HUMAN–COMPUTER INTERACTION AND OPERATORS' PERFORMANCE

OPTIMIZING WORK DESIGN WITH ACTIVITY THEORY

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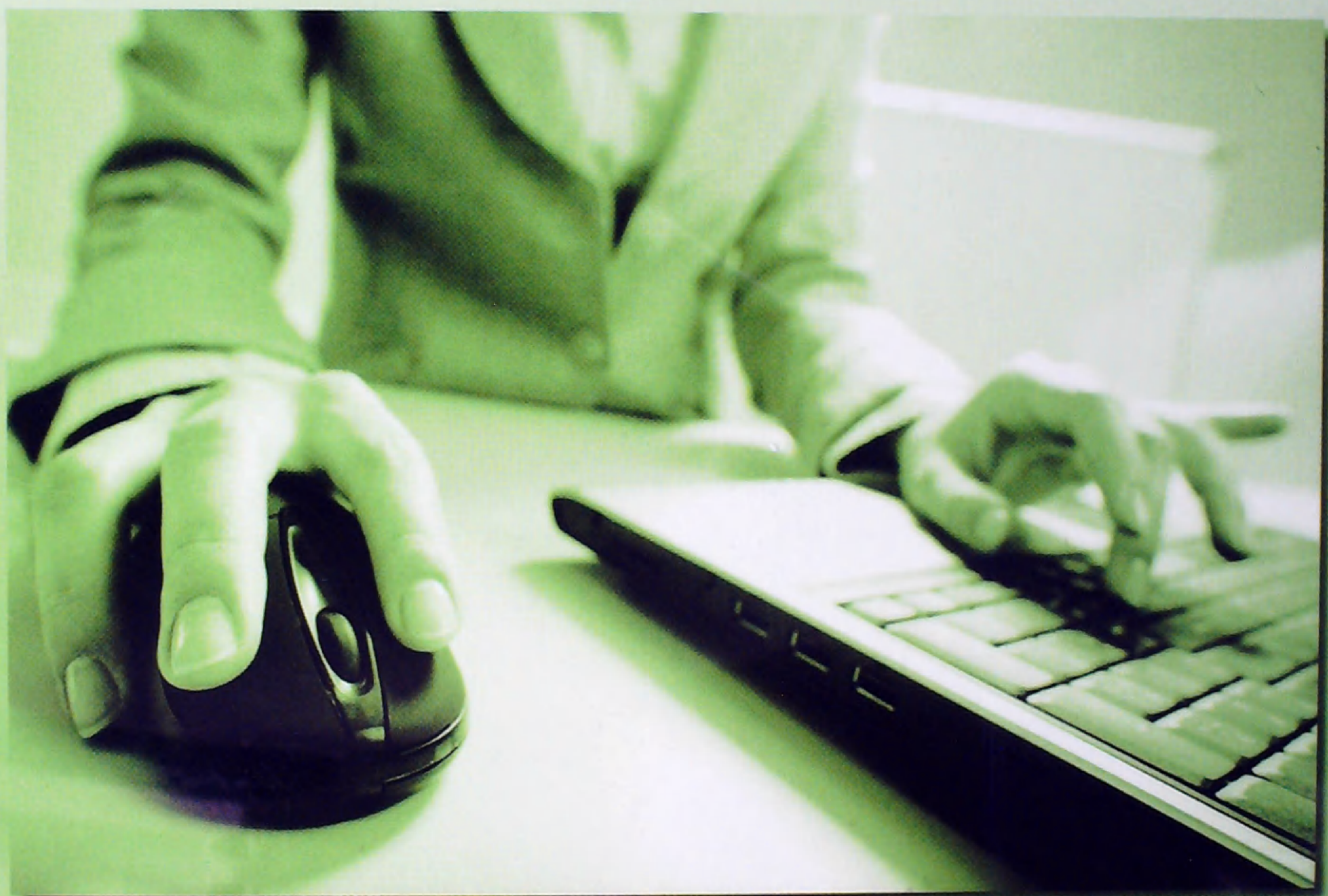

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14

Application of Laser-Based Acupuncture to Improve Operators' Psychophysiological States

A. M. Karpoukhina and O. Kokun

CONTENTS

14.1 Introduction

Constant development and an increase in the complexity of equipment due to ongoing technological changes make optimization of the psychophysiological state (PPS) of a person who manages his or her own equipment critically important. The operators' PPS is one of the predominant hindrances to their efficiency, affecting the safety and reliability of their work, and is a prerequisite for their professional upgrade (Karpoukhina 1985, 1990, 2005; Karpoukhina and One-Jang 2003; Kokun 2006). It is well-known that a mismatch between the objectives the operators have to meet and their PPS is often the cause of equipment breakdown, accidents, crashes, operators' occupational diseases, and increasing dissatisfaction with the activity they are charged with. Therefore, optimization of the operators' PPS is directed at the prevention and decrease of the so-called negative praxis conditions induced by factors such as fatigue, strain, and stress and can be considered one of the most important tasks for the modern ergonomics.

We address this task based on functional system (FS) theory, developed by Peter K. Anokhin, and on his comprehensive scheme of structure and functional organization (Anokhin 1978). Of crucial importance is the thesis of leading the "backbone" role that is assigned to the required result or goal. Nothing else but the required concrete result drives the specifics of the structure and functional organization for a concrete integral FS.

From the systematic approach perspective (Karpoukhina 1985, 1990; Kokun 2004, 2006), human PPS is contemplated as a dynamic FS underpinned by a multilayered hierarchical structure, where all the elements interact to achieve the required future result: provision of psychophysiological support for the individual's current motivated activity. The FS acts as an apparatus of self-regulation, which has a cyclic organization with feed-forward and feedback interconnections to present itself as a central-peripheral entity, which includes various components of the neural system. The FS of self-regulation of activity includes important mechanisms such as afferent synthesis, the predictor apparatus (which is called acceptor of "action effect"), program formation mechanism, the decision-making mechanism, and feedback influences. Each of these mechanisms performs particular functions in the regulation of activity (Karpoukhina and One-Jang 2003).

Based on the modern psychological models of self-regulation of activity (Bedny and Meister 1997; Bedny, et al. 2000; Bedny and Karwowski 2007), human PPS can be viewed as a sort of energetic foundation that an individual would rely on to self-regulate his or her activity. On the one hand, PPS is formed in a process under the impact of concrete activity, and on the other, it stipulates its efficiency.

Within the hierarchy of human PPS components (or conventionally speaking, levels), we can distinguish between social, psychological, psychic, physiological, biochemical, biophysical, and bioenergetic constituents (Karpoukhina 1990, 2005; Kokun 2004, 2006). The bioenergetic level is the foundation for the functioning of all superior PSS hierarchical components. Deficient bioenergy affects the implementation of internal information processes and, consequently, interferes with the functioning of superior system hierarchical components. Since a nonspecific activation of PPS bioenergy level promotes specific positive changes on other levels and in PPS as a whole through self-regulation, this level is considered one of the most promising in terms of PPS diagnostics and optimization (Karpoukhina 2005).

The aim of the operators' PPS optimization is to match the PPS parameters with the parameters, tasks, and conditions of their activity (Karpoukhina 1985, 1990. 2005; Kokun 2004). Correspondingly, PPS optimization can be interpreted as the establishment of a complete match between the activity parameters and the operators' PPS parameters (Kokun 2004).

In this chapter, we will study the theoretical, methodological, and practical substantiation to using a bioenergy-level activation method, laser-based acupuncture, to optimize the operators' PPS, and the results of experimental research, which prove the efficiency of this method.

14.2 Theoretical, Methodological, and Practical Substantiation of Applying Laser-Based Acupuncture

Modern science does not dispose of multiple methods and tools to evaluate, control, and optimize the PPS of operators, that is, virtually healthy persons in the process of their activity. Today, mostly pharmacological preparations and methods of psychoregulating training and psychic self-regulation are used to improve the operators' PPS. Sometimes, modifications of such methods use biological feedback to improve the PPS and rheoencephalography (REG) indexes. The common feature of all these methods is that they rely not on increasing the energy level of psychophysiological processes from outside, but rather focus on the redistribution of the internal energy resources of the human body to optimize any individual function.

