FINAL SCRIPT: APPROVED FOR FILMING

Submission ID #: 68588
Scriptwriter Name: Poornima G
Project Page Link: https://review.jove.com/account/file-uploader?src=20919388

Title: Soft Pneumatic Robot Modulates Graph Theory Metrics of Brain Network for Hand Rehabilitation After Stroke

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Author Questionnaire

1. Microscopy: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **NO**

2. Software: Does the part of your protocol being filmed include step-by-step descriptions of software usage? **YES, done**

3. Filming location: Will the filming need to take place in multiple locations? **NO**

4. Testimonials (optional): Would you be open to filming two short testimonial statements **live during your JoVE shoot**? These will **not appear in your JoVE video** but may be used in JoVE's promotional materials. **NO**

Current Protocol Length
Number of Steps: 11
Number of Shots: 25 (11 SC)

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

INTRODUCTION:

1.1. **Ze-Jian Chen:** We investigate the feasibility of a programmable soft pneumatic robot in modulating brain network dynamics in people who have had a stroke.

1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 2.3.1*

What technologies are currently used to advance research in your field?

1.2. **Ze-Jian Chen:** Diverse modes of human-robot interaction and fNIRS-based graph theory analysis are used.

1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 2.2.1*

CONCLUSION:

What significant findings have you established in your field?

1.3. **Ze-Jian Chen:** Soft robotic therapy effectively modulates the topological organization of distributed brain networks in clustering coefficient, average path length, and global efficiency.

1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 3.2.1*

How will your findings advance research in your field?

1.4. **Ze-Jian Chen:** These results underscore the potential of tailoring soft robotic interventions to enhance neural connectivity and facilitate brain network reorganization in stroke rehabilitation.

1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 3.3.1*

What questions will future research focus on?

1.5. **Ze-Jian Chen:** Refine robotic-assisted rehabilitation interventions, enhancing functional outcomes for stroke survivors. This should integrate advanced neuroimaging and computational techniques to tailor interventions to patients' neurophysiological profiles.

1.5.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 4.2.1*

Videographer: Obtain headshots for all authors available at the filming location.

Ethics Title Card

This research has been approved by the Ethics Committee of the Tongji Hospital

Protocol

2. Preparation of Soft Pneumatic Robotic System and Functional Near-Infrared Spectroscopy (fNIRS) System

Demonstrator: Jia-Hui Bian

2.1. To begin, turn on the robotic system **[1]** and connect the two air pump power cables to the power outlet and the soft pneumatic glove **[2]**.

2.1.1. Talent turning on the robotic system.

2.1.2. Talent plugging the two air pump power cables into the power outlet and then into the soft pneumatic glove.

2.2. Assist the participant in wearing the soft pneumatic robot on the affected hand, ensuring a secure fit around the palm and fingers **[1]**. Fasten the robot using the Velcro strap, positioning it securely from the dorsal side of the thumb to the thenar eminence on the palmar side **[2]**.

2.2.1. Talent helping the participant wear the soft pneumatic robot and adjusting it to fit snugly around the palm and fingers.

2.2.2. Talent fastening the Velcro strap and aligning it from the dorsal side of the thumb to the thenar eminence.

2.3. Now, select the appropriate inflation-deflation mode on the control interface **[1]**. Confirm the parameter settings without causing discomfort to the participant **[2]**.

2.3.1. SCREEN: 2.3.1.

2.3.2. SCREEN: 2.3.2.

2.4. Use the continuous wave functional near-infrared spectroscopy system to record data from all participants **[1]**. Emit near-infrared light at wavelengths of 690 nanometers and 830 nanometers to penetrate 2 to 3 centimeters beneath the cerebral cortex, with a sampling frequency of 100 Hertz **[2]**.

2.4.1. Talent operating the functional near-infrared spectroscopy system for data collection.

2.4.2. SCREEN: 2.4.2.

2.5. Now, select an appropriately sized functional near-infrared spectroscopy cap **[1]**. Position the sensor number label slightly above the center of the forehead and align the FPZ and CZ optodes of the 10-20 *(ten-twenty)* electroencephalography or EEG system **[2]**. Secure the detectors and light sources using a flexible headband to ensure optimal contact with the skin **[3]**.

