Analysis of students' functional state during computer training

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Abstract

In Activity Theory (AT), the concept of *functional state* (FS) represents the sum of those attributes of the acting subject which vary during the work process. FS evaluation can be used as a basis for comparing the effectiveness of different products and design versions. In the study described here, the functional state of 54 electrical engineering students was evaluated as they undertook training with two computer-based training (CBT) packages. Using physiological, psychophysiological and psychological methods, significant differences between the effects of the two packages on the students' functional state were identified. While one was found to promote an optimal activation and mobilization of psychophysiological processes, the other was associated with lower subjective satisfaction with the work, less concentration of attention, and an increase in non-productive functional tension.

Keywords: systemic-structural activity theory (SSAT), computer-based training, information technology

1. Introduction

In activity theory (AT) [1], the concept of *functional state* (FS) has been developed to represent the sum of those aspects of human psychological and physiological functioning which undergo change during the work process. Transitions between functional states are associated with shifts in the functioning of the main physiological processes, alterations in perception, attention, memory, and thinking, and changes in the emotional-motivational sphere.

Common types of FS include: comfort, exhaustion, tension, stress, monotony, and anxiety. Among the most important of these is the state of *functional tension*, which defines the relationship between the conditions of activity and a subject's functional possibilities [2]. Productive functional tension increases the level of *functional comfort*, an optimal FS which provides adequate mobilization (activation) of the worker's psycho-physiological processes, slows down exhaustion, improves efficiency, prolongs the ability to work without detriment to health, and promotes a positive attitude towards the activity. Non-productive functional tension is often linked to inadequate work conditions, and is characterized by an increase in physical and psychological expenditure, an inadequate activation of functional physiological systems, and a negative attitude toward the work.

Indexes of central nervous, cardio-vascular, respiratory, endocrine and other systems' activity are among the most important indicators of an individual's FS. Assessments based on such FS indicators can be used to inform the optimization of any work activity, and provide generalized criteria for the comparative ergonomic evaluation of different products or design versions. A central aim of FS evaluation is to identify product or work-process designs which support a maximal efficiency of activity at a minimal psychophysiological cost to the human organism.

Zarakovsky [3] has described different types of activity sub-system. A *goal-directed operational sub-system* is a psychological system organized as a self-regulating, goal-directed process which exists only during the formation and achievement of a conscious goal [4]. A *basic functional subsystem* integrates the physiological mechanisms that provide functionality to the organism, and is organized as a homeostatic self-regulation process. Other kinds of energetic sub-system also exist, including those which regulate the intention-related aspects of activity; as such systems include emotional-motivational components they are considered as psychophysiological sub-systems. Successful FS evaluation requires the selection of methods appropriate to the specific activity subsystems involved in the performance of the observed task, where each sub-system's state is represented by indexes that change during work performance. Not only the absolute values of these indexes but also their dynamic of change are taken into consideration, as it has been found that the same index value may designate different functional states of the organism at different periods of time [1].

2. Background

Computer-based training (CBT) packages are increasingly used in the teaching of technical disciplines such as electrical engineering. Their efficiency depends on a variety of factors, among which comfortable work conditions have been found to be one of the most important. Many users of CBT programs are freshmen, i.e. persons between the ages of 17 & 20 and at a relatively unfinished state of physiological development. For these young people the pace and demands of student life often give rise to considerable tension and anxiety. It can be useful to identify and use CBT packages that optimize the functional states they experience during training.

In educational activity, the concept of efficiency differs from its counterpart in ergonomics. Whereas in labour analysis efficiency is expressed in productivity, in learning activity it is expressed in the level of students' knowledge and skill acquisition and intellectual development. Chainova [5] evaluated pre-school children's functional state while playing with a computer game. It was found that games with optimal complexity engendered an improved FS; in overcoming obstacles the children not only acquired knowledge and skills but also developed positive emotions, including feelings of satisfaction. Similar results have been obtained in studies of vocational training [6], where introducing time standards increased students' productivity while reducing their fatigue, optimizing workload and improving motivation. These findings suggest that it may be useful to establish an optimum workload for students training with CBT packages.

3. The Study

A comparative evaluation of students' FS during training with two CBT applications was carried out using methods established by Zainutdinova and Yakovetc [7]. The study participants were 54 full-time sophomore students (average age 19), majoring in either Automated Systems for Information-Processing and Management (AS) or Automation of Technological Process and Enterprises (AP). Table 1 shows their gender and degree topics.

Table 1. Profile of study participants.

