How Virtual Reality Therapy Affects Refugees From Ukraine - Acute Stress Reduction Pilot Study

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***Abstract*—This article extends and builds upon our previous research concerning Virtual Reality (VR) with bilateral stimulation as an automated stress-reduction therapy tool. The study coincided with Russia's invasion of Ukraine, thus the software was tailored to reduce the stress of war refugees. We created a 28 minutes relaxation training program in a virtual, relaxing environment in the form of a cozy apartment in the mountains. An integral part of this tool is a set of sensors, which collects and records objective physiological measures to evaluate the system's effectiveness. A pilot treatment programme, incorporating the VR system mentioned above was carried out on the experimental group of 55 Ukrainian refugees who participated in up to five relaxation training sessions. Before starting the session, baseline features such as subjectively perceived stress, mood, galvanic skin response, and EEG were registered. The monitoring of physiological indicators was continued during the training session. Before and after the session, volunteers were asked to fill in questionnaires regarding their 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, anxiety, refugees, relaxation techniques, stress reduction, Ukraine, virtual reality.**

I. Introduction

THE Russian invasion of Ukraine began on February 24 2022 and led to massive emigration. More than five million Ukrainians have left for neighboring countries. As of June 21, more than 1.18 million refugees have been registered in Poland. Most of them are women and children, which adds to the stress of long-term broken family ties. They end up in refugee centers without any belongings, facing a cultural and language barrier, and often suffering from trauma and stress related disorders. It should also be mentioned that the events preceding the war, related to the COVID-19 pandemic, greatly affected the general population [1]. Recent studies indicate that people, in general, have become more stressed, oversensitive, and prone to anxiety disorders [2]. This predicament has befallen refugees as well. Many of them are not only afraid of war but still fear for their health and the return of the pandemic in unfamiliar circumstances. Trivial to say that war refugees live under severe stress due to the accumulation of trauma and loss and the need to act ad hoc, without preparation and planning. They have to act in unpredictable circumstances, making critical decisions based on incomplete and uncertain information. Common manifestations of this kind of stress are fears and anxiety.

Many refugees have been facing fear and anxiety arising from various life circumstances and ongoing traumas related to the war, separation from families, and post-migration stressors in the settlement environment [3]. Fear and anxiety are usually seen as separate phenomena but recent research and analysis seem to challenge this view as an oversimplification [4]. However for the purpose of this study we will refer to the classical distinction between these two entities.

Fear is one of the basic emotions originating in the survival instinct. It is a state of solid emotional tension that occurs in situations of real danger. The amygdala plays the core role in the fear reaction. It is the first rough analyzer of environmental stimuli in terms of threat. If something is recognised as the threat the amygdala will transmit impulses to the hypothalamus, after which the body produces the fear hormone - adrenaline. The so-called rush of adrenaline increases the blood pressure, dilation of bronchi, pupils, and muscle tension [5]. This natural body preparation to fight or flight from danger has evolved in many species through evolution. Fear should quickly expire if there are no unpleasant consequences after triggering the stimulus or the danger disappears. Then the reaction fades. In a case where the harmful effects of the stimulus continue, the experience of fear develops and intensifies to maintain the motivation for survival [6].

Although many bio-psychological manifestations of fear and anxiety overlap, there are some differences between them. First, the locus of danger: fear is a reaction to an external threat or to body sensations (e.g., breathlessness as a result of choking), while anxiety occurs when we anticipate a threat, even when it is hardly identifiable (e.g.a thought that something bad will happen). Second, the time frame: fear is induced by the immediate present situation and lasts as long as the threat is presented. Anxiety is rather evoked by concerns/worries about the future and may persist for a long time [7], [8]. It implies the cognitive evaluation of challenging situations while

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This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Research Ethics Committee of Lodz University of Technology under Application No. 3/2021, and performed in line with the Declaration of Helsinki.

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fear is a more automatic primary reaction to the threat for survival.

Experiencing fear and anxiety over a long period of time can lead to negative consequences in the form of mental health disorders [8]. One of the special risk groups are refugees fleeing conflicts, wars and violence to seek asylum in other countries. Fears and a high level of anxiety may lead to development of many problems including trauma and stress related disorders, anxiety and mood disorders. The situation of refugees in the host country, including the language barrier, often prevents them from benefiting from psychological support and regular psychiatric treatment. Considering that the number of refugees and internally displaced people has reached 100 millions [9], and the prevalence of mental health disorders among them is sometimes estimated even up to 80%, there is the huge need for development of measures which help this population to reduce stress burden and minimize the risk of ill health. Taking into account the war in Ukraine, by 19th of July, 2022 more than 9.5 million refugees have crossed borders into neighboring countries since 24th of February, according to the United Nations High Commissioner for Refugees [10]. This population of refugees consists mostly of women and young children - the most vulnerable in terms of risk of mental health problems related to trauma and adaptation in new settings. Moreover, multiple post-migration factors increase their vulnerability to mental health problems. Among these factors are the following: uncertainty about own status in the host country (including challenges to find stable job and accommodation, problems with getting into welfare and health system), separation from family and friends which results in loss of the existing support system, uncertainty about the future of both ones and relatives who stayed in Ukraine, and last but not least - acculturative stress [11]. War-related fears, anxiety, and acculturation challenges contribute to a general feeling of stress and lowered mood. Left unattended, in the long term they can lead to adaptive disorders and mental health problems.

Many scientists and experts in the field of public health and psychotraumatology appeal to decision-makers to provide comprehensive support for refugees, the permanent element of which should be support and psychological help [12]. However, with such massive humanitarian crises as the Ukrainian one, even the richest countries have a problem with ensuring such comprehensive care in a traditional way. Therefore, technology is used more and more often in humanitarian crises - from telemental health care programs to applications dedicated to mental health [13]. Some of these apps use VR as the environment which successfully supports the healing process and adaptation [14].

Taking into account the above facts, just after the war started, we decided to provide Ukrainian refugees with a VR application originally conceived as a support tool in coping with the effects of chronic and acute stress. Based on the assumption that the mechanism of the stress response is the same regardless of its source, we concluded that our VR application may also be helpful in alleviating the symptoms of stress in refugees.

Virtual reality (VR) is a technology that brings new opportunities to psychologists and psychotherapists [15]. It transfers the patient to an artificial world while leaving them in a safe, therapeutic environment. Furthermore, total immersion (VR cuts the user off entirely from the real world visually and aurally) supports imaginative and exposure therapy, as it's safer, less cumbersome, and less costly. Scientific research shows VR therapy's usefulness in treating stress symptoms [16], depression [17], anxiety disorders [18], phobias [19], and PTSD [20]. In addition, VR technology is also used to combat acculturative stress and facilitate refugees' adaptation in host countries [14].

This paper extends our previous research [21], where we presented an automated therapy tool for stress reduction in the form of a VR system providing an interactive virtual reality simulation. This time, we have prepared a new VR environment supported by an audio guide in the virtual world. While designing the VR environment and training scenario, we were aware of possible triggers which might induce stress reactions during the exercise and try to avoid them as much as possible. Therefore the audio guide to each session of VR training is presented in a non-directive form that allows users to possibly skip instructions that they do not want to follow and remain only immersed in a relaxing environment. Trials have been conducted on a group of 55 volunteers who participated in up to five relaxation training sessions. During each session, the system continuously monitored users' activities, such as electroencephalography and galvanic skin response. What is more, before and after the session, volunteers were asked to complete questionnaires regarding their current mental health status, stress level and mood.

Our study aims to verify the designed VR application's effectiveness in reducing stress and improving well-being. As indicators of the effectiveness of the application at the psychological level, we took: (1) reduction in stress levels, (2) lower intensity of negative mood, (3) higher intensity of positive mood, and (4) improvement in overall well-being. Additionally, at the physiological level, we took galvanic skin response as the indicator of application effectiveness. This parameter should decrease as the relaxation progresses. We also wanted to check if and to what extent the designed VR exercise affects brain function in the direction suggesting the progress of relaxation.

The rest of the paper is organized as follows: Section II reviews the related work in VR-based stress-reduction methods. In 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 Work

There have been several studies investigating the effect of VR on stress reduction. However, since this is our next paper on stress reduction in VR, and we have accumulated many articles related to the topic in the previous one [21], this section will focus only on the latest research (2020-2022).