2.5.1. Talent picking up a properly sized fNIRS cap from the available options.

2.5.2. Talent placing the cap on the participant and aligning the labeled sensors to the correct positions.

2.5.3. Talent securing the headband and adjusting the sensors and light sources for optimal contact.

2.6. Instruct the participant to remain in a quiet, relaxed state with their head still and eyes open during data collection **[1]**.

2.6.1. Talent giving instructions to the participant to stay still and relaxed with eyes open.

2.7. Before starting formal data collection, instruct the participant to rest quietly for 2 minutes without falling asleep **[1]**.

2.7.1. Talent setting a timer and guiding the participant to remain quietly at rest.

3. Data Acquisition

3.1. Select the experimental protocol from the software interface on the computer connected to the functional near-infrared spectroscopy system **[1]**. Perform signal calibration to minimize light leakage, targeting a signal strength of 75 percent or higher with minimal noise **[2]**. If calibration fails, adjust the placement of the sensor and perform the calibration again **[3]**. The optode sensors contain light-emitting diodes and photodetectors designed to emit and detect near-infrared light at specific wavelengths **[4]**.

3.1.1. SCREEN: 3.1.1.

3.1.2. SCREEN: 3.1.2.

3.1.3. Talent adjusting the placement of the optode sensor on the participant's scalp and reinitiating calibration from the software.

3.1.4. Talent pointing to the optode sensor highlighting the light-emitting diode and photodetector.

3.2. From the software interface, start cerebral cortex data recording while instructing the participant to stay relaxed and avoid moving their head **[1]**. Begin the experimental task following the randomized sequence and continuously collect data on cerebral oxygenation and hemodynamics **[2]**. Once the task is completed, stop the data acquisition and securely save the recorded experimental data **[3]**.

3.2.1. SCREEN: 3.2.1.

3.2.2. SCREEN: 3.2.2.

3.2.3. SCREEN: 3.2.3.

3.3. Then, create three-dimensional brain activation maps by visualizing the changes in oxyhemoglobin concentration across brain regions **[1]**. Use anatomical landmarks and the international 10-20 system to project the functional near-infrared spectroscopy channels onto the corresponding brain areas **[2]**.

3.3.1. SCREEN: 3.3.1.

3.3.2. SCREEN: 3.3.2.

3.4. Finally, extract graph theory metrics including clustering coefficient, average path length, small-world index, global efficiency, degree centrality, and eigenvector centrality from the functional connectivity matrices derived from functional near-infrared spectroscopy data **[1]**.

3.4.1. SCREEN: 3.4.1..

Results

4. Results

4.1. A total of 10 individuals with stroke were enrolled in the study and underwent resting-state assessment, slow-mode robotic therapy, and fast-mode robotic therapy in a randomized order **[1]**.

4.1.1. LAB MEDIA: Figure 2 A, B.

4.2. Following interaction with the soft pneumatic robot, significant improvements were observed in clustering coefficient **[2]**, average path length **[3]**, and global efficiency **[4]**, while small-worldness index, degree centrality, and eigenvector centrality did not change significantly **[5]**.

4.2.1. LAB MEDIA: Figure 3A. *Video editor: Highlight the bar labelled "C"*

4.2.2. LAB MEDIA: Figure 3B. *Video editor: Highlight the bar labelled "C"*

4.2.3. LAB MEDIA: Figure 3D. *Video editor: Highlight the bar labelled "C"*

4.2.4. LAB MEDIA: Figure 3C, 3E, and 3F.

- robotic

Pronunciation link: https://www.merriam-webster.com/dictionary/robotic
IPA: /roʊˈbɑtɪk/
Phonetic Spelling: roh-BOT-ik

- pneumatic

Pronunciation link: https://www.merriam-webster.com/dictionary/pneumatic
IPA: /njuːˈmætɪk/ or /nuː-ˈmætɪk/
Phonetic Spelling: noo-MAT-ik

- actuator

Pronunciation link: https://www.merriam-webster.com/dictionary/actuator
IPA: /ˈæktʃueɪtər/
Phonetic Spelling: AK-choo-ay-ter

