Psychophysiological Response Dynamics to Visual Stimuli Depending on Presentation Period

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Abstract: *Study of temporal dependences for the psychophysiological state parameters on the period of visual stimuli presentation, synchronicity of visual stimuli presentation in relation to chronobiological processes and vibraimage accumulation time were carried out. The patterns of the presentation period influence of visual stimuli on psychophysiological parameters measured by the adaptive vibraimage system (VibraNLP) were revealed. Proved that the decrease in the period of visual stimuli presentation from 15 to 5 seconds insignificantly affects the accuracy of a subject's predisposition determining to the investigated factor score. Shown that synchronization of visual stimuli presentation relative to the ongoing chronobiological processes affects the change in psychophysiological parameters. Proposed to use developed methodology of psychophysiological testing in high-speed security systems to control subject hostile intent in technical profiling systems during 60 seconds testing of 100% passengers in airports.*

Keywords: *vibraimage, psychophysiology, visual stimuli, dynamics, psychophysiological state, PPS, profiling, VibraNLP.*

Introduction

A significant number of periodical journals on psychophysiology are published annually in the world, such as Psychophysiology (Wiley), International Journal of Psychophysiology (Elsevier), Journal of Psychophysiology (Hogrefe), etc. The number of scientific publications with the keyword psychophysiology in Google Scholar is (at the time of this writing) 846,000 and is approaching to million. Textbooks on psychophysiology are periodically republished (Cacioppo et al., 2007; Danilova, 2012). At the same time, I am not aware of scientific publications and studies where you can find a clear answer to relatively simple questions from the field of psychophysiology — how does a person react to repeated presentation of a complex or simple visual stimulus? How does the dynamics of psychophysiological response (PPR) change when the period of visual stimuli presentation changes? Although such attempts were made earlier, for example, created by Levin dynamic theory of personality (Levin, 1935). In metrology, one of the main accuracy criteria (Minkin, 2019) is the reproducibility of measurement results and it cannot be evaluated without repeated measurements.

However, in psychophysiology, the presentation of the same stimulus understandably leads to different responses of a subject, because the primary presentation of the stimulus, changes the psychophysiological state (PPS) of the subject (Pinto et al., 2020), and the processes of habituation and learning take place. Thus, repeated presentation of the same stimulus occurs to the same subject, but in a slightly different PPS. This effect was noted

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by ancient Greek philosopher Heraclitus, who said "everything flows and everything changes", and "you cannot enter the same river twice" (Plato, 1990). The presence of such variability in a person should not stop researchers in the field of psychophysiology especially since obtaining reproducible information about PPR dynamics have great practical importance for reducing the testing time and increasing the accuracy of the result.

The aim of this work is to measure the dynamics of the psychophysiological response upon repeated presentation of complex stimuli with different periods of presentation and to identify patterns that improve the accuracy of the subject's predisposition detection to the investigated factor under in a minimum testing time.

Materials and Methods

A psychophysiological study of 10 people (6 men and 4 women, age from 20 to 65 years old, all of the Caucasian race) was carried out using vibraimage technology (Minkin, 2007; 2020; Minkin, Nikolaenko, 2008) by VibraNLP program (Minkin and Nikolaenko, 2020) with various settings. VibraNLP program with the standard LOf15 questionnaire includes 12 presented stimuli in the pretesting stage of multiple intelligences (MI) analysis of a subject (Gardner, 1983; Minkin and Nikolaenko, 2017) and 12 presented multifactorial stimuli on basic testing stage. Moreover, each neutral stimulus from MI testing has 6 close analogs, which are presented in a random order. In total, VibraNLP program contains $12 \times 6 = 72$ neutral stimuli and $12 \times 6 = 72$ multifactorial stimuli (24 stimuli in each test). The subject sequentially passed 18 tests with different settings (3 settings for the presentation period, 2 settings for the start of the start, 3 settings for different integration times of psychophysiological parameters).

