The relation between function connectivity and clinical outcomes in adult stroke survivors undergoing exoskeleton upper limb home therapy

Melissa Sandison[1,2], and Peter S. Lum[1,2]

[1]The Catholic University of America, Biomedical Engineering, Washington, DC. [2]MedStar National Rehabilitation Hospital, Washington, DC

Background

- In the chronic phase of stroke, 38% of people will have upper limb motor impairments [1], impeding activities of daily living.
- Heterogeneous levels of motor impairment and response to therapy among stroke patients.
- Optimization of stroke rehabilitation and prescription is dependent on improving our knowledge of brain plasticity.
- Studies have demonstrated post stroke changes in functional connectivity (FC) [2,3] are associated with level of motor impairment.
- Few studies have investigated neural network plasticity via electroencephalography (EEG) associated with motor outcomes of robotic therapy [3].

Objective

Investigate brain plasticity, via functional connectivity (COH), of stroke patients undergoing at home robotic upper-limb therapy. Additionally, identify biomarkers which may predict a patient's response to the robotic intervention, comparing these against age, initial level of impairment and time since onset of stroke.

Methods

Subjects

- Six hemiparetic chronic stroke patients (mean age= 56.8 years, 3 males, post stroke= 4 years).

Device

- Custom 3d printed exoskeleton, HandSOME II [4], was made for each subject.
- HandSOME II is a wearable, high DOF, spring powered exoskeleton.
- 11 spring and elastic actuators that apply extension torques to finger and thumb joints.
- Unique design provides independent and customizable assistance at metacarpophalangeal and interphalangeal joints, supporting training of dexterous movements.

Fig. 1 Connectivity groupings

Intervention

- 8 weeks of at home therapy using the HandSOME II.
- 1 session per week in clinic with occupational therapist, who prescribes weekly tasks which total 1.5 hours per day.

Data Collection

- Fugel Myer (FM) assessment of upper limb impairment was completed by an independent occupational therapist, pre and post intervention.
- EEG data was collected pre and post therapy during three minutes of wakeful rest , and during the Nine Hole Peg Test.
- EEG signals were recorded continuously from a 28 Ag/AgCl electrode cap.
- Current Source Density (CSD) estimates of signals were computed.
- Data was flipped, so all patients had right hand affected: left = ipsilesional EEG data.

Primary Outcome Measures

- COH was computed between all 28 leads using magnitude-squared coherence [4],
- We examined COH during wakeful rest (COHrest) and computed task-related COH during 9 hole peg task (TRCoh, Eq.1).

$$TRCoh = log(COHTask) – log(COHrest) \quad (1)$$

- COHrest and TRCoh results were then averaged to give 10 connectivity groupings of interest (Fig. 1) [4]

