ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

# Prediction of Creativity Level Based on Indicators of EEG With the use of Neural Network Models.

**Kozachuk NO[1]*, Gurianov VG[2], Kachynska TV[1], Shvartz LO[1], Poruchynskyi AI[1], Dmytrotsa OR[1], and Abramchuk OM[1].**

[1]Lesya Ukrainka Eastern European National University, Lutsk, Ukraine.
[2]Bogomolets National Medical University, State Scientific Institution "Scientific - Practical Centre of Preventive and Clinical Medicine", Kyiv, Ukraine.

**ABSTRACT**

This paper proposes a method of diagnosis of the creativity level based on indicators of the electrical activity of the cerebral cortex, which was developed by using artificial neural network. It was established that the probability of a high level of creativity is connected with the speed of decision-making; value of the coherence coefficient between the left anterior frontal and left occipital areas of the EEG alpha-2-range, the focus of interaction in the right posterior-temporal area in the delta range and the focus of interaction in the right parietal area of the beta range.
**Keywords:** artificial neural network, statistical moment, creativity, electrical activity of the cerebral cortex.

***Corresponding author***

## INTRODUCTION

The identification of the human level of creativity remains a live issue today and does not raise doubts. The already existing psychological methodologies give a possibility to significantly facilitate when identifying the most creative people. However, if the psychological tests diagnose poor results, we cannot be confident in the lack of creativity of an examinee because creative expressions are spontaneous and they cannot be controlled by the situation itself. That is why psychological methodologies of creativity diagnostics that are designed to detect the actual creative individuals in the sample survey at the time of testing, cannot provide a high level of diagnostics of creative people. It is clear that for a more precise selection of creative people not only psychological techniques should be used. One of the most promising directions in the development of such "non-psychological" criteria is the selection of characteristic patterns of interaction between different departments of the cerebral cortex by using the method of electroencephalography. EEG indices are sufficiently sensitive and yet very specific parameters for the evaluation of current cognitive activity. In human EEG, according to some authors [1] a lot of information about person’s reaction at the time of the survey is contained. EEG as a mirror reflects person’s condition and personal characteristics. The respondent cannot consciously regulate his EEG, as if “gambling” for a desired result. Therefore, unlike other methods, neuro-computer based diagnosis reveals an objective human relation to signals that a person perceives.

In order to identify a set of factors associated with the level of creativity of males and females, the method of constructing and analyzing of multifactorial models of classification was rationally used, including neural network modeling. Special features of this method make it possible to most effectively solve a number of biological and medical problems [2]. In particular, neural network models do not require formulation of any rules in order to make decisions, because their study is based on the examples. They have an ability to generalize (i.e. they have the ability to "see" through the noise), which is especially important when analyzing EEG data [3-5]. Neural models have ability to abstraction (ability to isolate the ideal of imperfect inputs) [6].

## EXPERIMENTAL

### Subjects

The study involved 95 men and 98 women aged 18-21 years. The research was conducted in accordance with generally accepted bioethical norms in compliance with relevant international provisions on experimental work and clinical research. Study participants (volunteers) gave a written voluntary consent to participate in the study.

### Data psychophysiology

The following physiological parameters were identified: intelligence level and cognitive styles ("Reflexivity/impulsivity", "Rigid-flexible cognitive control," "Narrow-wide equivalence range", "Fielddependence-fieldindependence").

The level of creativity was evaluated based on performance indicators (number of proposed options) when solving tasks of divergent type.

### Data electroencephalography

The electrical activity of the cerebral cortex of 193 men and women aged 18-21 was recorded during assignments of divergent types. The electrical activity of the cerebral cortex was recorded in monopolar way from 19 leads according to the international system 10/20 (Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz , O1, O2) with the help of the hardware-software complex "Neyrokom" developed by the scientific and technical center of electronic medical devices and technologies "HAI-Medika" National Aerospace University "KhAI" (certificate of registration № 6038/2007 from 26 January 2007 ).

The indicators of performance capacity and coherence of EEG in frequency ranges were analyzed: delta (0,5-4,0 Hz), theta, alpha-1, alpha 2, alpha 3 beta, gamma (35-40 Hz). Determining the frequency limits of theta, alpha-1, alpha 2, alpha 3 and beta rhythm was carried out based on the individual frequency of alpha rhythm of each patient [7].

**Mathematical Methods**

In order to detect pair ponding between individual indicators the methods of correlation analysis were used and Spearman's Rank Correlation Index was calculated [8.]. When analyzing multifactorial dependencies, such methods as constructing and analyzing methods of multifactorial statistical models were applied. Thus, one of the main objectives was to reduce the dimensionality of the input space of factor variables which are used to build a diagnostic test.

