A computational account of bilingual aphasia rehabilitation

Swathi Kiran
Speech & Hearing Sciences; Boston University
Department of Neurology; Massachusetts General Hospital
Communication Sciences & Disorders; University of Texas at Austin

Funding support from NIH/NIDCD: R21 DC009446; ASHF-Clinical Research Grant, ASHF New Investigator Grant
What is aphasia?

- Aphasia is characterized by language deficits such as problems speaking, understanding people, reading and writing.

- Approximately 80,000 people incur aphasia each year.

- It is estimated that 60% of the world is bi/multi-lingual.
Schematic of treatment for each participant

Pre-treatment assessment:
- Western Aphasia Battery
- BNT
- Bilingual Aphasia Test

Baselines: Naming across consecutive sessions & languages

Treatment on 1 set of examples in 1 language

Session 1: Training
Session 2: Testing & Training
Session 2: Testing & Training
Session 2: Testing & Training
Session 2: Testing & Training
Session 2: Testing & Training

Week 1
Week 2
Week 3
Week 4

Until 80% accuracy achieved on items trained

Post-treatment assessment:
- Standardized language tests

Treatment in English

Edmonds & Kiran, (2006) JSLHR
Bilingual Aphasia Rehabilitation

- Obviously, this translates to an increase in clinical need to address bilingual aphasia rehabilitation, but no clear guidelines on how to do so…

- No consistent results on rehabilitation of bilingual aphasia (Lorenzen & Murray, 2008; Faroqi-Shah et al., 2010)

- Few systematic studies that have examined and observed the extent of cross language transfer but results vary
  - (Croft et al., 2011; Edmonds & Kiran, 2006; Miertsch et al., 2009, Kiran & Roberts, 2009)
Schema for Bilingual Aphasia

L1 language exposure

L2 language exposure

Pre-stroke proficiency

L1 AoA

L2 AoA

L1 Post stroke impairment

L2 Post stroke impairment

Stroke
Is there another way to understand the nature of bilingual aphasia rehabilitation?

- Develop a computational simulation of bilingual aphasic naming deficits and rehabilitation of bilingual aphasia.

- Similar to predicting rehabilitation of naming deficits (Plaut, 1996) which has led to the complexity account of treatment deficits for naming deficits (Kiran, 2007)
Computational Modeling: SOM

- **Self Organizing Maps** (Kohonen, 1995) operate in two modes
  - Training - builds the map using input examples
  - Mapping - classifies a new input vector

- SOMs have been used to understand bilingual language learning (Li, Zhao & McWhinney, 2007) and biological/psychiatric conditions (Hamalainen, 1994; Hoffman, Grasemann, & Miikkulainen, 2011)
The Bilingual DISLEX Model

Semantic representations
260 hand-coded binary features

Phonetic representations
• Based on English and Spanish IPA transcriptions
• Numerical representations of phonemes

Grasemann et al., 2011; Mikkulainen & Kiran, 2009
The Bilingual DISLEX Model

Grasemann et al., 2011; Mikkulainen & Kiran, 2009
Naming Task in Bilingual DISLEX Model

Grasemann et al., 2011; Mikkulainen & Kiran, 2009
Model of Bilingual Lexical Access

Asymmetrical Model
(Kroll & Stewart, 1994
Kroll et al., 2010)
Develop a computational simulation of bilingual aphasic naming deficits and rehabilitation of bilingual aphasia.

**Step 1**
- Model pre-stroke/normal bilingual language performance
- Use AoA and exposure as training parameters
- DISLEX should be able to match pre-stroke English and Spanish performance

**Step 2**
- Simulate damage to the lexicon
- Distort associative connections with noise
- DISLEX should be able to model impairment in patients

**Step 3**
- Use the model to predict treatment outcomes
- Examine improvements in trained language and cross language transfer
Step 1

- Model pre-stroke/normal bilingual language performance
- Use AoA and exposure as training parameters
- DISLEX should be able to match pre-stroke English and Spanish performance

Grasemann et al., 2011; Mikkulainen & Kiran, 2009
Approach

Information about AoA, Language exposure, proficiency obtained from a language use question – Kiran et al. (2010, submitted)
Results of simulation of normal bilingual individuals

(Grasemann et al., 2010; Grasemann et al., 2011)
Step 2

- Simulate damage to the lexicon
- Distort associative connections with noise
- DISLEX should be able to model impairment in patients
Simulation of bilingual aphasia-DISLEX Model

- Lesion was applied to the connections from the semantic map to the phonetic maps.

- Adding Gaussian noise with $\mu = 0$ to all these connections.

- The amount of damage (the “lesion strength”) in each case was adjusted by changing the $\sigma$ of the noise between 0 and 1.0 in steps of 0.01.