The total time for person passing 18 tests averaged 2 hours, the tests differed in total time, since test with a 5 second period of external stimuli presentation (PESP) was about $5 \times 24 = 120$ seconds, with PESP = 10 second, respectively — $10 \times 24 = 240$ seconds, with PESP = 15 second, respectively — $15 \times 24 = 360$ seconds. All tests with the VibraNLP program were performed with feedback when measuring the current PPS of the subjects, and the presentation of stimuli began at the moment (more precisely, after 3 seconds) when the PPS passed the minimum (Min) or maximum (Max) position on the time axis.

The investigated factor in the questionnaire used was the subject's predisposition to terrorism or investigated factor score (IFC); accordingly, multifactorial stimuli (combining factors of MI and terrorism) were aimed at identifying a predisposition to terrorist activity and consisted of questions and photographs (Nikolaenko, 2020).

Results

Dependence of the PPR desynchronization relative to the presented stimuli

Figure 1 shows the histogram of PPR dependence to desynchronization parameter (measured in seconds) relative to the presented stimuli for the selected settings of psychophysiological testing. The desynchronization parameter is defined as the modulus of the time difference between the onset of stimulus presentation and the change in the direction of the PPS dynamics (Minkin, 2017; Minkin & Myasnikova, 2018), since the change in the direction of the PPS can be both ahead and delayed from the moment of stimulus presentation. The parameter of desynchronization is measured separately for the first and second half of the test, since neutral (MI) and multifactorial stimuli can have different effects on the subject.

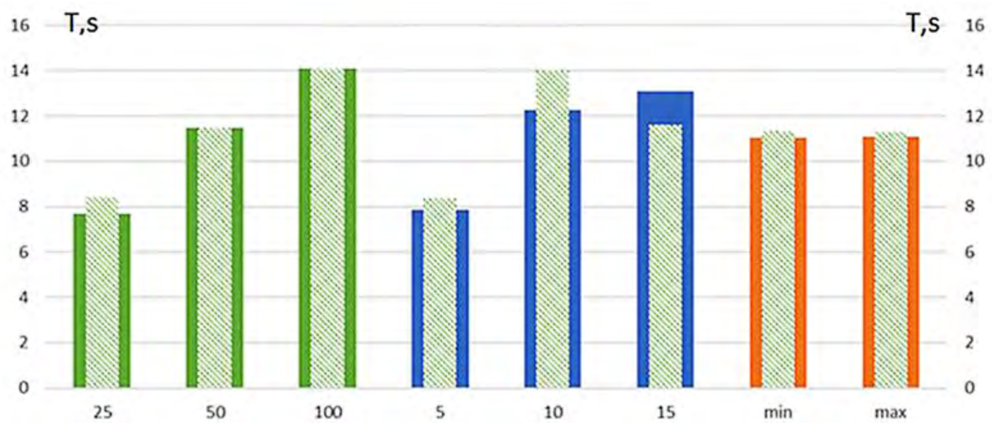

Fig. 1. *Dependence of PPR desynchronization parameter relative to the presented stimuli for Neutral stimuli (external column of the histogram) and Multifactorial stimuli (internal column of the histogram). The horizontal axis shows testing settings (from left to right): N = 25; 50; 100 — the number of accumulation frames for interframe difference. PESP = 5; 10; 15. Min-Max — testing start from minimum or maximum PPS value. Mean values of desynchronization parameter obtained for 24 stimuli of 10 subjects (180 tests) are given*

The data on Figure 1 showed both expected results and rather unexpected ones. As expected, a direct relationship was revealed between the PPR delays and the time of PPS accumulation. Relatively unexpectedly, the dependence of the delay on PEPS is complex.

PPR synchronicity dependence on the number of accumulation frames N = 25; 50; 100

An increase in the desynchronization time with an increase in the accumulation of the interframe difference is quite obvious, since the integration of the accumulated information about human movements leads to a slowdown in the response of vibraimage system to the recorded change in PPS. Pay attention to the obtained absolute values of the desynchronization, which are approximately 8 seconds for 25 accumulations of the interframe difference. The resulting 8 seconds fall on 12 presented stimuli, which means an average delay or, on the contrary, an early transition (hereinafter the backlash time) of a state change approximately in the range of about 0.67 seconds for each stimulus.

