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Stress Reduction Using Bilateral Stimulation in Virtual Reality

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ABSTRACT The goal of this research is to integrate Virtual Reality (VR) with the bilateral stimulation used in EMDR as a tool to relieve stress. We created a 15 minutes relaxation training program for adults in a virtual, relaxing environment in form of a walk in the woods. The target platform for the tool is HTC Vive, however it can be easily ported to other VR platforms. An integral part of this tool is a set of sensors, which serves as physiological measures to evaluate the effectiveness of such system. What is more, the system integrate visual (passing sphere), auditory (surround sound) and tactile signals (vibration of controllers). A pilot treatment programme, incorporating the above mentioned VR system, was carried out. Experimental group consisting of 28 healthy adult volunteers (office workers), participated in three different sessions of relaxation training. Before starting, baseline features such as subjectively perceived stress, mood, heart rate, galvanic skin response and muscle response were registered. The monitoring of physiological indicators is continued during the training session and one minute after its completion. Before and after the session, volunteers were asked to re-fill questionnaires regarding the current stress level and mood. The obtained results were analyzed in terms of variability over time: before, during and after the session.

INDEX TERMS Affective computing, bilateral stimulation, stress reduction, virtual reality.

I. INTRODUCTION

The first concept of stress, introduced by Hans Selye, defined it as a non-specific response of the body to any demand, which can occur in humans, animals, and even plants and bacteria [1]. In his further work [2] Selye claimed that stress is an inseparable part of human daily life because it is associated with different types of issues people struggle with such as surgical trauma, burns, emotional arousal, mental or physical effort, fatigue, pain, fear, the need for concentration, the humiliation of frustration, the loss of blood, intoxication with drugs or environmental pollutants. This phenomenon can also accompanying life changing positive events as basically it can be considered as the mobilisation reaction of the organism to external (being fired or promoted) and internal (worrying about the loss of job or waiting for the promotion) threats and challenges [3]. During stress reaction nervous system releases stress hormones such as adrenaline, noradrenaline and cortisol. The heart begins to beat faster, muscles tighten, blood pressure rises, breath quickens, senses become sharper. These physical changes increase strength and stamina, speed up reaction time, and enhance focus, preparing for confrontation [4]. Unfortunately, the stress reaction is nonspecific - any stimuli which affects homeostasis of the organism has the potential of starting it and prepare the body to the extensive energy expenditure which was needed to fight the predator or escape from danger. The modern man faces other challenges mostly of economical, and psycho-social nature, and such intense physical mobilisation of all the organism is not needed when facing everyday stressors. However, this evolutionary developed mechanism still works. When stress reaction is too intense or happens too often giving body no chance to calm down, many adverse effects can appear. Hundred years of research leaves no doubts - chronic and/or intense stress causes mental and physical health problems such as mental disorders (e.g. depression, anxiety, PTSD, substance abuse), cardiovascular, muscosceletal disorders, negatively affect immune

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system, fertility and produces many others minor symptoms [5]. What is more, it contributes to many disabilities worldwide and represents a severe economic burden [6]. The annual stress survey conducted by the American Institute of Stress reported that average stress levels in the United States rose from 4.9 to 5.1 on a scale from 1 to 10 in 2015. The main reasons given are employment and money [7]. Recently, World Health Organization (WHO) has named stress as the ''Health Epidemic of the 21st Century'' [3]. A first line treatment of excessive stress and its consequences is psychotherapy, which can be accompanied by bilateral stimulation for example in EMDR therapy.

Eye Movement Desensitisation and Reprocessing (EMDR) is one of the psycho-therapeutic approaches widely recognized as an empirically supported treatment for post-traumatic stress disorder (PTSD) [8]–[10]. The application of EMDR has expanded rapidly beyond PTSD and it has high, evidence-based efficacy in treating other mental disorders such as: phobia [11], [12], panic disorder [13], [14], generalized anxiety disorder [15] and depression [16], [17]. The method is predicated on the assumption that psychopathology is caused by memories, which were not processed or were processed incorrectly in the past. Disturbing memories (coded in the brain as the images, emotions and thoughts/cognition) may fade or be suppressed, but as they remain in memory as the network of associations, they are easily reactivated by various internal and external stimuli, manifest as maladaptive responses and, in long-term, as mental or somatic disorders. EMDR uses bilateral stimulation (BLS) (eye movements, tones, taps and vibrations) to ease the access to unprocessed or incorrectly processed memories. BLS enables a patient to start processing these memories so that they become less disturbing, stressful or traumatic. BLS is the key element of the therapeutic process in the EMDR. Bilateral stimulation is also used in EMDR to bring the patient into calm and relaxing state [18]. BLS has been recently supported with electronic devices that generate a light signal moving in the field of view, sounds and vibrations/pulsations (see Fig. 1). Thus, we believe that Virtual Reality (VR) technology, which allows for the variety of stimuli facilitating BLS, may have a promising contribution in EMDR therapy.

Virtual Reality is a technology that simulates user's physical presence in an artificially generated world and allows to interact dynamically with the environment. Most of VR applications and solutions focus on gaming and commercial industries, as these areas provide the largest groups of VR headsets recipients. However, possibilities of VR do not end with gaming. Dynamic growth and interest in the subject rendered it applicable in many other areas, such as military [23], psychology [24], medicine [25] and teaching applications [26]–[28]. What is more, recent studies have shown that VR may redefine psychological treatment by creating an environment which will help patients to cope with experiences that are a source of mental crises [24]. From the review of research using VR in the therapy of mental

FIGURE 1. Selected techniques for stress and anxiety reduction: (a) typical EMDR session, (b) device for Tactile Alternating Bilateral Stimulation [19], (c) TouchPoints solution dedicated for kids [20], (d) EMDR KIT: audio, visual, and tactile processing tools [21], (e) EMDR Elite - an application available on the App Store [22].

disorders, it appears that this type of technology may be conducive to alleviating the symptoms of depression and anxiety disorder [29]–[31]. What is more, VR allows for employment of multisensor stimulation which helps patients to discover the background experiences which feed their current symptoms, and support the process of resource installation. Thus, we believe that VR can facilitate the therapeutic process thanks to interactive scenarios which can be designed to address such symptoms as negative thinking, negative self-image, sleep problems, tension, powerlessness etc. In this study, we implemented bilateral stimulation and exercise based on safe place protocol of EMDR into VR to enhance the processing of relaxing stimuli and provide the background for adaptive coping. According to our best knowledge, such an approach has not yet been developed and tested.

In this paper, we propose automated therapy tool in form of a VR system, comprised of an interactive virtual reality (VR) simulation, based on scenarios created for psychotherapy treatment, together with a set of sensors to monitor patient's psychophysical condition. To measure the success rate of the tool, randomised trials have been conducted on experimental group of 28 healthy adult volunteers (office workers), participating in three different sessions of relaxation training. Patients' activities such as heart rate, galvanic skin response and electromyography of trapezius were continuously monitored by the system. Additionally, before and after session, volunteers were asked to fill in questionnaires regarding the current stress level and mood. Initial results are very promising and randomised clinical trials on ambulatory patients diagnosed with distress, anxiety, PTSD, depression and stress-induced disorders should be strongly considered.

