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Use of Virtual Reality in Polygraph Testing

Abstract. *The primary objective of this research is to investigate the potential use of virtual reality technology in the process of criminal investigations, specifically in relation to the use of polygraph technology. A comparative analysis of existing research on this topic was conducted to explore the relationship between immersion in VR and emotions, in order to understand how to effectively design and implement polygraph testing within VR.*

Streszczenie. *Głównym celem tego badania jest zbadanie potencjalnego wykorzystania technologii rzeczywistości wirtualnej w procesie śledztw kryminalnych, w szczególności w odniesieniu do wykorzystania technologii wariograficznej. Przeprowadzono analizę porównawczą istniejących badań na ten temat w celu zbadania związku między zanurzeniem w VR a emocjami, aby zrozumieć, jak skutecznie zaprojektować i wdrożyć testy wariograficzne w VR. (**Wykorzystanie wirtualnej rzeczywistości w testach wariograficznych**)*

Keywords: Virtual Reality, Polygraph, Immersion, Emotions.
Słowa kluczowe: Rzeczywistość Wirtualna, Wariograf, Immersja, Emocje.

Introduction

Virtual reality (VR) is a technology that allows users to immerse themselves in a computer-generated environment. It has been used in various fields such as gaming, education, aviation, and therapy. In this section, it is discussed the current state of VR technology and its applications.

One of the most common uses of VR is in the gaming industry which is experiencing steady growth driven by the increasing availability of VR headsets, such as the Oculus Rift and HTC Vive, and the development of more sophisticated VR games.

VR has also been used in education and training. A study found that VR-based training led to a significantly higher retention rate of information compared to traditional training methods [1]. VR can also provide a more engaging and interactive learning experience for students. For example, a VR field trip to a historical site can provide students with a deeper understanding of the topic than a traditional field trip or textbook.

Another potential use of VR is in exposure therapy as an effective treatment for a variety of mental health conditions including post-traumatic stress disorder, phobias, and anxiety disorders [2]. VR can also be used to alleviate pain and other symptoms in patients during burn wound care or chronic conditions such as fibromyalgia and rheumatoid arthritis [3].

The integration of virtual reality (VR) technology has the potential to significantly impact various industries, including gaming, education, therapy, criminal investigation, and personal profiling. However, further research is needed to fully comprehend the potential benefits and limitations associated with the utilization of VR in different fields. The primary objective of this research is to investigate the potential use of VR in the process of criminal investigation, as well as to explore the relationship between immersion in VR and emotions for the effective application of polygraph in VR. To accomplish these objectives, a comparative analysis including the examination of existing research on this topic was conducted.

Comparative Analysis

Comparative analysis is a useful tool for making informed decisions by evaluating and comparing different options based on specific criteria.

In this study, a comparative analysis is used as a method that compares and evaluates two distinct polygraph testing procedures to determine the most suitable and effective option. It involves comparing two options, the new concept of VR-polygraph testing and the traditional polygraph method, based on specific criteria and evaluating the differences and similarities between them to reach a conclusion. This type of comparative analysis is important in establishing the validity of VR-polygraph testing and evaluating its potential for use in a variety of applications.

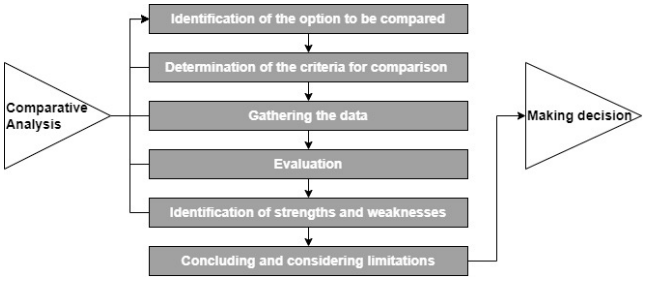

Fig. 1. Comparative analysis

Scheme on Fig. 1. provides a general outline of the comparative analysis process.

Forms of Virtual Reality

VR systems can be categorized into three main categories: non-immersive reality, augmented reality, and immersive reality according to the level of immersion and the type of components utilized within the system.

Non-Immersive VR

Currently, the most widely available and accessible form of VR simulation is non-immersive virtual reality, which is typically experienced on a desktop, laptop computer, or mobile phone. Users are able to interact with the simulated environment through a combination of visual, auditory, and movement-based input using devices such as a mouse, keyboard, touchscreen, or joystick. [4]

Augmented Reality

In the augmented reality, the user is able to perceive the real world while also being presented with computer-generated content. This content can include supplementary information pertaining to the user's surroundings, as well as the integration of three-dimensional virtual models into the physical environment. Users are typically able to interact with both the virtual and physical aspects of their surroundings. In education, augmented reality can be used to provide students with interactive and engaging learning experiences. In industrial training, augmented reality can be

used to provide workers with hands-on training in a safe and controlled environment.