For 50 accumulations of interframe difference, the desynchronization time approaches the integral 12 seconds, or 1 second for each stimulus.

For 100 accumulations of interframe difference, the desynchronization time approaches an integral 14 seconds, or 1.17 seconds per stimulus.

Note also that the difference between the columns of pretesting and basic testing is observed only for the minimum number of frame accumulation, N = 25 frames.

Dependence of PPR synchronicity on PESP = 5; 10; 15 s

In contrast to the monotonous and identical dependence obtained for different accumulation times, the change in PESP has a different type of dependence for neutral and multifactorial stimuli.

The dependence of desynchronization time of neutral stimuli on the period is close to the dependence on the accumulation frames (PESP increase leads to the increase in PPS desynchronization time).

For multifactorial stimuli, desynchronization time has a maximum at PESP = 10 seconds and decreases with an increase PESP = 15 seconds. The minimum desynchronization time between the stimulus and the response to it turned out to be at the minimum value of PESP.

PPR synchronicity dependence on the moment of stimuli start (min, max)

Figure 1 does not show significant changes in stimulus-response synchronization from the minimum or maximum PPS value at the beginning of testing. Despite the well-known processes of homeostasis and homeokinesis (Novoseltsev, 1978; Cacioppo et al., 2007), the synchronization of psychophysiological testing with internal chronobiological processes (Halberg, 1987) in the human body was not previously used in psychophysiological studies, probably due to for the difficulty of tracking the current PPS in real time. Vibraimage technology allows determining the PPS of a person and tracking its changes in real time, using various axes and coordinates (Minkin, 2017). The lack of synchronization between the stimulus and internal chronobiological processes leads to the need to repeat the presented stimuli many times (Drayton, 2009; Baur, 2006), since only the average estimate can be taken into account if the measured value changes significantly during the measurement (Novitsky, 1975). If vibraimage systems of the first and second generation (Minkin, 2021a), like other psychophysiological systems, did not use information about the subject's current PPS, and measurements were started at a random moment, then the VibraNLP system, depending on the selected settings, allows to start measuring in several positions of brain activity rhythm (Mnkin & Blank, 2019). At the maximum (more precisely, after 3 seconds of passing the maximum), at the minimum (after 3 seconds of passing the minimum) or at a random point of psychophysiological activity. Despite the fact that the synchronization of the measurement start to the minimum and maximum did not affect the amount of PPR desynchronization relative to the stimuli, we will consider the effect of the moment of the start of stimulus presentation on other characteristics of the PPS in the further sections of this work.

Dependence of information and energy components of PPS relative to the settings

Figure 2 shows a histogram dependence of information and energy components of PPS relative to the testing settings.

