Scientific Research Publishing

Journal of Behavioral and Brain Science, 2018, 8, 218-239
http://www.scirp.org/journal/jbbs
ISSN Online: 2160-5874
ISSN Print: 2160-5866

Using Vibraimage Technology to Analyze the Psychophysiological State of a Person during Opposite Stimuli Presentation

Viktor Minkin[1], Ekaterina M. Myasnikova[2]

[1]Elsys Corp., St. Petersburg, Russia
[2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnical University, St. Petersburg, Russia
Email: minkin@elsys.ru

How to cite this paper: Minkin, V. and Myasnikova, E.M. (2018) Using Vibraimage Technology to Analyze the Psychophysiological State of a Person during Opposite Stimuli Presentation. *Journal of Behavioral and Brain Science*, **8**, 218-239.
https://doi.org/10.4236/jbbs.2018.85015

Received: March 30, 2018
Accepted: May 7, 2018
Published: May 10, 2018

Abstract

The vibraimage technology is applied to evaluate the multiple intelligences by presenting the line-opposite stimuli. The analysis of testing results of 161 and 91 first-year students from two technical universities, St. Petersburg, Russia, is presented. A new method has been introduced for the assessment of the level of introversion and extraversion of a person being tested. Various equations for calculating the psychophysiological state have been studied and common patterns of the psychophysiological responses to the stimuli were revealed. The experiments showed a prevailing negative correlation between the parameters of a person's energy consumption and information exchange detected by the vibraimage technology. The article discusses the possibility of extending the obtained results to other psychophysiological tests.

Keywords

Psychophysiological Response, Vibraimage Technology, Multiple Intelligences, Information Exchange, Consumed Energy

1. Introduction

Modern psychophysiology for the last 150 years after the fundamental works of Darwin and Sechenov [1] [2], which determine the development of this science, has minimal progress, despite significant advances in the physical sciences and medical sciences directly related to man. The major cause of such a slow progress is that all the theoretical works anyhow focused on psychophysiological processes [3] [4] [5] were detached from the mainstream practical research [6] [7] [8]. The vibraimage technology [9] [10] [11] [12] introduced in the late 20th century and quickly developing now, attempts to combine the theoretical issues of general psychophysiology with the practical results and studies. The main practical application of the vibraimage technology is the representation of the reflex head movements through the psychophysiological parameters on the basis of the vestibular-emotional reflex [10].

2. Research Study Aims and Objectives

One of the trends of the vibraimage technology development is the practical study of the human abilities and construction of the multiple intelligences profile. The concept of multiple intelligences (MI) introduced by Gardner in 1983 [13] allowed scientists to unite the theories of evolution and multiple intelligences into the common system, and thereby objectively evaluate various individual abilities. The extended theory of multiple intelligences proposed by Minkin and Nikolaenko [11] is based on the application of line-opposite questionnaires. The vibraimages are used to represent the changes in the psychophysiological state of a person being tested in the information-energy axes [14]. However, the most of the conclusions from the extended theory of multiple intelligences are just made on the basis of hypotheses and assumptions since the proof of each assumption requires the extensive analysis and many experiments. One of such assumptions is the negative correlation, found in the most of experiments, between the energy expenditure and information exchange among the physiological systems during the line-opposite surveys. The current study is intended to investigate this, the previously made, assumption [11] in light of the testing results and their statistical analysis.

Since in this study we are only interested in unconscious responses we do not consider any conscious responses (Yes-No answers to the questions). Also, this article will not uncover the principles of the questions and stimuli formation, described in detail in the paper [15]. We just clarify here that in our MI tests, we mean not completely opposing questions and stimuli but just conventionally opposite ones, aimed at revealing various behavioral reactions [15]. Finally, this article does not include the principles of MI testing described in detail elsewhere [11] [15] [16] [17].

The structure of the questionnaire for the MI testing developed in [11] [15] implies the consequent presentation of questions of the conventionally opposite sense (in what follows we will omit the word "conventionally") to estimate the attribution of a person to each of the twelve types of MI. As the main measurable parameters characterizing individual psychophysiological responses, we use the parameters indicating the energy (consumed energy, E) and information (informational exchange efficiency coefficient, I) components of the psychophysiological response [11] [14]. Here, under the consumed energy, E, we mean the physical energy measured in natural units of physical quantities, e.g. joule or calorie. The information characteristic of a person is based on the classical concept of information theory introduced by Shannon and Wiener for cybernetic systems [18] [3], and the information efficiency indicates the ratio of information transmitted into the physiological systems without loss, related to the total information flow within the physiological systems [11] [14]. It is natural to assume that physical characteristics of the changes in these I-E parameters depend on the type of the posed questions and presented stimuli.

3. Theoretical Background

In testing the multiple intelligences, a respondent is presented with 24 opposite questions-stimuli on the computer screen. The web camera installed on the same computer registers the psychophysiological response when processing the micro movements of the head with the use of the vibraimage technology [11].

Current psychophysiological state of the person is defined as an intersection point of two coordinates in the I-E axes [11] [14]. Typical examples of the PPS change during the MI testing are shown in **Figure 1**, **Figure 2**.

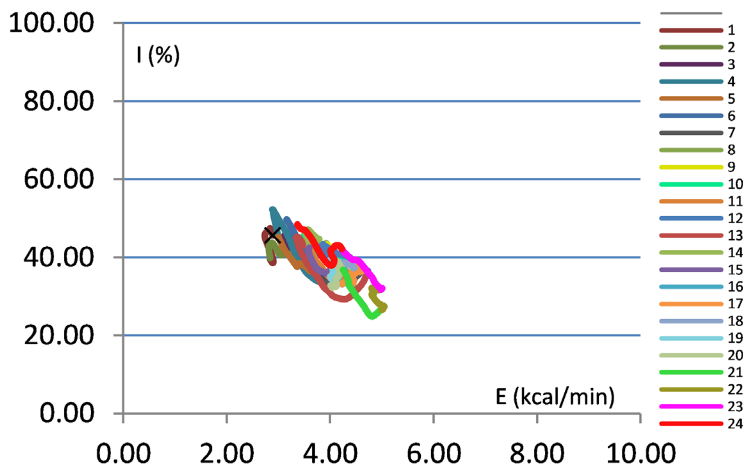

Figure 1. Trajectory of the PPS changes during the MI testing for a person being tested. Steps between the adjacent questions are given in different colors.

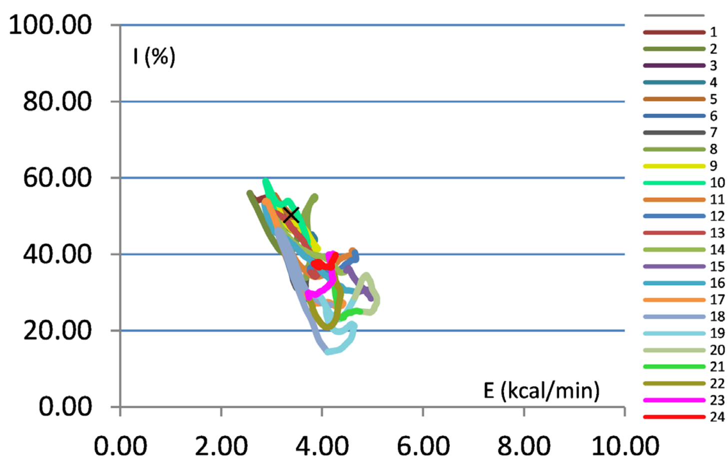

Figure 2. Trajectory of the PPS changes during the MI testing for another person being tested.

Different colors of the graphs in **Figure 1** and **Figure 2** highlight the PPS changes corresponding to the person's response to each of 24 questions-stimuli. The point corresponding to the initial psychophysiological state before the survey is marked by a cross. In spite of the seemingly chaotic nature of the PPS changes during the MI testing, we will try to determine the general patterns common for the changes in the information and energy parameters. For this purpose, we calculate the correlation coefficient between the information and energy parameters registered during the time of presentation of each stimulus-based question. Since the I-E parameters are detected for each frame, during the time of one stimulus-based question presentation, which is approx. 20 seconds, we get about 600 measurement results of I-E parameters representing a definite relationship between the parameters of interest. **Figure 3** shows the time dependencies of the change in the I-E parameters during the testing corresponding to the dependencies between these two parameters shown in **Figure 1**.

