Telemedicine and psychocorrection: a new paradigm through healthcare data processing innovations*

Dmytro Vakulenko[1,†], Olena Hevko[2,*,†], Liudmyla Vakulenko[3,†], Irina Smachylo[1,†] and Zoryana Kocherga[4,†]

[1] I.Horbachevsky Ternopil National Medical University, 1 MaidanVoli, Ternopil, 46001, Ukraine
[2] Ternopil Ivan Puluj National Technical University, 56, Ruska Street, Ternopil, 46001, Ukraine
[3] Ternopil Volodymyr Hnatiuk National Pedagogical University, Ukraine
[4] Ivano-Frankivsk National Medical University, Ukraine

Abstract

The authors have proposed a new approach for the creation of a telemedicine psycho-rehabilitation system, considering various methods of assessing stress responses. The methodology is developed based on the "Oranta-MIS" information system. The presented research will enable a comprehensive assessment of physiological imbalances caused by stress and their correction through the use of a feedback system.
The authors demonstrate the effectiveness of heart rate variability assessment, particularly its time and spectral characteristics, for stress diagnosis and the possibility of selecting these parameters using the arterial oscillography method. This takes into account the balance between sympathetic and parasympathetic activity and morphological characteristics. Experimental research has shown changes in indicators calculated using time and spectral analysis methods of oscillograms during stress and the possibility of their correction through video images included in the multimedia environment "Oranta-MIS". The proposed telemetric system for oscillogram selection allows for remote analysis. However, considering the literature data, new promising possibilities for creating a new telemetric system are shown, which would be able to perform a comprehensive stress assessment based on subjective examination, basic functional diagnostic methods, and laboratory data, thus relying on a multifaceted assessment of stress markers. This approach will make the diagnostic capability more informative, with the possibility of remote monitoring of relevant indicators.
The developed software will enable the telemetric system not only to detect stress but also its predictors, becoming a new starting platform for the possibility of correcting mental and functional imbalances remotely in real-time. As a therapeutic intervention, it is proposed to use a psychocorrective multimedia environment based on the "Oranta-MIS" information system.
Thus, the proposed comprehensive telemedicine system will be able to detect stress, monitor it by tracking stress markers, and simultaneously correct the patient's condition, making it effective and convenient in everyday life.

Keywords

arterial oscillography method, heart rate variability, stress, stress markers, telemedicine system, psychorelaxation, cortisol, myography, electroencephalography, spirography, skin conductivity

1. Introduction

Stress disrupts homeostasis and contributes to the development of various somatic and mental illnesses, negatively impacting cognitive functions of the brain [1-6] and the state of the cardiovascular system. The most common consequences are anxiety disorders and depression. Accurate and optimized monitoring of stress indicators and the ability to manage them are priority tasks in medicine, yet they remain debatable. Today, especially in wartime conditions, economically efficient and easy-to-use devices that can track and potentially correct stress levels remotely are of particular importance. Since stressors cause various biological reactions, the search

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[1*] Corresponding author.
[†] These authors contributed equally.
dmitro_v@ukr.net (D. Vakulenko); gevkolenka@gmail.com (O. Hevko); vakulenko3@ukr.net (L. Vakulenko); smachylo@tdmu.edu.ua (I. Smachylo); zkocherga@ifnmu.edu.ua (Z. Kocherga)
0000-0001-5062-9278 (D. Vakulenko); 0000-0003-1427-1699 (O. Hevko); 0000-0002-4723-3747 (L. Vakulenko); 0000-0003-4323-8628 (I. Smachylo); 0000-0003-0964-8463 (Z. Kocherga)

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for stress markers that can be monitored remotely is becoming increasingly relevant. The key pathogenetic links that immediately respond to stress factors are considered to be the hypothalamic-pituitary-adrenal axis and the autonomic nervous system. They play a major role both as the most sensitive elements in response to stress and in monitoring the dynamics of stress reactions. Moreover, the integration of telemetric devices into medicine is gaining momentum, and remote management of psychological states is already a reality today [4, 7, 8, 44]. However, modern telemetric systems need improvement, increased informativeness, and enhanced ease of use. A dominant factor remains non-invasiveness. Therefore, the goal of our approach to the timely detection and correction of stress is to create a comprehensive psycho-rehabilitation telemedicine system based on the general algorithms presented below.