This leaves open a question related to the possibility of durable repetitive application, harmlessness, and remote consequences of these pharmacological methods (Karpoukhina 1990). The practical application of psychic regulation methods took a considerable lead over their conceptual substantiation. The efficiency of some methods is not permanent and sometimes cannot be prognosticated. The major drawback of the existing psychic regulation methods is the long time and considerable effort they take to produce the effect, as well as the need of high motivation to master them. As a result, only an insignificant percentage of people are capable of utilizing them at the level sufficient to produce a noticeable effect in the optimization of their state and to increase their operational efficiency (Kokun 2004). In addition, these methods are difficult to automate and tend to divert operators from their activity.

Consequently, there is a need to conduct research and develop PPS regulation methods based on the enrichment of energy levels—first of all, the energy of informational (including psychic) human processes, that is, methods that rely on the energy support of the nervous system by virtue of phylogenetic and ontogenetic deterministic algorithms. The latter is all the more essential to provide for a nondoping nature of influence, produced on a human operator, and the elimination of any negative effects.

Such methods include laser-based acupuncture, which has acquired a good reputation in the field of therapeutic treatment of various diseases by using low-intensity laser or "soft laser." By now, we have 30 years of experience applying soft lasers for resolving new tasks such as regulating the PPS of virtually healthy individuals to ensure the efficiency and reliability of their (operator, professional, training, game, daily) activity.

Due to the mechanism of low-energy long-wave laser radiation in red and infrared ranges, this method targets the energy intracellular processes, which are based primarily on the photons functioning at molecular and submolecular levels. Targeting the biologically active points (BAPs), which are characterized by their high concentration of nervous system elements, allows that this effect is being pointed at a particular "address," that is, impacting the energy of physiological and psychic processes. Here, these processes are characterized by energy and informational interrelations, which make it possible through the energy level of nervous and psychic processes to produce an impact on the informational processes occurring in the nervous system and the brain, including perception, coding, transfer, storage, and presentation of information. These processes are mostly responsible for governing the efficiency of the operators' work.

From ancient times, BAPs have been known as acupuncture medicine in the Orient. This method has been widely used for the treatment of various illnesses. BAPs represent small parts of skin (1–3 mm in diameter) and hypodermic tela, which contain a number of mutually interdependent microstructures (vessels, nerves, cells, connective tissue). One individual skin point is distinguished from its neighbor points by an increased oxygen uptake, higher temperature, reduced electrical resistance, asymmetry in current conductivity, considerable electrical capacity, the value of quasistatic and dynamic biopotential, palpatory tenderness, and so on (Karpoukhina 1990; Kokun 2004, 2006). According to oriental medicine, different BAPs are connected to different inner organs and are interconnected into a sort of meridians.

Topographic analysis of BAPs and meridians, which connect them, shows that the path of these channels coincides with the layout of large nerve tracts or blood vessels, densely entwined with nerve fibers. In general, a BAP can be visualized as the localization of energy-labile biomolecules or as an electromagnetic structure (architecture) responsible for powering informational processes inside the human body, which also determines its changes.

From the time low-intensity laser radiation was introduced in medical practice (in the early 1960s) and all the more so in the practice of adjusting PPS in human activity, it was essential to understand its mechanics. Different hypotheses on the nature of its effect on the human body have been developed ever since. Today, we know that the initial mechanism of low-intensity lasers is related to exchange processes and bioenergetics inside the cell, predominantly, the nerve cell (Skulachev 1969, 1972; Rusakov 1988). It is considered to be the most adequate tool affecting the BAP system (Karpoukhina 1985, 1990, 2005). The response of the human body to soft-laser treatment can be explained not only by the specifics of its operation, but also to a considerable extent by the initial functional state of the human body. Since the FS operates at a very low energetic level, the low level of applied energy enhances the power balance within a cell by stirring up self-protective and self-recovery processes as soon as the body's functional state is disturbed. Large quantities of this energy, inhibiting the functional activity and in some cases even capable of destroying tissues, are used in surgery as a laser knife.

Optimization of the cell energetic at the base bioenergy level of the PPS system through energy-information relationships contributes to the optimization of information processes at all hierarchically superordinate PPS system levels. In other words, the reaction to laser-based acupuncture can be represented as a chain of reactions throughout the entire human PPS system. Such a reaction also increases the level of energy channeled to support the body's regulative algorithms, which results in staving off fatigue, enhancing work efficiency, and increasing tolerance to elevated emotional and exercise stresses.

Laser radiation is electromagnetic radiation in the optical band, possessing properties such as monochromaticity, coherence, polarization, and directionality. The radiation source in soft lasers is the electro-optical quantum amplifier or semiconductor oscillator of electromagnetic radiation in the red and infrared bands. The efficiency of such a laser impact depends on the flow rate, duration of the procedure, and length of the respective wave. It has been discovered experimentally that a high biotic level (or affinity with proper biotic process of energy conversion) can be achieved by the red band radiation with a wavelength of 0.6328 μm (Karpoukhina and One-Jang 2003; Karpoukhina 2005). The parameters of the laser radiation used on the BAPs are as follows: a wavelength of 0.6328 μm, a density of energies on the boarder of the skin 0.5–2 μWatt/mm^2, and a duration between 10–15 seconds and 1–2 minutes. As a rule, laser-based acupuncture is recommended to be applied in treatment courses of up to 12–14 days, but a one-time treatment can also be equally beneficial.

It is necessary to highlight some of the aspects of laser-based acupuncture, such as its normalizing (nonspecific) and nondoping nature. The normalizing effect is produced by soft lasers, which bring the parameters of regulated functions to norm, regardless of initial hypo- and hyperfunctions. This corroborates the fact that a laser operates not through any irritating or stimulating effects, but represents rather an infiltration of energy that underpins the self-regulation processes.

The nondoping nature of lasers was proven through special experimental research, which included the comparison between the efficiency of the signal (selectively) measured by operators of the experimental (exposed beforehand to laser treatment) and control (placebo) groups. They were made to operate in three modes: under no tension, under a certain tension, and with time limitations. In the first mode there were no tangible discrepancies in the groups' performance, but in the second and especially in the third (stress) mode, the performance of the operators who were subjected to laser treatment was considerably better (Karpoukhina 2005). It seems that when working under no stress, the operators had sufficient initial energy and did not need any power "additive" to boost them up; however, while operating in the modes of tension, the power "boost" the operators from the experimental group have enjoyed allowed them to considerably exceed the results achieved by their counterparts from the control group. Significantly, no negative effects were ascertained in any of the multiple experimental series.

The major advantages of laser-based acupuncture used to improve human PPS include the absence of painful sensations and undesirable side effects, the possibility of using cumulative effect, the minimal time required by the treatment, and the preparation procedure, which increases the rate of treatment (up to 60 persons per hour), automation, possibility of combining diagnostics, and optimization.

14.3 Experimental Research on the Optimization of the Operators' PPS Using Laser-Based Acupuncture

The objective of these experiments was to research the possibility of applying laser-based acupuncture for optimizing operators' PPS in the process of their training with a vehicle simulator. The experiment was performed by a group of scientists from the Laboratory of Psychophysiology, Institute of Psychology and Institute of Labour and Professional Diseases (Kiev, Ukraine). The scientific supervisor was A. M. Karpoukhina. Two series of experiments, varying in their structure, were conducted to achieve the established objective: to determine the extent to which laser-based acupuncture influenced the simulator training process of operator. To achieve this objective, the following goals had to be met:

- Study the dynamics of the operator's efficiency, when working with the vehicle simulator under the influence of laser-based acupuncture.
- Study the influence of laser-based acupuncture on the operator's PPS during simulator training, based on the indexes of various FSs of the body, which reflect the hierarchical levels of integral PPS.

