Distal and Proximal Components of Sensory Experience in Neural Network Modeling of the Success of Intellectual Activity

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Abstract. The article studies neural network structural models of the semantic abilities of the sensory type in the context of the level of formation of indicators of the success of the intellectual activity of older adolescents. The study involved 101 senior adolescent students (15 years old). The methodological base of the stud: "Visual semantics", a modified version of the "Semantic differential" methodology, "Conceptual synthesis", "Generalization of three words", "Composition". The results of the study allow us to conclude that the distal semantic abilities (visual, auditory and olfactory types), associated with the actualization of the sensory and emotional experience of a person, play the most important role in relation to the manifestation of the success of intellectual activity in comparison with the proximal sensory abilities (tactile and flavoring). At the same time, the leading role in the structure of the success of intellectual activity is played by the indicators of conceptual abilities, which determines the possibility of generating new mental contents due to the regrouping of available experience. Thus, evidence has been obtained that when carrying out neural network modeling of the success of intellectual activity, the semantic sensory abilities of the distal type are of paramount importance in comparison with the most onto- and phylogenetically early semantic abilities of the proximal type.

Key words: Semantic Abilities, Sensory-Emotional Components of Intellectual Activity, Conceptual Abilities, Manifestations of the Success of Intellectual Activity.

1. Introduction

The study of the mechanisms of organization and functioning of indicators of the success of intellectual activity in the context of the conceptual experience of a person as mental properties that ensure the formation of semantic networks, the use of categories of different degrees of generalization, the identification of implicit patterns and the generation of new ideas [7, 8] shows insufficient development as an integral component, i.e. conceptual structures, complex in cognitive composition, hierarchically organized mental formations that provide the ability to generate new content, and the basic component - semantic abilities. Within the framework of the presented research, semantic abilities are operationalized as an individual system of meanings, expressed in the interconnections of words in the case of verbal semantics or in the form of meanings of sensory-object impressions in a situation of non-verbal semantics.

The conceptual abilities themselves are components of the structure of conceptual experience, which also includes:

• semantic abilities are mental properties that characterize the processes of operating with the content of signs (verbal, visual) within the framework of an individual mental lexicon;

• categorical abilities determine the assignment of the corresponding object to a certain category on the basis of transformations in the system of categorical features of varying degrees of generalization.

In the framework of an earlier study [9] devoted to the study of conceptual, metacognitive and intentional abilities in the structure of intellectual competence, the author identified and analyzed different types of emotional-evaluative impressions as manifestations of semantic abilities. However, the study of their internal composition and organization in terms of semantic sensory abilities of the distal (visual, auditory, and olfactory) and proximal (tactile and gustatory) has not been carried out. We asked ourselves the question not so much about their hierarchical structure in accordance with the development principle, but about the ability of which type of semantic abilities to

the greatest extent determine the success of intellectual activity. We have led a more detailed study of the most basic component of conceptual experience - semantic abilities. This aspect of psychic reality in the world psychological literature has been insufficiently studied, despite a number of scientific works, for example, studies by Janosik S.M., Creamer C. don G., Kowalski G.J. [4], Alexandrov Yu.I., Sams M.E. [1] and Lakoff J. [5], Loginov, N.I., & Spiridonov, V.F. [6]. Thus, J. Lakoff argues that the mind is inherently "corporeal", arguing this statement by the fact that the individual's thinking, down to the most abstract reasoning, depends on such concrete and "low-level" means as the sensory-motor system and emotions. Consequently, this corporeality rejects the assertion that human mental activity can be cognized without resorting to the fundamental "executive elements."

Thus, along with the manifestations of the success of intellectual activity, conceptual, categorical and semantic abilities were investigated as sensory-emotional components of intellectual activity - mental properties that characterize the success of intellectual activity due to the semantization and categorization of information. The success of intellectual activity was determined by the example of school activity, in terms of a successfully written essay, i.e. in terms of the characteristics of textual activity. In our opinion, analyzing the features of a human-generated text, we can approach the identification of mental resources “embedded” in this text and, accordingly, assess the level of individual productivity of intellectual activity.

This research is devoted to the problem of constructing a conceptual model of intellectual competence (productive intellectual activity) in terms of one’s semantic experience.

1.1. Research Questions

The theoretical hypothesis of this study: the success of intellectual activity in relation to the level of formation of distal and proximal semantic, conceptual and categorical abilities can be described in terms of the interrelationships of these components.