Time dependencies of physiological parameters are traditionally used in the psychophysiological detection of deception (PDD). However, to construct and study the correlation dependencies, the two-way dependencies are commonly used. Thus, we will focus on these dependencies in our further analyses. The type of I-E dependence is determined primarily by the questions-stimuli, as it is the stimulus that detects the change in the PPS of the person being tested. Let us consider examples of three the most pronounced types of correlation dependencies between the I-E parameters during answering the one or pair of questions, namely: negative correlation, no correlation and positive correlation between the information-energy parameters. It follows from observing **Figure 1** and **Figure 2** that generally the PPS changes occur with respect to the certain center of mass, and this center does not coincide with the initial PPS point marked with the cross. From the psychological point of view, this is understandable since the psychophysiological state of a person before testing is determined by his or her expectations about the testing process; and it takes some time (depending on the reaction rate and psychophysiological inertia of the person being tested) for the

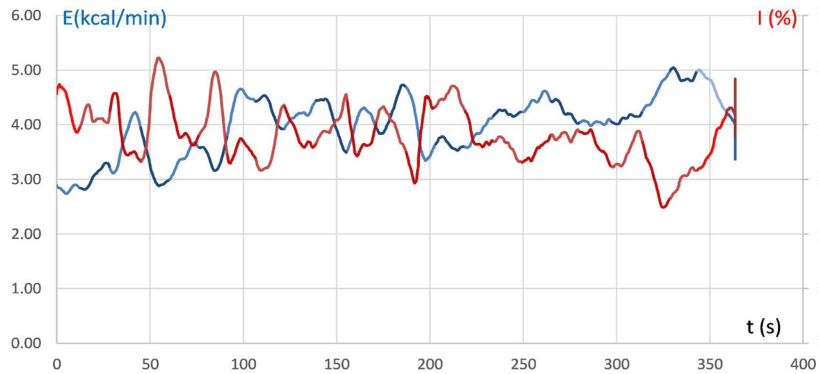

Figure 3. Time dependencies of parameters I-E presented as a function of time during testing. The two-way relationship between I-E corresponds to the testing result shown in **Figure 1**.

PPS state to be established directly in response to the presented stimuli. That being said, we believe that there is no need to waste time for the introduction and presentation of neutral questions (as it is usually done in the PDD tests [7]) since the line-opposite questionnaire and the differential method of the results processing allow the psychophysiological response to be used successfully in answering the initial questions with the actual re-evaluation of the response at the end of testing [11].

3.1. Negative Correlation between the Information-Energy (I-E) Parameters

Negative correlation in the PPS changes between two neighboring questions-stimuli primarily reflects the fact that the transition from one question to another increases the information efficiency and decreases the consumed energy, or vice versa, the information efficiency decreases, and the consumed energy increases. Schematically, a typical change in the PPS during the presentation of opposite questions-stimuli with an inverse or negative correlation between information-energy parameters is shown in **Figure 4**. The change in the psychophysiological response at answering the first question (interval 1 - 2) is depicted by a dashed line, and the second question (interval 2 - 3) by a solid line. This statistical dependence has a logical psychophysiological explanation: the presentation of significant stimuli increases the energy exchange and during the pause after the response, the PPS does not return to the initial state, but, possibly, slightly changes the original trend of the PPS changes. In answering the next question the PPS changes in the opposite direction, thereby preserving the negative correlation between the I-E parameters.

We intentionally show and examine the changes in the PPS just by presenting a pair of questions basing on the following considerations. The historical breakthrough and increasing accuracy in the psychophysiological detection of deception are mainly due to the Backster's concept of transition to comparative testing between close-in-time control and relevant questions [6] [7]. **Figure 1** and **Figure 2** show that the fluctuation of the person's PPS actually takes place with respect to a certain center of gravity of this particular individual PPS. This point the most correctly reflects the average PPS of a person during the testing. Each presented stimulus tends to change this average PPS value in a certain direction, and the more significant the stimulus is, the greater PPS change should be expected. Expected directions of the PPS changes are hypothesized in [11] [14]. Presumably, opposite questions-stimuli should shift the PPS in opposite directions, and this change should also take place regardless of the method used for the quantification of the final PPS. In addition, the opposite questions-stimuli approach allows us to constantly keep close to the PPS conventional center of gravity. This point seems to be quite important since a significant shift from the PPS center of gravity due to the presentation of unidirectional stimuli will lead to a situation where the change in the PPS is not only determined by the next stimulus, but also by the tendency of the physiological systems to return the body to the normal state, close to the PPS center of gravity. In this case, the response to the stimulus would be extremely noisy and obscured by the natural physiological reaction of the body, and therefore cannot be restored by our method.

Figure 4 shows an example with a correlation coefficient between the information-energy parameters close to minus 1. Certainly, not all the pairs of questions-stimuli and the corresponding psychophysiological responses, given in Figure 1 and Figure 2, have such clear graphical structure as shown in Figure 4.

3.2. Positive Correlation between the I-E Parameters

As the next explicit example, let us consider another graph of the possible type of changes in PPS (shown in Figure 5), when the person is answering a pair of opposite questions-stimuli, and explain what psychophysiological patterns characterize this scenario.

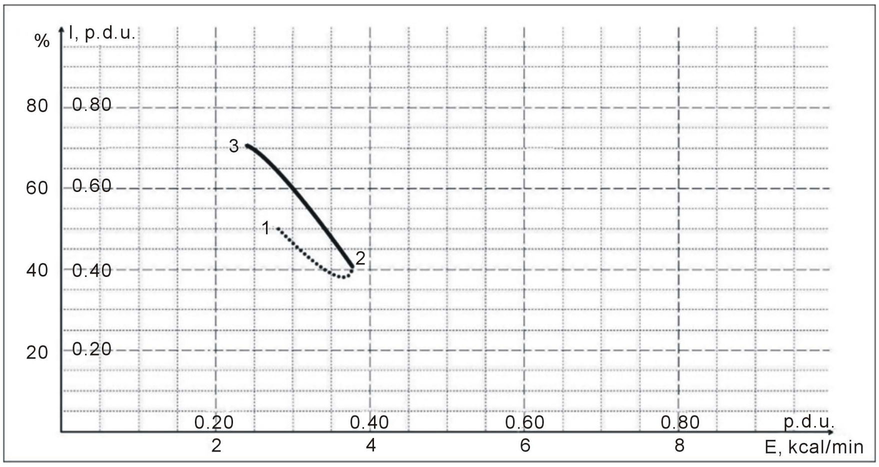

Figure 4. Typical PPS changes during the MI testing. Negative I-E correlation at the time of each question presentation.

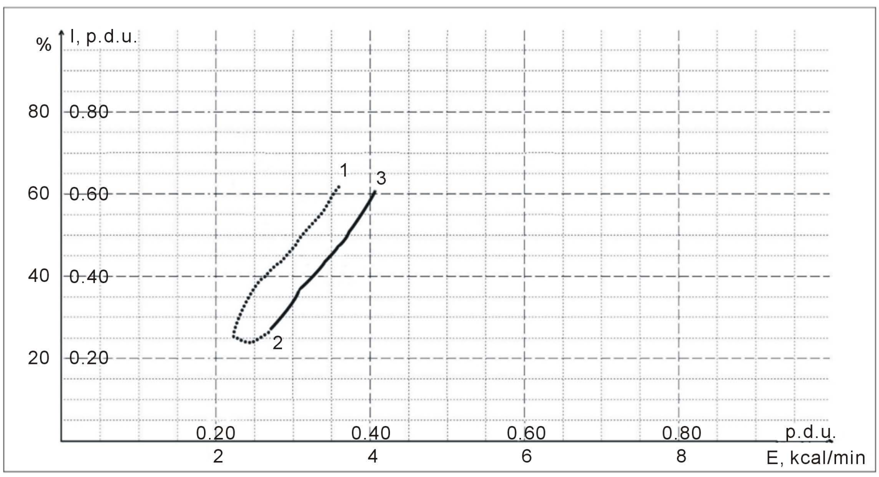

Figure 5. PPS change during MI testing. Positive correlation between I-E parameters at the time of presentation of each question in the pair.

