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Title: Standardized EEG Protocol for Comparing Cortical Responses to Mechanical and Electrical Tactile Stimuli

Authors and Affiliations:

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Author Questionnaire

1. We have marked your project as author-provided footage, meaning you film the video yourself and provide JoVE with the footage to edit. JoVE will not send the videographer. Please confirm that this is correct.

✓ Correct

2. Interview statements: Which interview statement filming option is the most appropriate for your group? **Please select one.**



Interview Statements are read by JoVE's voiceover talent.

Current Protocol Length

Number of Steps: 21

Number of Shots: 38

Introduction

Authors: Please note that **the questions will not appear on screen**. Please answer in **stand-alone full sentence with sufficient context**.

Answers are slightly edited in accordance with journal guidelines/ We have chosen 5 best answers.

NOTE to VO producer: Please record the interview statements

INTRODUCTION:

~~**REQUIRED:** Summarize your research focus and the main questions it aims to answer.~~

- 1.1. This research demonstrates whether electrical and mechanical stimuli can be interchangeably used as standard and deviant stimuli to study somatosensory mismatch negativity responses.

1.1.1. B roll: 2.2.1

~~**Describe the research gap or limitation in existing methods and how this protocol addresses them.**~~

- 1.2. Somatosensory mismatch has been studied using electrical or mechanical stimulation separately, but not interchangeably as standard and deviant within one paradigm.

1.2.1. B roll: 2.5.3

CONCLUSION:

~~What does this protocol allow researchers to study or measure?~~

- 1.3. This protocol enables measurement of neural responses to electrical and mechanical stimuli within oddball and roving paradigms.

1.3.1. B roll: 3.2.2

~~Describe the most important consideration or challenge when performing this protocol.~~

- 1.4. Maintaining consistent stimulation parameters and conditions is essential to avoid variability in perceived sensations during protocol execution.

1.4.1. B roll: 3.2.1

~~How can future studies build on this work? Describe the questions or research directions that can be investigated next.~~

- 1.5. The full pipeline can be extended to clinical and research settings to develop reliable biomarkers of somatosensory processing and dysfunction.

1.5.1. B roll: 4.4.1

Ethics Title Card

This research has been approved by the Sirius University Human Investigation Committee

Protocol

2. Preparation of the Participant for EEG

Demonstrator: Sergei Tugin

3412

2.1. To begin, turn on the custom-built multimodal stimulator developed to deliver precisely controlled and synchronized somatosensory stimuli [1]. The system includes a control unit and a stimulation module for high-fidelity neurophysiological research [2].

2.1.1. WIDE: VID_20260416_131442 OR VID_20260416_131324 OR VID_20260416_131357 *Video editor: Please use any one of the above takes that looks best.*

2.1.2. LAB MEDIA: VID_20260326_145606.mp4, VID_20260326_145814.mp4 00:00 – 00:10, VID_20260326_150024.mp4 00:00 – 00:10 and VID_20260326_150804.mp4 00:00 – 00:10 *Video editor: Please use split screens to show these 4 videos.*

2.2. Measure the participant's head circumference and identify anatomical landmarks [1] and select the electroencephalography or EEG cap size accordingly [2].

2.2.1. LAB MEDIA: VID_20260326_151342.mp4 and VID_20260326_151523.mp4

2.2.2. LAB MEDIA: VID_20260326_152022.mp4

2.3. Position the cap so that the central electrode Cz (*see-zet*) is located at the vertex [1]. Verify proper alignment by measuring the distances from Cz to the nasion, inion [2], and both the preauricular points to ensure symmetry [3]. Adjust the cap to follow the international 10-10 electrode placement system [4].

2.3.1. LAB MEDIA: VID_20260326_152538.mp4 00:01 – 00:10

2.3.2. LAB MEDIA: VID_20260326_152538.mp4 00:46 – 00:52

2.3.3. LAB MEDIA: VID_20260326_152538.mp4 01:03-01:10

2.3.4. LAB MEDIA: VID_20260326_152538.mp4 01:11-01:24

2.4. Connect all the electrode leads to the EEG amplifier according to the manufacturer's specifications [1].

2.4.1. LAB MEDIA: VID_20260326_153819.mp4 00:30 – 00:36 and VID_20260326_153944.mp4

- 2.5. Next, prepare each electrode placement site by gently abrading the skin and cleaning with alcohol [1]. Fill each electrode cavity with a conductive gel [2]. Then, apply the ground and reference electrodes first to ensure a stable connection [5].

