Brain Stimulation for Aphasia

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Disclosures

• I have no financial disclosures

• I am collaborating with Soterix Medical, Inc. on a clinical trial of transcranial direct current stimulation for aphasia, funded by NIH.
Outline

• Non-invasive brain stimulation techniques
• Brain basis of aphasia recovery (to guide new treatments)
• Evidence so far on non-invasive brain stimulation for aphasia
  – TMS
  – tDCS
  – Results of a new tDCS trial
Neuromodulation

rTMS
Transcranial Magnetic Stimulation

Lines of magnetic flux
Magnetic coil
Induced current in brain

tDCS
Transcranial Direct Current Stimulation

Medications
Speech-Language Therapy
rTMS and tDCS Commonalities

- Increase or decrease cortical excitability
- Effects last minutes-hours after stimulation
- Repeated sessions have long-term effects

Nitsche et al., 2003
## rTMS vs. tDCS

### Differences

<table>
<thead>
<tr>
<th>rTMS</th>
<th>tDCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makes neurons fire</td>
<td>Alters the probability of neurons firing</td>
</tr>
<tr>
<td>Focal, precise anatomical effect</td>
<td>Anatomically wide effect</td>
</tr>
<tr>
<td></td>
<td>Cheaper</td>
</tr>
<tr>
<td></td>
<td>Simpler</td>
</tr>
<tr>
<td>Patient must stay still</td>
<td>Can move during Tx</td>
</tr>
<tr>
<td>Noisy</td>
<td>Silent</td>
</tr>
<tr>
<td>Small risk of seizure</td>
<td>No serious adverse events</td>
</tr>
</tbody>
</table>
Understanding the brain basis of aphasia recovery will (hopefully) help to guide the treatment approach.
Recovery from aphasia (weeks- years)

- Depends on
  - Resolution of remote dysfunction
  - Strategic shifts
  - Brain plasticity

- Constrained by
  - Lesion size and location
  - Health of the rest of the brain

Influenced by experience
Bilateral Language Activity in Chronic Post-Stroke Aphasia

12 studies: 106 patients, 129 controls

Controls
Aphasia

Turkeltaub et al., Neurology, 2011
The roles of the two hemispheres in aphasia recovery

• Left Hemisphere
  – Sparing of language networks
  – Perilesional compensation
    (Fridrikkson et al, 2010)

• Right Hemisphere
  – Compensation (Barlow 1877, Basso 1989, Blasi 2002, Xing 2015)
  – Inefficiency, dysfunction or interference (Naeser 2005, Postman-Caucheteux et al., 2010)
  – Domain general cognitive functions (Geranmayeh et al., 2014)
  – Mixed roles (Saur 2006, Turkeltaub 2011, Anglade 2014, others)
Language is not one thing

Lacey et al., 2017
Different brain regions may be recruited by different mechanisms

- Right M1-mouth activity and Right STS activity relate to good naming outcomes
- Right motor cortex recruited for naming when left motor cortex is damaged (Skipper-Kallal et al., 2017a)
- Right STS recruitment is blocked by left STS damage (Skipper-Kallal et al., 2017b)
Emerging Consensus

- Native left hemisphere networks are best
- Most efficient available networks
  - Perilesional cortex in small strokes
- Right hemisphere can compensate to some degree
  - Varies by specific language function
  - May be more important in the subacute period
- Multiple biologically and behaviorally driven mechanisms of change
Framework guiding rTMS Treatments: Interhemispheric Inhibition Model

Mutual transcortical inhibition

Unopposed inhibition after unilateral injury

Exogenous manipulation restores inhibitory equilibrium

Figure courtesy of Roy Hamilton
Randomized double-blind trials of inhibitory TMS to right IFG
Total N = 139

Ren et al., 2014
### A. ATT Repetition Subtest

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Real rTMS</th>
<th>Sham rTMS</th>
<th>Std. Mean Difference</th>
<th>Std. Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>ATT repetition subtest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heiss WD 2013</td>
<td>3.5</td>
<td>3.44</td>
<td>15</td>
<td>1.3</td>
</tr>
<tr>
<td>Thiel A 2013</td>
<td>3.11</td>
<td>3.56</td>
<td>13</td>
<td>1.11</td>
</tr>
<tr>
<td>Weiduschat N 2011</td>
<td>15.67</td>
<td>27.24</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>34</td>
<td></td>
<td>29</td>
<td></td>
</tr>
</tbody>
</table>