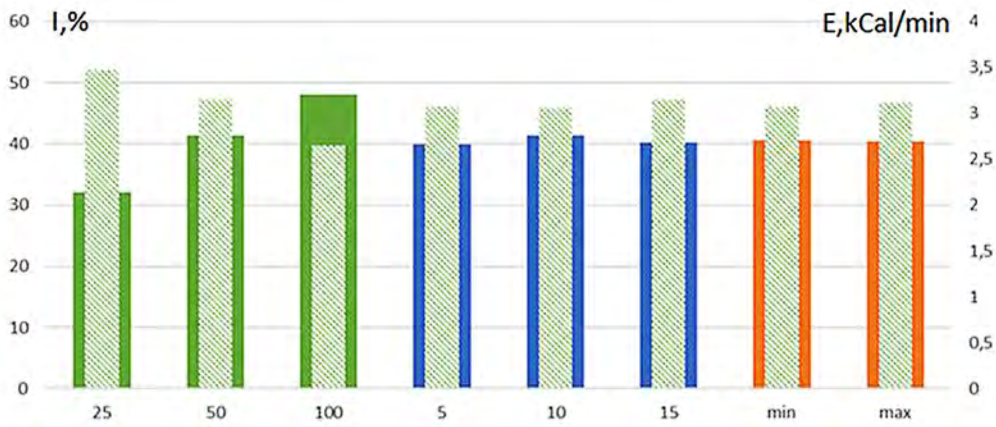

Fig. 2. *Dependence of the information (I) and energy (E) components of the PPS relative to the testing settings. Information component (external column) and energy component (internal column). The horizontal axis shows testing settings (from left to right): N = 25; 50; 100 — the number of accumulation frames for interframe difference. PESP = 5; 10; 15. Min-Max — testing start from minimum or maximum PPS value. Mean values of desynchronization parameter obtained for 24 stimuli of 10 subjects (180 tests) are given*

From the histogram shown in Figure 2 follows that the information and energy components of the PPS (Minkin, 2017; 2020) showed invariance to all settings used except for the number of frames for accumulating the interframe difference. The information component of the PPS turned out to be proportional to the number of accumulation frames, while the energy component was inversely proportional to the number of accumulation frames.

Dependence of BAP and IFS relative to the testing settings

Figure 3 shows a histogram of the dependence of brain activity period (BAP) and investigated factor score (IFS) relative to the testing parameters.

The group of subjects consisted of law-abiding citizens with no criminal record and unnoticed in political and terrorist activities. Therefore, IFS (Minkin, 2021b) (predisposition to terrorism) should be as high as possible and approaching score 5 for optimal settings of the psychophysiological testing method (5 — no predisposition to the factor, 0 — maximum dependence or predisposition to the factor under study). It is interesting to note the following revealed tendencies in the dependence of factor estimates on the study settings. The maximum IFS = 4.17 was detected for the start of testing upon presentation of stimuli with a period of 5 seconds (5). The minimum value of IFS = 4.16 and was obtained with a 10 second period of stimulus presentation. At the same time, there was a clear dependence of the factor assessment also on the start time. When stimuli are presented from the minimum point of the PPS, the higher IFS = 4.13, and when stimuli are presented from the maximum point of the PPS, the lower IFS = 3.8.

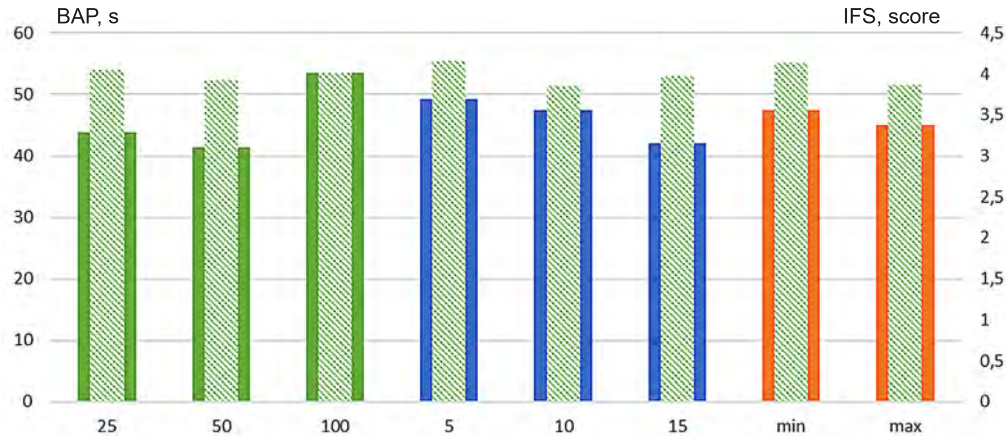

Fig. 3. *Histogram of BAP (external column) and IFS (internal column) relative to testing settings. The horizontal axis shows testing settings (from left to right): N = 25; 50; 100 — the number of accumulation frames for interframe difference. PESP = 5; 10; 15. Min-Max — testing start from minimum or maximum PPS value. Mean values of desynchronization parameter obtained for 24 stimuli of 10 subjects (180 tests) are given*

The maximum BAP value turned out to be at setting N = 100 and was 54.4 seconds. The minimum value of BAP was obtained when setting N = 50 accumulations of the interframe difference and was 41.4 seconds.

