Dorota Kamińska[1], Tomasz Sapiński[2],
Magdalena Kucharczyk-Pośpiech[3], Michał Wilczyński[4]

Ishihara Color Test Using a Mobile Virtual Reality Headset for Immobilised Patients

1. Introduction and the Current State of the Art

Virtual Reality (VR) is a technology that provides an interactive computer-generated environment in which one can see and move in a dynamically changing scenario[5]. VR simulates a user's physical presence in an artificially generated world and allows one to interact with it. Most VR applications and solutions focus on gaming and commercial industries, as these areas provide the largest groups of VR headsets recipients. However, the possibilities of virtual reality do not end with gaming. Dynamic growth and interest in the subject of virtual reality render it applicable in many other areas, such as military applications and psychological and medical research.

Scientists and medical professionals from the University of Southern California Institute for Creative Technologies use VR as a therapy for soldiers with Post Traumatic Stress Disorders (PTSD). Currently, VR is used at clinical sites, including VA hospitals, military bases and university centers and has been shown to produce a meaningful reduction in PTSD symptoms[6].

---

1 Politechnika Łódzka, Instytut Mechatroniki i Systemów Informatycznych.
2 Politechnika Łódzka, Instytut Mechatroniki i Systemów Informatycznych.
3 Politechnika Łódzka, Instytut Mechatroniki i Systemów Informatycznych.
4 Politechnika Łódzka, Instytut Mechatroniki i Systemów Informatycznych.

5 M.S. Cameirão, S. Bermúdez, P. Verschure, *Virtual Reality Based Upper Extremity Rehabilitation Following Stroke: A Review*, "Journal of Cybertherapy and Rehabilitation" 2008, vol. 1, no. 1.

6 A. Rizzo, J. Pair, K. Graap, B. Manson, P.J. McNerney, B. Wiederhold, M. Wiederhold, J. Spira, *A Virtual Reality Exposure Therapy Application for Iraq War Military Personnel with Post Traumatic Stress Disorder: From Training to Toy to Treatment*, in: *NATO Advanced Research Workshop on Novel Approaches to the Diagnosis and Treatment of Posttraumatic Stress Disorder*, M. Roy (Ed.), IOS Press, Washington D.C., pp. 235–250.

Exposure therapy for patients with phobias is a similar VR application in treatment. At the University of Louisville patients face their fears, such as flying or claustrophobia in a controlled simulated environment[7]. An Argentinian psychologist, Fernando Tarnogol, created a software platform called Phobos to treat acrophobia and arachnophobia[8]. Deep[9], the application for Oculus Rift, helps users dealing with anxiety, showing them how to take deep, meditative breaths in an underwater world.

Researchers from the University of Washington use VR as a distraction therapy for patients with extensive burns to reduce their pain during an extremely painful dressing changing procedure. Studies have shown that this kind of therapy works better than morphine[10]. In a similar vein, a study shows that virtual reality games may help patients with alleviate phantom limb pain[11].

Because of autistic children's intense interest in technology, VR interactive games are a good tool for socio-emotional therapy. Researchers from the University of Texas, Dallas, put young adults in various social situations such as job interviews or blind dates to train their reading of social cues and expression of socially acceptable behaviour [12].

VR can also improve the quality of life of those who do not have an ability to get out in the real world, whether they are disabled or elderly. Students from Stanford have created a virtual reality experience for seniors confined at home, which lets them experience the outside (a bike ride or a walk on the beach)[13]. ICT's Game Based Rehabilitation Lab develops interactive tools based on Kinect and Oculus Rift for rehabilitation, for patients recovering from trauma, such as stroke, mild traumatic brain injury and spinal cord injury and for high-risk

---

7 *Virtual Reality Therapy for Phobias*, Duke University School of Medicine, http://psychiatry.duke.edu/divisions/general-psychiatry/virtual-reality-therapy-phobias

8 C. Iozzio, *Virtually Revolutionary*, "Scientific American" 2014, vol. 311, no. 26.

9 Own ll Harris.com, http://owenllharris.com/deep/

10 H.G. Hoffman, D.R. Patterson, M. Soltani, A. Teeley, W. Miller, S.R. Sharar, *Virtual Reality Pain Control during Physical Therapy Range of Motion Exercises for a Patient with Multiple Blunt Force Trauma Injuries*, "Cyberpsychol & Behavior" 19.10.2008.

