Psychophysical Counseling—A Tool Revealing the Individual Ability to Learn

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Abstract

Not all students are dealing equally successfully with educational tasks. One of the reasons is the student’s lack of understanding of his/her memorial qualities in learning new knowledge. A metacognitive method is designed for psychological counseling, based on an experimental (“psycho-physical”) study of memory (Ebbinghaus). The method aims at revealing individual memory features on learning new theoretical information—the pace of memorizing and forgetting and as a result recommends a preparation time that the student should spend to achieve a desired level of preparation in the subject to be studied. Based on the data from the Ebbinghaus memory experiments, mathematical dependencies of the processes of memorization and forgetting were obtained. It was assumed that the mathematical form of the mentioned dependencies has a universal character for people. The individual specificity of these processes is reflected in the values of the parameters in the mathematical models. The models were included in the mathematical scheme of the psychophysical counseling method described. The application of the method requires the student to undergo a consultation procedure of three stages: (1) An experiment to memorize a short-written text on a topic from the subject to be studied; (2) Immediately after solving a computer test of the multiple-choice type for quantitative assessment of the degree of memorization of the material of the test topic. The method uses the obtained estimate to calculate the individual parameter values in the memorization model; (3) The same computer test is repeated a week later (the student is not warned about this) to quantify the degree of forgetting. The method uses the estimate from the second test to calculate the individual parameter values in the forgetting model. Through the obtained values of the individual parameters for memorizing and forgetting, for the student’s desired level of assimilation of the material to be studied, the counseling method calculates the necessary time that the student must devote to his preparation.

Keywords

Education; Ebbinghaus; Psychophysical counseling; Memorization pace; Forgetting pace

1. Introduction

A large part of human life is spent acquiring new knowledge. Modern education is group education—groups are formed from students with a similar level of preparation. The group members solve common educational tasks, the same preparation deadlines are set for all group members, and the progress in assimilating new knowledge is monitored through
periodic or final checks – exams, which are the same for all individuals in the group.

Individuals in a group do not cope equally successfully with educational tasks. One of the reasons is the individual differences in the abilities of individuals to assimilate the learning material—to become familiar with it, to understand it, and to remember it permanently. These differences manifest themselves to varying degrees depending on the specific type of learning material—in mathematics, literature, or history. Individual differences are reflected in differences in the study time that the student must allocate to achieve the desired level of knowledge in the specific subject. The modern education system has largely left it to the learner to develop his sense of the time he needs to study the subjects he studies. The process of selecting the right study time for the specific student and subject is based on trial and error, it is long and often associated with failures that bring unpleasant emotions to the individual being studied. Most often, the educated individual does not have an objective assessment of the qualities of his memory, he relies on someone else's experience to determine the time to devote to his preparation for learning a specific subject to successfully perform in an exam. The result is not infrequently an unpleasant surprise from the presentation in the exam. The learner often blames the examiner for his poor performance on the exam, due to an inadequate criterion of his level of knowledge, which is again related to ignorance of the specifics of his memory.

2. Aim

The learner can be supported in the process of learning new knowledge by providing him with information about his paces of both learning new knowledge in a specific subject and forgetting what he has learned, i.e. to help him determine his required preparation time to reach his desired level of new knowledge by the time of the exam.

This work describes a method of individual counseling, through which at the beginning of the training process in a specific subject, the student receives:

- Information about one's own pace—both of learning new knowledge in the subject and of forgetting what has been learned.
- Information, necessary to develop an adequate criterion for the level of own knowledge.

The proposed method examines the cognitive abilities of the individual. In the scientific literature of psychology, such a method is classified as metacognitive (Schraw, 1998).

3. Material and methods

The process of knowledge acquisition has been the subject of continuous scientific interest for over 100 years. Ehrlich explored the relationship between remembering and understanding (Ehrlich, 1982). Baker-Ward, Ornstein, & Holden, 1984, and Mastroianni et al., 1996 examined age-related changes in memory. Yoshida et al. used an electroencephalograph to study brain processes during learning (Yoshida, Hirai, & Miyaji, 2014).

Qualitative reflections on the processes of remembering and forgetting from the perspective of pedagogical psychology can be found in Trifu S., Trifu A. & Trifu I., 2016.