2.5.1. LAB MEDIA: VID_20260326_154407.mp4 00:04 – 00:06 and 00:20-00:25

2.5.2. LAB MEDIA: VID_20260326_154524.mp4 00:08-00:20

2.5.3. LAB MEDIA: VID_20260326_154619.mp4 00:04-00:08 and
VID_20260326_155635.mp4 00:15-00:18

- 2.6. Confirm that the electrode signal quality meets the manufacturer's recommended criteria, including low noise levels and impedance values below 10 kilohms [1].

2.6.1. LAB MEDIA: 2026.mp4 00:00 – 00:10 and 06:06-06:12

- 2.7. Arrange the electrode cables to minimize movement artifacts [1] and secure them to reduce strain on the connectors [2].

2.7.1. LAB MEDIA: VID_20260326_164322.mp4 00:00 – 00:08

2.7.2. LAB MEDIA: VID_20260326_164322.mp4 00:25 – 00:29

- 2.8. Seat the participant comfortably in front of a monitor. If possible, present a silent, neutral video to help maintain stable alertness during prolonged recordings [1].

2.8.1. LAB MEDIA: VID_20260326_180931.mp4

- 2.9. Inspect the raw EEG signal for a consistent baseline across channels [1]. Verify that the physiological artifacts, such as eye blinks [2] and muscle activity, are clearly identifiable [3].

2.9.1. LAB MEDIA: 2026-04-16 12-38-00.mkv 00:00-00:10

2.9.2. LAB MEDIA: 2026-04-16 12-38-00.mkv 03:38-03:46 **Author's NOTE: This timestamp shows reading during eye blink**

2.9.3. LAB MEDIA: 2026-04-16 12-38-00.mkv 02:08-02:15 - **Author's NOTE: This timestamp shows reading during muscle activity**

3. Stimulation Setup and Threshold Determination

- 3.1. Clean the stimulation site, such as the index finger of the participant's dominant hand, with an alcohol swab to reduce skin impedance [1].

3.1.1. LAB MEDIA: VID_20260326_164443.mp4 00:03 – 00:12

- 3.2. Position the finger on the stimulation pad and begin stimulation at 1 milliamperes. Instruct the participant to raise the index finger when the stimulation is first perceived [1]. Increase the intensity in 0.5-milliamperes increments until the participant first reports sensation [2].

3.2.1. LAB MEDIA: VID_20260326_173543.mp4 00:00-00:20 **TXT: 1 mA; Increase in 0.5 mA increments**

3.2.2. LAB MEDIA: VID_20260326_173543.mp4 00:21-00:27

- 3.3. Decrease intensity by 0.5 milliamperes and then, increase it in 0.1 milliamperes steps to refine the threshold. Present 10 stimuli at each candidate intensity and define the threshold as the lowest intensity at which at least 5 out of 10 stimuli are detected [1].

3.3.1. LAB MEDIA: VID_20260326_173637.mp4

- 3.4. Then, determine the discomfort threshold by identifying the stimulus intensity that becomes unpleasant or intolerable to the participant [1]. After repeating the staircase procedure 3 times, calculate the mean sensory threshold and the final stimulation intensity [2 and 3].

3.4.1. LAB MEDIA: MDzs3402 00:04-00:09

3.4.2. LAB MEDIA: VID_20260326_173729.mp4

3.4.3. **TEXT ON PLAIN BACKGROUND USING SPLIT SCREEN:**
Mean sensory threshold = $\frac{(\text{Trial 1} + \text{Trial 2} + \text{Trial 3})}{3}$

3

Final stimulation intensity = $\frac{(\text{Sensory Threshold} + \text{Discomfort Threshold})}{2}$

2

- 3.5. Next, set the mechanical stimulation intensity to a clearly perceptible level without causing discomfort or visible finger movement [1].

3.5.1. LAB MEDIA: VID_20260326_175035.mp4

- 3.6. In the oddball paradigm, present 5 to 8 standard stimuli followed by one deviant. Each block should include approximately 650 standard and 100 deviant stimuli [1-TXT]. Then, present 5 to 8 consecutive standards followed by 5 to 8 deviants in the roving paradigm [2].

