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Cardiometric detection of effects and patterns of emotional responses by a human individual to verbal, audial and visual stimuli

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Aims

The article presents the results of an experimental study of the cardiometric detection of a person's emotional reactions to verbal, audial and visual stimuli.

Materials and methods

To test the hypothesis of our study, we carried out a series of experiments in which two groups of stimuli have been used purposefully, one of which had to cause sthenic and the other asthenic reactions in our examinees. In order to activate various types of sensory systems, only stimuli of the audial modality (the A-type stimuli), only visual modality (the V-type stimuli), and also stimuli with a combination of audiovisual modalities (the VA -type stimuli) have been included in each group. In addition, as stimuli, we prepared a list of imaginary situations (the I-type stimuli) to initiate either sthenic or asthenic emotional reactions in the examinees. For the cardiological data recording and subsequent assessment of HRV, we used the Cardiocode PC-assisted hemodynamic analyzer. Portable eyetracker GP-3 has been employed to record the examinees' oculomotor reactions to visual stimuli.

Results

As a result of the study, it has been identified that the Baevsky stress index (SI) values, which are higher than the average values, can be considered as a fingerprint of a sthenic reaction to a stimulus, and the reduced SI value can be considered as a marker of an asthenic reaction to a stimulus. In addition, the data obtained confirm a more efficient use of the SI indicators in comparison with the heart rate parameters in assessing the nature of a human individual's emotional reactions. Oculographic manifestations of a moderate response to the presented visual stimuli may be the preferential fixation of respondents' gaze at the yellow, green and blue colors from the eight-color Lüscher test. The asthenic nature of the response is most often combined with an involuntary gaze fixation at grey, black and brown colors of the Lüscher test. The pronounced sthenic reaction is most often indicated by the involuntary gaze fixation at red and yellow, red and black, red and brown, yellow and brown, observed when one visual stimulus being exposed, with marked ignorance of blue and gray.

Conclusions

Consequently, our experiments confirm our main hypothesis that the increased Baevsky stress index values, in comparison to the average values, can be considered as a fingerprint of the sthenic response to a stimulus, and the reduced SI value can be considered as a marker of the asthenic one.

Keywords

Cardiometry, Cardiocode, Sthenic reaction, Asthenic reaction, Oculometric diagnostics, Eyetracker

Imprint

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Introduction

The Heart Rate Variability (HRV) analysis has long been one of the most effective cardiometric methods [1, 3, 4, 8-10, 14-17], and, from the very beginning of using HRV assessments in practice, a strong influence of the individual's emotional state produced in cardiac measurements on the obtained results has been noted as one of the HRV features [1, 3, 4]. Therefore, it is not surprising that for more than half a century many attempts to use the HRV values in studies of various types of mental processes and individual states have been made [3, 4].

Initially, HRV has been considered as a fingerprint of changes in psycho-emotional loading when solving mathematical tasks [4]. Later, as HRV parameter calculations have been improved, it has been applied to study different types of thinking and attention, cognitive control and motivation [3, 4]. Thus, for example, it has been found that as the individual's motivation increases, the contribution of the Mayer waves to HRV increases (as is known, this sort of waves is usually associated with vasomotor responses to a certain stimulus). A number of researchers have shown that the HRV wave changes in the range from 0.07 to 0.11 Hz can be utilized for an assessment of the subjective value of the current task to be solved by the subject tested.

Considering the HRV study results, taking into account the topic of our paper, of particular importance is the obtained evidence that the Mayer waves demonstrate a significant positive correlation with the Traube-Hering waves, observed during plethysmogram recording. Besides, similar correlations have been identified between HRV and galvanic skin reactions, occurring in individuals in response to various imaginary situations [4]. The identification of such correlations has initiated searching by some polygraph developers for ways of using HRV in concealed information detection. An example of the successfully realized engineering solution is the Baevsky stress index application in the "Epos" polygraphs for assessing the pre-test state of a suspect [2].

However, from the very beginning of using HRV in an assessment of human individual emotional responses, in particular, when applying the stress index (SI) parameter proposed by R.M. Baevsky as one of the markers thereof, researchers confused the nonlinear nature in their relationship [4]. Problems with the use of HRV in the study of mental processes and states have been aggravated by the ambiguity of the examined persons' responses to, for example, test tasks of the same level of complexity. The attempts to explain such contradictions by exclusively unaccounted artifacts or differences in the examined persons' temperaments turned out to be unproductive. At the same time, many researchers, with enviable persistence, ignore the pronounced subject-genesis nature of such responses. Thus, in our opinion, the differences in HRV manifested when solving the numerical and the Stroop test tasks of the similar complexity reveal the subject-genesis nature of this kind of responses [4]. The paradoxical differences, as it may seem, between the cosmonauts' HRV in the spacecraft and that in the scheduled training on the Earth and immediately before launching show a clear subject-genesis nature [8]. As a result, even some doubts about the applicability of HRV in assessing the human psycho-emotional states have appeared [2].