The amount of knowledge learned depends on the time the learner devotes to his preparation. Ebbinghaus, 1885 published the results of memory experiments, which he called "psychophysical". The researcher experimented with his memory by timing the amount of time he remembered and forgot nonsense syllables. Ebbinghaus's results are numerical data in the form of a table.

In the present work, mathematical functions (models) of the time dependences of the processes of remembering and forgetting are proposed. The models are an approximation of the Ebbinghaus numerical data. The reasoning below is based on the assumption that the appearance of models as mathematical functions is universal, i.e. applicable to all learning individuals. Individual differences in the processes of learning and forgetting are reflected in the mentioned mathematical models as differences in the numerical values of the constants contained in the models. If the constants in the memorization and forgetting models are determined for a specific individual learner and a given type of learning material, the individual time required to learn a certain amount of that type of learning material to the level desired by the learner can be calculated.

A metacognitive counseling method is proposed below, using the mentioned models to determine the individual time required to learn new knowledge with an account of the concurrent forgetting process. Following the terminology of Ebbinghaus, the method is referred to below as "psychophysical".

The proposed method of psychophysical counseling includes three consecutive stages. Students seeking counseling on their ability to memorize new knowledge in a specific subject should progress through these stages. The information obtained during the three stages is used to determine the numerical values of the constants in the models of remembering and forgetting, which, as explained above, depend on the individual qualities of memory.
3.1 Learning test material

The stage begins with a short instruction, in which the counselee is offered to study a test topic in the form of a printed text. The counselee is instructed to try to study the test topic as best as possible in the allotted time (in the counseling described below, a test time of half an hour was used)—to read it, understand it, and remember it. He may use his method of learning, for example, it is permissible to take written notes on a separate sheet of paper. In case it does not follow its method, it is recommended to follow the following learning algorithm:

1) Read carefully and thoroughly the text of the test topic, highlight the new concepts in the text, and understand them by using the given examples and by inventing similar examples of your own.
2) At the end of the test topic, there are control questions, answering which the counselee has the opportunity to check how well he has understood and remembered the new concepts. If he/she answers the control questions successfully, he/she goes to the final review of the text. Otherwise, he/she goes back to the unlearned part of the material.
3) Make a final review of the test topic.

3.2 Assessment of memorization pace

Immediately after the expiration of the allotted test topic time, the counselee, without using auxiliary materials, solves a computer test of the multiple-choice type, specially developed for the described counseling. The computer test evaluates the knowledge of the counselee on the test topic just studied and gives him a mark corresponding to the level of the displayed knowledge.

In Bulgaria, the assessment of knowledge is criterion-based – the assessment depends only on the knowledge of the assessee. In higher education practice a knowledge assessing system with “grades” is used. Grades are: “poor” (minimum grade corresponding to missing or unacceptably poor knowledge means failing the exam), “average”, “good”, “very good” and “excellent” (maximum grade corresponding to the maximum required level of knowledge). Because of its maximum grade corresponding to the objective computer score and the counselee’s self-assessment score of the counselee. The comparison of the two scores for the same knowledge—the objective computer score and the counselee’s self-score of his knowledge helps to build an adequate criterion for the level of his knowledge and, therefore, for a sense of the necessary intellectual effort when preparing for an exam.

1) The counselee receives a brief instruction for working with the computer test. The computer-based test contains 15 tasks, each consisting of a question and four answers, of which only one is correct. The tasks are related to the new concepts of the test topic. The maximum grade is called a ”six-grade scale”. The final exam assessment is presented in grade. In the present work, a scale with continuous numerical marks is also used in which the mark is a continuous positive number characterizing the level of knowledge with its numerical value between 2 and 6 ("scale of relations" according to the classification of scales of Stevens, 1946). The “scores” are the integer values of the numerical scale, corresponding to the grades, respectively: 2 (the minimum score) corresponds to "poor", 3 to "average", 4 to "good", 5 to "very good" and 6 (the maximum score) to "excellent" ("six-score scale").

