Anterior Temporal Involvement in Semantic Word Retrieval: VLSM Evidence from Aphasia

Myrna Schwartz, Dan Kimberg, Grant Walker, Olufunsho Faseyitan, Adelyn Brecher, Gary Dell & Branch Coslett

Versions of this talk were presented at the Academy of Aphasia meeting, Boston, October 2009 and the Neurobiology of Language Conference, Chicago, October 2009.
Computational case-series investigations of picture naming in aphasia

- Dell, Schwartz, Martin, Saffran & Gagnon (1997) *Psych Review*
- Foygel & Dell (2000) *JML*
- Schwartz & Brecher (2000) *Brain & Language*
- Schwartz, Dell, Gahl & Sobel (2006) *JML*
- Dell, Martin & Schwartz (2006) *JML*
- Kittredge, Dell, Verkuilen & Schwartz (2008) *CN*
- Nozari, Kittredge, Dell & Schwartz (in prep)
**Picture Naming**

- **Onsets**: FOG, D, G, K, M
- **Vowels**: æ, ò, o
- **Codas**: f, r, d, k, m, æ, ò, o, g, t

Words: FOG, CAT, RAT, MAT
Step 1

Onsets  Vowels  Codas

f  r  d  k  m  æ  o  g  t

FOG  DOG  CAT  RAT  MAT
Step 2
Semantic Error

Onsets: f r d k m
Vowels: æ o
Codas: g t
Semantics Error

FOG  CAT  RAT  MAT

Onsets: f r d k m
Vowels: æ o
Codas: g t
Semantic-Phonological Model of Aphasic Naming

- Model deviations cluster around zero
- Model explains 94.4% of total variance in naming response proportions

Schwartz, Dell, Gahl & Sobel (2006) *JML*
Where are the lesions that give rise semantic naming errors?
New case-series (n = 64)

- MRI/CT confirmed unilateral L cortical lesion
- Mn. MPO 68 (range 1-381); 92% were at least 6 months post
- Mn. 58 y.o. (28-78)
- Mn. 14 yrs. education (10-21)
Philadelphia Naming Test (PNT)

175 black and white line drawings of non-unique entities
Varied semantic categories (e.g., manipulable objects, 41%; animals, 15%)
Pictures have high familiarity, name agreement, and image quality
Names range in length from 1 to 4 syllables and in noun frequency from 1 to 2110 tokens per million (Francis and Kucera, 1982)

Semantic Errors

<table>
<thead>
<tr>
<th>Type</th>
<th>Target</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate</td>
<td>bus</td>
<td>car</td>
</tr>
<tr>
<td>Subordinate</td>
<td>flower</td>
<td>rose</td>
</tr>
<tr>
<td>Superordinate</td>
<td>necklace</td>
<td>jewelry</td>
</tr>
<tr>
<td>Synonym</td>
<td>frog</td>
<td>toad</td>
</tr>
<tr>
<td>Associated</td>
<td>cow</td>
<td>milk</td>
</tr>
</tbody>
</table>

Nonverbal Comprehension Tests

**Pyramids and Palm Trees** – Forced 2-choice decision, match picture of probe to picture of semantic associate. 52 trials. (Howard & Peterson, 1992)

**Camels and Cactus** – Forced 4-choice decision, match picture of probe to picture of semantic associate. 64 trials. (Bozeat et al., 2000)
Conceptual Semantic Error
### Table 1 Language test data and control norms

<table>
<thead>
<tr>
<th>Test/Measure</th>
<th>Participants with aphasia (n = 64)</th>
<th>Norms for healthy controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mdn</td>
</tr>
<tr>
<td>WAB Aphasia Quotient</td>
<td>76.8 (15.2)</td>
<td>81.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> Indicates a significant difference.
### Table 1  Language test data and control norms

<table>
<thead>
<tr>
<th>Test/Measure</th>
<th>Participants with aphasia (n = 64)</th>
<th>Norms for healthy controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Low</td>
</tr>
<tr>
<td>Aphasia Quotient</td>
<td>76.8 (15.2)</td>
<td>81.5</td>
</tr>
</tbody>
</table>