There are systems for diagnosing stress based on single indicators, whether laboratory or physiological. However, as with the comprehensive diagnosis of any disease, stress also requires both subjective and objective assessments. Subjective assessment of stress can be effectively monitored remotely through interviews and questionnaires. While interviews require the involvement of a psychotherapist, questionnaires can be independently analyzed by an automated system. For this, the patient only needs to determine which types of stress, by duration, should be surveyed. There are structured questionnaires that cover the assessment of stress over a long period, but there are also more time-limited ones. For example, the most commonly used is the Perceived Stress Scale (PSS) by S. Cohen, which was utilized at the beginning of the war in Ukraine for an online survey of Ukrainians [9]. Other informative tools include the Stress Overload Scale (SOS) and the Ecological Momentary Assessment (EMA) method. Since S. Cohen's scale is simple, accessible, and takes only a few minutes to complete, diagnosing the current stress state, it is advisable to prioritize its use. For chronic stress assessment, the Trier Inventory of Chronic Stress (TICS) [10], Ecological Momentary Assessment (EMA), and Stress Symptoms Inventory (SSI) are appropriate. The TICS questionnaire considers six aspects of chronic stress, including work, social factors, and intrusive memories. The EMA test allows for the assessment of behavior in everyday activities. Therefore, by conducting telemetric surveys, it is possible to target the patient with a differentiated approach (Figure 1) to the selection of questionnaires included in the database.

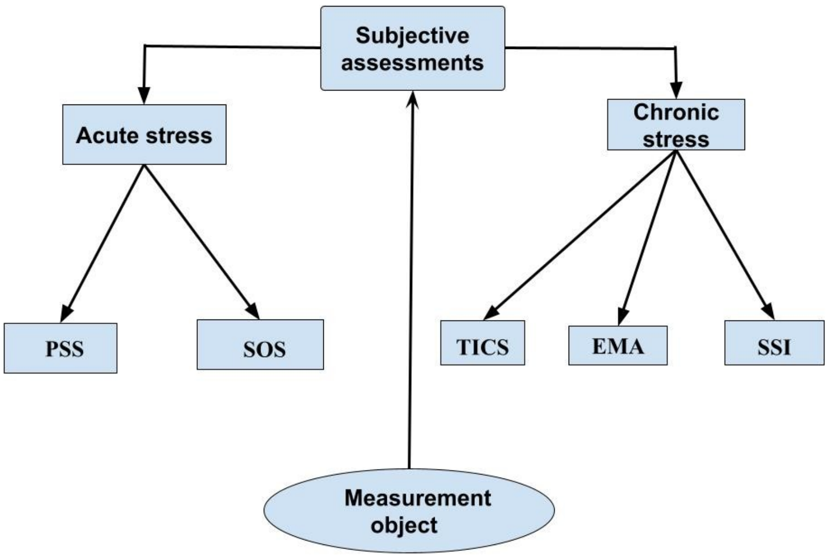

Figure 1: The diagnostic algorithm of subjective stress assessment.

However, subjective assessment using questionnaires does not always yield reliable results. For more informative analysis, it is necessary to include indicators that monitor the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system. Objective assessment of stress involves changes in bodily fluids and the functional state of various physiological systems in response to a stressor. Biochemical markers play a special role in stress assessment. These markers include cortisol, norepinephrine, adrenaline, alpha-amylase, and secretory immunoglobulin-A. Biochemical markers of stress can be detected in blood, urine, sweat [11], tear fluid, and saliva (Figure 2). However, all these methods have their advantages and disadvantages. For instance, the concentration of cortisol in saliva is very low, and migration from the blood occurs only after 30 minutes. At the same time, saliva collection is a non-invasive and simple method, convenient for the patient. Saliva contains many stress indicators, but the most studied and informative are cortisol and alpha-amylase. For example, salivary cortisol reflects acute stress from the past 15-20 minutes, while hair cortisol indicates prolonged stress (1 cm of hair contains the cortisol concentration for one month) [2, 12]. The highest peak of cortisol activity normally occurs in the morning, but an elevated level throughout the day is concerning [1]. This means that cortisol dynamics follow circadian rhythms. For rapid stress assessment, measuring alpha-amylase in saliva is also effective.

In recent years, methods for remote monitoring of salivary cortisol have been most intensively developed, even using smartphones, focusing on biosensor technologies and platforms [12-16]. Active development of smartphone applications using the phone's camera as a spectrometer, which reads pixel values instead of absorption, is ongoing. However, the most relevant methods for measuring cortisol are considered to be electrochemical and colorimetric [17]. In our opinion, colorimetric methods using blue tetrazolium, which forms a purple complex with cortisol, are more economical.