#### B. BDAE Repetition Subtest

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Real rTMS</th>
<th>Sham rTMS</th>
<th>Std. Mean Difference</th>
<th>Std. Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>Barwood CHS 2013</td>
<td>1.84</td>
<td>2.45</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Seniow J 2013</td>
<td>4.8</td>
<td>4.22</td>
<td>19</td>
<td>2.4</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>25</td>
<td></td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

#### Total (95% CI)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Total</th>
<th>Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (95% CI)</td>
<td>59</td>
<td></td>
<td>54</td>
<td></td>
<td>100.0%</td>
<td></td>
<td>0.54</td>
</tr>
</tbody>
</table>

#### Heterogeneity:
- Chi² = 0.38, df = 4 (P = 0.98); I² = 0%
- Test for overall effect: Z = 2.81 (P = 0.005)
- Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.97), I² = 0%

### B. ATT Writing Subtest

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Real rTMS</th>
<th>Sham rTMS</th>
<th>Std. Mean Difference</th>
<th>Std. Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>ATT writing subtest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heiss WD 2013</td>
<td>4.7</td>
<td>4.35</td>
<td>15</td>
<td>2.1</td>
</tr>
<tr>
<td>Thiel A 2013</td>
<td>4.94</td>
<td>4.44</td>
<td>13</td>
<td>1.94</td>
</tr>
<tr>
<td>Weiduschat N 2011</td>
<td>13.17</td>
<td>11.02</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>34</td>
<td></td>
<td>29</td>
<td></td>
</tr>
</tbody>
</table>

#### Total (95% CI)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Total</th>
<th>Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (95% CI)</td>
<td>34</td>
<td></td>
<td>29</td>
<td></td>
<td>100.0%</td>
<td></td>
<td>0.70</td>
</tr>
</tbody>
</table>

#### Heterogeneity:
- Chi² = 0.07, df = 2 (P = 0.97); I² = 0%
- Test for overall effect: Z = 2.68 (P = 0.007)

Ren et al., 2014
TMS Effect on Comprehension

Ren et al., 2014
### TMS Effect on Overall Severity

#### Real rTMS vs Sham rTMS

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>Weight (%)</th>
<th>Std. Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The global ATT score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weiduschat N 2011</td>
<td>19.83 (8.2)</td>
<td>8.5 (9.95)</td>
<td>10.1%</td>
<td>1.15 [-0.27, 2.57]</td>
</tr>
<tr>
<td>Hartmann A 2013</td>
<td>22.8 (12.36)</td>
<td>9.4 (12.79)</td>
<td>24.0%</td>
<td>1.02 [0.10, 1.95]</td>
</tr>
<tr>
<td>Thiel A 2013</td>
<td>23.6 (12.15)</td>
<td>7.55 (11)</td>
<td>25.1%</td>
<td>1.33 [0.43, 2.23]</td>
</tr>
<tr>
<td>Heiss WD 2013</td>
<td>22.4 (1.77)</td>
<td>8.6 (10.06)</td>
<td>25.4%</td>
<td>1.89 [0.99, 2.79]</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>45</td>
<td>39</td>
<td>84.8%</td>
<td>1.39 [0.90, 1.88]</td>
</tr>
<tr>
<td><strong>The global BDAE score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barwood CHS 2013</td>
<td>18.5 (36.68)</td>
<td>0.17 (28.73)</td>
<td>15.2%</td>
<td>0.51 [-0.65, 1.67]</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>6</td>
<td>6</td>
<td>15.2%</td>
<td>0.51 [-0.65, 1.67]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>51</td>
<td>45</td>
<td>100.0%</td>
<td>1.26 [0.80, 1.71]</td>
</tr>
</tbody>
</table>

- Heterogeneity: $\chi^2 = 3.79$, df = 4 (P = 0.44); $I^2 = 0\%$
- Test for overall effect: $Z = 5.44$ (P < 0.00001)
- Test for subarouo differences: $\chi^2 = 1.86$, df = 1 (P = 0.17), $I^2 = 46.3\%$

Ren et al., 2014
Limitations of TMS data

• Insufficient evidence for functional communication (i.e., measures of daily life communication)
• Mechanism of effect of right IFG inhibition is unclear
tDCS approaches

Left inferior frontal anodal stimulation

= anode (excitation)

= cathode (inhibition?)
tDCS approaches
Bi-frontal or left lateralizing frontal

= anode (excitation)