![Bar chart showing percentages of different types of aphasia]

Notes:
- ²Cut-off score is calculated based on the distribution of scores among the healthy controls.
<table>
<thead>
<tr>
<th>Test/Measure</th>
<th>Participants with aphasia (n = 64)</th>
<th>Norms for healthy controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mdn</td>
</tr>
<tr>
<td><strong>Aphasia Quotient</strong></td>
<td>76.8 (15.2)</td>
<td>81.5</td>
</tr>
<tr>
<td><strong>Cut-off score</strong></td>
<td>93.8^a</td>
<td></td>
</tr>
<tr>
<td><strong>Philadelphia naming test (PNT):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prop. Correct</td>
<td>0.69 (.26)</td>
<td>0.8</td>
</tr>
<tr>
<td>Prop. SemErr (SemErr)</td>
<td>0.03 (.03)</td>
<td>0.03</td>
</tr>
<tr>
<td>SemErr/TotErr</td>
<td>0.17 (.15)</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Note: ^a Cut-off score refers to the threshold for identifying aphasia. 

b Mn (SD) .97 (.018) indicates the mean (SD) for a different measure or metric.
### Table 1 Language test data and control norms

<table>
<thead>
<tr>
<th>Test/Measure</th>
<th>Participants with aphasia (n = 64)</th>
<th>Norms for healthy controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Median Low Highest</td>
</tr>
<tr>
<td>Aphasia Quotient</td>
<td>76.8 (15.2)</td>
<td>81.5 33.3 97.6</td>
</tr>
<tr>
<td>Philadelphia naming test (PNT):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prop. Correct</td>
<td>0.69 (.26)</td>
<td>0.8 0.02 0.97</td>
</tr>
<tr>
<td>Prop. SemErr (SemErr)</td>
<td>0.03 (.03)</td>
<td>0.03 0.00 0.12</td>
</tr>
<tr>
<td>SemErr/TotErr</td>
<td>0.17 (.15)</td>
<td>0.14 0.00 0.77</td>
</tr>
<tr>
<td>Nonverbal Comprehension tests:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyramids and palm trees test (pictures; max. 52)</td>
<td>46.4 (5.0)</td>
<td>47.8 24 52</td>
</tr>
<tr>
<td>Camel and cactus test (pictures; max. 64)</td>
<td>50.1 (7.6)</td>
<td>51.8 23 61</td>
</tr>
<tr>
<td>Composite measure (NVcomp; Mean of z-scores)</td>
<td>-0.04 (1.04)</td>
<td>0.16 -4.0 1.16</td>
</tr>
</tbody>
</table>
Lesion segmentation and warping

- MRI (n = 34 of 64) - lesions were segmented manually in native space
Lesion segmentation and warping

- MRI (n = 34) - lesions were segmented manually in native space
- Lesions were registered to a common template (Colin27) using an automated procedure (Avants et al., 2006; /www.picsl.upenn.edu/ANTS/)
Lesion segmentation and warping

- MRI (n = 34) - lesions were segmented manually in native space
- Lesions were registered to a common template (Colin27) using an automated procedure (Avants et al., 2006; /www.picsl.upenn.edu/ANTS/)
- Inspected by HBC, naïve with respect to the behavioral data
Lesion segmentation and warping

- MRI (n = 34) - lesions were segmented manually in native space
- Lesions were registered to a common template (Colin27) using an automated procedure (Avants et al., 2006; /www.picsl.upenn.edu/ANTS/)
- Inspected by HBC, naïve with respect to the behavioral data

- CTs (n = 30) – HBC drew lesion maps directly onto the template
Two VLSM Analyses

**Unfiltered** – Semantic error scores (SemErr) were mapped to lesions on a voxel-wise basis.

**Filtered** – (a) NVcomp scores were factored out of the SemErr measure by regression; (b) Residualized SemError scores were mapped to lesions on a voxel-wise basis.

Filtered analysis controls for faulty conceptualization processes that could give rise to SemErr at a pre-lexical stage.
Unfiltered – At each voxel, a t-test was performed comparing SemErr scores between patients with and without a lesion in that voxel.