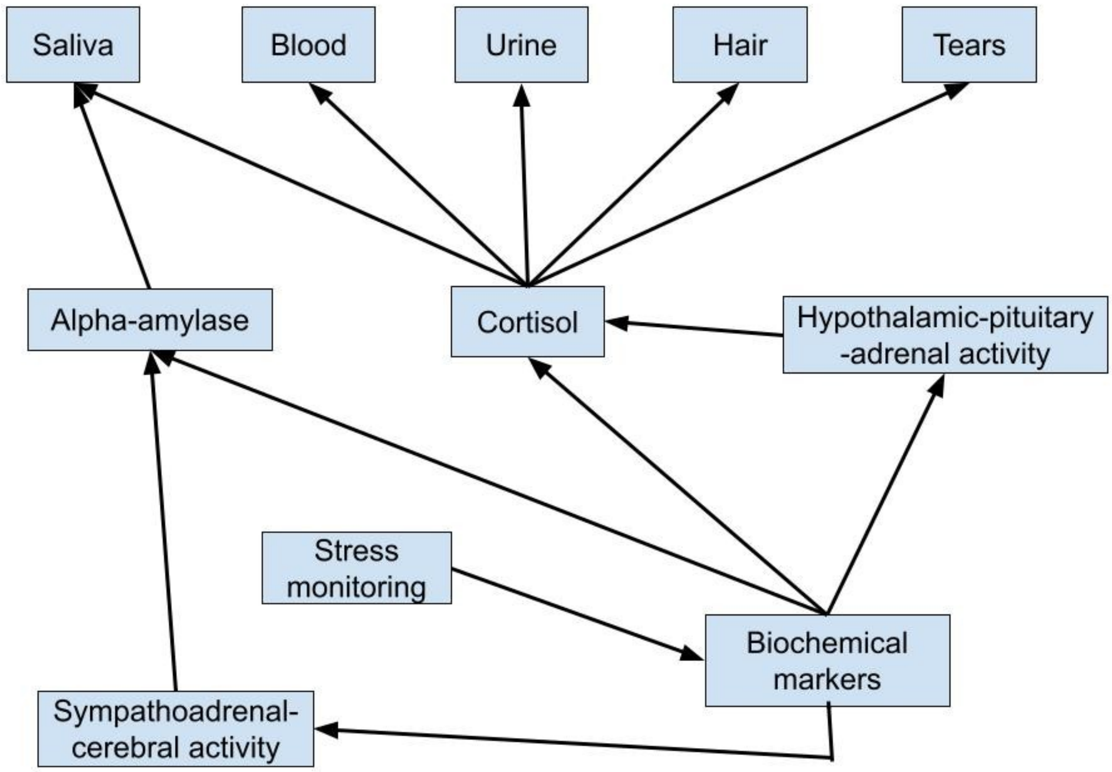

Figure 2: Informativeness of biochemical markers in stress assessment.

Physiological reactions that are easy to monitor include electrodermal activity [18, 19], changes in respiratory rate, heart rate variability, temperature, muscle activity, pupil diameter, and more.

Since autonomic homeostasis plays a key role in stress responses, an important aspect in diagnosing the balance between sympathetic and parasympathetic activity is heart rate variability [20-25], which is assessed through time and spectral analysis. The generally accepted method for analyzing heart rate variability is electrocardiography (ECG). However, the complexity of electrode placement and the bulkiness of the method make it challenging for remote monitoring. Therefore, the arterial oscillography method has proven effective in this regard, allowing the same temporal and spectral characteristics of the signal to be obtained [26-34]. It is known that several variability indicators reflect the state of parasympathetic activity, which is considered dominant during relaxation. These indicators should be focused on during psychotherapeutic interventions [27].

Electrodermal activity, along with heart rate variability, is often used to monitor emotional states [18], but it is a marker of only sympathetic activity. This method allows tracking skin conductance, which increases during stress and depends on sweat secretion by endocrine glands regulated by sympathetic innervation. In recent years, the galvanic skin response has been actively used in biofeedback methodology [35].

As a biomarker of the stress response, researchers have investigated [36, 37, 38] the electromyographic (EMG) signal. Numerous studies have focused on the EMG signal from the trapezius muscles. Recent publications indicate that low-frequency EMG functions have been the most effective in detecting stress. Additionally, stress is characterized by significantly higher amplitudes of EMG signals compared to a state of relaxation.