2) Before the start of the tasks in the computer test, an initial form appears on the computer screen, prompting the counselee student to self-assess – to evaluate his knowledge of the test topic just studied, by entering his six-score evaluation in the corresponding field of the screen form. All the required material for the consulted subject (the counseling described below was for the subject of climatology, studied by ecologist students at Trakia University, Bulgaria) is divided into separate topics of approximately the same volume and difficulty (syllabus). In the initial form of the computer test, the number of topics in the syllabus of the subject is entered. The test topic used for the counseling is one of the topics from the syllabus, with medium difficulty and suitable for an initial introduction to the subject.

3) After the test is completed, a form appears with the results. It contains, in addition to the score from the computer test:
   • The preliminary self-assessment score of the counselee. The comparison of the two scores for the same knowledge—the objective computer score and the counselee’s self-score of his knowledge helps to build an adequate criterion for the level of his knowledge and, therefore, for a sense of the necessary intellectual effort when preparing for an exam.
   • The time, in hours, that the advised student should devote to preparing for a theory exam, necessary to obtain the...
same score as from the computer test, if this score is greater than the minimum (2, "poor") and if the exam is held immediately after completion of learning the learning material. The individual time to learn the topics from the syllabus is calculated as the product of the time it takes the counselee to learn the test topic to a certain level (in this case to get the same exam mark as on the computer test) and the number of topics in the syllabus.

- The time in hours that the advised student would have to devote to exam preparation necessary to obtain an exam mark equal to his self-assessment score - if the computer score is greater than the minimum (2, "poor") and the exam is held immediately after completion of learning the learning material.
- The time in hours that the advised student should spend preparing for the exam required to obtain the maximum grade ("excellent" 6)—if the computer score is greater than the minimum (2, "poor") and the exam is held immediately after completion of learning the learning material.

### 3.3 Estimation of forgetting pace

The counselee repeats the computer test after a certain time (in the counseling described below, the counselee repeats the computer test a week later, during the next practical class on the subject). The constants in the mathematical models of the processes of memorizing and forgetting as a function of time are calculated from the scores of the two computer tests. The counselee gets acquainted with tables in which, based on the scores of the two computer tests, the necessary time for learning the material of the studied subject is determined to obtain the desired level of training in the subject.

### 4. Results

#### 4.1 Theoretical foundations of psychophysical counseling

The method of psychophysical counseling assesses the possibilities of the memory of the counselee to learn educational material in connection with a subject that he is about to study. The method is implemented in three stages:

1. During the first stage, the counselee studies for a certain time (for example half an hour) a suitable test topic related to the subject to be studied,
2. During the second stage, immediately after the completion of the first stage, the person being counselee solves a computer test and receives a first objective computer score of the level of mastery of the test topic, by which the individual pace of the memorization process is assessed.
3. In the third stage, held approximately one week after the second stage, the person being counselee solves the same computer test a second time (without being warned about it) and receives a second objective computer evaluation, which is used to assess the individual pace of the forgetting process.

Below, the processes of memorization and forgetting occurring during the three stages of counseling are examined quantitatively.

Following the stages of the counseling described above, the counselee learns during the first stage a test topic in written form for a test time interval \( \Delta t_m \) (from a conditionally selected zero moment to the moment \( t_m \), \( \Delta t_m = t_m - \theta_m = \theta_m \)).

Immediately after that, in the second stage, he/she solves a first computer test, assessing his/her knowledge concerning the test topic learned in the first stage. Receives from the computer test a first computer score \( \theta_m \) for his knowledge concerning the test topic. The two known parameters \( t_m \) and \( \theta_m \), depending on the individual specifics of memorization, are used to determine the time interval \( t_l (l = \text{learning}) \) required for the counselee to study the theoretical material of the studied subject to the level to obtain the desired score \( \theta_l \).

The same computer test is solved by the counselee a second time at a later point in time \( t_n > \theta_m \) (e.g. a week later) and he/she receives a second objective computer score \( \theta_n \) about his/her current knowledge of the test topic at the moment \( t_n \). The known parameters \( t_n \) and \( \theta_n \) depend on the individual pace of forgetting and are used to determine the score \( \theta_f (f = \text{forgetting}) \), which the counselee would receive if the time interval between the moments of the end of studying and taking the exam was \( t_f \).

The stages of memorization and forgetting are discussed in a sequence below.