3.6.1. LAB MEDIA: Oddball_vs_Roving *Video editor: Display picture from the footage folder named "oddball vs roving". Highlight the oddball and the row with lines below. When VO says "standard stimuli", highlight green lines. When Vo says "single deviant", highlight red lines in oddball row.* **TXT: Refer to the text protocol for the detailed stimulation parameters**

3.6.2. LAB MEDIA: Oddball_vs_Roving *Video editor: Display picture from the footage folder named "oddball vs roving". Highlight the roving and the row with lines below. Highlight the oddball and the row with lines below. When VO says "consecutive standard", highlight green lines. When Vo says "5 to 8 deviants", highlight red lines in roving row.*

Authors: We cannot have elaborate narration without accompanying visuals. Hence, the steps with no footage are summarized in a couple of lines as per journal guidelines

4. EEG Recording During Stimulation

- 4.1. Explain the experimental procedure to the participant, noting that no behavioral response to the tactile stimuli is required [1]. Inform the participant that withdrawal from the experiment is allowed at any time without consequences [2].

4.1.1. LAB MEDIA: VID_20260326_180721.mp4 00:00-00:10

4.1.2. LAB MEDIA: VID_20260326_180721.mp4 00:15-00:22

- 4.2. Ask the participant to use headphones with active noise cancellation to prevent brain responses from being affected by the actuator's noise [1].

4.2.1. LAB MEDIA: VID_20260326_180931.mp4 and VID_20260326_181110.mp4

- 4.3. Confirm synchronization between the stimulator and the EEG acquisition system using transistor-transistor logic triggers [1].

4.3.1. LAB MEDIA: 2026-04-16 12-38-00.mkv 04:37-04:47

4.4. Start EEG recording at a sampling rate of approximately 10,000 hertz [1]. Then, run the electrical, mechanical, or electro-mechanical stimulation sequences according to the assigned paradigm. Collect at least 100 deviant trials per condition [2].

4.4.1. LAB MEDIA: VID_20260326_182133.mp4 00:02-00:04 and LAB MEDIA: 2026-04-16 12-38-00.mkv 05:05-05:10

4.4.2. LAB MEDIA: Table 1

4.5. Provide short breaks every 10 to 15 minutes to reduce fatigue and maintain data quality. During these breaks, assess the participant's perception of stimulus intensity and adjust the intensity if significant changes in subjective perception are reported [1].

4.5.1. LAB MEDIA: VID_20260326_182524.mp4

4.6. Finally, run the control sequence with stimuli sent to the stimulator normally while the hand of the subject is placed outside of the stimulating surface [1].

4.6.1. LAB MEDIA: VID_20260326_182646.mp4

Results

5. Results

5.1. During mechanical stimulation in the oddball paradigm, rare deviant stimuli of 145 milliseconds among frequent standard stimuli of 100 milliseconds failed to elicit clear and reliable event-related potentials [1]. No significant difference was observed between the standard [2] and the deviant responses [2].

5.1.1. LAB MEDIA: Figure 1. *Video editor: Show the “Oddball: mechano” panels*

5.1.2. LAB MEDIA: Figure 1. *Video editor: Highlight the blue curves in the “Oddball: mechano” panels*

5.1.3. LAB MEDIA: Figure 1. *Video editor: Highlight the red curves in the “Oddball: mechano” panels*

5.2. In the oddball paradigm with electrical stimulation, discernible bilateral event-related potential waveforms were generated [1]. However, comparisons between standard and [2] deviant responses did not reveal a significant or consistent mismatch negativity component [3].

5.2.1. LAB MEDIA: Figure 1. *Video editor: Show the “Oddball: electro” panels*

5.2.2. LAB MEDIA: Figure 1. *Video editor: Highlight the blue curves in the “Oddball: electro” panels*

5.2.3. LAB MEDIA: Figure 1. *Video editor: Highlight the red curves in the “Oddball: electro” panels*

5.3. Electrical stimulation in the roving paradigm produced clear bilateral event-related potentials [1]. A discernible bilateral mismatch negativity-like component emerged 240 to 280 milliseconds after stimulus onset [2].

5.3.1. LAB MEDIA: Figure 2. *Video editor: Show the “Roving: electro” panels for both the contralateral and ipsilateral traces*

5.3.2. LAB MEDIA: Figure 2. *Video editor: Highlight the shaded area marked “MMN-like resp” in the “Roving: electro” panels*

5.4. During bimodal electro-mechanical roving stimulation [1], both mechanical and electrical stimuli elicited distinct bilateral event-related potential waveforms [2].

5.4.1. LAB MEDIA: Figure 3.

5.4.2. LAB MEDIA: Figure 3. *Video editor: Highlight all the traces*

5.5. A notable contralateral mismatch negativity-like component emerged in response to electrical deviants between 170 and 280 milliseconds after onset [1], but no equivalent mismatch negativity was observed for mechanical deviants [2].

