International Journal of Science Academic Research
Vol. 04, Issue 09, pp.6311-6314, September, 2023
Available online at http://www.scienceijsar.com
ISSN: 2582-6425

Research Article

WEARABLE HAPTIC FEEDBACK TECHNOLOGY FOR REHABILITATION

***Young-Wook Sohn**

Seoul International School, Seoul, Korea

Received 19th July 2023; **Accepted** 11th August 2023; **Published online** 30th September 2023

Abstract

Wearable haptic feedback devices have emerged as a promising technology for assisting rehabilitation processes. These devices provide tactile or vibratory sensations to the user, delivering real-time feedback and guidance during rehabilitation exercises. By integrating sensors, haptic feedback mechanisms, and advanced technology, wearable haptic devices could offer personalized and engaging rehabilitation experiences. This paper explores the key features and applications of wearable haptic feedback devices for rehabilitation. These devices are designed to assist in motor skill rehabilitation by correcting movement, improving posture, and guiding users towards correct motions. The integration of haptic feedback with virtual reality technology further enhances the immersive experience, allowing for more engaging and effective rehabilitation exercises. Remote monitoring and data analysis capabilities enable healthcare professionals to track patients' progress and provide personalized feedback remotely. The ability to collect and analyze data also facilitates the development of tailored treatment plans. Wearable haptic devices promote patient engagement and motivation by establishing a stronger mind-body connection through tactile sensations. The field of wearable haptic feedback devices for rehabilitation is continuously evolving, with ongoing advancements in design, functionality, and integration with other technologies. These research fields have great potential for improving rehabilitation outcomes and enhancing the overall patient experience.

Keywords: Small and Medium Scale Enterprises (SMEs), Framework, Cyber Attacks, Cyber Security, Cyber Threats.

INTRODUCTION

Rehabilitation plays a vital role in restoring motor functions and improving the quality of life for individuals recovering from injuries, surgeries, or neurological conditions. In recent years, wearable haptic feedback devices have emerged as a promising technology to augment rehabilitation processes (1-3). Basically, these devices have been developed for AR/VR (Augmented reality/Virtual reality) system to enhance the immersion of person to virtual world. There are many types of stimulators including vibrotactile system, thermal stimulator system and electrotactile stimulator system (4-6). In other words, haptic feedback system for rehabilitation originates from basic haptic technology which provides tactile or vibratory sensations, to deliver real-time feedback and guidance during rehabilitation exercises. By combining sensory cues with advanced technology, wearable haptic devices aim to enhance the effectiveness and engagement of rehabilitation interventions. Traditional rehabilitation methods often rely on visual and auditory cues, but they may lack the precision and immediacy required for optimal outcomes. Wearable haptic feedback devices overcome this limitation by adding a tactile information to the feedback loop, facilitating a stronger mind-body connection and improving the proprioceptive awareness of the user. This enables individuals to actively participate in their rehabilitation and make adjustments to their movements based on the tactile cues they received. The core components of a wearable haptic feedback device for rehabilitation typically include sensors, haptic feedback mechanisms, and connectivity features. Sensors detect the user's movements from information such as angle, distance, and location and transmit data to the device, enabling real-time monitoring and personalized feedback.

Corresponding Author:** ***Young-Wook Sohn
Seoul International School, Seoul, Korea

Haptic feedback mechanisms, such as vibrators, actuators, or pressure sensors, deliver tactile sensations to specific areas of the body, aiding in movement correction, posture improvement, and skill development. Furthermore, connectivity features facilitate remote monitoring and data analysis, enabling healthcare professionals to track patients' progress and provide feedback and guidance from a distance.