Filtered – At each voxel a t-test was performed comparing residualized Sem Err scores between patients with and without a lesion in that voxel.

In each analysis, voxels in which fewer than 5 patients were lesioned were excluded.

Correction for multiple comparisons - t-maps were thresholded to control the False Discovery Rate (FDR) at $q = 0.01$, where $q$ is the expected proportion of false positives among supra-threshold voxels.

Analyses were done using the VoxBo brain imaging package: www.voxbo.org
Voxel-wise Lesion-Symptom Mapping: Coverage

Fig. 2

Maps depicting lesion overlaps of the 64 subjects in the left hemisphere. Maps A-D are at MNI x coordinates of -60, -54, -48, and -42 respectively. Map E is a single axial slice at z=-27.
Voxel-wise Lesion-Symptom Mapping: Unfiltered (SemErr)

Fig. 4. Voxel-wise t-value map. Supra-threshold voxels rendered on red ($t = 3.27$) to yellow ($t > 5$) scale. Sub-threshold voxels rendered on scale of green (just below threshold) to blue ($t < 0$ or below).
Significant correlation between lesion status and SemErr in:

1. ATL (BA 21/38) -- highest concentration of significant voxels
2. pMTG (lateral superior BA 37)
3. IFG/MFG (BA 45/46)
Voxel-wise Lesion-Symptom Mapping: Filtered (residualized SemErr)

Controlling for conceptual processing weakened effects in all three areas.

Only voxels in mid to anterior MTG remain significant.
ATL effect survives lesion-size correction

Uncorrected t-test threshold

Partial correlations:

<table>
<thead>
<tr>
<th>Region</th>
<th>Partial Correl&lt;sup&gt;a&lt;/sup&gt;</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA 21</td>
<td>.34</td>
<td>.006</td>
</tr>
<tr>
<td>BA 38</td>
<td>.33</td>
<td>.008</td>
</tr>
</tbody>
</table>

<sup>a</sup> % damage w. SemErr, partiailling out total lesion volume
Negative Findings for Wernicke’s Area
Negative Findings for Wernicke’s Area

Unfiltered vs. Filtered
... despite adequate coverage there
ATL locus agrees with ....

Iowa lesion studies: “Convergence regions” for lexical retrieval in L-ATL

Damasio, Grabowski, Tranel, Hichwa, & Damasio, *Nature* (1996)
ATL locus agrees with ....

Meta-analysis of imaging studies (Indefrey & Levelt, 2004)
ATL locus agrees with ....

Meta-analysis of imaging studies (Indefrey & Levelt, 2004)
ATL locus agrees with ....

Site of maximal atrophy in semantic dementia

Conclusions - 1

• Specific and necessary role for L-ATL in mapping concepts to words in production

• Role may be to convey fine-grained distinctions to the lexical system
  – Which features of a concept are more important, which less important, for selecting the right name from a competing set
  – Information that in the interactive 2-step model is expressed in the weighted connections between features and lemmas

• Hypothesize that damage to left ATL blunts this finer grain of differentiation, thereby raising the probability of semantic errors
Conclusions - 2

• In line with evidence from convergence zone theory, functional neuro-imaging, and
• Fails to support causal link between semantic error production and Wernicke’s area dysfunction (Hopkins acute stroke studies: DeLeon et al., 2007; Cloutman et al., 2009; others)
• Acute and chronic damage may have different effects on the brain’s network for concept-word mapping in production
We gratefully acknowledge the dedicated patients and families who made this study possible.
And the dedicated labmates who helped out with recruitment, and behavioral testing and scoring:

Laura Barde
Laurel Brehm
Jacqueline Cairone
Krista Cullen
Jennifer Gallagher
Marisa Gauger

A. Cris Hamilton
Jesse Hochstadt
Rachel Jacobson
Laura MacMullen
Michelle Rapp
Paula Sobel
And the NIDCD, which funds this work
The Neuro-Cognitive Rehabilitation Research Network (NCRRN) offers consultation and pilot funds

Visit ncrrn.org
Thank you!

mschwart@einstein.edu