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An aptitude test to forecast success in the dispatching activities of graduating students

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ABSTRACT: In this article, the author presents the main results that are connected with adapting known ideas and methods that are destined for professional selection and adaptation of shift-personnel engaged by power enterprises. This is achieved by elaborating on the modified and automatic version of an aptitude test in order to forecast success in the professional activities of graduating students acting as supervisory personnel in electrical power systems. The aim of this article is to provide the reader with some information about analysis of findings obtained from the aptitude test application at the technical University. The author concludes that the number of students potentially meeting the demands for dispatching activities after graduation from a university is less than half. In this regard, the forecasting of graduating students in the field of their future industrial activities is of social importance, so as to reduce the possible erroneous actions of attending personnel.

INTRODUCTION

The problems associated with reliability and effectiveness of human activities in the capacity of dispatching personnel in electrical power system enterprises are of the great social importance. The shift-personnel attending the control boards of electrical networks and power plant units are responsible for the reliable operation of electrical systems. In a number of cases, their mistakes can lead to serious damages. Also, the practical activities of these mentioned specialists are highly stressful, both nervously and emotionally. These phenomena are caused by personal responsibility, intensive data flows to be processed, and the need to make decisions and carry out actions when there is a lack of time, hence leading to accidents occurring. In many respects, rapidly restoring the normal operations of an electrical system depends upon the personal ability and professional skills of the individual, such as quickly understanding an accident situation, self-reliance and composure.

One of the reasons for a control board operator's failure, when dealing with accidents, is professional unfitness, regardless of his/her level of proficiency. An operator's reliability has been found to directly impact his/her psychophysiological functions, such as attention, memory, ability to process visual information, etc. Attaining positive results in the aptitude test discussed in this article can be regarded as a guarantee of future successful activity and the preservation of one's health when selecting an operator for power systems.

CHARACTERISTIC FEATURES OF THE APTITUDE TEST PROGRAMME

The aptitude test has been developed from a well-known methodical source in the field of human psychophysiology [1]. The results of the check-up obtained at the special laboratory of the Power Production Amalgamation, *Donbassenergo*, are of decisive importance in the professional selection of shift personnel. The time taken to complete a full integral evaluation for the professional activity being forecasted amounts to eight hours.

A computerised version of the test program being used for students is represented in a reduced format. The physiological methods destined for skilled workers (in the field of

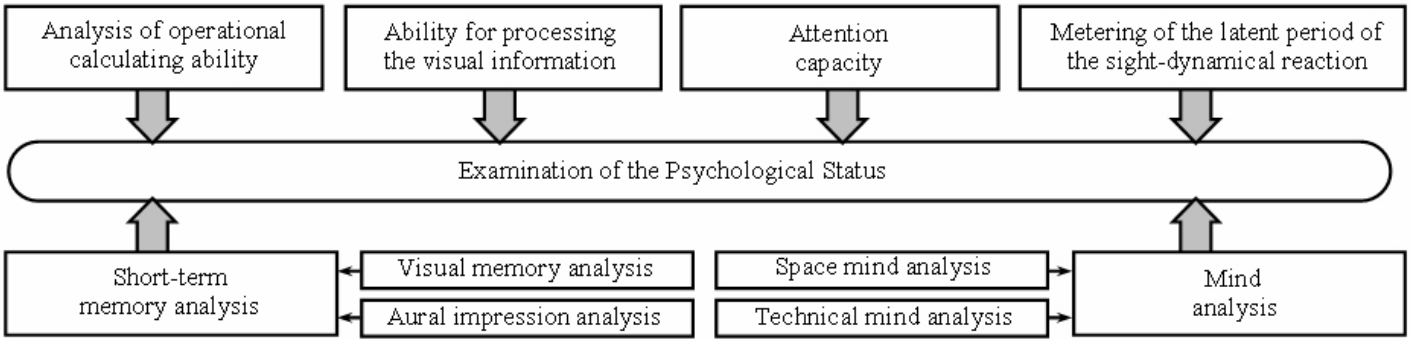

Figure 1: Composition of the psychological status for evaluating the level of graduating students in their dispatching activities.

anthropometry, respiratory system, cardio-vascular system, audiometry and acoustic reactions) were excluded from consideration. The structure of examining the psychological status of each student is shown in Figure 1. Brief descriptions of the separate program blocks are detailed below.