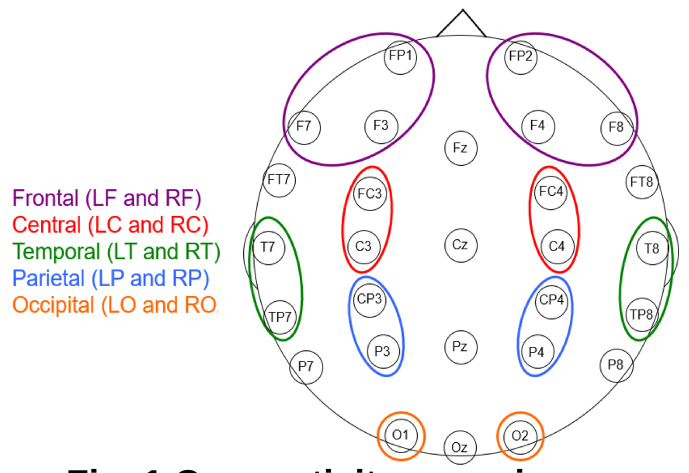

Fig. 1 Connectivity groupings

Results

Upper Limb Motor Function Response To Exoskeleton Therapy

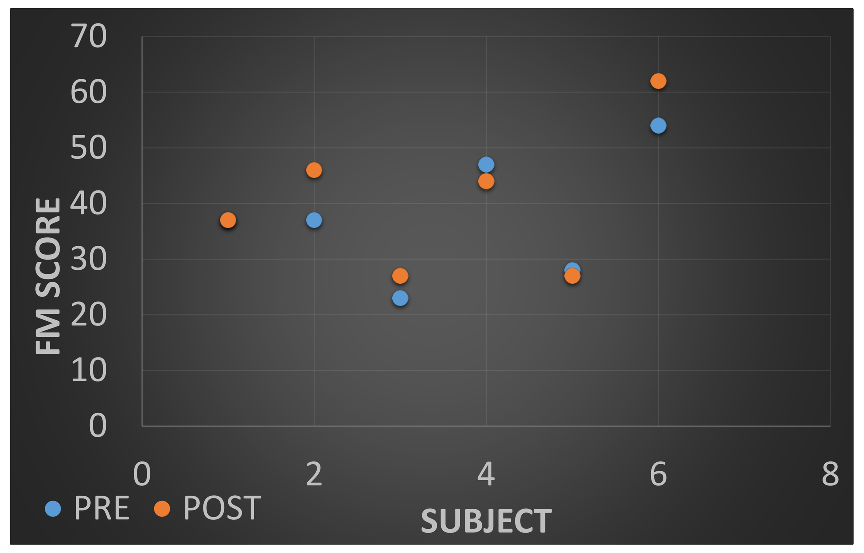

Fig. 3: Changes in Fugel Myer during HandSOME II Intervention

No significant difference pre and post HandSOME II intervention

Resting State COH Plasticity Is Associated with Changes in Motor Functions

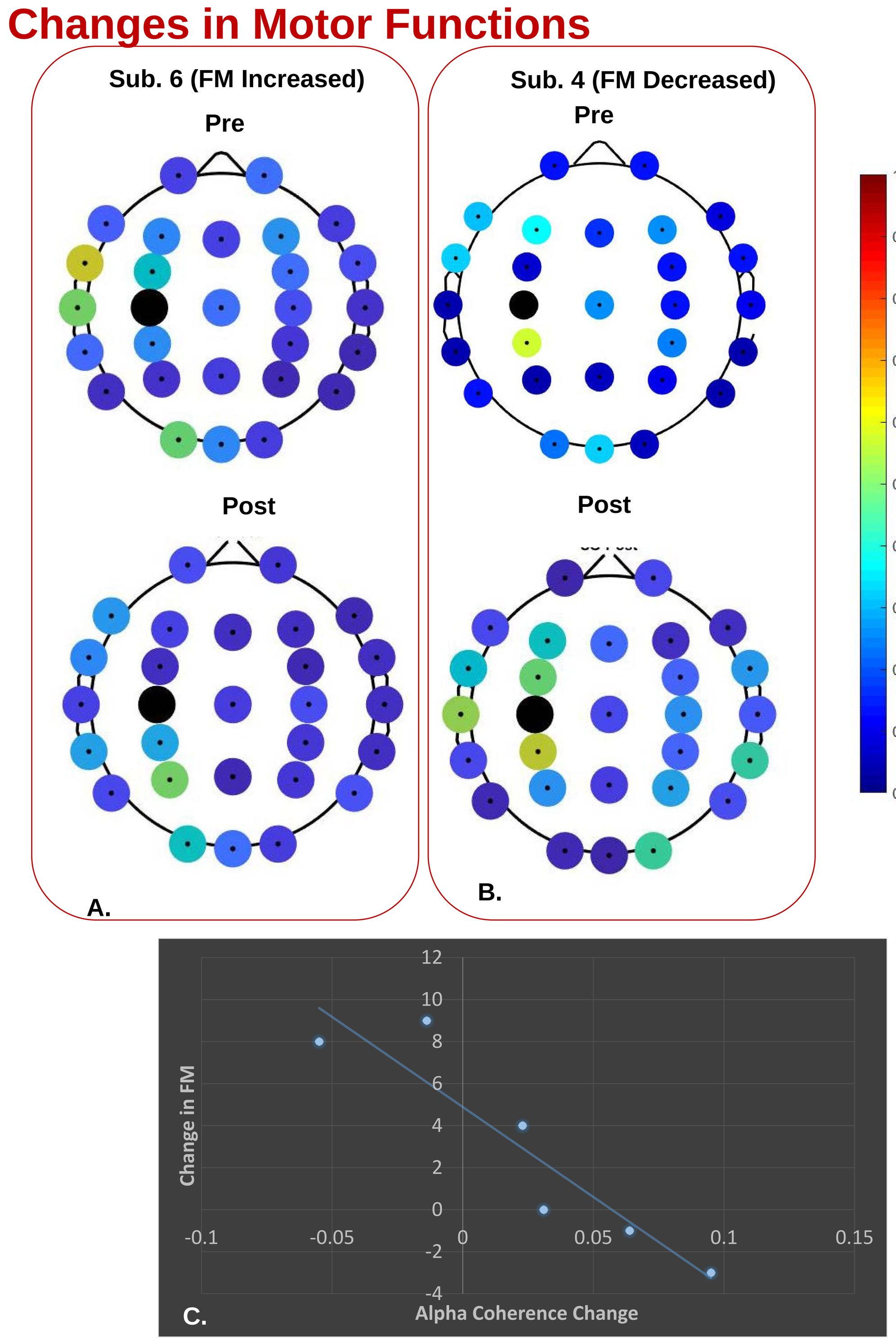

Fig. 4: Alpha Pre/Post C3 COHrest Change Vs FM Change. A) Data from a patient who improved during intervention. Shows decrease in C3-all other electrode coherence as FM improved. B) Data from a patient who FM decreased during intervention. Shows