Effective connectivity of the naming network in post-stroke chronic aphasia

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Introduction

- The integrated functioning of anatomically segregated anterior and posterior left-lateralized brain regions is vital for successful language processing (e.g., Friston, 2011; Price, 2012; Vigneau et al., 2006)
- Specifically, in the context of oral picture naming, the left medio-temporal gyrus (LMTG) has been implicated in conceptual processing and the left inferior prefrontal gyrus (LIFG) has been found to be critical in controlled processing of semantic and phonological information (e.g., Indefrey & Levelt, 2004; Thompson-Schill et al., 2001; Wagner et al., 2001)
- Additionally, activation in regions associated with domain-general cognitive control, such as left middle frontal gyrus (LIFG), has been found for demanding language tasks, including picture naming (e.g., Fedorenko & Thompson-Schill, 2014; Murtha et al., 1999)
- During naming, multiple lexical and sub-lexical representations may be activated, and the cooperation of all aforementioned regions is required to generate a correct response
- Focal lesions to critical brain regions within this distributed network disrupt retrieval processes (Jeffries & Lambon Ralph, 2006)

While it is known that a picture naming task would activate regions involved in cognitive control such as LIFG, lexical selection such as LIFG, and semantic processing regions such as LMTG, little is known about the dynamic connectivity of this activation in persons with aphasia (PWA)

Study Aims

1. To investigate the nature of task-specific left hemisphere cortical reorganization in PWA relative to intact language networks in healthy individuals by examining effective connectivity via Dynamic Causal Modeling (Friston, Harrison, & Penny, 2003)
2. To examine the relationship between connectivity parameters, cortical structural damage and behavioral performance

Participants

- 13 participants with chronic aphasia secondary to left hemisphere CVA and 10 neurologically-intact controls participated in the study
- PWA also were administered a battery of tests assessing overall aphasia severity (Western Aphasia Battery-Revised, WA-BR) and naming skills (e.g., Boston Naming Test, BNT; picture naming screening)

Data Acquisition and Analysis

- MR images were acquired on a Siemens Trio TIM with a 20-channel head-neck coil
- T1 images were acquired with the following parameters: TR = 2300ms, TE = 2.91ms, 176 sagittal slices, 1x1x1mm voxels
- Functional images were acquired with the following parameters: TR = 2570ms, TE = 30ms, 40 axial slices, interleaved with 2x2x2mm voxels
- All participants completed 2 runs of an overt picture-naming task including experimental stimuli from 3 of 5 categories (i.e., birds, vegetables, fruit, clothing, and furniture) naming image
- Lesion masks were hand-drawn in Mircron
- SPMM was used for fMRI analysis
- ART Repair within the SPM toolbox applied for volume displacement > 0.5mm

Dynamic Causal Modeling (DCM)

- VOI selection
  - LIFG: anterior / middle / posterior regions; LMTG and LMFG: around the border of the LIFG and LMTG, respectively
  - Model specification
  - Input LMTG
  - Input LIFG
  - Family-wise BMS
  - Single-subject: data-driven approach

Lesion Information

- Lesion overlap in PWA (n = 13)
- % spared tissue

<table>
<thead>
<tr>
<th>% Spared Tissue per Region in PWA</th>
<th>LIFG</th>
<th>LMTG</th>
<th>LMFG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWA 1</td>
<td>95.66</td>
<td>100.00</td>
<td>79.70</td>
</tr>
<tr>
<td>PWA 2</td>
<td>65.55</td>
<td>98.28</td>
<td>68.69</td>
</tr>
<tr>
<td>PWA 3</td>
<td>99.06</td>
<td>100.00</td>
<td>61.33</td>
</tr>
<tr>
<td>PWA 4</td>
<td>82.80</td>
<td>100.00</td>
<td>14.20</td>
</tr>
<tr>
<td>PWA 5</td>
<td>92.47</td>
<td>96.44</td>
<td>70.39</td>
</tr>
<tr>
<td>PWA 6</td>
<td>89.59</td>
<td>100.00</td>
<td>76.11</td>
</tr>
<tr>
<td>PWA 7</td>
<td>99.98</td>
<td>100.00</td>
<td>65.91</td>
</tr>
<tr>
<td>PWA 8</td>
<td>100.00</td>
<td>100.00</td>
<td>91.84</td>
</tr>
<tr>
<td>PWA 9</td>
<td>99.98</td>
<td>100.00</td>
<td>97.00</td>
</tr>
<tr>
<td>PWA 10</td>
<td>80.77</td>
<td>73.95</td>
<td>99.69</td>
</tr>
<tr>
<td>PWA 11</td>
<td>49.52</td>
<td>53.33</td>
<td>45.53</td>
</tr>
<tr>
<td>PWA 12</td>
<td>58.48</td>
<td>98.66</td>
<td>56.14</td>
</tr>
<tr>
<td>PWA 13</td>
<td>53.89</td>
<td>98.75</td>
<td>59.95</td>
</tr>
</tbody>
</table>

- The values above reflect the amount of spared tissue in each cortical region of interest and were used in subsequent analyses

Models

- For connections, PWA had significantly less task-induced coupling from LMTG to LIFG (Ep.63 = 6.75, p < .02); this effect was observed across families

Results: Differences between PWA & Controls

- Best-fit model family differed between groups
- Variability seen at individual level in PWA
- No significant differences between groups in perturbation strength (Ep.C)
- For connections, PWA had significantly less task-induced coupling from LMTG to LIFG (Ep.B = 0.006 for PWA; Ep.B = 0.011 for Controls)

Conclusions

- The best-fit model families for each group indicate that PWA rely on more preserved LMTG to modulate other regions (e.g., Turkenbaum et al., 2013) while healthy older controls rely on regions associated with increased semantic control demands to drive naming (e.g., Valenciano et al., 2006)
- Significantly less task-induced coupling between LMTG and LIFG was seen for PWA relative to controls, which may have been influenced by the amount of damage to LMTG across the group
- Greater spared tissue in a given region was typically associated with a reduction of information flow between regions, excluding the relationship between spared tissue in LMTG and the LMTG-LIFG connection
- Significant associations were found between behavioral accuracy and spared tissue in prefrontal regions but surprisingly, not with LMTG