Stroke Rehabilitation Using Virtual Environments

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KEYWORDS

• Virtual reality • Motor relearning • Hemiparesis • Neuroplasticity • Stroke

KEY POINTS

- Virtual environment interventions for motor relearning are popular and well received, but they have a small positive effect over conventional therapy.
- Common consensus is that virtual environment interventions are low risk and are likely beneficial if used as an adjunct to conventional therapy.
- There is a lack of effective and widely available virtual environment treatments for nonmotor deficits such as speech, cognitive function, and sensory dysfunction.
- Future approaches may need to strategically combine multiple interventions to address the multifaceted nature of stroke rehabilitation.

INTRODUCTION

Despite our best efforts, stroke continues to be a leading cause of acquired disability throughout the world and is responsible for approximately 102 million disability-adjusted life years annually.[1] Even more concerning to care providers, 66% of the 666,000 new stroke survivors each year may suffer chronic cognitive or physical impairment after 6 months of conventional care.[2,3]

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Evidence for neurologic recovery through cortical reorganization[4] has led to new interventions that try to accelerate functional recovery. One promising approach uses virtual environments (VEs) in the form of video games or therapeutic tasks to train impairments. A definition of VEs is computer-simulated objects that respond to speech or motor input. Many VE therapies for stroke are now commercially available and attract intense interest.

This review focuses on VEs for stroke that are widely available outside of research programs. Those interested the broader academic field can refer to texts such as that by Dietz and Ward.[5] This article begins with the rationale for VE training along with potential mechanisms of action. It groups interventions by their targeted impairments, discusses their efficacy, and concludes with challenges for the field.

FEATURES FOR MOTOR LEARNING IN VIRTUAL ENVIRONMENTS

Human training was the first application for VEs beyond their conception as entertainment in the form of stereoscopes and video arcades. Circa 1960, VEs enhanced military flight simulators with visual information that followed pilots' head movements. Since 1990, the following features associated with promoting neuroplasticity[6] were incorporated into effective VEs for stroke rehabilitation.[7]

- Performance feedback
- Repetitive, goal-oriented tasks with variability covering a range of conditions
- Controlled environment where mistakes have minimal consequences
- Task difficulty scaled to a stroke survivor's capabilities and skill[8]
- Assist,[9] resist,[10] or repel movement and exaggerate errors[11]
- Focus on targeted skills by reducing contributions from unwanted movements[12]
- Increase motivation and engagement using features from video games[13]
- Facilitate remote social interaction with peers or therapists[12]

POTENTIAL MECHANISMS OF ACTION

Effect of Augmented Feedback on Motor Learning

There is sufficient evidence that providing stroke survivors with information about movement quality and task outcome benefits the acquisition and retention of motor skill.[14] Delivering feedback only about task measures leads to immediate improvements in the measures with no gain in movement quality. If feedback is provided only about motor performance (path deviations or compensatory behavior), participants immediately improve both task outcomes and movement quality.

Effect of Virtual Environments on Cortical Networks

Imaging reveals that visuomotor network activation occurs when both able-bodied and stroke survivors view hand motion from a virtual avatar. As the visual quality[15] and sense of immersion[16,17] increases, so does the recruitment of visuomotor networks, which is maximized when the avatar moves in synchrony with the physical hands.[17] In initial reports, recovery from VE training seems to also demonstrate similar patterns of cortical network change as observed in nonvirtual therapy.[18]

Another method of assessing the state of cortical networks is to infer motor corticospinal excitability using motor-evoked potentials induced by transcranial magnetic stimulation. In stroke survivors, lower conduction time,[19] higher baseline motor-evoked potential amplitude,[20] and greater motor-evoked potential amplitude[21] may benefit motor performance and learning. However, few studies have investigated