Title: High-Definition Transcranial Direct Current Stimulation over Right Dorsolateral Prefrontal Cortex to Enhance Metacognitive Sensitivity

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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, all 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: 23
Number of Shots: 51

Introduction

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

1.1. **Xiangyi Lyu:** Our study focuses on human–AI collaboration. We examine the effect of HD-tDCS on human metacognition in a human-AI delegation task.

    1.1.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B.roll:3.1*

What research gap are you addressing with your protocol?

1.2. **Xiangyi Lyu:** Our protocol proposes a new approach using HD-tDCS to improve human–AI collaboration efficiency.

    1.2.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B.roll:2.2*

What research questions will your laboratory focus on in the future?

1.3. **Xiangyi Lyu:** Our lab will study the effect of co-learning on human–AI collaboration performance.

    1.3.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

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

Ethics Title Card

This research has been approved by the Institutional Review Board (IRB) at Jiangsu University of Science and Technology

Protocol

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2. Implementation of HD-tDCS in Human Subjects with Pre- and Post-Test Image Classification Tasks

Demonstrator: Xiangyi Lyu , Weijie Xiao

2.1. To begin, ensure that the participant has no contraindications to high-definition transcranial direct current stimulation or HD-tDCS *(H-D-T-D-C-S)* and does not meet any exclusion criteria **[1]**. Introduce the experimental procedure to the participants and obtain written informed consent after confirming their understanding **[2]**.

 2.1.1. WIDE: Talent greeting the participant and reviewing screening questions.

 2.1.2. Talent explaining the experimental procedure and obtaining written consent from the participant.
  Videographer's Note: Step 2.1.1 and 2.1.2 are combined in one clip

2.2. Verify that the HD-tDCS stimulation device is fully charged **[1]**.   Make sure that all accessories including electrodes, electrode gel, the syringe provided with the instrument and electrode cables are ready for use **[2]**.

 2.2.1. Talent checking the device's battery status.

 2.2.2. Talent arranging all accessories on the table.

2.3. Now, randomly select one of the two experimental tasks as the pretest condition and instruct the participant to complete the image classification task **[1]**.

 2.3.1. Talent instructing the participant to begin the image classification task of either one experiment.

2.4. Insert the bottom portions of the five electrodes directly into the designated positions on the neoprene headcap **[1].**

 2.4.1. Talent inserting the bottom portions of the electrodes into the designated positions on the neoprene headcap.

2.5. Instruct the participant to sit comfortably in a chair **[1]**. Position the front edge of the neoprene headcap approximately one to two centimeters above the eyebrows **[2]**, ensuring that Cz *(C-Z)* is aligned with the midpoint between the two preauricular points **[3-TXT]**. Fit the headcap securely on the participant's head ensuring proper alignment **[4]**.

 2.5.1. Shot of the participant sitting in a chair.

 2.5.2. Talent placing the headcap on the participant.

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<mark>Videographer's Note:Step 2.5.1 and 2.5.2 are combined in one clip</mark>

    2.5.3. Talent pointing to the Cz between the midpoint of the 2 preauricular points. **TXT: Cz: Central zero**

    2.5.4. Shot of the headcap alignment being adjusted.

2.6. Next, using the syringe provided with the instrument, fill the syringe with electrode gel **[1]**. Part the participant's hair with the syringe, for each electrode site to expose the scalp **[2]**.

    2.6.1. Talent filling the syringe with electrode gel.

    2.6.2. Talent parting hair with the syringe to reveal scalp.

2.7. Inject a sufficient amount of electrode gel onto the exposed scalp inside the bottom parts of all the electrodes **[1]**. Then, screw together the top and bottom parts of all the electrodes **[2]**.

    2.7.1. Talent applying gel inside the bottom parts of electrodes.

    2.7.2. Talent screwing the electrode halves together on each site.
<mark>Videographer's Note :Step 2.7.1 and 2.7.2 are combined in one clip</mark>

2.8. Turn on the high-definition transcranial direct current stimulation device **[1]** and launch the corresponding control software **[2]**.

    2.8.1. Talent pressing the power button on the device.

    2.8.2. SCREEN: 68824_screen_shot_1.mp4   00:00-00:05 .
<mark>Videographer's Note:Clip 3263 covers screen recordings from 2.8.2 to 2.15.1</mark>

2.9. Enable WiFi on the computer and in the control software, select **USE Wi-Fi Devices** to begin the connection process **[1]**. When the device's MAC *(mack)* address appears in the list, select the device **[2]**.

    2.9.1. SCREEN: 68824_screen_shot_2.mp4   00:00-00:07 .

    2.9.2. SCREEN: 68824_screen_shot_2.mp4   00:08-00:13.

2.10. In the **Line Noise Filter** setting of the control software select **50 Hz** *(Hertz)* to eliminate electrical interference **[1]**. Then click the **Use This Device** button in the bottom of the settings panel to establish a connection with the device **[2]**.