The integration of wearable technology with haptic feedback devices has opened up new possibilities for rehabilitation. By using the stretch ability and elasticity, these kinds of wearable haptic feedback system could be integrated on the human skin, immersing continuously users in virtual environments. VR also provides a realistic and interactive platform for engaging in rehabilitation exercises. When combined with haptic feedback, VR can simulate real-world scenarios and offer a more dynamic and engaging rehabilitation experience. This integration has shown promise in improving motor learning, balance training, and overall functional recovery. The purpose of this paper is to explore the various features and applications of wearable haptic feedback devices for rehabilitation. We will investigate basic neurological aspect of our body. Then, review the ability of wearable haptic feedback system used for facilitating movement correction, improving motor skill rehabilitation, enhancing patient engagement, and enabling remote monitoring and data analysis. By understanding the potential of wearable haptic feedback devices, healthcare professionals and researchers can harness this technology to optimize rehabilitation outcomes and enhance the overall rehabilitation experience for patients.

Fundamental aspects of biology

The nervous system is a complex network of specialized cells called neurons that transmit signals between different parts of the body. It consists of two main components: the central nervous system (CNS), which includes the brain and spinal cord, and the peripheral nervous system (PNS), comprising the nerves that extend throughout the body (Figure 1).When it comes to prosthetic hands, the biological aspect of the nervous system is crucial for their successful integration. The PNS plays a vital role as it contains the nerves responsible for transmitting signals between the brain and the hand. These signals allow us to control and perceive sensations from our hands, such as touch, temperature, and proprioception. The biological aspect of nerve stimulation systems involves understanding how the nervous system responds to and interacts with electrical stimulation. Nerve stimulation is a technique used to modulate the activity of nerves by delivering electrical impulses to specific areas of the body. It has a wide range of applications in both research and clinical settings, including pain management, muscle control, and the restoration of sensory or motor function. We will review more closer for looking at the biological aspects of nerve stimulation systems.

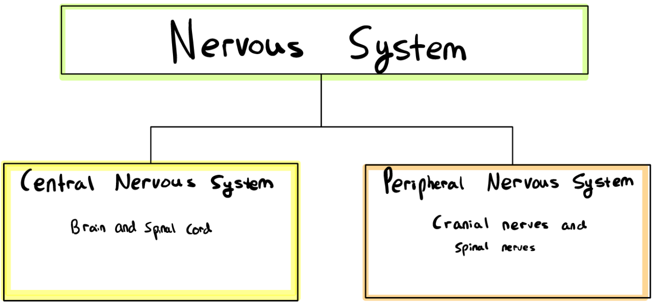

Figure 1. Nervous system consisting of central nervous system and peripheral nervous system

Nerve cells, or neurons, are the fundamental building blocks of the nervous system. They are specialized cells that transmit electrical signals, known as action potentials, to communicate information throughout the body. Neurons have a cell body, which contains the nucleus and other cellular components, and long extensions called axons and dendrites. When an electrical stimulus is applied to a nerve, it can initiate an action potential, which is a rapid and temporary change in the electrical potential across the cell membrane of the neuron. This action potential propagates along the length of the nerve fiber, allowing the signal to be transmitted to other neurons or target tissues (Figure 2) (7).

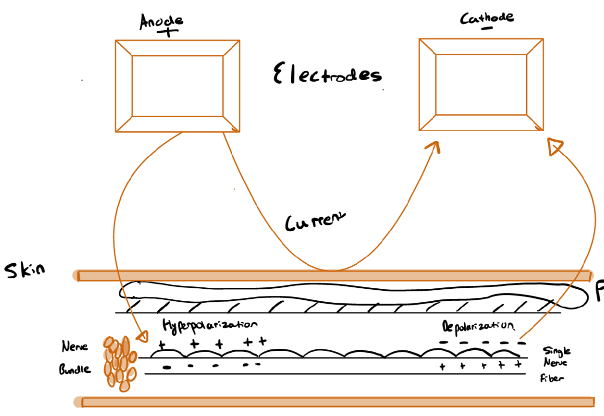

Figure 2. Principle of transcutaneous electro tactile stimulation

There are two different types of nerve stimulation techniques that target specific areas of the nervous system: Peripheral Nerve Stimulation and Spinal Cord Stimulation. Peripheral Nerve Stimulation involves the application of electrical stimulation directly to peripheral nerves, which are nerves outside the brain and spinal cord. It can be used to manage chronic pain, improve muscle function, or restore sensation in individuals with nerve injuries. Spinal Cord Stimulation involves the implantation of electrodes along the spinal cord to modulate the transmission of pain signals. It is commonly used for chronic pain management, particularly for conditions like failed back surgery syndrome or neuropathic pain. When electrical stimulation is applied to nerves, it can evoke various biological responses, depending on the specific parameters of the stimulation and the target tissue.