Immersive VR

Immersive VR is a technology that aspires to create a sense of psychophysical presence within a computer-generated 3D environment that is designed to simulate the sensory experience of the real world as closely as possible in terms of visual, aural, and haptic perception.

The user accesses the virtual environment through a combination of hardware, software, and interaction devices, such as a head-mounted display (HMD) which utilizes stereoscopy to display images in three dimensions, and other computer interfaces devices such as position tracking devices, fiber-optic wired gloves, and audio systems.

Aim of these devices is to create a VR that appears realistic and fulfils three key points: Immersion, Interaction, and Imagination that form the virtual reality triangle presented in Fig. 2.

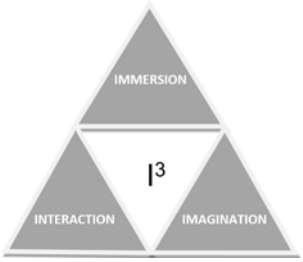

Fig. 2. Virtual reality triangle: Immersion-Interaction-Imagination

The VR triangle is a useful framework for understanding the key components of VR technology and how they work together to create an immersive and engaging experience for the user. In order to create a truly immersive VR experience, all three elements of the VR triangle must be present and working in harmony.

The fully immersive VR experience completely separates the user from the real world and enables full interaction with the virtual environment. [4, 5]

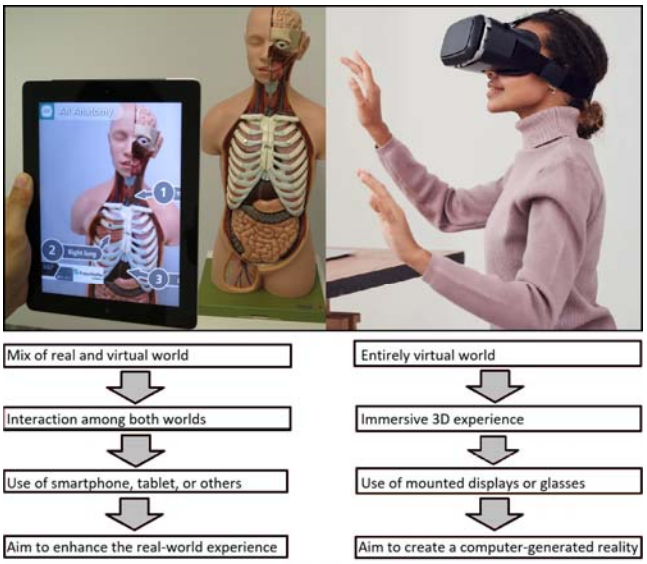

Fig. 3. Augmented Reality vs Virtual Reality

Polygraph

The polygraph is a widely used technology for evaluating an individual's credibility that has been utilized in law enforcement, federal agencies, and private companies.

One of the most modern polygraph systems is polygraph LX6 (Fig. 4) including various sensors (blood pressure cuff, photoelectric plethysmograph, electrodermal electrodes, pneumograph tubes, and activity sensor pads), as well as data acquisition subsystem that records the physiological data, and software that analyzes measured data.

Fig. 4. LX6 Polygraph System by Lafayette Instrument [6]

The polygraph is an instrument that measures several physiological reactions, such as changes in blood pressure, pulse blood volume, breathing, and skin conductivity. In addition, it detects minor movements of arms, feet, and bottom during a questioning process conducted by a trained examiner. When a person under investigation lies to any asked question, stress is produced as a response. It triggers the release of hormones such as adrenaline and cortisol increasing physiological arousal and significant physiological changes can be detected.