#### 4.2 Memorization process

Figure 1 shows with dots the numerical data in the Ebbinghaus publication for the time required to learn a given volume of nonsense syllables.

The time is expressed in the number of repetitions necessary to absorb a certain volume of the studied material. It can be seen from the figure that the exponential function well models the dependence of the volume of memorized material on the learning time. The discussion below is based on the notion that during learning both the learning and forgetting.
processes occur simultaneously, but the learning process is more efficient, so the curve shown in Figure 1 is a model of the resulting process—of increasing knowledge—the difference between the processes of memorization and forgetting.

The acquired knowledge is characterized by the mark \( \theta \), representing a number from the numerical scale of knowledge assessment—from the minimum mark \( \theta_{\text{min}} \) to the maximum mark \( \theta_{\text{max}} \), the first of which corresponds to a lack of knowledge, and the second – to the reached maximum level of the evaluated knowledge.

![Figure 1. An approximating curve of the dependence of the amount of learned knowledge on the learning time. The curve was obtained from the numerical data of the Ebbinghaus experiment.](image)

From the above it follows that the mark \( \theta \) depends on the learning time \( t \) according to an exponential law:

\[
\theta(t) = A \cdot e^{Bt},
\]

(1)

Where \( A \) and \( B \) denote constants depending on:

- The constant \( A \) – from the knowledge assessment scale,
- The constant \( B \) – from the individual abilities of the counselee person to learn new material.

If the process of learning has not started \((t = 0)\), there is no new knowledge and the corresponding mark is the minimum mark \( \theta_{\text{min}} \).

I.e. from Equation (1) it follows:

\[
\theta_{\text{min}} = A \cdot 1, \quad A = \theta_{\text{min}}.
\]

The formula takes the form:

\[
\theta(t) = \theta_{\text{min}} \cdot e^{Bt},
\]

whence it follows:

\[
\ln \frac{\theta}{\theta_{\text{min}}} = Bt_{\text{m}}, \quad \Rightarrow
\]

\[
B = \frac{1}{t_{\text{m}}} \ln \frac{\theta}{\theta_{\text{min}}}, \quad \Rightarrow
\]

\[
\theta = \theta_{\text{min}} \cdot e^{\frac{1}{t_{\text{m}}} \ln \frac{\theta}{\theta_{\text{min}}}}
\]

Hence, for the time \( t \) that the student must invest in learning to obtain the desired score \( \theta \) immediately after completing the learning process, assuming that during the study time \( t_{\text{m}} \) he/she received a score \( \theta_{\text{m}} \) from the computer test, the formula is obtained:
In the particular case, when $t_m = \frac{1}{2}$ (half an hour), and the six-score assessing numerical scale adopted in Bulgaria is used, for which $\theta_{\text{min}} = 2$, Equation (3) takes the form:

$$t_i = \ln \frac{\theta_i}{\theta_{\text{min}}} - \frac{1}{t_m} \ln \frac{\theta_i}{\theta_{\text{min}}}.$$  

(4)

Time $t_i$ is expressed in hours.

The time required for the counselee to learn a topic from the syllabus at a level sufficient to obtain the desired grade $\theta_l$, given that the first computer test obtained a score $\theta_m$ greater than the minimum 2, “poor” was calculated from Equation (4). The results are shown in Table 1.

<table>
<thead>
<tr>
<th>Score $\theta_m$ from the first computer test (0.5 study hours)</th>
<th>Desired score $\theta_l$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>0,50</td>
<td>0,85</td>
</tr>
<tr>
<td>1,13</td>
<td>1,35</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>0,29</td>
<td>0,50</td>
</tr>
<tr>
<td>0,66</td>
<td>0,79</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>0,22</td>
<td>0,38</td>
</tr>
<tr>
<td>0,50</td>
<td>0,60</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>0,18</td>
<td>0,32</td>
</tr>
<tr>
<td>0,42</td>
<td>0,50</td>
</tr>
</tbody>
</table>

4.3 A process of forgetting

The process of learning is accompanied by the opposite process – forgetting. After ceasing to learn, only the process of forgetting takes place.