The participants were 19- to 21-year–old males, without previous driving skills, who were divided into two groups, each including 14 persons: the experimental group (subjected to laser-based acupuncture) and the control group (with a simulated treatment). The simulated treatment was conducted keeping in place all the exterior attributes of a regular procedure: conducting light to the BAP by light-carrying fibers, fixing the time of influencing each BAP with a stopwatch, and so on. As there are no painful, tactile, or temperature sensations while applying the low-intensity laser beam on the skin surface, the test subjects could not differentiate between the modes, either real or simulated, that they had been working in.

The experiment had five series (including the standard training session), during which the subjects covered 30 kilometers of road shaped in a particular configuration. They were instructed to go at maximum speed, but at the same time try to minimize cases of running into the restrictive lines. Their efficiency was measured by the speed of movement through the route and the number of errors they made (cases of running on the restrictive lines and driving glitches were registered automatically).

The dynamics of achieving the experiment's objective was traced by breaking down the 30-kilometer stretch into six 5-kilometer portions and fixing the performance rates at each of them. This allowed us to represent the obtained experiment data as learning curves with the x-axis representing the duration of learning process, expressed by the ordinal number of task (N) that was assigned, and the y-axis representing the performance efficiency, expressed by the time the subject took to cover the route (t) (Figure 14.1) and the number of errors he or she committed when doing so (n) (Figure 14.2).

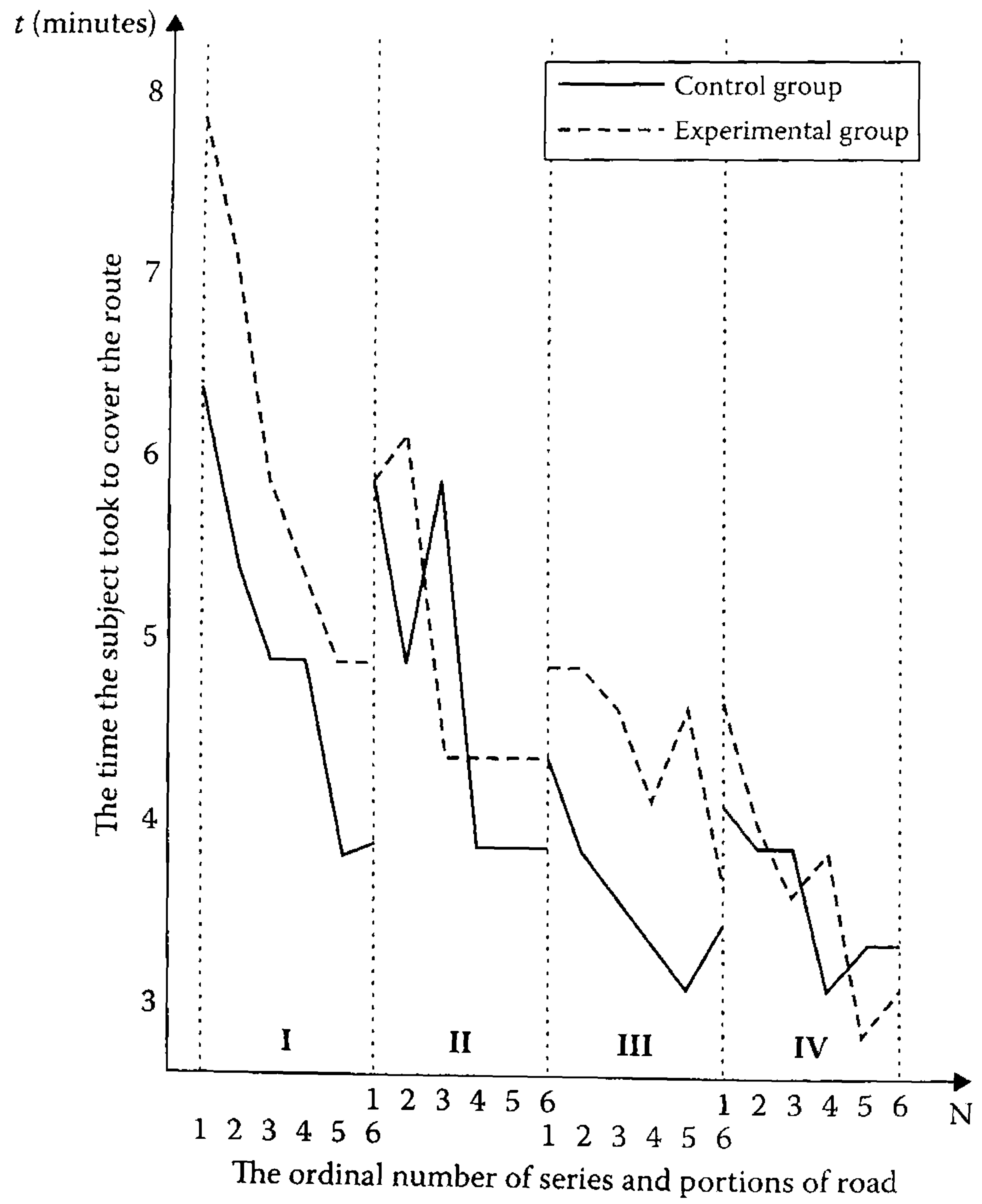

FIGURE 14.1
Influence of laser-based acupuncture optimizing the PPS of the operators on their performance efficiency (by the time the subject took to cover the route, t).