To solve this problem the methods of 'step-by-step inclusion' or 'step-by-step exclusion' of factor variable can be used. However, these methods often become ineffective, which may be due to a very strong (often non-linear) connection between factor variables.

In the work the method of "genetic algorithm" selection was applied in order to select factors that are most likely related to high levels of creativity. Genetic algorithm is the optimization method based on the idea of the evolution of the population of "individuals" (in this case, the term "individual" means a mathematical classification model characterized by its own set of factors).

Each model is characterized by "adaptability" (in this case under the "adaptability" one should understand prediction accuracy improvement and reduction of the number of factor variables in this mathematical model classification). The task of optimization is to maximize the adaptability function. Construction and patterns assortment during genetic algorithm are usually carried out by using neural networks. The use of such algorithm can significantly improve the quality of factor variable selection, in comparison to the use of the "step-by-step inclusion" or "step-by-step exclusion" variables.

Optimization of acceptance/rejection threshold of multifactorial mathematical models [8] was carried out by using methods of building curves of operating characteristics (Receiver Operating Characteristic - ROC). The quality of the built models was evaluated according to their sensitivity and specificity [8], it was calculated 95% of confidence interval (95% CI) of indicators [8]. To assess the adequacy of multifactorial mathematical prediction models, the indicators of area under the ROC-curve (Area Under Curve - AUC), indicators of likelihood ratio tests (+ LR and -LR) and 95% their confidence interval was calculated. To assess the impact of factor variable on the probability of a high level of creativity, the method of construction of logistic regression models was used. For estimation odds ratio was calculated and its 95% of odd rate. Construction of neural network models was conducted in a statistical package Statistica Neural Networks v.4.0 B (StatSoft Inc., 1996-1999). Construction of logistic regression models, models analysis was performed in a statistical package MedCalc v.14.12.0 (MedCalc SoftWare bvba, 1993-2014).

## RESULTS AND DISCUSSION

In the process of model building as factor variables 135 parameter were subjected to analysis: gender, level of creativity (measured by indicators of task performance of divergent types); sensory/verbal cognitive style, flexible/rigid cognitive style, synthetic/analytical cognitive style, level of nonverbal intelligence, speed and accuracy selection of identical figures (indicators that are taken into account to determine cognitive style "impulsiveness/reflexivity") and EEG parameters (depth of depression of alpha-1, alpha-2, alpha-3 during the transition from dormancy with closed eyes to quiet contemplation, coherent communications, interaction focus of 16 EEG leads in all frequency bands calculated as the sum of coherent connections in all other areas). In the course of model building as the resulting characteristics such creativity level of the examinee was projected: Y = 0 - low or average level of creativity; Y = 1 - a high level of creativity. The analysis was conducted on the results of the study of 193 people, 29 of whom had low levels of creativity, 96 - the average level of creativity and 68 - a high level of creativity.

The analysis was based on the study results of 193 people, 29 of them had a low level of creativity, 96 - an average level of creativity, and 68 - a high level of creativity.

In order to check the quality of prediction models and to prevent restudy of models, all cases (using random number generator) were divided into three sets: training set cases (used to build the model including 143 persons), a control set of cases (used to control the conversion model, included 30 persons) and a set of test cases (used for quality assurance of prediction models including 20 examinees).

In the first phase of the analysis linear neural network model of prediction of the probability of a high level of creativity was built, based on all 136 variables. After model study and selection of the critical threshold of decision acceptance/rejection (using a set of the control cases), sensitivity model on training set was 66.7% (95% CI 52.9% -79.1%), specificity - 69.6% (95% CI 59.7% -78.6%).

In order to determine the factors associated with the level of creativity of an examinee, the selection of significant characteristics using the method of genetic algorithm was conducted. In the course of the analysis four indicators were selected: time of decision-making, which was one of the indicators used to determine cognitive style "impulsivity/reflexivity" (imp/ref) – (X1); coherent connection of pre-left frontal and left occipital areas of the alpha-2-range (α2Fp1-O1) - (X2); focus interactions in the right posterior-temporal area in the delta range (ΔT6) - (X3); focus interactions in the right parietal area of the beta range (βP4) - (X4).
In this set of variables a linear neural network model of predicting high levels of creativity was built. After model study critical threshold of acceptance/rejection ($Y_{cr}$=0,3848) was selected, in the case of $YY_{cr}$ in the model a high level of creativity is predicted, in $Y<Y_{cr}$ - low or average level of creativity is predicted. Constructed model can be expressed by equation (1):

$$Y = -0{,}0030\times X1 - 0{,}75\times X2 + 0{,}037\times X3 + 0{,}030\times X4 + 0{,}233 \quad \textbf{(1)}$$

Figure 1 depicts the architecture of neural network models.