= cathode (inhibition?)
tDCS approaches
Bi-frontal or right lateralizing frontal

= anode (excitation)
= cathode (inhibition?)
tDCS approaches
Individually targeted

= anode (excitation)

= cathode (inhibition?)
tDCS approaches
Individually targeted

= anode (excitation)
= cathode (inhibition?)
Lots of small studies

<table>
<thead>
<tr>
<th>Articles</th>
<th>Number and type of patients</th>
<th>Target</th>
<th>Control condition</th>
<th>Stimulation polarity and intensity</th>
<th>Duration and number of sessions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polanski et al. [105]</td>
<td>24 (post-acute stroke/non-fluent aphasia: 3-24 weeks after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Anodal 1 mA</td>
<td>10 min, 15 sessions (followed by 45 min of picture naming task)</td>
<td>Improvement in naming accuracy and naming response time in both groups (A-DCS and sham).</td>
</tr>
<tr>
<td>Polanski et al. [105]</td>
<td>37 (post-acute stroke/non-fluent aphasia: 3-24 weeks after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Anodal 1 mA</td>
<td>10 min, 15 sessions (followed by 45 min of picture naming task)</td>
<td>Improvement in the BDAE in both groups (A-DCS and Sham) both at post-treatment and at 3 months follow-up.</td>
</tr>
<tr>
<td>Marangolo et al. [105]</td>
<td>12 (chronic stroke/non-fluent aphasia: 5-94 months after stroke)</td>
<td>LPG Left Wernicke’s area</td>
<td>sham</td>
<td>Anodal, 1 mA</td>
<td>20 min, 10 sessions (during conversational therapy)</td>
<td>Improvement in repetition accuracy and response time for syllables, words and sentences (as trained and untrained stimuli) after hemispherically (A-DCS at post-treatment and at 1 week follow-up).</td>
</tr>
<tr>
<td>Marangolo et al. [105]</td>
<td>12 (chronic stroke/non-fluent aphasia: 6-74 months after stroke)</td>
<td>LPG and Cathodal (A-DCS over LPG)</td>
<td>sham</td>
<td>Cathodal, 2 mA</td>
<td>20 min, 10 sessions (during repetition task)</td>
<td>Improvement in verb naming after A-DCS over the LPG at post-treatment and at 1 month follow-up.</td>
</tr>
<tr>
<td>Marangolo et al. [105]</td>
<td>8 (chronic stroke/non-fluent aphasia: 12-84 months after stroke)</td>
<td>LPG Left Wernicke’s area</td>
<td>sham</td>
<td>Anodal, 1 mA</td>
<td>20 min, 5 sessions (during verb naming)</td>
<td>Improvement in naming response time in the BNT after LPG.</td>
</tr>
<tr>
<td>Lee et al. [108]</td>
<td>11 (chronic stroke/6 non-fluent and 5 fluent aphasia: 6-180 months after stroke)</td>
<td>Bilaterally, (A-DCS Anodal (A-DCS over LPG and Cathodal (A-DCS over LPG)</td>
<td>sham</td>
<td>Cathodal, 2 mA</td>
<td>30 min, 1 session (during picture naming task)</td>
<td>Improvement in naming accuracy after single A-DCS.</td>
</tr>
<tr>
<td>Fiore et al. [17]</td>
<td>7 (chronic stroke/non-fluent aphasia: 9-4 months after stroke)</td>
<td>LPG, Left Wernicke’s area</td>
<td>sham</td>
<td>Cathodal, 1 mA</td>
<td>20 min, 5 sessions (during noun and verb naming)</td>
<td>Improvement in name naming after A-DCS over the LPG at post-treatment and at 1 and 4 weeks follow-up.</td>
</tr>
<tr>
<td>Chermay et al. [15]</td>
<td>1 (chronic stroke/aphasia: 190 months after stroke)</td>
<td>Right Wernicke area</td>
<td>sham</td>
<td>Cathodal, 1 mA</td>
<td>13 min, 30 sessions (during SLT)</td>
<td>Improvement in auditory comprehension at post-treatment.</td>
</tr>
<tr>
<td>Von et al. [27]</td>
<td>21 (post-acute stroke/non-fluent aphasia: 26-38 days after stroke)</td>
<td>Left or right Wernicke’s area</td>
<td>sham</td>
<td>Anodal over left Wernicke’s area or cathodal (right Wernicke’s area, 2 mA</td>
<td>30 min, 10 sessions (during SLT)</td>
<td>Improvement in auditory verbal comprehension after C-DCS at post-treatment. No follow-up.</td>
</tr>
<tr>
<td>Vieni et al. [59]</td>
<td>6 (chronic stroke/non-fluent aphasia: 15-20 months after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Anodal, 1.2 mA</td>
<td>20 min, 3 sessions (during repetition task)</td>
<td>Improvement in verbal fluency after A-DCS at post-treatment. No follow-up.</td>
</tr>
<tr>
<td>Marangolo et al. [105]</td>
<td>9 (chronic stroke/non-fluent aphasia: 15-28 months after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Anodal, 1 mA</td>
<td>20 min, 5 sessions (during repetition task)</td>
<td>Improvement in naming accuracy and response time after A-DCS at post-treatment and at 2 weeks follow-up.</td>
</tr>
<tr>
<td>Jung et al. [36]</td>
<td>37 (post-acute stroke/chronic stroke: average 221 days after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Cathodal, 1 mA</td>
<td>30 min, 10 sessions (during SLT)</td>
<td>Improvement in the WAB AQ. No follow-up.</td>
</tr>
<tr>
<td>Kang et al. [36]</td>
<td>10 (chronic stroke/9 non-fluent and 2 fluent aphasia: 6-381 months after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Cathodal, 2 mA</td>
<td>20 min, 5 sessions (during word-retrieval training)</td>
<td>Improvement in naming accuracy in the BNT at 1 h following the last C-DCS session, no changes after sham. No follow-up.</td>
</tr>
<tr>
<td>Friedl et al. [15]</td>
<td>10-150 months after stroke)</td>
<td>LPG</td>
<td>sham</td>
<td>Cathodal, 1 mA</td>
<td>20 min, 5 sessions (during repetition task)</td>
<td>Improvement in naming accuracy after A-DCS at post-treatment and at 3 weeks follow-up.</td>
</tr>
<tr>
<td>Friedl et al. [15]</td>
<td>12 (chronic stroke/9 non-fluent aphasia and 3 fluent aphasia: 14-200 months after stroke)</td>
<td>Right temporo-parietal cortex</td>
<td>sham</td>
<td>Cathodal, 1 mA</td>
<td>20 min, 3 sessions (2 × 1 h/day of computer-assisted training)</td>
<td>Improvement in naming accuracy after A-DCS at post-treatment and at 2 weeks follow-up.</td>
</tr>
<tr>
<td>Friedl et al. [15]</td>
<td>12 (chronic stroke/9 non-fluent aphasia: 21-71 months after stroke)</td>
<td>Left Wernicke’s area</td>
<td>sham</td>
<td>Anodal, 1 mA</td>
<td>20 min, 5 sessions (during SLT)</td>
<td>Improvement in naming accuracy and response time after A-DCS at post-treatment and at 3 weeks follow-up. (continued on next page)</td>
</tr>
</tbody>
</table>