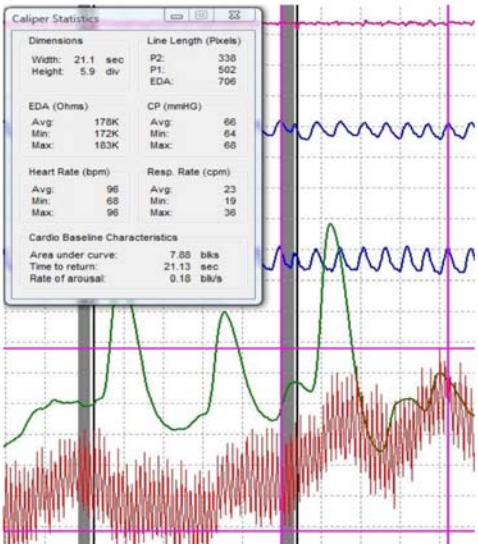

Fig. 5. Analyzing Polygraph Data Using LX6 Software [7]

Virtual reality use in polygraph testing

Forensic scientists primarily utilize polygraph results as a means of guiding the direction of an investigation. These results serve as indicia, which can subsequently lead to the discovery of additional evidence that is crucial in resolving a criminal case. For now, the polygraph results are still not admissible as evidence in court in many countries due to concerns about their reliability. Although they are not the unique determinant of truthfulness, they are often used as a part of a larger evaluation. Polygraph tests are also used for profiling persons related to the criminal investigation or security industry.

Fig. 6. VR Models with Crime Items Used in the Study

Virtual reality in connection with polygraph could find an effective application in criminal investigations to expose suspects and increase the reliability of polygraph testing.

The present study sought to investigate the utility and potential of VR technology in criminal investigations to expose suspects. To do so, a mock crime scenario was devised, in which participants were incentivized to conceal their recognition of crime-related details, such as the stolen item or crime scene (Fig. 6). Then, these details were laser-scanned and converted into photo-realistic VR models, which were then presented to the participants in conjunction with traditional 2D images (Fig. 7).

The participants' physiological responses, as measured by heart rate and skin conductance, were recorded via a Concealed Information Test (CIT). Results revealed that the detection of concealed recognition was significantly enhanced by over 25% when the VR models were utilized as opposed to the 2D images. These findings suggest that the use of VR technology in forensic investigations may serve to increase the recognition and salience of crime-related stimuli, and so enhance the accuracy in detecting concealed information [8].

Virtual reality's impact on emotions

In order for polygraph technology to be effectively utilized within a virtual reality environment, it is essential to explore the relationship between immersion in VR and emotions. A deeper understanding of this association will provide insight on how to effectively design and implement polygraph testing within VR, to accurately measure and analyze physiological responses to emotional stimuli.

Research has demonstrated that VR environments can elicit a higher degree of emotional arousal. For example, the cognitive psychological experiment was presented in a separate research study that aimed to investigate the effects of 2D and 3D visual modes on emotional arousal within the context of VR. The study recruited 40 participants who were asked to view a series of positive, neutral, and negative short VR videos in both 2D and 3D. The data collected from the participants' electroencephalographic and skin conductance responses measurements indicated that emotional stimulation was more pronounced in the 3D environment, resulting in a higher degree of emotional arousal [9].

The other study investigated the effects of VR on players' sense of presence and emotional and physiological responses when playing games compared to traditional screen-based media. Results showed that VR led to a stronger sense of presence and fear and that the sense of presence mediated the effects of VR on fear. The study suggests that VR games can affect players' sense of presence and physiological and emotional states [10].

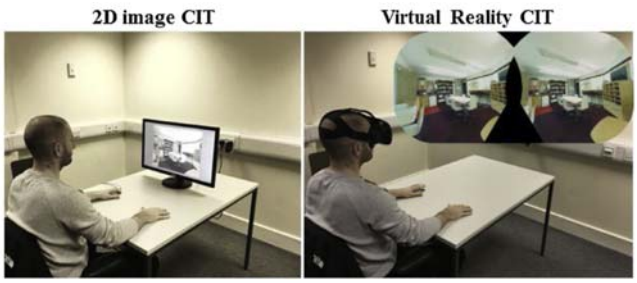

Fig. 7. Exploring Crime Scenes through 2D Images (left) and Virtual Reality (right)

Another research examined the effects of immersion on individuals' emotions in VR, using horror and empathy films. Results showed that VR increased fear in the horror film but not in the empathy film, suggesting that the level of immersion and the presence of strong perceptual cues influence emotional responses in VR. The study confirms VR's potential as an emotional amplifier and the relationship between immersion and emotion in VR [11].

Therefore, understanding how immersion in VR influences emotions is vital for the successful implementation of polygraph technology in this context.

Deepening of physiological reactions

One of the key advantages of VR is its ability to tap into our imagination, enabling us to explore new environments, characters, and scenarios in ways that were previously impossible. Engaging with VR involves a high level of immersion in a digital world, where a sense of presence - the feeling of being physically present in the virtual environment is a crucial factor. Additionally, the level of interactivity in VR environments, allowing users to manipulate objects or interact with avatars, also contributes to the overall immersive experience.