Figure 5 shows that in answering the first question-stimulus the values of the information and energy parameters decrease, while during the answer to the second question-stimulus both of these parameters increase. Hence, the correlation between the information-energy parameters is positive and close to 1. Psychologically, this may be explained as follows: the first question-stimulus is unpleasant for the individual (the information state worsens), but at the same time the question-stimulus does not cause the irritation and the consumed energy also decreases. When the tested person is answering the second question-stimulus, an opposite reaction is observed; this stimulus causes an improvement in the psychological and information states and, at the same time, the higher energy consumption.

3.3. No Correlation between the I-E Parameters

The next example in Figure 6 shows the dependency between the information-energy parameters during answering the opposite questions-stimuli in the absence (or minimal) correlation between the I-E parameters measured over the total time of presentation of each question-stimulus in the pair.

In this case, when answering the first and second questions, the psychophysiological response of the person demonstrates the multidirectional movement that includes time intervals with both negative and positive correlation between the information-energy parameters, and the duration of these time intervals is approximately equal. Therefore the total correlation between I-E parameters during the presentation of each question in a pair is close to zero.

In the graphical examples (Figures 4-6) the return to the initial state occurs, however, in practice (Figure 1 & Figure 2) this does not always happen. On the contrary, the range of I-E coordinates between the beginning of the first question and the end of the answer to the second question can be quite big. This means that when one only takes into account the state at the end of answering the question, the correlation between I-E parameters can be either positive or negative. However, in an ideal case (or at the large sample size), at presenting

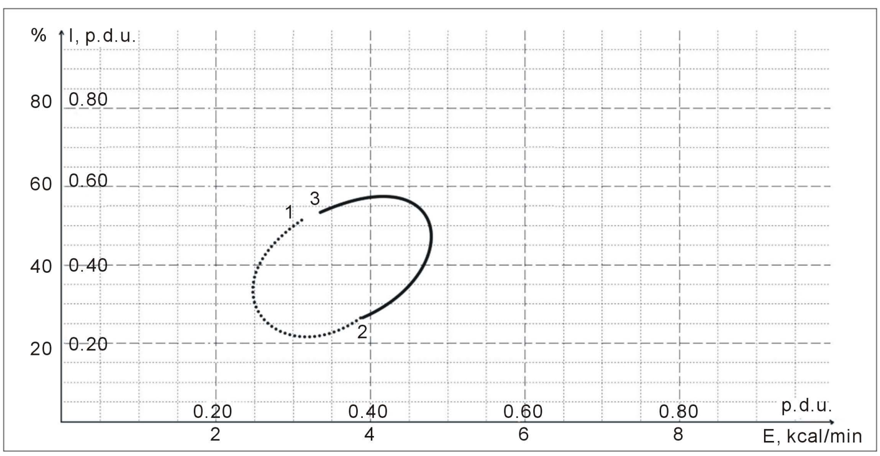

Figure 6. Possible change in PPS during MI testing. Absence of I-E correlation.

pairs of opposite questions-stimuli the range turns out to be significantly less. If the questionnaire also contains neutral questions, it becomes even more difficult to reveal any common patterns. One of the problems in this case is the practical impossibility to expect a similar statistical reaction at answering the neutral questions by different people. This problem is well known to experts in the psychophysiological detection of deception [19] [20].

3.4. Equations for Calculating PPS Changes

To quantify the changes in the PPS we used several equations, each reflecting a certain model of the PPS changes.

In Equation (1) for calculating PPS introduced in [11], the main parameter characterizing the PPS change is the change in the information state of a person being tested. The change in the energy state always takes a positive value and makes an insignificant contribution to the overall result.

$$dP_1 = \left(I_i - I_{i-1}\right) + 2\left|E_{i-1} - E_i\right| \cdot \sin A, \quad (1)$$

where:

I_{i-1} is the initial reference coordinate of the information characteristic at the initial state of the person within the ith time interval of the observation period;

I_i is the final reference coordinate of the information characteristic at the current state of the person within the *i*th time interval;

E_{i-1} is the initial reference coordinate of the energy consumption at the initial state of the person within the *i*th time interval;

E_i is the final reference coordinate of the energy consumption at the current state of the person within the *i*th time interval;

$$\sin A = \left(I_i - I_{i-1}\right) \Big/ \sqrt{\left(I_i - I_{i-1}\right)^2 + \left(E_{i-1} - E_i\right)^2}\,.$$

The next Equation (2) for calculating the psychophysiological state proposed in [14] is based on an approach of equivalent contribution to changing the information and energy characteristics of the person being tested:

$$dP_2 = \left(I_{i-1} - I_i\right) + \left(E_{i-1} - E_i\right), \quad (2)$$

where the basic parameters are similar to Equation (1):

I_{i-1} is the reference coordinate of the informational comfort at the initial state of a person;

I_i is the changed reference coordinate of the informational comfort at the current state of a person;

E_{i-1} is the reference coordinate of the energy expenditure of the initial state of a person;

E_i is the changed reference coordinate of the energy consumption at the current state of a person.

In Equation (3), proposed in this paper, the PPS changes are considered as deviations with respect to the common PPS center, computed as a sum of respective deviations of the information and energy components. Thus this characteristic takes into account two factors: the effect of the questions-stimuli and the tendency of the psychophysiological system to stabilize and return to the equilibrium state.

$$dP_3 = (I_i - I_0) - (E_i - E_0), \tag{3}$$

where the basic calculation parameters are similar to those in Equation (1):

I_0 is the reference coordinate of the integral (central or average) information state of a person;

I_i is the changed reference coordinate of the information comfort at the current state of a person;

E_0 is the reference coordinate of the integral (central or average) energy state of a person;

E_i is the changed reference coordinate of the energy consumption at the current state of a person.

4. Methods

4.1. Participants

To test the research hypothesis (the prevailing negative correlation between the information and energy parameters for the line-opposite MI testing) and reveal the common patterns of the psychophysiological response in answering opposite questions, two groups of first-year students of technical universities of St. Petersburg, Russia, were tested for multiple intelligences. The first group consisted of 161 technical students of the St. Petersburg State Electrotechnical University (LETI), the second group consisted of 93 economist students from the St. Petersburg State Technological University (SPSTU). The number of tested students was determined in a natural way. The students of selected specialities came to the test for additional information on their abilities. The tested students were from 17 to 24 years old. 86% of the participants were white Russian, 14% were Caucasian. An almost equal gender distribution was observed: 60% of males in LETI and 65% females in PPSTU. All the test participants gave their verbal consent. The testing was conducted in the second half of 2017 with the use of the VibraMI software [17]. The students have not been familiarized with the questions before the testing. In addition, they believed that the ongoing testing could affect the results of their academic performance; therefore, the presented questions and stimuli were significant for the examined students.

4.2. Method. Analysis of the Correlation Dependencies

Apart from constructing the multiple intelligences profile for each student, the VibraMI software detects and records a considerable amount of statistical characteristics and dependencies of the psychophysiological parameters obtained during the MI testing into Excel files. The statistical software VibraStatMI [21] performs automated processing of measured parameters saved in Excel files. The VibraStatMI software allows us to detect the common patterns for the tested groups, including the correlation dependencies between different parameters.

One of the informative parameters is P_near, a parameter characterizing the correlation between adjacent psychophysiological responses computed for the whole test group. This parameter is only defined at the extreme points of the PPS position after each question and does not take into account the I-E correlation during the time of the question presentation. We will consider the correlation diagrams obtained for this parameter from different Equations (1), (2), and (3) indicating the correlation of the PPS changes over neighboring questions.