increase in C3-all other electrode coherence as FM decreased. C) Linear regression analysis significantly supporting the observed trend in figure A and B, p = 0.008, r=0.926, r^2 = 0.857.

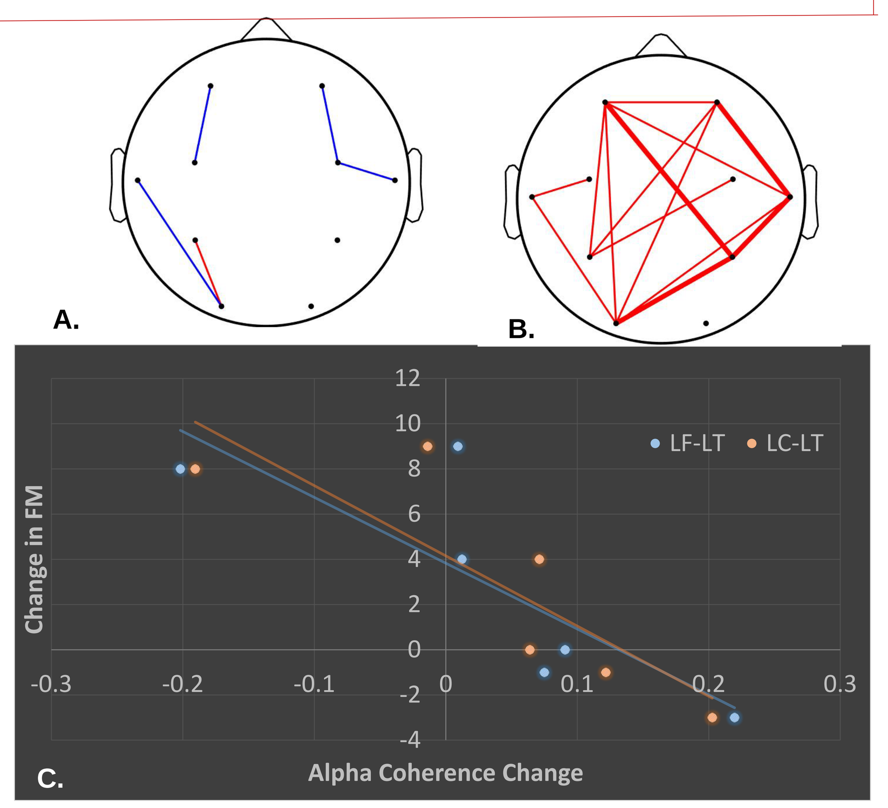

Fig. 5: Alpha Pre/Post COHrestChange Vs FM Change. A) Data from a patient who improved during intervention. Shows decrease in COHrest. B) Data from a patient who FM decreased during intervention. Shows increase in alpha COHrest after HandSOME intervention. C) Linear regression analysis significantly supporting the observed trend in figure A and B. Specifically, LF-LT p = 0.048, r=0.66, r^2 = 0.58 and LC-LT p = 0.035, r=0.71, r^2 = 0.64.

