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REACTION PARAMETER AND MODIFIED SENSORIMOTOR REACTION METHOD FOR ASSESSMENT OF FUNCTIONAL POTENTIAL OF NERVOUS SYSTEM

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Abstract. The article deals with the evaluation of sensorimotor responses with a view to professional selection. For a comprehensive assessment of functional potential of the nervous system we proposed the integral reaction parameter and modified method for determining of sensorimotor reaction time, which uses additional stress factors. Our study of the experimental group of athletes and the reference group of respondents shows that the difference between the result of standard and modified methods may be a criterion for human stress tolerance simultaneously evaluating the functionality of neuromotor system.

Keywords: Sensorimotor reaction; Psychophysiological testing; Sensorimotor integration; Reaction parameter; Stress tolerance; Professional selection.

Introduction. Sensorimotor reaction (SR) time is an importanf factor in different psycho-physiokogical examinations and research. It is used as: a) the psycho-physiological variable dependent on external impacts; b) the unit for determining individual differences in man or for assesment of functional state; c) the mean to analyze cognitive processes of man [1]. This information finds application in ergonomics, aerospace and underwater medicine, the physiology of work and sport, differential psychophysiology, and higher nervous activity investigations [2], medical diagnostics and professional selection. Selection is required if some kind of professional activity is related to the rapid perception and processing of large amount of external information, as well as the response to it. Therefore, the quality of such job performance (and usually general system safety and personal security of employee) depends on individual phycho-motor characteristics. Sensorimotor reaction time indexes may be a selection criterion for such positions as a driver, pilot, machinist, operator of complex technical devices and systems, dispatcher, police officer, Special Forces soldier, worker in extreme consitions and other.

Reaction time (or latent period of sensorimotor response) is determined by the duration of physical and chemical processes in the receptor, nerve impulse transmission throught pathways, analytical and synthetic activity of brain structures and muscle triggering. Accuracy (i.e. correctness) of SR describes the efficiency of cognitive signal differentiation process and motor response options. Time and accuracy SR indexes are relatively constant properties of man over limited segments of ontogenesis [3]. SR methods study the spatial and temporal coordination characteristics of psychomotor organization of human and changes of SR indexes are associated with the state of central structures of nervous system [3]. Mathematical description of the distribution of individual values of RS was obtained in [4].

Cognitive and motor acts operate in sensorimotor integration (SMI) – harmonization and unification of sensory and motor processes on different levels of the nervous system that mainly contains convergence of neuronal impulses of the sensor system structures and centers motor system [3, 5]. It is known that reducing intervals between stimuli increases the rate of SR by maintaining an optimal level of SMI [5], while [6] shows the topological and functional dependency of sensorimotor reactions of multilateral and bilateral body parts.

Effectiveness of SR is an informative indicator of the functional state of the central nervous system, which enables its control, prediction and correction. RT indexes are used for assessment of the functional state in children [7], help to predict memory failures, cognitive and motor disabilities in older adults [8] and other diseases [9] that is especially important for drivers [10]. SR is also widely used for assessing the functional state of CNS in healthy people because the reaction speed is proportionate to locomotor activity of man [3].

The diagnostics of CNS functional state using RT should be performed taking into account factors related of person activity approaching the real conditions and accordingly to significant signal modulation [11] as far as RT depends on emotional stress [3]. Such diagnistics includes playing typical conditions of professional activity during testing. It is important, for ezample, in sport training that requires correct evaluation of RT according to the tipe of sport activity [12]. That is why the need for improved methods of SR measurement exists [13].

The goal of this article is to develop parameter that assesses SR and indicates the level of sensorimotor integration of respondent’s nervous system for the purposes of professional and sport selection. The components of a task are elaborating modified method of SR testing and SR study in experimental group of athletes.

Materials and Methods. To assess the impact of additional external conditions on the SRT we choose an experimental group of 30 athletes aged between 20 and 25 years old. Any of them goes in for one of dinamical kinds of sport (football, handball, table tennis, bascketball) for not less then 5 years. The

reference group consisted of 22 students from 18 to 25 years old not involved in regular sport activity. Investigations were held using authoring software package, which implemented standard and modified methods of simple and complex sensorimotor reaction. The method of simple sensorimotor reaction (SSR) determines the duration of the latent period of SR [1], which is the time from the appearance of a certain visual stimulus on the PC screen to the moment of left mouse click or when “Enter” button on a keyboard is pressed. As a stimulus the colored geometric shapes are used. Respondents were shown 30 stimuli, exposure time was 1 second, and the length of the pauses between two signals changed pseudorandomly (but did not exceed 10 seconds). Early click or button press was recognized as a mistake.