Short-Term Memory Analysis

The visual analysis of actual memory functions (VMA) is based on a direct reproduction of six geometrical figures (triangles) that are presented to be memorised for 10 seconds. The figures to be observed are different in internal hatching or shading (see Figure 2). The memory function is evaluated according to the number of correctly selected figures (N) from the six found in the image bank by a probabilistic approach. One minute is allocated for students to identify and select the correct figures. The calculation formula for the VMA test is N/6.

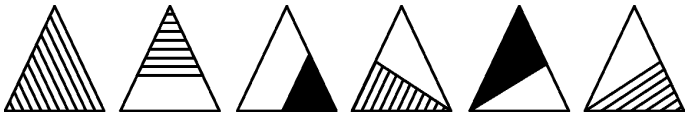

Figure 2: An example of the VMA test.

When fulfilling the Aural Impression Analysis (AIA), the person being examined listens to 10 words played on a recorder, for example: panel, key, scheme, boiler, device, light, steam, scale, turbine, needle, etc. A one-second interval between the words should be provided. An examinee must reproduce the words immediately after listening. The test is repeated six times with words selected from the word series by probabilistic approach. The calculation formula for the AIA test is as follows:

$$10\sum_{n=1}^{10}\frac{m_i}{n} \qquad (1)$$

This takes into account the quantity of correct reproductions of the *i-th* word (m_i) in n attempts made.

Attention Capacity Analysis

The Attention Capacity Analysis (ACA) is based on the *digits distribution* test, shown in Figure 3 in the form of two elements.

99	65	54	40	67
7	80	98	29	59

Figure 3: A fragment of the task for the ACA test.

The test form designed for the ACA test has 25 figures placed in a disordered manner. The requirement is to put the figures in order of increasing number into the blank spaces of the control test form. The time limit set is equal to two minutes. The number of digits arranged correctly (N) should be taken into account when calculating the index ACA (equal to N/120).

Ability to Process Visual Information

The proof-reading tables of Langdolt's rings are used (see Figure 4) to evaluate visual information processing ability (PVI). The rings rifts have eight different positions alternating in an accidental sequence. An examinee is suggested to highlight the rings of the same rift as those showing 13 and 15 o'clock. The test time (t) is measured by a computer (in seconds). The total amount of information processed (Q) is determined by the use of special tables containing the information obtained in the test. According to the first table, the amount of information processed (the PVI index) is determined by the quantity of rings with each type of rift not highlighted. The second table is used in case of any false rings highlighted. Another criterion, calculated by the formula Q/t, takes into account the speed of processing (the SPVI index).

Analysis of Operational Calculating Ability

Figure 5 shows the screen picture of the six-needle zero-centre meters. The examinee in the Operational Calculating Ability (OCA) test is asked to evaluate and summarise the indications of 3-4 needle meters regarding the signs (plus or minus) and the multiplying factor according to the schemes given below the meters. The quantity of correct answers (N) is registered, as well as the testing time taken (t). The final result, in the form of indexes $K = 10^4N/t$ and $R = KS(N)$, takes into account the coefficients of efficiency and labour productivity, respectively.

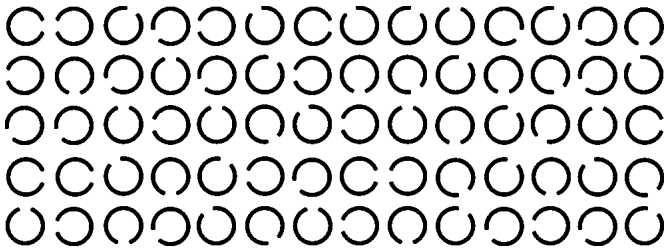

Figure 4: A fragment of the task for the PVI test utilising Langdolt's rings.