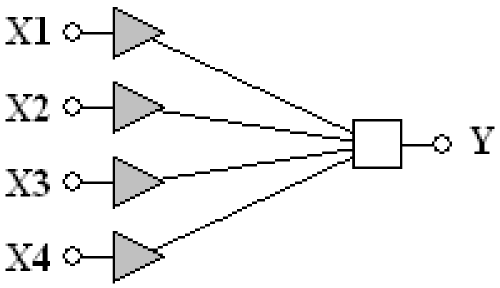


**Figure 1: Architecture of neural network model of forecasting (gray triangles depict neurons in the input layer, white square depicts output neuron).**

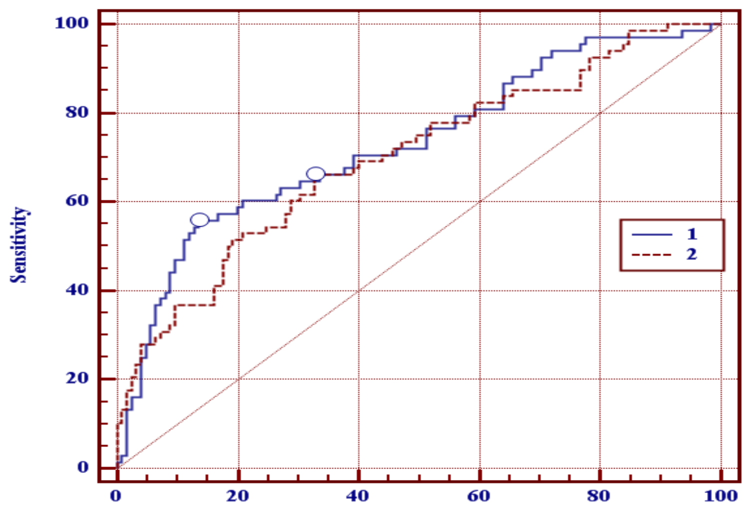


**Figure 2: ROC-curves prediction models of creativity of an examinee (analysis conducted in all 193 cases): 1 - linear neural network model built on 136 input features; 2 - linear neural network model built on four selected input features.**

The sensitivity of this model on the training set was 60.8% (95% CI 46.8% -73.9%), specificity - 70.7% (95% CI 60.8% -79.6%). The sensitivity and specificity of the model on the training and test set did not statistically differ (p = 0,66 and p = 0,66, the criterion $\chi^2$, respectively), indicating the adequacy of the constructed model.

To assess the significance of the chosen variables used to predict the level of creativity of examinees, ROC-curves method of analysis was used (Fig.2).

In the course of the analysis it was found out that the area under the ROC-curve for model built on 136 input features $AUC_1$=0,73±0,04, is significantly statistically (p <0,001) higher than 0.5. For the model built on four selected input features $AUC_2$=0,70±0,04, is significantly statistically (p<0,001) higher than 0,5. This is evidence of the adequacy of the constructed models. When comparing the ROC-curves no statistically significant differences of the constructed models (p=0,50) were detected. Thus, when conducting the analysis it was found out that reducing the number of input features from 136 to 4 does not lead to a deterioration of prognostic characteristics of the model (p=0,50), which is the evidence of high significance of 4 selected indicators (impulsiveness/reflexivity, α2Fp1–O1, ΔT6, βP4) to predict the level of creativity of the examinee.
To assess the quality of creativity prediction of an examinee in the linear neural network model built on four selected input characteristics (impulsiveness reflexivity, α2Fp1–O1, ΔT6, βP4) the index of likelihood was calculated in all 193 cases. For the selected threshold of decision-making meaning +LR = 1,5 (95% CI 1,2–1,9), –LR = 0,6 (95% CI 0,4–0,8) - the model is adequate.

To determine the strength and direction of impact of selected factor characteristics on the likelihood of a high level of creativity a logistic regression model was constructed, the model is adequate ($\chi^2$=23,5, p<0,001). Table 1. shows the analysis results of the model coefficients.