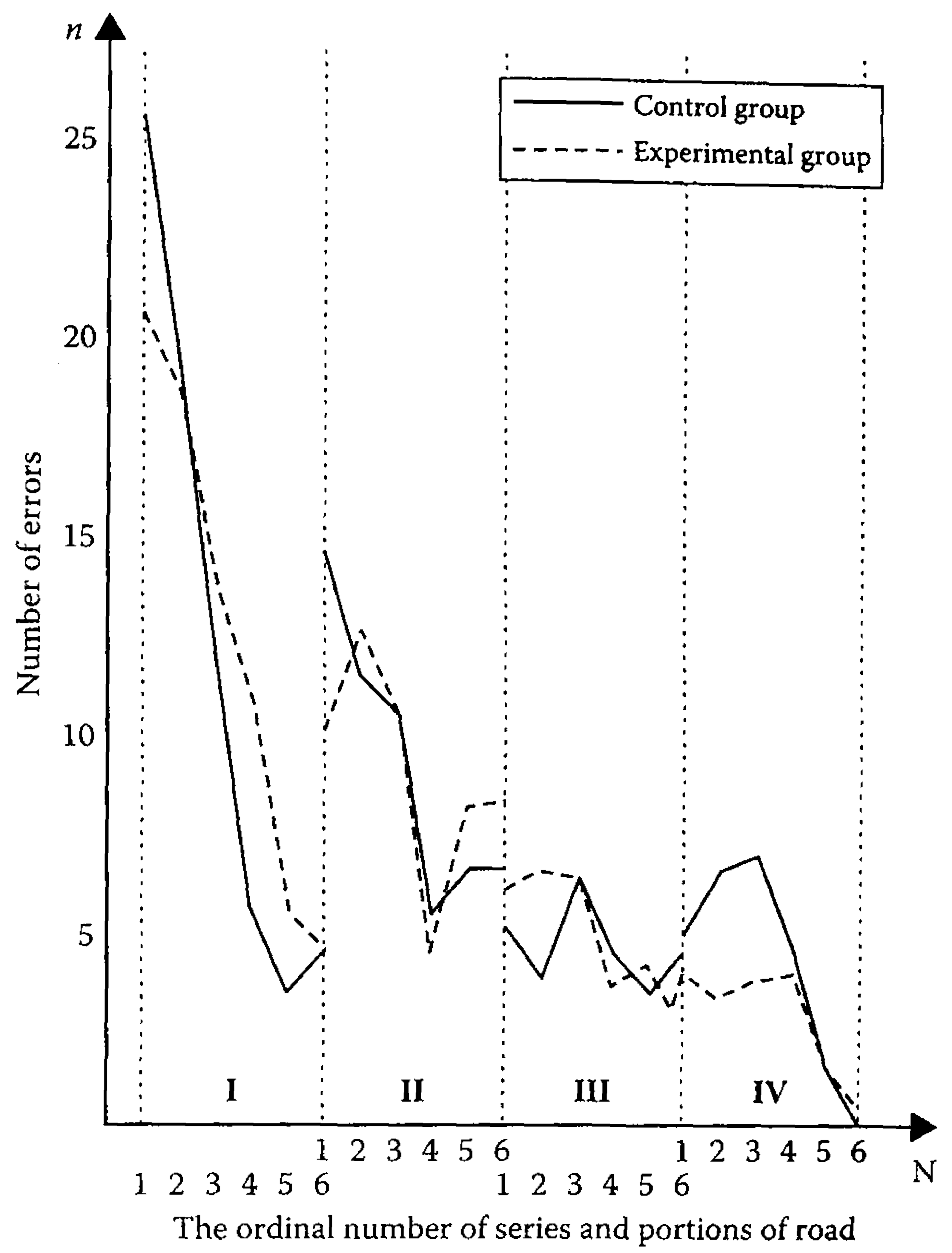

FIGURE 14.2
Influence of laser-based acupuncture optimizing the PPS of the operators on their performance efficiency (by the number of errors, *n*).

While working with the simulator, the optimization of operators' PPS under the influence of laser-based acupuncture was estimated by a number of dynamic parameters, characterizing their body FSs:

- Central nervous system (simple sensor–motor reaction and the mobility of nervous processes by method of A. E. Khilchenko (1960); ability of nervous processes by the method of "critical frequency of light glimpses")
- Cardiovascular system (systolic, diastolic, and pulse blood pressure; heartbeat frequency; rate of cardiovascular system's endurance; cardiovascular integral Shiposh index)
- General health, activity, and mood parameters (by subjective scaled evaluation)
- Reactive anxiety index (Spielberger method)

Quantitative and qualitative comparison of the value and direction, characterizing the psychophysiological shifts in the background and post-stimulation measurements, was made before and after work with the vehicle simulator.

Laser-based acupuncture was performed for 3 days using an LG-12 helium-neon laser with a wavelength of 0.6328 μm and PC86 pliant light-carrying dissector fibers for 10 BAPs placed at the fingertips. Here, the BAP formula was in conformity with the approved international classification (Tabeeva 1994; Luvsan 1986). The exposure time per each BAP was 15 seconds, and the total exposure time was 2.5 minutes. The analysis of the learning curves highlights some specifics of the dynamics of this process.

First, it is evident that the accumulation of information in the course of the learning and training process is accompanied by changes occurring in the (information, algorithmic, graphic) structure of activity. This can be observed from the decrease in the time spent on an individual task, enhanced reliability, or lesser rates of power inputs (a decrease in emotional excitement—the psychophysiological "price associated with the operation") to perform an activity.

Second, the performance improved stepwise. The increase in the efficiency of the operators who were trained at the simulator during one series took place predominantly at the initial stage of this process. The improvement in the operator's efficiency has not occurred over one series but rather from one series to another. Before beginning a new experimental series, the psychological system of the test subject was at a new, higher organizational level as compared to the preceding series. Usually, the achieved level was maintained while performing the new task, and the freshly acquired information was implemented in the next series.

Third, the operator's simulator training was characterized by certain spells of relatively stable levels in terms of efficiency. Each new level was reached by leaps, which makes the graph look more like a staircase. The quantitative characteristic of this process, based on the total data for each temporary period, is represented in Figure 14.3. It is apparent that with the time of the learning process approaching infinity, the efficiency increases step by step (with each step, the efficiency increments become smaller, and the time the efficiency takes to increase gets longer).

When comparing the learning curves built by the fractional exponents of performance efficiency for the control and experimental groups, the similarity in the training processes should be highlighted. The absolute values of the activity's success, both in terms of time and the number of committed errors, do not warrant the conclusion that the subjects from the experimental group have an edge. However, the relative values, that is, the increments of efficiency against the background of the first series' results, speak in favor of the subjects from the experimental group. This can be seen from Figure 14.4, where the x-axis is the learning time and the y-axis is the mean value of the efficiency for each series taken separately (Δt and Δn).

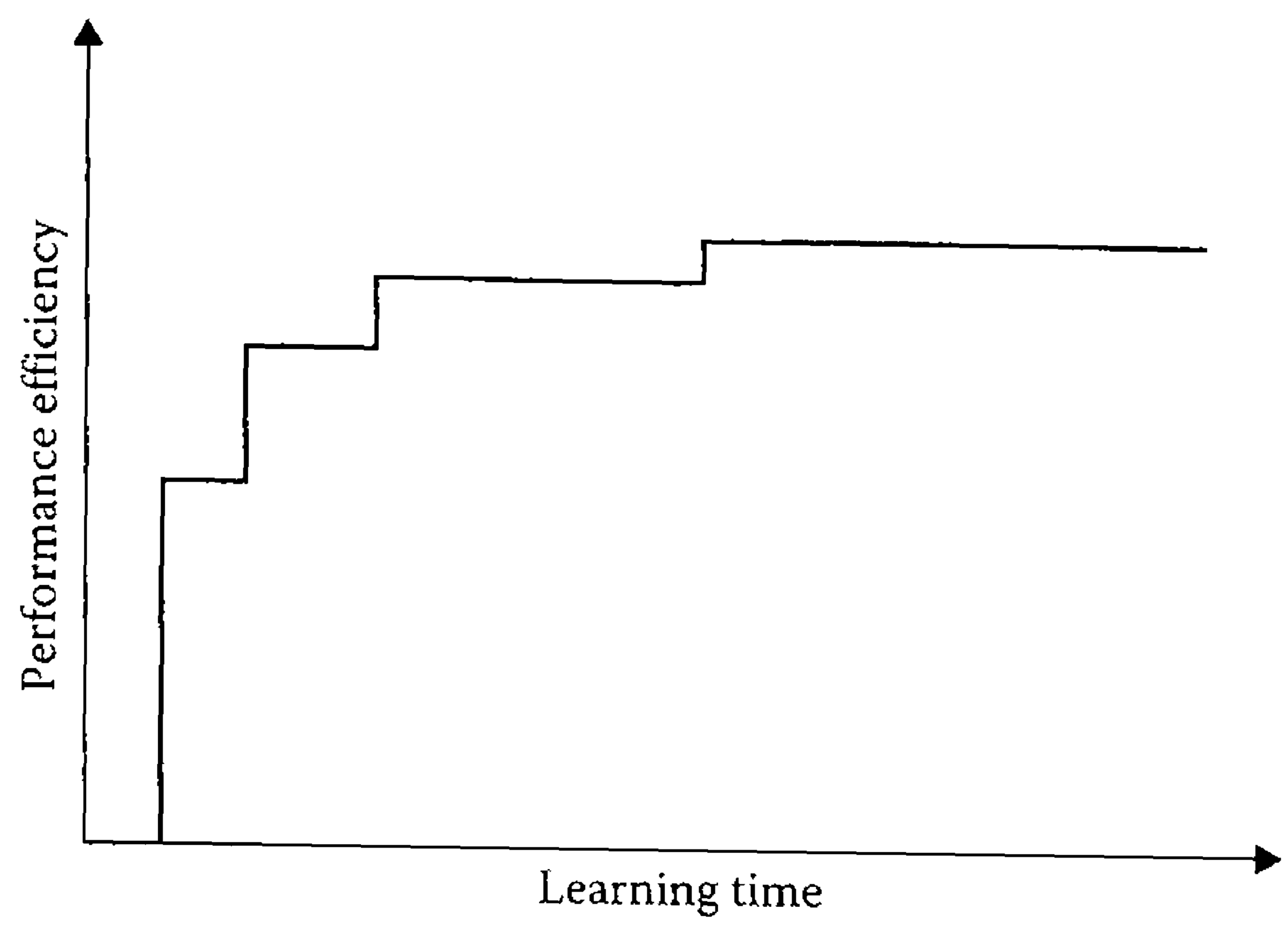

FIGURE 14.3
Features of dynamics performance efficiency during the process of simulator training (in standard units by the average results to cover the portions of road).