The psychological processes and emotions involved in a VR experience can be understood through the examination of three key elements: immersion, presence, and embodiment. These elements are crucial for creating powerful and impactful VR experiences, as well as for understanding how individuals think, feel, and respond to virtual stimuli or scenarios. Together, they can amplify the psychological effects of emotion or induce individuals to experience emotions that may be challenging to elicit in the physical world.

Immersion

Immersion refers to the extent to which the VR technology accurately simulates typical human actions and behaviours.


Fig. 8. Virtual Reality Immersion [12]

For individuals to experience a virtual reality as authentic, the VR technology must precisely track head, hand, and body movements and render them seamlessly on-screen without lag or distortion. When immersive VR technology fails to meet this standard, individuals may experience simulator sickness or question the realism of their experience. Immersion and presence are closely interconnected, as research suggests that immersive experiences with superior tracking and stereoscopic visuals are perceived as more psychologically impactful than less immersive experiences.

Presence

Presence refers to the feeling of being situated in a virtual environment. It is a fundamental element for immersing an individual in a virtual experience. When VR is designed and implemented effectively, individuals behave naturally within the virtual environment despite the use of equipment such as head-mounted displays, controllers, and sensors. The degree of presence experienced by an individual can be quantified through self-report measures, which assess the degree to which individuals feel psychologically attached and connected to the virtual experience, social entities within the experience, or other objects. For example, Markowitz and colleagues (2018) conducted an experiment in a virtual ocean affected by climate change and measured how much people knew about ocean acidification before and after the immersive experience. The results showed that in some cases, the degree of psychological presence in the virtual underwater world was related to how much people learned about climate change in VR. Therefore, presence is not only associated with how individuals feel connected to virtual objects or experiences but also with a sense of ability to act within the virtual world. With a high level of realism in the virtual environment, psychological effects are intensified.

Embodiment

The embodiment refers to the ability of individuals to adopt objects or entities in the virtual world. This enables users to experience a range of emotions that may not be possible outside of an embodied virtual experience. Furthermore, it can encourage users to feel closer to objects or experiences that may be foreign to them.

In the field of virtual reality, there are two types of avatars: those that represent the participant controlling them, and simulated avatars that can be programmed with specific personality characteristics or behaviours. Today, the behaviour of these simulated avatars is not always easily predictable due to the use of advanced software that develops increasingly realistic reaction patterns. As a result, the emotional patterns programmed into avatars can now be highly convincing and realistic.

However, it is important to note that the characteristics of objects or entities in virtual reality may be altered and it can have an impact on an individual's behaviour. Research by Yee and Bailenson (2007) found that people who adopted more attractive or taller avatars in immersive VR disclosed more intimate information to partners and behaved more confidently and aggressively in a negotiation game than those with less attractive or shorter avatars. This phenomenon, known as the Proteus effect, highlights the significance of embodiment as an affordance of immersive VR that can reveal social and psychological processes [13].

Results of comparative analysis

The main criteria for evaluation of differences between polygraph testing with VR and classical polygraph testing are accuracy, validity, reliability, complexity, and cost. As stated before, adding VR has potential to improve accuracy, validity, and reliability because of more pronounced physiological responses and these three key points can be the reason for implementation.

Weaknesses are mainly in cost and complexity of testing. While cost of VR equipment is not high adding VR to polygraph testing means spending more time with test preparation and evaluation, as examiner need to create virtual scenes, which are suitable for questions intended for the tested individual. In addition, the examiner must have a thorough understanding of both VR technology and polygraph testing techniques.

In conclusion, both Polygraph testing and VR-polygraph testing have their strengths and weaknesses (Table. 1), and the most suitable option will depend on the specific circumstances and requirements. Future research should involve empirical investigation to establish accurate settings and guidelines for VR-based polygraph testing. Furthermore, more in-depth investigation of the psychological factors intrinsic to VR technology that can impact polygraph testing is essential.

Table 1. Strengths and Weaknesses of VR-Polygraph Testing

Factors	Strengths	Weaknesses
Environment	VR technology can create a realistic simulated environment and provides the ability to create custom scenes.	An accurate setting of VR technology is necessary to prevent simulator sickness and maintain the realism of users' experience.
Immersion	VR technology allows users to immerse themselves in virtual scene and encounter prepared scenarios.	The characteristics of objects or entities in virtual reality may be altered and it can have an impact on an individual's behaviour.
Emotions	VR systems increase physiological arousal, affecting the validity of the test results.	
Expertise	The examiner's comprehensive knowledge of both VR technology and polygraph testing techniques is essential for obtaining reliable and precise results.	

