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CHALLENGES OF INTEGRATING VIRTUAL REALITY INTO POLYGRAPH TESTING

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Abstract

The use of virtual reality (VR) is on the rise due to technological advances. One way to utilize VR is by incorporating it into polygraph testing. The main focus of this research paper is to investigate the possibility of integrating these two technologies to improve the polygraph testing process, whether for lie detection or individual profiling. Important factors of polygraph testing in VR are analysed in this work, with an emphasis on movement, as traditional polygraph examinations are conducted in a neutral, quiet environment and do not involve any movement. For effective implementation of VR into polygraph testing, it is therefore necessary to analyse the impact of movement on the accuracy of evaluation. The research also presents and describes VR technology and the entire polygraph examination process, including the specialized LX software.

Keywords: polygraph testing, virtual reality, physiodetection, movement, analysis.

1. Introduction

The pursuit of a method for verifying truthfulness has a long history. But only since the 19th century, there have been efforts to find scientific ways to expose lies, including polygraph testing. With the advancement of technology in recent years and the growing interest in virtual reality (VR), the integration of polygraph devices with VR has become a topic of discussion, but it has been rarely researched. The use of polygraph technology in VR environments holds promise as a powerful tool for criminal investigation and assessment of credibility, and has the potential to significantly advance the field of polygraph examination.

Current research papers focus on the effects of 2D and 3D environments on individuals and on the potential for VR environments to elicit a higher degree of emotional arousal. Although these studies are important for the integration of VR and polygraph, there are still many aspects to be explored in this promising application for the successful implementation of these two technologies together.

One such aspect is the impact of navigating in virtual environment on polygraph test results. The traditional polygraph examinations are conducted in a quiet, distraction-free setting, with the examinee seated and answering questions posed by the polygraph examiner. However, in the environment of virtual reality, it needs to be researched whether it is possible to accurately detect physiological responses during basic movements related to VR control. As movement can cause

physiological changes, it is necessary to investigate whether movements during navigation in VR have a significant impact on polygraph results. Therefore, research devoted to the determination whether important data can be distinguished from distractions caused by movement is relevant.

2. Virtual Reality Technology

Virtual reality (VR) is an immersive simulation of an artificial environment, that is modelled by a computer [1]. The user of VR usually sees created scenes with a headset and hears environmental sounds through headphones placed on this headset. However, it is possible to enhance immersion exploring the other human senses [2].

For interaction with the environment are used VR controllers that tracks user movement in 3D space and for more interaction users can use gestures and press buttons on wearables. Typical example of VR headset with controllers can be seen in Fig. 1.

Fig. 1. VR HTC Vive Pro Full kit [18]

Tracking of movement can be done using tracking base stations or inside-out tracking systems. Tracking base stations scan the whole room with synchronization beams many times per second. Controllers' relative position to base stations is then found using simple triangulation which is based on the time when controllers were hit by beam signal. Inside-out tracking systems use cameras located on the headset and detect infrared light from LEDs on wearables. With this system, the position is triangulated relatively to the headset position. For best simulation results, VR needs high precision of feedback with low latency, high resolution of the headset and high sound quality. The main driver for improving VR quality was mainly the military, space, and entertainment industries [3-5].

3. Polygraph System

The polygraph measures and records physiological changes in a person's body as they answer questions from a polygraph examiner. The whole polygraph system is composed of a DAS, software, and several sensors:

- Blood pressure cuff that records blood pressure and its changes.
- Pneumograph tubes placed over the chest and abdomen to record breathing.
- Electrodermal (EDA) electrodes attached to fingers for measuring the skin conductivity.
- Photoelectric plethysmograph that records rapid changes in pulse blood volume.
- Activity sensor pads used to detect minor movements of the arms, feet, or bottom.

3.1. Process of Polygraph Screening

The polygraph examination procedure consists of four stages: preparation and consultation, polygraph examination, evaluation of results, and drawing conclusions.

First, it is necessary to assess and decide when to conduct the polygraph examination. It has been found that the most effective time for the use of physiodetection is at the beginning of a criminal investigation in the initial stages of clarifying the crime, as the individual being investigated does not have access to other sources of information at this time. The next step in the preparation phase is the creation of a series of questions, which are tailored to each specific case.

At the start of the examination, the entire process is explained to the examinee and he is asked to confirm their written consent for voluntary participation in the examination. Furthermore, the examined person is asked about his current situation and health problems. Any information that could negatively impact the objectivity of the examination must be taken into account. Subsequently, the individual is asked to provide information about the case. At the end of the examination, the person is asked to sign the graphic record which confirms the date and duration of the examination and the person's voluntary consent.