In Figure 2, the dependence of the residual knowledge in Ebbinghaus's memory on the time elapsed after the termination of learning is graphically represented by dots. It can be seen that the experimental data are well approximated by a power function.

Figure 2 shows that in Ebbinghaus's memory, the forgetting process was most intense in the first 48 hours after learning. After 48 hours, about 28% of the initially learned material remained in his memory, after which the residual knowledge changed little – up to about 21% for the next 30 days, i.e. was stored in his long-term memory.

![Figure 2](image-url)
For the time interval from the moment $t_l$ of the termination of the learning process to the moment $t$ ($t > t_l > 0$), the decrease in the memorized knowledge is due to the process of forgetting.

Among the functions suitable for modeling the decline of stored knowledge over time, i.e. of the decrease in the residual knowledge estimate over time, a power function with a negative exponent was preferred. It is a decreasing nonlinear function, which on the one hand nicely models Ebbinghaus's experimental results of time-dependent forgetting (Figure 2) and on the other hand has a simple mathematical appearance – with only two constants.

As noted above, the learning process is seen as resulting from the processes of accumulating new knowledge and forgetting what has been learned, taking place at different intensities. After ceasing the learning process, only the forgetting process continues. The moment after which only the process of forgetting takes place is $t_l$ (Figure 3).

![Figure 3. The process of learning new knowledge consists of two phases – the "learning" phase and the "forgetting" phase. Notations: the learning time interval ends at the moment $t_l$ when the level of learned knowledge is the largest and its corresponding mark is $\theta_l$. From this moment the process of forgetting begins. $t_f$ denotes the time of the residual knowledge check (for example, the time of the exam). $\theta_{\min}$ denotes the minimum mark in the used scale ($\theta_{\min} < \theta < \theta_{\max}$). The mark corresponding to the residual knowledge at the moment $t_f > t_l$ depends on the difference $t_f - t_l$. The power function modeling the change of the mark over time under the influence of the forgetting process has the following form:]

$$\theta(t_f) = C_f (t_f - t_l)^{-D_f} \quad t_f > t_l,$$

where $\theta(t_l)$ denotes the mark that the counselee would receive at the moment $t_l$, $C_f$ and $D_f$ denote constants subject to determination.

At time $t_0$ very close to $t_l$, but slightly later, the forgetting is negligible and the current mark is $\theta(t_0) \approx \theta_l$, i.e.:

$$\theta(t_0) \approx \theta_l = C_f (t_0 - t_l)^{-D_f} \quad 0 < (t_0 - t_l) << 1.$$

The second computer test takes place at time $t_n > t_0$. The counselee receives a score $\theta_n$ from the second computer test, i.e.:

$$\theta(t_n) \equiv \theta_n = C_f (t_n - t_l)^{-D_f} \quad t_n > t_0 \geq t_l.$$

Dividing Equation (7) by Equation (6) yields:

$$\frac{\theta_n}{\theta_l} = \left(\frac{t_n - t_l}{t_0 - t_l}\right)^{-D_f} \quad t_n > t_0 > t_l.$$

$$\ln \frac{\theta_n}{\theta_l} = -D_f \ln \left(\frac{t_n - t_l}{t_0 - t_l}\right).$$

$$-D_f = \frac{\ln \theta_n}{\theta_l}$$
An expression for the coefficient $C_f$ follows from the above equalities:

$$C_f = \frac{\theta_n}{\ln \frac{\theta_n}{\theta_0}} \left( t_n - t_l \right)^{\frac{\ln \frac{\theta_n}{\theta_0}}{\ln \frac{\theta_n}{\theta_l}}}$$

Finally, for the mark of the residual knowledge at time $t_j > t_l$, the expression is obtained:

$$\theta(t_j) = \frac{\theta_n}{\ln \frac{\theta_n}{\theta_0}} \left( t_j - t_l \right)^{\frac{\ln \frac{\theta_n}{\theta_0}}{\ln \frac{\theta_n}{\theta_l}}}$$

The resulting Equation (9) applies to any scale for evaluating knowledge, as long as it is at least of the interval type—occupying a continuous interval of positive numerical values (Stevens, 1946, [8]).