The electroencephalographic (EEG) signal also exhibits specific behaviors in response to stress [39-42]. The absence of alpha activity and the reduction of theta rhythm power in the central-frontal region of the brain are among the manifestations of stress, and their dynamics can be monitored. It has been proven that the alpha rhythm does not respond to internal and external stimuli during stress. Meanwhile, beta and delta activities are activated under stress. Additionally, under normal conditions, there is a predominance of right-sided beta activity. Under stress, the asymmetry shifts towards left-sided beta activity. Stress also triggers strong gamma activity. Many psychotherapeutic methods aim to enhance alpha activity and reduce beta activity. For example, binaural beat therapy synchronizes external auditory stimuli with brain activity. Listening to alpha waves can induce a corresponding state of relaxation. Meditation is also studied in this context. Effective online EEG monitoring allows for the development of innovative approaches, such as neurofeedback. This method is based on influencing the brain with various types of waves under EEG biofeedback control, enabling individuals to learn to control their brain waves. Therefore, electroencephalographic markers of stress are undoubtedly effective therapeutic targets that can be monitored throughout the treatment course.

Anxiety levels affect respiratory rate and volumes, causing hyperventilation symptoms, which can be studied using spirometry. To correct breathing disorders, various methods are employed, including Buteyko [43] breathing exercises. Since hyperventilation lowers arterial carbon dioxide pressure (PaCO2) below 36 mm Hg, resulting in hypocapnia and increasing alkalosis, it is also advisable to monitor the capnogram to assess the level of CO2 tension at the end of exhalation.

Therefore, the comprehensive integration of stress markers into a unified system will allow remote monitoring of stress response dynamics and enable influence on it through possible online interventions.

2. Goal and tasks

The aim of this work is to develop methods and algorithms for creating a telemedicine system for comprehensive diagnosis and correction of stress.

To achieve this goal, the following tasks have been set:

1. Evaluate experiments that confirm the role of arterial oscillography in stress diagnosis.
2. Present the importance of time and spectral analysis of arterial oscillography for diagnosing stress conditions.
3. Develop an algorithm for the operation of a telemedicine system for stress psychocorrection using a pressure meter to obtain an arterial oscillogram.
4. Develop an algorithm for the operation of a telemedicine system for remote monitoring of a patient's psychological state using a comprehensive selection of informative stress markers.

5. Develop an algorithm for the operation of a comprehensive telemedicine system for stress psychotherapy.
6. Design the architecture of the Oranta-MIS information system component, enabling the construction of a comprehensive telemedicine system with feedback for psychocorrection of stress reactions.

3. Telemedical automated systems for psychocorrection

3.1. The role of arterial oscillography methodology in a telemedical automated system for stress psychocorrection

We conducted an experimental study on stress levels using the "Oranta-AO" information system, employing questionnaires and arterial oscillography methodology.

Anxiety and depression levels were assessed using the Hospital Anxiety and Depression Scale (HADS), the State-Trait Anxiety Inventory (STAI), and neuroticism was evaluated using Eysenck's methodology. We examined 260 patients with anxiety data closely correlating with heart rate variability based on arterial oscillography, tracking dominant sympathetic activity [27].

Specifically, in a separate sample [27], more than 30% of students exhibited high neuroticism levels and high anxiety levels. However, for future research, we propose using questionnaires to identify stress, with a differentiated approach to types of stress (chronic, acute).

Spectral indices of heart rate variability, such as LF (low-frequency power, 0.04-0.15 Hz) and HF (high-frequency power, 0.15-0.4 Hz), closely correlated with corresponding anxiety scales. A negative correlation was observed between HF and anxiety, while a positive correlation existed between LF and anxiety. In temporal analysis, the Index of Nervous System Strain (IN) positively correlated with anxiety levels in 30% of students. Additionally, temporal indices of variability sensitive to dominant parasympathetic influence proved effective for monitoring. These included SDNN (standard deviation of NN intervals) and RMSSD (square root of the mean of the sum of the squares of differences between adjacent NN intervals).

Based on the above findings, we proposed a general algorithm for a telemedical diagnostic system to detect stress based on the selection of arterial oscillography and questionnaires integrated into the "Oranta-AO" system (Figure 3).

An experiment was conducted to study the influence of multimedia calming compositions integrated into the telemetry system "Oranta MIS" on the spectral and temporal characteristics of heart rate variability and stress questionnaire data. Special emphasis was placed on video images of natural elements: water bubbling (Figure 4), flickering flames, and forest bird songs.

