Upper Limb Stroke Rehabilitation combining Electrode-Arrays with Low-cost Sensing and Advanced Control

Kutlu M. C., Freeman C. T., Hallewell, E., Hughes, A.-M. and Laila, D. S.

University of Southampton, University Road, Southampton, UK, SO16 1BJ

mck1e12@ecs.soton.ac.uk

Introduction

Functional electrical stimulation (FES) has shown effectiveness in restoring upper limb movement post-stroke when applied to assist patients' voluntary intention during repeated, motivating tasks. Recent clinical trials at Southampton have employed advanced controllers that precisely adjust the stimulation applied to three muscle groups in the upper limb in order to assist functional reach and grasp tasks, giving rise to statistically significant reduction in impairment.

Method

A novel system is developed that advances the state-of-the-art by integrating: (i) an FES electrode array to activate wrist/finger extensors together with single pad electrodes to activate the anterior deltoid and triceps, (ii) PrimeSense and Kinect sensors to record the arm, hand, and wrist positions for use in real-time feedback control, (iii) an interactive touch table to present motivating virtual reality tasks, (iv) a SaeboMAS arm support. An advanced model-based iterative learning controller uses position data from previous attempts at each task to update the FES applied to each muscle on the subsequent trial. This facilitates accurate task completion while encouraging voluntary effort.

Results

Stroke participants (N=4) undertook seventeen intervention sessions, each of one hour duration. During each session FES was applied to assist participants in performing functional tasks comprising: 1) pressing low or high light switches, 2) closing a drawer, 3) grasping-replacing-releasing an object. Participants completed clinical assessments (Fugl-Meyer and Action Research Arm Test) pre- and post-intervention, as well as FES-unassisted tasks during each intervention session.

Discussion

Statistically significant improvements were observed in FES-unassisted tasks over the course of the intervention. In particular, range of movement (ROM) increased at the shoulder, elbow, wrist and index finger joints over a range of tasks; the high light switch demonstrated the most significant gain in shoulder flexion ROM, the contralateral reach in elbow extension ROM, the near reach in wrist extension ROM and the far reach in index finger extension ROM.

Conclusion

The feasibility of applying precisely controlled FES to multiple muscle groups in the upper limb using advanced sensors, controllers and array hardware was demonstrated. This technology is expected to lead to significant reductions in upper-limb impairment following chronic stroke. This compact low-cost rehabilitation technology also has potential for future transfer to patients' homes.