### 4.4 Practical application of psychophysical counseling in the educational process

The psychophysical counseling method described above was applied to first-year students from Trakia University, Stara Zagora, Bulgaria, who wanted to check the individual specificity of their memory in connection with the upcoming study of the subject of climatology. Almost all students who are about to study climatology as a compulsory subject expressed a desire to receive psychophysical counseling. It was explained to the students in advance that the procedure they undergo in connection with the psychophysical counseling reveals the individual ability to learn the subject of each one of them, but the procedure is strictly confidential. Result information will be provided separately to each student and will not be made public. The climatology exam grade will not be affected by computer test scores during counseling. The counseling was conducted by administrative groups of students during the first two practical classes (two consecutive weeks) in climatology.

The test topic contained material on climatology with brief descriptions of basic concepts such as meteorological phenomena and their properties, characteristics of phenomena, and understanding of weather and climate. The test topic was similar in scope and difficulty to the other topics in the climatology syllabus. The test topic contained 800 words (2.7 standard pages of 1800 characters, printed on four pages of A5 format, half of which is occupied by a large illustration). If the reading technique of the average student is like that of an average adult (140-160 words per minute), reading the test topic would take him 5-6 minutes (Bulgarian norms for reading technique, 2016). For studying the test topic, the students were given a time interval five times longer-half an hour. The majority of students coped with the test topic in significantly less time than the prescribed time (half an hour) and had to be persuaded to continue with their preparation in the remaining time.

The actual time to learn the material of the type of test topic is less than that calculated by Equation (3) because the information is logically related, and as Ebbinghaus found, logically related information is remembered faster than meaningless syllables. i.e. $t_l$ is the upper bound on the learning time to achieve the student's target mark $\theta_l$.

The computer tests were conducted in a computer room, where all students worked simultaneously and independently of each other on separate computers, without the possibility of exchanging information between them.

For a score from the first computer test greater than the minimum 2 ("poor"), Equation (3) calculates the time in hours for studying the test topic depending on the desired score (Table 1). Syllabus topics are approximately equal in volume and difficulty to the test topic, i.e. the time required for the counselee student to study all topics was estimated as the product of the time (from Table 1) to study the test topic and the number of topics in the syllabus. On the final screen after the first computer test, the counselee student receives his test score, and in case the computer score is greater than the minimum 2, he/she receives three recommended preparation times:

1) **To obtain a mark corresponding to his self-assessment of the test topic before the computer test.** For example, let's say that before the computer test the counselee student self-assessed the knowledge of the test topic that he had just memorized with a score of 5 ("very good"), and on the computer test he got a score of 4 ("good"). From Table 1 it can be seen that for this student the average time required to learn one topic from the syllabus of a subject with 60 topics is 0.66 hours (row 4 and column 5 of Table 1). i.e. to get a mark on the exam equal to his self-assessment score for the test topic, the student must spend 60 x 0.66 = 39.6 hours on preparation.

2) **To obtain a mark corresponding to his computer test score.** In the example above, the counselee student received...
a computer test score of 4 ("good"). To achieve this score, he has spent 0.5 hours studying. In the final screen of
the computer test, the counselee student is advised to spend a recommended study time of $60 \times 0.5 = 30$ hours to
achieve a mark of 4 during the exam.

3) To get the maximum mark. In the example above, the counselee student received a score of 4 on the computer
test, i.e. to achieve the maximum mark of 6 ("excellent") during the exam, he would have to spend 0.79 hours
(Table 1, row 4, column 6) studying each of the topics in the syllabus. The total study time that a student must
spend to receive an exam mark of 6 is $60 \times 0.79 = 47.4$ hours.

The times calculated for all three cases discussed above are based on the marks the student would have received if the
exam had taken place immediately after the completion of the studies.

Of those who took the first computer test, 48% received a score of 3, 17% received a score of 4, 3% received a score
of 5, and 1% received a score of 6.

A score of 2 ("poor") from the first computer test is an indicator that the counselee student experiences difficulties in
the learning process. A more in-depth study of the reasons for students' poor performance should be conducted. It is
possible that for some of them, the time of half an hour is not enough to master the test topic at the "medium" grade level.
Students with the minimum score on the computer test (32% of those who took the first computer test) were advised to
invest at least three times more time in their preparation than the time needed by those who received a score of 3 ("average")
on the computer test. In some cases, the difficulties experienced by these students in learning new knowledge may
be related to peculiarities in the psyche of the individual (for example, dyslexia), for which they should be referred for
psychological counseling.