Discussion

As the technology continues to advance, it is expected that we will see an increase in the number of applications of immersive VR, such as its use in conjunction with polygraph technology in criminal investigations.

In connection with this, the impact of immersive VR on emotional responses was a key focus of this research, particularly due to the high level of immersion and realism that VR technology provides. The analyzed studies have shown that the degree of arousal and the presence of strong perceptual cues are closely related to the impact of immersive viewing experiences on emotional responses in VR. However, the effects of immersion on emotions in VR systems are complex and may vary depending on the nature of the emotions under study. Some studies have found that more immersive VR systems lead to stronger emotional responses compared to less immersive systems, while others have not found any effects of immersion on emotion. Although negative emotions, such as fear and anxiety, were found to be strongly arousing in VR

environments, positive emotions appear to be less influenced. For use with polygraph, this could be beneficial as the polygraph examiner is usually aiming at negative emotions [14].

Given the complexity of the relationship between immersion and emotions in VR, further research is necessary in order to ensure the successful implementation of polygraph technology in this context.

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REFERENCES

[1] Dede Ch. Immersive interfaces for engagement and learning. (2009). Science, vol. 323, pp. 66-69, DOI: 10.1126/science.1167311.

[2] Carl E., Stein A. T, Levihn-Coon A., Pogue J. R, Rothbaum B., Emmelkamp P., Asmundson G. J G, Carlbring P., Powers M. B. (2019). Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials. Journal of Anxiety Disorders, pp. 27-36, DOI: 10.1016/j.janxdis.2018.08.003. Epub 2018 Aug 10. PMID: 30287083.

[3] Hoffman HG, Doctor JN, Patterson DR, Carrougher GJ, Furness TA 3rd. (2000). Virtual reality as an adjunctive pain control during burn wound care in adolescent patients. Pain, vol. 85, pp. 305-9, DOI: 10.1016/s0304-3959(99)00275-4. PMID: 10692634.

[4] Al-musawi R., Farid F. (2016). Computer-Based Technologies in Dentistry: Types and Applications. Journal of Dentistry, vol. 13, pp. 215-222.

[5] Mathivanan K., Swathi T., Ashapriya B., Sruthi R. (2017). A Study of Virtual Reality. International Journal of Trend in Research and Development, vol. 4, pp. 2394-9333.

[6] LX6 Polygraph System [online]. [cit. 2023-01-25]. Available at: https://lafayettepolygraph.com/products/lx6/

[7] LX User Manual [online]. [cit. 2023-01-24]. Available at: https://lafayetteinstrument.com/downloads/manuals/LXUserMan.pdf.

[8] Norman D., Wade K., Williams M., Watson D. (2020). Caught Virtually Lying—Crime Scenes in Virtual Reality Help to Expose Suspects' Concealed Recognition. Journal of Applied Research in Memory and Cognition, vol. 9, DOI: 10.1016/j.jarmac.2019.12.008.

[9] Tian F., Hua M., Zhang W., Li Y., Yang X. (2021). Emotional arousal in 2D versus 3D virtual reality environments. PLoS One, vol. 16, DOI: 10.1371/journal.pone.0256211. PMID: 34499667; PMCID: PMC8428725.

[10] Lemmens J., Simon M., Sumter S. (2022). Fear and loathing in VR: the emotional and physiological effects of immersive games. Virtual Reality, vol. 26, pp. 223-234, DOI: 10.1007/s10055-021-00555-w.

[11] Kim A., Chang M., Choi Y., Jeon S., Lee K. (2018). The Effect of Immersion on Emotional Responses to Film Viewing in a Virtual Environment, pp. 601-602, DOI: 10.1109/VR.2018.8446046.

[12] BASHARA, Richard. Long Term VR Immersion: Exploring the Effects of a Long VR Session. VR Fitness Insider [online]. 2017 [cit. 2023-02-14]. Available at: https://www.vrfitnessinsider.com/long-term-vr-immersion-exploring-effects-long-vr-session/

[13] Markowitz D. M., Bailenson J. N. (2021). Virtual reality and emotion: A 5-year systematic review of empirical research (2015-2019). Oxford University Press, DOI: https://doi.org/10.31234/osf.io/tpsmr

[14] Diemer J., Alpers G., Peperkorn H., Shiban Y., Mühlberger A. (2015). The impact of perception and presence on emotional reactions: A review of research in virtual reality. Frontiers in Psychology, vol. 6, DOI: 10.3389/fpsyg.2015.00026.