

Use of cardiometry and oculography in concealed information detection

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Aims

The article presents the results of an experimental study on the use of cardiometry and oculography to detect concealed information. It has been shown that a complex assessment of the person's emotional-cognitive state based on cardiometric and oculographic recording of reactions to specially selected stimulus material of visual and audial modality can be successfully used in concealed information detection.

Materials and methods

We used the Cardiocode single-lead cardiograph and the GP-3 eyetracker as the instrumental basis for testing the hypothesis of the study. We have selected the above devices taking into account the previous analysis of their functional features and the basic possibility to use both devices together, the availability of the devices for a wide range of researchers and practitioners. To prove the hypothesis of the study, a complete set of the relevant subtests has been developed that implied both verbal (tests No. 1-3) and visual graphic presentation of stimulus material (tests No. 4-6).

Results

It has been established that a combination of the average Baevsky stress index (SI) values, with mostly involuntary fixation of the examinee's attention at the main colors of the Lüscher test (primarily at green and yellow) and the calm response of the respondent to the presented stimuli in the absence of forced or suppressed respiration, can be considered as evidence for the trustworthiness of the information reported. In order to increase the effectiveness of detecting concealed information, it is advisable to separate the asthenic and sthenic variants of the involuntary manifestation of the respondent's fears of a disclosure of that concealed information. The respon-

dent's blocking fear of disclosing information, i.e. the asthenic response variant, manifests itself in a sharp decrease in the SI values compared to the performance indicators upon presentation of neutral stimuli. The fear initiating the hectic internal activation of cognitive and affective processes, i.e. the sthenic variant of response, manifests itself in a sharp increase in the SI values compared to the performance indicators upon presentation of neutral stimuli.

Conclusions

Consequently, significant signs of a desire to conceal information are any considerable deviations in the Baevsky stress index values from its averages. When using eyetrackers as means of presenting visual stimuli with elements of the eight-color Lüscher test, such SI variations are usually combined with a sharp increase in the duration of fixation of the respondent's gaze at the verbal stimulus components (usually more than 40% of the total stimulus exposure time) and at grey and brown colors for more than 10% of the total stimulus exposure time. The effective means of overcoming the respondent's resistance to revealing his true attitude to the objects being evaluated is the alternation of verbal and visual components of stimulus presentation.

Keywords

Cardiometry, Cardiocode, Eyetracker, Lie detection, Psychoemotional reaction

Imprint

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Introduction

The use of such hemodynamic parameters as features of the pulse, changes in blood pressure, heart rate variability in assessing the truthfulness of human responses has a centuries-old history [1, 8, 11]. There have already been both many disappointments and encouraging achievements in this history. Nevertheless, researchers and practitioners continue seeking for opportunities to use the response of the human individual's cardiovascular system to certain stimuli

in studying his/her personality, in making personnel decisions, in various types of investigations. A successful combination of this type of diagnostics with an analysis of other manifestations in a person's desire to conceal information, supported by an intensive development of equipment and instrumentation for recording various types of human psychoemotional reactions, can vigorously contribute thereto [1-8, 11].

Significant difficulties in identifying the true attitude of a person to certain types of information by the nature of his/her psycho-physiological reactions are associated with a multi-factorial influence of various functional systems on recorded parameters. Attempts to record only one type of such responses or reactions have been found to be ineffective, so that it initiates further search for productive combinations in recording reactions and responses of different types of the human body systems. In our opinion, a serious contributor to an adequate solution of this problem can be an approach to consider the manifestations of the affect and intelligence in various psychophysiological reaction types as integral, but not identical in their nature. We assume that a bounded set of possible combinations of affective responses and permissible cognitive processes under these conditions will minimize ambiguity in interpretation of the observed reactions and, therefore, will also increase the accuracy in lie detection. As a hypothesis in our research, we have suggested that a complex assessment of a person's emotional-cognitive state, based on the cardiometric and oculographic recording of his/her responses to some specified sample materials of visual and audial modality, can be successfully used for concealed information detection. Based on our own original research [1-8, 11], we have also anticipated that for such cardiometric and oculographic recording, the estimates of the Bayevsky stress index and the respondent's gaze parameters can be effectively used.

Materials and methods

We have decided to employ single-lead cardiograph Cardiocode and portable eyetracker GP-3 as the instrumental basis for verification of our research hypothesis. This decision has been made taking into account the previous analysis of the functional features of the instrumentation and the basic potential of effectively combining the above devices [3-6, 9, 10, 13-15, 17-19], considering the availability of the equipment

and easiness in use of these instrumental techniques for a wide range of researchers and practitioners.