The method of complex sensorimotor reaction (or choice reaction, CSR) uses the same stimuli, but for one of them (key shape and color may be configured) the respondent is required to press left mouse button, and for another one – to press right mouse button, the rest of the stimuli should be left without response. Every wrong or early click is recognized as a mistake.

Modified method of SSR and CSR contains additional stress-factors for the respondent –moving visual and variable sound effects as a permanent background of testing process (Fig. 1). Application has different modes: “movie”, “on road”, “flight through the universe” and other. Testing procedure should be performed using wide screen monitor and sound speakers. We used versatile simulation, and it may be modified for specific testing tasks.

Fig. 1. Screenshots of PC application for modified SR method in “flight through the universe” mode and the setting bar

Respondents passed each test fot three times and the best result was taken as a value. Studies were performed before 12 pm outside working hours. For data processing the MS Office Excel package was used.

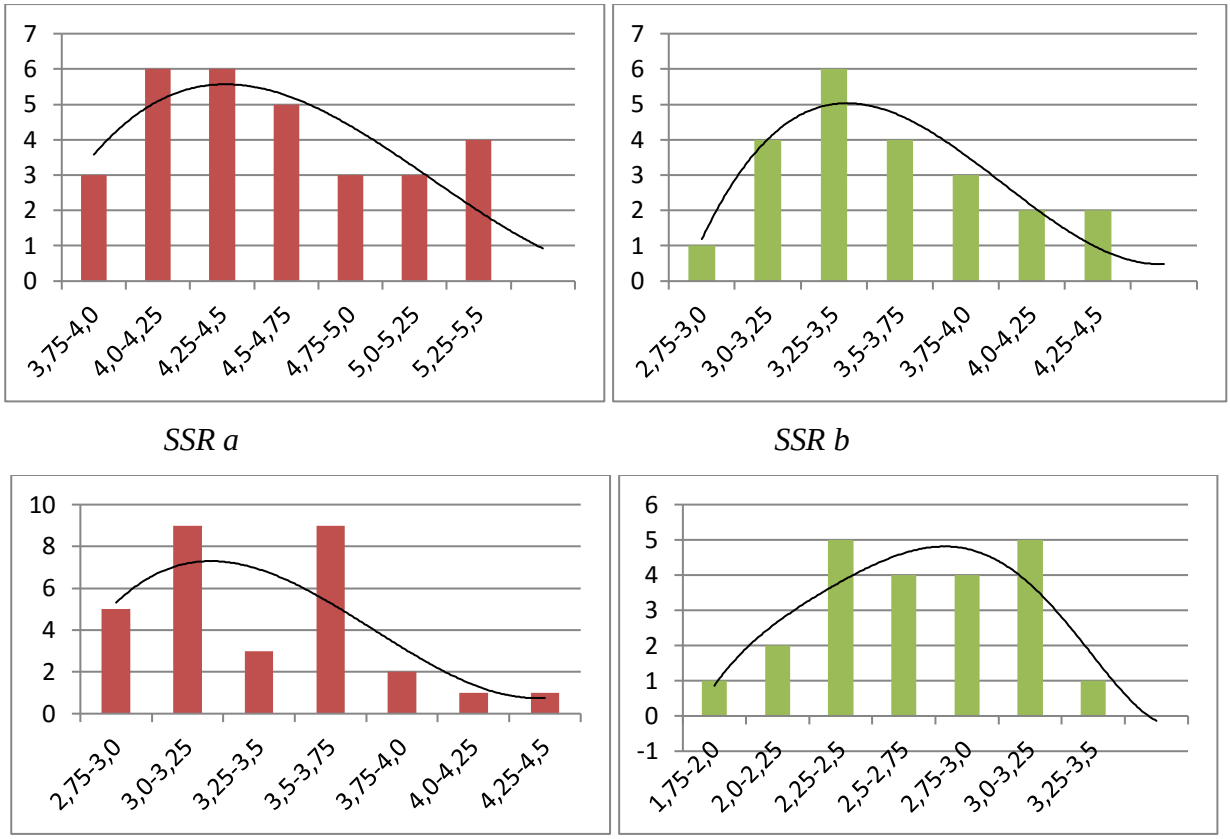
Results. Our hypothesis was that we can use an integral reaction parameter to describe the functional potential of human cognitive and motor activity in conditions of workload and to distinguish people who are capable of some kind of activity (for example, sport).