The correlation coefficient P_Ref is computed between the parameters of the psychophysiological state for the questions equidistant from the questionnaire center. It is also defined at the extreme points of the PPS position after each question.

5. Results

5.1. Comparative Analysis of Algorithms for the PPS Calculation

Figure 7 shows the distribution of the correlation coefficient between the parameters of the psychophysiological state P_near calculated from Equation (1) for the adjacent questions, obtained from a sample of 161 MI tests of LETI students.

From Figure 7 it is clear that the psychophysiological response to practically all the neighboring questions-stimuli shows the significant negative correlation between the values of I-E parameters at the extreme points. We again clarify that the calculation of the psychophysiological state according to Equation (1) only takes into account the extreme values of the PPS change, *i.e.* the resulting diagram indicates that for the group of 161 students the changes in PPS response in answering neighboring questions-stimuli are negatively correlated.

The Pearson correlation coefficient is computed for each pair of responses to the neighboring questions-stimuli of the MI test (Figure 7). For example, the correlation coefficient (P_near) between the PPS values at answering the first and second questions is −0.45. Further, for the pair between the second and third questions, the correlation coefficient P_near = −0.47. A pair between questions 17 and 18 has the maximum negative correlation coefficient P_near = −0.66. From the psychophysiological point of view, the maximum negative correlation coefficient indicates that the reaction to the presented questions is the most opposite, which means that this pair of questions-stimuli (17 - 18) turned out to be the best chosen in terms of the opposite character of the questions-stimuli presentation.

Figure 8 shows the distribution of the correlation coefficient between the parameters of the psychophysiological state P_near, calculated according to Equation (2) for the adjacent questions, obtained from the same sample of 161 MI tests of LETI students.

It is important to note that, despite the significant difference in Equations (1) and (2), the form of the correlation diagrams is almost identical and the correlation values deviate only in the third digits.

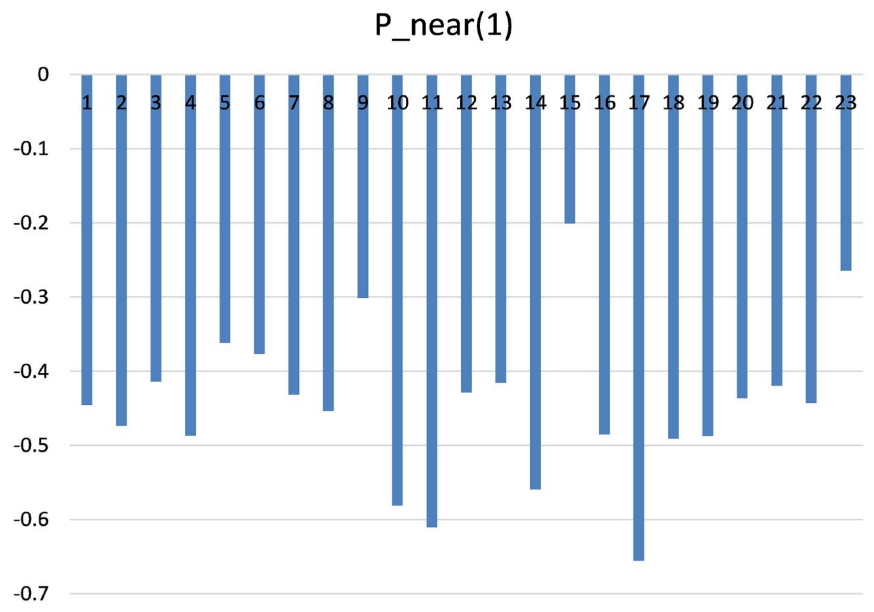

Figure 7. Correlation coefficients between the parameters of the psychophysiological state P_near (1) for neighboring questions, obtained from the sample of 161 MI tests.

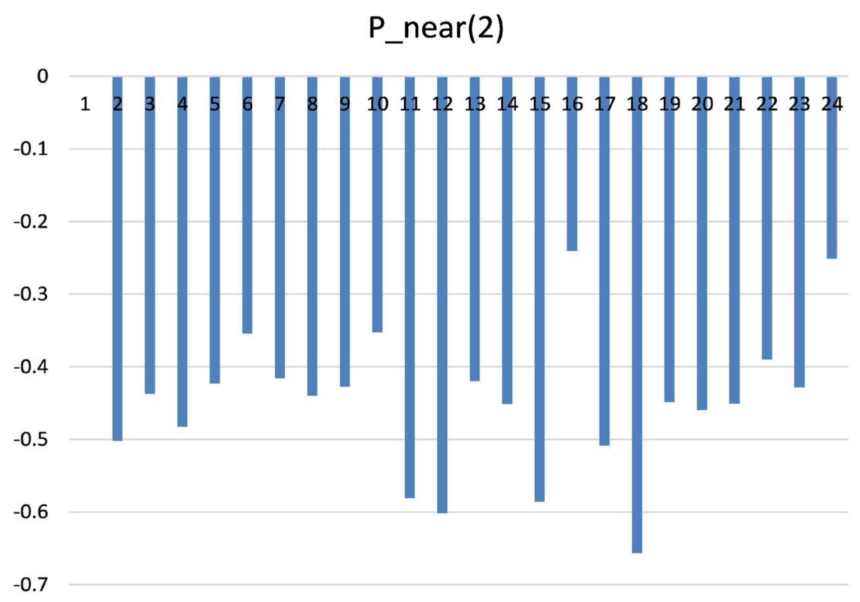

Figure 8. Correlation coefficients between the parameters of the psychophysiological state P_near (2) for neighboring questions, obtained from the sample of 161 MI tests.

Figure 9 shows the distribution of the correlation coefficient between the parameters of the psychophysiological state P_near, calculated according to equation (3) for the adjacent questions-stimuli, obtained from the same sample of 161 MI tests.

The correlation between the PPSs for neighboring questions-stimuli, computed from Equation (3), gives us a completely different picture of the distribution than those from Equations (1) and (2).

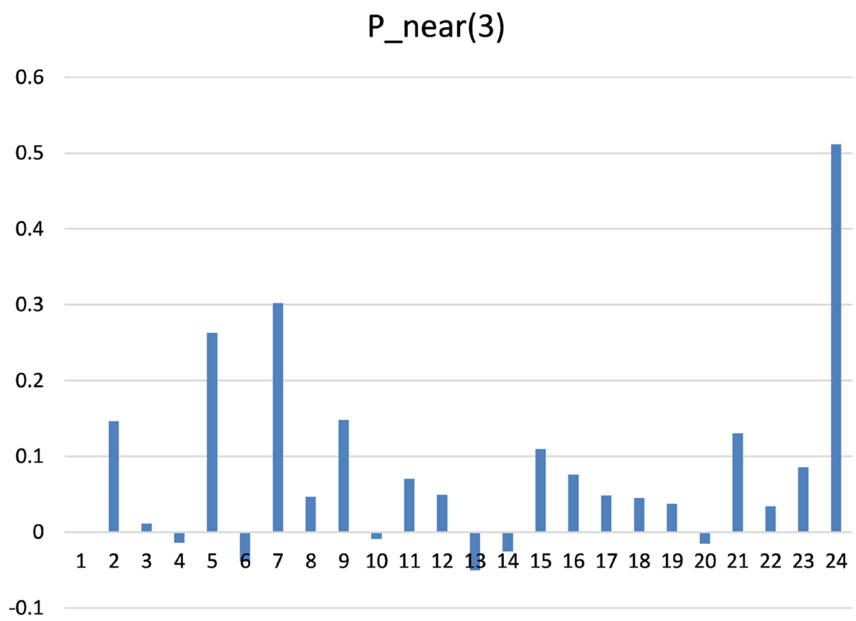

Figure 9. Correlation coefficients between the parameters of the psychophysiological state P_near (3) for neighboring questions, obtained from the sample of 161 MI tests.