- flexor / dorsum / thenar eminence

- flexor: Pronunciation link: https://www.merriam-webster.com/dictionary/flexor
  IPA: /ˈflɛksər/
  Phonetic Spelling: FLEK-ser
- dorsum: Pronunciation link: https://www.merriam-webster.com/dictionary/dorsum
  IPA: /ˈdɔːrsəm/ or /ˈdɔrsəm/
  Phonetic Spelling: DOR-sum
- thenar eminence:
  - thenar: Pronunciation link: https://www.merriam-webster.com/dictionary/thenar
    IPA: /ˈθiːnər/
    Phonetic Spelling: THEE-ner
  - eminence: Pronunciation link: https://www.merriam-webster.com/dictionary/eminence
    IPA: /ˈɛmɪnəns/
    Phonetic Spelling: EM-i-nents
    Combined: thenar eminence --> THEE-ner EM-i-nents

- functional near-infrared spectroscopy (fNIRS)

  - functional: Pronunciation link: https://www.merriam-webster.com/dictionary/functional
    IPA: /ˈfʌŋkʃənəl/
    Phonetic Spelling: FUNK-shuh-nul
  - near-infrared:
    - near: https://www.merriam-webster.com/dictionary/near
      IPA: /nɪər/ or /nɪr/ (American)
      Phonetic Spelling: neer
    - infrared: https://www.merriam-webster.com/dictionary/infrared
      IPA: /ˌɪnfrəˈrɛd/
      Phonetic Spelling: IN-fruh-RED
  - spectroscopy: https://www.merriam-webster.com/dictionary/spectroscopy
    IPA: /spɛkˈtrɒskəpi/ or /spɛkˈtrɑskəpi/ (American)
    Phonetic Spelling: spek-TROS-kuh-pee
    Combined: functional near-infrared spectroscopy → FUNK-shuh-nul neer IN-fruh-RED spek-TROS-kuh-pee

- optode

Pronunciation link: https://www.merriam-webster.com/dictionary/optode
IPA: /ˈɒptoʊd/ or /ˈɑptod/ (American)
Phonetic Spelling: OP-tohd

- convolution / connectivity matrix / clustering coefficient / degree centrality / eigenvector centrality

  - convolution: https://www.merriam-webster.com/dictionary/convolution
    IPA: /ˌkɒnvəˈluːʃən/ or /ˌkɑnvəˈluːʃən/
    Phonetic Spelling: kon-vuh-LOO-shun

- connectivity: https://www.merriam-webster.com/dictionary/connectivity
  IPA: /kəˌnɛkˈtɪvɪti/
  Phonetic Spelling: kuh-nek-TIV-i-tee
- matrix (plural: matrices): https://www.merriam-webster.com/dictionary/matrix
  IPA: /ˈmeɪtrɪks/
  Phonetic Spelling: MAY-triks
- clustering (as a noun): https://www.merriam-webster.com/dictionary/cluster
  IPA: /ˈklʌstər/ → clustering /ˈklʌstərɪŋ/
  Phonetic Spelling: KLUS-ter-ing
- coefficient: https://www.merriam-webster.com/dictionary/coefficient
  IPA: /ˌkoʊɪˈfɪʃənt/
  Phonetic Spelling: koh-ee-FISH-ent
- degree: https://www.merriam-webster.com/dictionary/degree
  IPA: /dɪˈgriː/
  Phonetic Spelling: di-GREE
- centrality: https://www.merriam-webster.com/dictionary/centrality
  IPA: /ˌsɛnˈtrælɪti/
  Phonetic Spelling: sen-TRAL-i-tee
- eigenvector: https://www.merriam-webster.com/dictionary/eigenvector
  IPA: /ˈaɪgənˌvɛktər/
  Phonetic Spelling: EYE-gun-VEC-ter
  Combined: e.g., eigenvector centrality → EYE-gun-VEC-ter sen-TRAL-i-tee

- hemodynamics

Pronunciation link: https://www.merriam-webster.com/dictionary/hemodynamics
IPA: /ˌhiːmoʊdaɪˈnæmɪks/
Phonetic Spelling: HEE-moh-dy-NAM-iks