Baseline Resting State COH as A Biomarker Predictor of Motor Function Response to Therapy

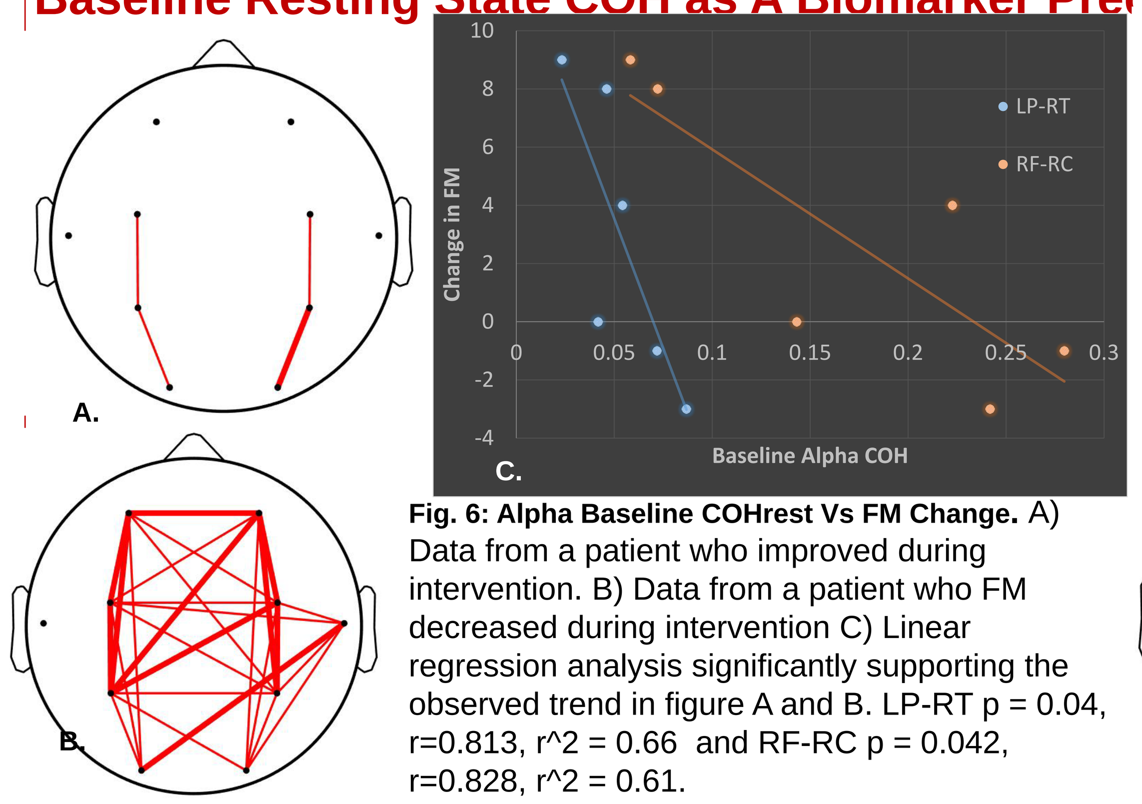

Fig. 6: Alpha Baseline COHrest Vs FM Change. A) Data from a patient who improved during intervention. B) Data from a patient who FM decreased during intervention C) Linear regression analysis significantly supporting the observed trend in figure A and B. LP-RT p = 0.04, r=0.813, r^2 = 0.66 and RF-RC p = 0.042, r=0.828, r^2 = 0.61.