To verify the research hypothesis, a complete set of the relevant subtests targeted both for verbal-communication (tests Nos.1-3) and visual graphics (tests Nos.4-6) presentation of stimuli has been developed.

A classical test involving the name of the respondent (stimulus test) has been offered as the No.1 test. The symptomatic question addressing the respondent's intentions has been put in the first place. The third, fourth and fifth items have been conventional stimulus test questions such as "Are you called ... <then the examiner is usually using the name of the respondent in the form, which has been preferred by the latter before > ...?". Taking into account the results of research by S.V. Popovichev [7, 8], the control questions, involving doubt, have been used in the second and the last place in test No.1. As a result, the following questions have been included in test No.1:

1. Are you going to honestly answer the subsequent tests questions?
2. Do you doubt that when you tell a lie, it will not manifest itself in any way?
3. Are you called ... <then called has been the name, consonant with the respondent's real name, which does not cause him any significant associations, strong emotional experiences> ...?
4. Are you called ... <then the examiner is using the name of the respondent in the form, which has been preferred by the latter before> ...?
5. Are you called ... <then called has been the name, consonant with the respondent's real name, which does not cause him any significant associations, strong emotional experiences, but which differs from the No.3 question name> ...?
6. Do you doubt that when you tell a lie, it has not manifested itself in any way?

During the testing procedure, the given test has been presented four times, but with different tasks for the examinee. During the first presentation, the respondent has been asked to give truthful answers to all questions; during the second presentation the same individual has been requested to give false answers; during the third presentation the examined subject has been instructed to give answer "no" to all questions, and during the fourth presentation the same tested subject has been asked to say "yes" to all test questions. The cardiometric recording of every exam-

inee's reaction or response has been started immediately upon administering of each question.

Test No.2 has been compiled by analogy with tests of control comparison questions, which are widely used in various types of polygraphic tests [1, 7, 8, 10, 11].The following questions have been included in test No.2 after preliminary pilot studies:

1. Are you in a sitting position now?
2. Are you going to honestly answer the questions about alcohol use?
3. Are you a man?
4. Are you a woman?
5. Have you ever used alcohol?
6. Have you ever smoked?
7. Are you a student?
8. Are you an associate professor?
9. Did you ever take anything of value without authorization?
10. Have you ever been late for studies?

It has been assumed that for the majority of respondents in test No. 2, the "no" answers to questions 1, 5, 9, 10 and the "yes" answers to questions 2, 4, 6, 9 shall be their deliberate lie.

Test No. 3 has been developed using questions that are usually incorporated in a manual scoring system of the conventional psychological survey techniques. In addition, the control questions involving doubt as mentioned above have been included in the given test. As a result, the following questions have been utilized in our test No.3:

1. Do you doubt that when you tell a lie, it will not manifest itself in any way?
2. Do you never gossip?
3. Do you sometimes gossip?
4. Do you always tell the truth?
5. Do you sometimes tell untruth?
6. Are you never late?
7. Are you sometimes late?
8. Do you sometimes brag?
9. Do you never brag?
10. Do you doubt that when you were telling your lie, it has not manifested itself in any way?

It has been assumed that for the majority of respondents in test No. 3, the "no" answers to questions 1, 3, 5, 7, 8, 10 and the "yes" answers to questions 2, 4, 6, 9 shall be their deliberate lie.

Tests No.2 and 3 have been presented to each respondent four times. According to the experimental conditions, at the first time, the respondent is instruct-

ed to intentionally give an incorrect answer to each question using the "yes" or "no" variants. At the second time, he or she should give a truthful answer, using "yes" or "no" again. The opposite order of such test tasks as compared to test No. 1 has been purposefully chosen by us to reduce the respondent's resistance influence on the quality of the results obtained. At the third time, as it is the case with passing test No.1, the respondent has been instructed to give the "no" answers to all the questions. At the fourth time, he/she is requested to answer "yes" to all the questions.

Test No. 4, involving the use of the eyetracker, has contained a set of visual stimuli, when each of them has incorporated a color figure component common to all stimuli and a verbal part to be varied from one stimulus to the next.