Many papers focus on transferring the user to a different environment, with no additional exercises or stimuli. For example, in [22] during the relaxation session, the volunteers were walking on a simulated trekking course with natural scenery and a relaxing soundtrack. In this study, the authors compared the differences between subjective stress reduction and physiological parameters when VR or biofeedback treatment (a kind of treatment that uses electronic monitoring devices to provide information about the body's physiological processes to help individuals gain awareness and adjust them to improve their general condition) was applied. The experiment was conducted among 74 participants in the Clinical Trial Center in Samsung Medical Center. Samsung Gear VR was used as a head mounted display (HMD) device. As evaluators, several physiological parameters were collected by sensors attached to the subject's body (biofeedback and HRV parameters) and the Korean version of psychological scales. The results have shown that both VR relaxation and biofeedback significantly reduced the stress among participants, but the difference between the treatments was not significant.

A similar study was conducted in [23] where the authors aimed to evaluate the effectiveness of VR technology in reducing stress among night-shift anesthesiologists. A total of 30 anesthesiologists were randomized and allocated 1:1 to either the VR immersion group (intervention group) or the routine group (control group). The results have shown that VR videos can reduce the long hours of night-shift work and allow them to rest.

Green meadows experience in VR was delivered during a workday to induce a positive mood among NHS clinicians in [24]. Besides subjective measures of emotional state, physiological arousal in the form of heart rate was observed to evaluate the experience. Data obtained from 39 clinicians revealed that VR experiences boost one's mood, specifically by increasing happiness and relaxation, simultaneously reducing sadness, anger, and anxiety. Additionally, subjective measurements correlated with a significant reduction in heart rate.

Undoubtedly, COVID-19 has negatively affected society and increased stress worldwide, especially among front-line healthcare workers. In [25], a short (three-minute) VR simulation of a nature scene was used to reduce subjective stress among front-line healthcare workers in COVID-19 treatment units located in the United States. One hundred two participants took a tour in a 360-degree green nature video scenery in an Oculus Go or Pico G2 4 K HMDs. Before the simulation, participants were asked to rate their subjective stress on a 10-point scale, from one (not at all stressed) to ten (extremely stressed). Findings from this study suggested that the VR simulation positively reduced subjective stress among the analyzed group in the short-term period. However, as the researchers noted, more research is needed to compare the VR application simulation to a control condition and assess subjective and objective measures of stress over time.

In [26] the researchers investigated if the control over one's actions affects how people respond to the VR nature experiences. They tested 64 participants by measuring their perceived stress, mood, and vitality before and after the VR experience. Surprisingly, the collected results indicate that additional activity in the VR environment might generate additional stress, compared to passive VR experiences. This leads to the conclusion that additional research must be conducted on the effects and best practices of implementing interactive elements into VR experience.

Vaquero-Blasco [27] propose an alternative to the traditional chromotherapy color-loop treatment through 360-degree VR experiences. Tests were conducted on a group of 23 healthy participants in a single-session divided into four phases. First, the participants were stressed via the Montreal imaging stress task, and then relaxed using the proposed VR session. To evaluate the effect of the application, they analised EEG signal and self-perceived stress surveys. The results have shown that the application significantly reduced the level of stress of participants.

In [28], the authors went a step further and juxtaposed the effects of VR relaxation with standard relaxation exercises among patients with psychiatric disorders (anxiety, psychotic, depressive, or bipolar disorder). As in previous examples, the VR environment was in the form of immersive 360° nature videos. However, this time the environment was extended by interactive elements in an extra layer in the form of guided meditation and progressive muscle relaxation. A randomized trial was conducted on 50 patients. They were randomly assigned to use VR-based or standard relaxation therapy for ten days at home. Perceived stress was measured before and after the session based on eight visual analog scales of momentary negative and positive affective states. The results showed that VR-based therapy may provide a much-needed, effective, easy-to-use and self-managed relaxation intervention to enhance psychiatric treatments.

As it can be seen, the development of new virtual environments in recent years is qualitatively high and rapid, but the VR usage in clinical practice is still negligible. That is why the technology is striving for research that is not only based on one experiment, but comprises a long-term series of VR usage, to identify its effect on chronic stress and its long-term decrease while subjected to VR-supported treatment. In addition, most VR therapies are solely expositions to nature or different calming environments without possibility of interaction. The third issue is connected with validating the effectiveness of used solutions, as it has most commonly relied solely on subjective evaluation of the participant. Thus, we still feel there is a knowledge gap in the discussed topic, especially concerning the above-mentioned issues.

III. Materials and Methods

A. Bilateral Stimulation

The bilateral stimulation (BLS) technique can be defined as providing left- right sensory stimulation to reduce the level of arousal by shifting from sympathetic to parasympathetic activation. To obtain the effect of de-arousal, a visual, tactile, or auditory signal is given rhythmically on the left and right sides of the body. In EMDR (Eye Movement Desensitisation and Reprocessing) therapy, BLS is a crucial component of the so-called dual attention task, when the patient recalls traumatic memories being simultaneously involved in the distracting activity, e.g., visual tracking of the point of light [29]. There is evidence that BLS not only does reduce psychophysiological arousal but also has a beneficial effect on memory and information processing [30]. According to the testimony of Korn and Leeds [31], at an early stage of EMDR therapy development, Neal Daniels suggested a method that involves merging a picture of a secure location with side-to-side eye movement to help war veterans feel more

Fig. 1. VR environment in the form of a cozy apartment in the mountains. The real chair was mapped in the VR environment identical.

relaxed and improve their ability to process traumatic events. There are many studies confirming the effectiveness of BLS in obtaining a calm state [32] and eye movement BLS is the first choice option in treatment [33].

The inspiration for using BLS together with visualization to reduce psychophysiological arousal related to stress came from calm/safe place exercise and Resources Development and Installation phase of EMDR [33], [34]. Our goal was to reduce participants' stress by providing a safe and relaxing environment and instilling in their memory a positive association between slow pace of breathing, visualization and relaxed body and mind. We decided to use eye movement BLS, as it seems to be the most effective one according to some studies [35], and provide relatively short sets of slow BLS (around 0,16(6) Hz) [36], [37]. In line with standard EMDR protocol, BLS sets were displayed horizontally, and participants were asked to follow the light sphere with their eyes without moving their head. The participants were reminded of this during the exercise. In addition to using breathing techniques, visualization, and bilateral stimulation, we decided to use images of nature to enhance the relaxation effect. According to Attention Restoration Theory (ART) [38] and Stress Reduction Theory (SRT) [39], [40], focusing on images of nature with a large green component can facilitate restoration from mental fatigue, relief from stress, and reduction of negative moods [41].

Fig. 2. Snapshot of a subject during VR therapeutic session.

B. VR Application

The VR application extends our previous application presented in [21]. We modified the concept of the VR environment and audio guide. This time the environment took the form of a cozy apartment in the mountains (see Fig. 1). The first scene was designed as a kind of tutorial for the user and it serves configuration purposes as well. What is more, it provides an opportunity to adjust user's and virtual camera location. During the session, each participant relaxes on a comfortable chair (exactly the same is mapped in the VR environment) in a chosen position (see Fig. 2). The scene is calibrated automatically (based on the user's head position) to make sure that the main element (a window with the mountain view) of the scene is centered vertically and horizontally for a particular participant.

Due to a phenomenon called VR sickness or cybersickness [42] it is suggested to use an adaptation session to reduce potential adverse feelings during the simulation [43]. Thus, the second scene starts with a 2-minute adaptation session (the user is guided by the voice instructions on what to do, which gives additional time for minor position corrections, getting acquainted with the local environment as well as principles of performed exercises, and deepening the immersion).

The following scenes are purely therapeutic. The exercises involve various relaxation techniques such as breathing methods, visualization and bilateral stimulation (BLS). The latter is facilitated by a sphere moving along an invisible straight horizontal line outside the window. When the sphere is visible in the subject's field of view the proper performance of the exercise is controlled by an eye tracking system embedded in HMD. The core part combines seven 90-second long BLS sets interspersed with 30 s no BLS sets (see in Fig. 3). No BLS sets were introduced to give participants the chance to relax their eyes and avoid possible dizziness.