The rest of the paper is organized as follows: Section II reviews the related work in the field of EMDR technique and stress recognition methods. In the Section III the details of the proposed method are described followed by the experimental results and discussion provided in Section IV. Finally, conclusions are presented in Section V.

II. RELATED RESEARCH

This section first reviews main tools based on bilateral stimulation, and then approaches to stress recognition using physiological signals.

A. TECHNIQUES FOR STRESS AND ANXIETY REDUCTION

Nowadays stress is considered as the second health problem affecting people in developed countries, and many efforts are put in searching for effective methods to reduce it at individual and macro level (WHO, 2011). As stress has been accompanying people since their beginning, humans have developed variety of strategies and approaches to cope with it. The methods differs depending on the sources of stress, its durability, culture and historical time. Some of proposed way of stress reduction are short lived others established their position in clinical and everyday life. To give the short description of the most acknowledged methods we refer to research on them. The presentation of techniques is the subjective choice of authors address the criteria of evidence-based treatment and scope of application of given method.

Autogenic training (AT) – the core exercises were described in 1932 by the neuropsychiatrists Johannes Schultz. The method was developed with the help of Wolfgang Luthe [32]. The authors were inspired by yoga and zen practice. AT is a structured meditative set of exercises which allow to obtain the mind-body balance and relaxation [33]. Six standard exercises are based on imaginary and verbal self-cues to make body heavy, warm and relaxed. Effectiveness of AT is related to experience in practicing and personal involvement. Recent studies found the use of this technique in various categories of health problems – from everyday tension, headaches, ADHD, psychiatric disorders (anxiety, depression, bulimia nervosa) to stress causing life-threatening illness [32], [33]. Meta-analyses of studies on effectiveness of Autogenic Training showed that AT had medium to high effects on the main clinical outcomes in comparison with untreated control conditions, moreover these effects are stable in time [34]–[36].

Progressive Muscle Relaxation (PMR) - a method developed by Edmund Jacobsen based on the observation that relaxed muscles improve the mood of a person Jacobsen's progressive muscle relaxation (PMR) [37] is a procedure for achieving a deep relaxation of the body through the voluntary and conscious tensing and relaxing of muscle groups. While exercising an individual tenses muscle groups in a specific order, the muscle tension is held for a brief time and then released. Jacobsen proposed 16 muscle groups to exercise with but latter Bernstein & Borkovec reduced that number to 6-7 muscle groups with the same effect of the programme effectiveness [37]. According to recent studies and meta-analyses PMR is an effective method of tension reduction. It is widely used as a technique supporting psychotherapy, medical treatment of various conditions [38] and occupational stress prevention tool [34], [36]. It was proven that long term effect of PMR includes: decrease of salivary cortisol level, blood pressure and heart rate and reduction of anxiety [32].

Biofeedback - is the method employed sensitive electronic instrument which provide information about body functioning. This information is used to develop greater awareness and control over the body processes and enhances self-regulation processes which help individuals do obtain the state of balance/ homeostasis [39]. There different kind of indices that can be used in biofeedback including: breathing, heart rate, muscle tension, skin temperature, brain waves etc. Biofeedback is provided at the presence of a biofeedback therapist who teaches a person how to interpret body signals and how to influence them to gain the positive state of relaxation (for a review see [40]). Biofeedback is successfully used in controlling alleviated blood pressure, reduction of headaches and also helps in combating everyday stress [41], [42].

Diaphragmatic breathing - a technique which employ diaphragm muscle to enhance the effectiveness of breathing. It is seemed to an efficient integrative body–mind training for dealing with stress and psychosomatic conditions There are numerous studies which have shown that diaphragmatic breathing facilitate relaxation response of the body [43]. It was successfully applied to reduce depression, anxiety and stress [44]–[47].

Mindfulness-Based Stress Reduction (MBSR)- a technique based on the work of Kabat -Zinn [48], [49]. He developed the mindfulness based training program for people suffering from chronic pain and emotional problems in 1982. The MBSR intervention is designed to make participants to be more aware of, and relate differently to thoughts, feelings, and body sensations which are experienced right now. The important characteristic of mindfulness is the non-judging observation of any stimuli which appears in the scope of human awareness. Studies revealed that MBRS is effective in treatment of elevated stress [50].

Cognitive Behavioral Therapy (CBT) – the psychotherapy developed by A. T. Beck in 60. of XX based on the assumption that the way we think influence well-being. Restructuring dis-functional cognitive schemata followed by behavioural changes appeared to be essential in the process of symptoms reduction. This is a highly structured, time restricted form of psychotherapy. The effectiveness of CBT was proven in the great number of studies. The strongest support for CBT efficacy was obtained for treatment of anxiety disorder, somatoform disorders, bulimia, anger control problems, and general stress [51].

Eye movement desentization and reprocessing (EMDR) – as it was mentioned earlier, EMDR is a relatively young mode of psychotherapy with many studies on its usefulness for different health conditions [20], [46], [52]–[54] The theoretical framework for EMDR is Adaptive Information Processing model (AIP). The model assumes that recovering past negative information and processing them to be included in a new cognitive and emotional network reduces negative symptoms related to the past experiences. Recently EMDR has been successfully used for reduction of stress and anxiety both in adults [52], [55] and children and adolescents [56], [57].

Recently VR has been implemented in treatment of anxiety and stress. Virtual reality replaced *in vivo* exposure or imaginary exposure in the treatment modes based on the concept of desensitization. Thus one of the first attempts was implementation of VR in the treatment of Post-traumatic stress and anxiety disorders (mainly simple phobias). After the years of research this approach was proven to be effective [58], [59]. The evidence based efficacy of VR based treatments has encouraged health professionals and scientists to develop VR based programs aimed for stress reduction in various occupational settings. The example of such implementation is stress management training for military [60]. There is also increasing evidence that treatments employing VR are effective in improving well being and quality of life in various populations – from healthy people under stress conditions, depression sufferers to cancer patients.

B. STRESS RECOGNITION USING PHYSIOLOGICAL DATA

Currently stress is one of the major issues in modern society, thus its detection has become a challenging task in computer science and affective computing [61]. Monitoring stress technology, which can objectively measure psychological state of an individual, may allow people to better understand their psycho-physical condition and improve the outcomes of psychotherapy [62]. The literature regarding stress detection is extensive, and very often constitutes a part of emotion recognition process, since stress can be reflected through subject's emotional state or mood such as frustration, anger, agitation, preoccupation, fear, anxiety, and tenseness [63]. As in case of emotion recognition, it is mainly based on facial [63], [64], speech [65], [66] and gestures [67]–[69] signals analysis. The undoubted benefit of this approach is the possibility of interpreting the through less or non-intrusive methods which do not require physical contact [63]. Physiological signal acquisition is closely related to a different type of sensors and requires them to be calibrated and placed on specific locations of the body, which can be inconvenient [70]. However, there are evident stress-related signs, which are reflected through variation of blood pressure, heart rate, muscle tension, skin conductance, cortisol or pupil diameter [62]. Thus, physiological measuring is becoming an increasingly popular approach.