Let us consider an analogous series of correlation diagrams obtained in the PPS analysis using the same equations, but between the similar in meaning questions that have the opposite (centrally symmetric) order numbers in the line of questions in the MI questionnaire (e.g., first-last, second-last-to-one, etc.).

Figure 10 shows the distribution of the correlation coefficients between the parameters of the psychophysiological state P_Ref, calculated from Equation (1) for the questions equidistant from the questionnaire center, obtained from the sample of 161 MI tests of LETI students.

The diagram in Figure 10 only shows the maximum negative correlation between the neighboring questions-stimuli, while the correlation between other similar in meaning but time-separated questions is practically absent.

Figure 11 shows the values of the correlation coefficient between the parameters of the psychophysiological state P_Ref, calculated from Equation (2) for the questions-stimuli equidistant from the center, obtained from the sample of 161 MI tests of LETI students.

The type of diagram in Figure 11 is similar to that in Figure 10. The maximum negative correlation is only observed between the closest in time psychophysiological responses to questions-stimuli 12 and 13.

Figure 12 shows the values of the correlation coefficient between the parameters of the psychophysiological state P_Ref, calculated from the Equation (3) for questions-stimuli equidistant from the center, obtained from the sample of 161 MI tests of LETI students.

The diagram shown in Figure 12 differs significantly from those in Figure 10 and Figure 11, with the maximum negative correlation observed for pairs of questions-stimuli quite remote, namely, 4th vs 21th and 8th vs 17th.

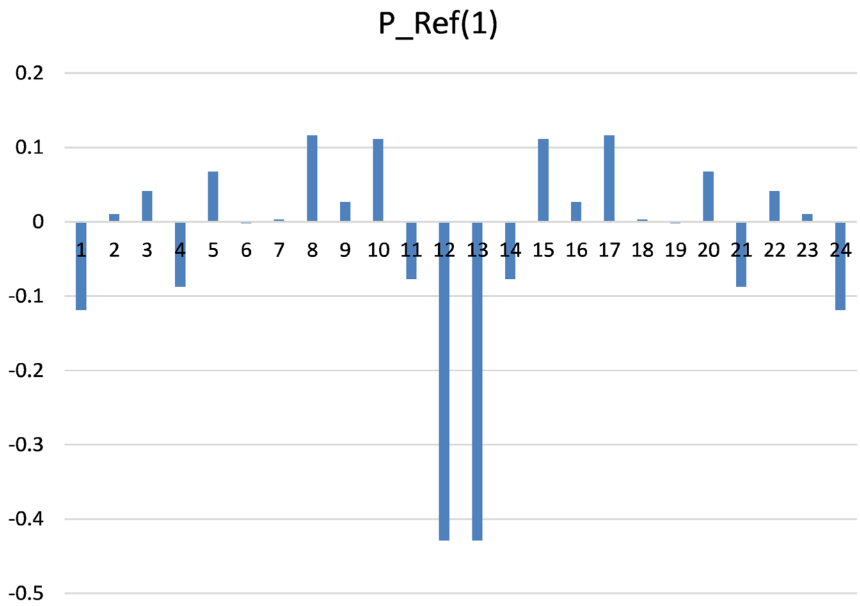

Figure 10. Correlation coefficients between the parameters of the psychophysiological state P_Ref (1) for closely related questions, obtained from the sample of 161 MI tests.

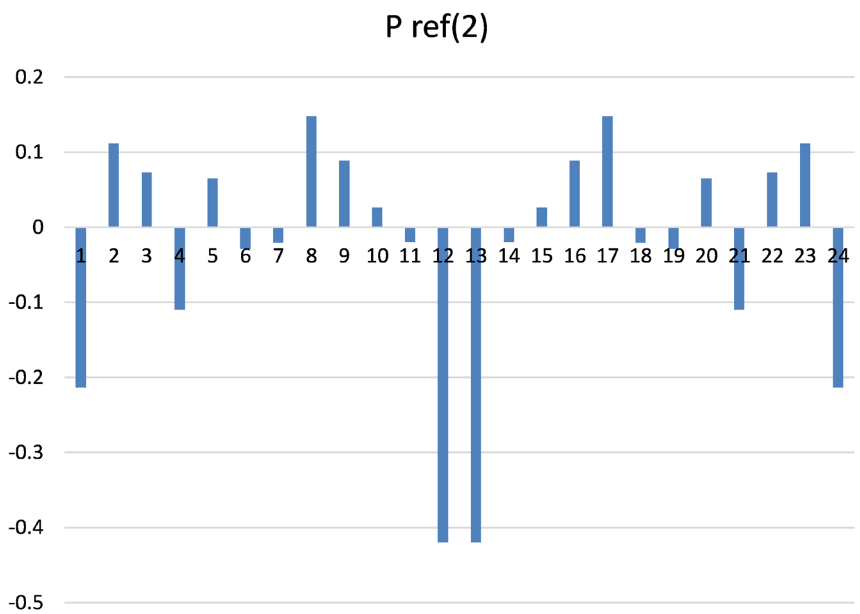

Figure 11. Correlation coefficients between the parameters of the psychophysiological state P_Ref (2) for closely related questions, obtained from the sample of 161 MI tests.

The type of the same diagrams obtained from the testing of another sample of 91 economist students is approximately analogous to those shown in Figures 7-12.

5.2. Correlation between I-E Parameters during the Time of Each Question Presentation

Now we will consider the correlation between the increment of information and

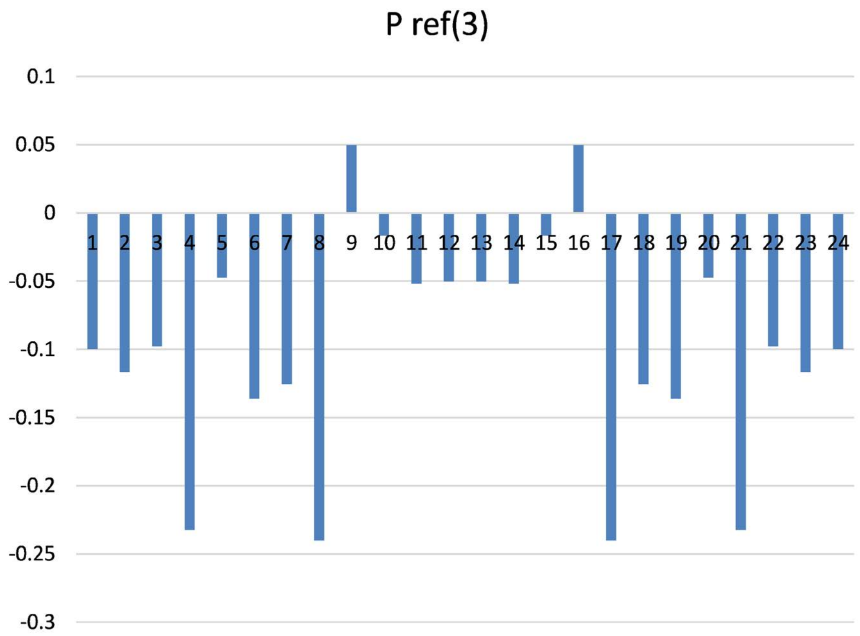

Figure 12. Correlation coefficients between the parameters of the psychophysiological state P_Ref (3) for closely related questions, obtained from the sample of 161 MI tests.

energy (changes in I and E parameters), *i.e.* the correlation coefficient dIdE computed within the time of answering each question-stimulus. Values of the correlation coefficient dIdE for the test of 161 students group is shown in Figure 13.

The difference between Figure 13 and seemingly similar Figure 7 and Figure 8 is that Figure 13 shows the coefficient of I-E correlation at presentation of each question, while Figure 7 and Figure 8 show the correlation between the PPS changes at answering the adjacent questions-stimuli.