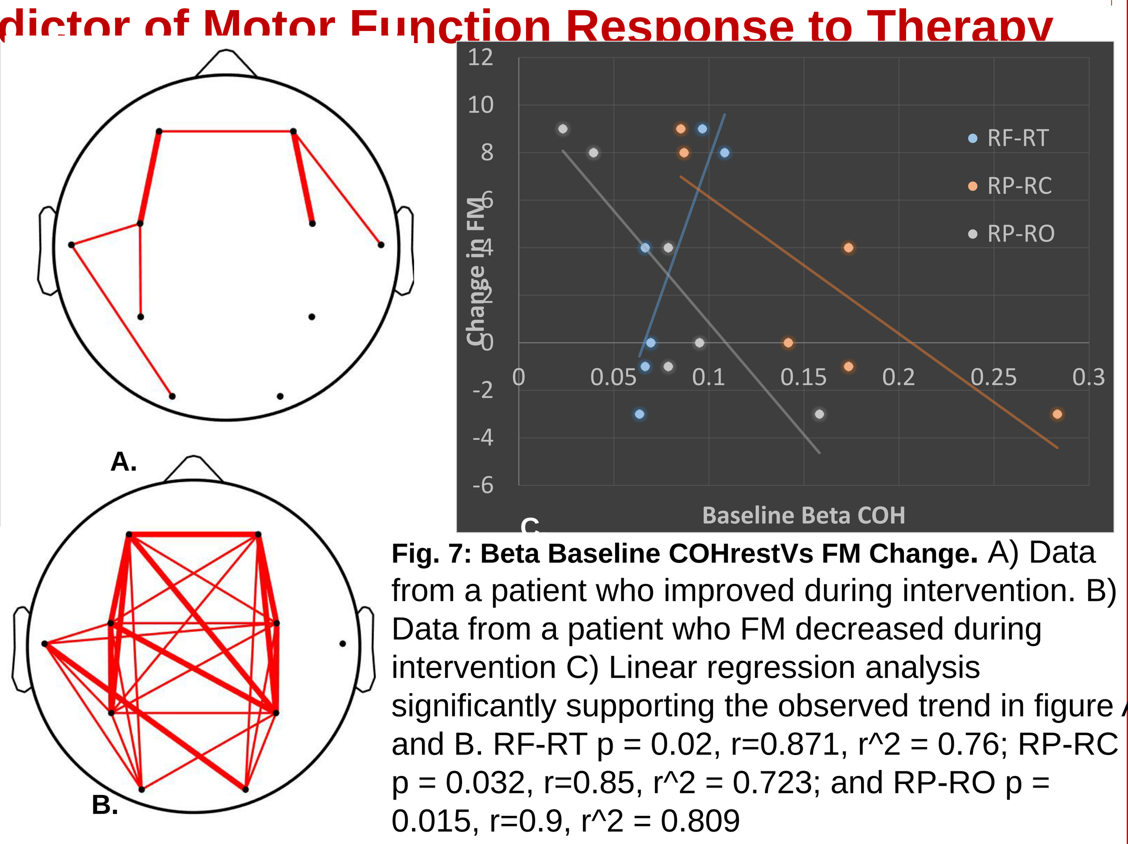

Fig. 7: Beta Baseline COHrestVs FM Change. A) Data from a patient who improved during intervention. B) Data from a patient who FM decreased during intervention C) Linear regression analysis significantly supporting the observed trend in figure A and B. RF-RT p = 0.02, r=0.871, r^2 = 0.76; RP-RC p = 0.032, r=0.85, r^2 = 0.723; and RP-RO p = 0.015, r=0.9, r^2 = 0.809

Discussion

- Plasticity elicited from HandSOME-II therapy was correlated with changes in motor function. This was only observed in Alpha band.
- Identified baseline biomarkers associated with gains or losses in motor function.
- No significant interaction between TRCoh and motor improvements.
- The range of changes in FM score highlight the heterogeneous nature of stroke recovery, emphasizing the need for a measure that can predict and track the capacity for rehabilitation
- Resting state alpha and beta COH are potential biomarkers for predicting motor outcome and quantifying brain reorganization, while initial impairment, age and time since stroke did not predict recovery in our sample.
- The ability to assess the neuronal network at rest has vast implications in stroke rehabilitation and research focusing on plasticity, particularly in severely impaired stoke survivors where completing a motor task may not be possible.
- Increased contralesional COH associated with decreased in motor outcome found in this study could indicate a supportive compensation strategy of the damaged hemisphere[2,3].
- We showed that home based exoskeleton therapy using the HandSOME-II device elicits plasticity associated with motor function improvements, validating its use.

Acknowledgments

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