1.2. Purpose of the Study

The object of the study is older adolescents (students of the 9th grade of secondary comprehensive schools), whose conceptual, categorical and semantic abilities are formed in the process of schooling.

The subject of this research is the neural network structure of the success of intellectual activity in the context of distal and proximal semantic abilities.

Purpose of the research: description of the neural network structure of the success of intellectual activity in relation to the level of formation of distal and proximal semantic, conceptual and categorical abilities.

2. Study participants

The study was conducted on a sample of 101 older adolescents (54 girls and 47 boys) aged 15 years.

3. Research methods

3.1. Techniques aimed at identifying the level of conceptual abilities:

Semantic (visual semantics technique [2], in which the research participants described indefinite visual forms, interpreting them and highlighting their semantic features):

Based on the analysis of the protocols, four types of semantic features of the sensory type were identified:

- semantic sensory features of a tactile type (cold, soft, rough, etc.);
- semantic sensory features of taste type (bitter, sour, etc.);
- semantic sensory features of olfactory type (pleasant odor, etc.);
- semantic sensory features of auditory type (loud, noisy, sounding, etc.);
- semantic sensory features of the visual type (colorful, bright, etc.).

Indicators: the number of sensory semantic features of each of the four types of semantic abilities, which were calculated for each study participant, and were grouped

into two common indicators: distal type of sensory abilities (visual, auditory and olfactory) and proximal type of sensory abilities (tactile and gustatory).

3.2. A modified version of the Semantic Differential technique [7].

This technique was used to assess the degree of participation of sensory-emotional experience in the process of semantization of indefinite visual forms (Fig. 1):

Fig. 1. Examples of graphic images in the method "Visual semantics" [2].

The form included 20 bipolar scales in the form of adjectives denoting sensory and emotional-evaluative signs (calm - anxious, small - large, colorful - colorless, etc.), with the help of which the study participant had to evaluate each of five indefinite visual forms

A protocol was filled out for each of the five images: the research participant had to tick one of the 7 columns - "strong", "medium", "weak", "no", "weak", "medium", "strong" - on each of the 20 scales, assessing the extent to which, according to his feelings, one of the two poles of the scale is expressed in relation to a certain image (choices in the columns "weak", "medium", "strong") or to fix the absence of any impressions (choice in the column "no"). There is no time limit for completing the assignment, but participants in the study were asked to try to work faster based on their first impressions.

The assessment was made for each of the 5 graphic images by counting the number of choices in the “no” column (a measure of insufficient participation of the sensory-emotional component of intellectual activity), the number of choices in the “weak and medium” columns (a measure of the differentiated participation of sensory-sensory impressions) and the number of choices in the “strong” columns (a measure of excessive participation of sensory-emotional impressions). The number of elections

according to the columns "no", "medium - weak", "strong" was summed up over 5 images.

Indicators: 1) the number of choices in the “no” column SD is an indicator of the measure of insufficient participation of sensory-emotional impressions in the process of semantisation of indefinite visual forms; 2) the number of choices in four columns "medium and weak" SD (SD_ss) - an indicator of the measure of the differentiated participation of sensory-emotional impressions in the process of semantisation of indefinite visual forms; 3) the number of choices in two columns “strong” SD is an indicator of the measure of excessive expression of sensory-emotional impressions in the process of semantisation of indefinite visual forms.

Moreover, the methodology for diagnosing conceptual abilities (“Conceptual synthesis”, [8]) - the study participants searched for generalizing categories based on identifying common essential features between three dissimilar concepts).

Along with this, a methodological technique was used to assess the level of success of intellectual activity in terms of indicators of the complexity of the text of the essay [9].

4. Results

In the correlation analysis (according to Spearman), ambiguous connections of indicators of semantic abilities with indicators of conceptual abilities were recorded.

Thus, no significant correlations were found with the ability to form semantic interpretations, while correlations with the ability to generate semantic features turned out to be highly significant. The results are presented in Table 1.