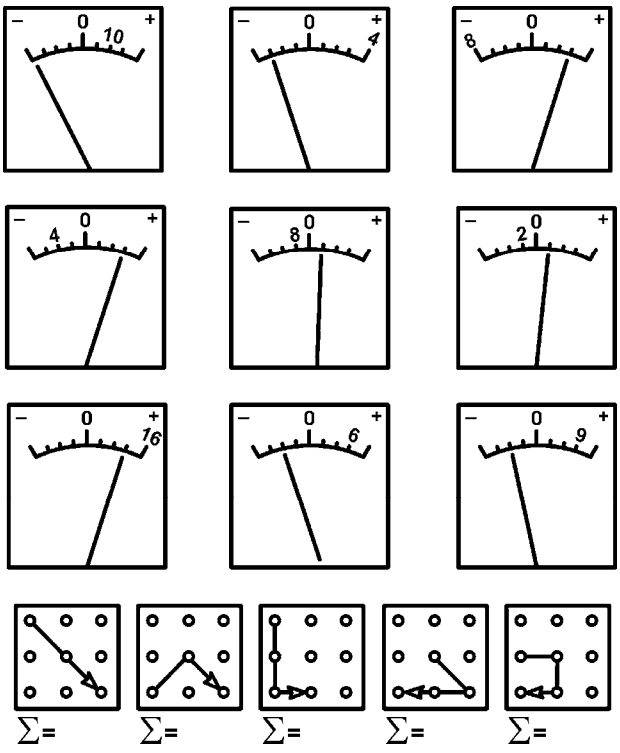

Figure 5: Test for investigating a person's OCA.

Technical Mind Analysis

The Technical Mind Analysis (TMA) test, based on an analysis of eight kinematic diagrams, requires that the examinee find and cross out the correct answers from all the possible answers given,

when chosen from a test bank shown partially in Figure 6. The number of correct answers (N_1) is then registered. The testing time (t) is measured with a DC stopwatch (in seconds). The output indices of the test (K_1, R_1) are calculated using the algebraical expressions analogous to those given in the OCA test.

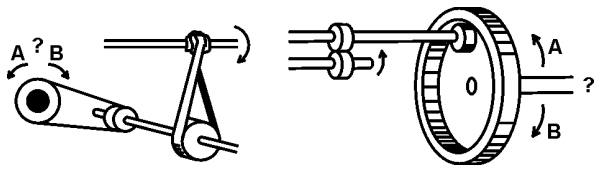

Figure 6: Two fragments of the bank for the TMA test.

Space Mind Analysis

Investigation of the Space Mind Analysis (SMA) is carried out with the use of pictures that represent 39 volumetric geometrical patterns (see Figure 7). The time limit allocated is five minutes. An examinee is asked to highlight the figure that corresponds to the number of geometrical figures.

The time taken to complete the test (t_2) is registered, as well as the number of correct (N_2) and false (N'_2) answers. The output indices of the test are calculated by the following set of formulae:

$$K_2 = 10^2 N_2/t_2 \text{ and } R_2 = K_2 S_2(N'_2) \quad (2)$$

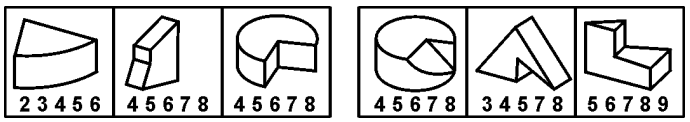

Figure 7: Two fragments of the pictures for the SMA test.

The coefficients of efficiency (K, K_1, K_2) and productivity (R, R_1, R_2) in the OCA, TMA and SMA tests take into account the factors of successful solution (S, S_1, S_2) versus the quantity of correct (N, N_1, N_2) and incorrect (N'_2) answers.

