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INDUSTRIAL REVOLUTION 4.0 IN NEUROREHABILITATION: THE IMPLEMENTATION OF VIRTUAL REALITY FOR NEUROLOGICAL DISORDERS

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ABSTRACT

Background: The industrial revolution 4.0 has changed the health industry. Medical treatments derived from the latest technologies are expected to improve the health and economic status. The rapid development of technology has influenced the learning and clinical practice of medicine. Virtual Reality (VR) is one of the latest technologies that is currently being implemented as a treatment for neurological disorders. This article seeks to give an overview about development of VR implementation on neurorehabilitation. The data source of this article are research and studies published in NCBI, PubMed, Cochrane and other relevant online databases. From this article, it is found that VR can be used as a pain reliever and motor function rehabilitation for patients with balance and gait deficits. VR is used to distract patients' attention to pain for a short-time period. VR also improves motor function recovery in stroke patients. Cybersickness is usually reported as a side effect of using VR and it depends on each individual. The implementation of VR for patients with neurological disorders has showed advantages in reducing pain and improving motor function but still need further research about applicability and authorization of virtual reality in the world of medicine.

Keywords: Industrial revolution 4.0, virtual reality, neurological disorders

Introduction

The industrial revolution 4.0 combines the physical, digital, and biological aspects based on the information and communication technology which change the paradigm of industry. Health industry is one of the industries which are transformed by the new era. Some medical devices were developed based on cyber-physical system and artificial intelligence. Medical treatments and healthcare derived from latest technologies are expected to increase the health status and boost the economy.[1]

One billion people in the world are estimated to suffer from neurological disease. Globally, 50 million people are living with epilepsy and 24 million people are living with Alzheimer and other neurological condition. Neurological condition could affect the functional capacity of patients which could limit their daily activities and participation. Early diagnosis and rehabilitation could help patients with neurological condition and increase their quality of life.[2]

The development of technology in health sectors in the era of industrial revolution 4.0 could open new opportunities to improve patient's quality of life. This article seeks to describe an overview in development of industrial revolution 4.0 and the current state of Virtual Reality (VR) as one of latest technologies for pain management, stroke rehabilitation, and balance-gait training.

Development of Industrial Revolution

The first industrial revolution happened in the end of eighteenth century and in the beginning of nineteenth century which changed the manufacturing process through steam energy. The second industrial revolution occurred in the end of nineteenth century which was represented by the use of electrical energy. The third revolution industry began in the middle of twentieth century which was represented by digitalization and automation and microelectronic technologies. Nowadays, the fourth industrial revolution currently has been developed by the use of smart automation from cyber-physical system and high connectivity of Internet of Things.[3,4]

Neurotechnology is an emerging field which combines technical components and nervous system through assembly of methods and instruments. The technical components in neurotechnology includes electrodes, computers or intelligent prostheses which are used to interpret signals from the brain, or to manipulate human brain activity through electrical or optical stimuli.[5]

Virtual Reality (VR) is one of powerful neurotechnologies which are able to provide immersive live experiences. VR generates illusory realities through multisensory stimulations (visual, auditory, tactile, smell, kinesthetic,

proprioceptive). This mechanism are purposed to get the mind to believe and accept the virtual as real.[6]

Development of Virtual Reality

Virtual Reality (VR) is a realistic artificial environment which are simulated by computer, experienced by the users using human-machine interface and combining multisensory channel.[7] In recent years, VR is not only used for entertainment purpose and has played important role in world of medicine both for learning processes and clinical medicine.[8,9]

Some studies have reported the impact of VR in learning processes. For example, the use of VR were beneficial for laparoscopy surgery training in several medical groups.[10,11] Another implementation is for medical students in studying neuroanatomy via interactive virtual reality environment. This randomized controlled study found the impact of VR to improve knowledges, increase study motivation and reduce neurophobia among medical students.[12]

In clinical medicine, VR has been used for pain management, neurological disorders rehabilitation such as stroke, mild cognitive impairment, Parkinson's disease, balance and gait disorders and psychiatric disorders like phobia, anxiety, depression and post-traumatic stress disorder.[8,9,13]