The crucial part of this study is VR based EMDR relaxation technique, which requires the participants to wear Head-Mounted Display (HMD) and not to move their head during the session. These assumptions cause limitations in possibilities of automatic stress recognition: the main part of the face is covered by VR headset and participants do not speak or move. Thus, facial expressions, speech signal and gestures can not be taken into consideration. However, the stable position and immobility of the subject favor the use of sensors, which is why we use GSR, EMG and HRM for monitoring. Therefore, in this section, we cover the recent advancements in automatic stress recognition from physiological signals. An overview of sensors commonly used for assessing the user's stress level is presented in Tab. 1. The reader interested in stress recognition from facial expressions, gestures or speech is encouraged to consult dedicated articles and surveys [70]–[76].

One of the most effective affect-recognition methods is based on brain waves analysis, thus electroencephalogram has been widely applied to assess individuals' stress in laboratory conditions. For example in [82] the authors present an investigation on the feasibility of exploiting EEG signals to distinguish different stress levels. They propose a protocol where the stress level is represented by the complexity of mental arithmetic task (at three levels of difficulty), and the stressors are time pressure and negative feedback. The analysis of EEG responses in controlled and stress conditions gathered among 18-male subjects allowed them to extract patterns of brainwaves for different stress levels. Using multi-class SVM with error-correcting output code they obtained an average classification accuracy of 94.79%.

Certainly one of the most important disadvantages of EEG is its setup. It requires a precise placement of several electrodes along the scalp (very often in a form of cap) and the use of gels or saline solutions. Thus this kind of experiments are mainly conducted in a controlled laboratory environment [83]. However, recently a few manufacturers have miniaturized medical EEG technology and created low-cost, wireless and wearable EEG devices. This kind of solution is used in [84], where the authors propose a procedure to automatically recognize stress of construction workers while they were working on site. They analysed time and frequency domain features from EEG signal captured by a wearable EEG device (Emotiv EPOC) and applied several different supervised learning algorithms, obtaining the highest classification accuracy of 80.32% using the Gaussian Support Vector Machine. These results are very promising, since similar results were obtained in laboratory conditions.

In most studies a set of sensors, sometimes in the form of a wearable system, is used for stress or emotional state recognition [85]–[87]. For example in [79] the authors present an automated system for emotional state detection (high stress, low stress, disappointment, and euphoria) of car-racing drivers based on features extracted from facial electromyograms (EMGs), ECG, RIP, and EDA. Support vector machines and adaptive neuro-fuzzy inference system were used for classification. The system was validated on ten subjects in simulated racing conditions, giving the classification rates of 79.3% and 76.7% for SVM and ANFIS respectively. Similar approach is presented in [88], where the authors introduced a wearable sensor platform, combining HRM, RIP, EDA and EMG to monitor a number of physiological correlates of mental stress. Subsequently they propose new spectral features that estimate the balance of the autonomic

TABLE 1. An overview of sensors commonly used for assessing the user's stress level.

Sensor	Description / stress indicator
Electroencephalography (EEG)	EEG is a method to monitor electrical activity of the brain. The relationship between brain activity and stress was repeatedly proven. For example, it has been found that females with PTSD have an increased activation in the anterior and middle insula when they are recalling previous stressful events [70]. However, this method may be inconvenient since electrodes are placed along the scalp.
Electromyography (EMG)	EMG is a technique used to measure electrical potential produced by skeletal muscles. For example, muscle activity has been shown to increase during stress. These signal is measured by bio sensors located on face (e.g. zygomaticus major) [77], shoulder or upper trapezius muscle [78].
Electrocardiography (ECG / EKG)	Electrocardiography is a process which monitors the electrical activity of the heart (voltage versus time). ECG is used to calculate the rate and regularity of heartbeats. The sensor can be located above the chest or limbs. Heart-rate acceleration is generally associated with stress and nervousness, while lower heart-rate reflects relaxation or reaction to pleasant stimuli [79].
Electrodermal activity (EDA) or Galvanic Skin Response – (GSR)	EDA measures the conductivity of the skin. One of the main indicators of stress is sweating, which results in EDR increase. Since this signal is strongly influenced by external factors (outside temperature), it requires calibration before measurement [80].
Respiratory inductance plethysmography (RIP)	RIP measures the respiration patterns such as respiration rate and volume. The sensor is usually in the form of a strap, which may be placed on chest or abdomen. It is proved that faster and deeper respiration is associated with arousal, whereas rest and relaxation with slower and shallower respiration. Thus, a state of stress is usually indicated by more frequent respiration [79].
Skin Temperature (TEMP)	Skin temperature can be measured using a standard resistance thermometer as well as using infrared thermopile or camera [81]. It was shown that during *fight-or-flight* response the blood flow to the extremities is restricted in favor of the vital organs, which causes a decrease in temperature in the extremities [61].

nervous system by combining information from the power spectral density of respiration and heart rate variability. The effectiveness of proposed features set was evaluated on binary discrimination problem (mental stress or relaxation) using logistic regression model. The overall recognition rate was 81% across subjects.

Research presented in [78] investigated physiological signals such as electrocardiogram, skin conductivity and respiration changes, as reliable channels for emotion recognition. The authors collected physiological data set from multiple subjects by a musical induction method. Basing a wide range of physiological features, classification of four emotional states (positive/high arousal, negative/high arousal, negative/low arousal, and positive/low arousal) was performed using an extended linear discriminant analysis, which was juxtaposed with an original scheme of emotion-specific multilevel dichotomous classification. Implementation of proposed classification scheme resulted in an improvement in recognition accuracy.

Lewandowska [89] addressed the issue of physiological measurements being disturbed by a motion typical for human-computer interaction such as keyboard typing or mouse movements. Several different locations of sensors (skin conductance, blood volume pulse and temperature sensors) were evaluated for relevance and measurement precision. The analysis provided alternative locations showing correlation with the original ones, but with lower sensitivity to movements like typing or operating a mouse.

Another approach is presented in [81], where the authors proposed a methodology for monitoring the affective states of computer users based on thermal imaging of the face. They proved that state of stress is strongly associated with increased blood flow in the frontal vessel of the forehead, which can be monitored through thermal imaging. The method was evaluated on 12 subjects, and the results were juxtaposed with real-time measurements of energy expenditure using invasive cardiopulmonary device. They proved that proposed method is highly correlated with the EE methodology.

Garcia *et. al* [90] consider the use of smartphones to monitor stress levels in real working environments basing on data from smartphone's built-in accelerometer. Thirty subjects, recruited from two different organizations, participated in 8 week study. The perceived stress level was reported three times during working hours using self-assessment questionnaire by each participant. Based solely on data from an accelerometer and using combination of statistical models to classify self reported stress levels, they achieved a maximum overall accuracy of 71% for user-specific models, which is comparable to the state of the art results in stress recognition based on more sophisticated sensors. More extensive research is presented in [62], where 5-day physiological and behavioral data including wrist sensor output (skin conductance and accelerometer), mobile phone usage (call, short message service, location and screen on/off) and surveys (stress, mood, sleep, tiredness, general health, alcohol or caffeinated beverage intake and electronics usage) from 18 subjects was

FIGURE 2. Subsequent scenes of application: the first image presents the configuration scene, next seven images present the session steps.