Table 1. Correlation links of indicators of conceptual, categorical abilities and indicators of semantic abilities, as well as indicators of the success of intellectual activity

Variable	Synthesis	Generalization	SD_ss	Distal	Proximal	Essay
Synthesis	1,000	0,105	0,064	**0,359**	-0,065	**0,422**
Generalization	0,105	1,000	-0,002	0,143	0,074	0,156
SD_ss	0,064	-0,002	1,000	0,118	0,189	**0,246**
Distal	**0,359**	0,143	0,118	1,000	0,054	**0,413**
Proximal	-0,065	0,074	0,189	0,054	1,000	0,186
Composition	**0,422**	0,156	**0,2459**	**0,413**	0,186	1,000

Note: significant indicators are highlighted in bold.

These facts indicate that the indicators of the success of intellectual activity require a great generalization and abstraction of the material provided by conceptual abilities, a differentiated degree of participation of the sensory-emotional component of intellectual activity and the most late (onto- and phylogenetically) formed sensory abilities of the distal type, but which does not have more cognitively simple semantic abilities of the proximal type. Nevertheless, we took the risk of including them in the subsequent neural network analysis.

Based on the results of the correlation analysis of conceptual abilities and the ability to generate semantic features, we have established ourselves in the opinion that the internal structure of the semantic abilities themselves is hierarchical, where the basic level is occupied by the semantic sensory ability of the proximal type, over which the distal type of sensory abilities is "built up", which depends on the degree of differentiation of semantic abilities. In addition, we hypothesized that in older adolescence, the more cognitively simple abilities of the proximal type are replaced by more abstract and highly differentiated abilities of the distal type.

In the course of studying how the data is distributed in space, a categorized graph was built, i.e. categorized scatter diagram with overlapping, where the variables were the manifestations of the productivity of intellectual activity, the degree of formation of sensory abilities of the distal and proximal types. The resulting distribution of classes in space demonstrated the fact that high and average indicators of the productivity of intellectual activity are characterized by high or above average indicators of semantic abilities (not necessarily consistent), while the role of the semantic abilities of the distal type is more significant than the proximal type of semantic sensory abilities. In general, the identified classes are very heterogeneous, which is reflected in the results of further

analysis.

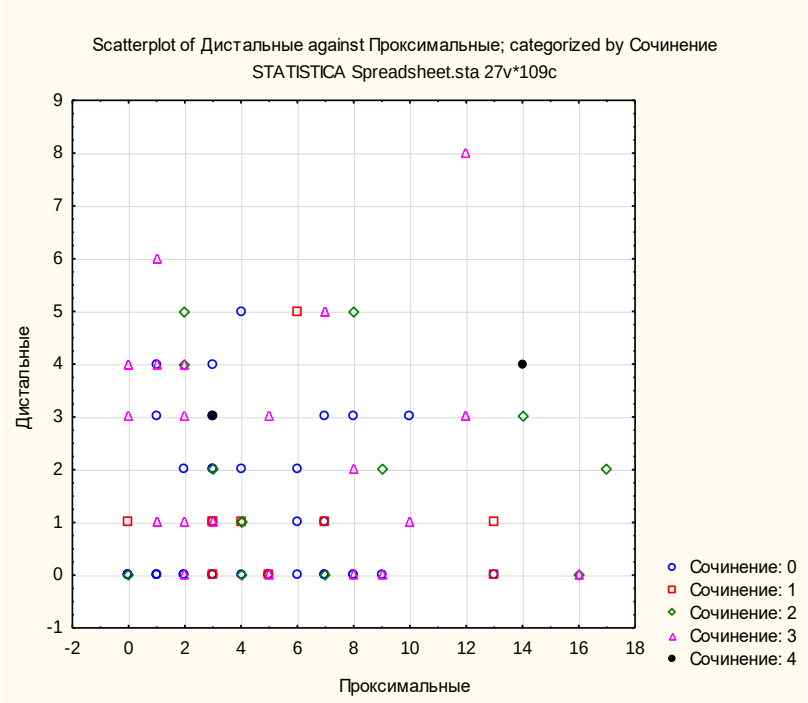

Fig. 2. A categorized overlapping scatter plot.