After the physiodetection examination phase, the obtained results are evaluated and the conclusions are drawn [6-8].

3.2. LX Software

During the examination, physiological data are controlled, displayed and recorded by LXSoftware that is a specialized software platform designed for analysis of polygraph examinations. Fig. 2 presents an example of a polygraph measurement taken using LXSoftware.

Fig. 2. Sample of polygraph measurement from LX Software

The bottom line represents time, with markers indicating each task that the examinee performed. The blue line depicts the signal from the pneumograph sensor, the red line illustrates the signal from the photoelectric plethysmograph, and the green line denotes the signal from the EDA sensors.
This software seamlessly integrates with the polygraph instrument, facilitating real-time monitoring and capturing of various physiological parameters. The software ensures precise and synchronized data acquisition, enabling examiners analysing physiological reactions in relation to specific stimuli using on-screen calipers, as depicted in Fig. 3. These calipers provide the measurement of minimum, maximum, and average EDA, heart rate, respiration rate, cuff pressure, and cardio baseline characteristics. Respiration line lengths are also automatically measured.

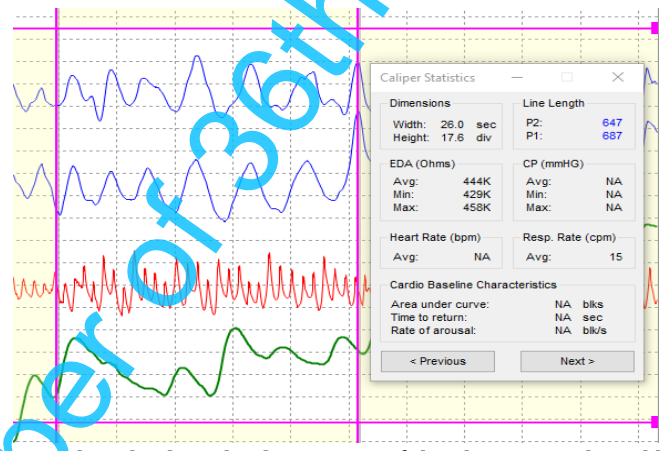

Fig. 3. The Caliper Statistics window displays the dimensions of the chart area selected by the calipers. This feature enables the measurement of distinct patterns in the obtained data.

4. Challenge of Integrating Virtual Reality into Polygraph Testing

The polygraph, or lie detector, is a widely used technology for assessing credibility. It is frequently employed by law enforcement and federal agencies for detecting deception and profiling individuals. It is used in criminal investigations, security clearance processes, and managing deviant sexuality. The recent study [9] has firmly established the validity and effectiveness of lie detection methods, demonstrating an impressive accuracy rate that surpasses 90%. However, a significant concern persists regarding the relatively high occurrence of false positive responses, estimated to be around 25%. It is suggested that the changes in physiological responses immediately after the act of lying are not adequately distinguishable.

Virtual reality is a rapidly growing field of research with expanding applications across multiple disciplines. VR is utilized not only in the entertainment and gaming industries but also in sectors such as information technology, biomedical engineering, and training aids. VR visualization offers an enhanced simulation environment with the potential to improve and accelerate human learning, treat various mental health conditions and behavioural disorders, and explore human

immersion in artificial environments. Therefore, new simulators and therapy solutions have been developed, with ongoing research into their effectiveness and long-term impact on individuals.
There are a few potential issues that could arise when integrating virtual reality into polygraph testing:

- technical difficulties: There may be challenges with setting up and running the virtual reality equipment, as well as ensuring that it is functioning properly during the test;
- participant discomfort: Some individuals may experience discomfort or dizziness when using virtual reality, which could affect their ability to complete the test;
- ethical concerns: There may be ethical concerns to consider when using virtual reality in polygraph testing, such as participant privacy and consent;
- validity of test results: It is important to ensure that the virtual reality environment does not interfere with the accuracy of the polygraph test.

All of the aforementioned points must be considered for future use. While the first three points may not be difficult to address, the validity of the test must be thoroughly examined. The following section addresses individual research studies and analyses the aforementioned issues.

5. Analysis of Polygraph Screening in VR

5.1. VR as an Amplifier of Presence Levels

In the field of aerospace training, research [10,11] has been introduced that presents new simulators developed by combining the use of VR and realistic computational models. These studies comparing VR simulator training and real flight training suggest that the strong feeling of immersion generates high presence levels. It showed higher heart rate and lower heart rate variability in the real flight condition compared to the VR one. However, similar patterns of subjective rating and cardiac activity were found across different segments of the scenarios for both conditions. Despite lower physiological values in VR due to the lack of real risk, the same physiological changes occurred as in a real environment. However, the research only evaluated cardiovascular activity and none of these studies take into account the influence of movement on physiological responses. It is necessary to assess not only deviations in measured values but also the influence of movement in VR on these values.

