Task-Independent Vibraimage Parameters and Successful Performance in Sensorimotor and Intelligence Tests

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Abstract: *The analysis of statistically significant differences between groups of male volunteers of the most and least successful in performing cognitive tasks of various difficulty levels in terms of vibraimage was done. In studies involving 204 male volunteers, was shown that vibraimage parameters recorded in a state of relative rest contain information about cognitive abilities. Apparently, the obtained data reflects the existence of stable functional connections between the structures of the human brain, ensuring the successful implementation of various cognitive tasks at consistently high level.*

Keywords: *vibraimage technology, cognitive abilities, sensorimotor reactions, intelligence tests.*

One of the most important tasks facing researchers using the new method is to determine its strengths and weaknesses, and, in particular, to determine the range of tasks whose solution with its help is possible and optimal in terms of both the result obtained and the necessary resources. This work is, in this sense, a continuation of a number of works aimed at finding the place of vibraimage (VI) technology in the existing set of classical and modern psychophysiological tools.

Hypotheses of this study:

1. VI parameters recorded in a state of relative rest (task-independent state) can contain information about a person's abilities to successfully perform certain types of activities.

2. The relationship between the success of the test task and VI parameters is more pronounced, by easier activity is performed, or closer to the reflex in its content.

The purpose of the study: analysis of the peculiarities of the relationship between vibraimage parameters (Minkin, 2017; 2020) at rest with the success of sensorimotor and intelligent tests.

Sensorimotor and intellectual tests selected for the study can be classified as tools for assessing various cognitive abilities (Lapteva, 2017; Rzhanova et al., 2018). The test procedure "simple reaction task" (SRT) involves the same type of motor reaction to a repetitively known visual stimulus.

Although the reaction rate in humans is controlled by consciousness (Boyko, 1964), in the series of cognitive tasks used, SRT requires the least involvement of the cortical structures of the brain, which K. K. Platonov called the "central moment" (Platonov, 1972). The main indicators of SRT are the reaction rate and its variability, as well as possible rarely encountered errors in the form of omissions of signals or premature reactions.

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When conducting the test “choice reaction task” (CRT), subject is asked to respond to two or more different stimuli that are presented to him in a random or pseudo-random order, with each stimulus corresponding to its own reaction, for example, pressing to a specific button on the keyboard.

The complexity of the task, and accordingly the role of the central moment and the average reaction rate, increases with an increase in the variety of stimuli presented. The difference between the time of CRT and SRT from the appearance of the stimulus to the beginning of the motor response is called the “central delay”. Incorrect keystrokes are added to erroneous reactions while performing CRT.

The intellectual tasks performed by the subjects were of different directions and reflects the level of fluid (Raven’s Progressive Matrices) and crystallized intelligence (factor B of the Cattell’s 16 Personality Factors — 16PF). Both terms proposed by Raymond Bernard Cattell (Cattell, 1971; 1987) to denote complex cognitive functions. Fluid intelligence depends on the flexibility of thinking and determines the ability to logical thinking and success in solving new and non-standard tasks that go beyond experience. Crystallized intelligence reflects the amount of knowledge and experience of a person and the ability to put them into practice.

Thus, the methods chosen for the study of cognitive functions occupy places in the continuum from the simplest (SRT) to the most complex tasks (intelligence tests) with an intermediate location of the CRT. At the same time, two factors that unite them can be distinguished. The abilities measured with their help: 1) are significantly affected by the properties of the central nervous system (CNS) inherited by a person (Cattell, 1971; 1987; Panteleeva, 1977; Saraykin, 2017); 2) undergo significant age-related changes in adults (Ananyev, 2001; Shutova S. V. and Muravyova, 2013; Raven, 2008; Horn&Cattell, 1967).

In adulthood, the speed of sensorimotor reactions and the success of solving intellectual tasks undergo different dynamics; therefore, it is not possible to talk about any general patterns for them. Given the above, when planning this work, the authors considered it necessary to limit the circle of examined individuals of average age.

A significant stimulus for the formation of the idea of this study was the recent publication of the works of Viktor Minkin et al (Minkin&Blank, 2019; Minkin&Kachalin, 2019), confirming the existence of a relationship between the parameters of the VI and the functional state of the CNS. They describe the dependence of the duration of periods of brain activity, measured by the technology of VI, on the type of activity and brain load of a person, however, to date, there have been no studies on the relationship of vibraimage parameters with the success of cognitive tasks.

Materials and Methods

The study involved 204 male volunteers aged 27 to 47 years. The limitation of the circle examined by middle-aged males allowed avoiding the influence of sexual, age, and anthropometric factors on the results of the study of vibraimage parameters.

