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Title: Estimate the Cognitive Load Using Electrocardiographic Measure: A Human-AI Collaborative Task

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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: 22

Number of Shots: 48 (28 SC)

Introduction

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

INTRODUCTION:

- 1.1. **Xiangyi Lyu:** We study how people's cognitive load changes when working with AI in a delegation setting.
 - 1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

CONCLUSION:

- 1.2. **Xiangyi Lyu:** We found that people adjust their cognitive load by delegating tasks when working with AI.
 - 1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.
- 1.3. **Xiangyi Lyu:** In future, we will look at how different co-learning approaches affect outcomes when humans and AI learn together.
 - 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 of Jiangsu University of Science and Technology

Protocol

2. Patient Preparation and Instrument Setup

Demonstrators: Xiangyi Lyu, Kangjie Xu

2.1. To begin, introduce the experimental procedure to the participant and ensure they are fully informed about the study [1-TXT].

2.1.1. WIDE: Talent explaining the experimental procedure to the participant using printed study materials. **TXT: Obtain written informed consent from the participant**

2.2. Prepare the electrocardiogram data acquisition system and gather all necessary materials, including the pre-gelled disposable electrocardiogram electrodes [1].

2.2.1. Talent arranging all required materials on the workstation, including electrocardiogram electrodes and cables.

2.3. Connect the data acquisition system to the electrocardiogram data receiver module [1]. Using the male-to-female ribbon cable, establish a connection between the data acquisition system and the computer used for stimulus presentation [2]. Using an Ethernet cable, establish a connection between the data acquisition system and the computer used for data recording [3].

2.4.1 Talent attaching the receiver module to the data acquisition unit using the expansion slot on the right side of the system. **NOTE: 2.4.1 is moved here and this may have been slated as 2.3.1**

2.3.2 Talent connecting the ribbon cable between the data acquisition system and the computer.

Added shot: Talent connecting the Ethernet cable from the data acquisition system to the data acquisition computer.

2.4. Plug the system into a stable power supply [1].

2.4.2 Talent connecting the power cable to the data acquisition system and plugging it into a power outlet. **NOTE: This may have been slated as 2.4.1. or 2.4.2, no clear notes**

2.5. Now, clean the participant's skin with alcohol wipes at three sites: below the left rib,

below the right clavicle, and on the right abdomen [1]. Attach one disposable electrocardiogram electrode patch to each cleaned site [2].

2.5.1. Talent cleaning the designated skin areas with alcohol wipes.

2.5.2. Talent placing an electrode patch at each of the cleaned skin sites.

2.6. Then, attach the lead-wire connector securely to the electrocardiogram transmitter [1] and connect the metal clip of the lead wire to the corresponding electrode [2].

2.6.1. Talent plugging the lead-wire connector into the electrocardiogram transmitter and ensuring a secure fit.

2.6.2. Talent clipping the lead wire's metal clip to the designated electrode.

2.7. Secure the electrocardiogram transmitter to the participant's body using stretchy hook-and-loop fastener straps [1] and adjust the strap tension to ensure the transmitter stays in place and remains comfortable for the participant [2].

2.7.1. Talent wrapping and fastening the hook-and-loop strap around the participant's torso to secure the transmitter.

2.7.2. Talent adjusting the strap to stabilize the transmitter while checking for participant comfort.

3. Data Acquisition and Processing

3.1. Turn on the switch of the electrocardiogram transmitter [1] and power on the electrocardiogram data acquisition system [2]. Check the wireless connection status between the transmitter [3] and the receiver module of the data acquisition system [4].

3.1.1. Talent switching on the electrocardiogram transmitter **Author's NOTE: 3.1.1 was split into 3.1.1 and 3.1.2 and next 2 were renamed**

3.1.2. Talent powering up the data acquisition system.

3.1.3. Talent checking the status light on the transmitter.

3.1.4. Talent checking the status light on the receiver module.

3.2. Now, launch the electrocardiogram data acquisition software [1]. Create a new graph

file [2], select the electrocardiogram receiver module from the device list [3], choose the appropriate electrocardiogram recording channel [4], and click **OK** in the newly displayed transmitter connection status window [5].

