BRIEF REPORT

Cortical Reorganization and Associated Functional Motor Recovery After Virtual Reality in Patients With Chronic Stroke: An Experimenter-Blind Preliminary Study

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ABSTRACT. Jang SH, You SH, Hallett M, Cho YW, Park C-M, Cho S-H, Lee H-Y, Kim T-H. Cortical reorganization and associated functional motor recovery after virtual reality in patients with chronic stroke: an experimenter-blind preliminary study. Arch Phys Med Rehabil 2005;86:2218-23.

Objective: To investigate the effects of virtual reality (VR) on cortical reorganization and motor recovery.

Design: Nonparametric pre- and posttest design with experimenter blinded.

Setting: University medical center.

Participants: Five patients with hemiparesis (age, 59.8±3.4y) were recruited.

Intervention: Five patients received VR for 60 minutes a day, 5 times a week for 4 weeks. VR was designed to provide a virtual rehabilitation scene where the intensity of practice and sensory feedback could be systematically manipulated to provide the most appropriate, individualized motor retraining program.

Main Outcome Measures: Cortical activation and associated motor recovery were measured before and after VR using functional magnetic resonance imaging and standardized motor tests, respectively. Nonparametric tests were used at *P* less than .05.

Results: Prior to VR, the bilateral primary sensorimotor cortices (SM1s), contralesional premotor cortex, and contralesional or ipsilesional supplementary motor area were activated. After VR, the altered activations disappeared and predominantly the ipsilesional SM1 was activated ($P<.05$). Motor function was improved ($P<.05$).

Conclusions: This is a novel demonstration of VR-induced neuroplastic changes and associated motor recovery in chronic stroke.

Key Words: Computer-assisted instruction; Hemiplegia; Magnetic resonance imaging; Rehabilitation.

HEMIPARETIC STROKE IS A LEADING cause of disability in the affected limbs,[1] which may have a significant influence on disuse or learned nonuse of the affected limbs.[2] Consequently, this may result in suppression of the cortical representation of the affected limb (ie, hand) and further inhibit its spontaneous use.[3,4] Such cortical suppression has been shown to be evident in the cortical motor representation of the paretic hand that was decreased by one half of the size of the nonparetic hand after stroke.[3]

Several studies have attempted to investigate the efficacy of stroke rehabilitation approaches,[5-8] yet have yielded inconsistent results. Liepert et al[8] have reported enlarged cortical motor representation and associated hand motor recovery of selected stroke patients (highly motivated and relatively spared hand motor function) after intensive constraint-induced movement therapy (CIMT). However, major patient compliance, cost, and safety issues have been raised.[8,9] For example, a more recent CIMT case study noted that although highly motivated, the patient ". . . grew tired of wearing the mitt and had difficulty with full adherence at home . . . cheating with the uninvolved hand was a frequent temptation for the patient."[10(p851)] CIMT involves intensive intervention (6–8h daily for 6d/wk) and a home exercise program. Potential risk of serious falls may exist because the nonparetic hand is constrained, which may prohibit protective extension of the nonparetic arm if the patient falls.[7,9] Virtual reality (VR) studies have demonstrated that 45 to 60 minutes of VR intervention (3 times/wk) is effective in obtaining measurable motor recovery in stroke patients.[11,12] If this holds true, the cost of VR intervention would be considerably reduced. Because no constraint is involved in VR, patients can maintain their protective reaction if they lose their balance. Our VR is partially immersive and therefore does not present inherent lags and associated delayed latency, which could potentially produce symptoms similar to motion sickness reported in other full-immersion VR systems. VR studies have reported that patients consider VR intervention as interactive and enjoyable exercise games rather than therapy. Consequently, patients are likely to be more motivated by and compliant with the VR intervention than conventional therapy.[11] VR can provide both objective testing and motor retraining in simulated real-life environments, and that can be tailored based on an individual patient's baseline motor performance.[13] However, the neural control mechanisms supporting VR-induced motor recovery have never been investigated. We examined cortical reorganization and motor recovery, our basic hypothesis being that VR could produce practice-dependent enhancement of the

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Table 1: Clinical and Demographic History