Sensorimotor and intellectual tests were carried out using the hardware-software complex “PFS-Control”. At the beginning of the study, two sensorimotor tests were performed:

1) Simple reaction task (SRT) — a red rectangle was used as an incentive, to the appearance of which in the center of the monitor screen the subject had to react as quickly as possible and simultaneously with both hands by pressing the shift keys to the right and left of the keyboard.

2) Choice reaction task (CRT) — random, red, yellow, and green rectangles were used as stimuli. The subject should respond to the appearance of one of the stimuli in the center of the monitor screen as quickly as possible by pressing the key corresponding to the signal. To determine the success of each of the sensorimotor tests, the target indicator "average reaction time" was used. An additional condition for inclusion in the group of the most successful was the absence of a large (above average) number of errors.

Subjects then performed two intellectual tests:

3) Raven's Progressive Matrices

4) The tasks included in Cattell's factor B, which were solved during the execution of 16PF (form A). The criterion for the success/failure of each of the tests was the number of correctly solved items.

Thus, in the course of the study, the subjects consistently performed tasks of increasing complexity: SRT, CRT and intellectual tests aimed at studying various aspects of general intelligence (factor "g") — fluid and crystallized intelligence. Since the results of these tests may reflect the functional state of the CNS, testing was carried out only in the morning and afternoon.

According to the results of each test, two groups were formed, the most and least successfully completed the 4 tasks proposed by him. As a result, 8 (4 pairs) groups were identified from the total number of study participants, and each pair was a group of subjects polar in the success of one of the 4 cognitive tasks. Subsequently, in each of the pairs of groups, a comparison was made of 164 parameters of VI in order to identify statistically significant differences.

The quantitative composition of the selected groups is presented in table 1.

Table 1

The number of volunteers included in the groups that most (Group 1) and least successfully (Group 2) completed various cognitive tasks

Group number	SRT	CRT	16PF, Factor B	Raven's Test
Group 1	48	55	45	36
Group 2	57	51	31	31

No significant differences between the best and worst subjects were revealed in either pair by age or by anthropometric indicators.

The average values of the target (determining the success of the task) indicators in the selected groups shown in table 2.

Table 2

The average values of the target indicators of the tests used to form the groups of the most (group 1) and least (group 2) successful participants in the study

Test indicators used to form groups	Group 1	Group 2
Latent period of SRT, ms	264,7	352,32
Latent period of CRT, ms	543,8	725,21
The values of the 16PF factor B, stens	9,5	4,3
The number of correctly solved items in Raven's test, raw scores	51	34,1

On the same day, using the VibraMed program (VibraMed8, 2015 or VibraMed10, 2020), vibraimage was processed during 1 minute test, the video quality was maintained at a level of at least 70%.

The results of the study were analyzed using the STATISTICA v. Software package 8.0.

Results and Discussion

According to the results of the study, 4 pairs of groups of its participants were formed, the most and least successful in completing tasks of increasing complexity: a) SRT; b) CRT; c) intellectual tests (tasks of 16PF factor B and the Raven's Progressive matrices).

Figure 1 and tables 3 and 4 show the results of pairwise comparison of the VI indicators in groups that performed cognitive tasks of varying complexity.

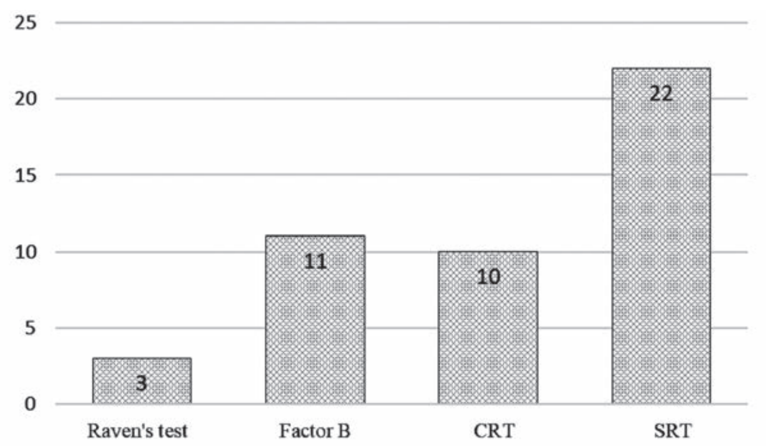

Figure 1. The number of statistically significant differences in the parameters of the VI between the most and least successful subjects who performed cognitive tasks of different difficulty levels

As can be seen from figure, the results of the study as a whole confirm the hypothesis that the relationship between the success of the test task and the parameters of the VI is all the more pronounced, the easier the activity is performed, that is, the closer it is to the reflex in its content. Noteworthy is the high number of statistically significant differences in the VI parameters between groups that are polar in terms of success in solving the tasks of the 16PF factor B, which does not coincide with the expected one.