11 M. Ortiz-Catalan, N. Sander, M.B. Kristoffersen, B. Håkansson, R. Brånemark, *Treatment of Phantom Limb Pain (PLP) Based on Augmented Reality and Gaming Controlled by Myoelectric Pattern Recognition: A Case Study of a Chronic PLP Patient*, "Frontiers in Neuroscience" 2014.

12 M.R. Kandalaft, N. Didehbani, D.C. Krawczyk, T.T. Allen, S.B. Chapman, *Virtual Reality Social Cognition Training for Young Adults with High-Functioning Autism*, "Journal of Autism and Developmental Disorders" 2013, vol. 43, no. 1, pp. 34–44.

13 *Virtual reality helps home-bound seniors enjoy the outdoors*, http://www.paloaltoonline.com/news/2014/05/04/virtual-reality-helps-home-bound-seniors-enjoy-the-outdoor

groups, including elderly adults at risk for falls and athletes and soldiers at risk for concussive head injuries[14].

Neurosurgeons at the Mayo Clinic, Ronald Reagan UCLA Medical Center are planning complex brain surgeries using the virtual reality technology. Wearing the Oculus Rift, they can navigate through 3D models based on MRI or CT scans to find the safest path to a hard-to-reach tumour [15].

Psychologists from Stanford shown how VR can change real-life behaviour. In their experiment, the participants were asked to chop a tree using a virtual mechanical saw. As their future studies have shown, people who personally destroyed the virtual forest use less paper in the real world than the other group which was ask to imagine the same process[16].

Although virtual reality headsets are strongly associated with the sense of sight, no research in optomathology was found.

2. Color Perception Test

The perception of colours is an ability to distinguish objects, based on the sensitivity to the wavelength of light that these objects reflect, emit or absorb. The human nervous system captures colour by comparing the feedback of several kinds of eye cones to the light. Cones are sensitive to different wavelengths of visible light and for people visible light is about 380–740 nm.

Colour blindness (also known as colour vision deficiency) is an inability to perceive differences between some or all colours that are normally perceived by others. It is usually a birth defect, however, it can also be a result of physical or chemical damage to the eye, optic nerve, or parts of the brain. Diagnosis is typically conducted with the Ishihara color test or the Farnsworth-Munsell 100 hue test.

The Ishihara color test consists of coloured plates, called Ishihara plates, which contain a circle of dots appearing randomized in colour and size. Those

[14] Institute of Creative Technologies, University of Southern California, http://ict.usc.edu/news/video-games-for-rehabilitation/

[15] J.A. Gardner, *Augmented and Virtual Reality in medicine: 6 applications we're keeping our eye on*, MedTech Boston 2016.

[16] P.K. Kaiser, *Prospective Evaluation of Visual Acuity Assessment: A Comparison of Snellen Versus ETDRS Charts in Clinical Practice: An AOS Thesis*, "Transactions of the American Ophthalmological Society" 2009, vol. 107, pp. 311–324.

dots form a number or shape clearly visible to those with normal colour vision, and invisible, or difficult to see, to those with a red-green colour vision defect. The test is given in a random sequence, and the patient has three seconds per plate to answer. This method is most commonly used because of its easy use and high accuracy. It is available as the original paper version and online[17]. An example of an Ishihara color test plates is presented in Fig. 1.

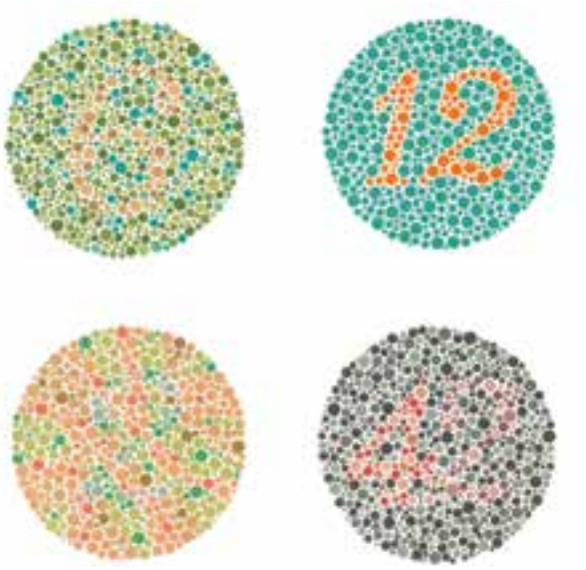

Figure 1. Color Perception Test: Example of an Ishihara color test plate, http://www.colour-blindness.com/colour-blindness-tests/ishihara-colour-test-plates/

3. Virtual Reality Environment

Virtual Reality (VR) is a computer technology that provides interactive virtual environment in which one can see and move in a dynamically changing scenario. VR simulates a user's physical presence in a virtual world and allows interacting with it. Because of this, most of the dedicated applications and solutions focus on gaming and commercial industries. However, some research centres use virtual reality technology to treat patients with anxiety disorders and

[17] E. Kindel: *Ishihara*, "Eye Magazine", 3.12.2013.

phobias achieving promising results. Moreover, recent research shows that physical rehabilitation can be enhanced by VR applications.