Reflexology

The aptitude test under consideration for graduating students includes an easy test in the field of reflexology, namely measuring the latent period of a simple sight-dynamic reaction. The essence of the test is the appearance of a red flash on a display screen, which requires immediate clicking to stop a DC stopwatch. The test records 20 pulse irritants (flashes) produced at random intervals. The average value of the examinee's reaction, with the exception of minimum and maximum measured quantities, is taken into account as the average time quantity (RTQ).

EVALUATION CRITERIA AND CALCULATION INDICES

The summary index used to forecast a student's success in future dispatching activities is determined by the following formula:

$$I = (I_1 + I_2) \quad (3)$$

where I_1, I_2 = the generalised marks of the psychophysiological trait of the personality being calculated, with the use of total or concrete numerical indices (the time spent for fulfilling the test, coefficients of efficiency, productivity, etc).

Without considering the social and psychological features of each personality, particularly his/her health and length of service in the profession, and without taking into account the results of the AIA test,

$$I_1 = \alpha - \beta \cdot \text{RTQ} + \gamma \cdot \text{VMA} - \delta \cdot \text{ACA} + \varepsilon \cdot \text{PVI} + \zeta \cdot \text{SPVI} \quad (4)$$

$$I_2 = \eta + \theta \cdot \kappa + \lambda \cdot N - \mu \cdot t + \nu \cdot R + \xi \cdot \kappa_1 + \pi \cdot N_1 - \rho \cdot t_1 + \sigma \cdot R_1 + \tau \cdot R_2 + \varphi \cdot N_2 - \chi \cdot t_2 + \psi \cdot \kappa_2 \quad (5)$$

where the coefficients are equal to the following values: $\alpha = 2.86$, $\beta = -1.6 \cdot 10^{-3}$, $\gamma = 0.25$, $\delta = -0.70 \cdot 10^{-3}$, $\varepsilon = 2.7 \cdot 10^{-3}$, $\zeta = 0.44$, $\eta = -2.82$, $\theta = 3.0 \cdot 10^{-3}$, $\lambda = 0.05$, $\mu = -7.4 \cdot 10^{-3}$, $\nu = 3.5 \cdot 10^{-3}$, $\xi = 3.0 \cdot 10^{-3}$, $\pi = 0.24$, $\rho = -2.0 \cdot 10^{-3}$, $\sigma = 6.0 \cdot 10^{-3}$, $\tau = 0.37$, $\varphi = 0.085$, $\chi = -6.0 \cdot 10^{-3}$, $\psi = 0.28$.

Some values of the above coefficients, taken from Maximovich et al, were specified in the process of developing the aptitude test program in conformity with the new conditions of its applicant [1]. It is obvious that the coefficients in formulae (4) and (5) reflect, to a large measure, the subjectivity of their choice. The latter peculiarity is conditioned by the vagueness of the cause and effect connections between the separate psychophysiological characteristics of a personality and the notion of the emergency.

ANALYSIS OF THE APTITUDE TEST-PRODUCED FINDINGS

The records of the data being utilised to evaluate the various elements of students' individual psychological status were achieved using formula (3), with the integral mark required for forecasting the success in their future dispatching activities. The character references revealed as a result of the aptitude test investigations have been ranked according to the following qualitative scale of ability estimations to the mentioned professional activities: high (≥12.5 marks), heightened (9.7-12.5), normal (6.8-9.7), depressed (4.0-6.8) and low (<4.0). The two latter ranks exclude favourable reference.

Summary information of the use of the aptitude test to investigate students from Donetsk National Technical University, Donetsk, Ukraine, is given in Table 1. It follows from these findings that the quantity of students potentially meeting the demands for dispatching activities after graduation from the University is as low as 44%. The relationship between the maximum and minimum marks obtained by students of the 2nd, 3rd, 4th and 5th-6th years gives, respectively, the following sequence: 6.58, 6.81, 9.95, 12.14. The favourable references obtained by 2nd and 3rd year students, and 5th-6th students were 42% and 40%, respectively.