In test No. 4, an image with its center in the form of a white field has been employed as the first stimulus. Along the edges of stimulus 1 and all subsequent stimuli from test No. 4, colored square boxes have been arranged in correspondence to the eight-color table of M. Lüscher in the printed version of the test set [16]. In test No.4 applied has been the following arrangement of the colored squares:

- along the upper edge of the screen located are squares of green, blue, yellow and red colors;
- along the lower edge placed are the squares of brown, black, grey and purple colors.

The variable part of the visual stimuli in test No. 4 has contained the following words exhibited in the center of the screen:

- stimulus 2: "truth";
- stimulus 3: "lie";
- stimulus 4: "I am sitting now.";
- stimulus 5: "I am standing now.";
- stimulus 6: "Have you ever used alcohol?";
- stimulus 7: "Have you ever smoked?";
- stimulus 8: "I am in Moscow now.";
- stimulus 9: "I am in Kostroma now.";
- stimulus 10: "I am a student.";
- stimulus 11: "I am an associate professor.";
- stimulus 12: "I am a man.";
- stimulus 13: "I am a woman.";
- stimulus 14: "I study at MGU.";
- stimulus 15: "I study at RosNOU."

We have anticipated that for the majority of respondents (undergraduate and postgraduate students from RosNOU), stimuli 4-8, 10 and 15 automatically reflect reality.

To reduce the influence of every preceding stimulus on the gazer parameters, when looking at the stimulus, which is being displayed at a given time, a masking stimulus of sky-blue color has been shown to the respondent for 5 seconds.

During the experiment, all respondents have been asked to simply view the images, automatically displayed on the screen after calibration of the eyetracker. The exposure time of each stimulus should be 20 seconds. Within this specified period of time, an ECG and a rheogram of each examinee have been recorded.

Test No. 5, also involving the use of the eyetracker, has offered a set of visual stimuli; in this case, each stimulus has a color figure component common to all stimuli and a verbal part to be varied from stimulus to stimulus. Four stimuli have been included in test No. 5, the invariable part of which (colored squares from the eight-color Lüscher test) has been the same as it is the case with test No. 4. Their variable part has incorporated the following verbal components:

stimulus 1: "I am in the past";

stimulus 2: "I am in the future";

stimulus 3: "I am in the present";

stimulus 9: "I like it".

In test No. 5, a combination of image-related and verbal components has also been employed by stimulus 8. A sentence "similar to me" typed in Font size 72 has been placed in the center of the mentioned stimulus, and four pairs of fighting animals, namely, tigers, foals, kittens and dogs, have been arranged along the edges. There has been a clear-cut distinction between an offending animal ("pursuer") and a defending animal ("victim") found in each pair demonstrated.

In addition, in test No. 5, the following stimuli have been used as visual image-type stimuli (free of any verbal component):

- stimulus 4: the image of a man at the edge of a sea cliff;

- stimulus 7: the two-row photos showing animals, looking at the viewer, who include a lion, a gorilla, a wolverine, a huski dog, a mare, a piglet, a cow and a cow elephant.

The following stimuli incorporating the verbal component only have been involved in test No. 5:

- stimulus 5: the phrase "I do preferably" placed in the center of the screen and typed in Font size 88, combined with the words "ask", "advise", "listen to" and "dispute" typed in Font size 72 in the screen corners;

- stimulus 6: the phrase "I am a man" placed in the center of the screen and typed in Font size 88, combined with the words "strong", "weak", "successful" and "unsuccessful" typed in the screen corners in Font size 72.

Similar to test No. 4, in test No. 5, between the working stimuli, a sky-blue masking stimulus has been demonstrated to the respondent for 5 seconds.

Test No.5 has been presented twice to each respondent. During the first presentation, the respondent has been asked to decide where he would "truly" desire to gaze at, and then deliberately focus his/her attention on something diametrically opposite (a fictitious variant of gaze fixation). During the second presentation, the respondent has been requested to gaze exactly where he would "truly" desire (an authentic variant of gaze fixation). The exposure time of each stimulus is 20 seconds for both variants of the testing procedure. Within this entire time span, an ECG and a rheogram of the respondent have been recorded.