3.2.1. SCREEN: SCREEN 3.2.1.

3.2.2. SCREEN: SCREEN 3.2.2.

3.2.3. SCREEN: SCREEN 3.2.3.

3.2.4. SCREEN: SCREEN 3.2.4

3.2.5. SCREEN: SCREEN 3.2.5.

3.3. Click **Start** in the data acquisition software interface to begin electrocardiogram data collection [1]. Verify that the electrocardiogram waveform appears stable on the screen [2].

3.3.1. SCREEN: SCREEN 3.3.1.

3.3.2. SCREEN: SCREEN 3.3.2.

3.4. Now, instruct the participant to begin the experimental task [1].

3.4.1. Talent giving verbal instructions to the participant to begin the task.

3.5. After the task is completed, click **Stop** in the data acquisition software to end the recording session [1].

3.5.1. SCREEN: SCREEN 3.5.1.

3.6. Detach the lead-wire clips from the electrode patches [1]. Loosen the stretchy hook-and-loop fastener straps and remove the electrocardiogram transmitter from the participant's body [2].

3.6.2, Talent unfastening and removing the electrocardiogram transmitter from the participant

3.6.1, Talent unclipping the red, white, and black lead-wire clips from the electrode patches.

Author's NOTE: Move shot 3.6.2 (Talent unfastening...) above shot 3.6.1 (Talent unclipping...).

We had already discussed this adjustment with the videographer during filming, and the action described in Shot 3.6.2 was filmed before the action described in Shot 3.6.1. Therefore, only the text order in the final script needs to be updated; the filming sequence is already correct..

3.7. Instruct and assist the participant in gently removing the disposable electrode patches by hand [1].

3.7.1. Talent guiding the participant to peel off each electrode patch carefully.

3.8. Next, open the recorded electrocardiogram data file in the data analysis software [1].

3.8.1. SCREEN: SCREEN 3.8.1.

3.9. Select the electrocardiogram channel and apply digital filtering. In the menu bar, navigate to **Transform** followed by **Digital Filters** and **Comb Band Stop** [1]. Then, in the dialog box, select **Fixed at** under **Base Frequency**, enter 50 hertz, and click **OK** to apply the filter [2].

3.9.1. SCREEN: SCREEN 3.9.1.

3.9.2. SCREEN: SCREEN 3.9.2..

3.10. Next, click **Transform** in the menu bar, select **Digital Filters**, then **FIR**, followed by **Band Pass** [1]. In the dialog box, under **Low Frequency cutoff**, select **Fixed at** and enter 1 hertz, under **High Frequency cutoff**, select **Fixed at** and enter 35 hertz [2].

3.10.1. SCREEN: SCREEN 3.10.1.

3.10.2. SCREEN: SCREEN 3.10.2.

3.11. Now, create **Focus Areas** based on the experimental design [1].

3.11.1. SCREEN: SCREEN 3.11.1.

4. Heart Rate Data Analysis

Demonstrator: Xiangyi Lyu

4.1. Generate and export heart rate data by selecting **Analysis** followed by **Hemodynamics** and **ECG Interval Extraction** from the menu bar [1]. In the **Analyze** option, choose **Focus Areas Only** , and in the **Display results as** option, select **Excel Spreadsheet Only** [2]. Click **OK** to confirm and complete the export [3].

4.1.1. SCREEN: SCREEN 4.1.1.

4.1.2. SCREEN: SCREEN 4.1.2.

4.1.3. SCREEN: SCREEN 4.1.3.

- 4.2. To generate heart rate variability data, open **Analysis** and select **HRV and RSA** followed by **Multi-epoch HRV – Statistical [1]**. In the **ECG Channel** field, select the preprocessed electrocardiogram channel [2] and under **Extract HRV statistics for**, choose **Focus Areas**. Go to **Output results to**, select **Spreadsheet** and click **OK** to generate and export the time-domain results [3].