Table 1: Statistical characteristics of the aptitude test findings.

Course of Studies	No. of Students	$\bar{x}$	$\sigma(x)$
Second	9	5.66	3.83
Third	15	6.82	3.41
Fourth	15	7.52	3.39
5th and 6th (external students)	20	6.38	3.71
Total	59	6.67	3.54

When analysing the test results, the less credible (extremes) values of the highest (24.2) and the lowest (1.2) marks were eliminated from consideration. Statistical characteristics of the measured test data (marks), as listed in Table 1, were

calculated for the mean and root-mean square values by the following formulae, respectively:

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n} \tag{6}$$

$$\sigma(x) = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n-1}} \tag{7}$$

where x_i = the *i-th* measured mark.

The aptitude test findings and an analysis of the statistical material obtained (histograms representing a frequency distribution of the marks of the dispatching activities being forecasted, statistical and theoretical distribution functions, etc) were supported by the use of Kolmogorov's criterion that the distribution law of the test statistical series obtained should meet the requirements for the Gaussian law. In the case under consideration, the function being analysed was represented with the use of the well-known expression:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{(x-\bar{x})^2}{2\sigma}} \tag{8}$$

As may be inferred from a discriminant analysis of the tests connected with an analysis of the Operational Calculating Ability (test time t), Technical Mind Analysis (time limit t_1) and Space Mind Analysis (time limit t_2), which were used in order to attain the adequacy of the indices being used for the case under consideration, as well as for the purpose of equalising the total indices of the separate tests, it is worthwhile to introduce a time limit for the time t value (t_{max} = 300 s), so as to reduce the time t_1 (t_{1max} = 200 s) and to increase the time t_2 (t_{2max} = 360 s).

When conducting the correlating analysis, it was found that there was no interrelation between the results of the aptitude test being considered and students' ability with regard to the humanities. An analogous analysis in relation to the technical sciences pointed to an insignificant value of the correlation factor. Latter analyses were based on the marks achieved by the same students in examinations for subjects in the humanities (ie philosophy, theory of economics and political science) and technical sciences (physics, mathematics and electrical engineering theory). As such, the above-mentioned findings lend support to the validity of the widely believed opinion on this point.

Random selection was used to determine which students should be tested. As can be readily observed, the best results for testing were obtained for 4th year students, in view of the fact that the root mean square (rms) value had a maximum at the minimum mean mark value.

It is interesting to note that the number of positive marks needed for gain a favourable reference added up to 60% from the range of the feasible estimate gradations. The analogous feature for the ordinary examinations, in countries of the former USSR, with the four accepted grades (excellent, good, satisfactory and bad) equals 75%. A special feature of the educational tests is associated with establishing the requirements on the knowledge quality regarding the limits of the estimation diapason for the definite marks. In the case being considered, the sought limits were fixed by the use of actual test results. The approach taken may offer a great promise.

The experiment of applying the aptitude test industrially for professional dispatchers in electrical networks (the average age is twice as high as that for students) indicated their inadequacy for this work and the need for recovery of their psychophysiological qualities by way of carrying out corresponding training to perfect their attention capacities and memory functions.

The amplitude test considered above can be used analogously to the electrical amplitude test developed by Pudlowski in the then Electrical Engineering Education Research Group (EEERG) at the University of Sydney [2]. This can be used for special training with the objective of strengthening the student's memory so that he/she may acquire the requisite habits to tackle the problems described above.

CONCLUSIONS

The psychophysiological tests described in this article target the forecasting of the success rate for dispatching activities of graduating students from Donetsk National Technical University. An analysis of the findings obtained from an application of the modified aptitude test (graduating students' version) at the University is considered.

The number of students potentially meeting the demands for dispatching activities (at electrical power systems control boards) after graduating from the University is less than half. It is evident that forecasting the skills level of graduating students in the field of their future industrial activities is of social importance, as it is connected with reducing possible erroneous actions of such personnel, especially when clearing up any accidents.

ACKNOWLEDGEMENTS

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