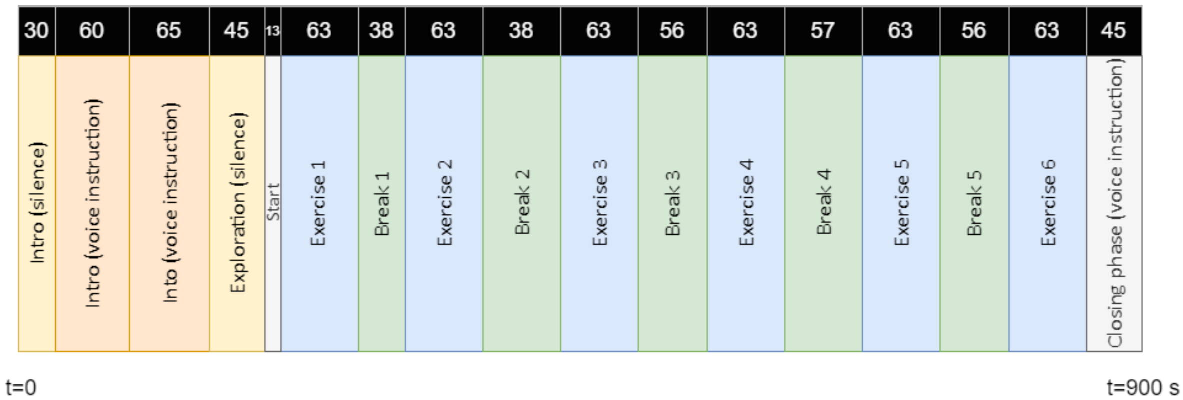

FIGURE 3. Subsequent scenes of application: time course of the scenario.

analysed to find physiological or behavioral stress markers. Obtained results showed over 75% accuracy of perceived low and high stress level using the combination of the above mentioned data. What is more, they proved that the patterns associated with the activity level (such as SMS and screen on/off) are the most correlated with the stress level.

Although VR technology is increasingly being used in psychology to generate stimuli for mental health research and therapy, in the literature there is very little research examining changes in affective reactions of VR users. Most of them use questionnaires which are then analyzed in details [91], however they remain based on subjective assessment. Only a few works use objective measurements from sensors for analysis. For example, Dongrae *et al.* [92] analysed a photoplethysmogram, electrodermal activity, heart-rate variability, skin conductance and temperature of twelve healthy participants performing mental tasks using VR to monitor stress. They applied a kernel-based extreme-learning machine to classify five different levels of stress situations: baseline, mild stress, moderate stress, severe stress, and recovery. The average classification accuracy was about 95% using K-ELM and features extracted from physiological signals. Similar approach is presented in [93], where the authors describe a Decision Support System (DSS) for automatic classification of stress levels during exposure to VR environments. Proposed system integrates ECG, RIP and EEG sensors as well as behavioral data (body gestures tracking with Kinect). Self-rated and clinical-rated stress levels were used as a ground truth. During the session, detected stress level (ranging from 0 to 1) is reported to the therapist and graphically displayed on a diagram, which can be accessed via web interface. However, it should be noted that in this case virtual reality is understood by the authors as an environment displayed on the monitor screen, not in HMDs.

III. METHODOLOGY

A. VR APPLICATION

The virtual environment was developed using Unity - Game Engine and C# programming language in the form of two scenes (see Fig. 2 and Fig. 3). The first scene has primarily configuration purpose and allows for adjustment of the patient's location and virtual camera as well as general familiarization with the experience offered by HMD's. During the session, each participant should relax on a comfortable bean bag in a chosen position. Because of the differences in overall body structure and preferences (sitting position, semi-recumbent position etc.), in the first step the scene is calibrated to make sure that the main element of the scene is centered vertically and horizontally for a particular participant.

Simulated motions can affect one's perception of time and space and thus induce dizziness and nausea. This phenomenon is called VR sickness or cybersickness [94] and various research suggested the use of adaptation and if needed, anti-motion sickness drugs to reduce this kind of side-effects [95]. Thus, the second scene starts with adaptation session (a walk in the forest without bilateral stimulation).

The rest of the second scene has a solely therapeutic purpose. The VR environment is composed of the forest scenery enriched by a delicate, instrumental theme with the sounds of chirping birds. The exercise involves following the golden sphere, which is moving horizontally. The sphere moves constantly in the subject's field of view, and a properly performed exercise denies the possibility of head movements. The therapeutic session may be run in one of four operating modes (see Tab. 4).

A single session begins with the introductory part, which gives additional time for minor corrections and getting acquainted with the principles of performed exercises. The core part follows, combining six 63-second sets. Subsequent sets are conducted in various forest scenes. Possible stress related to a sudden change of the virtual location is minimized using graphical screen blur. During the whole session, selected biomedical parameters and head motor activity (for 6 degrees of freedom) of the examined volunteers were recorded (see Sec. III-B). The application is incorporated directly with an electronic questionnaire system (pre- and post-questionnaire) to maintain the consistency of the measurement data with the questionnaire's results. The application is available to academic community upon request.

B. BIOSENSORS

For the purpose of this research physiological signals were acquired using GSR, EMG and HRM sensors, which are briefly described in the following section. The position of biosensors and the typical wave-forms are illustrated in Fig. 4.

1) GALVANIC SKIN RESPONSE

Galvanic Skin Response (GSR) (skin conductance) is a measure of the continuous variations in electrical resistance of the skin. It depends on the degree of skin hydration caused by the variation of sweat glands activity controlled by the sympathetic nervous system. The most common model of GSR reaction assumes that the reduction of skin resistance occurs as a result of sweating and filling of sweat glands. Measurement of GSR is based on the assumption that the level of stimulation of the cerebral cortex and skin resistance are correlated: stimulation of the cerebral cortex is reflected in a decrease in skin resistance, and a decrease in the level of stimulation is associated with an increase in skin resistance. Thus, GSR is influenced by a psychological condition. Usually, the measured value is skin resistance or its inverse - conductance ($G = 1/R$)). The measurement process is relatively simple: the sensor, in the form of two dry electrodes, is placed on two fingers (see Fig. 4). In case of this research, especially during sessions type 3 and 4, the haptic feedback may affect the measurement and be inconvenient for the subject holding controllers. Additionally, another limitation is the need to maintain appropriate temperature conditions inside the room. In the case of high temperatures, a small resistance associated with sweat on the hands may dominate in the measurement. In this research sensor values represent skin resistance.

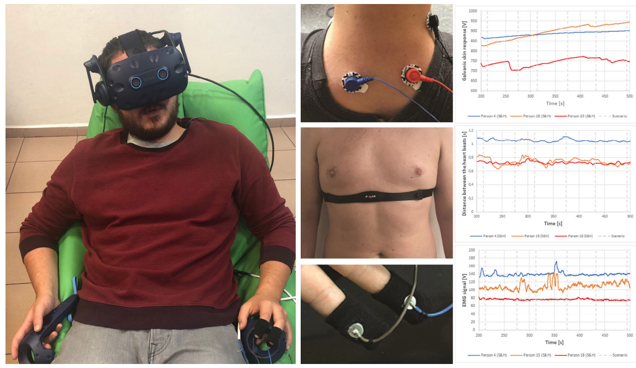

FIGURE 4. A snapshot of a subject wearing physiological signals acquisition system (chest strap, GSR and EMG sensors, and VR HDM) as well as the corresponding wave-forms registered during the first 60 seconds of EMDR session.