Note that the BAP turned out to be inversely proportional to the period of presentation of stimuli, although it did not show limiting values in the study.

The mathematical description of IFS shown in Figure 3 for the classical differential assessment of the psychophysiological response to paired stimuli is given in the work (Minkin, 2021b) presented at this conference.

Discussion

At the beginning of results discussion, note a noticeable scatter in PPR during the passage of this study, determined by various psychological types and age indicators of the subjects. To assess the parameters deviation, see Table 1, which shows not only the average values of psychophysiological parameters presented on previous Figures, but also the standard deviation (SD) for each parameter.

Starting analyzing the data from Table 1 from the final result or IFS in the right column, we see that the maximum estimate with the minimum spread (M-SD) was obtained when testing on PESP = 5. The second higher IFS is at the beginning of stimulus presentation from the minimum PPS point. Considering IFS maximum, as a confirmed fact that the subjects did not have a predisposition to terrorism, means that testing with a PESP = 5, synchronously tied to the minimum PPS point, gives a noticeably more adequate and accurate result than the start, synchronously tied to the maximum point of the PPS, as well as to other periods of stimulus presentation.

Table 1

Average values of psychophysiological parameters (M) and standard deviation (SD) of parameters for carried out groups of measurements for different settings

M / SD	[1-24]	[1-12]	[13-24]	avgI	avgE	FFT max	Final result
25	15,99 / 5,02	7,65 / 2,72	8,34 / 3,06	32,30 / 7,60	3,45 / 0,70	43,78 / 21,87	4,05 / 1,00
50	22,97 / 7,15	11,48 / 4,52	11,49 / 4,38	41,42 / 5,36	3,15 / 0,70	41,44 / 19,19	3,93 / 0,90
100	29,32 / 12,36	14,60 / 6,59	14,72 / 7,92	47,96 / 9,39	2,64 / 0,70	53,52 / 28,15	4,02 / 0,75
5	16,16 / 5,18	7,83 / 2,98	8,32 / 3,01	40,14 / 9,21	3,05 / 0,73	49,31 / 30,77	4,17 / 0,78
10	26,98 / 8,90	12,51 / 5,00	14,47 / 6,08	41,40 / 10,53	3,04 / 0,76	47,40 / 20,02	3,85 / 0,95
15	25,15 / 12,05	13,39 / 6,62	11,76 / 6,83	40,15 / 10,19	3,15 / 0,82	42,03 / 18,62	3,98 / 0,89
min	22,64 / 11,03	11,12 / 5,34	11,51 / 7,02	40,60 / 9,78	3,06 / 0,77	47,41 / 26,66	4,13 / 0,85
max	22,88 / 9,49	11,37 / 5,91	11,52 / 4,99	40,52 / 10,17	3,10 / 0,77	45,08 / 20,70	3,87 / 0,90

The test is structured in such a way that the first 12 stimulus questions refer to neutral stimuli, and the next 12 stimulus questions identify the response to the factor stimulus. Moreover, the processing takes place both between pairs of neutral and multifactorial stimuli, and for all neutral against all multifactorial ones. When the interframe difference is accumulated over 100 frames, PPS is integrated in 20 seconds, which significantly exceeds the time of presentation of single stimuli with a 5–10-second presentation, however, 100 frames accumulation gives high IFS.

The fact is that, although such a blurring of the reaction makes it difficult to accurately assess of multifactorial stimuli, it better conveys the subject’s impression of neutral and multifactorial stimuli. The addition of reactions occurs at the internal level of vibraimage technology, while the presentation of the shortest 5-second stimuli only enhances the influence of the unconscious attitude to the test subject. It was noted that the PPS of a subject significantly depends on his speed of reaction to stimuli, and irrelevant and relevant stimuli can affect changes in the PPS rhythm and the speed of reaction to stimuli in different ways.