Thus, the hypothesis of the negative correlation between I-E parameters is corroborated by the testing results of the groups of students. The typical changes in the PPS shown in Figure 4 correspond to the correlation graphs shown in Figure 7 and Figure 8 (as the I and E changes while answering the first question are oppositely directed along the vertical axis) and the correlation graph shown in Figure 13 (as the decrease in information is compensated by the increase in energy, and vice versa).

At the same time, it should be noted that the revealed common patterns have been obtained for a sufficiently large statistical sample homogeneous in age and education level. In addition, this testing was significant for the respondents, and they worried about the result. In order to approach the conclusions from a different perspective we also consider examples of correlation diagrams between the I-E parameters obtained with individual tests and get the average results.

In each particular case of testing, the correlation between the I-E parameters usually is of the oppositely directed type. Examples are shown in Figure 14 and Figure 15.

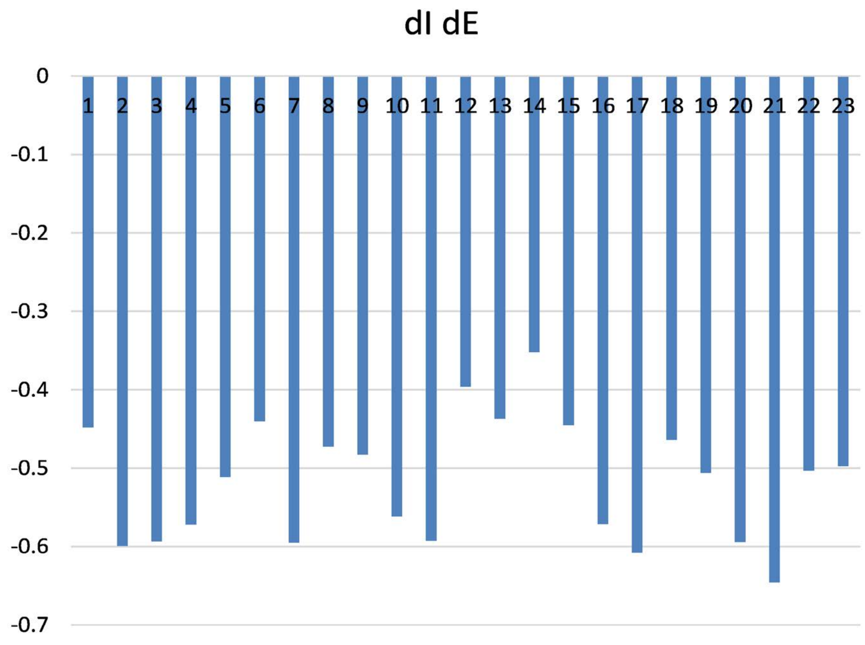

Figure 13. Correlation coefficients between the parameters of I-E changes for each question, calculated from the 161 MI group test.

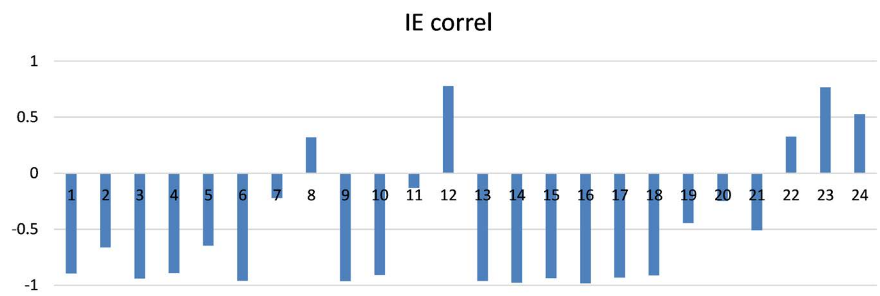

Figure 14. Sample diagram of the correlation coefficients between I-E parameters for an individual testing.

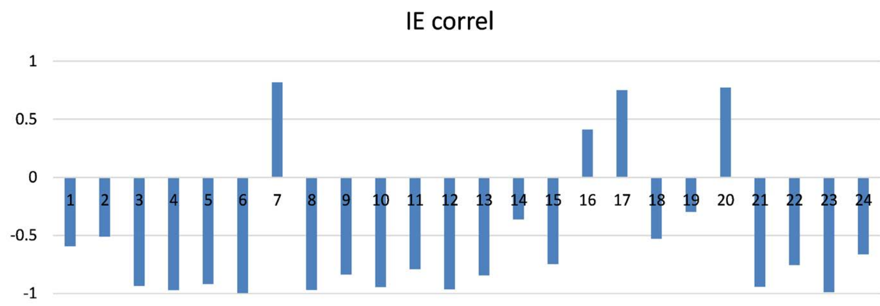

Figure 15. Correlation coefficient between I-E parameters for another individual testing.

It is worth noting that in the example in Figure 14 and Figure 15, at presenting the majority of stimuli a rather high in absolute value correlation coefficient between I-E parameters is observed. The response to 21 of 24 questions-stimuli has a correlation coefficient above 0.6 (in absolute value). This is also a typical phenomenon explained by the fact that usually the response to the stimulus has a preferential direction of change.

Despite the fact that some of the individual cases of MI testing show positive I-E correlations for some questions, the group-average correlation is generally negative for each question. An example of such averaging over the testing group of 161 students is shown in Figure 16.

The result shown in Figure 16 also corroborates that the negative correlation between I-E parameters from Figure 4 is predominant for the first year students testing.

6. Discussion

The conclusions about the correlations of the psychophysiological responses can be considered consistent as our results practically coincide for two independent tested groups of several hundred people. The study has revealed an additional rule: the more uniform the group structure is, the more pronounced the leading types of intelligences will be in the resulting MI profile of the group. For example, the subdivision of 161 students into unsuccessful students (Figure 17) and successful students (Figure 18) results in different prevailing intelligences types for these groups. The horizontal axis labels are 12 types of intelligences based on the classification given in the article [16].

On the contrary, the uniting people with different abilities and life interests into the common tested group leads to the equalization of the general statistics and the uniform distribution of the types of multiple intelligences over a large group of different people. This result is quite important and can be used to check the adequacy of the questions-stimuli presented in testing. For example, if after checking a large sample it turns out that one type of MI is the leading, then the most likely this is due to the incorrect assignment of stimuli responsible for the leading type of intelligence. This effect was observed in the first version of the questionnaire where the natural intelligence (NL) was found predominant for the most of non-related groups. Only after correction of questions-stimuli aimed at revealing the natural intelligence, the relative importance of the natural

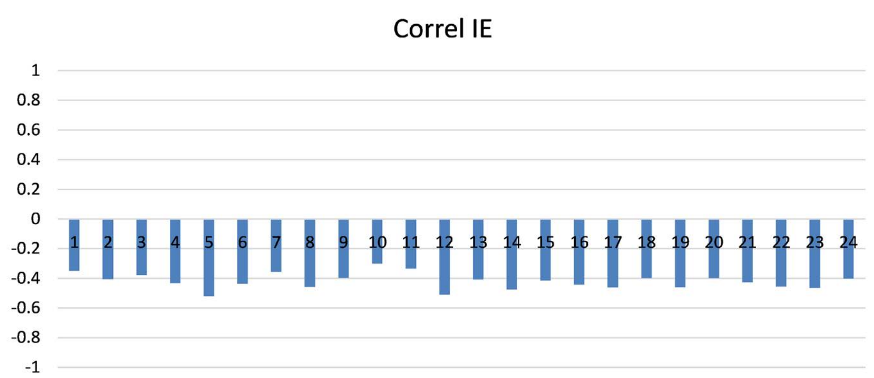

Figure 16. The averaged correlation coefficients between I-E parameters for the 161 student testing.