As an evaluation criterion, we used a reaction paremeter *RP*, which is a quantity that combines values of reaction time and number of errors during the test:

$$RP = \frac{(N - n)}{N \cdot \overline{RT}},$$

where N is the total number of test signals (N=30); n is the number of errors (mistakes) made by the respondent while performing test; $\overline{RT}$ is the mean time of motor reaction (the mean of N responses) of each respondent. The unit of *RP* measurement is s^{-1}.

The study of experimental groups with standard SSR and CSR methods has given the following results (Fig. 1).

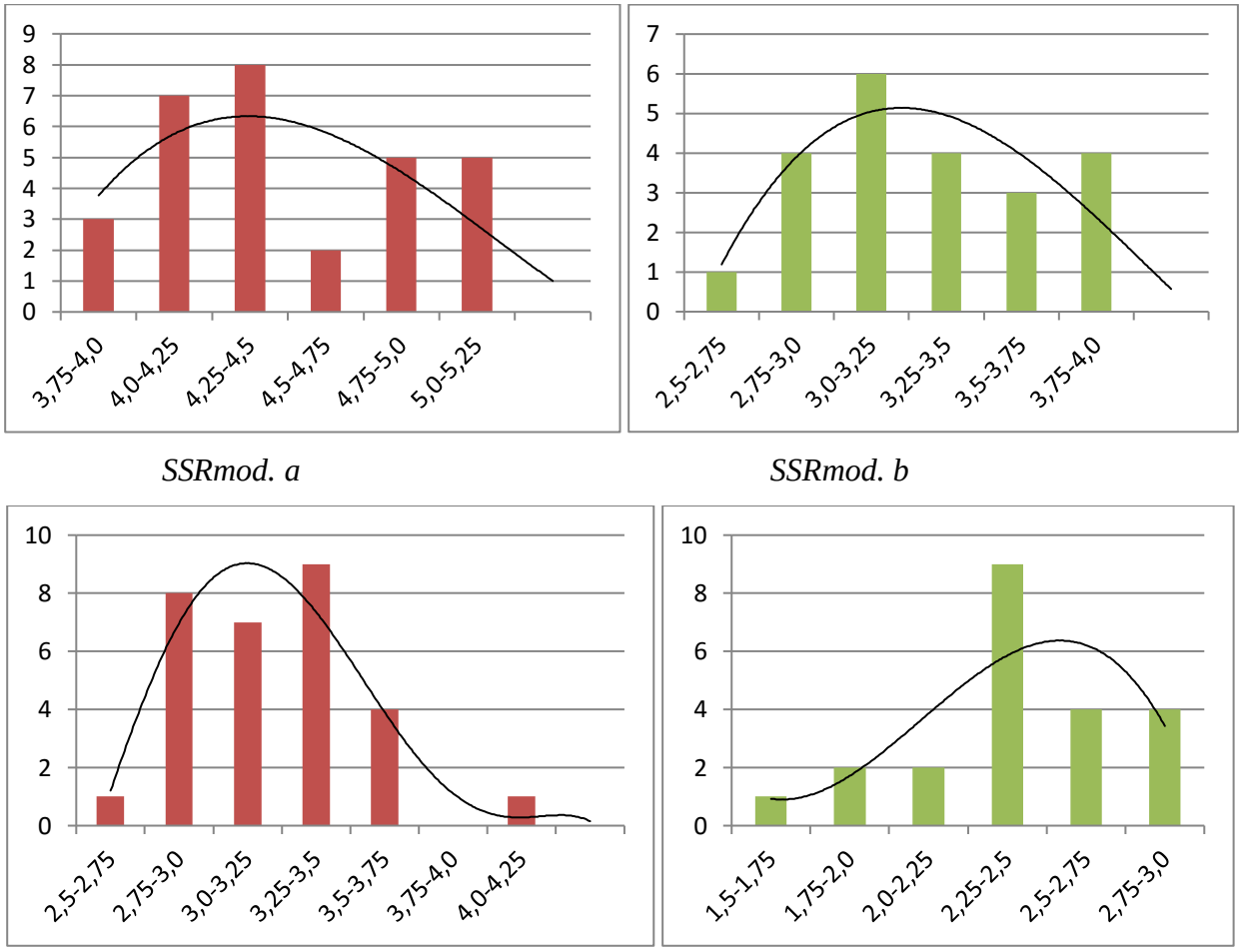


SSR a *SSR b*

CSR a *CSR b*

Fig. 1. Distributions of the RP values for SSR and CSR in experimental group of athletes (*a*) and in reference group (*b*) supplemented with the polynomial trend lines

The study of experimental groups with modified SSR and CSR methods showed the results depicted on Fig. 2.



SSRmod. a *SSRmod. b*

CSRmod. a *CSRmod. b*

Fig. 2. Distributions of the RP values for modified methods of SSR and CSR inside additional stress conditions in experimental group of athletes (*a*) and in reference group (*b*) supplemented with the polynomial trend lines

Analyzing the obtained results, we can highlight the basic key characteristics of data distributions (Table 1).

Table 1

Main characteristics of experimental distributions of RP values among experimental group of athletes and reference group

Respondents	Method	Mean	Minimum value	Maximum value	Mode	p-level for normal distribution
Experimental group (athletes)	SSR	4,58	3,85	5,37	4,35	0,3 %
	SSR mod.	4,49	3,82	5,21	4,35	3,5 %
	CSR	3,37	2,83	4,30	3,15	0,0008 %
	CSR mod.	3,20	2,54	4,08	3,35	5,5 %
Reference group	SSR	3,61	2,76	4,38	3,35	39,6 %
	SSR mod.	3,32	2,75	3,95	3,15	3,7 %
	CSR	2,69	1,86	3,26	2,4	34,5 %
	CSR mod.	2,40	1,52	2,91	2,35	1,5 %

The mean of SSR and CSR time in two groups significantly differ. It is indicative that the difference between mean *RP* for standard and modified method in experimental group is from half to three times less than in reference group. So it can be used as a stress tolerance index that reveals the individual resistance to stress factors from functional point of view.

The distribution shapes of experimental data are far ftom normal one (p-level ≤ 5) except standard SSR and CSR results in reference group. Generaly all the data sets approach to the shape of gamma distribution (k=2…5, θ=1…2).