During the whole session, selected biomedical parameters, head motor activity (for 6 degrees of freedom) and eye movement were recorded (see Section III-C).

The application natively provides an electronic questionnaire before and after the session (pre- and post-test) and such subjective data is juxtaposed with objective data collected by sensors.

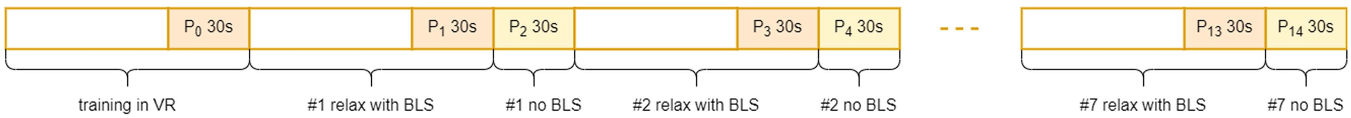

Fig. 3. Whole relaxation scenario: the length of training in VR depends on the participant and may differ (on average 92 s); The relaxation session (1050 s) consists of seven consecutive periods of 120 s with bilateral stimulation (BLS) AND 30 s without BLS.

Fig. 4. Biosensors used in the research: a) GSR b) Looxid Link - outside view of the glasses c) Looxid Link - inside view of the glasses.

Originally, we were going to test this version of the application in a study of people experiencing chronic stress and people with anxiety disorders. However, due to the outbreak of the war and the appearance of refugees from Ukraine, we decided to start the action ”Relaxation in VR” dedicated to adult refugees. While the main reason for our decision was humanitarian, it cannot be denied that the sown circumstances became an occasion for scientific research. The study protocol was approved by the local Ethical Committee (resolution no. 3/2021 dated October 21, 2021). During the study all Ukrainians were supported by the trained Ukrainian assistant.

C. Biosensors

For the purpose of this research objective data was collected using sensors which are completely unobtrusive and do not affect subject’s feeling, make them feel uncomfortable or restrict their movement. Thus, we used a GSR sensor and built-in the HMD, dry EEG electrodes that do not require gel application. The position of biosensors is illustrated in Fig. 4(a).

1) Galvanic Skin Response: Galvanic Skin Response (GSR, skin conductance) is used to trace and record variations in electrical resistance of the skin. The skin is subject to different levels of hydration caused by sweat glands controlled by the sympathetic nervous system. A typical GSR reaction involves a correlation between skin resistance and sweating - the more sweat glands are filled, the more conductive the skin becomes. GSR is assumed to be influenced by a psychological state of the subject - increased activity of the cerebral cortex is reflected in sweating and thus higher GSR. Likewise, the decrease in the level of stimulation results in higher skin resistance and lower GSR. Typically, the measured value is skin resistance or its inverse - conductance ($R = 1/G$)). The process is fairly simple and involves two dry electrodes mounted on two fingers (see Fig. 4(a)). The only precaution that needs to be taken is maintaining appropriate temperature in the room where the experiment is taking place, so as not to induce additional sweating, which would affect the validity of collected measurements. Additionally, participants were asked not to move their hands during the session to prevent artifacts in the signal. For the purpose of this research, we used Grove - GSR sensor together with Raspberry Pi 3.

2) Electroencephalography: Our main concern using EEG in this study was the comfort of the target group - we needed to provide them with relatively the most non-invasive and comfortable experience possible. Looxid Link (see Fig. 4(c)) was our choice because of that concern, especially to eliminate the cumbersome EEG wet/gel can by replacing it with HDM-integrated dry EEG Looxid Link. We are aware that it resulted in the reduction of 6 channels with sensors mounted on the user’s frontal lobe, however it was a cost that was, in our opinion, worth paying to gain additional comfort. The EEG system remains almost unnoticeable. Users did not complain about the inconvenience (preparation for the session, soaking the hair, and the need to wash the hair afterward). In this particular case, we had to accept a loss of signal quality relative to the participants’ comfort.

Looxid Link is an EEG system which proved to be the most unobtrusive system to collect relevant data while using a VR headset. The system is equipped with gold-plated sensors that collect data from the subject’s prefrontal area. The collected signals are streamed to the computer at 500 samples per second. It has made possible collecting EEG signals and identifying the user’s affect with as little discomfort as possible. The device is able to gather data on brainwaves including delta, alpha, beta and gamma per 100 ms and this data collection can be synchronized in time with the progress of the VR scenario making it possible to connect a particular stress level with a specific moment in the VR therapeutic experience.

3) Embedded Sensors: In this study the HTC Vive pro Eye Headset was used [44] which provides an embedded accelerometer and gyroscope as well as a precision eye tracking system. They were used to track the displacement of one’s head from the original position and eye movement to verify the correct performance during BLS sessions (see Fig. 5). In the case of HTC Vive Pro Eye, which utilizes eye tracking, optical IR sensors are employed to monitor eye movements. We have

Fig. 5. Snapshot from BLS therapy: stimulating one brain hemisphere at a time (left-right-left, etc.) through eye movements following an object (a red sphere). The figure presents the object's trajectory.

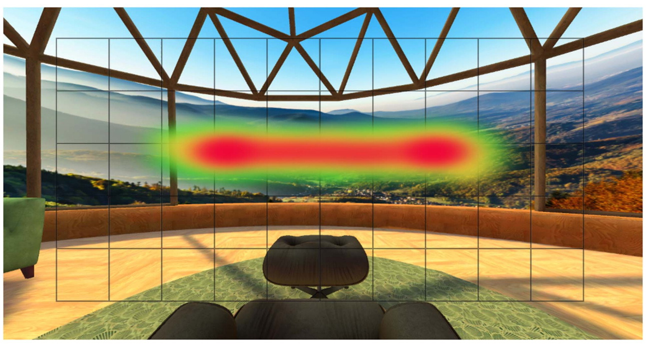

Fig. 6. Averaged heat map showing how gazing was distributed over the BLS stimulus from S1.

not found any information indicating that the Looxid device is sensitive to IR radiation, especially considering that the design of the goggles prevents direct interaction of IR sensors with EEG sensors. From the perspective of the user's visual perception in VR experiences, it is dominated by frequencies within the visible light spectrum (HMD display). We have not come across any literature mentioning the parasitic effects of IR in the context of reading EEG signals. In addition, many research papers analyze both EEG and eye-tracking signals (e.g., for emotion recognition) at the same time. In conclusion, we believe that EEG recording and eye tracking can be used at the same time without any effect on the result.

The correct performance includes lack of head movement and proper horizontal eye movement (see Fig. 6). Those signals are not used to analyze the level of stress, but serve as a support to recognise the deviations and irregularities in above mentioned biosensors.

The correctness of the exercise based on eye-tracking heat maps and head movement trajectories did not exclude any data. This fact demonstrates the high level of involvement of all study participants.

D. Subjective Assessment Evaluation

Pre and post-tests are based on the following evaluation methods:

- GHQ-12, developed by Goldberg and Williams in 1988 [45], has been the most popular and broadly applied screening method to evaluate well-being. It has been adapted into Polish by Makowska and Merecz in 2001 [46]. The method is based on questions about severity or frequency of 12 symptoms that signal a deterioration of well-being in the previous 3 weeks. Each of the 12 General Health Questionnaire questions is followed by a Likert-like answer scale. For example, the respondent answering the question: Have you been feeling unhappy and depressed? has to choose the answer from (1- not at all, 2-no more than usual, 3-rather more than usual, and 4- much more than usual).
- General Mood Scale (GMS) is a set of statements made in such a way as to express general mood- positive or negative [47]. It comprises 10 self-descriptive statements. Subjects are told to express how much they agree with sentences describing the mood at the moment of the examination. A 5-point response scale (from 1 - completely not agree to 5 - I agree) is used. All questionnaire items can be divided into two subscales: Positive and Negative Mood Subscales (PMS and NMS). For this study, we used two indices: mean score in PMS and mean score in NMS. PMS and NMS were calculated according to the following equations:

$$NMS = \sum_{i=1}^{N} NMS_i \tag{1}$$

$$PMS = \sum_{i=1}^{N} PMS_i \tag{2}$$

where N - number of participants;

$$NMS_i = \frac{1}{5}\left(q_{1i} + q_{3i} + q_{5i} + q_{8i} + q_{9i}\right) \tag{3}$$

$$PMS_i = \frac{1}{5}\left(q_{2i} + q_{4i} + q_{6i} + q_{7i} + q_{10i}\right) \tag{4}$$

where i - participant number; q_{ji} - result of the answer to $Q_{(1-10)i}$ question (scale from 1 to 5);
- Current Stress Level (CLS) – an one-item measure developed for the purpose of the study to assess the level of participants' stress at the time of examination. The response scale is from 0 to 10 (0 - not stressed at all, 10 - so stressed that I can't stand it) is used. In this study, we analyzed responses to each statement separately and also calculated general scores of positive and negative mood
- Virtual Reality Sickness Questionnaire (VRSQ) is a motion sickness measurement index in a virtual reality environment [48].