Stroke Subject	Age/Sex	Handedness	Risk Factors	Site of Stroke (Topography)	Time From Stroke (mo)
Control group					
1	43/M	Right	Cig	Left corona radiata infarct	9.0
2	40/M	Right	Hchol, HTN	Right thalamic hemorrhage	12.0
3	63/F	Right	Hchol, NIDDM	Left corona radiata infarct	10.0
4	63/M	Right	HTN, Cig	Right corona radiata infarct	21.0
5	63/M	Right	HTN	Left thalamic hemorrhage	15.0
Mean	54.4				13.4
SE	5.3				2.2
VR group					
1	68/F	Right	Hchol, HTN	Left thalamic hemorrhage	24.0
2	55/M	Right	HTN, Cig	Right thalamic hemorrhage	21.0
3	50/M	Right	Afib	Right cortical infarct	9.0
4	66/F	Right	HTN, NIDDM	Left corona radiata infarct	7.0
5	60/F	Right	Hchol	Right corona radiata infarct	8.0
Mean	59.8				13.8
SE	3.4				3.6

Abbreviations: Afib, atrial fibrillation; cig, cigarette smoking; F, female; Hchol, hypercholesterolemia; HTN, hypertension; M, male; NIDDM, non-insulin-dependent diabetes mellitus; SE, standard error of measurement.

affected hand, which may help remediation of altered cortical reorganization by means of reversal or normalization of the aberrant organization.

METHODS

Participants

Ten patients with hemiparetic stroke (6 men, 4 women; mean age, 57.1±4.5y) were recruited. Inclusion criteria included: (1) more than 6 months elapsed from the onset of stroke, (2) ability to move the elbow against gravity, and (3) no prior stroke. Exclusion criteria included: (1) severe spasticity (Modified Ashworth Scale score >2) or tremor, and (2) severe visual and cognitive impairments. Informed consent was obtained from all subjects prior to the study. In an experimenter-blind randomized controlled trial, patients were randomized into either the control or intervention group. Intervention allocation was done by one of the experimenters who was unaware of the information obtained during the initial examination. The control group did not receive any intervention whereas the intervention group received VR training. Routine clinical examination was conducted to determine the presence of risk factors associated with stroke (table 1).

Procedure

Motor function. An experienced physical therapist performed the box and block test (BBT),[14] the Fugl-Meyer Assessment (FMA),[15] and the manual function test (MFT).[16] In addition, after completion of VR training, the therapist conducted the modified Motor Activity Log (MAL) interview[17] by asking each patient about amount of use (AOU) and quality of movement (QOM) of the affected upper extremity during ac-

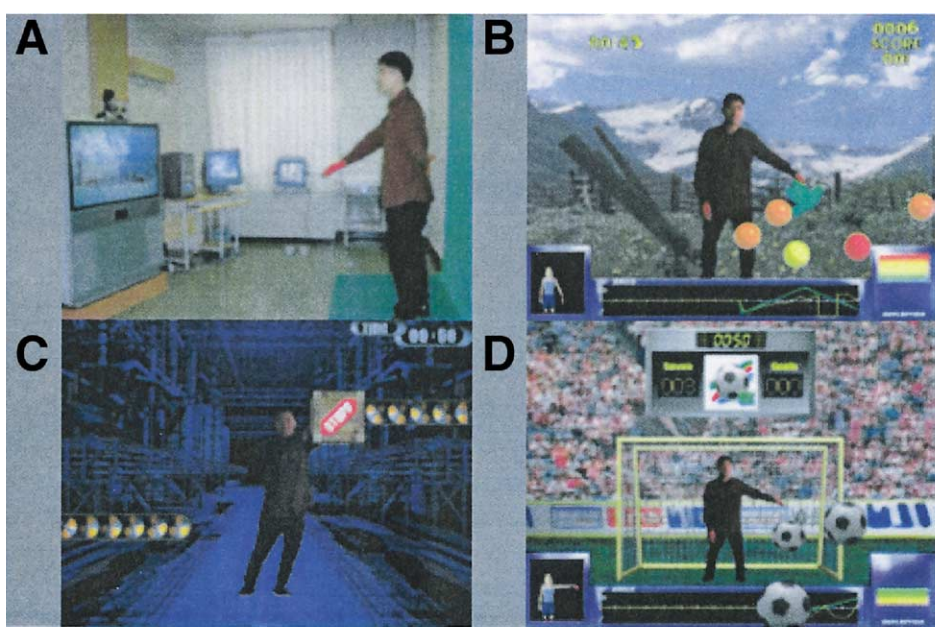

Fig 1. (A) VR exercise setup, (B) bird-ball exercise game, (C) conveyor exercise game, and (D) soccer exercise game. Reprinted with permission of Vivid Group Inc.[25]