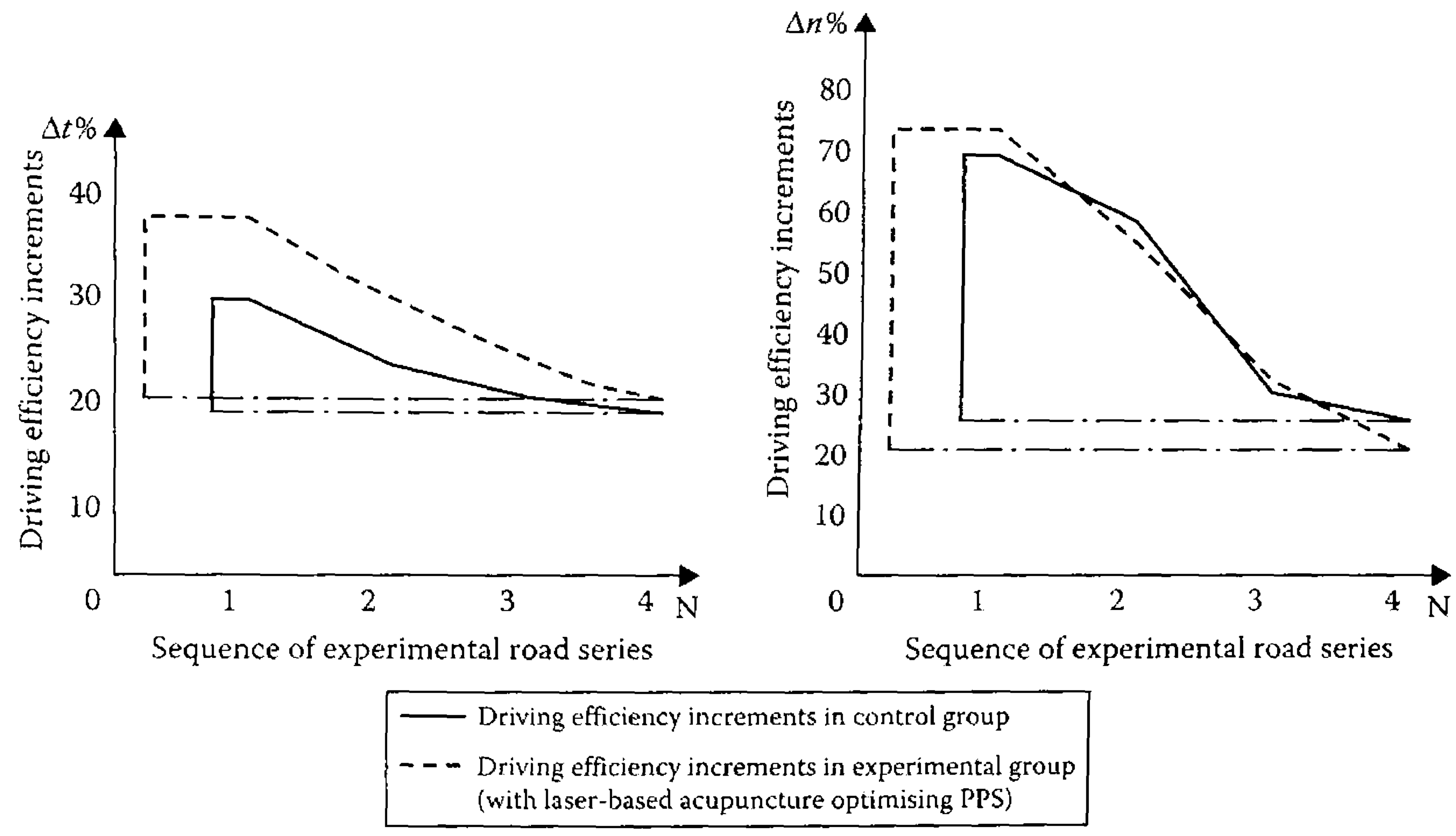

FIGURE 14.4
Comparative estimation of the driving efficiency increments during the process of simulator training in groups with laser-based acupuncture optimizing the PPS and in the control group of the operators.

The analysis of dynamics inherent to the psychophysiological indexes changing under the influence of laser-based acupuncture (in experimental group) and its simulation (for control group) in the process of vehicle simulator training revealed the changes in the principal (registered by us) FSs of the operators' bodies, reflecting various hierarchical levels of integral PPS. The tensity of these systems can be correlated with the efficiency at different stages of the learning process. In the initial stage of training, the subjects showed low efficiency and psychophysiological indexes as registered by objective research methods and demonstrated considerable tension in the functioning of different operators' body systems (central nervous system, cardiovascular systems, etc.).

In the subsequent stage of training, as the subjects accumulated driving skills, the emotional tension (the price of the activity) decreased in both groups, but in the experimental group (against the background of laser-based acupuncture), the changes observed in the psychophysiological parameters were more pronounced and positive. By the end of the 3-day treatment (or its simulation) course, both groups demonstrated increases in the efficiency and decreases in the tension of human body systems, that is, a decrease in the price of the activity. However, in the control group, after work with the simulator as opposed to the background (before work), the psychophysiological indexes either decreased (i.e., got worse) or remained unchanged. In the experimental group, the same indexes either remained at the level of the background quantitative values or improved, even though insignificantly, by 1.5–5%.

Therefore, by experimental research, we revealed a positive effect of laser-based acupuncture treatment on the operators' simulator training process. We made objective records of the changes in the indexes, and their qualitative and quantitative analyses provide the evidence of the operators' integral PPS optimization under the laser-based acupuncture treatment, which eventually resulted in the better performance they demonstrated during the vehicle simulator training. The mean positive changes of the psychophysiological indexes in the experimental group were not so impressive (1.5–5%), probably due to the minimal time (15 seconds) BAP PC86 was exposed to the effecting factor. In further studies, we plan to test for other temporal parameters of laser-based acupuncture treatment to reveal the most suitable modes of impacting BAP PC86, which will ensure attaining a sufficiently higher effect of laser-based acupuncture.

The objective of the second series of experiments was to look into the possibility of improving the operators' driving skills by laser-based acupuncture. REG was used to evaluate the effects, and we also evaluated muscular efficiency. The operators were trained 1 hour per day for 2 days. The high intensity of work was achieved by issuing them 15 orders per minute. The success of the training was controlled by the dynamics of the operators' performance at the simulator. To measure the extent of the laser-based acupuncture treatment, the experimental group (consisting of nine subjects) underwent BAP stimulation before and during their work with the simulator on the second training day. The second group (eight subjects) underwent the simulated treatment.

Laser-based acupuncture was performed by using the following BAP formulas and exposure times:

- Before working with the simulator:
  PC86: 15 seconds per each of 10 BAPs
  TR17 (symmetrical): 10 seconds per BAP

GI4 (symmetrical): 10 seconds per BAP
AP34 (symmetrical): 15 seconds per BAP
AP83 (symmetrical): 15 seconds per BAP

- In the process of working with the simulator (in this case, the flexible light guides were fixed by cuffs to the shin's BAPs):
  GI3 (symmetrical)
  E36 (symmetrical)

The REG research included the following:

- Study of the influence of the loads on the operators' REG indexes in the process of vehicle simulator training
- Study of the interconnection between the training efficiency indexes and cerebral blood circulation parameters
- Research on the possibility of laser-based acupuncture to produce regulatory impact on the cerebral blood circulation to improve the operators' PPS in the process of their simulator training

The REG method was chosen because of the rather high sensitivity of cerebral blood circulation parameters to the changes in the functional state of humans (Nersesian 1992; Fedorov, et al. 1989). REG is recorded by rheoplethysmograph in the (left) frontomastoidal abduction, which made it possible to study the cerebral blood circulation in the internal carotid artery basin.