In our opinion, one of the reasons for the difficulties, when using HRV in solving applied psychological problems, is that ignored are personological factors, especially the ability and desire of a human to be the subject of his/her own life, to act as the primary generator of his/her own activity. But without regard for the desire of a human to be the primary generator of his/her own activity, any analysis of emotional responses as an integral part of his/her self-regulation system loses its meaning. In our opinion, a way out of the difficulty can be found by treating the HRV variations as indicators of the character of a decision made by a human individual. In this case, for example, a significant excess in the Baevsky stress index (SI) values of average indicators can be considered as a marker of the examinee's choice in favor of intensification of his/her active actions, i.e. as a sthenic response to a stimulus. Following this logic, the SI values, which are much less than the average values, can be judged to be a sign of the examinee's choice in favor of his/her inaction, or a reduction in his/her activity, i.e. to be an asthenic response to a stimulus.

Materials and methods

To test the hypothesis of the study, we have carried out a set of experiments with the targeted use of two groups of stimuli: the first group thereof is presumed to cause sthenic responses, while the second one assumes to initiate asthenic responses in the examinees. In order to activate different types of the sensory systems, we have included in each group the stimuli of the audial modality only (the A-type stimuli), the visual modality only (the V-type stimuli) and the combined audio-visual modalities (the VA -type stimuli). Besides, for further stimulation type, we have prepared a list of imaginary situations (the I-type stimuli), which can produce either sthenic or asthenic emotional responses in the examined individuals.

The following audio recordings have been included into the scope of the A-type stimuli to induce the sthenic response:

A-1 is the solemn patriotic song of the Great Patriotic War period "The Sacred War" (the lyrics are by V. Lebedev-Kumach, music by A. Alexandrov) performed by the A. V. Alexandrov Twice Red-Bannered and Red-Starred Academic Song and Dance Ensemble of the Russian Army;