It would be more natural to assume a coincidence or similarity in this indicator between the intellectual tests, despite their different directions. The fact that the 16PF factor B does not quite fit into the general described trend can be related both to the content of the activity and to the special conditions for its implementation.

Perhaps the developed crystallized intellect suggests the existence of stable functional connections between brain regions involved in solving the corresponding problems. Unlike other cognitive tasks used, 16PF is performed at an arbitrary pace, while for the Raven's test there is a time limit, and in the instructions for sensorimotor tests, the key is to respond "as quickly as possible".

An unexpected result was the analysis of coincidence of the parameters of the VI, according to which statistically significant differences were obtained between the groups of the most and least successful in performing various cognitive tasks (tables 3 and 4). According to the authors, the number of matching VI parameters for different tasks can be a criterion for the degree of generality of the brain mechanisms involved in their implementation.

Table 3

The number of coincidences of the VI parameters for which statistically significant differences obtained between the groups of the most and least successful in performing various cognitive tasks

Methods	Raven's Test	16PF, Factor B	CRT	SRT
Raven Test	–	0	0	0
16PF, Factor B	0	–	1	9
CRT	0	1	–	6
SRT	0	9	6	–

Table 3 shows that for Raven's test there are no such matches, factor B has 1 coincidence of the parameters of the VI with CRT, 9 matches with the SRT, and finally, 6 matches between the parameters of the VI were detected between the sensorimotor tests. Moreover, if the direction of differences in the parameters of the VI between the best and worst subjects performing sensorimotor tests is the same, then for all 9 similar coincidences between 16PF factor B and SRT, it is the opposite (table 4). In other words, if for any of these parameters, for example, for "anxiety", the group of the best by factor B is characterized by lower values, then the group of the best by SRT is characterized by large values (table 4).

A meaningful description of the regulatory processes behind the obtained results in the CNS at this stage is not possible. This is primarily due to the lack of theoretical understanding of the parameters of VI, and not only those that have only alphanumeric designations. The content of the named parameters (for example, “stress”) should also be treated with caution, since they can carry a semantic load that contradicts the classical concepts (Bobrov&Shcheblanov, 2018).

Viktor Minkin, the inventor of VI technology, in his recent work also emphasizes (Minkin, 2020) that in the direction of psychology, the development of a thesaurus is far from complete and is the task of further theoretical generalizations. He believes that at this stage in the development of the VI methodology, from the point of view of the cybernetic approach, emotions, psychophysiological parameters and character traits, it is advisable to “combine them under the general term behavioral characteristics”.

It can be assumed that the distinction in the direction of statistically significant differences between the groups of the subjects most and least successful in their SRT and 16PF logical tasks performing is explained by the provision of the Yerks-Dodson law on the existence of an optimal level of activation for various types of activities. Robert Yerks and John Dodson experimentally found that the more complex the task, the lower the level of activation to achieve maximum performance (Fress, 2006).

A similar relationship was found between the level of anxiety and the productivity of intellectual activity (Gribanov et al., 2019). If this assumption is true, then at least two variants of the mechanism of action of this law can be proposed:

1) the parameters of the VI in a state of relative rest reflect the level of activation or anxiety of the subjects on the day of testing as their personal characteristics, or as a reaction to the testing itself;

2) VI parameters in a state of relative rest contain signs of a predisposition of the CNS to its changes in the direction of greater or lesser activation.

However, taking into account the fact that the differences between groups 1 and 2 in terms of their target indicators are very large (Table 2), it is more likely that the selected parameters of the VI characterize not so much the current psychophysiological state of the examined individuals as more stable characteristics of the CNS.

To understand the identified relationships between the parameters of the VI and the success of cognitive tasks, the results of a study by I. Tavor et al. (Tavor I. et al., 2016) may be useful. The authors showed that it is possible to successfully predict the features of activation of the cerebral cortex in a particular person when he performs various (linguistic, social, motor, etc.) tasks based on the data of functional magnetic resonance imaging (fMRI), obtained at rest. They concluded that functional neural connections in a relatively calm state already contain scenarios that are then realized when a person performs various tasks and are expressed in individual fMRI patterns that differ in localization, form and degree of activation.

Apparently, the differences that we revealed by task-independed VI parameters between the study participants the most and least successful in performing various cognitive activities also reflect the characteristics of brain activity inherent in these groups as a result of the interaction of various factors genetically determined or formed during ontogenesis.