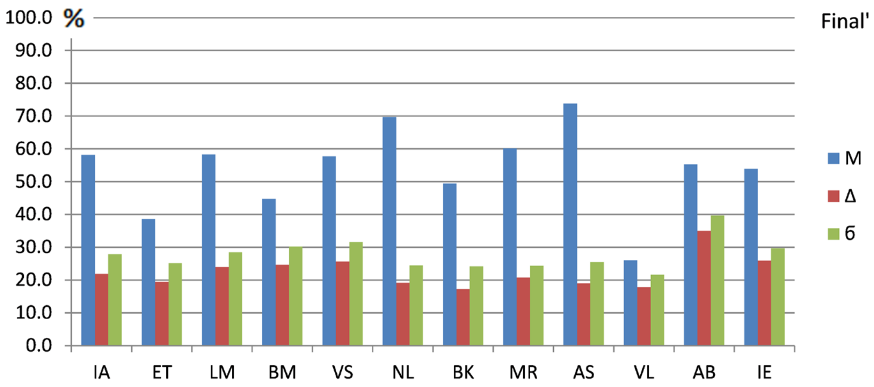

Figure 17. Integrated MI profile in the group of unsuccessful students.

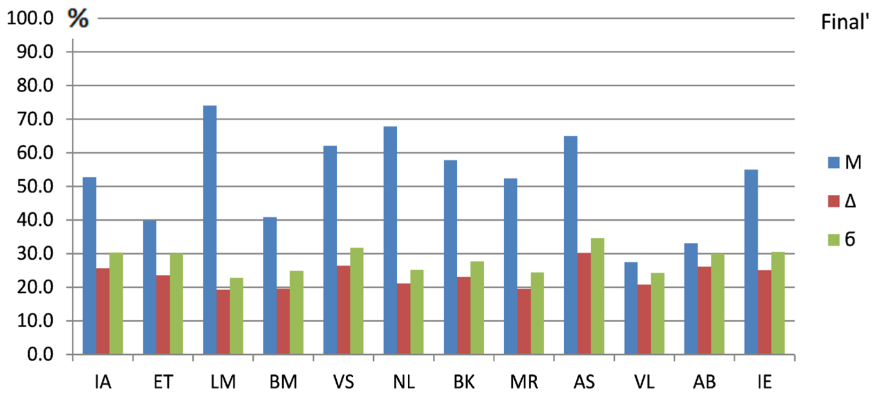

Figure 18. Integrated MI profile in the group of successful students.

intelligence in the MI profile returned to normal and was no longer the leading type in non-specific groups [15].

The new Equation (3) proposed in this paper, based on the deviation from the common center of gravity, showed the basically expected result: the increase of values of the inverse correlation coefficients between psychophysiological responses to distant in time but similar in meaning questions-stimuli (**Figure 11**). However, Equation (3) was not very effective for detecting correlations between responses that are close in time (**Figure 8** and **Figure 11**). In this case, using the center of gravity introduces a considerable error into the PPS value.

According to the previous algorithms, the main effect is made by the stimulus while the other effects can be neglected. However, as shown in **Figure 10** and **Figure 11**, a noticeable correlation between pairs of questions was only noted for the closely adjacent (nearby) responses (12th and 13th). Hence, a significant change in the PPS is caused not only by the stimulus, but also by the deviation of the current value of the PPS from the normal value, corresponding to the central state of the PPS. Thus, the change in PPS during testing is determined by two main factors: the stimulus presented and the psychophysiological equilibrium force aimed at returning the PPS to the normal (central) state (integral center). Therefore, the magnitude of the stimulus effect on the PPS is determined by the vector from the central state to the current one, rather than the vector that connects the current PPS to the previous one. In this case the practical task of determining the response to a stimulus is reduced to solving a problem from mechanics where two forces act on an ideal moving object. However, this seemingly good logical model of the change in PPS (3) showed less significant results of the correlation in the response to the answers to neighboring questions. The case requires additional research and clarification of the causes of the results. The simplified model of the effect of two forces on the change in PPS (stimulus and regulation of physiological balance) may not take into account the additional physiological characteristics. The model differs from a real human as much as an ideal mechanical system differs from the real one, including the frictional force, the inertia of the object, and other additional factors.

Near identical correlation diagrams (**Figure 6** & **Figure 7** and **Figure 9** & **Figure 10**) constructed using Equations (1) and (2), can have the following explanation. Recall that Equation (1) practically takes into account the information component only, while Equation (2) two independent components: information and energy. In this case, as shown by the statistics, for the most of respondents there was an inverse correlation between the information and energy parameters in the process of answering the questions. Hence in this case, the PPS changes calculated from Equation (2) will be similar to those from Equation (1) since the changes in energy and information have the opposite signs. Practically, in this case the results of PPS calculation from Equations (1) and (2) are strongly correlated having a correlation coefficient of 0.89, which is logical since with a negative correlation between the parameters I-E, calculations from formulas (1) and (2) must be positively correlated, as it confirms on **Figure 19**.

If the prevailing inverse correlation between I-E parameters was not observed in the tested groups, the correlation diagrams calculated from Equations (1) and (2) could differ significantly. Now we will try to answer the question, "Why the correlation between I-E parameters was predominantly negative, although it is known that in some cases it can be close to zero or positive?". As mentioned above, this paper presents the results of testing the first-year students who were afraid that the test results could lead to their expulsion from the university. Such psychological pressure during the testing process itself definitely affected the students' PPS. For comparison, the test results for a professor are given below. The professor absolutely did not care about the testing result, but rather showed interest and a positive attitude to obtaining the test results. As a result, the type of correlations strongly differs from those shown by the students (see **Figure 20** and **Figure 21**).

The above results can be explained in a somewhat unexpected way, using the concepts of introversion and extraversion introduced by Jung about 100 years ago [22]. Jung divided these PPSs primarily based on the movement of energy [22]. For a long time such an assumption remained in the form of a hypothesis and all psychologists, including the most influential ones [23] [24] used the

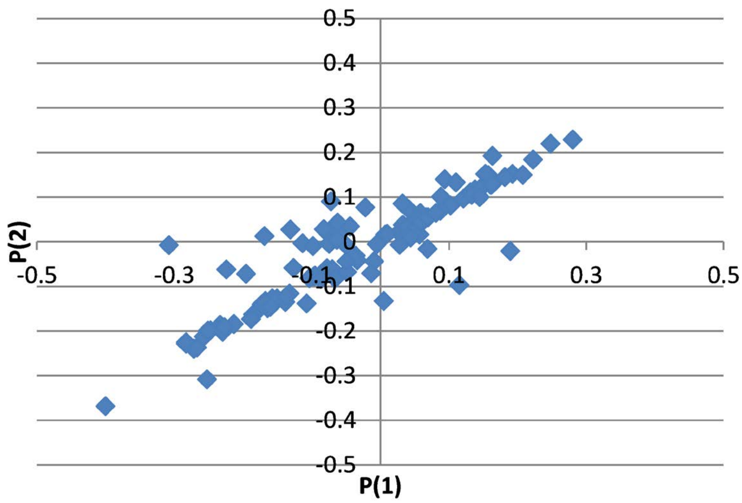

Figure 19. PPS values calculated from Equations (1) and (2) after the reply to the first question for the 161 student group.

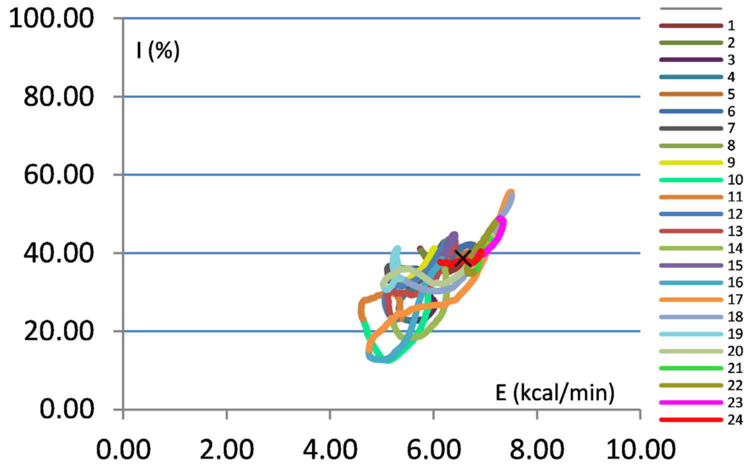

Figure 20. Trajectory of the PPS changes during the professor's MI testing.