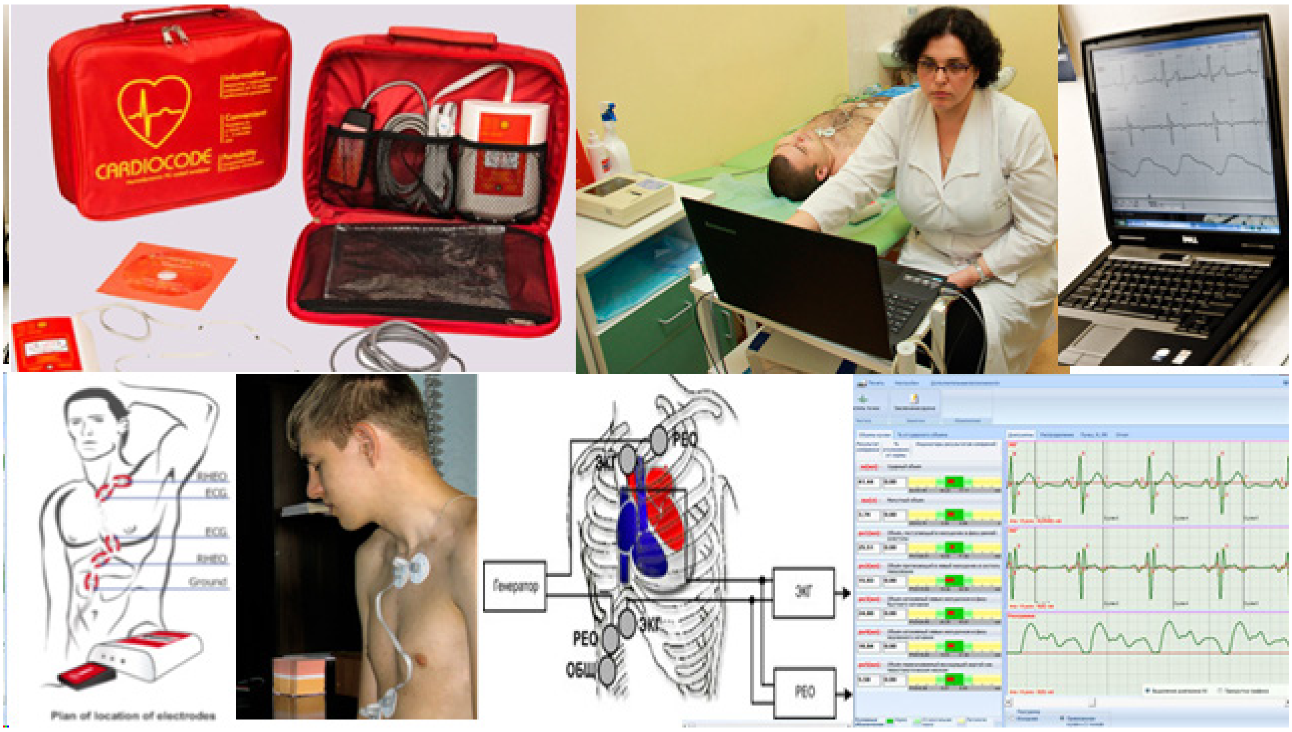

Figure 1. Cardiographic examination using the Cardiocode device


Figure 2. Oculographic examination using the eyetracker

A-2 is the March of the Soviet Tankmen “Three Tankmen” performed by Nikolai Kryuchkov (lyrics by B.Laskin, music by Pokrass brothers);
A-3 is the “Peremen” song («Changement!») by the Soviet rock group “Kino” performed by Victor Tsoi.
The following audio recordings have covered the A-type stimuli to initiate the asthenic reaction:
A-4 and A-5 are referred to the audio recordings of songs “Cuckoo” and “Be wary!” performed by Victor Tsoi.
A-6 is represented by song “The Isle of Bad Luck” performed by Andrei Mironov (lyrics by L. Derbenev, music by A. Zatsepin).

As the VA-type stimuli in the experiments, used have been the video clips, the visual, musical and textual components of which have been:
either clear-cut sthenic in their nature: “Go, Russia!” (Mark Tishman), “Black or White” (Michael Jackson), “I Believe” (Lyapis Trubetskoy) should be referred to as the VA-1, VA-2 and VA-3 stimuli, respectively;
or asthenic in their nature: “Pechal” (Viktor Tsoi, Kino), “My Love” (Aleksandr Uman, Egor Bortnik, Bi-2), “Two ships” (rock group “Agata Kristi”) should be related to the VA-4, VA-5, VA-6 stimuli, respectively.

As to the V-type stimuli, we have prepared a series of pictures that examinees have viewed on an eyetracker screen that has been accompanied by parallel measuring their cardiometric parameters. The series has included stimuli with colored square boxes, not variable from one image to the next, as well as varying animal photos and test-related value judgments, located in the center of the screen. The invariable constituent of such stimuli has been created by the square boxes of green, blue, yellow and red color placed along the upper edge area line of the screen, and the squares of brown, black, gray and lilac color (the side length of the square has been chosen of the same size (28 millimeters), as it is the case with the color squares in the Lüscher eight-colors test in the printed version of the complete set of the relevant subtests [16]), arranged along the lower edge area line. The variable part of this stimulation group consists of the photos of a lion (stimulus V-1) and a newborn defenseless kitten (stimulus V-2), which change each other in the center of the screen, when moving from stimulus to stimulus, as well as words "active" (stimulus V-3), "passive" (stimulus V-4), "movement" (stimulus V-5) and "rest" (stimulus V-6), "depressive" (stimulus V-7) and "joyful" (stimulus V-8).

The I-type stimuli incorporate the test tasks for examinees to imagine the following situations upon instructing by the experimenter:

I-1 is a scandal involving someone of their relatives;

I-2 is a quiet peaceful conversation with any of their friends;

I-3 is a sleepy, relaxed state experienced in warm water, when taking bath;

I-4 is the vigorous exercise performed in the morning;

I-5 is a leisurely walk in the forest under comfortable conditions;

I-6 is a sudden attack by an aggressive dog;

I-7 is a trip in a crowded public transport in the close neighborhood of a casual fellow traveler who is loudly talking on a mobile phone;

I-8 is a comfortable trip in a half-empty public transport vehicle.

In the described experiments, 188 respondents aged from 15 to 69 years, have taken part in our studies, and 103 persons in the cohort are female. For recording of the cardiological data and the subsequent assessment of HRV, we have employed the Cardiocode PC-assisted hemodynamic analyzer (Fig.1), the general principle of operation and the functional features of which are described in detail in [9, 10, 14-17].