All psychological measurements but GHQ-12 were performed twice - before and after the VR experience. A space for general comments was also provided. All questionnaire items but the fully copyrighted GHQ-12 are presented in Table I.

E. Experiment Procedure

The trial had been preceded by a recruitment and information campaign held in cooperation with Lodz City Council. It started with a press conference which was later widely described in local TV, newspapers and social media, mainly dealing with Ukrainian issues.

TABLE I
OVERVIEW OF PSYCHOLOGICAL MEASUREMENTS USED IN OUR RESEARCH

Type	Measure items	Response scale
GMS	1. I am in a bad temper, 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 in a bad temper, 7. I am cheerful, 8. I feel depressed, 9. My mood is bad, 10. 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.
CSL	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.

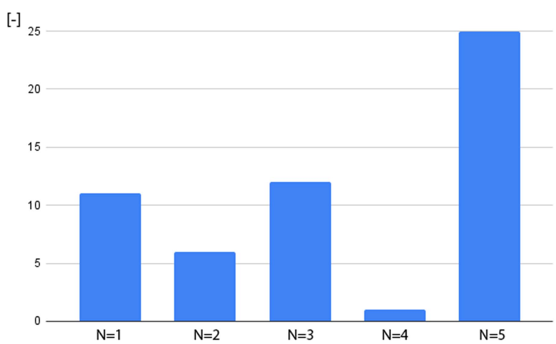

Fig. 7. Number of participants attending N-sessions.

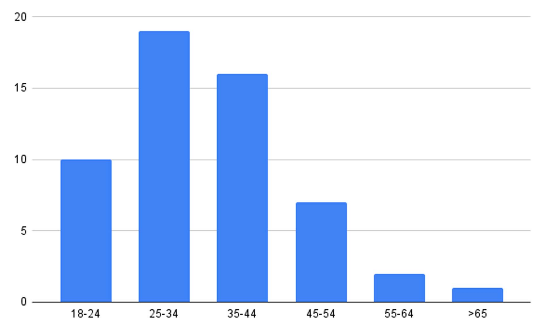

Fig. 8. Age of participants according to WHO age range classification.

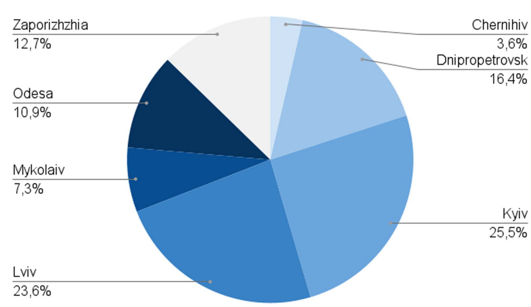

Fig. 9. Percentage distribution of participants in relation to where they lived before the Russian invasion.

All of the subjects were informed about the purpose of the study and the procedure was clearly explained and all questions were answered. They were informed about their right to withdraw their consent to participate in the study at any moment and the employed measures of data protection.

The standard protocol of the experiment was presented to each volunteer at the beginning of the procedure. It includes information on physical steps that need to be taken to install the sensors on a participant's body, the time of VR immersion and psychological tests. Subjects had an opportunity to ask any questions they considered relevant.

Each person could attend one session per week for five consecutive weeks. Unfortunately, due to the dynamic situation in Ukraine, opportunities for permanent residence in Poland, and personal issues, only 25 (45,45%) people completed the therapeutic sequence (see Fig. 7).

F. Participants

We recruited 55 Ukrainian participants to the study. Most of them were women (92,73%) which corresponded with the structure of refugees population in Poland. On average, samples were 35,96 years old (median - MD = 35, standard deviation - SD = 11,04, range = 19–71). The group comprised 51 women (92,73%) with an average age of 36,6 years (MD= 35, SD= 10,97, range = 19–71) and four men (7,27%) with an average age of 28 years (MD = 27,5, SD= 9,9, range = 19–38). Age of participants is presented in Fig. 8. In Fig. 9 the percentage distribution of participants in relation to where they lived before the Russian invasion is presented, in Fig. 10 in relation to their education level. Detailed participant characteristics are presented in Table II.

IV. RESULTS

In this section, we illustrate the result from GSR, EEG signals and subjective assessment analysis as well as the statistical analysis.

TABLE II
PARTICIPANT CHARACTERISTICS

Partic.	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20
Sex	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	M
Age	31	24	29	46	26	33	28	40	41	24	31	22	32	45	52	54	31	31	71	35
edu.	H	H	H	Sec.	H	H	Sec.	Sec.	Sec.	S	H	S	H	Sec.	Sec.	Sec.	H	H	P	Sec.
prov.	K	K	K	K	O	O	M	Z	K	K	K	K	D	D	Z	K	K	L	L	L
# sess.	3	5	5	5	5	5	5	4	3	3	5	5	3	5	5	5	5	5	5	5
res.	HC	-	-	-	-	-	-	HC	HC	HC	-	-	HC	-	-	-	-	-	-	-
Partic.	#21	#22	#23	#24	#25	#26	#27	#28	#29	#30	#31	#32	#33	#34	#35	#36	#37	#38	#39	#40
Sex	F	F	F	F	F	F	F	F	F	F	F	M	F	F	F	F	M	F	F	M
Age	47	35	35	31	22	44	45	35	58	45	36	19	39	33	39	44	38	31	51	20
edu.	P	H	H	H	S	Sec.	Sec.	Sec.	Sec.	H	S	Sec.	H	H	Sec.	Sec.	Sec.	Sec.	Sec.	Sec.
prov.	Z	L	K	L	D	Z	Z	Z	L	K	L	D	O	M	O	M	M	Z	D	L
# sess.	3	3	3	1	2	2	5	5	2	5	5	5	5	1	3	3	3	3	2	3
res.	R	HC	R	ND	ND	ND	-	-	ND	-	-	-	-	ND	R	HC	HC	R	R	R
Partic.	#41	#42	#43	#44	#45	#46	#47	#48	#49	#50	#51	#52	#53	#54	#55					
Sex	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F					
Age	19	24	31	25	46	32	23	28	31	24	35	39	39	57	36					
edu.	S	S	H	S	H	Sec.	Sec.	Sec.	Sec.	H	S	Sec.	S	H	H					
prov.	L	L	L	L	K	D	D	D	L	K	O	D	O	C	C					
# sess.	5	1	1	1	1	1	1	2	1	1	1	2	5	5	5					
res.	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-					

sess - number of sessions participated in; res. - reason for early resignation (HC - homecoming; R - relocation; ND - no data); edu. - education level (H- higher, Sec. - secondary education, P - primary, S - student); prov. - province (oblasts: C - Chernihiv, D - Dnipropetrovsk, K - Kyiv, L - Lviv, M - Mykolaiv, O - Odesa, Z - Zaporizhzhia).

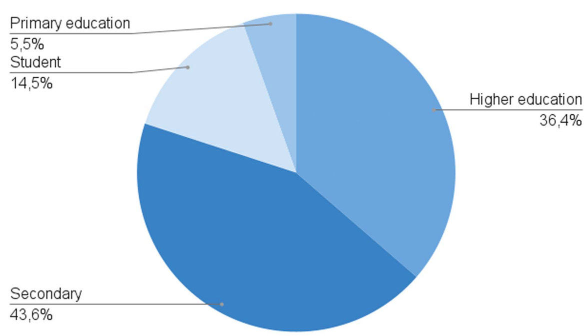

Fig. 10. Percentage distribution of participants in relation to their level of education.