In analyzing the time-domain oscillogram, attention was focused on positive extrema indicative of centralized heart activity control, as well as negative extrema indicating vascular components. Specifically, IN-neg, which was 45.29±4.034 in a state of rest, significantly decreased to 10.89±0.810 after visualizing "water bubbling." This was accompanied by an activation of parasympathetic tone represented by the spectral component HF, which increased from 48.13±5.81 to 64.63±3.43.

These findings demonstrate promising prospects for the influence of multimedia calming compositions, easily integrated into an automated system for psychorelaxation.

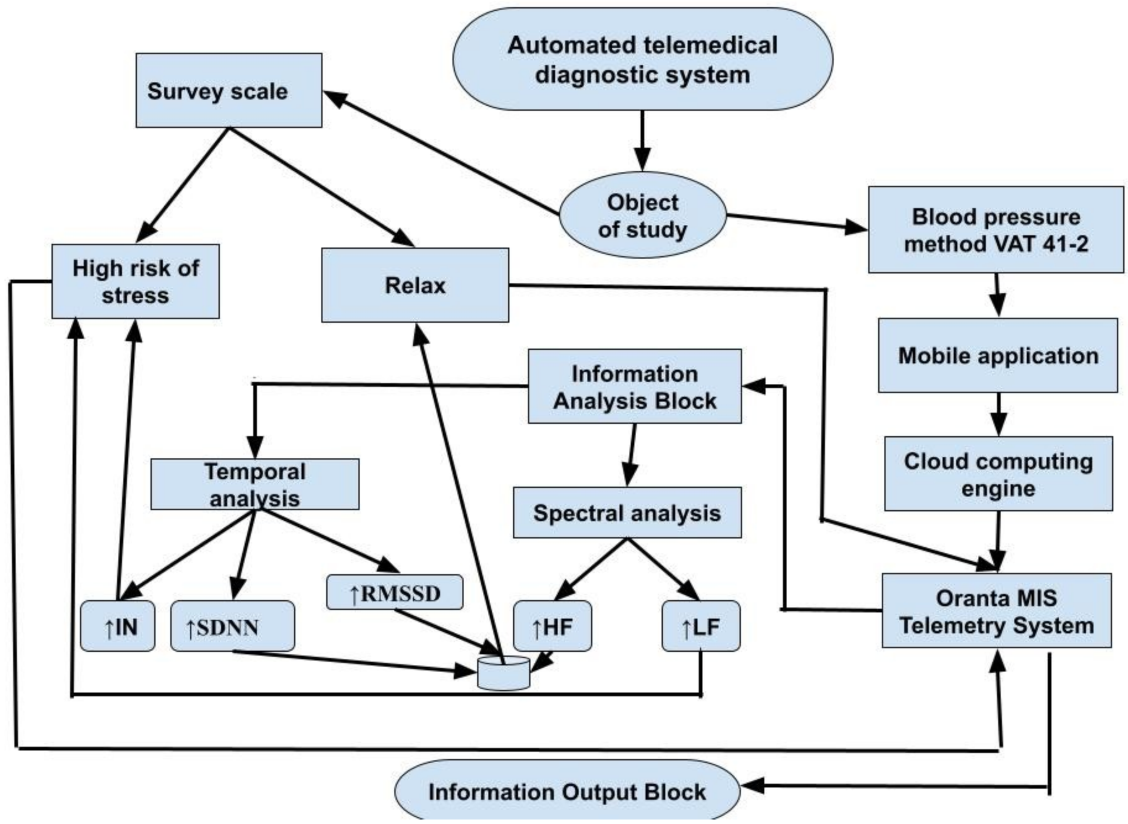

Figure 3: The general algorithm of the telemedical stress diagnostic system using the method of arterial oscillography.