257 respondents in total, aged from 18 to 38 years, who are RosNOU under- and post-graduate students in the humanities and engineering, have taken part in our experimental studies as mentioned above. Within the experimental framework, only tests Nos.1-4 have been presented to a subgroup of 102 individual; tests Nos. 4-6 have been offered to a subgroup covering 86 test subjects, and the complete set of the tests has been demonstrated to the rest of the respondents. Since the processing of the obtained data (for this purpose the "Extended version" of the STADIA 8.0 statistical software package has been applied) has not revealed statistically significant differences for the same type of tests in different groups, there is no need to treat hereinafter the above mentioned groups separately. Upon completion of a series of pilot test studies, in which the reaction recording time has been fixed for 10, 20 and 30 seconds, in order to obtain the best combination of the completeness and the adequate performance in the respondents in the main part of the study, as already noted above, their cardiometric and oculographic parameters have been recorded for 20 seconds calculated from the time of the stimulus presentation.

Results and discussion

Our analysis of the obtained data has revealed statistically significant differences in the Baevsky stress index (SI) values calculated for each stimulus between

all the paired answers, with one of which true and another false. The most noticeable differences between the truthful and false answers have been observed in case, when the answer “no” has been given as a false one. It has also been found that, in certain groups of questions, false answers caused a reaction in the respondents, which is characterized by a sharp increase in the SI value as compared to the SI value recorded for the truthful answers, and in some cases reported has been a sudden decrease in the SI parameter against that reported for the truthful answer. The use of post-test conversations, recommended as additional techniques aimed at detecting concealed information and the behavioral indicators of veracity/deception of testimony used in forensic science [1, 7, 8, 10-12], have made it possible to refine the following results.

Without exception, all cases of reporting false information have been perceived by the examinees as something unpleasant, producing their internal discomfort. At the same time, in cases when the Cardiocode device has recorded a significant increase in the SI values against those found under the truthful answers, the respondents have experienced unpleasant excitement. At such moments, involuntary hard swallowing and throat clearing, forced respiration, intensified fidgeting and involuntary movements with the hands, fingers, legs and feet and facial mimic expressions are frequently observed. Some test subjects have reported that at such moments they have experienced a state similar to a panic attack. Some of them have described this sort of states using definitions and attributes like “a desperate search for a suitable behavior pattern (response)”, “vigorous emotional turbulence”, “intense internal activity”. As a whole, all the above observed fingerprints are evidence for a pronounced sthenic affective reaction exactly to the process of reporting false information.

At the moments, when Cardiocode recorded a sharp decrease in SI, it was possible to observe some rigidity in the respondents, their pronounced decrease in movements. At such moments, our respondents often have demonstrated respiration apraxia. In these cases, as a rule, they have given their voice answers with a clear delay in time (as compared to the truthful answers to the similar questions), and very often their voice tones have been found to produce more dull and hollow sounds. Our respondents have defined their experienced states using expressions like “stupor”, “an inside self-concentration” and “longer

tensful response latency”. As opposed to the situations described above, a sharp decrease in the SI values, as a whole, has been found to be closely associated with pronounced manifestations of an asthenic affective reaction to the process of reporting false information.

Mathematical processing of the portable eyetracker data has allowed us identifying the following, essential for solving the research problem, sample averaged indicators of our test gazers, when they have surveyed various visual stimuli from test No. 4.

When respondents viewed stimulus 2 with the word “truth” framed in colored squares from the Lüscher test, they spent most of their time by examining the squares of green (26% of the total stimulus exposure time), blue (15% of the time) and yellow (11% of the total exposure time) colors. At the same time, the shortest time their gaze has been fixed at the squares of grey (4% of the total stimulus exposure time) and brown (3% of the total stimulus exposure time) colors. The transition to stimulus 3 with the word “false” in the same frame of the squares from the Lüscher test has produced a significant redistribution in the gaze fixation duration. In this case, the time of gaze fixation at the squares of green, blue and yellow colors has decreased to 5-6%, and the time of fixation at the squares of brown and grey colors has been recorded to be 13 and 7% of the total stimulus exposure time, respectively. The similar twofold redistribution of attention between the squares of green, yellow, brown and black has been also observed, when changing the stimuli with the words “I am in sitting position” to “I am in a standing position”. It is noteworthy that the gaze fixation preferably at the squares of blue and green colors, as a rule, has been reported to be accompanied by the average SI index values recorded with Cardiocode.

The appearance of sensitive uncomfortable statements on the screen such as “Have you ever smoked?” (stimulus 7) has involved a significant decrease in SI and a simultaneous increase in gaze fixation at the squares of black and grey, up to the values that have been observed when the phrase “the worst” has been displayed in the center of the stimulus.