Table 4

Statistically significant differences in vibraimage parameters between the groups of the most (group 1) and least (group 2) successful subjects in performing intellectual and sensorimotor tests

VI parameters (M and Vi)	Raven's test (μ ± σ)			B Factor, 16PF (μ ± σ)		
	Group 1	Group 2	P	Group 1	Group 2	P
Stress (P6)						
Tension (F5X)				36,0±12,9	44,48±17,31	<0,05
Balance (P16)						
F3	20,81±6,1	24,93±9,66	<0,05			
F5 (fast)				0,4±0,1	0,44±0,17	<0,05
F7				0,1±0,0	0,05±0,04	<0,05
F8						
P2	27,73±5,6	31,66±6,6	<0,05			
A3-S						
F5-S						
Stress (P6)-Vi						
Tension (F5X)-Vi						
Charm (P17)-Vi						
Self-Regulation (P18)-Vi						
A2-Vi						
A3-Vi						
F2-Vi						
F4-Vi				16,5±18,6	27,2±26,43	<0,05
F6-Vi						
F7-Vi				21,3±27,2	168,18±340,9	<0,01
F8-Vi						
F9-Vi				13,0±14,6	22,54±18,33	<0,05
P1-Vi						
P2-Vi				6,8±7,8	12,64±12,33	<0,05
A1 (fast)-CMin						
A4 (fast)-CMin				0,00±0,0	0,02±0,05	<0,05
F1 (fast)-CMin						
F5 (fast)-CMin				0,1±0,1	0,19±0,15	<0,05
F7-CMin				0,00±0,0	0,02±0,01	<0,01
S6-CMin	–0,2±0,2	–0,11±0,16	<0,05			
F5 (fast)-CMax				0,5±0,1	0,62±0,17	<0,01

Table 4 (*end*)

CRT (μ ± σ)			SRT (μ ± σ)			VI parameters (M and Vi)
Group 1	Group 2	P	Group 1	Group 2	P	
34±6,2	36,51±6,75	<0,05				**Stress (P6)**
			41,7±16,47	35,01±12,1	<0,05	**Tension (F5X)**
			66,9±7,96	63,07±9,8	<0,05	**Balance (P16)**
						F3
			0,4±0,16	0,35±0,1	<0,05	**F5 (fast)**
						F7
			0,1±0,03	0,15±0,0	<0,01	**F8**
						P2
2,9±2,1	4,05±3,27	<0,05				**A3-S**
			0,0±0,02	0,05±0,0	<0,05	**F5-S**
			10,9±5,69	13,77±7,9	<0,05	**Stress (P6)-Vi**
			21,4±9,87	25,44±10,1	<0,05	**Tension (F5X)-Vi**
14,7±11,2	21,8±17,48	<0,05				**Charm (P17)-Vi**
9,4±5,5	12,06±7,03	<0,05				**Self-Regulation (P18)-Vi**
36,2±33,7	23,71±30,82	<0,05	31,8±27,76	16,68±22,6	<0,01	**A2-Vi**
			15,1±14,17	8,98±13,2	<0,05	**A3-Vi**
11,8±8,2	7,6±9,24	<0,05	11,4±8,61	6,06±7,8	<0,01	**F2-Vi**
			19,2±18,19	11,31±17,8	<0,05	**F4-Vi**
13,1±20,6	6,57±9,52	<0,05	14,4±25,13	5,74±8,0	<0,05	**F6-Vi**
			131,5±367,32	20,2±41,4	<0,05	**F7-Vi**
47,8±76,5	20,36±27,42	<0,05	55,0±106,27	19,9±26,7	<0,05	**F8-Vi**
			17,8±15,84	10,91±15,2	<0,05	**F9-Vi**
11,7±8,2	7,86±9,59	<0,05	11,1±8,52	6,47±8,4	<0,01	**P1-Vi**
10,8±9,6	6,75±10,08	<0,05	9,7±9,3	6,14±8,9	<0,05	**P2-Vi**
			0,005 ±0,014	0,001±0,0028	<0,05	**A1 (fast)-CMin**
			0,013±0,037	0,002±0,007	<0,05	**A4 (fast)-CMin**
			0,001±0,0018	0,000±0,00048	<0,05	**F1 (fast)-CMin**
			0,2±0,17	0,12±0,1	<0,01	**F5 (fast)-CMin**
						F7-CMin
						S6-CMin
			0,6±0,15	0,53±0,1	<0,05	**F5 (fast)-CMax**

Further verification of the discussed ideas about the nature of the relationship between the parameters of VI at rest and the success of sensorimotor tests and intelligent tests will allow us to come closer to understanding the capabilities of this technology and its place among other psychophysiological research methods.

Conclusion

1. Statistically significant differences were revealed in vibraimage parameters of recorded at rest between the groups of the most and least successful participants in the study, successively performing activities of varying complexity. Besides, the number of such differences tends to decrease with increasing complexity of activity.

2. The results of the study show that VI parameters recorded in a state of relative rest contain information on the ability to perform some cognitive tasks of various directions and levels of complexity.

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