Figure 4 shows the scale distribution of the self-assessment scores and the first computer test score for participants in
psychophysical counseling. It can be seen that the main discrepancy between the self-assessment score and the objective
assessment score from the computer test for the same knowledge is for the two lowest scores on the scale – 2, "poor" and
3, "average".

Table 2 shows the degree of agreement between the counselee students' self-assessment of their knowledge of the test
topic and their assessment score of the first computer test.

The table shows that almost two-thirds of the counselee students do not have an exact criterion for the level of their
knowledge at the beginning of the training in the subject. Large discrepancies – of two or more units – between the self-
assessment score and the computer test score (20%) may also be a symptom of a deliberate refusal of frank self-assessment,
which is why they were excluded from the subsequent analysis. Of the remaining students without an exact criterion for
their level of knowledge (45%), those who self-assess one unit higher than the objective score from the computer test are
4 times more than those who self-assess one unit lower than it. I.e. the data showed a clear tendency for more than a third
of students, those with the lowest scores from the beginning of the scale, to overestimate their memory capabilities (an
effect studied by Dunning & Krueger, 1999). For these students, psychophysical counseling is most useful, for many of
them the conclusions of the counseling had a visibly shocking effect.

Figure 4. Scale distribution of the self-assessment scores and the score from the first computer test of the participants in psy-
chophysical counseling.
Table 2. Correlation between the self-assessment of the counselee students about their knowledge of the test topic and their assessment from the first computer test

| Self-assessment equals computer assessment | 35% |
| Self-assessment disagrees with computer assessment | 65% |
| Self-assessment is one unit higher than computer assessment | 36% |
| Self-assessment is one unit less than computer assessment | 9% |
| Self-assessment deviates from the computer assessment by two or more units | 20% |

The second computer test was conducted during the next climatology practical classes – one week after the first computer test ($t_n = 168$ hours). The “poor” scores on the second computer test were 71%. All poor grades from the first computer test were confirmed on the second. On the second test 44% of those who scored higher than "poor" on the first test scored 2, "poor", the same number scored 3, "average", 12% scored 4, "good".

Based on the scores and the times for conducting the two computer tests from Equations (2) and (9), it is possible to determine the score that the person counselee would receive if he appeared for the exam after time $t_f$.

From Equation (9), with counseling parameters $t_l = t_m = 0.5$ hours, $t_n = 168$ hours (one week), $	heta_l = \theta_m$ and assuming that the difference ($t_0 – t_l$) = 0.001 hours (3.6 s, the mark would decrease by less than one hundred millionths of unity) is negligible, it follows:

$$\theta(t_f) = \frac{\theta_n}{(167.5)^{0.191424 \ln \frac{\theta_n}{\theta_n}} \left(\theta_f - 0.5\right)^{0.191424 \ln \frac{\theta_n}{\theta_n}}}, \quad t_f > t_m. \quad (10)$$

A large number of students prepare for the exam in their hometowns, and for their participation in the exam, time is needed for their movement to the university, during which the student ends his preparation. If it is assumed that the time interval from the end of preparation to taking the exam is $t_f = 24$ hours, the formula for the expected mark from the exam takes the form:

$$\theta(24) = \frac{\theta_n}{(167.5)^{0.191424 \ln \frac{\theta_n}{\theta_n}} \left(23.5\right)^{0.191424 \ln \frac{\theta_n}{\theta_n}}}, \quad (11)$$

The mark that the student would receive 24 hours after the end of learning the test topic was calculated using Equation (11), in which the scores from the two computer tests were substituted. The results are shown in Table 3. For example, let’s say a student got a score of 4 on the first computer test, a score of 3 on the second computer test, spent 30 hours preparing for the exam, aiming to get a "good" grade in the exam as well. From Table 3, it can be seen that when he/she ends the learning and his knowledge corresponds to a score of 4, 24 hours later, the remaining knowledge would be for exam mark 3.14, i.e., a decrease of approximately 79%. Again, due to the logical interdependence of the knowledge studied in the specific subject, the marks in Table 3 should be considered as a pessimistic scenario (lower bounds) of the actual exam marks.