Samsung Gear VR (Fig. 2) is a headset developed by Samsung Electronics, in collaboration with Oculus. The Gear VR unit acts as the controller while a compatible Samsung Galaxy device acts as the headset's display and processor connected via micro-USB [18] [19]. The application presented in this paper consists of a VR headset equipped with a Samsung Galaxy S6 smartphone.

Figure 2. Samsung Gear VR for Galaxy S6
Source: Wikimedia Commons.

4. The Application for the Color Perception Test

The application consists of two main components – a control panel and display module. The former can be launched on any computer or laptop, the latter is a dedicated application for a Samsung device which is a part of the Gear VR headset. Both modules communicate with each other using a wireless network. Since the Gear VR headset can operate without any additional cabling, the examination hardware is portable and can be used even by bedridden patients. The control panel allows the operator to choose a particular Ishihara plate. The panel allows creating different sets of displayed plates in order to vary the

[18] *What are the buttons on my Samsung Gear VR Innovator's Edition, and what do they do?*, Samsung Electronics America, 2015.

[19] *Gear VR: How Samsung Makes Virtual Reality a Reality*, Samsung Electronics Official Blog.

examination or to change the set for different patients. The full test consists of 38 plates, but the operator can decide how many and which plates will be displayed. We also created tests consisting of 10, 14 and 24 plates according to Ishihara recommendations.

The display module is a dedicated mobile VR application (Fig. 3), which displays a set of Ishihara plates acquired from the control panel (Fig. 4.). Ishihara's plates in original colours were transferred in a vector format so that their size can be adapted to the requirements of the operator. The communication between the patient and the operator is verbal.

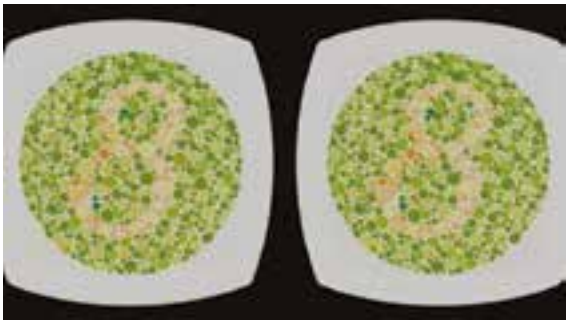

Figure 3. A Screenshot from the Mobile Application
Source: the authors' own resources.

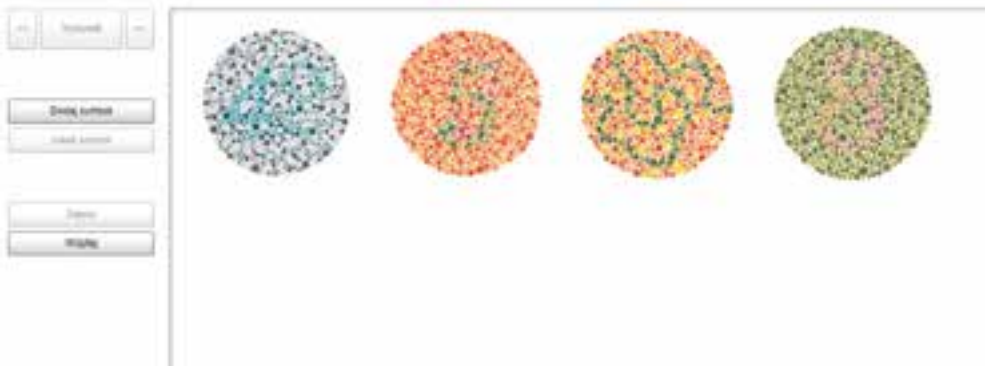

Figure 4. The Control Panel of the Color Perception Test
Source: the authors' own resources.

5. Conclusion and Future Works

The application was initially tested by ophthalmologists and is consistent with the assumptions. The next step is to perform laboratory tests on patients who have impaired colour perception or who are totally colour-blind.