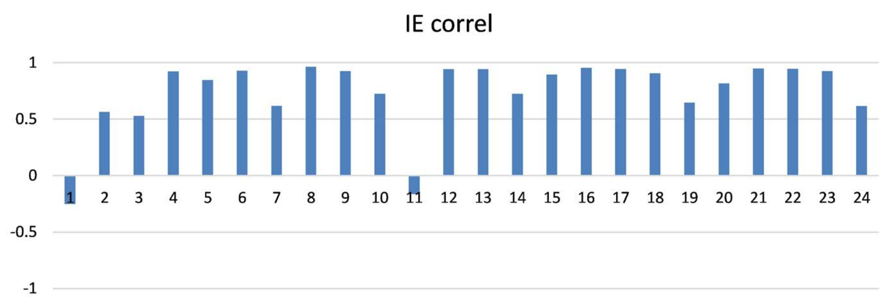

Figure 21. Correlation coefficients between I-E parameters for an individual professor's testing.

terms extraversion and introversion rather freely, attributing their own psychological meanings to these concepts and ignoring Jung's original assumption of an opposite direction of the energy flow in extraverts and introverts. However, our experiments make it possible to explicitly distinguish two of these PPSs by the direction of the energy movement. In this case, a PPS should be called introverted if a negative correlation between the energy and information parameters of the person is observed when responding to the opposite stimuli (positive and negative). Accordingly, a PPS should be called extraverted if a positive correlation between the energy and information parameters of the person is observed when responding to the opposite stimuli. In the tests conducted, the psychological pressure exerted on the students created the prerequisites for their generally introvert behavior, while their professor, interested in cooperation, showed himself as an extravert.

The next question is whether the conclusions drawn are applicable to other types of psychophysiological testing, for example, for lie detection, also remains open. The results give hope that the approach might be helpful in making the psychophysiological detection of deception more scientifically grounded and practically applicable. It is certainly tempting to use the obtained results for various psychological and psychophysiological tests aimed at identifying potential personal qualities, for example, human variability [25], as well as for fixed or changeable questionnaires to verify loyalty or identify potential supporters of terrorism.

It cannot be ruled out that the method of assessing the PPS changes in information-energy coordinates can be the basis for any psychophysiological testing, and the direction of the PPS vector more objectively represents the subject's response to the stimulus than the relatively subjective positive or negative perception of the stimulus.

7. Conclusions

In spite of their apparent mathematical abstractness, the above examples allow us to draw the specific practical conclusions:

1) The relationship between the information and energy personal characteristics, revealed using the vibraimage technology, makes it possible to assess the changes in the individual PPS and determine the combination of the psychophysiological characteristics of a person.

2) The proposed methodology for the classification of a person as an introvert/extravert by monitoring the direction of energy changes in response to the opposite questions-stimuli presentation will enable us to more objectively evaluate this characteristic of personality.

3) The PPS changes during the MI testing with the presentation of significantly opposite stimuli show a predominantly inverse correlation between the information-energy (I-E) parameters (see **Figure 4**).

4) The PPS changes during MI testing with the presentation of opposite stimuli can be described by Equation (1) (with the priority of the information component) and (2) (with equal importance to the information and energy components). The calculation of the PPS according to Equations (1) and (2)

shows similar results. Presumably, Equation (1) has a wider application and can be used to characterize people with various personality types.

5) The line-opposite questions-stimuli method provides the maintenance of the normal PPS in the quasi-stationary state because each pair of opposite stimuli shifts the PPS state from the integral center in opposite directions. It is an open question whether any neutral questions should be included into the questionnaire because the effect of neutral questions on the PPS is unpredictable. This leads to the uncertainty complicating the analysis of the psychophysiological response to opposite questions.

6) The better understanding of the PPS changes in response to stimuli will address a wide range of issues in conducting practical tests, since a deviation from the typical statistical behavior can be considered abnormal, caused, for example, by an attempt to hide information or evade an answer to a question. Of course, each case must be considered separately as there may be single deviations associated with random or methodological errors.

7) This work is an essential step towards developing the efficient testing methodology. The study of a particular case of the opposite testing allowed us to establish the statistical relationship between the presented stimuli and trends of the PPS changes. The chosen information-energy scale for the PPS characteristic proved to be effective and relevant for tracking even minor changes in the PPS of the person being tested.

References

[1] Darwin, C. (1872) The Expression of the Emotions in Man and Animals. John Murray, London. https://doi.org/10.1037/10001-000

[2] Sechenov, I. (1965) Reflexes of the Brain. The MIT Press, Cambridge.

[3] Wiener, N. (1961) Cybernetics: Or Control and Communication in the Animal and the Machine. 2nd Revised Edition, MIT Press, Paris.

[4] Bernstein, N.A. (1967) The Co-Ordination and Regulation of Movements. Per-gamon Press, Oxford.

[5] Lorenz, K. (1966) On Aggression. (Das sogenannte Böse. Zur Naturgeschichte der Aggression, 1963) Original Edition: Verlag Dr. G Borotha-Schoeler.

[6] Backster, C. (1963) Polygraph Professionalization through Technique Standardization. *Law and Order*, **11**, 63-64.

[7] Baur, D.J. (2006) Federal Psychophysiological Detection of Deception Examiner Handbook. Counterintelligence Field Activity Technical Manual.

[8] Cacioppo, J. (2007) Handbook of Psychophysiology. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511546396

[9] Minkin, V.A. and Shtam, A.I. (2008) US7346227, Method and Device for Image Transformation.

[10] Minkin, V.A. and Nikolaenko, N.N. (2008) Application of Vibraimage Technology and System for Analysis of Motor Activity and Study of Functional State of the Human Body. *Biomedical Engineering*, **42**, 196-200. https://doi.org/10.1007/s10527-008-9045-9

[11] Minkin, V.A. and Nikolaenko, Y.N. (2017) Vibraimage and Multiple Intelligence.

Saint Petersburg, Renome.

[12] Minkin, V.A. (2017) Vibraimage. Saint Petersburg, Renome.

[13] Gardner, H. (1983) Frames of Mind. The Theory of Multiple Intelligences. Basic Book, New York.

[14] Minkin, V.A. (2018) RU 2017109920, A Method for Assessing a Person's Psychophysiological State.

[15] Nikolayenko, Y.N. (2018) Development and Research of the Method of Presentation of the Optimal Stimulus for Revealing the Statistically Stable Psychophysiological Response of the Subject during the Testing of Multiple Intelligence. Elsys Corp Publishing.

[16] Minkin, V. and Nikolaenko, Y. (2017) Application of New Concept for Multiple Intelligences Calculation for Personality and Social Groups Comparison Research. *Journal of Behavioral and Brain Science*, **7**, 447-463. https://doi.org/10.4236/jbbs.2017.710032

[17] Vibra, M.I. (2018) System of Psychophysiological Profiling. Elsys Corp Publishing.

[18] Shannon, C. (1948) A Mathematical Theory of Communication. *Bell System Technical Journal*, **27**, 379-423, 623-656. https://doi.org/10.1002/j.1538-7305.1948.tb00917.x

[19] ASTM E2386-04 (2017) Standard Guide for Conduct of PDD Screening Examinations.

[20] Varlamov, V.A. and Varlamov, G.V. (2010) Computer Detection of Lies, Iligar, Orisset.

[21] VibraStatMI (2018) Statistical Processing of VibraMI10 Software Results. Elsys Corp.

[22] Jung, C.G. (1921) Psychological Types. Routledge, London.

[23] Eysenck, H.J. (1952) The Structure of Human Personality. Methuen, London.

[24] Leonhard, K. (1999) Classification of Endogenous Psychoses and Their Differentiated Etiology. 2nd Edition, Springer-Verlag, New York/Wien. https://doi.org/10.1007/978-3-7091-6371-9

[25] National Academies of Sciences, Engineering, and Medicine (2016) Assessment of the Army Research Laboratory: Interim Report. The National Academies Press, Washington DC.