2) ELECTROMYOGRAPHY

Electromyography (EMG) is a measure of electrical activity produced by skeletal muscles. For this purpose, three disposable gel electrodes (two regular and one reference) are attached to the skin above the trapezius muscle. An electromyograph detects the electric potential generated when the muscle cells are activated [61]. The purpose of this research is to track neurological activation of muscles (muscle tension under stress), however even a small head movement affects the measurement and average results. Thus, the signal should be denoised by simultaneous observation from ACC and gyroscope information. Additionally, it is very difficult to determine the appropriate sensitivity of the device for a given subject, because it depends on individual's muscle structure.

3) HEART RATE MONITORING

Heart Rate Monitoring (HRM) allows to measure and record the heart rate data such as the number of heartbeats in a given period and interval. For the purposes of this research we used POLAR H10 Heart Rate Sensor with Pro Chest Strap, which was placed around the subject's chest, just below the chest muscles. The measurement process is relatively simple: transmitter is wireless, the receiver must be within a range of about 0.5 meter. The results depend considerably on the personal characteristics i.e. age, sex and physical condition, thus the signal should be normalized to the reference one (recorded just before the start of the session). Various emotional states and stress result in acceleration of the heart rate.

4) INERTIAL SENSORS

Inertial sensors such as accelerometer and gyroscope are commonly used in human activity recognition [61].

The 3-axis accelerometer (ACC) is a device to measure linear acceleration along three axes. A gyroscope is used for measuring orientation and angular velocity. For the purpose of this research we used accelerometer and gyroscope built in HTC Vive Headset [96] to track the displacement of one's head from the original position, which provides context information about the physical activity of its user. Since an important assumption of EMDR session is lack of head movement, we decided to track this activity to verify whether the subjects followed all instructions correctly and possibly identify the elements/moments that can cause irritability or boredom. The ACC and gyroscope signal is not used to analyze the level of stress, but serves as a support to recognise the deviations and irregularities in above mentioned biosensors.

C. SUBJECTIVE ASSESSMENT

Pre and post-questionnaires are based on the following assessment methods:

- GHQ-12 is the most extensively used screening method to assess well being developed by Goldberg and Williams in 1988 [97] (Polish adaptation of the questionnaire was made by Makowska and Merecz in 2001 [98]). Subjects are asked about severity or frequency of 12 symptoms indicating a decrease of well being in the period of last 3 weeks. In this study we used 4-point Likert scale for scoring (0-1-2-3).
- Scales for the measurement of mood and six emotions [99] - there are three scales measuring mood and six scales measuring frequency of discrete emotions. For the purpose of the study we used one of them - the General Mood Scale (GMS) which consists of 10 self-descriptive statements. Subjects are instructed to state how much they agree with statements describing their mood at the moment of examination by using 5-point response scale (from 1- I don't agree to 5- I agree).
- Actual Stress Level – the one item measure to assess stress at the moment of examination developed for the purpose of this study. Subjects are asked to self-assess their stress level in that moment using 10-point response scale from 0 - not at all to 10 - so stressed that I can't bear it.
- VRSQ – Virtual Reality Sickness Questionnaire - a motion sickness measurement index in a virtual reality environment [100].

All psychological measurements were performed twice – before and after immersion in VR. Additionally, after the session each subject was asked to score the application answering 10 items with one of five responses that range from strongly agree to strongly disagree. A field for general comments was also available. All questionnaire items are listed in Tab. 2.

D. EXPERIMENT PROCEDURE

The pilot study included 28 volunteers. They were informed about the purpose of the study. Procedure of the experiment was explained to them step by step. Volunteers were informed that they had the right to withdraw their consent to participate in the study at any moment. At the beginning of the experiment the operator presents the subject with the standard protocol of experiment. The protocol includes information on psychological tests, procedure of sensor installation and time of VR immersion. All subjects are free to ask any questions they deem necessary.

Each subject was tested four times in modified experimental conditions which are presented in Tab. 4. Such procedure was developed to study the effectiveness of different kinds of BLS in stress reduction.

The order of experimental conditions for the given subject was random to avoid the bias in self-assessments related to number of repetitions and learning effect. The sequence of the actions was the same in each experimental session: information to the subject, psychological testing, sensors and VR headset mounting, immersion, sensor and VR headset unmounting and psychological testing.

E. TECHNIQUES FOR BIO-SIGNAL ANALYSIS

For the purpose of this project we gathered 84 samples from 28 subjects (3 sessions per subject). Next, all samples underwent a selection process in order to check the usefulness for further analysis. The correct execution of the activity requires head stillness and simultaneous eye movement. Thus, we analysed head movements (based on HMD trajectory) in three axes, although only changes in rotation of axis Y were taken into consideration for the final assessment.

As it was presented in Sec. III, the whole process is divided into several different scenes. The first scene (Introductory) and the last part (Closing) were not taken into account as their role was to prepare for the exercise and finish the exercise respectively (those scenes allow movements). Starting from the 90th second, we analysed every core scene (every second scene, when the subject is supposed to follow the sphere). Every core scene is preceded by a break, which allows movements. Typical Y axis rotation is presented in Fig. 5 and Fig. 6. Rotation is measured relative to the virtual environment.

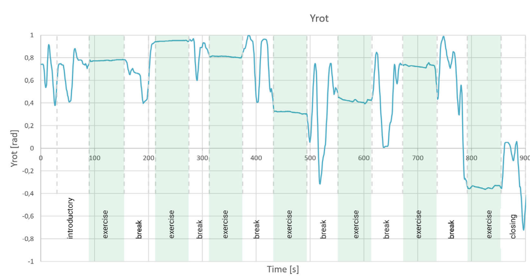

FIGURE 5. Typical Y axis rotation: incorrectly executed exercise.

In order to select only correct samples (no head movement in core scenes), we calculated the standard deviation in each core scene. If std value exceeds a threshold of 5°, the sample is rejected for further analysis.

TABLE 2. An overview of psychological measurements used in our research.

Type	Questions	Scale
GHQ-12	1. Able to concentrate, 2. Lost much sleep, 3. Playing useful part, 4. Capable of making decisions, 5. Under stress, 6. Could not overcome difficulties, 7. Enjoy normal activities, 8. Face up to problems, 9. Feeling unhappy and depressed, 10. Losing confidence, 11. Thinking of self as worthless, 12. Feeling reasonably happy.	1 - not at all, 2 - no more than usual, 3 - rather more than usual, 4 - much more than usual.
GMS	1. I am in a bad humour, 2. I feel great, 3. I am in a bad mood, 4. I feel relaxed and calm, 5. I feel blue and hopeless, 6. I am cheerful, 7. I feel depressed, 8. My mood is bad, 9. My mood is good.	1 - I disagree, 2 - I rather disagree, 3 - kind of yes, kind of no, 4 - I rather agree, 5 - I agree.
ASL	How stressed are you at the moment?	0 - no stress, 10 - the greatest stress you can imagine
VRSQ	1. general discomfort, 2. fatigue, 3. eye strain, 4. difficulty concentrating, 5. headache, 6. difficulty thinking, 7. lack of visual acuity, 8. fluctuation when the eyes are closed.	1 - absence, 2 - slight, 3 - moderate, 4 - significant.
TS	1. I felt very comfortable during the session. 2. Nothing bothered / interrupt the immersion. 3. I found the visual part of VR environment realistic. 4. I found the sound part of VR environment realistic. 5. I found the haptic stimuli sufficient. 6. I do not feel eye strain. 7. I do not feel any discomfort. 8. I would like to use the app in everyday life.	1 - I disagree, 2 - I rather disagree, 3 - kind of yes, kind of no, 4 - I rather agree, 5 - I agree.

