Virtual Reality in Stroke Rehabilitation

Written By Emma Hitt, PhD

Stroke is a leading cause of adult disability, and around two thirds of stroke survivors continue to experience motor deficits in their arms and hands that are associated with diminished quality of life [Saposnik G et al. *Stroke* 2011]. The current paradigm in stroke rehabilitation involves repetitive, high-intensity, task-specific stimulation to improve motor recovery [Luft AR, Hanley DF. *JAMA* 2006; Kalra L, Ratan R. *Stroke* 2007]. However, only a few of the current techniques have effectively shown a significant improvement in arm function after stroke [Langhorne P et al. *Lancet Neurol* 2009]. Gustavo Saposnik, MD, MSc, St. Michael's Hospital, University of Toronto, Toronto, Ontario, Canada, presented the benefits of using virtual reality (VR) gaming technology in stroke rehabilitation and how VR may engage the brain reward system.

Conventional stroke rehabilitation has several limitations [Langhorne P et al. *Lancet Neurol* 2009]. It is time consuming, and labor and resource intensive. It provides modest effects that are initially underappreciated by stroke survivors, and compliance problems and high dropout rates can limit recovery. In addition, in certain regions the availability and conventional rehabilitation may be costly.

VR allows a user to interact with a multisensory computer-simulated environment and receive instant feedback on performance. Neuroplasticity and the reorganization of cerebral activity are the basis of stroke rehabilitation, and VR has the potential to affect neuroplasticity through repetition, intensity, and task-oriented training [Kalra L, Ratan R. *Stroke* 2007; Saposnik G et al. *Stroke* 2011]. The availability of VR video game systems for home use has made this technology less expensive, and more accessible to clinicians and patients.

A meta-analysis of the available data on VR in stroke rehabilitation revealed that 11 of 12 studies showed a significant benefit of VR in stroke rehabilitation [Saposnik G et al. *Stroke* 2011]. Five small clinical trials showed that patients randomized to VR were nearly 5 times more likely to benefit compared with controls. Among observational studies, there was a 20.1% (95% CI, 11.0 to 33.8) improvement in motor function and a 14.7% (95% CI, 8.7 to 23.6) improvement in motor impairment after several 30- to 60-minute VR sessions in a 4- to 6-week time period (Figure 1).

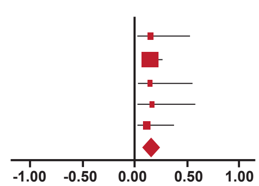
Figure 1. Meta-Analysis of Observational Studies Using Virtual Reality Systems in Upper Limb Stroke Rehabilitation

A. Motor Impairment

Statistics for Each Study

Study Name	% Improve	Lower Limit	Upper Limit	z Value	p Value
Holden	0.150	0.028	0.524	-1.858	0.063
Piron	0.150	0.075	0.277	-4.380	0.000
Merians	0.150	0.025	0.551	-1.752	0.080
Kamper	0.165	0.026	0.592	-1.592	0.111
Yong	0.122	0.030	0.383	-2.584	0.010
Total	0.147	0.087	0.236	-5.900	0.000

% Improvement and 95% CI



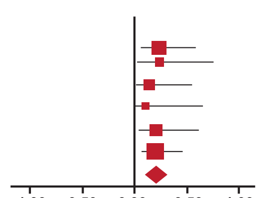
Heterogeneity: X^2=0.102; df=4 (p=0.99); I^2=0%

B. Motor Function

Statistics for Each Study

Study Name	% Improve	Lower Limit	Upper Limit	z Value	p Value
Holden	0.240	0.064	0.593	-1.477	0.140
Boian	0.250	0.034	0.762	-0.951	0.341
Merians	0.150	0.025	0.551	-1.752	0.080
Broeren	0.110	0.007	0.671	-1.463	0.144
Kamper	0.207	0.040	0.619	-1.440	0.150
Yong	0.206	0.072	0.466	-2.183	0.029
Total	0.201	0.110	0.338	-3.822	0.000

% Improvement and 95% CI



Heterogeneity: X^2=0.52; df=5 (p=0.99); I^2=0%

Adapted from Saposnik et al. *Stroke* 2011.