Feedback system for prosthetic device

In prosthetic technology, feedback device module has drawn attention for high quality of control. The existing prosthetic upper- and lower-limb devices do not offer natural sensory data. Lower-limb amputees may be vulnerable to severe falls and struggle to maintain symmetry when standing and walking if they are unaware of when the prosthesis will encounter an obstruction. Additionally, compared to non-amputees, amputees may face a twofold greater risk of heart failure, an increased metabolic expenditure of typical physical exercise, and decreased mobility. For this reason, prosthetic device requires optimized feedback control system.

A "Feedback System for Prosthetic Device" refers to the integration of sensors, actuators, and control mechanisms in a prosthetic device to enhance its functionality and usability by providing users with sensory information and better control. This technology aims to bridge the gap between the user's intention and the prosthetic device's response, leading to more natural and intuitive interactions. A prosthetic device with a feedback system can greatly improve the user's quality of life. Traditional prosthetics lack sensory feedback, which makes it challenging for users to sense the force, position, and movement of the artificial limb. A feedback system can provide this missing sensory information, allowing users to have a better sense of their prosthetic's interactions with the environment.

Incorporating sensors such as force sensors, pressure sensors, and accelerometers can provide real-time information about the prosthetic's interaction with objects and the ground. This data can be translated into tactile, visual, or auditory feedback, allowing the user to feel and understand the prosthetic's actions. Feedback systems can also provide motor feedback, allowing users to control the prosthetic more accurately. This can involve using sensors to detect the user's muscle signals (electromyography - EMG) to trigger specific movements in the prosthetic device. The user receives feedback through sensory cues when the intended movement is successfully executed. Feedback systems create closed-loop control systems. This means that the prosthetic device not only receives commands from the user but also sends back information about its actions. This closed-loop communication enables smoother and more precise control over the prosthetic limb's movements. Users may need time to adapt to the feedback system, as incorporating new sensory perceptions can be overwhelming initially. Training and rehabilitation programs play a vital role in helping users effectively utilize and benefit from the feedback system. In conclusion, a feedback system for prosthetic devices holds significant promise in enhancing the functionality and usability of artificial limbs. By providing sensory and motor feedback, it allows users to have a more natural and intuitive interaction with their prosthetics, ultimately improving their overall quality of life.

TENS (Transcutaneous electrical stimulation), EMS (Electrical muscle stimulation) technology for feedback system

Electrical Muscle Stimulation (EMS) and Transcutaneous Electrical Nerve Stimulation (TENS) are two distinct yet related therapeutic techniques that utilize electrical impulses to promote various physiological responses in the human body. EMS involves the application of controlled electrical currents to stimulate muscle contractions, making it a valuable tool for muscle rehabilitation, and even could be promising haptic feedback device in prosthetic system. EMS provides various kinds of information regarding proprioceptive feeling in prosthetics. We perceive forces by means of our proprioceptive sense. Proprioception allows sensing the position, orientation, and movement of our limbs, joints, and muscles (8). Proprioception works by combining the information of mainly three mechanoreceptors: the muscle spindles (receptors lodged in our muscle fibers),which detect changes in the length of the muscle; the Golgi tendon organs (receptors atthe interface between muscles and tendons), which sense changes in muscle tension, and, lastly, sensors inside the joint capsules, which sense the joint's rotation (Ref). In case of events like "pick up the heavy box", this means you can feel the force that the heavy box exerts on you. This proprioceptive feedback could give feelings totally different from tactile sensations to users (Figure 3). On the other hand, TENS targets nerve pathways by delivering electrical pulses through the skin to provide tactile sensation. Basically, this method is widely used for managing chronic pain conditions, such as arthritis or back pain, by disrupting pain signals and triggering the release of endorphins. By using the TENS technology prosthetic device transfer the vivid mechanical sensations including touch, vibration, sliding, tickling and stretching. Both EMS and TENS have gained popularity in the medical and fitness fields due to their non-invasive nature and potential to improve quality of feedback information for amputees from the prosthetic device.