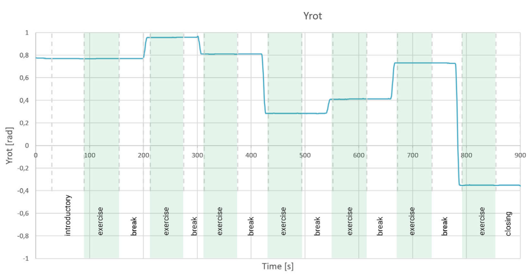

FIGURE 6. Typical Y axis rotation: correctly executed exercise.

Finally, 68 samples from 23 subjects were selected for the study (see Tab. 3).

In order to smoothen out short-term fluctuations and highlight more long-term trends, from all signals samples a 10-second simple moving average (SMA) was calculated (see Fig. 7) [92]. Finally, we used z-score to standardise all samples.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. SUBJECTIVE ASSESSMENT RESULTS

The analysis of compliance with the assumptions in various tests was performed for all data types (according to Tab. 2). The Shapiro-Wilk test was used to confirm the normality of the analyzed distributions. Bartlett's test was used to confirm the statement of equal variants of the analyzed results.

We compared the scores of subjective measures obtained by each vol before (T1) and after (T2) the experimental session. The comparisons were made using Student t-test for dependent samples. First, we analysed changes in stress level and mood between T1 and T2. All participants declared relatively low stress at the beginning of experiment and a significant reduction just after (see Tab. 5). The similar effect was found for 10 mood states (see Tab. 6). After the experimental session, we obtained significant improvement of the mood – negative feelings were reduced and positive ones increased (see Fig. 8).

We believe that mental health status could be a significant confounder of relationships we studied. Thus, we decided to control it by the means of General Health Questionnaire, which was filled in by the participants before the experimental session.

The mean score in General Health Questionnaire (GHQ12) was 11.93 (SD = 5,39), which reflected average mental health status of the group on the day of the first experimental session. It appeared that mental health status affected the level

TABLE 3. Participant characteristics.

Partic.	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20	#21	#22	#23
Sex	F	M	F	M	F	M	M	F	M	M	M	F	F	F	F	F	F	M	M	F	F	F	M
Age	37	35	35	52	35	31	44	35	41	58	41	45	26	21	28	39	30	20	29	46	40	53	35

TABLE 4. Description of different experimental condition types.

#Mode	Description
Type 1: visual only	VR immersion and visual bilateral stimulation - the subject, located in virtual forest, follows the moving sphere;
Type 2: visual and auditory	VR immersion, visual and auditory bilateral stimulation - the sound of a gong emphasizing the extreme position of the moving sphere (sound appears in left or right ear)
Type 3: visual and tactile	VR immersion, visual and tactile bilateral stimulation - the haptic stimuli (left or right controller vibration) emphasizing the extreme position of the moving sphere;
Type 4: visual, auditory and tactile	VR immersion and visual, auditory and tactile bilateral stimulation - the combination of visual, sound and haptic stimuli.

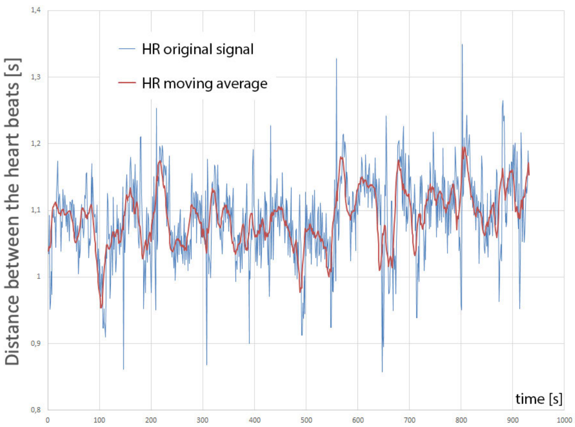

FIGURE 7. For the sake of the sensor-obtained data analysis, we assumed two different approaches. In the first one we calculated the mean value of 60-second intervals of each sample. The second one is based on the application scenario: the mean value was calculated in specific scenes (exercise1, break1, exercise2, break2 … exercise7, break7.

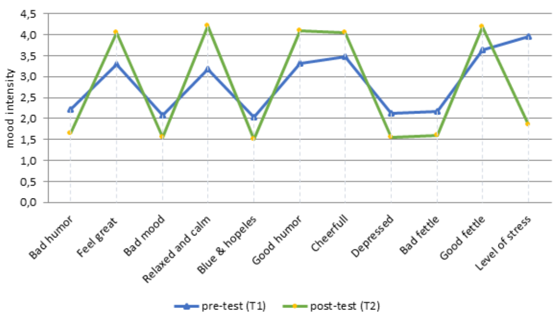

FIGURE 8. Changes in mood states before (T1) and after experimental session (T2).

of stress declared by people before the session. The subjects who scored higher at GHQ-12 (13 points and above) had higher level of stress than those who scored lower (see Tab. 7). However, the results of t-Student test proved a significant reduction of declared stress level after the experimental session in both group of subjects (see Tab. 8).

We did not find any negative effect of VR stress management session in terms of VR sickness symptoms.

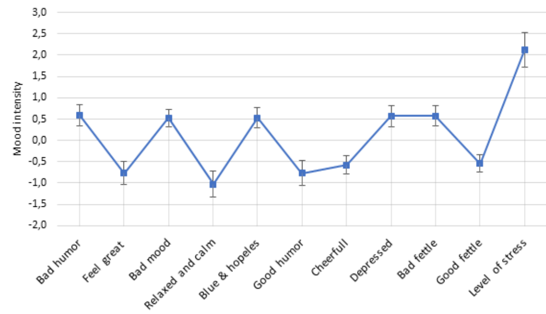

FIGURE 9. Graph of means and confidence intervals (95.00%) T1-T2.

TABLE 5. Mean stress levels before (T1) and after(T2) experiment. How much are you stressed right now? (0-not at all; 10 – the highest stress I can imagine).

Session	Mean (N=68)	Standard deviation	Standard error
T1	3.956	2.536	0.308
T2	1.838	1.929	0.234

Counterintuitively, we could even observe a small reduction in mean general VRSQ score after the experimental session (see Tab. 9).

In the next step we compared three different experimental condition types. As is presented in Fig. 10 the mean values ΔT of each method is different. What is worth to mention, all result in stress level decrease (best results were obtained for type 1: visual only.).

In order to analyze the impact of experimental condition type on ΔT the analysis of variance (ANOVA) was used. Summary of calculations for experimental condition type is presented in Tab. 10, results analysis in Tab. 11.