There are two types of VR that are found around the world; immersive VR and non-immersive VR. The differences between both types are the system and the display. Immersive VR contains head mounted displays (HMD) which could create real-world experience for patients, whereas non-immersive VR only give flat images and displayed through a projector.[14]

Implementation of Virtual Reality for Pain Relief

VR has been used for pain and stress management caused by invasive medical procedure. VR combines multisensorial distraction include visual, auditory, tactile and olfactory which can produce real experience for the user. This process can be defined as multisensorial stimulus. VR software produce real picture of beautiful nature or fun game that aim to divert user attention from their pain.[8,9]

International Association Study of Pain (IASP) defined pain as unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.[15] Pain is classified into nociceptive pain and neuropathic pain. Nociceptive pain is caused by mechanical, chemical or thermal stimuli from skin, muscles, joint or the other parts of body, then neuropathic pain is caused by damage on nerves and its surroundings. In general, pain pathway starts from transduction, transmission, modulation and perception in the cortex.[16]

One theory called Gate Control theory hypothesized the process of pain perception in the cortex. This theory explain that pain perception is caused by the level of attention to pain, emotional respond of pain and previous experience feeling pain. Later on, there is another theory which explain more about Gate Control theory that there is a limit of human attention to pain and every individual must have full attention in order to feel pain. This theory explains that VR can be used as adjunctive pain management with the mechanism of taking and diverting human attention from pain.[8,17]

A research by Jones et al. (2016) found a significant decrease of pain intensity in people who use VR. This research used Numerical Pain Rating Scale (NPRS; scale 1–10) to measure the intensity of pain in 30 participants with chronic pain. They measured the intensity of pain pre-session, during-session and post-session using VR. The result found significant change on the average of pain intensity during-session (2.6) and post-session (4.1) compared to pre-session (5.7). Some participants also felt the pain disappeared when using the VR.[17] An exploratory study by Garrett et al. (2017) also found similar result which showed significant reduction of pain intensity when using VR, but there was no difference between pain intensity on pre-session and post-session.[18]

VR was also reported as promising adjunctive tool to support patients with cancer during chemotherapy. VR has been proven to improve patients' emotional condition and reduce cancer-related symptoms and pain during hospitalization and painful medical procedures.[19]

In the last decade, many researchers have approved that VR can divert individuals' attention to pain which reduce pain intensity and anxiety in short-term period. Nowadays VR is more affordable and inexpensive, many individuals can buy it and get adjunctive pain management in outpatient setting.[9]

Implementation of Virtual Reality for Stroke Rehabilitation

VR has more advantages over conventional rehabilitation in implementation of motor training strategies, specifically facilitating the combination of several principles of motor learning such as real-time multisensory feedback, task variation, objective development, and task-oriented repetitive training. Doing this type of training using VR can induce reorganization of the neural structure and help the recovery of motor skills patients with neurological defects.[20]

VR was initially applied to the rehabilitation of upper limbs with paresis in stroke patients to encourage the movement and functional of hands, elbows and shoulders. The application of VR uses three components, namely a tool for recording movements, a computer and software for developing three-dimensional simulations with various levels of task complexity. Patients are assigned to follow the path that has been arranged. The movement of upper limbs will be monitored and then recorded. VR is also designed for lower limb recovery regarding walking ability in stroke patients. A study that observed about training the gait by using a treadmill that installed on a motion platform that provides simulation features and also provides visual and auditory stimulation as a negative or positive feedback. Patients used 3D glasses to visualize the virtual environment, the results of this study showed an increase in walking speed after they get the exercise.[7]

Two systematic reviews in 2018 show evidence of VR effectiveness at a certain level to improve balance and gait in stroke patients. These reviews compare the use of combination VR and conventional therapy with conventional therapy alone. VR The increase of compliance level, motivation, and enjoyment was reported

in the application of VR and provide maximize motor function recovery when combined with conventional rehabilitation. Improvement of balance and gait also obtained when VR used as home training as in-clinic VR intervention. VR has got support by researchers that will provide maximum results from rehabilitation process for stroke patients as combined therapy with conventional one.[20,21]