The idea of our research is to create a low-cost, intuitive and transportable device which simulates various ophthalmological examinations for immobilised patients. In the future, transfer to virtual reality headsets of other ophthalmology tests such as the visual acuity test, visual field test and contrast sensitivity test could be possible. The main objective of the proposed tool, as well as the examination, is to substantially improve the daily activities and quality of life of people with impaired movement and allow them to better function in the society. The solution could be used outside of hospitals, at home or even in remote locations.

Bibliography

Cameirão M.S., Bermúdez S., Verschure P., *Virtual Reality Based Upper Extremity Rehabilitation Following Stroke: A Review*, "Journal of Cybertherapy and Rehabilitation" 2008, vol. 1, no. 1.

Gardner J.A., *Augmented and Virtual Reality in Medicine: 6 Applications We're Keeping Our Eye on*, MedTech, Boston 2016.

Hoffman H.G., Patterson D.R., Soltani M., Teeley A., Miller W., Sharar S.R., *Virtual Reality Pain Control during Physical Therapy Range of Motion Exercises for a Patient with Multiple Blunt Force Trauma Injuries*, "Cyberpsychol & Behavior", 19.11.2008.

Iozzio I., *Virtually Revolutionary*, "Scientific American" 2014, vol. 311, no. 26.

Kaiser P.K., *Prospective Evaluation of Visual Acuity Assessment: A Comparison of Snellen Versus ETDRS Charts in Clinical Practice: An AOS Thesis*, "Transactions of the American Ophthalmological Society" 2009, vol. 107.

Kandalaft M.R., Didehbani N., Krawczyk D.C., Allen T.T., Chapman S.B., *Virtual Reality Social Cognition Training for Young Adults with High-Functioning Autism*, "Journal of Autism and Developmental Disorders" 2013, vol. 43, no. 1.

Kindel E., *Ishihara*, "Eye Magazine", 3.12.2013.

Ortiz-Catalan M., Sander N., Kristoffersen M.B., Håkansson B., Brånemark R.: *Treatment of Phantom Limb Pain (PLP) Based on Augmented Reality and Gaming Controlled by Myoelectric Pattern Recognition: A Case Study of a Chronic PLP Patient*, "Frontiers in Neuroscience" 2014.

Rizzo A., Pair J., Graap K., Manson B., McNerney P.J., Wiederhold B., Wiederhold M., Spira J., *A Virtual Reality Exposure Therapy Application for Iraq War Military Personnel with Post Traumatic Stress Disorder: From Training to Toy to Treatment*, w: *NATO Advanced Research Workshop on Novel Approaches to the Diagnosis and Treatment of Posttraumatic Stress Disorder*, ed. M. Roy, IOS Press, Washington D.C.

Online sources

Institute of Creative Technologies, University of Southern California, http://ict.usc.edu/news/video-games-for-rehabilitation/

Owen ll harris, http://owenllharris.com/deep/

Virtual reality helps home-bound seniors enjoy the outdoors, http://www.paloaltoonline.com/news/2014/05/04/virtual-reality-helps-home-bound-seniors-enjoy-the-outdoors

Virtual Reality Therapy for Phobias, Duke University School of Medicine, http://psychiatry.duke.edu/divisions/general-psychiatry/virtual-reality-therapy-phobias

* * *

Badanie rozróżniania kolorów przy użyciu tablic Ishihara w wirtualnej rzeczywistości dla pacjentów z ograniczeniami ruchowymi

Streszczenie

W swojej codziennej praktyce lekarze okuliści spotykają się często z problemem wykonywania badań pacjentom unieruchomionym. Najlepszym przykładem są pacjenci po udarach czy też dotknięci chorobami demielinizacyjnymi, którzy bardzo często są przykuci do łóżka albo cierpią z powodu zaburzeń ruchowych. W takich przypadkach wykonanie nawet najprostszego badania (jak np. ostrości widzenia) może okazać się niemożliwe. Celem niniejszej pracy było przeniesienie tablic Ishihary (badanie sprawdzające zdolność rozróżniania kolorów) do wirtualnej rzeczywistości i stworzenie w ten sposób urządzenia diagnostycznego dla pacjentów z ograniczeniami ruchowymi. Okulary rzeczywistości wirtualnej odwzorowują naturalną ludzką percepcję przestrzeni i izolują pacjenta od światła zewnętrznego, co pozwala w pełni kontrolować kolor i intensywność wyświetlanego obrazu. Dodatkowo są lekkie i przenośne, dzięki czemu można je wykorzystywać w badaniach pacjentów unieruchomionych, co przyczynia się do poprawy jakości ich życia.

Słowa kluczowe: wirtualna rzeczywistość, tablice Ishihary, badania okulistyczne