Marangolo, 2017
tDCS trial in chronic aphasia

• Phase II randomized double-blind sham-controlled trial
  – Real vs. sham tDCS (2:1) with speech therapy
  – > 6 months post-stroke (broad inclusion)
  – Funded by Doris Duke Charitable Foundation and the National Center for Advancing Translational Sciences via the GHUCCTS
Study Design

Clinical eval + MRI

Sham + speech therapy x 5 days

Clinical eval + MRI

Clinical eval

Clinical eval + MRI

Week
1 3 4 6 16

Prespecified Primary Outcome Measure = WAB Naming and Word Finding
## Participants

<table>
<thead>
<tr>
<th></th>
<th>Active tDCS (N=24)</th>
<th>Sham tDCS (N=14)</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>60.2 (10.9)</td>
<td>60.1 (8.6)</td>
<td>P=.97</td>
</tr>
<tr>
<td>Sex</td>
<td>16M, 8 F</td>
<td>9M, 5F</td>
<td>P&gt;.99</td>
</tr>
<tr>
<td>Time since Stroke (mo)</td>
<td>55.1 (44.0)</td>
<td>44 (26.9)</td>
<td>P=.51</td>
</tr>
<tr>
<td>WAB AQ (/100)</td>
<td>66.3 (21.1)</td>
<td>65.1 (26.8)</td>
<td>P=.88</td>
</tr>
<tr>
<td>WAB N&amp;WF (/10)</td>
<td>6.1 (2.9)</td>
<td>6.1 (3.0)</td>
<td>P=.99</td>
</tr>
<tr>
<td>PNT (%)</td>
<td>53.6 (29.9)</td>
<td>53.6 (39.2)</td>
<td>P&gt;.99</td>
</tr>
<tr>
<td>Written PNT (%)</td>
<td>21.8 (16.25)</td>
<td>25.5 (21.7)</td>
<td>P=.57</td>
</tr>
</tbody>
</table>