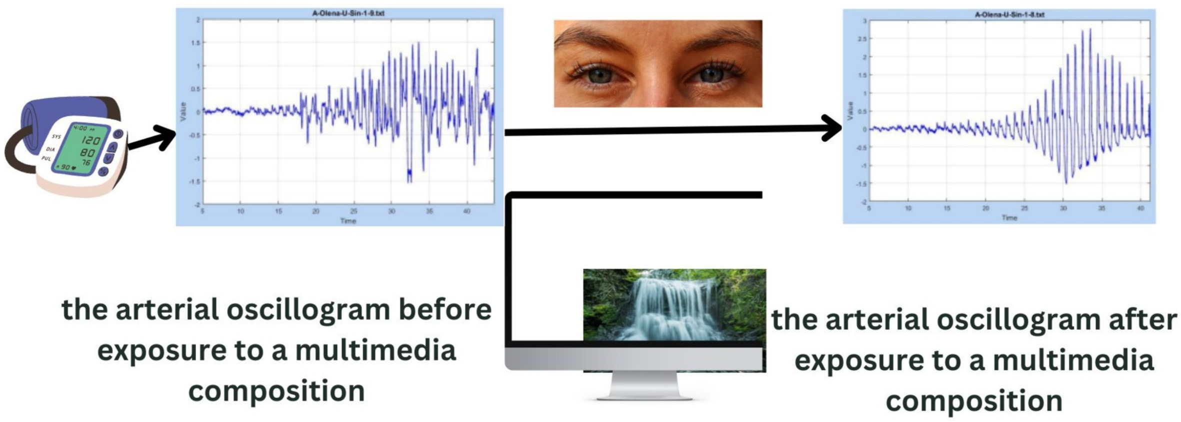

Figure 4: The Influence of the Multimedia Environment 'Murmuring Water' on the Parameters of the Arterial Oscillogram.

Thus, following the experimental study on the impact of multimedia compositions on the stress indicators mentioned above, a component was developed for the telemedical stress psychocorrection system. This rehabilitation system additionally integrated a block of multimedia compositions into the previously described telemedical diagnostic stress system, using arterial oscillography methodology, which operated within a feedback loop mechanism.

3.2. Consideration of stress markers in the development of a psychorelaxation telemedical system

However, the results obtained solely through heart rate variability data and questionnaires are not fully informative. Therefore, we propose the development of a comprehensive stress diagnostic system that incorporates multifactorial stress markers, including surveys and characterization of the hypothalamic-pituitary-adrenal (HPA) axis and autonomic nervous system as a complex.

Regarding monitoring of the HPA axis, we believe cortisol monitoring is most appropriate. We suggest employing a salivary cortisol colorimetric analysis method using blue tetrazolium in our system. This method appeals due to its simplicity, ease of saliva sample collection, and capability for remote assessment.

For further tracking of stress response, we consider it beneficial for comprehensive diagnosis to include not only arterial oscillography but also: electrodermal activity, EEG, EMG, and spirometry (Figure 5). This scheme forms the basis for constructing a signal acquisition module for monitoring stress response in our proposed comprehensive automated system.

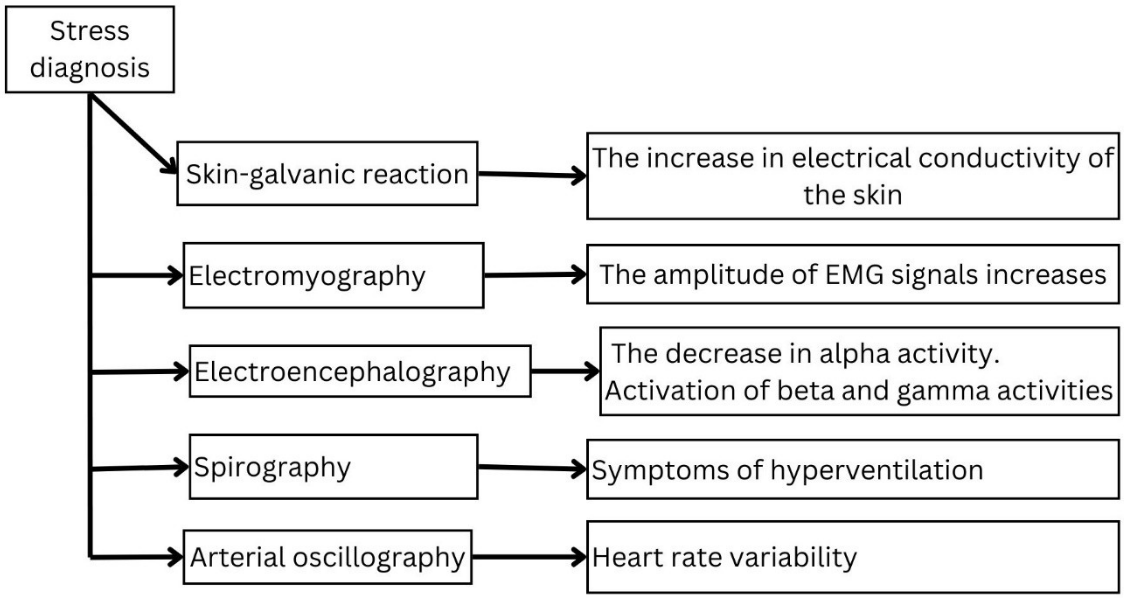

Figure 5: The algorithm of functional methods of stress research.