Table 3. Dependence of the exam mark $\theta_f$ for the residual knowledge 24 hours after the completion of learning the test topic, on the ratio in the scores $\theta_m$ and $\theta_n$ of the two computer tests – immediately after the completion of the learning of the test topic and a week later, respectively

<table>
<thead>
<tr>
<th>Exam mark $\theta_f$ corresponding to residual knowledge after $t_f = 24$ hours</th>
<th>First computer score $\theta_m$ (after 0.5 hours of learning)</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second computer score $\theta_n$ (168 hours after discontinuation of study)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3,00</td>
<td>3,14</td>
<td>3,26</td>
<td>3,36</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3,82</td>
<td>4,00</td>
<td>4,15</td>
<td>4,27</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4,60</td>
<td>4,82</td>
<td>5,00</td>
<td>5,15</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5,36</td>
<td>5,62</td>
<td>5,82</td>
<td>6,00</td>
<td></td>
</tr>
</tbody>
</table>
It should be noted that the learning process continues during the computer test, in which the counselee student sees the correct answers to the questions he was unable to answer, and the learning process during the computer test proceeds at a higher speed (Hamidi, Kharamideh, & Ghorbandordinejad, 2011). As a result, cases are not excluded in which the score from the second computer test is greater than that for the first. Equation (11) calculates the marks in this case as well, with increasing marks given in Table 3 in smaller (red) font.

5. Discussion of the results of the psychophysical counseling

The effect of counseling on learning outcomes was assessed by comparing students' climatology marks during the years of psychophysical counseling—from 2015 to 2019, (the last year before the pandemic) with those of the previous 3 academic years when no such counseling was held. Psychophysical counseling was administered to 250 voluntarily participating students.

The results were processed statistically by comparing the average marks of the practical tasks during the semester and of the theoretical exam after the end of the semester.

As a result of the counseling, a noticeable number of students reconsidered and changed in a positive direction their attitude towards the learning process in the subject of climatology during the semester. To the greatest extent, this is evident from the average mark from the practical classes in the subject, for which there is a statistically significant increase for the years after the application of psychophysical counseling (Figure 5). Practical tasks in climatology develop practical skills for working with data, and personal qualities such as persistence, and accuracy, but require less intellectual effort compared to the preparation for the theory exam. The mark of the practical tasks is a part of the final grade in the subject, i.e. a high mark from the practical tasks increases the chance of successfully passing the exam in the subject with less effort to absorb theoretical knowledge. To a greater extent, such a reorientation in preparation was observed among students who were disappointed with their result of the psychophysical counseling, which helped them realize that learning the theoretical material of climatology was not their strong point.

The average mark of the theoretical exam for the studied years with psychophysical counseling has also increased compared to the previous years.

![Figure 5. The average mark from practical classes increases statistically significantly during the years of application of psychophysical counseling—after 2014.](image-url)

6. Conclusions

A quantitative method of psychophysical counseling was developed, revealing the individual abilities of students to understand and remember the educational material in a subject they are about to study. Applied at the entrance to the educational process, the described psychophysical counseling allows the student:
to assess his opportunities to acquire new knowledge in the subject;
• based on the information received through the counseling, plan the allocation of time and effort for his exam preparation;
• to develop an approach to his preparation that is adequate to his abilities—to choose the best strategy for the exam. For example, in this case, if the student considers that he experiences certain difficulties in learning theoretical material in the subject of climatology, and at the same time possesses qualities such as consistency, accuracy, patience, etc., he could redistribute his efforts between learning theoretical knowledge and solving the demanding less intellectual effort practical tasks that also contribute to the successful passing of the exam.
• to develop an unbiased criterion for the level of his knowledge and for the assessment he deserves for it.

The described counseling helps the counselee student to develop a system for learning the subject that would provide him with the desired grade in the exam and to build a realistic criterion for evaluating his knowledge. The described counseling should not be a one-time act. To the extent that human memory is selective—it remembers different learning material at a different pace, any newly studied subject should begin with such counseling.

References


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