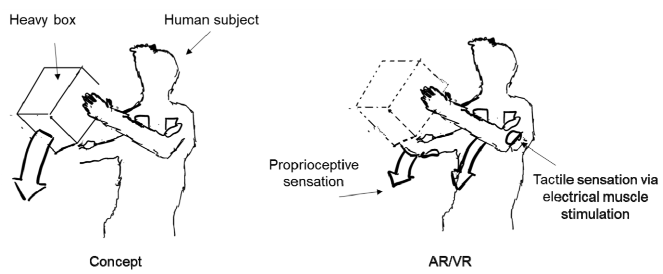

Figure 3. Examples showing how to provide proprioceptive sensation by using EMS

Applications for rehabilitations

Robotic limbs and prosthetic hand can help amputees regain their sensation as well as movements. Such prostheses are developed by using approaches that interpret desired movements from signals collected from the user's nervous system. Control signals can be extracted from the user's muscles, nerves, brain, or residual movements using a variety of technologies. Nonetheless, the limited sensory feedback for users have limited the effectiveness of one-way outgoing neuroprosthetic systems. These systems typically rely mostly on visual guidance, although proprioceptive signals from the remaining forearm muscles used formyoelectric control of the bionic hand, as well as aural cues from the robotic actuators may also play a role. In contrast, in amputees, limb control mainly depends on somatosensory signals that monitor the limb's status and interactions with objects. Nerve fibers connected with muscles, tendons, joints, and skin transmit information regarding the posture, movements, and forces exerted by the limb. Nerve fibers attached to the skin convey information about all contacts with in real-world, and which parts of the hand are in contact with the object, the forces exerted at each point, and information about the object itself, such as size, shape, and texture. Tactile signals allow us to retain contact with an object. Our ability to manipulate items skillfully strongly depends on touch and proprioception, as seen by the deficiencies that occur when these sensory inputs are removed. For example, our sense of touch is critical in exerting the optimum amount of force to securely hold items, as illustrated by the fact that when our fingertips are numbed with a local anesthetic, we tend to exert more force than is necessary. In cases where there is a total loss of sensory input, including both touch and proprioception, the ability to perform delicate movements with the hands is completely compromised (9). This results in awkward and challenging hand usage, even the motor system is well operated. The realization that reliance on visual feedback limits prosthetic control, as well as the psychological value of somato-sensation, has fueled efforts to restore tactile and proprioceptive feedback in bionic limbs. Several strategies have been investigated for this aim. Some approaches use mechanical or electrical stimulation of the skin to relay information on the status of the limb (e.g., posture and movements) and its interactions with objects (10). Other ways involve surgically implanting devices that interface with the external nerves or the brain in order to directly activate neurons using tiny currents. These various technologies have varying prices and benefits, and their applicability varies based on the user group, such as amputees or people with tetraplegia.

