Effects of Cranial Electrotherapy Stimulation on Brain Activity in the Resting State

Jamie D. Feusner, M.D., Teena D. Moody, Ph.D., Emily Hembacher, B.A., Sarah Madsen, B.S., Susan Bookheimer, Ph.D., Alexander Bystritsky, M.D., Ph.D.
Semel Institute for Neuroscience and Human Behavior, Department of Psychiatry; Center for Cognitive Neuroscience; Ahmanson-Lovelace Brain Mapping Center
University of California, Los Angeles

Introduction

Cranial electrotherapy stimulation (CES) is an FDA-approved treatment for insomnia, depression, and anxiety that consists of a pulsed, alternating microwave applied to the head using electrodes placed on the forehead (Fig. 1). The mechanism of action of CES remains unclear, but the primary effect is postulated to be cortical and subcortical inhibition in the brain.

Methods

Safety testing

• CES device was safety tested in the MR environment before subject participation using a whole-body phantom, thermistor, and thermometer. Simultaneous CES activation and MR scanning did not produce heating or significant changes in voltage or current, and no artifacts were observed in the MR image.

Subject demographics

• 11 healthy right-handed male and female subjects 18-55 years old recruited from the community.

Current intensity determination

• Subjects underwent testing outside of scanner to determine sensory threshold for CES stimulation current.

Scan acquisition

• Using this individualized current intensity, subjects then engaged in a forced-choice test to ensure that he or she could not guess correctly if the device was on (at all greater than chance level).

Procedure

• Instructions: “Please keep your eyes closed for the duration of the scan, but try not to fall asleep. You do not have to think about anything in particular.”

• CES device cycled between 5 ON blocks of 22 sec (12 sec in middle due to device constraints) and 6 OFF blocks of 22 sec, for a total of 6 min, 30 sec. (Fig. 2)

• Completed two MRI runs at 0.5 Hz and 100 Hz order was counterbalanced across subjects.

• Administered “Stable” portion of Stroop-Traub Anxiety Inventory (STA) before and after scan session.

Results

Table 1: Individual subject data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Gender</th>
<th>STA</th>
<th>Current 0.5 Hz</th>
<th>Current 100 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>M</td>
<td>60</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>F</td>
<td>50</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>M</td>
<td>40</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 2: Local maxima for significant activations for ON vs. OFF

<table>
<thead>
<tr>
<th>Structure</th>
<th>Z score</th>
<th>x,y,z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral paraspinal cortex</td>
<td>3.34</td>
<td>6,12, 50</td>
</tr>
<tr>
<td>Pre- and post-central gyrus</td>
<td>3.30</td>
<td>40, 10, 50</td>
</tr>
<tr>
<td>Bilateral precuneus</td>
<td>3.13</td>
<td>-7, 24, 46</td>
</tr>
<tr>
<td>Middle frontal gyrus</td>
<td>2.86</td>
<td>-30, 6, 54</td>
</tr>
<tr>
<td>Left frontal pole</td>
<td>2.86</td>
<td>-38, 50, 6</td>
</tr>
<tr>
<td>100 Hz Deactivation</td>
<td>Z score</td>
<td>x,y,z</td>
</tr>
<tr>
<td>Postcentral gyrus</td>
<td>3.16</td>
<td>-42, -34, 58</td>
</tr>
<tr>
<td>Precentral gyrus</td>
<td>3.12</td>
<td>-22, -18, 70</td>
</tr>
<tr>
<td>Right superior parietal lobule</td>
<td>2.94</td>
<td>12, 12, 70</td>
</tr>
</tbody>
</table>

Conclusions

• CES stimulation is associated with cortical deactivation for 0.5 Hz and 100 Hz frequencies in bilateral frontal, parietal and posterior midline regions.

• No significant regional difference evident between the two frequencies, but greater effect for 0.5 Hz.

• Cortical deactivation may depend more on frequency of stimulation than on current intensity.

• CES stimulation produced changes in connectivity between the posterior cingulate and several nodes of the default-mode network.

• Whether cortical deactivation may relate to decrease in EEG frequencies found in other studies and to therapeutic action for anxiety and sleep needs to be directly tested in future studies.

References


Fig. 1: Regional deactivation associated with 0.5 Hz (blue) and 100 Hz (yellow).

Fig. 2: Changes in connectivity in DMN using posterior cingulate activated unit ON stimulation.

Fig. 3: Changes in connectivity in DMN using posterior cingulate activated unit OFF stimulation.

Fig. 4: Regions positively associated with increased connectivity for 0.5 Hz (blue).