The significant scatter of the measured psychophysiological parameters in Table 1 is caused not only by the individual characteristics of the subjects, but also by the method of averaging the results used in table 1 and when constructing histograms in Figures 1–3.

The presented results combine the values of psychophysiological parameters measured at different settings of vibraimage systems. For example, on Figure 1, the leftmost column N = 25 shows the average value of the stimulus-PPR desynchronization obtained during measurements with different stimulus presentation periods T = 5, 10, 15 seconds, as well as when the stimuli start from the minimum and maximum positions of PPS.

Naturally, such a combination of various settings, most likely, reduces the significance of the recorded changes. But if, even with such a combination of different settings, the difference in values is visually noticeable, then this was the subject of further research described in subsequent works (Minkin, 2021b; Minkin & Blank; 2021), also presented at this conference. For example, the difference between IFS (Fig. 3) estimates at the start of stimuli from the minimum and maximum PPS values, is only 0.27 scores. While in the work (Minkin, 2021b) it is shown that for fixed values of settings (max_25_5; min_25_5) this difference is already 1.6 points (3.7 — max; 4.3 — min).

Figure 4 shows an example of the time dependence of psychophysiological signals in response to neutral stimuli recorded by VibraNLP program upon presentation of the LOf05_NLP questionnaire with a pronounced sinusoidal response of the subject to paired stimuli.

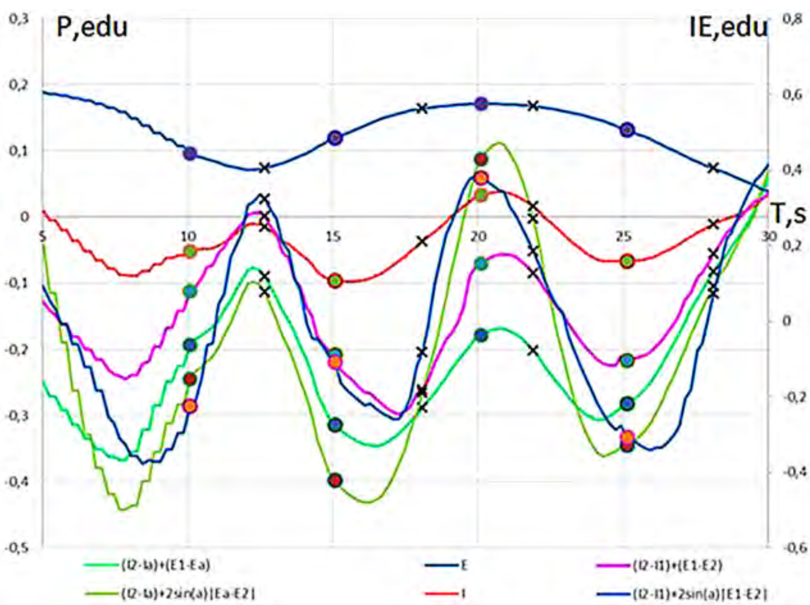

Fig. 4. PPS calculation by various equations. PPR for neutral stimuli. Point mark indicates the moment of stimuli presentation, a cross indicates the response time to a stimulus. PESP = 5 seconds. VibraNLP program, LOf05_NLP questionnaire, file M, IEP page

From Figure 4, it follows that various calculations of the current PPS, determined on the basis of the information and energy components of the PPS, may differ slightly in level, but the general trend of the PPS change slightly changes from used equations, shown in the right side of Figure 4.

Figure 5 shows the transition from neutral stimuli to multifactorial ones and the change in PPS during the entire test, the beginning of which shown on Figure 4. The transition is characterized by a significant decrease in the amplitude of the PPS changes, a person becomes more tense upon presentation of multifactoreal stimuli.