Currently, the Efficacy of Virtual Reality Exercises in Stroke Rehabilitation [EVREST; NCT01406912] multicenter trial is evaluating the effectiveness of the Nintendo Wii gaming technology in promoting motor function improvement of the upper extremities in stroke survivors. Initiated in Canada, and funded by Heart and Stroke Foundation of Canada and the Ontario Ministry of Health, EVREST is being expanded to other countries, including Argentina, Brazil, Peru, Thailand, and possibly the United States. This trial is applying the basic concepts in stroke rehabilitation. It may also engage the "mirror neuron" system, which is a set of neurons activated when individuals observe an action performed by someone else, and the "brain reward system" to promote motor recovery.

The brain reward system, which can be activated by a VR game, involves the mesolimbic structures of the brain and is dopamine-mediated. For the brain reward system to be activated, the game has to be emotionally engaging; give credit for everything the patient does; provide rapid, frequent, and clear feedback; and involve an element of uncertainty.

Prof. Saposnik said, "Virtual reality is a novel, affordable, and enjoyable intervention that may help intensify treatment and promote motor recovery after stroke." He also emphasized that larger randomized studies are needed before changing practice. He noted that "rewarding the brain is a powerful mechanism to embrace rehabilitation after stroke."

Reward Improves Long-Term Retention of a Motor Memory Through Induction of Offline Memory Gains

Written by Muriel Cunningham

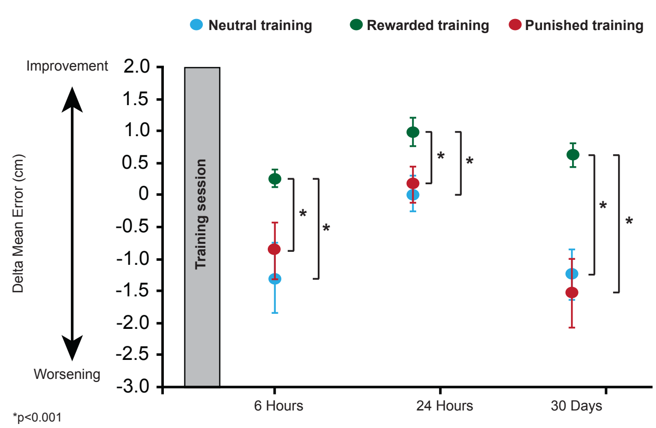
Steven C. Cramer MD, University of California, Irvine, California, USA, discussed the findings of a study on the effects of reward-based training on motor learning (originally to be presented by Leonardo G. Cohen, MD, National Institutes of Health, Bethesda, Maryland, USA) [Abe M et al. *Curr Biol* 2011]. "I think what Leo[nardo] has done has given us a completely new way of thinking about that subject in the context of stroke recovery," said Dr. Cramer. "I'm not familiar with a study that used reward principles to modulate motor learning, particularly in the long term."

The study used a tracking pinch force task to determine the effects of reward versus punishment in training. Right-handed healthy subjects were randomly assigned to a rewarded (n=13), punished (n=12), or neutral control (n=13) training group. Subjects were instructed to pinch a force transducer between the right thumb and index finger so that a red cursor remained within a blue target [Abe M et al. *Curr Biol* 2011]. The blue target moved in a pattern similar to a sine wave. Greater force moved the cursor up, and lesser force moved the cursor down.

Baseline measurements of task performance were taken for all subjects, followed by a training session (4 blocks of 20 trials) under different conditions. Subjects in the rewarded group were told they would earn money based on the amount of time they were on the target, while those in the punished group were told they would lose money for any time off the target. The neutral subjects were told they would receive $40 at the end of the training regardless of the time. Feedback was given after each trial. After training was completed, subjects were tested without the influence of reward or punishment immediately, and after 6 hours, 24 hours, and 30 days.

Mean error was similar across all 3 groups at baseline (p=0.86 for rewarded vs neutral; p=0.91 for rewarded vs punished) and when measured just after training (p=0.77 for rewarded vs neutral; p=0.23 for rewarded vs punished). The groups' performance began to diverge at subsequent time points. At 6 hours post training, the rewarded group performed significantly better than the other 2 groups (p<0.05)—an effect that persisted through 30 days (Figure 1).

Figure 1. Effect of Reward and Punishment on Motor Skill Retention After Training



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Training people under a reward-based system led to substantial long-term retention of a newly acquired motor memory—an advantage that developed through stabilization of offline memory gains in subsequent days [Abe M et al. *Curr Biol* 2011]. Dr. Cramer said, "Day 30 is long-term learning, and it begins to sound relevant to our patients and the kind of plasticity we want to induce through whatever means possible." According to the authors, training in rewarded conditions may be beneficial both in education and in the treatment of patients with neurocognitive disorders and brain injuries [Abe M et al. *Curr Biol* 2011].