Changes in skin electrical characteristics in response to stress can be measured using special electrodes attached to the index finger of the hand, and then the data can be transmitted via Bluetooth to monitor dynamics. In the proposed system, we also plan to capture EMG signals from the trapezius muscles, using signal amplitude to guide the appropriateness of psychocorrection.

Since alpha and beta rhythms play a leading role in EEG stress research, we propose conducting monitoring in this system with frontal and occipital electrodes to track these wave activities.

Spirometry, with step-by-step instructions displayed on the screen, is also straightforward to administer to patients. We suggest analyzing key respiratory volumes and breathing frequency in our system to assess hyperventilation, which is characteristic of stress responses. In the future, it may be worthwhile to consider capnography monitoring.

All the presented indicators can be remotely monitored and adjusted using a calming multimedia environment integrated into the "Oranta MIS" system.

4. Creating a comprehensive telemedical system for stress psychocorrection

The system for stress psychotherapy should, in addition to determining stress reactions through questionnaires and heart rate variability data from arterial oscillography analysis, also include cortisol monitoring in saliva, electromyography, electroencephalography, spirometry, and determination of skin conductance response. Furthermore, such a system should naturally comprise: a signal acquisition module primarily via a mobile application, a signal analysis block in a cloud computing service, and incorporate a therapeutic intervention block for the patient, which is tailored based on relevant diagnostic data using a feedback system (Figure 6, 7) in the user's personal digital dashboard.

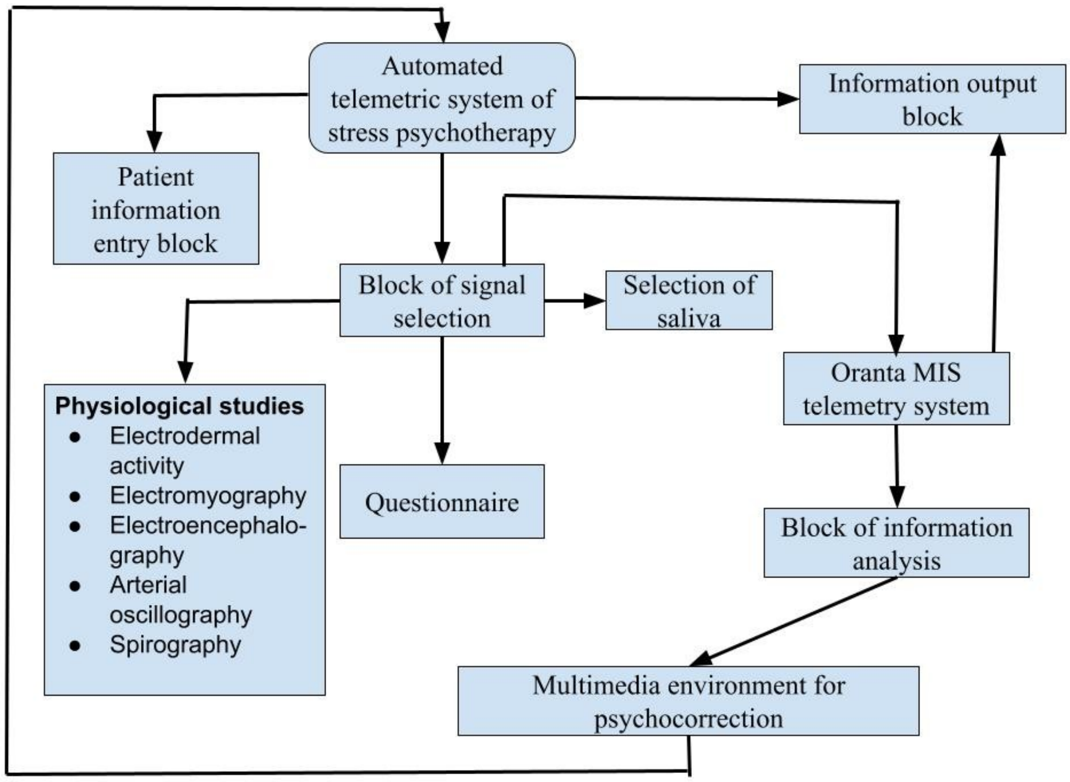

Figure 6: The scheme-algorithm of the automated telemetric system of stress psychotherapy.