5.5.1. LAB MEDIA: Figure 3. *Video editor: Show upper contralateral panel and include the label roving: electro-mechano. Highlight the shaded area marked “MMN-like resp” in the “contralateral” panel*

5.5.2. LAB MEDIA: Figure 3. *Video editor: Show upper contralateral panel. Highlight the dashed red and blue traces in contralateral panel*

5.6. Ipsilateral mismatch negativity components were absent regardless of stimulus modality [1].

5.6.1. LAB MEDIA: Figure 3. *Video editor: Show the ipsilateral pane and include the label roving: electro-mechano*

5.7. In the control session, no detectable event-related potentials [1] were observed in either the contralateral [2] or ipsilateral regions of interest [3].

5.7.1. LAB MEDIA: Figure 4. *Video editor: Highlight “contra” trace*

5.7.2. LAB MEDIA: Figure 4. *Video editor: Highlight “ipsi” trace*

Electroencephalography

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

IPA: /ɪˌlek-troʊ-ən-ˌse-fə-ˈlā-grə-fē/

Phonetic Spelling: ihˌlekˌtrohˌenˌsehˌfuhˌlaaˌgruhˌfee

Multimodal

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

IPA: /ˌmʌl-ti-ˈmoʊ-dəl/

Phonetic Spelling: muhlˌteeˌmohˌduhl

Somatosensory

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

IPA: /sə-ˌma-tə-ˈsen(t)-s(ə-)rē/

Phonetic Spelling: suhˌmatˌuhˌsenˌsuhˌree

Neurophysiological

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

IPA: /,nʊr-ou-,fɪz-ē-ə-'lə-ji-kəl/

Phonetic Spelling: noor·oh·fiz·ee·uh·laa·ji·kuhl

Anatomical

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

IPA: /,an-ə-'tä-mi-kəl/

Phonetic Spelling: an·uh·taa·muh·kuhl

Electrode

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

IPA: /ɪ'lek,troʊd/

Phonetic Spelling: ih·lek·trohd

Vertex

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

IPA: /'vər-,teks/

Phonetic Spelling: vur·teks

Nasion

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

IPA: /'neɪzi,ɑ:n/

Phonetic Spelling: nay·zee·on

Inion

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

IPA: /'mi,ɑ:n/

Phonetic Spelling: in·ee·on

Preauricular

Pronunciation link: <https://www.howtopronounce.com/preauricular>

IPA: /,pri:ə:'rɪkjələr/

Phonetic Spelling: pree·aw·rik·yuh·ler

Abrading

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

IPA: /ə'breɪd/

Phonetic Spelling: uh·brayd

Conductive

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

IPA: /kən'dʌk-tɪv/

Phonetic Spelling: kuh·duhk·tiv

Impedance

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

IPA: /ɪmˈpiːdəns/

Phonetic Spelling: im·pee·duhns

Physiological

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

IPA: /ˈfiːzē-ə-ˈlā-jī-kəl/

Phonetic Spelling: fiz·ee·uh·laa·ji·kuhl

Artifacts

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

IPA: /ˈär-tə-ˌfakt/

Phonetic Spelling: ar·tuh·fakt

Milliamperes

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

IPA: /ˌmɪliˈæmˌpɪr/

Phonetic Spelling: mil·ee·am·peer

Staircase

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

IPA: /ˈster-ˌkās/

Phonetic Spelling: stair·kays

Oddball

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

IPA: /ˈäd-ˌbòl/

Phonetic Spelling: ahd·bawl

Deviant

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

IPA: /ˈdē-vē-ənt/

Phonetic Spelling: dee·vee·uhnt

Paradigm

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

IPA: /ˈper-ə-ˌdīm/

Phonetic Spelling: pair·uh·dyme

Transistor-transistor

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

IPA: /trən-ˈzi-stər/

Phonetic Spelling: tran·zis·ter

Synchronization

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

IPA: /,sɪŋ-krə-nə-'zā-shən/

Phonetic Spelling: sing·kruh·nuh·zay·shuhn

Hertz

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

IPA: /'hɜrts/

Phonetic Spelling: hurts

Contralateral

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

IPA: /,kän-trə-'la-t(ə-)rəl/

Phonetic Spelling: kon·truh·lat·uh·ruhl

Ipsilateral

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

IPA: /,ip-sə-'la-t(ə-)rəl/

Phonetic Spelling: ip·suh·lat·uh·ruhl

Event-related

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

IPA: /ɪ'vent/

Phonetic Spelling: ih·vent

Mismatch

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

IPA: /,mɪs'mætʃ/

Phonetic Spelling: mis·mach

Negativity

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

IPA: /,neg.ə'tɪv.ə.ti/

Phonetic Spelling: neg·uh·tiv·uh·tee