Years later, a systematic review and meta-analysis by Lee et al (2019) has showed that training with VR for 8 weeks has proven a moderate-sized effects on chronic stroke patients rehabilitation. VR training for 8 weeks has proven benefits for upper limb and lower limb rehabilitation.[22]

Another systematic review by Wardani et al (2021) has reported that VR for example, Nintendo Wii can be included as adjunctive therapy that have significant improvement in various aspects of exercise therapy, like balance and gait, statistical and dynamic strengths, increase motivation as well as socialization, and recovery of physical function in stroke patients. There is no side effects reported after Nintendo Wii-based training.[23]

Implementation of Virtual Reality for Balance and Gait Training

Balance and gait deficits are usually found after neurological disorders like Parkinson's disease, multiple sclerosis, stroke and traumatic brain injury. A systematic review and meta-analysis in 2016 have suggested that VR-based training can maximize the result of balance and gait rehabilitation. This result showed improvement of score in some tests like gait speed, Berg Balance, Scale and Timed-up and Go. Within that suggestion further research was recommended to know the length of VR-based training, which tests should be performed and time to follow-up after training.[24]

A study in 2018 that cover large scale medical center in Israel has claimed a significant improvement in balance-gait recovery using VR-based intervention. A total of 167 patients with neurological disorder history was performed VR-based training. Some tests have been done before and after VR-based training with positive results for example higher score in 10-Meter Walk Test and Timed-up and go test after VR-based training. VR improves patient confidence in balance training and has been approved as one of neurorehabilitation method by the patients.[25]

Many studies suggest that VR-based training in neurorehabilitation may be useful to assists the conventional rehabilitation methods. But authorization from VR-based training is still necessary. First line clinicians also needed to perform VR-based training.[26] Overview of VR implementation in neurorehabilitation is described at Table 1.

Synthesis of VR Implementation for Neurorehabilitation

Based on several studies above, the author support the using of VR during several medical procedures, like chemotherapy as adjunctive pain reliever. VR can help calm people especially children who are afraid of pain during chemotherapy by its mechanism that distracts patient's attention from feeling pain.

For stroke rehabilitation including balance and gait rehabilitation, although many studies in developed countries have claimed benefits from VR as a part of rehabilitation process and the patients feel suitable with VR-based training, there is few evidence in developing countries like Indonesia.

Application of VR in neurorehabilitation still needs further research so that VR can take an important role in rehabilitation program combined with conventional one.

Table 1. Overview of Implementation VR for Neurological Disorders

No	Neurological disorders	Main outcome	References
1.	Pain	Reduced pain in short-term period by distract patient's attention from pain	17, 18, 27–30
2.	Stroke	Improvement motor function after taking VR-based training combined with conventional one	20, 21, 23, 31–33
3.	Balance and gait deficits	Increase of post training score tests and increase patient's confidence to perform VR-based training	24, 25, 34, 35

Side Effects of Virtual Reality

VRs aren't associated with serious adverse effects. Side effect that usually reported is cybersickness. The symptoms of cybersickness such as dizziness, headache, fatigue, vertigo, nausea and vomiting. Presentation of cybersickness is vary and depends on each individual. It occurs usually on immersive VR with the use of HMD. Cybersickness symptoms usually disappear after stopping use of VR.[13,14] Reducing this side effects still become an important challenge in the future for VR designers and creators to increase applicability of VR in the world of medicine.[13]
Another article explain that although there is side effect when using VR, overall patients enjoyed while use VR and willing to use it again. Moreover, VR is easy to use and minimizing the nursing time.[19]

Conclusion

Industrial revolution 4.0 has made rapid development in technology that also play important role in world of medicine both for learning processes and clinical uses. For the first time launched, VR is used only for entertainment but recent years many researchers have thought that VR is more than entertainment. Nowadays VR implementation is not only for entertainment, but also it has important role in world of medicine both for learning processes and clinical practice. In conclusion, the implementation of virtual reality for patients with neurological disorders has showed promising results and there still many benefits from VR. It

is necessary to do further research about applicability of virtual reality in world of medicine especially in developing countries like Indonesia and newer devices that will minimalized VR side effects.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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