Study Topic	Total No. of Students	Male		Female	
		No.	%	No.	%
AP	22	18	82	4	18
AS	32	24	75	8	25

Two CBT were packages used in the study: Theory of Electrical Circuits (TEC) and Three-Phase Circuits (TPC). Both are designed to provide training in electrical engineering within the subject area known as General Technical Disciplines. Although both applications present students with theoretical materials, their designs differ in some important respects. Whereas users of TEC are essentially passive viewers of the material and are not graded on completion of the program, TPC provides exercises and interactive feedback and allows students control over the level of knowledge acquisition

4. Methods

The evaluations of students` functional state during CBT in electrical engineering were carried out using a variety of psychological and psychophysiological methods. The evaluations took place during scheduled training sessions and were designed to minimise disruption to the educational process, taking around 5 minutes at the beginning and end of each class.

4.1. Psychophysiological evaluation methods

Non-instrumental procedures were utilized in order to evaluate the strength, mobility and balance of subjects' nervous systems, as individual characteristics such as temperament, resistance to fatigue, resistance to stress, the specificity of tension during work, etc have been found to be linked to these features [8, 9, 10]. The strength of the nervous system reflects the robustness and endurance of the neural cells and their structure. The ability to function in conditions of stress and/or overload is partially dependent on this strength, but as it is also affected by motivational factors it is always necessary to include considerations of the subject-situation relationship in FS evaluations. In the experiment described here a tapping test was used to evaluate nervous system strength. This is a quick and approximate method based on an analysis of the frequency of hand movements during five-second periods. The mobility and balance of students' nervous systems were measured using Strelau's Questioner method [11]. Mobility reflects the "speed of reconditioning" when the conditioning stimulus is altered and is important for adaptation in dynamic environments. Evaluating the balance of the nervous system involves comparison of the strengths of excitation and inhibition of neuro-processes.

On the basis of the pre-study diagnoses of the properties of their nervous system outlined above 34 students with weak and unstable nervous systems were selected for additional physiological evaluations. These involved recording the arterial pressure and pulse frequency of selected students, with measurements taken at the beginning and end of each lesson.

4.2. Psychological evaluation methods

Psychological methods used in the study included both psychometric procedures and subjective self-evaluation. As a deterioration of the subject's functional state during activity is usually accompanied by deterioration in cognitive processes, test procedures were used to evaluate the capacity of short-term visual memory and the ability to distribute and switch attention. The tests were carried out at the beginning and at the end of each class. In order to eliminate the effect of training and habituation several sets of tests were applied.

4.2.1. The "number recall" test

A number recall test was used to evaluate changes in the capacity of short-term memory. At the beginning and end of each CBT session students were presented with tables of 12 numbers and instructed to memorize as many numbers as possible in 20 seconds. The tables were then removed and the students wrote all the numbers they could recall on an answer sheet, in any order. Different versions of the number tables were used for each test and CBT package, so that each subject was tested with four different tables.

4.2.2. The "number square" test

Each participant was given a sheet of paper containing a square of 25 numbers ranging from 1 to 40 and a linear sequence of 40 numbers. Students were asked to cross out from the sequence numbers missing from the square. They were given 1.5 minutes for this task. At the beginning of the class one group of students was presented with an odd-numbered square and the other with an even-numbered square. At the end of the class the tasks were switched. When working with different educational programs different tables were used as well. Thus, four different number squares were completed by each student.

4.2.3. The self-evaluation questionnaire

A questionnaire was developed in order to elicit students' self-evaluation of their functional state during training. The questionnaire – an abbreviated version of the DSE (differentiated self-esteem) test – was administered at the end of each training session. Students were asked to choose one of three options related to the following variables:

1. Health (a-good; b-bad, c- not sure);
2. Tension (a-tense; b-relaxed; c- not sure);
3. Vivacity (a-vigorous; b-languid; c- not sure);
4. Mood (a-good; b-bad; c- not sure);
5. Satisfaction with the work (a-satisfied, b-not satisfied, c- not sure)
6. Degree of concentration of attention (a-attentive; b-absent-minded; c- not sure).

4. Results

The same sample and number of students ($n = 54$) were analyzed at the beginning and at the end of the class in order to evaluate their FS and thus compare training with TPC with TEC. The mathematical mean (average), confidence interval for the average, and coefficient of excess and asymmetry were calculated for each functional state index. The distribution of the data was found to be non-normal. Therefore, the statistical analysis of changes in students' functional state utilized nonparametric methods for interdependent samples (Fisher's criterion -φ). Statistically significant ($p<0.05$) differences were discovered between the students' FS when working with the two programs. As changes in arterial pressure during the evaluation were found not to be statistically significant, these measurements were excluded from the analysis.