    2.10.1. SCREEN: 68824_screen_shot_3.mp4   00:00-00:04.

    2.10.2. SCREEN: 68824_screen_shot_3.mp4   00:05-00:12.

2.11. To configure the stimulation protocol, click the head-shaped icon on the left panel of the control software **[1]**. Then press **ADD NEW PROTOCOL** ~~to create a new protocol~~ **[2]** and name the new protocol and step **[3].**

    2.11.1. SCREEN: 68824_screen_shot_4.mp4   00:00-00:02.

2.11.2. SCREEN: 68824_screen_shot_4.mp4   00:03-00:04 .

2.11.3. SCREEN: 68824_screen_shot_4.mp4   00:05-00:15.

2.12. Set the total protocol duration to **20 min** *(minutes)* , including a **30 s** *(second)* **ramp-up** and a **30 s ramp-down** period **[1]**.

    2.12.1. SCREEN: 68824_screen_shot_5.mp4   00:00-00:12 .

2.13. Now, drag the **F4 electrode** into the **Stimulation column** on the right, set the **channel** to **stimulation mode**, enter a **current intensity** of **2000 μA** *(microamperes)*, then select **anodal stimulation [1]**.

    2.13.1. SCREEN: 68824_screen_shot_6.mp4   00:00-00:15 .

2.14. Drag electrodes **Fp2** *(F-P-Two)*, **Fz** *(F-Z)*, **C4** *(C-four)*, and **F8** *(F-Eight)* into the **Stimulation column [1].** Set each **channel** to **return mode**, assigning 25 percent of the total current to each **[2]**, and save the protocol **[3]**.

    2.14.1. SCREEN: 68824_screen_shot_7.mp4   00:00-00:10.

    2.14.2. SCREEN: 68824_screen_shot_7.mp4   00:11-00:32 .

    2.14.3. SCREEN: 68824_screen_shot_7.mp4   00:33-00:38 .

2.15. Select the configured stimulation protocol **[1].** Then attach the device to the Velcro strap at the back of the headcap **[2]** connect the device and the electrode cables **[3]**.

    2.15.1. SCREEN: 68824_screen_shot_8.mp4   00:00-00:04 .

    2.15.2. Talent attaching device to the Velcro strap at the back of the headcap.
       ==Videographer's Note:Step 2.15.2 and 2.15.3 are combined in one clip==

    2.15.3. Talent connecting the device and the electrode cables.

       ==AUTHOR'S NOTE: Please move shot 2.15.3 before shot 2.15.2==

2.16. Connect and confirm that all cables are properly attached **[1].** Click the **LOAD PROTOCOL** button **[2]**. Press the **CHECK IMPEDANCE** button to perform an impedance check **[3]**. Now, click the **START STIMULATION** button to initiate the stimulation **[4]**.

    2.16.1. Talent connecting and checking all cable connections.

    2.16.2. SCREEN: 68824_screen_shot_9.mp4   00:00-00:01 .
       ==Videographer's Note:Clip 3266 covers screen recordings from 2.16.2 to 2.16.4==

    2.16.3. SCREEN: 68824_screen_shot_9.mp4   00:02-00:14 .

    2.16.4. SCREEN: 68824_screen_shot_9.mp4   00:40-00:50 .

2.17. Instruct the participant to report their sensations at multiple time points during the stimulation session **[1]**.

    2.17.1. Talent reminding participant to note sensations at intervals.

2.18. Once the experiment is complete, turn off the device **[1]**. Disconnect the cables from the electrodes **[2]** and carefully remove the device **[3]**.

    2.18.1. Talent closing thedevice.

    2.18.2. Talent unplugging cables from the electrodes.

    2.18.3. Shot of the device being removed.
    <mark>Videographer's Note:Step 2.18.1 to 2.18.3 are combined in one clip</mark>

2.19. Remove the headcap from the participant's head **[1].** Then detach all electrodes **[2]**.

    2.19.1. Talent lifting the headcap off.

    2.19.2. Talent removing electrodes fromheadcap.

2.20. ~~Select the other experimental program that has not yet been completed **[1]**. Instruct the participant to complete the image classification task as the post-test **[2]**.~~ Ask the participant to complete the other experimental program as a post-test **[1].** Then provide the participant with supplies to clean their hair **[3]**.

    2.20.1. The participant finishing the second program.

    2.20.2. ~~Talent instructing participant to begin post-test task.~~
    <mark>AUTHOR'S NOTE: This shot was not filmed – the introduction has already been completed.</mark>

    2.20.3. Talent handing over cleaning supplies.

2.21. Ask the participants to complete a sensation questionnaire after the stimulation session to assess their tolerance and subjective experience **[1]**.

    2.21.1. Talent handing over a questionnaire to the participant.

2.22. Now, rinse the headcap thoroughly with water **[1]**.

    2.22.1. Talent rinsing the headcap under running water.

2.23. Gently rinse the gel from the electrodes in tap water **[1]**. Leave the electrodes to air-dry on a paper towel **[2]**. Once they are dry, place them in their packaging for long-term storage **[3]**.

