Virtual Reality for Enriched Rehabilitation of Stroke Patients with Spatial Neglect Diagnostics and the Rehabilitation Effect on Spatial Attention and Neuronal Activity

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av medicine doktorsexamen framläggs till offentligt förvar i Salen E04, R1 Norrlands Universitetssjukhus, Fredagen den 8e december, kl. 09:00.
Avhandlingen kommer att förvaras på engelska.

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Background. Approximately a third of all stroke patients develop spatial neglect, a debilitating symptom associated with poor outcome. Spatial neglect is clinically defined as a deficit in processing and responding to stimuli presented on the contralesional side of the body, or the space surrounding that side of the body. The heterogenetic, multisensory nature of the symptoms renders it difficult to diagnose and treat; therefore effective methods for screening and intervention for neglect are needed. Virtual reality (VR) is a method of brain–computer interaction that involves real-time simulation of an environment, scenario or activity that allows for user interaction and targets multiple senses. We hypothesize that Virtual Reality, VR can facilitate identification of spatial neglect in stroke patients and that training with this interface will improve patient’s functional outcome, through stimulation to neuronal networks including those controlling attention. Objective The objective was to construct and validate a computerized test battery for spatial neglect and to investigate its usability in stroke patients. Also to design and develop a virtual reality rehabilitation method for spatial neglect and to evaluate its effects on spatial attention and on neuronal activity in the brain.

Method We designed, developed and evaluated a new concept for assessment (VR-DiSTRO®) and training (RehAtt®) of spatial attention, using virtual reality technology. The hardware consisted of a PC, monitor, 3D-glasses and a force feedback device to control the tasks (i.e., a robotic pen). The software enabled targets to be moved, rotated and manipulated in the 3D environment using the robotic pen. RehAtt® made it possible to combine intense visual scanning training, multi-sensory stimulation (i.e., audio, visual, tactile) and sensory-motor activation of the contralesional arm. In a first study on 31 stroke patients we performed a construct validation of VR-DiSTRO® against Rivermead Behavioural Test Battery (BIT) and investigated the usability. In a second study, 15 subjects with chronic spatial neglect (symptoms >6 month) had self-training, 3 x 1 hour for 5 weeks using RehAtt®. Outcome was measured by changes in neglect tests and in Cathrine Bergego Scale (CBS). Training related changes in neuronal activity of the brain was studied using fMRI during task and in resting state. Results VR-DiSTRO® correctly identified all patients with neglect. The sensitivity was 100% and the specificity 82% for VR-DiSTRO® compared to BIT. Usability was high and no side-effects were noted. Using repeated measurement analysis, improvements due to the RehAtt® intervention were found for Baking tray task (p < 0.001), Star cancellation test (p = 0.006) and Extinction test (p = 0.05). Improvements were also seen in the Posner task as fewer missed targets (p = 0.024). Improvement in activities of daily living (CBS) was shown immediately after training (p < 0.01) and patients still reported improvement at 6 months follow-up. Training related changes in neuronal activity was seen as an increased task-evoked brain activity in prefrontal and temporal cortex, mainly outside the attention network but in related cortical areas. During resting state, changes in network connectivity were seen after intervention with RehAtt® in the Dorsal Attention Network (DAN) and interhemispheric connectivity. Conclusion VR-DiSTRO® identified visuospatial neglect in stroke patients quickly and with a high accuracy. RehAtt® training improved in spatial attention in chronic neglect with transfer to functions in daily living. Increased neuronal brain activity was found in and between attention networks and related brain structures. This could represent a compensatory effect in addition to sign of a restorative effect from the RehAtt training. The results obtained in this study are promising, encourage further development of the methods and merit for further studies.

Keywords Stroke, spatial neglect, rehabilitation, virtual reality, enriched environment, fMRI, plasticity