Table 2. Physiological evaluation of students' FS.

Students	No.	%	No.	%
Pulse rate	TEC		TPC	
Increased	14	41	5	15
Unchanged	9	26	15	44
Decreased	11	32	14	41

Some results of the physiological evaluation of students' FS while working with TEC and TPC are presented in Table 2, which shows that students experienced no change in their pulse rate while working with TPC 44%, as compared to only 26% when using TEC. It can also be seen that a larger proportion of the students experienced some increase in pulse rate when working with TEC (42%) as compared to TEC (15%). This finding can be partly explained as an increase in visual tension during interaction promoted by the more "aggressive" visual environment of TEC, which presents the user with many small, bright, visual elements which frequently change their position on the screen.

The results of the psychometric evaluation of students' FS while working with TEC and TPC are presented in Tables 3 & 4. It can be seen that a greater proportion of the students experienced some decrease in the capacity of their short-term memory when using TPC (almost 50%) as compared to when working with TEC (28%). A larger decrease in the ability to distribute and switch attention was also observed in students when working with TPC (43%) as compared to when using TEC (30 %). These results suggest that the students experienced greater fatigue and tension when working with TPC. This can be explained by noting the more intensive learning activity involved in work with TPC, which requires that students calculate electrical circuits and draw charts and vector diagrams, each task being graded. In contrast, using the TEC modelling program mainly involves simply observing ready-made charts, and tasks are not graded.

Table 3. **C**hanges in short-term memory capacity.

Students	No.	%	No.	%
Changes in the capacity of short-term memory	TEC		TPC	
Increased	20	37	7	13
Unchanged	19	35	16	30
Decreased	15	28	31	57

Table 4. Changes in the capacity to distribute and switch attention.

Students	No.	%	No.	%
Changes in the capacity to distribute and switch attention	TEC		TPC	
Increased	15	28	13	24
Unchanged	23	43	16	30
Decreased	16	30	25	46

The students' self-evaluation of their functional state while working with TEC and TPC are summarized in Tables 5 & 6. The results demonstrate perceived advantages of TPC over TEC according to the indicators: "vivacity" (over 19%); "satisfaction with the work" (over 26%); "mood" (over 16%); "health estimation" (over 16%). The work with TPC was accompanied by a greater degree of concentration of attention (over 26% compared with that TEC), and demanded somewhat more tension than the work with TEC (37% - TPC and 30% - TEC. These facts can be explained by noting the greater intensity of learning activity involved.

Table 5. Students' self-evaluation of their functional state while working with TEC ($n = 54$).

Health		Tension		Vivacity		Mood		Satisfaction		Concentration	
good	24	tense	16	vigorous	17	good	29	satisfied	22	attentive	14
bad	12	relaxed	30	languid	13	bad	12	not satisfied	21	absent-minded	17
not sure	18	not sure	8	not sure	24	not sure	13	not sure	11	not sure	23

Table 6. Students' self-evaluation of their functional state while working with TPC ($n = 54$).

Health		Tension		Vivacity		Mood		Satisfaction		Concentration	
good	33	tense	20	vigorous	27	good	38	satisfied	36	attentive	28
bad	7	relaxed	27	languid	12	bad	7	not satisfied	14	absent-minded	11
not sure	14	not sure	7	not sure	15	not sure	9	not sure	4	not sure	15

5. Conclusion

This study demonstrates the use of techniques of functional state evaluation to compare the effectiveness of two computer-based training packages. The underlying assumption was that the less a students' psychophysiological characteristics deteriorated during computer-based training, the better the design of the CBT application, at least in terms of its correspondence with the students' functional state. Statistically significant ($p<0.05$) differences were discovered between the students' FS when working with the programs "The theory of Electrical Circuits (TEC)" and "Three-phase Circuits (TPC). Working with TPC involved intense learning activity and was accompanied by an increase in functional tension. However, this tension did not exceed permissible levels and, taken in conjunction with students' positive self-evaluation of their own functional state during the training process, this suggests that working with TPC brought about an adequate mobilization and optimal mobilization of students' psychophysiological processes. On the other hand, students working with TEC negatively evaluated their own functional state, experienced lower satisfaction with the work, showed a lower level of concentration and experienced a non-optimal increase in functional tension. Hence, it is possible to draw the general conclusion that according to functional state criteria the TPC package is better suited for supporting effective computer-based training in general technical disciplines for freshmen students.

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