Once the data in the information analysis block is processed, results that deviate from the norm are immediately selected by the Expert System, and a multimedia composition is chosen based on the feedback system. The system also includes an information output block capable of presenting results in both printed format and storing them in an archive.

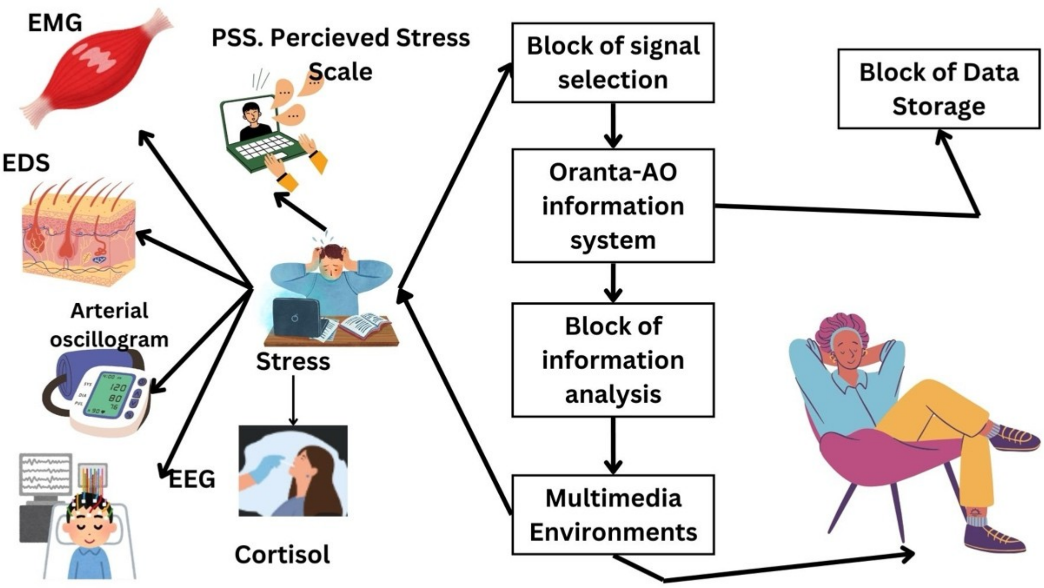

Figure 7: The Telemedicine system for stress correction.

Such careful monitoring of psychological health will ensure timely detection of stress and the possibility of its correction under the control of relevant indicators. Accordingly, individuals will be able to actively monitor their condition and take specific measures to address it.

Conclusion

The authors have proposed for the first time a comprehensive telemedical feedback system for stress psychocorrection.

Such a system will allow for a multifaceted assessment of stress levels. The continuous feedback loop, which forms the basis of the system, will enable diagnostic processes to conduct individual psychocorrection and select specific types of interventions.

The basis for this development is a previously created similar telemedical system for stress psychocorrection, which collected arterial oscillography data to analyze heart rate variability and conducted remote patient surveys for stress diagnosis. Subsequently, it employed psychocorrection through multimedia environments in the "Oranta-AO" system. The development was grounded in experimental studies demonstrating the relationship between temporal and spectral indicators of heart rate variability, survey data on psychological states such as stress. Of particular significance were the spectral LF index and the temporal IN index, which positively correlated with stress reactions, indicating sympathetic activity. Conversely, the spectral HF index and the temporal VR and RMSSD indices negatively correlated with stress, reflecting parasympathetic tone.

Based on the experimental impact conducted with multimedia environments of the "Oranta-AO" system, positive dynamics in stress correction were observed due to the activation of the parasympathetic branch and the inhibition of the sympathetic branch.

Based on these presented research findings, a new comprehensive approach is proposed for creating a telemedical integrated system for psychocorrection. This system will include surveys, arterial oscillography, as well as modules for electroencephalography, electromyography, spirometry, and determination of skin conductance response.

An essential component in studying the state of the hypothalamic-pituitary-adrenal axis will be the additional capability for salivary cortisol monitoring.

Thus, the information system "Oranta-MIS" serves as a promising starting platform for developing advanced telemedicine technologies across various fields of application.

The proposed new stress psycho-correction system will open new horizons in this direction, helping psychotherapists better understand the pathogenesis of stress reactions, thus facilitating their timely detection and effective correction.

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Declaration on Generative AI

The authors have not employed any Generative AI tools.

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