This approach was used in [12] where the body's response to movement was measured, however the study was more focused on gradually increasing physical activity until reaching very high intensity. The researchers used an electrodermal activity (EDA) sensor, but their measured values were very low when measuring during rest. The low measured EDA values that the researchers achieved in the resting phase are most likely due to the size of the electrodes or it may also be due to incorrect settings during some of the tests.

Human immersion in artificial environments has also been used in psychological treatment [13,14] to treat various mental health conditions and behavioural disorders. Interactive and immersive realistic 3D graphic scenes allow patients to experience different emotions or become accustomed to fearful feelings. Due to the immersion and strong sense of presence, VR amplifies emotional responses to stimuli, showing positive effects such as overcoming fear. From this study, it is clear that using VR in polygraph examination can enlarge physiological reactions to emotional stimuli. This knowledge could help to streamline profiling or criminal investigations by assuming that if there is an artificial realistic visualization, the physiological reaction is then stronger, and it is more difficult to deny a physiologically false statement. These studies primarily focus on the impact of VR on psychological health. But they do not provide any information how to distinguish between emotional and movement physiological responses which is important for polygraph testing.

5.2. Enhancing Polygraph Accuracy with VR Technology

Owing to its potential, the integration of virtual reality and polygraph technology could prove effective in criminal investigations by enhancing the exposure of suspects and increasing the reliability of polygraph testing. However, there is only one isolated study [15] investigating the use of VR technology in conjunction with polygraph testing. This study showed that the use of VR technology in forensic investigations can increase recognition of crime-related stimuli by over 25 %, enhancing accuracy in detecting concealed information. However, in this study, the VR environment did not include independent object motion and only sensors measuring electrodermal activity and heart rate were used in just one artificially created crime – theft. Therefore, despite the significance of these results, all factors of polygraph testing in VR have not been included and further research is needed to fully understand this implementation.

5.3. Physiological changes caused by movement¨

The evaluation of the impact of movement on measurement accuracy was achieved by thoroughly testing volunteers who had to perform predetermined movements while attached to polygraph sensors. The types of movements that examinees had to perform were chosen to simulate movements that might be necessary in virtual reality. The aim of the study [16] was to investigate whether it is possible to correctly detect physiological responses during basic movements related to VR control and to determine whether important data, such as emotional arousal, can be distinguished from the changes caused by this movement. Due to movement constraints, only some sensors were used in this study, including

pneumograph tubes, EDA electrodes to record electrodermal activity, and a photoelectric plethysmograph to measure heart rate.

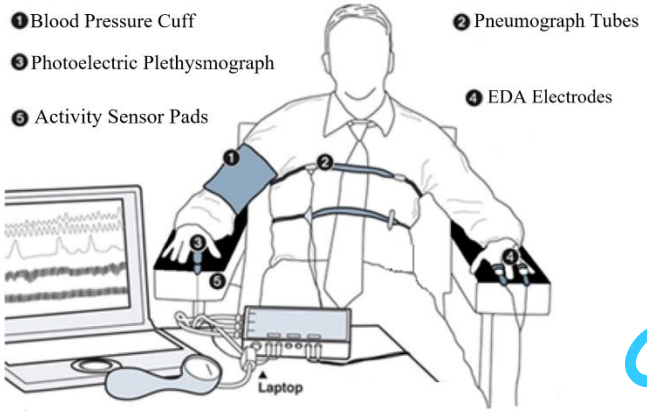

Fig.4. Attached polygraph sensors [17]

During the measurement process, five situations were chosen to encompass the primary movements observed during VR navigation. Each situation lasted for approximately 20 seconds, representing the time between initiating a movement and commencing the subsequent movement. This duration was predetermined within LXSoftware and corresponds to the minimum time between question onsets required for valid scoring results in traditional polygraph testing. All tested individuals without any health problems or other issues completed the following tasks:

1. Sitting in a relaxed position on a chair.
2. Head movement in a 3D scene.
3. Standing up and remaining still without any other movement.
4. Slow walking in VR – simulation of movement in VR.
5. Hand movement with controllers.
6. Falling in VR - inducing fear of a fall.