Conclusion

In conclusion, haptic prosthetic hands represent a significant advancement in the field of prosthetics, offering individuals who have lost a hand or limb the opportunity to regain a sense of touch and dexterity. These devices incorporate haptic feedback technology, which enables users to feel sensations and interact with their environment more intuitively. Haptic prosthetic hands have demonstrated the potential to greatly enhance the quality of life for amputees by restoring a crucial aspect of human interaction and sensory perception. Users are able to experience textures, pressure, temperature, and even pain through the integration of sensors and actuators within the prosthetic. This sensory feedback can lead to improved motor control, reduced cognitive load, and a more natural integration of the prosthesis into daily activities. While haptic prosthetic hands have shown promising results, there are still challenges that need to be addressed. Technical complexities, such as developing reliable and durable sensors and actuators, as well as achieving seamless integration with the user's nervous system, remain areas of active research. Additionally, accessibility and affordability are important considerations to ensure that these advancements are accessible to a broader range of individuals. As technology continues to evolve, haptic prosthetic hands are likely to become more sophisticated, customizable, and widely available. The interdisciplinary collaboration between engineers, neuroscientists, and medical professionals will play a crucial role in refining these prosthetic devices, making them more responsive, versatile, and adaptable to the unique needs of each user.

Acknowledgement

I would like to thank Dr. Sunny Kim and the members of his laboratory for their invaluable contributions and guidance throughout the process of completing this research.

REFERENCES

1. Margarida F. Pereira a, Cosima Prahm b, Jonas Kolbenschlag, Eva Oliveira,Nuno F. Rodrigues. “Application of AR and VR in hand rehabilitation: A systematic review”. Journal of Biomedical Informatics. 2020, 111, 103584
2. Yang, Tae-Heon, Jin Ryong Kim. Jin, Hanbit. Gil, Hyunjae. Koo, Jeong-Hoi. Hye Jin. “Recent Advances and Opportunities of Active Materials for Haptic Technologies in Virtual and Augmented Reality.”Adv. Funct. Mater. 2021, 31, 2008831.
3. Fleury, Mathis. Lioi, Giulia. Barillot, Christian. Lécuyer. Anatole. “A Survey on the Use of Haptic Feedback for Brain-Computer Interfaces and Neurofeedback.” Frontiers in Neuroscience, 2020, 14, 528.
4. Carpenter, Cody. Malinao, Marigold. Rafeedi, Tarek. Rodriquez, Daniel. Siew Ting Melissa Tan. Root, Nicholas. Skelil, Kyle. Ramírez, Julian. Polat, Beril. Root, Samuel. Ramachandran, Vilayanur. Lipomi, Darren. “Electropneumotactile Stimulation: Multimodal Haptic Actuators Enabled by a Stretchable Conductive Polymer on Inflatable Pockets.” Adv. Mater. Technol. 2020, 5, 1901119.
5. Yao, Kuanming. Zhou, Jingkun. Huang, Qingyun. Wu, Mengge. Ki Yiu, Chun. Li, Jian. Huang, Xingcan. Li, Dengfeng. Su, Jingyou. Hou, Senlin. Liu, Yiming. Huang, Ya. Tian, Ziyan. Li, Jiyu. Li, Hu. Shi, Rui. Zhang, Binbin. Zhu, Jingyi. Hung Wong, Tsz. Jia, Huiling. Gao, Zhan. Gao, Yuyu. Zhou, Yu. Park, Wooyoung. Song, Enming. Han, Mengdi. Zhang, Haixia. Yu, Junsheng. Wang, Lidai. Jung Li Wen. Yu, Xinge. “Encoding of tactile information in hand via skin-integrated wireless haptic interface.” Nature Machine Intelligence. 2022, 893-903.
6. Oh, Jinhyeok. Kim, Suin. Lee, Sangyeop. Jeong, Seongmin. Hwan Ko, Seung. Bae, Joonbum. “A Liquid Metal Based Multimodal Sensor and Haptic Feedback Device for Thermal and Tactile Sensation Generation in Virtual Reality.” Adv. Funct. Mater. 2021, 31, 2007772,
7. Akhtar, Aadeel. Sombeck, Joseph. Boyce, Brandon. Bretl. Timothy. “Controlling sensation intensity for electrotactile stimulation in human-machine interfaces.” Akhtar et al., Sci. Robot. 2018, 3, eaap9770.
8. Pfeiffer, Max. Stuerzlinger, Wolfgang. “3D Virtual Hand Selection with EMS and Vibration Feedback.” 2015, 1361–1366.

****