Combining VR with Current Rehabilitation Techniques to Help Athletes with Spinal Cord Injuries

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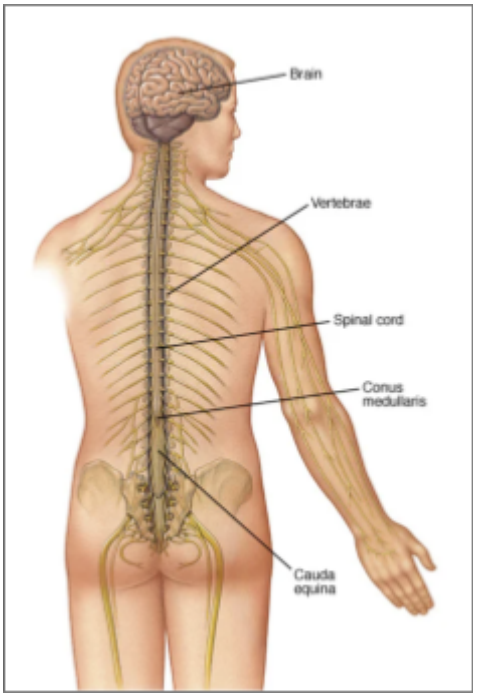
Abstract

Sports-related injuries are the fourth leading cause of spinal cord injuries. Athletic activities, such as high-impact sports, cause about 10% of spinal cord injuries, and around 6.1 million injuries in sports per year are spinal cord injuries. Given that spinal cord injuries are so common among these athletes, how do we help treat this?

Clinical Problem



In an SCI (spinal cord injury), depending on the injury, it can run through the entire CNS (central nervous system). The spinal cord spans from the bottom of the base of the brain to a region just right above the waist, called the conus medullaris. Along the spinal cord, nerve groups and cells that carry messages from the brain to the rest of the body, called tracts, extend out from the spinal cord. Motor tracts carry messages from the brain to control muscle movement, while sensory tracts carry signals from the body to the brain relaying messages about temperature, pressure, pain, etc. [1] Damage to the spinal cord can affect the use of these tracts.

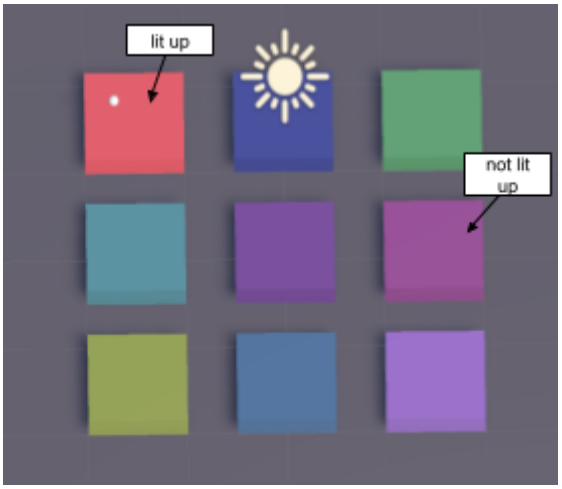
There are two major parts of the injury when we talk about SCI: the primary and secondary phases. The primary phase is the initial impact on the spinal cord which can disrupt blood vessels, axons, and neural cell membranes, causing an expansion of the zone of neural tissue damage, leading to the secondary injury phase [2]. The secondary phase deals with the cognitive decline and after-effects of SCI, slowing a patient's reaction time and affecting their mind/body coordination. SCI can result in both motor and cognitive symptoms. Motor impairments include symptoms like tissue damage, slowed/lack of movement in certain areas of the body (usually arms or legs), incoordination, muscle weakness or stiffness, delayed reaction time, and damaged muscle memory [1]. Meanwhile, cognitive impairments include symptoms like depression, anxiety, anger issues, sleeping disorders, bipolar disease, decreased concentration capacity, shortened attention span, and memory [3].

Current physical therapy (PT) and rehabilitation focus on strengthening lost muscle control, working through muscles in spasm, and other physical movements, which have proved to be effective, but patients have been shown to have trouble with the motivation aspect [4], which is where virtual reality (VR) and music rehabilitation come into play. Music and VR rehabilitation have been shown to have positive effects on keeping patients motivated while exercising not only their motor control but also their coordination, reaction time, and memory. In my VR game, I want to target both motor and cognitive symptoms, and I will do this by using a test that is known to help with sustained attention and reaction time, while at the same time having the patients work through the scar tissue of their injury through repeated motions, which has also shown to help build back muscle memory. Lastly, the music aspect of my game will help the patients work on their coordination by performing a task at a definite period.

My VR Solution

In my VR game, I am taking inspiration from the Human Benchmark Sequence Memory Test, but also incorporating a rhythmic aspect into it. In this test, there is a grid of boxes that will light up in a certain sequence, and the goal is for the patient to click the boxes in the same order. Over time, the sequences get longer and longer, and the grids get bigger and bigger. Once the patient makes a mistake, the game ends.

In this VR environment, I will address both the motor and cognitive features of SCI. Concerning the motor symptoms, I've incorporated reaching and twisting motions (which is helpful for working through tender areas of muscle tension and regaining the range of motion in your spine), coordination (which can address both the cognitive and motor aspects of the injury), moving arms and back so scar tissue can't develop, and working through the muscles that are in spasm all into my VR game. Moreover, it addresses cognitive features such as keeping a rhythm, coordination with both arms, and auditory features of VR games, increased reaction time (how long it takes to intake information and respond physically), working memory as the series gets longer (and as the board gets bigger), and strengthening muscle memory with repetition of movement.



So far, I have made the first three levels of this VR game, where the first level has a 7-sequence pattern on a 3x3 board, the second level has an 11-sequence pattern on a 5x5 board, and the third level has a 15-sequence pattern on a 5x5 board. Additionally, I've added features to each block where, if it is clicked, it lights up, but as soon as the mouse is released, the blocks return to their original state. This feature is to help patients visualize the movements they make, and because the sequence is presented in a series of blocks that light up, it will make it easier for them to recreate the same pattern if the blocks also light up on touch.

Future Goals

This project is still a work in progress, and there are many other features that I will have to address before I am ready to test it out, such as incorporating the rhythmic and musical aspects of the game. So far, I just have patterns and sequences, but I plan on having each block make a different tone when it is hit, so that when the patterns get longer, the patients can also memorize the patterns through the auditory aspects. Lastly, I haven't made a "checking system" that determines if the patient presses the correct block in the sequence, so I would also like to work that out. I plan to continue working on and perfecting this game until it's finished, so hopefully one day I can test it on real SCI patients!

References:

[1] Spinal cord injury - Symptoms and causes - Mayo Clinic

[2] Spinal cord injury-induced cognitive impairment: a narrative review - PMC

[3] Spinal cord injury-induced cognitive impairment: a narrative review - PMC

[4] Rehabilitation of spinal cord injuries - PMC