This conclusion also supports the result of plotting the response surface, which is shown in Figure 3:

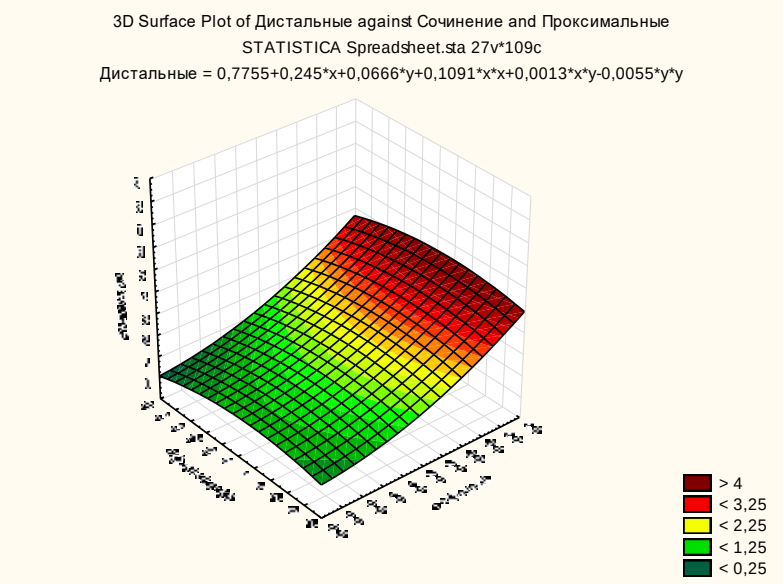

Fig. 3. Response surface.

With the existing data distribution, it is not productive to construct simple linear models, so in the further analysis we resorted to neural network modeling, which allows us to model nonlinear dependencies.

The main idea of neural network modeling is to reconstruct various phenomena and processes based on available information about them, while the neural network itself is a set of mathematical functions with many parameters that can be configured in the learning process on a subgroup of current or previously obtained data. Then the trained neural network makes its own forecast about the structure of this data or the future behavior of the system being studied.

Forty-five models (automated selection with damping) were identified in the course of constructing neural network models of indicators of the productivity of intellectual activity. They were trained using radial basis functions with interactive learning with an increase in the number of epochs from 200 to 3000. The results of the work done demonstrated a

large learning error for the correction of which multiple subsamples were built using radial basis functions, but increasing the number of hidden neurons from 3 to 32 pieces. Final table 2 shows 7 models, that were highlighted:

Table 2. Trained neural network models of indicators of the productivity of intellectual activity

Index	Net. name	Training performance	Test performance	Validation performance	Training algorithm	Output activation
8	RBF 3-20-5	80,282	71,429	42,857	Entropy	Softmax
13	RBF 3-26-5	88,732	57,143	35,714	Entropy	Softmax
15	RBF 3-32-5	90,141	64,286	21,429	Entropy	Softmax
17	RBF 3-39-5	81,690	50,000	28,573	Entropy	Softmax
41	RBF 3-29-5	85,915	57,143	28,571	Entropy	Softmax
42	RBF 3-29-5	87,324	57,143	35,714	Entropy	Softmax
45	RBF 3-27-5	83,099	57,143	42,86	Entropy	Softmax

According to the performance indicator (correct classification), one model was selected: RBF 3-32-5, the training performance of which was 90,141, and the test performance was 64,286, the learning algorithm was RBFT, the error function was entropy, the activation function of hidden neurons was Gaussian, and output neuron activation function - softmax. As can be seen from the obtained results of constructing a neural network model of indicators of the productivity of intellectual activity, the accuracy of the resulting model is low, allowing a percentage of 9,859 errors in correct identification, which is unacceptable for trusting the most accurate model.

When considering sensitivity analysis, i.e. analysis of the importance of variables, such an important fact was established that the first place in terms of significance in the constructed model is occupied by the differentiated degree of participation of sensory-semantic experience in intellectual activity (10,870), the second place belongs to the semantic sensory abilities of the distal type (10,564), and only the third, and respectively, and less significant - conceptual abilities (10,283). Therefore, it was

concluded that, probably, the initial arsenal of variables that was taken for analysis influenced such a low reliability of the resulting neural network model. So, on the one hand, low correlations of the variable "differentiated degree of participation of sensory-semantic experience in intellectual activity" with indicators of the productivity of intellectual activity can serve as the removal of this characteristic from the analysis. On the other hand, the results of the conducted neural network analysis demonstrated a lesser significance of the variable “conceptual abilities”. This contradiction deserves further research on the topic.

5. Findings

Thus, in the course of neural network modeling of the success of intellectual activity, 1 model was identified, which, with an accuracy of 90% (90,141%), describes / predicts research variables, namely: indicators of the productivity of intellectual activity in older adolescence, where the conceptual and semantic abilities of the sensory type in terms of distal and proximal types.

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