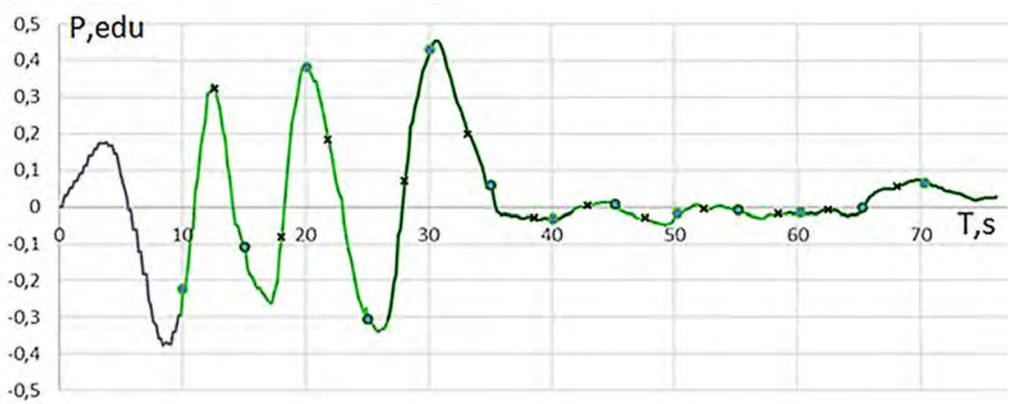

Fig. 5. *Time dependence of PPS during testing with 12 stimuli questionnaire LOf05_NLP. Point mark indicates the moment of presentation of stimuli, a cross indicates the response time to a stimulus. PESP = 5 seconds. VibraNLP program, file M, page IEG*

Fourier spectrum of the PPS during testing the subject with the detailed dynamics shown in Figures 4 and 5 is shown in Figure 6.

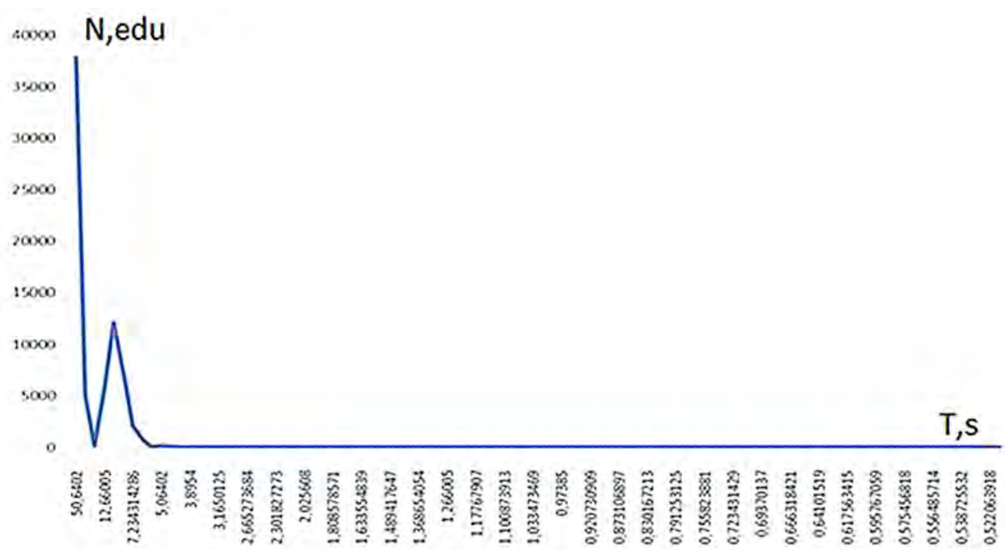

Fig. 6. *Fourier spectrogram of the PPS during testing. PESP = 5 seconds. VibraNLP program, file M, page FFT*

The local maximum on the spectrogram (10 s) in Figure 6 approximately coincides with the doubled PESP = 5. It follows from Figures 4 and 5 that the subject (woman, 39 years old) has a good reaction and manages to answer questions a couple of seconds before the end of the stimulus presentation, which not all subjects were able to do when the stimuli were presented for 5 seconds. Sometimes the subjects did not have time to answer the presented question in time. The lack of an answer to the stimulus question does not affect the calculation of the result according to the developed methodology of VibraNLP program, since the result is determined precisely by the psychophysiological response to the stimulus, and not by the conscious response to it.