ANOVA was used to test the null hypothesis - if means of several populations are all equal. Conclusion: if the p-value is less than the significance level (in this case 0.05), reject the null hypothesis; if F > F crit., reject the null hypothesis. In this case p-value ($p = 0.65$) is greater than 0.05, that means there is no statistically significant difference between the means due to this factor. Additionally, ($F = 0.55$) > (F crit. = 2.75), thus the hypothesis that the averages are equal

TABLE 6. Results of Student t-test for dependent samples (T1:T2).

Variable		Differences in dependent samples						t	df	significance (two sided)
		Mean	Median	Standard deviation	Standard error of the mean	95% confidence interval for difference in means				
Emotion	T1-T2					Lower bounds	Upper bounds			
Bad humor	T1-T2	0.588	0.0	1.011	0.123	0.344	0.833	4.798	67	0.000
Feel great	T1-T2	-0.765	-1.0	1.108	0.134	-1.033	-0.497	-5.692	67	0.000
Bad mood	T1-T2	0.529	0.0	0.837	0.102	0.327	0.732	5.216	67	0.000
Relaxed and calm	T1-T2	-1.029	-1.0	1.233	0.150	-1.328	-0.731	-6.882	67	0.000
Blue & hopeles	T1-T2	0.529	0.0	0.969	0.118	0.295	0.764	4.504	67	0.000
Good humor	T1-T2	-0.765	-1.0	1.223	0.148	-1.061	-0.469	-5.156	67	0.000
Cheerfull	T1-T2	-0.574	0.0	0.886	0.107	-0.788	-0.359	-5.336	67	0.000
Depressed	T1-T2	0.574	0.0	1.012	0.123	0.329	0.819	4.673	67	0.000
Bad fettle	T1-T2	0.574	1.0	0.982	0.119	0.336	0.811	4.815	67	0.000
Good fettle	T1-T2	-0.544	0.0	0.854	0.104	-0.751	-0.337	-5.254	67	0.000
Level of stress	T1-T2	2.118	2.0	1.689	0.205	1.709	2.526	10.341	67	0.000

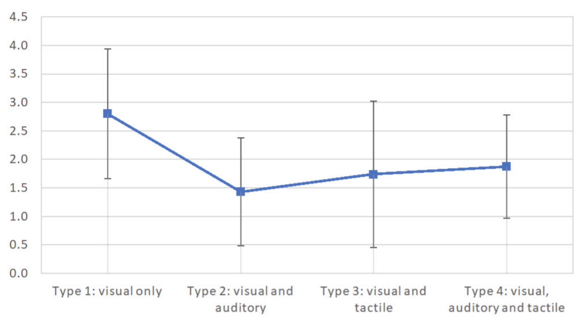

FIGURE 10. Mean values and confidence interval (95,00%) ΔT.

TABLE 7. Comparison of a current stress level in groups with lower and higher GHQ-12 score (t- Student). MSS - mean stress score.

group	MSS	SD	t	df	p
$GHQ-12 < 13$	3.159	2.458	-4.198	53.96	0.001
$GHQ-12 \geq 13$	5.542	2.105			

cannot be rejected, and there is no evidence of this factor influence.

The above is consistent with the interviews carried out after each session, where subsequent people indicated large differences in perception of individual stimuli. For example, some people tactical stimuli allowed them to focus better, for others it did not matter. There were also people for whom tactical sensation was distracting.

The actual mood of a subject was also of great importance. The perception of individual stimuli was therefore very diverse, but different for individuals. The impact of additional stimuli could therefore be better studied if the number of sessions for people using a given stimulus would be increased. The test would also have to take into account the dependency of results for a particular individual.

Fig. 11 presents results of the survey on general feelings about the application. Most subjects appreciated the opportunity offered by VR and would like to use VR as a part of daily life (69.6%), finding this kind of relaxation therapy comfortable (95.6%). Only 8.3% of the subjects indicated some discomfort during the session, 8.7% felt eye strain. Haptic and auditory sensations were sufficient for 86.9% and 95.6% subjects respectively. Solely in case of question three (I found the visual part of VR environment realistic) and two (Nothing bother, interrupt the immersion), which are both concentrated on the realism of the experience, the assessment leaves room for improvement. 69.6% of respondents could not immerse themselves in the VR environment, 34.8% indicated graphic issues.

TABLE 8. Result of t-Student test for comparison of T1 and T2 levels of stress in two groups of subjects (split by GHQ-12 scores).

Group	N	T1		T2		t	df	p
		Mean stress score	SD	Mean stress score	SD			
GHQ-12 <13	44	2.932	2.266	1.205	1.519	7.076	43	0.000
GHQ-12>=13	24	5.833	1.857	3.000	2.085	8.642	23	0.000

TABLE 9. Motion sickness measurement index in a virtual reality environment before (T1) and after(T4) experiment. Motion sickness measurement index in a virtual reality environment (0 - no symptoms; 1 - the highest level of symptoms).

Session	Mean (N=68)	Standard deviation	Standard error
T1	0.257	0.181	0.022
T2	0.151	0.132	0.016

TABLE 10. Calculations for experimental condition type.

Experimental condition type	Count	Sum	Average	Variance	Confidence interval
Type 1: visual only	5	14	2.8	1.7	1.14
Type 2: visual and tactile	21	50	2.38	5.25	0.98
Type 3: visual and auditory	19	33	1.74	4.43	0.95
Type 4: visual, auditory and tactile	23	43	1.87	4.94	0.91
Sum:	68	140			

TABLE 11. Analysis of variance ANOVA.

Source of variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit.*
Between groups	7.72	3	2.57	0.55	0.65	2.75
Within groups	300.05	64	4.69			
Total	307.76	67				

TABLE 12. Results of physiological measurements.

		1st approach			2nd approach			ASL %
		HRM [%]	GRS [%]	EMG [%]	HRM [%]	GRS [%]	EMG [%]	
positive values:		57.4	75.0	55.9	58.8	83.8	57.4	89.7
gender	Female	64.3	82.1	46.4	66.4	85.7	46.4	87.5
	Male	47.5	70.0	45.0	42.5	70.0	40.0	75.0
age	<=35	69.7	78.8	45.7	48.6	84.8	42.4	85.7
	>35	40.0	71.4	45.5	39.4	82.9	42.4	69.7
type	visual	40	80	40	40	100	40	100
	visual and auditory	61.9	76.2	47.6	71.4	85.7	57.1	85.7
	visual and tactile	68.4	63.2	42.1	52.6	78.9	47.4	78.9
	visual, auditory and tactile	52.2	60.9	47.8	65.2	78.2	56.5	82.6

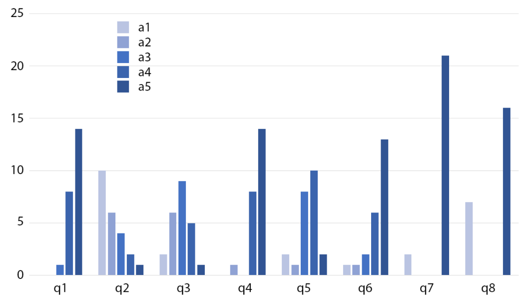

FIGURE 11. Results of the survey on general feelings about the application.