Portable eyetracker GP-3 has been employed to record the eye movement responses to visual stimuli; the various capabilities of the eyetracking equipment in oculometric diagnostics and its successful application in combination with the Cardiocode PC-assisted hemodynamic analyzer have been detailed in [5-7, 11, 12]. The time covering the exposure of each stimulus and recording of the related cardiological data is 20 seconds (Fig.2).

When working with each examinee, we have determined the respective stimulus-conditioned stress index (SI) values in the regulatory systems and the heart rate (HR) parameters. When employing the V-type stimulation, in addition thereto, the time of the examinee's gaze fixation at certain fragments of the visual stimulus has been recorded with the eyetreker and its percentage (%) of the total stimulus exposure time have been calculated.

The statistical analysis of the obtained data has been performed using universal statistical software package STADIA 8.0 ("Big version" with a data volume of 64000 digits).

A normality test has been applied to determine that the obtained data sets are well-modeled by a Gaussian distribution with the use of the Kolmogorov criteria as well as the omega-squared test and the chi-squared test. It has been found that the HR values only are well-modeled by the Gaussian distribution. Therefore, to assess the degree of similarity and difference between the SI values and the fixation durations analyzed by the eyetracker, the non-parametric criteria such as the Chi-square, the Spearman's rank correlation coefficient and the Kendall correlation coefficient have been applied, and for an analysis of the HR values applied have been the parametric criteria such as the Pearson correlation coefficient, the Fisher and Student statistics, as well as all the above non-parametric criteria.

Results and discussion

Main statistical parameters of the obtained experimental data distributions are presented in Tables 1–4 herein.

When processing the average statistical indicators obtained with the eyetracker, objective experimental evidence to support our idea of the sthenic and asthenic nature of the V-type stimuli has been found.

Table 1. Main statistical data upon analysis of measured parameters upon exposure to stimulus Type A

Stimulus	Measured parameter	Sample mean	Standard deviation
A-1	SI	657	538
	HR (beats per minute)	89	10
A-2	SI	391	269
	HR (beats per minute)	84	9
A-3	SI	521	340
	HR (beats per minute)	87	9
A4	SI	276	211
	HR (beats per minute)	84	9
A-5	SI	344	454
	HR (beats per minute)	83	9
A-6	SI	224	249
	HR (beats per minute)	82	8

Table 2. Main statistical data upon analysis of measured parameters upon exposure to stimulus Type VA

Stimulus	Measured parameter	Sample mean	Standard deviation
VA-1	SI	797	735
	HR (beats per minute)	87	11
VA-2	SI	500	488
	HR (beats per minute)	83	10
VA-3	SI	636	570
	HR (beats per minute)	85	10
VA-4	SI	377	411
	HR (beats per minute)	83	10
VA-5	SI	469	604
	HR (beats per minute)	82	10
VA-6	SI	310	350
	HR (beats per minute)	80	10

Thus, when using pictures with an unchanged set of the colored square boxes, it has turned out that when a lion picture (the V-1 stimulus) has appeared in the center of the screen, the respondents' gaze has been concentrated on the yellow and red squares for a longer time (14% and 12% of the total stimulus exposure time, respectively). As is known, the respondents' choice of such color combinations from the Lüscher test is among the markers of the inspiration and excitement experienced by the test subjects [14]. In the case under consideration, the respondents' fixation at the gray and brown squares has taken their shortest time (2% of the total stimulus exposure time).

Analyzing the picture with the same unchanged set of the colored squares, but showing a photo of a defenseless kitten in the center of the screen (stimulus V-2), the respondents' gaze has been concentrated on the grey square for the longest period of time (15% of the total stimulus exposure time). It is known that the choice of this color usually indicates the respondent's latency [14]. In this case, examining the yellow, green and red squares has taken the respondents the shortest time (3-4% of the total stimulus exposure time).

As a result of this part of the study, it has been also found that when displaying the word "active" (stimulus V-3) in the center of the screen, for the longest time respondents have focused their attention on such colors as

Table 3. Main statistical data upon analysis of measured parameters upon exposure to stimulus Type V

Stimulus	Measured parameter	Sample mean	Standard deviation
V-1	SI	829	651
	HR (beats per minute)	79	10
V-2	SI	425	348
	HR (beats per minute)	77	10
V-3	SI	704	614
	HR (beats per minute)	79	10
V-4	SI	277	193
	HR (beats per minute)	78	9
V-5	SI	519	484
	HR (beats per minute)	77	10
V-6	SI	220	117
	HR (beats per minute)	74	8
V-7	SI	257	245
	HR (beats per minute)	74	8
V-8	SI	425	322
	HR (beats per minute)	78	7