Also matched on lesion size, apraxia, education

No serious Adverse Events
1 drop out (active tDCS, unclear reason, came to 2 week follow up only)
WAB Naming and Word Finding

![Bar graph showing WAB Naming and Word Finding change over time.]

- Post 1 Day
- Post 2 Weeks
- Post 3 Months

Active
Sham

$F_{(3,105)} = 1.78, \ P = .16, \ \text{partial } \eta^2 = .048$
WAB Aphasia Quotient

![Graph showing WAB Aphasia Quotient](image)

\[ F_{(3,105)} = 0.82, \ P = .48, \ \text{partial } \eta^2 = .023 \]
Spoken Naming

F_{(3,105)} = 0.28, P = .84, partial \eta^2 = .008
Written Naming

![Bar graph showing written naming performance over time for Active and Sham conditions.]

- Post 1 Day
- Post 2 Weeks
- Post 3 Months

N=34, F_{(3,96)} = 4.68, P = .004, partial η² = .128
tDCS Effect on Noun Naming Post-tDCS

Elsner et al., 2019
### tDCS Effect on Noun Naming at Follow-Up

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>tDCS N</th>
<th>Mean(SD)</th>
<th>Sham N</th>
<th>Mean(SD)</th>
<th>Std. Mean Difference</th>
<th>Weight</th>
<th>Std. Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meinzer 2016 (1)</td>
<td>11</td>
<td>24.3 (11.6)</td>
<td>11</td>
<td>8.7 (11.2)</td>
<td>32.4 %</td>
<td>1.32 [0.38, 2.26]</td>
<td></td>
</tr>
<tr>
<td>Spielmann 2016 (2)</td>
<td>26</td>
<td>12.5 (3.78)</td>
<td>32</td>
<td>10.6 (1.88)</td>
<td>67.6 %</td>
<td>0.65 [0.12, 1.18]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>37</strong></td>
<td><strong>43</strong></td>
<td><strong>100.0 %</strong></td>
<td><strong>0.87 [0.25, 1.48]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.07; Chi² = 1.47, df = 1 (P = 0.23); I² = 32%

Test for overall effect: Z = 2.77 (P = 0.0056)

Test for subgroup differences: Not applicable

---

Elsner et al., 2019
Other notes from the meta-analysis

• Moderate quality of evidence for naming
• No effect on functional communication
• No significant effect of stimulation site/polarity
• No significant effect of aphasia type
• Analysis of naming at follow-up did not include several papers for unclear reasons
• “Current evidence does not support the routine use of tDCS for aphasia after stroke.”

Elsner et al., 2019
Summary of Findings

• Negative trial

• Small to medium effects
  – Not clinically significant

• Largest effect was on written naming

• Variance in treatment group suggests individual differences
Recent positive developments

• Increasing sample sizes
  – Meinzer et al., 2016 (n=26)
  – Polanowska et al., 2013 (n=37)
  – Fridriksson et al., 2018 (n>60)
  – Turkeltaub et al., forthcoming (n=38)
  – Hillis, Tsapkini, Sebastian, in progress

• Multi-site RCTs
  – NORTHSTAR, completed enrollment (?)
  – TEASER, in progress (planned n = 58)

• Brain imaging pre and post
Needed areas of investigation for tDCS and rTMS

- Larger multi-site studies
- Systematic parameter exploration
  - Electrode placement
  - Polarity and intensity
  - Length of treatment
  - Timing (after stroke and in relation to therapy)
  - Stimulation- Therapy pairings
  - Individualized treatment approach
- Brain imaging measures to understand biological mechanisms of effect
- Clinically meaningful outcome measures
Conclusions

• rTMS and tDCS are both promising
• Both appear to be safe
• Efficacy not clearly established yet
• More research needed
  – Understanding brain basis of aphasia recovery
  – Understanding mechanisms of effect
  – Optimizing treatment protocols
  – Test for clinically meaningful effects
Thank You!

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