It turns out a relatively paradoxical thing, in order to identify the subject's correct response to stimuli, it is necessary to turn off the subject's consciousness, then the unconscious response more adequately reveals the subject's true attitude to stimuli. Moreover, for this it is not necessary to present stimuli in a latent form, such as 25-frame technology (Loftus & Klinger, 1992); it is enough to minimize the time of stimulus presentation to 5 seconds and offer the correct sequence of stimuli and coordinated processing.

Initially, it was planned to conduct a series of experiments for each subject with a lack of synchronization between the presentation of stimuli and the change in PPS. Moreover, this mode presents in VibraNLP program. However, testing the subject in the current mode takes 18 psychophysiological tests, lasts about 2 hours, which leads to noticeable fatigue of the subject. The addition of 9 more tests in the absence of synchronization increased the testing time by another hour, which led to an even more noticeable change in PPS relative to the beginning of testing and distortion of the results. Therefore, in this study, I decided to abandon testing without synchronization, especially since such testing was repeatedly carried out by second-generation vibraimage systems and their results were described in sufficient detail earlier (Minkin, 2020).

Obtained results allow looking optimistically at the possibility of conducting short tests with the presentation of a significant number of stimuli. For example, 12 stimuli in 60 seconds are able to reveal the latent hostile intentions of a subject, which will allow using the developed technology in security systems and providing 100% passenger's control of arrivals at airports or at state borders.

The developed VibraNLP program is publicly available on the Psymaker website (psymaker.com) and allows everyone to conduct their own research, including creating their own questionnaires and incentives.

The studies carried out in this work have shown general tendencies in the dynamics of the psychophysiological responses of the subjects to the stimuli presented. Moreover, I deliberately mixed different settings in one study to show that it is impossible to consider the result without reference to the method and the settings of vibraimage system. It was shown that the settings of the accumulated frames N = 25; 50; 100 in vibraimage system significantly affect the results. As well as external conditions, first, PESP = 5; 10; 15 s has also significant impact on the results. In addition, the synchronization of stimulus presentation with chronobiological processes and the onset of stimulus presentation have a significant effect on the result obtained. On the one hand, such a number of multidimensional dependencies in vibraimage technology from various factors complicates research for non-specialists, however, understanding the ongoing technical and psychophysiological processes allows one to achieve an unambiguous result that is unattainable for other psychophysiological detection technologies.

Thus, this work outlined the most promising areas of research, more fully disclosed in further works, also presented at this conference on synchronizing stimulus information with chronobiological processes (Minkin & Blank, 2021) and minimizing the period of external stimuli presentation at optimal fixed settings (Minkin, 2021b).

Conclusion

The studies of PPR dynamics of the subjects to various stimuli (insignificant-irrelevant-neutral, significant-relevant-multifactorial) showed noticeable changes from PESP. The proposed method of adaptive testing with the selection of individual stimuli for each subject has shown its effectiveness in studies with multiple presentation of similar and different stimuli.

The results shown insignificant changes in the accuracy of IFS predisposition detection (predisposition to terrorism) with a decrease in PESP from 15 to 5 seconds during adaptive testing by pretesting and basic testing.

Probably, the accuracy and stability of predisposition detection to investigated factor (predisposition to terrorism) increases with the introduction of biofeedback (synchronization of the presentation of stimuli with a chronobiological process — BAP) and the start of testing at the lowest point of the current PPS. The results of psychophysiological testing accuracy with a decrease in PESP from 15 to 5 seconds should be checked with fixed settings and is worthy of separate study. It may be necessary to develop special algorithms to improve the accuracy for presenting stimuli with a minimum period. Since vibraimage technology based on the processing of big data, each result obtained should be considered in direct connection with a specific algorithm and settings, it this case it would be transparent and repeatable.

Based on this study, it was decided to conduct the additional studies of IFS dependence on stimuli start moment and PESP with the fixed settings of vibraimage system (Minkin, 2021b) and the relationship between chronobiological processes and PPR (Minkin & Blank, 2021). These papers also presented on VIBRA2021 conference.

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