The following REG parameters were analyzed:

- Rheographic index (I), which reflects the level of blood in the vessels of the studied brain portion
- Minute rheographic index (I_m), which reflects the blood supply to the studied brain portion
- Dicrotic impulse (DCI), which reflects the tone of small arteries and arterioles and determines the peripheric resistance to the blood flow
- Diastolic index (DSI), which reflects the tone of veins and is the parameter for blood outflow
- Relative time for maximum blood filling of the vessels (α/T), that is, the tone parameter for average and big arteries
- Relative duration of the diastolic period ($T - \alpha/T$)

The results, obtained by research, showed that the work with the simulator on the first day of training provoked an increase in the peripheral resistance. Changes in the vein tone in different groups were insignificant and divergent. A minor (invalid) reduction in the main artery tone was observed. Changes in the pulse blood level and blood supply indexes were divergent: in the control group, I_m increased, and in experimental group, it decreased (Figures 14.4 and 14.5).

On the second day of training with the simulator, the subjects showed an increased peripheric resistance and vein tone. Valid increases of DCI ($p \leq .01$) and DSI ($p \leq .05$) were observed only in the control group. These changes, indicating the augmentation of psychic tension, were more pronounced on the second day of training as opposed to the first day. The lack of valid DCI and DSI changes in the experimental group is evidence of the lesser level of

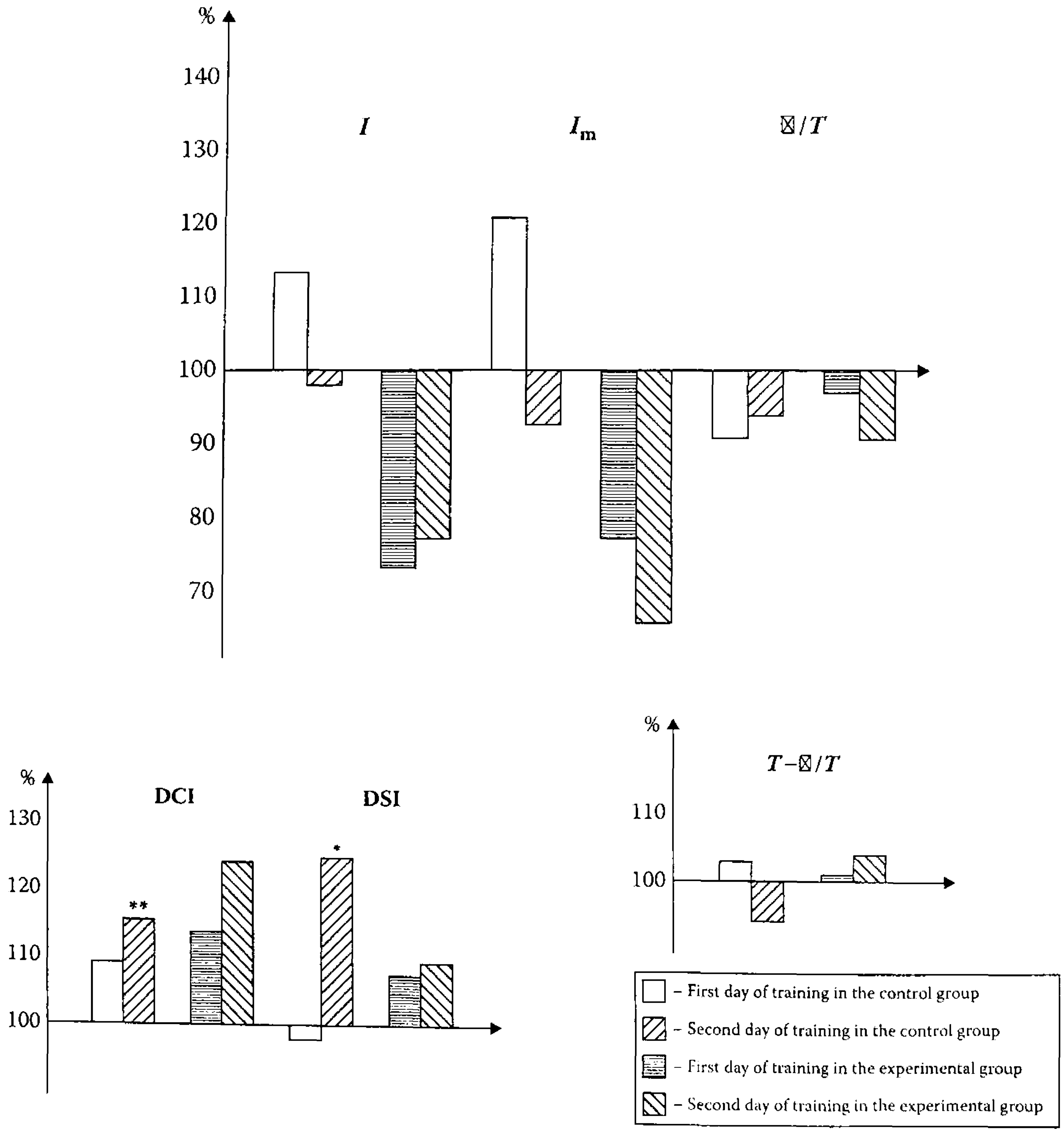

FIGURE 14.5
Influence of simulator training on cerebral blood circulation indexes (according to rheoencephalography data). Comparative assessment of indexes in groups with laser-based acupuncture optimizing the PPS and in the control group of the operators. The group's mean values at repose (before training session) are taken to be equal to 100%. * means $p \leq 0.05$; ** means $p \leq 0.01$.

psychic tension in this group as opposed to the control group on the second day of training (this coincided with the laser-based acupuncture treatment).

We have conducted a correlation analysis to determine the interrelation between the indexes of cerebral blood flow and performance parameters while working with the simulator (number of errors, number of kerb touches, duration of touches, number of emergency brakings, speed of emergency braking). The analysis showed no relationship between the REG indexes at rest (before operation) and the efficiency of training at its beginning, that is, on the first day. On the contrary, the after-operation REG indexes correlated with some efficiency indexes. The most constant was the negative correlation between the number of errors and number of touches on the one hand and peripheric resistance and the state of blood outflow (DCI and DSI) on the other. In total, we have observed four significantly valid correlations between the REG indexes and the efficiency of working at the simulator for groups on the first training day (Table 14.1).

On the second training day, two significant correlation links, between the efficiency of working at the simulator and pretest cerebral blood circulation indexes, were observed (in each of the groups), and there were three significant links between the efficiency and after-test REG indexes.

The obtained results lead to the following conclusions:

- The operators' activity, related to the simulator training, are accompanied by distinct changes in cerebral blood circulation.
- There is a link between the cerebral blood circulation indexes and the efficiency of such activity; the highest dependency (in terms of significant correlation rates) can be observed at the initial stage of training.
- The correlation links between the efficiency of working at the simulator and pretest indexes of cerebral blood circulation at the second training stage are an indication of the mobilization processes; that is, the body's setting up for a future activity.
- The decrease in the number of significant correlation links between the after-test cerebral blood circulation indexes and the efficiency of working with the simulator on the second day, as opposed to the first one, reflects the decrease in the dependency of successful activity on physiological supply and indirectly indicates the depreciation of the price of the activity over the training process.
- Indexes of peripheral resistance and outflow can be used as correlators of psychic tension over the period of simulator training.

