The success of mastering the English language by foreign students is associated with: a) the functional activity of the hemispheres: the severity of activity of the left hemisphere is observed with more successful learning at the school stage; b) the dynamics of autonomic regulation: the high activity of the ANS provides an advantage at all stages, minimizing the severity of stress reactions at the school stage; c) hand-eye coordination: similar characteristics of saccades and fixations when working with texts in Russian and English are a marker of the success of the result of mastering the English language.To identify the mechanisms that underlie our results, an analysis was made of the relationship between physiological indicators and indicators of success in mastering the English language for different age groups. Comparison of correlation diagrams in terms of functional interhemispheric asymmetry at different stages of mastering the English language shows a reduction in intrasystem relationships with age. Such a reduction indicates a decrease in the degrees of freedom in the system of interhemispheric

relations and, as a result, an increase in specialization and a decrease in the adaptability of the physiological system. Comparison of correlation diagrams by spectral indicators of heart rhythm variability at different stages of mastering the English language shows, on the one hand, the reduction of intrasystem relationships with age, and on the other, the absence of any connection between the activity indicators of regulatory systems and the sympathovagal balance index in the pubertal period. In general, such results indicate a decrease in the degree of freedom in the neurovisceral sphere with age. Comparison of correlation diagrams in terms of activity during classes at different stages of learning the English language shows, in general, an increase in the number of intra-system connections with age. Still, the maximum number of connections was noted in the puberty period. Similar results can be explained either by the uneven maturation of different linguistic functions with age or by special psychophysiological conditions for the formation of linguistic functions in the puberty. Thus, as you master the English language, there is a reduction in intrasystem connections in psychophysiological indicators and an increase in connections in linguistic indicators.

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