Discussion: Reaction parameter *RP* was developed in order to combine two important characteristics of reaction time testing – response time and the number of errors, which respectively reflect the current state of motility and strength of nervous processes. Our task was to compile these two values to obtain single integral parameter that describes the functional potential of human body. The value of reaction parameter indicates the balance between motility and strength of nervous processes, which is important in many tasks of professional and sport selection. *RP* is clearly associated with current level of SMI and characterises it.

The unit of *RP* is s^{-1}, so we may interprete it as "times per second" – how many times during 1 second a person can make right decision and perform appropriate action (taking into account possible mistakes).

Mathematical idea of the formula for *RP* is as follows. First, lets note that the lower response time value, the better rate of sensorimotor reactions. To provide a point character of reaction parameter, which is natural for human, we placed the mean response time in the denominator. Coefficient $(N-n)/N$ describes the impact of errors on the total value of the resulting *RP*. In our investigations we noticed that any false reaction of respondent (premature or bad time response) scatters his attention and launches motor response. This is an inhibitory factor for the next efficient answer. In about 87 % of cases after false pressing the next reaction time was higher than mean response time. Thus, the false response reduces cognitive sensitivity of respondent to the new incentives, especially in a short period.

The good performance of the reaction rate combined with a big amount of errors indicates respondent's imbalance and shows his attempts to predict the appearance of the stimulus. It is known that a conscious reaction time cannot be less than 100 ms, due to the limited velocity of nerve impulses proliferation [3]. Therefore, in our study, response time less than 100 ms is considered as an error (successful divined outcome). Respondents were asked to guess intentionally the moment of stimulus emergence. They shared that if their guess had been successful visual image often occurred already after pressing a button. Therefore, the introduction of restrictions on the minimum of allowable response time should be considered appropriate.