The analysis of efficiency in the activity related to learning the skills of driving the simulator vehicle shows a slightly better performance in the experimental group: the trainees there had more emergency braking, drove

TABLE 14.1

Correlation Links between Operators' Simulator Training Efficiency Indexes and Rheoencephalography Indexes

Training Efficiency Indexes	Group	Rheoencephalography Indexes											
		I				DCI				DSI			
		First Day		Second Day		First Day		Second Day		First Day		Second Day	
		Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work
Number of emergency brakings	Exper.	–	–	–	–	–	–	–	–	–	–	–	–
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–
Number of errors	Exper.	–	–	–	–	–	–	–	–	–	–	–	–
	Contr.	–	–	–	–	–	−0.77	–	−0.72	–	−0.79	–	–
Speed at emergency brakings	Exper.	–	–	–	–	–	–	–	–	–	–	–	0.69
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–
Time of scratches	Exper.	–	−0.71	–	–	–	–	–	–	–	–	–	–
	Contr.	–	–	–	–	–	–	–	–	–	−0.73	–	–
Number of scratches	Exper.	–	–	–	–	–	−0.71	–	–	–	−0.76	–	0.69
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–

Training Efficiency Indexes	Group	*Im*				*α/T*				*T − α/T*			
		First Day		Second Day		First Day		Second Day		First Day		Second Day	
		Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work
Number of emergency brakings	Exper.	–	–	–	–	–	–	–	–	–	–	–	–
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–
Number of errors	Exper.	–	–	–	–	–	–	–	–	–	–	–	–
	Contr.	–	–	–	0.77	–	–	−0.74	–	–	–	–	−0.74
Speed at emergency brakings	Exper.	–	–	–	–	–	–	–	−0.72	–	–	–	−0.72
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–
Time of scratches	Exper.	–	–	–	0.73	–	−0.69	–	–	–	−0.69	–	–
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–
Number of scratches	Exper.	–	–	–	–	–	–	–	–	–	–	–	–
	Contr.	–	–	–	–	–	–	–	–	–	–	–	–

at better speed, committed less errors, and had a significant decrease in curb scratches ($p \leq .01$). The control group had opposite changes: it showed reduction in the rate of training.

This study allows us to draw a conclusion that laser-based acupuncture produces a regulating effect on cerebral blood circulation, which contributes to the optimization of the operators' PPS and, as a consequence, promotes better performance in the simulator training.

The principal indexes of muscular efficiency were the following:

- Experimental study of the operators' muscular efficiency dynamics in the process of 2-day simulator training
- Research on possibility of optimizing the operators' muscular performance in the process of simulator training by applying the laser-based acupuncture
- Comparative evaluation of the operators' muscular efficiency in the process of simulator training between the real and simulated laserpuncture

The research focused on the following indexes of muscular efficiency, which are most critical for the operators' simulator training:

- Coordination of hand movement (by using a Rupp device)
- Statistic muscle endurance (according to V. V. Rozenblat, 1971) by using a manometric dynamometer
- Maximum muscle strength by using a hand-operated spring dynamometer

The static endurance and muscle strength indexes of the test subjects in the experimental (nine persons) and control groups (nine persons) have been registered in the course of 2-day daily training sessions before the session, in the process of training session (30 minutes after driving lessons), and within an hour after the session. The state of hand movement coordination was studied daily before and after working with the simulator.

The analysis focused on the dynamics of results on the first and second days of training. We also performed a comparative analysis with the first day of training, the results of which were taken as the background data, and the second training day after laser-based acupuncture or its simulation. On the first day, the discrepancy between the groups was insignificant. The laser acupuncture or its simulation was carried out only on the second day. Therefore, the intergroup fluctuations of the first training day can be explained by the differences between its participants selected on a random basis.

The analysis of results obtained on the first training day revealed a tendency of all studied indexes in both groups to gradually worsen by the end of the day. For example, the static muscle endurance in the experimental group deteriorated after 30 minutes of training by 28.4% ($p \leq .01$) and by 24.6% ($p \leq .01$) after 60 minutes. In the control group, this index decreased by 34.8% ($p \leq .01$) and 52.1% ($p \leq .01$), respectively. The maximum muscle strength in the experimental group after 30 minutes of driving lessons was 7.9% worse than before, and after 60 minutes, deteriorated by 8.7%. In the control group, the changes also worsened by decreasing correspondingly by 9.5% ($p \leq .05$) in both measurements.

Since the test conditions made it possible to register the hand movement coordination only before the training sessions and after 1-hour work with the simulator, we could establish its downturn at the end of the test in the experimental group by 13.7% ($p \leq .05$) and by 3.4% in the control group. Such unidirectional change of indexes toward their lessening by the end of the test on the first day was caused by the rapidly encroaching weariness induced by activity that was novel for test subjects.

Table 14.2 represents the mean group dynamics of studied indexes (in percentage) over the 2-day training period 30 and 60 minutes after driving the simulator, as opposed to the same indexes registered before the training sessions. Since the operators, while working with the simulators, were subject to static rather than dynamic stress to maintain their posture over a

TABLE 14.2

Dynamics of Changes in Group Mean Values Applicable to Static Muscle Endurance, Hand Movement Coordination, and Muscle Strength in the Process of Operators' 2-Day Simulator Training in Laser-Based Acupuncture and Simulated Laser-Based Acupuncture

Values	First Day			Second Day		
	Before Work	**After 30 Min**	**After 60 Min**	**Before Work**	**After 30 Min**	**After 60 Min**
Experimental Group						
Static muscle endurance	100%	71.6% ($p \leq .01$)	75.4% ($p \leq .01$)	100%	108.3%*	130.1% ($p \leq .01$)
Hand movement coordination	100%		86.3% ($p \leq .05$)	100%		95.6%
Muscle strength	100%	92.1%	91.3%	100%	110.9%*	97.7%
Control Group						
Static muscle endurance	100%	65.2% ($p \leq .01$)	47.9% ($p \leq .01$)	100%	67.3%** ($p \leq .01$)	55.6% ($p \leq .001$)
Hand movement coordination	100%		97.56%	100%		98.8%
Muscle strength	100%	90.5% ($p \leq .05$)	90.5% ($p \leq .05$)	100%	94.9%**	88.2% ($p \leq .05$)

Notes: *Laser-based acupuncture influence.
**Simulated laser-based acupuncture influence.

long time, this was accompanied by increased fatigue. The index of static muscle endurance, to control the operator's physical performance, was the most informative, and consequently, its dynamics over the process of training were the most significant.

While analyzing the results obtained over the second day of simulator training, we discovered that the static muscle endurance in the experimental group 30 minutes after the start of the session improved by 8.3%, and after 60 minutes by 30.1% ($p \leq .01$) as opposed to before-the-session indexes. At the same time, in the control group, as observed on the first day, the static endurance gradually decreased by 32.7% after 30 minutes of operation ($p \leq .01$) and by 44.4% after 60 minutes ($p \leq .001$).

This opposite trend of the changes in the groups was caused by performing laser-based acupuncture in the experimental group and simulated laser-based acupuncture in the control group prior to simulator training on the second day. The higher static endurance in the experimental group after laser-based acupuncture reveals its beneficial impact on muscle performance in the process of simulator training.

These results are corroborated also by the maximum muscle strength of the subjects in the experimental group, which increased on the second training day by 10.9% after 30 minutes of operation, as compared with the indexes taken before the simulator training and receding gradually after 60 minutes of operation down to the initial level. In the control group, muscle strength was smoothly deteriorating: after 30 minutes by 5.1% and after an hour by 11.8% ($p \leq .05$). However, the hand movement coordination of the tests subjects in both groups on the second day of simulator training fluctuated very little as opposed to the initial data. Due to the lack of maximum physical exertions that the subjects would experience while working at the simulator, resulting in a pronounced physical exhaustion, no significant changes in the hand movement coordination indexes have been revealed. Nor, as a consequence, were any significant effects of laser-based acupuncture discovered.

A comparative analysis of the test subjects' results in both groups between the first and the second training days, represented as group means (%) in Table 14.3, showed no considerable difference between the indexes of static endurance and maximum muscle strength registered before the simulator training both in the experimental and control groups on the second day as opposed to the first day because these indexes on both days were registered before laser-based acupuncture or its simulation.