    2.23.1. Talent rinsing each electrode under tap water.

    2.23.2. Talent placing electrodes on towel to dry.
    <mark>Videographer's Note:Step 2.23.1 and 2.23.2 are combined in one clip</mark>

    2.23.3. Talent packaging the dried electrodes for storage.

Results

3. Results

3.1. Metacognitive sensitivity significantly increased following anodal stimulation between the pre-test and post-test conditions **[1]**, while no significant changes were observed under cathodal **[2]** or sham stimulation **[3]**.

    3.1.1. LAB MEDIA: Figure 6. *Video editor: Highlight the red bars under "anodal"*

    3.1.2. LAB MEDIA: Figure 6. *Video editor: Highlight the orange and red bars under "cathodal"*

    3.1.3. LAB MEDIA: Figure 6. *Video editor: Highlight the orange and red bars under "sham"*

3.2. A significant interaction was found between time and stimulation type in the repeated measures ANOVA **[1]**, despite no significant main effects of time **[2]** or stimulation type alone **[3]**.

    3.2.1. LAB MEDIA: Table 1. *Video editor: Highlight the row "Time × Stimulation",*

    3.2.2. LAB MEDIA: Table 1. *Video editor: Highlight the row "Time"*

    3.2.3. LAB MEDIA: Table 1. *Video editor: Highlight the row "Types of stimulation"*

Pronunciation Guide:

☐ **dorsolateral**
Pronunciation link: https://www.howtopronounce.com/dorsolateral-prefrontal-cortex
[howtopronounce.com+2pronouncekiwi.com+2](#)
IPA: /ˌdɔːrsoʊˈlætərəl/
Phonetic spelling: dor-soh-LAT-uh-rəl

☐ **prefrontal**
Pronunciation link:
https://dictionary.cambridge.org/us/pronunciation/english/prefrontal-cortex [Cambridge Dictionary+1](#)
IPA: /ˌpriːˈfrʌn.təl/
Phonetic spelling: pree-FRUN-tul

☐ **cortex**
Pronunciation link:
https://dictionary.cambridge.org/us/pronunciation/english/prefrontal-cortex [Cambridge Dictionary+1](#)
IPA: /ˈkɔːr.teks/
Phonetic spelling: KOR-teks

☐ **transcranial**
Pronunciation link: No confirmed link found
IPA: /ˌtræn.skɹeɪˈni.əl/
Phonetic spelling: tran-skray-NEE-uhl

☐ **stimulation**
Pronunciation link: No confirmed link found
IPA: /ˌstɪm.jʊˈleɪ.ʃən/
Phonetic spelling: stim-yoo-LAY-shun

☐ **metacognitive**
Pronunciation link: No confirmed link found
IPA: /ˌmeɪ.tə.kəˈgnɪ.tɪv/
Phonetic spelling: MAY-tuh-kuh-GNI-tiv

☐ **anodal**
Pronunciation link: https://youglish.com/pronounce/anodal/english/us [youglish.com+1](#)
IPA: /əˈnoʊ.dəl/
Phonetic spelling: uh-NOH-duhl

☐ **cathodal**
Pronunciation link: https://www.howtosay.co.in/pronounce/cathodal-in-english/
[howtosay.co.in](#)
IPA: /ˈkæθ.ə.dəl/
Phonetic spelling: KATH-uh-duhl

☐ **neoprene**
Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/neoprene

Cambridge Dictionary
IPA: /ˈniː.oʊˌpriːn/
Phonetic spelling: NEE-oh-preen

☐ **impedance**
Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/impedance
Cambridge Dictionary+1
IPA: /ɪmˈpiː.dəns/
Phonetic spelling: im-PEE-duhns

☐ **syringe**
(Check: though common, pronunciation may be confused)
Pronunciation link: https://www.merriam-webster.com/dictionary/syringe
IPA: /səˈrɪndʒ/
Phonetic spelling: suh-RINJ

☐ **neuroscience**
Pronunciation link: https://www.merriam-webster.com/dictionary/neuroscience
IPA: /ˌnʊɹ.өʊˈsaɪəns/
Phonetic spelling: noo-roh-SY-uhns

☐ **metacognition**
Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/metacognitive
Cambridge Dictionary+1
IPA: /ˌmɛtəˈkɑːgnɪʃən/
Phonetic spelling: meh-tuh-KAUG-ni-shun

☐ **neural**
Pronunciation link: https://www.merriam-webster.com/dictionary/neural
IPA: /ˈnʊr.əl/
Phonetic spelling: NOOR-uhl

☐ **electrode**
Pronunciation link: https://www.merriam-webster.com/dictionary/electrode
IPA: /ɪˈlɛkˌtroʊd/
Phonetic spelling: ih-LEK-trohd

☐ **protocol**
Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/protocol
IPA: /ˈproʊ.təˌkɑːl/
Phonetic spelling: PROH-tuh-kawl