The true phrase “I am in Moscow now” (stimulus 8) has been accompanied by the preferable gaze fixation at the squares of green (20% of the total stimulus exposure time), yellow and red colors (12% each, respectively). At the same time, the respondents (on the average) have paid no more than 3% of the time to the brown and grey squares.

The presentation of the false statement “I am in Kostroma now” (stimulus 9) in the center of the screen has resulted in a reduction in the attention to the green square to 3% of the total stimulus exposure time, and to the yellow one - to 4%. At the same time, the gaze fixation at the squares of brown and grey has increased to 9% and 11% of the time, respectively. The same pattern has been observed when changing the statement “I am a student” (stimulus 10), that is true for the participated respondents, to statement “I am an associate professor” (stimulus 11) that is false for them. In that case, the percentage of gaze fixation at the squares of grey and brown has demonstrated an increase from 2% and 1% to 8% and 9%, respectively.

A transition from one stimulus, showing the true gender of the respondent, to another, indicating the opposite gender (stimulus 12 and 13 with phrases “I am a man” and “I am a woman”, respectively) has been characterized by a considerable redistribution of the attention between the normatively accepted colors (green, blue, yellow and red) and those normatively rejected (brown, black and gray) characterized. That has been also accompanied by a multiple change in the SI values.

Similar changes have been reported when replacing the phrase “I study at MGU” (stimulus 14) with another “I study at RosNOU” (stimulus 15). Thus, the response to stimulus 14, which contains the false statement, has been detected as the preferred fixation of the respondents' gaze at the squares of brown (29% of the total stimulus exposure time), black (19% of the time) and purple (16% of the total stimulus exposure time) colors. When the true statement has been presented (stimulus 15), 27% of the time of the respondents' gaze has been devoted to the green square and 12% of the total stimulus exposure time to the yellow one, respectively. At the same time, the respondents have paid greatest 2% of the time to the brown and purple square and no more than 1% of the total stimulus exposure time to the black square (on the average).

The gaze parameters, traced by the eyetracker at the first presentation of the stimuli from test No. 5 (the fictitious variant of gaze fixation), have statistically significant differences from those recorded at the second presentation of the stimuli of the same test (the authentic variant of gaze fixation). A descriptive exemplary case of such differences may be the data on the averaged indicators of gaze fixation at various regions of the stimulus, when each of which has a color

figure component, as mentioned above, common to all of them, and a verbal component, varying from stimulus to stimulus (stimulus 1, 2, 3 and 9, when the variable components of which are phrases “I am in the past”, “I am in the future”, “I am in the present” and “I like it”, respectively) are offered. The distribution of the gaze parameters for these stimuli is presented in Table 1 herein.

In Table 1, the squares of the following colors correspond to the numerical designations of the stimulus fragments as listed below: No. 1 is referred to green, No. 2 is referred to blue, No. 3 is referred to yellow, No. 4 is referred to red, No. 5 is referred to yellow, No. 6 is referred to purple, No. 7 is referred to black and No. 8 is referred to brown. Variant 1 (Var.1) in the Table corresponds to the gaze parameters at the first presentation of Test No. 5, when, according to the instructions received from the examiner, the choice by the respondent shall be deliberately fictitious. Variant 2 (Var.2) in the Table corresponds to the gaze parameters at the second presentation of Test No. 5, when, according to the instructions received from the examiner, the choice by the respondent shall be authentic.

The subsequent correlation and factor analysis of the obtained data has revealed a slight, but statistically significant, inverse relationship between the SI values and the duration of the respondents' gaze fixation at the green and blue square boxes in the Test No. 5 visual stimuli. Using the Spearman correlation coefficient, a slight, but statistically significant, direct relationship has been also found between the heart rate (HR) and the gaze fixation duration at dangerous areas of stimulus 4, incorporated a picture showing a person on a cliff top. Using the Kendall coefficient of concordance, a statistically significant relationship has been detected between the HR values and the gaze fixation duration at the “dispute” fragment in stimulus 5, as well as between the gaze fixation duration at the “successful” fragment in stimulus 6 and the SI and HR values recorded during the demonstration of this stimulus. It has been also established that the above noted statistically significant differences in cardiometric parameters for all pairs of the same stimuli, without exception, at the first (fictitious gaze fixation) and second (authentic gaze fixation) variants of their presentation have been identified for the Baevsky stress index (SI) only. Similar statistically significant differences have not been revealed for the heart rate, when using the