The fall mentioned in the sixth point was performed in the VR environment. The examinee was instructed to hold onto a desk, and the timing of the drop was unknown to the examinee to induce a sense of increasing tension. The obtained data indicated that physical activity has a significant effect on polygraph measurement. This is likely due to changes in physiological responses that occur during different levels of physical activity. Surprisingly, the findings showed that the physiological differences between sitting in a relaxed position and head movement are similar, in contrast to the comparison between any other movement and the relaxed position. The standard deviations also indicated a significant amount of variation in the measured values, which could be attributed to the individual physical differences among the examinees. For some individuals, the tasks were simple, and responses were not as high as for others. The results suggest that emotions can elicit more pronounced physiological reactions compared to movement. However, changes caused by movement were also significant and in some cases could be mistaken for emotional arousal.

6. Discussion of Results of the Analysis Focused on the Use of the Polygraph in VR

From the study [movement], it is obvious that each movement has a certain physiological impact on people, which usually increases together with amount of movements. The movement induce increased values of physiological reactions mostly during the movement itself or shortly after it. This research confirms the results achieved in [12], which, however, emphasized higher physical load and did not use a pneumograph and photoelectric plethysmograph. This study also established the precise behaviour of EDA values during movement. Typically, EDA values range from 0.5 µS to 20 µS, depending on factors such as skin dryness, individual physiological differences, and electrode site. This is in contrast to the aforementioned study, where these values were even negative. The results of this study demonstrate that during simple movement, values cannot be negative and fall within the standard range. In addition, the measured values show an increase in values even at low load caused by simple movements. Apart from head movement all values increased on all measured sensors.

As can be seen from [16,18] physiological reactions caused by emotions were very pronounced in observed persons. It shows that emotional arousal in reaction to virtual reality can be really pronounced and it also means that the emotions can sometimes evoke more pronounced physiological reactions than the movement itself. The study [movement] excluded movements that require increased physiological activity and are not essential for controlling VR. Other research, as cited in [12], has shown that such movements can lead to elevated physiological responses.

The main disadvantage of VR-polygraph testing could be the confusion of physiological reactions caused by movement with those caused by emotional reactions. This could reduce the main advantage of VR-polygraph testing, which is the enhancement of physiological reactions to emotional stimuli.

This disadvantage can be eliminated by limiting the movement of the test subject to necessary minimum, for example, to only head movements. As highlighted in [movement] the physiological values associated with sitting in a rest position and head movement demonstrate similarity. Consequently, head movement can be considered as an effective movement to be employed in the context of polygraph screening. To avoid any other movements than those by head, the examinee would be placed within a 3D scene without any possibility of self-navigation and polygraph examiner would maintain control over the VR movement within the designated scene.

If movements in VR were used, it could lead to the emergence of false positives. However, with limited movement, this will not occur. The amplification of physiological responses to emotional stimuli also facilitates the differentiation between false positives and detected lies, as larger differences make it easier to distinguish, potentially improving accuracy.

It is important to note that the movement testing [movement] was performed on a small sample of volunteers and usage of VR-Polygraph screening method proposed by this research would require analysis of precise scenarios tailored for specific polygraph usage, such as criminal case investigations. Additionally, the VR-Polygraph is a high-priced technique that requires the cooperation of multiple experts. These include a polygraph specialist with the appropriate qualifications to conduct polygraph examinations and experts in virtual reality for 3D scene reconstruction. These two factors are the main limitations of this study.

When using virtual reality, it is necessary to consider the ethical implications of its use. Virtual reality can enhance emotional experiences through visual stimuli, and it is therefore important to prevent negative impacts on the mental well-being of tested individuals. Polygraph testing itself can be stressful, and insensitive VR-Polygraph testing, such as in a recreated environment depicting a crime scene, can evoke strong emotional responses and cause psychological harm. Therefore, when creating VR scenes for polygraph testing, these considerations must be taken into account.

The results of this research should serve for the future application of virtual reality in the polygraph testing process. However, as previously mentioned, future research must conduct a broader study for specific cases of using this new method. Once ethical and legal obstacles are overcome, this method could potentially be used to improve the efficiency of criminal investigations or individual profiling.

7. Conclusion

It should be mentioned that a more pronounced movement observed in the examinee during a conventional polygraph examination may indicate their effort to conceal a lie. In this way, the examinee may attempt to undermine the results by employing deliberate movement during control or non-relevant questions, but the mere fact that they are making an effort through movement can be valuable information. And as demonstrated, the detection of even minor movements can be achieved, even in the absence of activity sensor pads.

Based on the analysis, for the effective use of the polygraph in VR environment, the movement of the examined person in this environment should be avoided, as it distorts the results, and it is difficult to distinguish the reactions caused by movements from changes caused by emotions. Therefore, VR should be used in fixed scenes where examinee movement is restrained, and he can only explore the space in head-rotation. The transitions between scenes should be then done by examiner.

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