The most pronounced, though, were the changes in hand movement coordination: the experimental group demonstrated a 5.2% progress and the control group showed a 12.6% progress. This can be explained by the learning curve gradually going up as the subjects had to perform the same training routine repetitively. The comparison of this index between the first and second days of training showed that on the second day both groups did better when compared to the first day: in the experimental group, this change was statistically significant ($p \leq .05$) by 16.4%, and in the control group by 14.1%.

TABLE 14.3

Comparative Assessment of Changes Occurring in Group Mean Indexes to Static Muscle Endurance, Hand Movement Coordination, and Muscle Strength of the Operators between the First and the Second Training Days

Values	Experimental Group			Control Group		
	Before Work	**After 30 Min***	**After 60 Min**	**Before Work**	**After 30 Min****	**After 60 Min**
Static muscle endurance	103%	156.9% ($p \leq .01$)	178.1% ($p \leq .001$)	101%	102.3%	109.9%
Hand movement coordination	105.2%		116.4% ($p \leq .05$)	112.6%		114.1%
Muscle strength	95.6%	115.2%	102.4%	94.5%	89.8%	92.2%

Notes: *Laser-based acupuncture influence.
**Simulated laser-based acupuncture influence.

Further comparison of static endurance and muscle strength indexes between the first and the second training days demonstrated the unilateral direction of changes for the better in the experimental group on the second day as compared to the first day. The statistic endurance registered 30 minutes after working at the simulator on the second day was statistically significant ($p \leq .01$), up by 56.9% as compared to the first day. In 60 minutes, the results increased by 78.1% ($p \leq .001$). The muscle strength on the second training day in experimental group increased correspondingly by 15.2% and 2.4% as opposed to the first day. Consequently, laser-based acupuncture in the experimental group on the second training day produced a positive effect on the studied indexes.

The same data registered in the control group showed that the muscle strength on the second training day both in 30 and 60 minutes of simulator training decreased as opposed to the first day and equaled 11.2% and 7.8%, respectively. However, the static muscle endurance of test subjects from the control group on the second training day, after 30 minutes of simulator training, was the same as on the first day and augmented by 9.9% after 60 minutes of operation. This can be explained by the fact that as the test subjects acquired driving skills in the process of training, static stress was gradually relieved, resulting in a better static endurance index. On the other hand, the operators in the experimental group had significantly higher results after laser-based acupuncture as opposed to the control group operators who underwent only simulated treatment.

Based on the obtained results, we can draw the conclusion that the laser-based acupuncture, by targeting the above BAPs, contributes to and hampers the development of physical exertion. Application of laser-based acupuncture in the process of the operators' simulator training promotes the growth of their static endurance, increases muscle strength, and regulates hand movement coordination. Treating BAPs with laser acupuncture in the process of simulator training contributed to optimization of muscle performance if the subjects showed pronounced physical tiredness at the end of the training session or improvement of static stress if they had to preserve the same posture over long periods of time. If the tiredness was less evident, the impact of laser-based acupuncture on muscle performance was not assimilated and its effect was weak. Therefore, we can conclude that laser-based acupuncture optimizes the operators' PPS in the course of vehicle simulator training by means of improving their muscle performance.

14.4 Conclusion

The studies we have conducted were convincing in showing a rather high efficiency of laser-based acupuncture in optimizing the operators' PPS. We have identified a pronounced positive impact of laser acupuncture on the progress of the operators' simulator training, which was registered by us in an objective manner. Studying diagnostic indexes by quantitative and qualitative analyses shows the optimization of the operators' integral PPS. In particular, we have established that the laser-based acupuncture produced a regulating effect on the state of the operators' cerebral blood flow, improved their static muscle endurance, enhanced their muscle strength, and exercised a regulating influence on hand movement coordination.

Positive shifts in the indexes of psychophysiological provisions of activity systems under the controlling effect of laser-based acupuncture were accompanied by improvements in the operators' training indexes. It enables us to reach a conclusion on the ergonomic significance of laser-based acupuncture in PPS regulation. The interrelation and interaction of two FSs PPS and activity can be construed from the perspective of systematic approach and FS theory as interrelations between hierarchical sub- and supersystems. The results of the system activity are conceived by the PPS system as a component of afferent synthesis block, which, along with other components such as the information on external conditions and initial background PPS, form motivation and participate in making a decision as to what the future result should be; that is, they provide for the "psychophysiological provision of activity" and vice versa. The result of the PPS FS enters as a component into the result-achieving block of activity supersystem.

Further studies will focus on building a single comprehensive method that will make it possible to carry out operators' PPS assessment using BAP diagnostic biophysical indexes in real time and, based on this assessment, perform laser-based acupuncture optimization of their PPS, which will eventually lead to improvement of their performance and efficiency ratios.

References

Anokhin, P. K. 1978. *Contribution to the General Theory of Functional Systems*. Jena, Germany: G. Fischer.

Bedny, G., and D. Mester. 1997. *The Russian Theory of Activity: Current Application to Design and Learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bedny, G., and W. Karwowski. 2007. *A Systemic—Structural Theory of Activity: Application to Human Performance and Work Design*. Boca Raton, FL: Taylor & Francis.

Bedny, G., S. Seglin, and D. Mester. 2000. Activity theory: History, research and application. *Theor Issues Ergon Sci* 1(2):168–206.

Fedorov, Б. M., T. I. Sebekina, and E. N. Streltsova. 1989. Cerebral blood circulation during intense mental work. *Hum Physiol* 15(2):48–55 (in Russian).

Karpoukhina, A. M. 1985. *Control and Regulation of Men Psychophysiological State As Method of Increasing Human Productivity*. Kiev: Knowledge Publishers.

Karpoukhina, A. M. 1990. *Psychological Method of Increasing Efficiency of Work Activity*. Kiev: Knowledge Publishers.

Karpoukhina, A. M. 2005. Optimization of relations between man and computer via regulation of the operator's psychophysiologic state. *Relevant Issues Psychol* 5(4):64–7.

Karpoukhina, A. M., and J. One-Jang. 2003. Systems approach to psycho-physiological evaluation and regulation of the human state during Performance. In *Proceedings of the XVth Triennial Congress of the International Ergonomics Association and The 7th Joint Conference of Ergonomics Society of Korea*, 451–54. Seoul: Japan Ergonomics Society.

Khilchenko, A. E. 1960. The mobility of nervous processes: Some research results. *Physiological Journal* 6(1):21–28 (in Russian).

Kokun, O. M. 2004. *Optimization of Man's Adaptative Capacities: Psychophysiologic Aspect of Activity Backup*. Kiev: Millenium.

Kokun, O. M. 2006. *Psychophysiology*. Kiev: Center of Educational Literature.

Luvsan, G. 1986. *Traditional and Modern Aspects of Eastern Reflexotherapy*. Moscow (in Russian): Nauka.

Nersesian, L. S. 1992. *Psychological Aspects of Enhancing Reliability in Controlling Moving Objects*. Moscow: Promedek, Nauka.

Rozenblat, V. V. 1971. *Principles of Physiological Evaluation of Hard Labor and Establishing Time Standards Based on Pulse Measurement Procedures (Methodical Recommendations)*. Sverdlovsk, Russia: Sverdlovski Research Institute of Hygiene.

Rusakov, D. A. 1988. *Comparative Study of Spinal Neurons' Functional and Structural Parameters in Normal State and After Radiation with Low-Intensity Laser*. Unpublished PhD's thesis. Kiev: Institute of Physiology AS of Ukraine.

Skulachev, V. P. 1969. *Accumulation of Energy with in a Cell*. Moscow: Nauka.

Skulachev, V. P. 1972. *Transformation of Energy in Bio-Membranes*. Moscow: Nauka.

Tabeeva, D. M. 1994. *Acupuncture*. Moscow (in Russian): Medicine.

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