Thereby the value of *RP* can be the same for different people with unlike indexes of mean reaction time and number of errors (Fig. 3). However, as we observe in real activity (for example in sport) the result of a person with slower nervous processes and strong nervous system may be similar to that one with rapid but weaker nervous processes. If the respondent makes no mistake (n=0) *RP* value is invertable to mean reaction time. Making mistakes reduces *RP* value (and potential of adequate response). If the number of errors n=N than *RP* becomes zero.

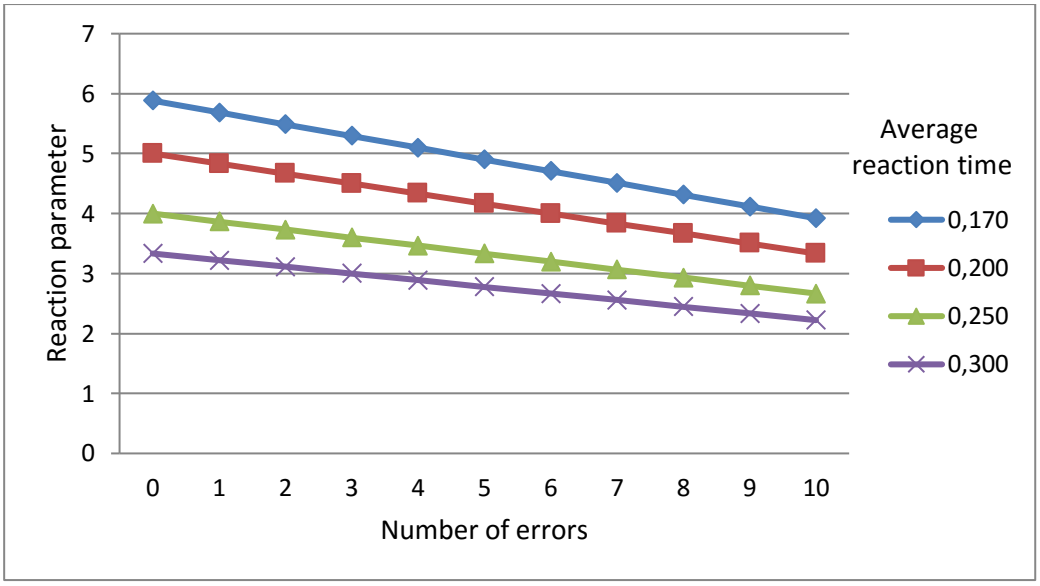


Fig. 3. Dependence of reaction parameter (*RP*) values on the number of errors for different indexes of mean reaction time

Real human professional activity often relates to increased stress level is especially while working in extreme conditions. That`s why we simulated stress-factors during performing the SR test using variable visual and sound effects as a permanent but changeable background of test software. This mode was called modified SSR and CSR method. We observed a strong correlation between results obtained with standard and modified methods (Table 2).

Table 2

Correlation coefficients between sets of experimental data within experimental group of athletes and reference group for standard and modified methods of SSR and CSR testing

Respondents	Method	SSR	CSR	SSR mod.	CSR mod.
Experimental group	SSR	–	0,724	0,957	–
	CSR	0,724	–	–	0,975
Reference group	SSR	–	0,594	0,944	–
	CSR	0,594	–	–	0,993

As we can see, results of standard SSR and CSR methods possess the average level of correlation in both groups of respondents. These data are consistent with [14] that describes complex or low correlation between SSR and CSR. However, correlation between results of standard and modified methods within each group is very strong. At the same time, changing of separate values from standard to modified method has an unpredictable nature. We can conclude that results of modified methods are strongly connected, but we cannot determine or calculate the values for modified method from standard one for every respondent.

Using standard and modified methods of SR successively, we can determine the difference of proper means and thus to assess the individual potential of stress tolerance in different unexpected situations.

Conclusion. Proposed reaction parameter is convenient and easy to use index to assess the integral potential of nervous system and sensorimotor integration level of respondent using sensorimotor reaction testing. Newly designed modified method uses variable stress factors and allows to determine the level of stress tolerance in comparison with the results of standard reaction time method. Such approach provides opportunities for professional selection in different spheres of human activity. The SR study in athletes showed that the mean reaction parameter in the experimental group was (0,7…1,1) s^{-1} more than in reference group. Athletes also had lesser difference between standard and modified reaction time results. Therefore, the reaction parameter can be a criterion for determining the individual neuromotor abilities of a person. The further studies should identify the scope of its application.

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