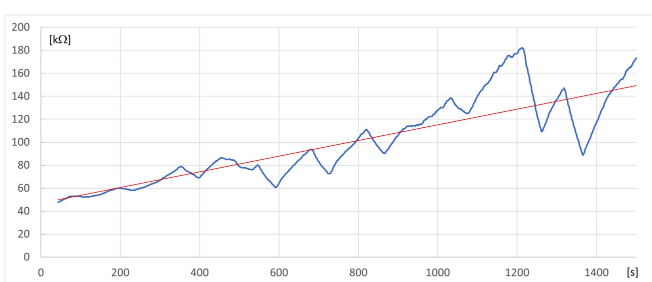

Fig. 11. Example of a GSR waveform with a trend line (in red) of one participant during the first session.

A. GSR Signal Analysis

The GSR sensor returns a vector of resistance changes in time. First, we smoothed those vectors with a moving average (30 samples) to reduce measurement noise. An example of a GSR waveform of one participant during the first session is presented in Fig. 11.

In order to determine the changes in signal waveforms at the beginning and end of the session, we performed a group analysis, i.e., we averaged GSR waveforms for all subjects for each session separately. Next, the mean resistances of P_2 (first

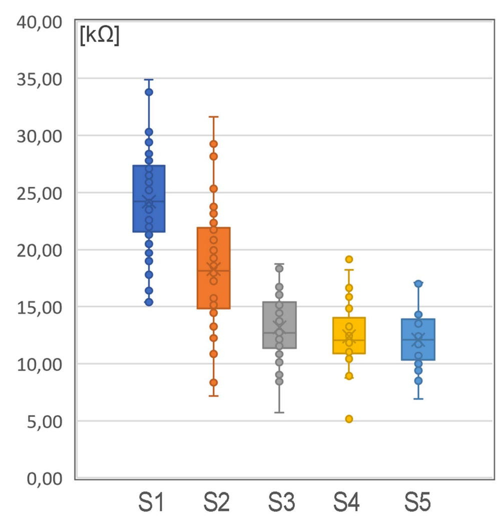

Fig. 12. Boxplot of GSR data - differences in mean values between periods P_2 and P_{14} within a given session.

30 s of the session without BLS) and P_{14} (last 30 s of the session without BLS) were calculated. Average resistance gain during the session is represented as the difference between the mean resistances of P_2 and P_{14} normalized by the mean resistance of P_0, which represents the benchmark (the 30 s period before relaxation begins when the subject sits comfortably in the HDM) - see (5).

$$\Delta r_M = \frac{R_M(P_{14}) - R_M(P_2)}{R_M(P_0)} \tag{5}$$

where $R_M(P_k)$ - mean value of the resistance in the k interval;

Differences in mean values between periods P_2 and P_{14} within a given session are presented in Fig. 12. Statistical analysis was performed to investigate whether GSR biomarkers alteration in time was significant. Specifically, we applied a t-test to determine whether the means Δr_M of P_2 and P_{14} differ significantly for a given session (see Table III). In this

TABLE III
GROUP ANALYSIS (AVERAGE ACROSS ALL SUBJECTS FOR EACH SESSION) IN THE FORM OF MEAN, STANDARD DEVIATION AND VARIATION VALUES OF Δr (S# - SESSION NUMBER)

	S1	S2	S3	S4	S5
Δr_M	24,2	18,3	13,2	12,4	12,1
Δr_{SD}	4,51	5,14	3,22	3,85	2,41
Δr_{var}	17,98	23,69	9,10	8,45	6,90
$p-value^*$	0,000	0,000	0,000	0,000	0,000

*- refers to the compared data series from P2 and P14.

TABLE IV
ONE-WAY ANOVA TEST FOR 5 SERIES OF Δr

SofVar	SS	df	MS	F	p-value	F crit
BetweenG	4438	4	1109	74,7	0,000	2,42
WithinG	2571	173	14,9			
Total	7009	177				

TABLE V
TUKEY'S POST HOC TEST ANALYSIS RESULTS FOR $Q_{.05} = 4.00, k = 5, df = 50$. DISTRIBUTIONS WITH SIGNIFICANT DIFFERENCES ARE MARKED IN GREEN

diff SE q	S1	S2	S3	S4
S2	**5,903** **0,575** **10,266**			
S3	**11,002** **0,600** **18,348**	**5,100** **0,630** **8,101**		
S4	**11,800** **0,677** **17,442**	**5,898** **0,703** **8,387**	0,798 0,724 1,103	
S5	**12,102** **0,686** **17,649**	**6,199** **0,712** **8,707**	1,100 0,732 1,502	0,302 0,796 0,379

Distributions with significant differences are marked in green.

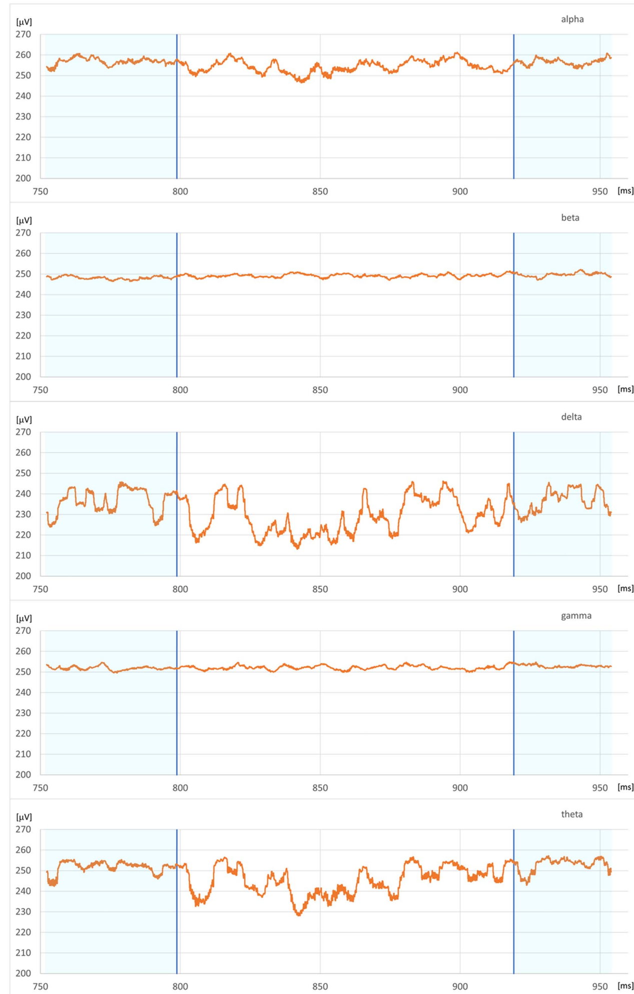

Fig. 13. Example of EEG signal waveforms. Blue-colored areas represent the subsequent no-BLS relax (P_6 and P_8) intervals separated by BLS-enhanced relax (P_7).

case p-value is lower than 0,05 that means there is statistically significant difference between the means at the beginning and at the end of each session.

Additionally, to analyze the impact of the number of performed sessions, we applied a one-way ANOVA test (p=0,05) (see Table IV). After eliminating the H_0 hypothesis, we applied Tukey's post hoc test (see Table V).

For the vast majority of measurements, skin resistance increased evenly throughout each session. As can be seen, the intensity of this gain decreases with each successive session. This may indicate that the initial stress level for subsequent sessions is lower. In addition, it can be seen that the trends among all participants are more convergent with each session.

B. EEG Signal Analysis

Since the Looxid Link returns EEG signal values in specific waveforms (alpha, beta, delta, gamma, theta) for each electrode, signal processing was reduced to removing ocular and heartbeat artifacts using independent components analysis (ICA) and smoothing with a moving average (30 samples) to reduce measurement noise. An example of EEG signal waveforms for $P_6 - P_8$ intervals recorded for one participant during the first session is presented in Fig. 13.