**Table 1: The coefficients of logistic regression model predicting the probability**

| Factor variable | Values of the coefficients of prediction model, b±m | Significance level difference from 0 | CI (95%CI) |
|---|---|---|---|
| Imp/ref | –0,024±0,014 | >0,05 | – |
| α2Fp1–O1 | –4,1±1,4 | 0,004* | 0,017 (0,001–0,27) |
| ΔT6 | 0,18±0,06 | 0,003* | 1,2 (1,1–1,3) |
| βP4 | 0,15±0,07 | 0,044* | 1,2 (1,0–1,3) |

The analysis shows that with increasing ratio α2Fp1-O1 the probability of a high level of creativity statistically significantly (p=0,004) decreases, OR=0,017 (95% 0,001-0,27 CI) per each unit change factor. It was found out that with the increase of the ΔT6 coefficient the probability of high level of creativity statistically significantly (p = 0,003) increase es, OR=1,2 (95% CI 1,1-1,3) per each unit of coefficient change. In addition it was discovered that with the increase of βP4 coefficient the probability of high level of creativity statistically significantly (p=0,044) increases, OR=1,2 (95% 1,0-1,3 CI) per each unit of coefficient change.

For practical use of the constructed neural network models a computer program was created in order to predict the level of creativity (implemented in the environment of spreadsheet Excel - «prognose.xls»).

To assess the level of creativity, in the corresponding cell of the program the received indicators of the values of the examinees are inserted. Calculations are carried out on the basis of the proposed 4-factor model. As a result, the parameter Y is inserted, which can be interpreted as the probability of high evaluation of creativity. Based on these calculations the system provides the prediction: "The high level of creativity" or "Negative prediction". Based on the analysis the sensitivity of this designed test is 60,8% (95% CI 46,8% - 73,9%), specificity – 70,7% (95% CI 60.8% -79,6%).

Here are some examples of creativity level prediction within the proposed system. Accordibgly, the examinee N (gender: male; imp/refl. α2Fp1–O1=0,06; ΔT6=11,65; βP4=3,72). Calculations in neural network models give the result Y=0,67 - the system predicts a high level of creativity (true score - 2).

The examinee M (gender: female, imp/refl. =27,05; α2Fp1–O1=0,31; ΔT6=1,84; βP4=5,39). Calculations in neural network models give the result Y = 0,15 - the system predicts a negative result (true score - 0).

The examinee D (gender: male, imp/refl.=27,65; α2Fp1–O1=0,20; ΔT6=1,00; βP4=9,34). Calculations in neural network models give the result Y = 0,31 - the system predicts a negative result (true score - 1).

To test the effectiveness of creativity prediction for the developed neural network model the recording of the electrical activity of the brain of 10 people (5 men and 5 women) aged 19-20 years was held, and besides these examinees did not participate in the main study. EEG was recorded at rest and during the task performance of divergent types. The tasks were the same as in the main study. In addition, each of the participants passed the test in order to determine the cognitive style "Impulsivity/reflexivity", one of the indicators of which, namely, the time of task performance was required was a factor of neural network model. The factor values were recorded in cell of the developed computer program, which made a prediction of creativity level. Out of 20 cases (each examinee performed two divergent tasks) there were 15 correct predictions, which amounted to 75%. A more detailed analysis showed that the error in the forecast was observed in cases when the examinees showed the unstable performance productivity result of two tasks: when performing the first divergent task showed a high level of creativity and during the execution of the second one - average.

## CONCLUSION

The use of artificial neural networks has allowed to establish a reliable link between the level of creativity and EEG indices and to develop a computer program predicting the level of creativity. This model can be used independently or in conjunction with the recognized tests to determine creativity of a human.

## REFERENCES

[1] Lebedev AN. Psychological Journal 2002; 23: 56-59.
[2] Subasi Abdulhamit, Ercelebi Ergun. Computer Methods and Programs in Biomedicine 2005; 78: 87–99.
[3] Dreiseitl S., Ohno-Machado L. J. Biomed. Inform. 2002; 35: 352– 359.
[4] Basheer I.A., Hajmeer M. J. Microbiol. Methods 2000; 43: 3–31.
[5] Sun M., Sclabassi R.J. IEEE Trans. Biomed. Eng. 2000; 47: 1044–105.
[6] Robert C., Gaudy J.F., Limoge A. Clin. Neurophysiol. 2002; 113: 694–701.
[7] Klimesch W. Brain Res. Brain Res. Rev. 1999; 29: 169–195.
[8] Petrie Aviva, Sabin Caroline. Medical Statistics at a Glance John, Wiley & Sons, 2009. 180 p.