

Multi-joint force-coordination training of healthy subject with our energy-dissipating exoskeleton Dampace

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Abstract

To facilitate force-coordination training of upper extremities of stroke patients, we developed a computer controlled energy-dissipating exoskeleton, called the Dampace. As an addition to the intended application in functional training for stroke rehabilitation, further usability is investigated by implementing a training protocol for multi-joint force and position control.

Background

In stroke rehabilitation, combating the effects of unwanted multi-joint muscle synergies^[2] is important for patients to regain more functional use in their affected side. Other research has confirmed the strong, unwanted coupling of humerus elevation with elbow flexion^[1]; i.e., stroke patients are severely limited in using elbow extension when the shoulder is sustaining a significant humerus elevation torque. The goal of this study is to investigate if healthy subjects can improve the simultaneous coordination of isometric torques or isotone displacements of the elbow and isometric humerus-elevation torques with our exoskeleton. Secondly, we like to get a feel for these types of applications. If the results with healthy subjects are favourable, the protocol will be adapted to study if it might help in stroke rehabilitation with patients.

Setup

The Dampace can apply resistive torques of up to 50Nm (resolution: 0.25Nm, bandwidth: 5Hz) around each of the three rotation axes of the shoulder and one of the elbow, and allows unrestricted forearm pro-and supination and shoulder translations. As the resistance is applied via pure torques, alignment of the exoskeleton axes to the arm axes is not required, minimising setup times. And although maximum possible torques are high, the exoskeleton only dissipates energy, making it inherently safe. Finally, the Dampace measures the rotation angles of and resistive torques around the four controlled axes in real time. A computer controller can use these measured angles and torques to set and control the amount of brake torque. In this way, many virtual braking profiles can be created, from constant braking or velocity dependent braking over the entire range of the joint rotation, to more complex end-point control. To motivate subjects, the human movement and force execution can be linked to a gaming console; for this study the car racing game Gran Turismo 4 on a Sony Playstation 2.



Protocol

In the training protocol, isometric humerus-elevation torque is mapped to the gas paddle in the racing game, and either the isometric torques or the isotone displacements of the elbow to the steering wheel. Good coordination of simultaneous shoulder and elbow torques is thus required for good driving control in the game and should motivate the subjects to keep exercising. The subjects undergo daily racing sessions of 30 minutes for two weeks. Before, after one, and after two weeks, evaluating trials are performed with the subject connected to the Dampace, but without using the game. In these trials, subjects are asked to simultaneously follow two multi-sine signals with shoulder isometric torques and isometric torques or isotone displacements of the elbow. The hypothesis is that the tracking error will be significantly reduced with training.

References

- [1] RF Beer, JPA Dewald, ML Dawson, and WZ Rymer. Target-dependent differences between free and constrained arm movements in chronic hemiparesis. *Exp Brain Res*, 156(4):458–70, Jun 2004.
- [2] S Brunnstrom. *Movement therapy in hemiplegia: a neurophysiological approach*. Harper and Row, New York, 1970.