Since all the electrodes were placed on the frontal part very close to each other and their waveforms are highly correlated (in a range of 0,724 - 0,916), we used the average waveform for all six electrodes for further analysis. An example of theta waveforms from six frontal electrodes and their average is presented in Fig. 13.

Then, we calculated the differences between the average values of the subsequent intervals for each waveform using the following formula:

$$\Delta sig_M = \frac{Sig_M(P_{i+1}) - Sig_M(P_i)}{Sig_M(P_0)} \quad (6)$$

where: $Sig_M(P_k)$ - average value of the the signal (alpha, beta, gamma, delta, theta) (see Fig. 14) in the k-interval; $Sig_M(P_0)$ represents the benchmark;

An example of differences in the mean values in each period $P_1, P_2 \ldots P_{14}$ for alpha and theta waves, and GSR obtained for the example subject from S1, are presented in Fig. 15.

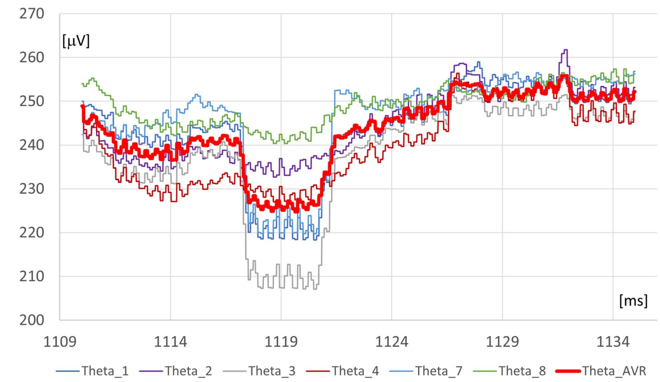

Fig. 14. Example of theta waveforms from six frontal electrodes and their average.

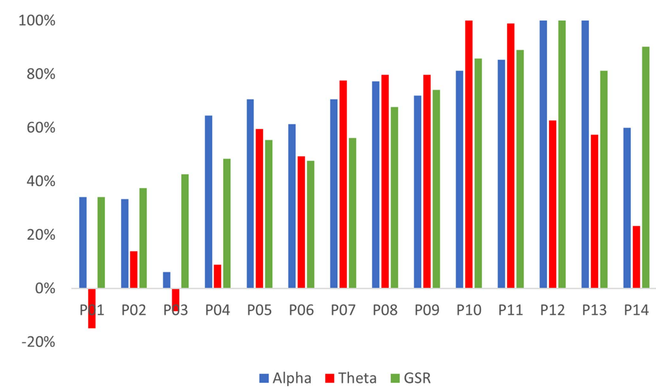

Fig. 15. Graphical interpretation of the correlation between GSR and alpha and theta waves - differences in the mean values in each period P1...P14.

Similarly, as in the case of the GSR signal, to determine the changes in signal waveforms at the beginning and end of the session, we performed a group analysis, i.e., we averaged the signal waveforms (alpha, beta, gamma, theta) for all subjects for each session separately. Next, the mean values of P_2 and P_{14} for each waveform, normalized by its mean value of P_0, were calculated. Statistical analysis was performed to investigate whether EEG biomarkers alteration was significant. Specifically, we applied the t-test to determine whether $\Delta sig_M(2, 14)$ were statistically significant for a given session (see Table VI) .

It has been established that beta waves indicate alertness, attention and the state of being awake, which all can be summarized as active, conscious thinking. Similarly, gamma waves are connected with different stages of conscious awareness. That is why it is not surprising that the beta and gamma waveforms are rather stable and no major changes can be seen during our, because the research focused on relaxation and stress reduction. Those states are not conducive to increased production of the aforementioned waves.

In contrast, a significant increase in volatility was observed for alpha and theta waves. The former are present in a less alert state of mind and they are characteristic of a state of deep relaxation [49], [50]. The latter indicate a state of meditation of drowsiness [51], [52], which is especially noticeable in the period of BLS, which shares many features with meditative state.

TABLE VI
GROUP ANALYSIS (AVERAGE ACROSS ALL SUBJECTS FOR EACH SESSION) IN THE FORM OF MEAN, STANDARD DEVIATION AND VARIATION VALUES OF $\Delta sig_M(2, 14)$ FOR EACH WAVEFORM (S# - SESSION NUMBER)

		alpha	beta	gamma	delta	theta
S1	Δsig_M	**4,16%**	3,22%	2,83%	6,35%	**5,26%**
	Δsig_{SD}	**2,89%**	2,84%	2,69%	3,44%	**3,29%**
	Δsig_{var}	**5,58%**	-	-	-	**8,11%**
	p-value*	**0,001**	0,233	0,642	0,435	**0,040**
S2	Δsig_M	**3,94%**	**4,06%**	**3,96%**	**5,60%**	**4,34%**
	Δsig_{SD}	**1,94%**	**1,83%**	**2,61%**	**4,48%**	**3,09%**
	Δsig_{var}	**3,63%**	-	-	-	**8,07%**
	p-value*	**0,001**	**0,001**	**0,001**	**0,024**	**0,008**
S3	Δsig_M	**2,78%**	**3,14%**	**3,65%**	3,32%	**2,81%**
	Δsig_{SD}	**1,55%**	**2,06%**	**2,24%**	2,51%	**1,96%**
	Δsig_{var}	**2,55%**	-	-	-	**3,14%**
	p-value*	**0,010**	**0,006**	**0,011**	0,155	**0,037**
S4	Δsig_M	**3,40%**	**3,67%**	**4,05%**	4,97%	**4,08%**
	Δsig_{SD}	**1,17%**	**2,20%**	**3,70%**	2,28%	**1,61%**
	Δsig_{var}	**1,20%**	-	-	-	**2,38%**
	p-value*	**0,001**	**0,002**	**0,008**	0,135	**0,039**
S5	Δsig_M	3,42%	**3,64%**	**3,71%**	4,56%	**4,19%**
	Δsig_{SD}	1,67%	**2,07%**	**2,68%**	2,67%	**2,15%**
	Δsig_{var}	**3,44%**	-	-	-	**3,34%**
	p-value*	0,051	**0,024**	**0,040**	0,417	**0,028**

Bold font indicates a statistically significant difference (the p-value of the t-test was < 0,05).*- refers to the compared data series from P_2 and P_{14}.

TABLE VII
CORRELATIONS BETWEEN AVERAGED WAVEFORMS OF ALPHA, THETA AND GSR SIGNAL

	alpha	theta	GSR
alpha	1,000		
theta	0,774	1,000	
GSR	0,771	0,656	1,000

TABLE VIII
ONE-WAY ANOVA TEST FOR 5 SERIES OF EEG ALPHA

SofVar	SS	df	MS	F	p-val	F crit
BetweenG	49,72	4	12,43	3,425	0,010	2,42
WithinG	664,20	183	3,63			
Total	713,92	187				

The average increase in alpha and theta wave activity has been steadily decreasing for successive sessions, as has been the case for recorded GRS signals (see Fig. 15). The parameters of the statistical tests indicate that this fact can be taken as a regularity.

Delta waves are characteristic of a state of deep stages of sleep, especially during non-REM sleep. High intensity of these waves indicate resting and regenerating. Large discrepancies were registered among participants in the stability of the increase in delta wave activity. The implication is that although the participants in the sessions were put into a relaxed state, the individual susceptibility varied strongly.

Correlations between averaged waveforms of alpha, theta and GSR signal are presented in Table VII. The results show that the correlation between the data is high, and the values change almost synchronously.

Additionally, to analyze the impact of the number of performed sessions, we applied a one-way ANOVA test (see Table VIII for alpha and Table X for theta). After eliminating the

TABLE IX
TUKEY'S POST HOC TEST ANALYSIS RESULTS FOR $Q_{.05} = 4.00, k = 5, df = 50$

diff SE q	S1	S2	S3	S4
S2	0,221 0,272 0,811			
S3	**1,382** **0,284** **4,864**	1,161 0,298 3,893		
S4	0,761 0,321 2,372	0,540 0,333 1,620	0,622 0,343 1,813	
S5	0,740 0,325 2,276	0,519 0,337 1,538	0,642 0,347 1,852	0,021 0,377 0,055

Distributions with significant differences are marked in green.