4.2.1. SCREEN: SCREEN 4.2.1.

4.2.2. SCREEN: SCREEN 4.2.2.

4.2.3. SCREEN: SCREEN 4.2.3.

- 4.3. Finally, open **Analysis** again and select **HRV and RSA** followed by **Multi-epoch HRV and RSA – Spectral [1]**. In the **ECG Channel** field, select the preprocessed electrocardiogram channel [2]. Under **Extract HRV and RSA for**, choose **Focus Areas**. In **Output type**, select **Excel Spreadsheet Only** and click **OK** to export the frequency-domain results [3].

4.3.1. SCREEN: SCREEN 4.3.1.

4.3.2. SCREEN: SCREEN 4.3.2.

4.3.3. SCREEN: SCREEN 4.3.3.

Results

5. Results

5.1. Mean heart rate was significantly lower under the difficult image condition [1] compared to the easy image condition [2].

5.1.1. LAB MEDIA: Figure 3A. *Video editor: Highlight the bar labelled “Hard”*

5.1.2. LAB MEDIA: Figure 3A. *Video editor: Highlight the bar labelled “Easy”*

5.2. High frequency heart rate variability was significantly higher during the difficult image condition [1] compared to the easy image condition [2].

5.2.1. LAB MEDIA: Figure 3C. *Video editor: Highlight the bars labelled “Hard”*

5.2.2. LAB MEDIA: Figure 3C. *Video editor: Highlight the bars labelled “Easy”* .

5.3. Root mean square of successive differences followed a similar trend and was significantly higher during the difficult image condition [1].

5.3.1. LAB MEDIA: Figure 3D. *Video editor: Highlight the bar labelled “Hard”*

5.4. Participants delegated significantly more frequently under the difficult image condition [1] than the easy image condition [2].

5.4.1. LAB MEDIA: Figure 4. *Video editor: Highlight the bar or data point labelled “Hard”*

5.4.2. LAB MEDIA: Figure 4. *Video editor: Highlight the bar or data point labelled “Easy”*

1. Electrocardiogram

Pronunciation link: <https://www.merriam-webster.com/dictionary/electrocardiogram>

IPA: /ɪˌlek.troʊˈkɑːr.dɪ.ooˌgræm/

Phonetic Spelling: ihˌlekˌtrohˌkahrˌdeeˌuhˌgram

2. Electrodes

Pronunciation link: <https://www.merriam-webster.com/dictionary/electrode>

IPA: /ɪˈlek.troʊdɪz/

Phonetic Spelling: ihˌlekˌtrohdz

3. Transmitter

Pronunciation link: <https://www.merriam-webster.com/dictionary/transmitter>

- IPA: /trænz'mɪtər/
Phonetic Spelling: tranz·mit·er
4. Receiver
Pronunciation link: <https://www.merriam-webster.com/dictionary/receiver>
IPA: /rɪ'si:vər/
Phonetic Spelling: rih·see·ver
5. Clavicle
Pronunciation link: <https://www.merriam-webster.com/dictionary/clavicle>
IPA: /'klævɪkəl/
Phonetic Spelling: klav·ih·kuhl
6. Abdomen
Pronunciation link: <https://www.merriam-webster.com/dictionary/abdomen>
IPA: /'æb.də.mən/
Phonetic Spelling: ab·duh·muhn
7. Hemodynamics
Pronunciation link: <https://www.merriam-webster.com/dictionary/hemodynamics>
IPA: /,hi:.moʊ.dai'næmɪks/
Phonetic Spelling: hee·moh·dy·nam·iks
8. Spectral
Pronunciation link: <https://www.merriam-webster.com/dictionary/spectral>
IPA: /'spektrəl/
Phonetic Spelling: spek·truhl
9. Ethernet
Pronunciation link: <https://www.merriam-webster.com/dictionary/ethernet>
IPA: /'i:θərˌnet/
Phonetic Spelling: ee·ther·net
10. Clipping
Pronunciation link: <https://www.merriam-webster.com/dictionary/clipping>
IPA: /'klɪpɪŋ/
Phonetic Spelling: klip·ing