Table 4. Main statistical data upon analysis of measured parameters upon exposure to stimulus Type I

Stimulus	Measured parameter	Sample mean	Standard deviation
I-1	SI	384	293
	HR (beats per minute)	86	11
I-2	SI	220	140
	HR (beats per minute)	80	10
I-3	SI	205	145
	HR (beats per minute)	77	10
I-4	SI	346	262
	HR (beats per minute)	83	11
I-5	SI	220	171
	HR (beats per minute)	78	10
I-6	SI	317	243
	HR (beats per minute)	81	10
I-7	SI	292	198
	HR (beats per minute)	82	11
I-8	SI	228	163
	HR (beats per minute)	79	11

red (21% of the total duration of the corresponding stimulus), yellow (19% of the total duration) and green (14% of the total duration). The least attention in this case has been paid to such colors as brown (2% of the total duration), black (3% of the total duration) and grey (4% of the total duration). When the word “passive” (stimulus V-4) has appeared in the center of the screen, the respondents have paid their greatest attention to such colors as grey (24% of the total duration), brown (11% of the total duration) and blue (11% of the total duration).

During an alternate demonstration of the pair “movement” (stimulus V-5) and “rest” (stimulus V-6), which are logically connected with the previous conceptions, it has been revealed that in the first case (when the word “movement” is in the center), the respondents have paid their greatest attention to red (17% of the total duration), yellow (15% of the total duration) and lilac (14% of the total duration) colors, and the least attention has been given to grey (6% of the total duration) and black (7% of the total duration). When demonstrating the word “rest”, the respondents have paid their greatest attention to grey (19% of total duration), blue (17% of the total duration) and black (12% of the total duration).

The word “depressive” (stimulus V-7) in the center of the screen has stimulated the respondents to attentively focus on the squares of grey (38% of the total duration) and black (11% of the total duration) colors and pay their least attention to the squares of blue (4% of the total duration) and lilac colors (2% of the total duration). The word “joyful” (stimulus V-8) has encouraged the respondents to fix their attention at the squares of yellow (21% of the total duration), blue (15% of the total duration) and red (11% of the total duration) and ignore the squares of grey (2% of the total duration) and black color (1% of the total duration).

The data given in Tables 1-4herein demonstrate that the sample mean values of SI and HR for the sthenic stimuli exceed those recorded for the asthenic stimuli, which have been presented immediately after the sthenic stimuli or before them. However, upon the mathematical processing of the obtained data using universal software package STADIA 8.0, the statistical significance of these differences at an error level of no more than 5% has been confirmed for the obtained SI values only.

Conclusions

To summarize the overall data of the study, we can state that the higher SI and HR values correspond to the stimuli of the sthenic nature. The obtained evidence bears also witness to the fact that the lower SI and HR values are referred to the stimuli of the asthenic nature. However, as a rule, only the SI values have statistically significant differences for the sthenic and asthenic stimuli. So, it follows that the conducted experiments confirm our main hypothesis that an increased, in comparison with the average values, Baevsky stress index (SI) value can be considered as a fingerprint of the sthenic response to a stimulus, and its decreased value can be deemed to be a marker of the asthenic response to a stimulus, respectively. Besides, the obtained evidence is treated to be in favor of a more efficient use of the SI values, as against the heart rate values, to assess the nature of a human subject’s emotional responses.

The preferred fixation of the respondents' gaze at yellow, green and blue colors from the eight-color Lüscher test may serve as oculographic manifestations of a moderate response to the exposed visual stimuli. The asthenic nature of the response is most often combined with an involuntary fixation of the gaze at grey, black and brown colors of the Lüscher test. The pronounced sthenic response is most often indicated by an involuntary fixation of the gaze, observed under the same visual stimulus, at red and yellow, red and black, red and brown, yellow and brown, under a distinct ignorance of blue and grey. Gaze fixation at red and purple color, which in the Lüscher test appears under the name "magenta", can also be treated as a marker of the sthenic response.

The obtained evidence has also confirmed the applicability and effectiveness of using short-term recordings (from 10 to 30 seconds) to assess a subject’s psychoemotional response to presented stimuli.

Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

V.A.Z., E.V.L., L.P.N. and M.Y.R. conceived and planned the experiments, interpreted the results. D.D.D., D.S.Y. P.A.M. and N.V.M. carried out the experiments. A.S.O. took the lead in writing the manuscript. All the authors read the ICMJE criteria for authorship and approved the final manuscript.

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