TABLE X
ONE-WAY ANOVA TEST FOR 5 SERIES OF EEG ALPHA

SofVar	SS	df	MS	F	P-val	F crit
BetweenG	136,48	4	34,12	5,997	0,000	2,42
WithinG	1041,08	183	5,69			
Total	1177,56	187				

TABLE XI
TUKEY'S POST HOC TEST ANALYSIS RESULTS FOR $Q_{.05} = 4.00, k = 5, df = 50$

diff SE q	S1	S2	S3	S4
S2	0,925 0,341 2,712			
S3	**2,454** **0,356** **6,898**	**1,529** **0,374** **4,094**		
S4	1,179 0,401 2,936	0,254 0,417 0,608	1,275 0,429 2,971	
S5	1,070 0,407 2,630	0,145 0,422 0,343	1,384 0,434 3,187	0,109 0,472 0,230

Distributions with significant differences are marked in green.

H_0 hypothesis, we applied Tukey's post hoc test (see Table IX for alfa and Table XI for theta). The analyzed data for both alpha and theta waves show moderate distinguishability only for the first three sessions. For alpha, significant differences were found for pairs of measurement series S1/S2 and S2/S3, while for theta, only between series S1 and S3.

C. Analysis of Psychological Data

The analysis of compliance with the assumptions in various tests was performed for all data types. 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 participant before (T1) and after (T2) for each experimental

TABLE XII
MEAN STRESS LEVELS BEFORE (T1) AND AFTER (T2) EXPERIMENT FOR EACH SESSION (S1-S5) TOGETHER WITH STUDENT-T STATISTICS

#session		M	SD	SE	t	sig.(2s)
S1 (N=55)	T1 T2	5,49 2,77	2,41 2,15	0,35 0,31	5,657	0,000
S2 (N=44)	T1 T2	4,29 2,38	2,57 2,63	0,42 0,42	3,085	0,000
S3 (N=38)	T1 T2	5,11 2,41	2,57 2,47	0,51 0,46	3,759	0,000
S4 (N=26)	T1 T2	5,72 3,06	2,70 2,25	0,64 0,55	3,320	0,000
S5 (N=25)	T1 T2	4,56 2,00	1,94 1,87	0,65 0,62	2,842	0,004

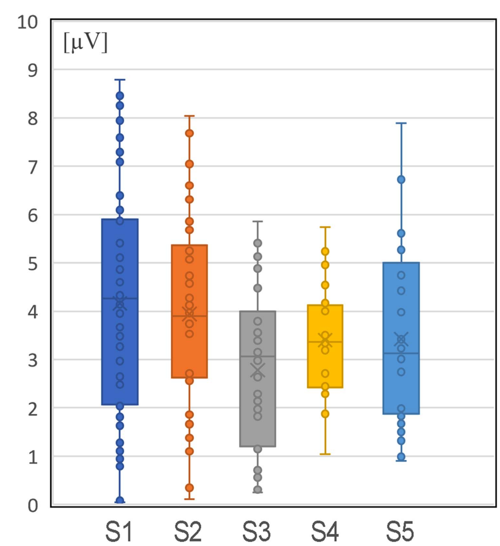

Fig. 16. Boxplot of EEG alpha data differences in mean values between periods P2 and P14 within a given session.

session (S1-S5). The comparisons were made using Student T-Test for dependent samples. First, we analyzed changes in stress level and mood between T1 and T2. All participants declared medium stress (about 5 points) at the beginning of the experiment and a significant reduction just after (see Table XII). To our surprise, stress levels suddenly increased in sessions 3 and 4 and went down in S5. After analyzing the dates of S3 and S4 (see Fig. 16–17), we noticed that it coincided with media reports regarding the Bucza crime (information about the mass graves discovered in Bucha was reported in the media from April 12 to 23).

The similar effect of positive changes in mood was found for each session. After each experimental session, we obtained significant mood improvement – negative feelings were reduced and positive ones increased, which can be seen in values of means in positive (see Fig. 18) and negative (Fig. 19) mood subscales.

Additionally, we asked about the stability of these effects over time. The results of analyses aimed to compare mood between T1 of session S1 and T1 of session S5, and T2 of S1 and S5 shows only the stable and significant improvement of positive mood within 5 weeks. The analyses also showed that the level of mood improvement and the level of stress reduction after VR

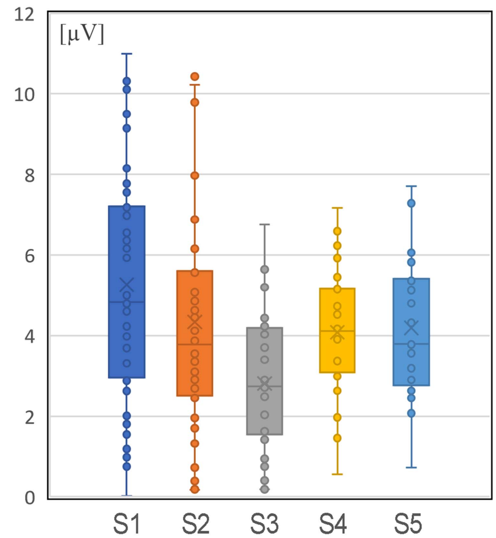

Fig. 17. Boxplot of EEG theta data - differences in mean values between periods P2 and P14 within a given session.

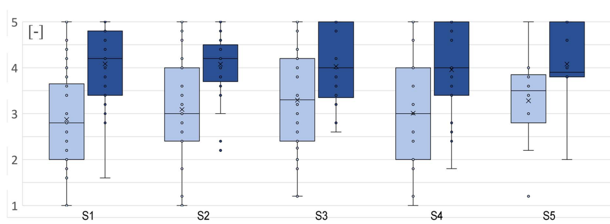

Fig. 18. Changes in PMS - Positive Mood Subscale of GMS before (T1 - light blue) and after experimental session (T2 - dark blue) for each session (S1-S5).

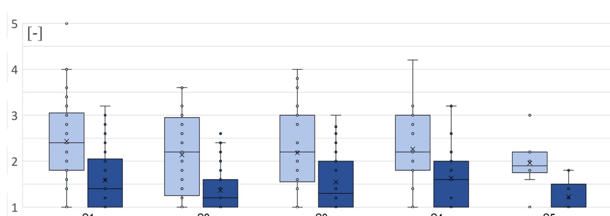

Fig. 19. Changes in NMS - Negative Mood Subscale of GMS before (T1 - light blue) and after experimental session (T2 - dark blue) for each session (S1-S5).

TABLE XIII
SIGNIFICANCE OF CHANGE IN MOOD AND STRESS LEVEL BETWEEN T1 OF S1 AND S5, AND BETWEEN T2 OF S1 AND S5

		positive mood		negative mood		stress level	
		S1	S5	S1	S5	S1	S5
T1	M	2,49	3,22	2,53	2,45	5,93	5,11
	p	0,023		0,570		0,186	
T2	M	3,96	4,04	2,17	2,07	3,11	2,26
	p	0,742		0,515		0,085	

sessions did not differ between the first and the last session of VR (see Table XIII).

Another analyzed variable was mental health measured by GHQ-12 before each session of the VR exercise. Mean GHQ12 score before S1 was 17,42 (Var = 53,43), which reflected

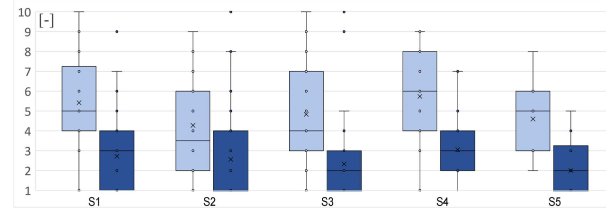

Fig. 20. Changes in CSL (Q11) before (T1 - light blue) and after experimental session (T2 - dark blue) for each session (S1-S5).