Table 1. Distribution of the gaze fixation duration between various fragments of visual-verbal stimuli in Test No. 5

Stimulus No. and Test Variant	Specific fixation duration as % referred to the total exposure time							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
No. 1, Var. 1	9	6	9	7	9	9	17	11
No. 1, Var. 2	10	10	12	10	12	14	14	11
No. 2, Var. 1	5	6	6	6	9	15	18	21
No. 2, Var. 2	12	17	13	17	4	8	5	3
No. 3, Var. 1	4	4	10	4	13	15	17	19
No. 3, Var. 2	20	13	13	10	6	14	6	5
No. 4, Var. 1	6	8	9	5	12	7	16	18
No. 4, Var. 2	13	12	13	13	8	5	7	4

Table 2. The main statistical parameters of the SI values delivered in Test No.5

Stimulus	Arithmetic mean for the SI values		Standard deviation	
	First presentation	Second presentation	First presentation	Second presentation
Stimulus 1	316	280	246	257
Stimulus 2	338	289	225	211
Stimulus 3	368	285	349	246
Stimulus 4	374	275	293	242
Stimulus 5	341	296	264	247
Stimulus 6	324	304	239	225
Stimulus 7	361	356	372	317
Stimulus 8	314	303	256	210
Stimulus 9	329	258	230	180

Table 2 shows the main statistical parameters of the SI values, obtained by the Cardiocode device, when the respondents have completed Test No.5.

same estimation methods (in our case, using the Chi-square test with the Bonferroni correction).

Conclusions

1. A combination of the average Baevsky stress index values (SI), the primarily involuntary fixation of the examinee's attention at the Lüscher test main colors (first and foremost to green and yellow), the examinee's peaceful posture & tonus and facial expression reactions to the presented stimuli in the absence of forced respiration or respiration suppression can be judged to be the evidence for the truthfulness of the reported information.
2. To increase the efficiency of the concealed information detection, it is reasonable to separate the asthenic and sthenic variants of the involuntary manifestation of the respondent's fears of the detection of information concealed by him. The fear of revealing the information, which disables the re-

spondent's activity, is an asthenic variant of his/her response, and it manifests itself in a sharp decrease in the SI values against those recorded in case of neutral stimuli. Such decrease is usually combined with an involuntary fixation of the examinee's attention at the normatively rejected colors of the Lüscher test (primarily brown, black and grey), accompanied by a stiff posture, gestures inconsistent with the situation, and disorders in the respiration rhythm (involuntary sighing, appearance of delayed exhale of breath and so on). The fear, which results in a hectic internal activation of the cognitive and affective processes, being the sthenic variant of the response, appears as a sharp increase in the SI values against those recorded in case of presentation of the neutral stimuli. This sort of activations is usually combined with an involuntary preferable fixation by the examinee's attention either at black and red, or red and brown, or yellow and black, or yellow and brown col-

ors of the Lüscher test. Complementary fingerprints of such response are involuntary abrupt (cramping) movements of the respondent, eloquent and quickly changing facial expressions, an increased rate of respiration, interrupted breathing and respiration arrhythmia in the respondent.

3. The informative markers of the subject's desire to conceal information are any significant deviations in the Bayevsky stress index (SI) values from the SI averages. When using eyetrackers to present the visual stimuli with elements of the eight-color Lüscher test, the above SI fluctuations are usually combined with a sharp increase in the duration of the respondent's gaze fixation at the stimulus verbal components (usually more than 40% of the total stimulus exposure time) and an increase in the percentage of the gaze fixation at the grey and brown colors by more than 10% of the total stimulus exposure time.

4. An effective way to overcome the respondent's resistance to revealing his/her true attitude to the objects being evaluated is an alternation of verbal and visual components within the stimulus presentation session. As to the verbal part of the tests, the best calibration comparison questions are the questions, the "no" answers to which should be intentionally given false. With regard to the visual part of the tests, along with the use of hemodynamic recorders of the Cardiocode type and the eyetrackers, the effectiveness of concealed information detection can be improved by alternating stimuli with various combinations of image- and text-related fragments. A particularly noticeable increase in the accuracy of determining the associative relation between the image fragments of a stimulus and its verbal components is achieved by a repeated, shortened in time, presentation of the same image elements without any test.

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. A.A.T., D.S.Y.

P.A.M. and N.V.M. carried out the experiments and prepared the manuscript. 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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