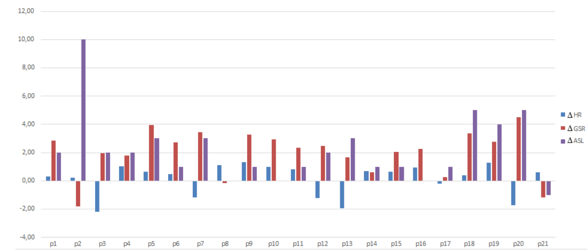

FIGURE 12. Difference between mean value of the first exercise scene and mean value of the last break obtained for all subjects of type 2 (visual and auditory) session.

B. BIO-SIGNALS ANALYSIS

In order to evaluate the effectiveness of the proposed method, we applied a comparison of sensor measurements before and after the whole session in two different methods. We calculated the difference between the mean value of the first break scene and mean value of the closing break (first method) as well as the mean value of the 3rd minute and the mean value of the 15th minute of the session (second method). We decided to take into consideration extreme break phases (first and last) because during those phases the subject does not focus on the exercise and should be fully relaxed. The 3rd and 15th minutes (second method) are contained in these particular phases.

The value of the difference should be positive when the stress level of the subject is reduced in case of HRM and GSR and negative in the case of EMG signal. Table 12 illustrates obtained results. The values represent the percentage of positive differences for all signals in both methods. The results are juxtaposed with the subjective assessment of stress level (ASL) of each subject. ΔASL in % represents the number of positive differences between ASL before and after the session. Zero-crossing is relevant in case of ASL and that is why this value has not been standardized.

We compared the correspondence of physiological measurements with a subjective evaluation during the ASL test. As one can easily observe the best results are obtained for GSR signal, similar in both methods: 75% (1st method) and 83.8% (2nd method) cases where the subject's stress level was reduced. These results are close to ΔASL, which indicates that 89.7% of the same subjects assessed that their stress level was reduced during the sessions. Definitely worse results were observed in case of HRM signal. The values in both approaches are slightly higher than 50% namely: 57.4% and 58.8% for the first and the second method respectively. Similar results were obtained for EMG signal: stress reduction confirmed in 55.9% (1st method) and 57.4% (2nd method) cases.

Next, we compared the results divided for each gender. According to ΔASL, the EMDR session was 12.5% more effective for females. It is also confirmed by all sensor indications and as in the previous case the best results were obtained for GSR signal, similar in both methods: in 82.1% (1st method) and 85.7% (2nd method) cases the female's stress level was reduced. Next, we compared the results divided for age groups. In the group of younger subjects (<=35) the session was 16% more effective than in the group of older ones (>35). Similarly, this phenomenon is best indicated by GSR signals. Young generation is more familiar and used to modern technology thus we suspect that participation in VR session did not caused arousal related to the novelty of situation as in the group of younger participant. Technological literacy of participants might have an impact on the results.

According to ΔASL, the EMDR session was most effective using type 1 mode (visual). It is also confirmed by GSR sensor indications, in both methods: in 80% (1st method) and 100% (2nd method). However, in this case the sample was the smallest.

Figure 12 presents the results of 21 individual subjects taking part in type 2 mode (visual and auditory). The figure illustrates the comparison of differences between mean value of the first break scene and mean value of the last break of HR and GSR with Δ ASL. As can be seen, 18 subjects evaluated their stress level as reduced after the session. This evaluation is confirmed in case of 17 subjects' GSR signal and by 15 subjects' HR.

The results of HR and EMG are not fully relevant. This might be explained by the fact that the study did not involve stress induction. Our assumption is that because the subjects' stress level oscillated around 5 according to their own assessment it might have not evoked clearly observable heart rate acceleration, thus the changes, even after relaxation, were not significant.

As far as muscle tension is concerned the fluctuation is the least observable. Our working theory is that one session is not enough to observe significant changes and as it was emphasized before, the initial stress level estimated during the ASL test was not conducive for extreme, measurable changes in muscle tension. Further examination will involve people with anxiety disorders, stress induction and multiple sessions for checking changes in muscle tension to prove or disprove its validity in stress measurement for our purposes.

Finally, we compared four different experimental condition types (as presented in Tab. 4). Best results (ASL and GRS: 85%) were obtained for the second type, where the visual stimulation is reinforced by auditory one. However, type one is only 2% (according to ASL) and 4% (according to GRS) less effective, which uses solely visual stimulation. Similarly, EMG and HRM sensor indications are much lower, if not marginal (especially in case of EMG). Vibrating controllers might have influenced the results as well, but it seems to be a highly individualized factor, as some subjects claimed that they actually helped them focus and some considered them disruptive and made focusing on three stimuli simultaneously impossible.

V. CONCLUSION

In this study an automated therapy tool comprising an interactive VR simulation was developed to demonstrate that VR may serve as a tool supporting relaxation training program. Thus, we integrated VR with the bilateral stimulation together with a set of sensors to monitor a subject's psycho-physical condition. A pilot treatment programme was carried out on an experimental group consisting of 28 healthy adult volunteers (office workers). All subjects participated in three sessions of relaxation training, which differ only by the mode of bilateral stimulation (visual, visual + auditory, visual, auditory and tactile). Data collected from questionnaires shows that VR can be useful for reducing the acute stress level. We obtained the significant reduction of subjectively measured stress and improvement of participant mood after relaxation sessions. The results of assessment via questionnaires were compared with automated sensor measurement. The highest correlation of ASL was observed based on GSR signal. Measurements of muscle tension and heart rate did not prove significant convergence with ASL and they were not effective enough as a stress indicator in this research. The pattern of results may reflects at least three phenomena: (1) limitations and drawbacks of self-reported questionnaires as e.g. response or social desirability biases; (2) the fact that participants in the study were healthy adults, in good mental shape thus we could not expect high variability of HR and muscle tension indicators; (3) short duration of the experimental session, which was not preceded by training.

This pilot study was aimed to test usefulness of bilateral stimulation in VR environment for treatment people under stress, and this goal has been obtained. Promising results show that VR based BLS may improve the mood and reduce stress. However further studies are needed. Future works may focus on: (1) finding the best physiological indicator of mood and stress changes due to the training; (2) comparison of effectiveness of single session versus multiple session programme; (3) long term effects of VR based relaxation training; (4) added value of VR to BLS in EMDR. All above mentioned directions of studies should be based on randomises clinical trial methodology. We plan to continue our research in clinical samples of patients with depression and anxiety disorders to compare the effectiveness of standard BLS relaxation and BLS relaxation in virtual reality in longer time perspective.

From the technical side, further development of this project would have to take into consideration the possibility to select the environment in which the subject prefers to relax, for example starry night, meadow or underwater world. According to general comments more than 50% of subjects felt their immersion was not total because the environment did not feel real. To provide a realistic experience, focus should be put on the surroundings, thus in the future the object and scene will be developed in a more attractive way.

The expected result of the application is to improve the quality of therapy by introducing an innovative tool and reducing the time professionals have to dedicate to a single patient, which will result in both better treatment outcomes and increasing the number of patients who can be treated by a single specialist. Implementation of an innovative VR-based technology will enrich depression and anxiety disorder treatment. It may improve efficiency and reduce cost and time of therapy, and will provide the possibility to be used outside of medical units, even in developing countries, and enhance universal access to health care.

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