TABLE XIV
COMPARISON OF MEAN GHQ SCORE IN THE GROUP THAT COMPLETED FIRST VR SESSION PROGRAM AND THE GROUP THAT COMPLETED FIFTH SESSION (SUMMARY OF T-TEST RESULTS FOR INDEPENDENT SAMPLES)

	all S1	*all S5*
M	17,42	11,34
variance	53,43	15,34
n	55	25
Difference of means according to the hypothesis	0	
df	76	
t Stat	4,685	
P(T<=t) one-sided	0,000	
Test T one-sided	1,665	

TABLE XV
COMPARISON OF A CURRENT STRESS LEVEL BEFORE EACH VR SESSION IN GROUPS WITH LOWER AND HIGHER GHQ-12 SCORE

#session	group	M	SD	n	t	sig.(2s)
S1 (N=55)	GHQ1	2,538	2,603	17	-15,658	0,000
	GHQ2	6,618	2,425	38		
S2 (N=44)	GHQ1	2,400	4,400	20	-9,025	0,000
	GHQ2	5,522	4,261	24		
S3 (N=38)	GHQ1	3,667	8,061	18	-5,438	0,000
	GHQ2	6,267	3,638	20		
S4 (N=26)	GHQ1	4,500	10,000	12	-3,471	0,005
	GHQ2	6,700	3,567	14		
S5 (N=25)	GHQ1	4,833	4,567	15	-3,846	0,003
	GHQ2	6,700	3,567	10		

GHQ1: GHQ - 12 < 13, GHQ2: GHQ - 12 ≥13, n is a number of subject in particular group.

average mental health status of the group on the day of the first experimental session. The mean GHQ-12 score decreased after 5 weeks to 11,34 points just before S5, and the difference in mean scores was statistically significant (see Table XIV). It means that significant reduction of psychopathological symptoms was obtained during the time of the study. As expected, mental health status affected the level 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 Table XV). We were also interested in mental health status differences between participants who completed the relaxation program and those who did not. The results of Student t-test showed no significant difference between group (see Table XVI).

We did not find any negative effects of VR stress management sessions in terms of VR sickness symptoms. Experimentally we asked the participants to fill in VRSQ before each session to check if they experienced any oculomotor or disorientation symptoms. It appeared that the number of negative symptoms of VR sickness reported before the session is significantly higher

TABLE XVI
COMPARISON OF MEAN GHQ SCORE IN THE GROUP THAT COMPLETED THE 5 VR SESSION PROGRAM AND THE DROP OUT GROUP (SUMMARY OF T-TEST RESULTS FOR INDEPENDENT SAMPLES)

	less than five sessions	*five sessions*
M	16,53	18,52
variance	49,50	57,51
n	30	25
Difference of means according to the hypothesis	0	
df	50	
t Stat	-0,999	
P(T<=t) one-sided	0,161	
Test T one-sided	1,676	

TABLE XVII
MOTION SICKNESS MEASUREMENT DIFFERENCE IN A VIRTUAL REALITY ENVIRONMENT BEFORE (T1) AND AFTER(T2) EXPERIMENT FOR EACH SESSION

#session		M	SD	t	sig.(2s)
S1 (N=55)	T1	9,490	37,855	5,554	0,000
	T2	4,020	11,620		
S2 (N=44)	T1	7,195	33,411	4,428	0,000
	T2	2,732	8,251		
S3 (N=38)	T1	7,067	26,616	3,853	0,000
	T2	2,833	9,592		
S4 (N=26)	T1	7,895	44,544	2,070	0,047
	T2	4,053	20,942		
S5 (N=25)	T1	5,900	22,322	2,237	0,042
	T2	2,100	6,544		

TABLE XVIII
IMPROVEMENT OF POSITIVE MOOD STATES AFTER EACH OF 5 VR SESSIONS (THE HIGHER MEAN THE MORE POSITIVE MOOD)

PMS		*mean*	*var*	df	DM	t Stat	sig.(2s)
S1	T1	2,872	1,113	88	1,212	-13,257	0,000
	T2	4,084	0,559				
S2	T1	3,090	1,288	79	0,988	-9,548	0,000
	T2	4,078	0,436				
S3	T1	3,295	1,311	52	0,732	-5,710	0,000
	T2	4,027	0,659				
S4	T1	3,011	1,478	35	0,947	-5,216	0,000
	T2	3,958	1,029				
S5	T1	3,280	1,068	18	0,800	-3,674	0,002
	T2	4,080	0,828				

TABLE XIX
CORRELATION BETWEEN PHYSIOLOGICAL DATA AND PSYCHOLOGICAL DATA

	alpha	theta	GSR	GMS
alpha	1,000			
theta	0,849	1,000		
GSR	0,812	0,789	1,000	
GMS	0,845	0,849	0,949	1,000

than that reported after experienced immersion (see Table XVII and XVIII).

Finally, we investigated the correlation between physiological data and psychological data. For this purpose we calculated the average gain for each signal and GMS test results for all sessions. The results are presented in Table XIX.

V. CONCLUSION

The assumption this study set out to examine was that VR may serve as a tool supporting relaxation training and reduce number of psychopatological symptoms by mood improvement and reduction of stress. For this purpose, an automated therapy tool based on an interactive VR simulation was developed. The VR was integrated with bilateral stimulation and sensors to collect objective data on psycho-physical condition of the subject. A pilot treatment programme comprised five sessions of relaxation training conducted for a group of 55 healthy Ukrainian refugees. They were asked to fill in questionnaires about their subjective perception of stress and relaxation and their answers suggest a significant reduction in subjective stress and mood improvement after the sessions. The subjective answers were juxtaposed with objective automated sensor measurement. The conformity of CSL, GSR signal and EEG (alpha and theta) waveforms was observed: objective measurements and subjective answers indicate the reduction in stress after each session (see Fig. 20).

The goal of the pilot study was to test the efficacy of VR-based bilateral stimulation for treating subjects with acute stress. The results were promising and showed that VR-based BLS is efficient in mood improvement and stress reduction. These effects are also related to decrease of psychopathological symptoms measured by GHQ-12. Data analyses showed that the repetition of VR training does not affect negatively its effectiveness in symptoms reduction which is relatively stable from one session to another. Taking into account the special sample we worked with (Ukrainian refugees at first weeks of the war affected by ongoing profound stress, crisis and trauma) our results are more than promising. However we need to mention some limitations of our pilot study. The first group of limitations concerns the sample. First, it was a sample of random volunteers who responded to media announcements. Second, participants faced constant pressure from circumstances beyond their control, such as temporary relocation and uncertainty about the fate of loved ones. They also had to make sudden decisions and adapt to new situations. These factors were impossible to control in the study but may have influenced the results. Third, the group was relatively small, with a high dropout. Another group of limitation concerns the way we measured mental health status and study design. Although GHQ-12 is well recognized and reliable measure, possessing an independent clinical diagnosis of mental health would be additional advantage. Moreover, taking into account the complexity of uncontrollable problems, challenges, stress and trauma faced by our participants – case-control design of study might increase the reliability of our result. At the same time, it is important to mention that monitoring EEG using the Looxid product proved to be troublesome. Since most participants were women, applying face makeup was a source of some problems, i.e., dry Looxid electrodes sometimes lost good connection with the skin. In one case, getting a stable EEG signal was impossible due to the very "low" forehead of the participant. It is worth mentioning that the HMD mounting procedure included the need to expose the forehead by moving away the fringe, as contact of hair with EEG electrodes virtually always leads to temporary or permanent signal loss. However despite of the limitation mentioned above the results seems to be very promising and guide our imagination to the era of cheap, commonly available, home -based treatment of ill-health symptoms.

Future work may focus on measuring the long-term effects of VR-based relaxation training. We set out to continue the research on clinical trials of subjects suffering from depression and anxiety disorders to gather long-term data on the effectiveness of VR-based BLS relaxation compared with standard bilateral stimulation.

The opportunities for technical development of the tool are vast as well. Further development might include subject's personal preferences about their most relaxing environment, e.g., starry night, beach sunset or underwater environment.

We expect that providing an innovative tool that aims to reduce the time the professionals have to devote to a single patient will result in the increase of quality of therapy in general. This might lead to better efficacy of treatment and subsequently more availability of the specialist to treat other patients. The use of cutting-edge VR technology has the potential to not only increase efficiency and lower the cost and duration of therapy but also enable some therapy to take place outside of medical facilities. The affordability of this solution, even in developing countries, could have a positive impact on global access to healthcare.

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