Grasemann et al., 2011; Kiran et al., 2010
Results from DISLEX Model – Modeling Impairment in one patient

Grasemann et al., 2011; Kiran et al., 2010
Results DISLEX Model – Modeling Impairment in one patient

Grasemann et al., 2011; Kiran et al., 2010

Patient BNT scores
English = 35%
Spanish = 1.7%
DISLEX Model: Modeling impairment for 16 patients with aphasia
Accounting for pre-stroke proficiency and lesion damage adequately simulates naming impairment in bilingual aphasia
Step 3

- Use the model to predict treatment outcomes
- Examine improvements in trained language and cross language transfer
Patient Study 3:  (N = 17)

<table>
<thead>
<tr>
<th>Code</th>
<th>AOA</th>
<th>Lifetime Exposure</th>
<th>Treatment Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTBA01</td>
<td>Native native</td>
<td>high low</td>
<td>12.70 0.58</td>
</tr>
<tr>
<td>UTBA02</td>
<td>late native</td>
<td>low high</td>
<td>4.95 11.08</td>
</tr>
<tr>
<td>UTBA07</td>
<td>native native</td>
<td>moderate moderate</td>
<td>3.11 12.41</td>
</tr>
<tr>
<td>UTBA09</td>
<td>early native</td>
<td>moderate moderate</td>
<td>2.07 10.97</td>
</tr>
<tr>
<td>UTBA11</td>
<td>late native</td>
<td>moderate high</td>
<td>14.90 1.15</td>
</tr>
<tr>
<td>UTBA16</td>
<td>native native</td>
<td>high low</td>
<td>6.82 0.83</td>
</tr>
<tr>
<td>UTBA17</td>
<td>early native</td>
<td>high low</td>
<td>5.32 1.19</td>
</tr>
<tr>
<td>UTBA18</td>
<td>late native</td>
<td>moderate moderate</td>
<td>1.73 15.17</td>
</tr>
<tr>
<td>BUBA01</td>
<td>late native</td>
<td>low high</td>
<td>4.92 1.42</td>
</tr>
<tr>
<td>BUBA04</td>
<td>early native</td>
<td>high low</td>
<td>2.61 16.50</td>
</tr>
<tr>
<td>BUBA07</td>
<td>late native</td>
<td>low high</td>
<td>2.89 4.08</td>
</tr>
<tr>
<td>UTBA19</td>
<td>late native</td>
<td>low high</td>
<td>1.44 4.90</td>
</tr>
<tr>
<td>UTBA20</td>
<td>late native</td>
<td>low high</td>
<td>0 0</td>
</tr>
<tr>
<td>UTBA21</td>
<td>early native</td>
<td>low high</td>
<td>0 0</td>
</tr>
<tr>
<td>UTBA22</td>
<td>late native</td>
<td>low high</td>
<td>0.13 12.73</td>
</tr>
<tr>
<td>UTBA23</td>
<td>early native</td>
<td>low high</td>
<td>10.68 13.84</td>
</tr>
<tr>
<td>BUBA12</td>
<td>late native</td>
<td>low high</td>
<td>8.16 0</td>
</tr>
</tbody>
</table>
Schematic of treatment for each participant

Pre-treatment assessment:
Western Aphasia Battery, BNT, Bilingual Aphasia Test

Baselines: Naming across consecutive sessions & languages

Treatment on 1 set of examples in 1 language

Session 1: Training
Session 2: Testing & Training
Session 2: Testing & Training
Session 2: Testing & Training

Session 1: Training
Session 2: Testing & Training
Session 2: Testing & Training
Session 2: Testing & Training

Until 80% accuracy achieved on items trained

Post-treatment assessment:
Standardized language tests

Treatment in English

Edmonds & Kiran, (2006) JSLHR
Treatment protocol in Behavioral studies

1. Name picture
2. If incorrect, told correct name
3. Choose 6 correct features from 12 cards
4. Answer 15 yes/no questions about the item
5. Named item again with feedback

- Treatment always provided only in one language (either English/Spanish) and amount of improvement examined
- Generalization (cross language transfer) examined to untrained language

Edmonds & Kiran, 2006; Kiran & Roberts, 2009
Rehabilitation in the DISLEX Model

- The starting point was set to either a severe impairment in naming (30% or less accuracy) or mild impairment (70% or high naming accuracy).

- Model retrained trained with different number and schedule of presentations of words in one language.

- Treatment always provided only in one language (either English/Spanish) and amount of improvement examined.

- Generalization (cross language transfer) examined to untrained language.

Edmonds & Kiran, 2006; Kiran & Roberts, 2009
In order to evaluate the model

- Match the patient and model’s parameters on AoA, exposure and damage parameters and see if the model’s predictions match the actual data obtained.

Cross-correlation coefficient > .6 significant; > 2 SD errors
Patient and computational results:
Both languages high damage
Treatment in English

UTBA 01:
English: Early
Spanish: Native

English: High exposure
Spanish: Low exposure

Spanish ES: .58
English ES: 12.7
UTBA16:
English: Early
Spanish: Native

English: Moderate exposure
Spanish: Moderate exposure

Spanish ES: .83
English ES: 6.8
BUBA04:
English: Early
Spanish: Native

English: High exposure
Spanish: Low exposure

Spanish ES: 16.5
English ES: 2.52
Patient and computational results: Both languages low damage
BUBA01
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 1.42
English ES: 4.92
Patient and computational results:
Both languages differential damage
UTBA 17:

English: Early
Spanish: Native

English: Moderate exposure
Spanish: Moderate exposure

Spanish ES: 5.32
English ES: 1.19
UTBA 22:
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 12.7
English ES: 1.89
The model also does not always predict correct performance
BUBA07
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 4.08
English ES: 2.8
UTBA11
English: Late
Spanish: Native

English: High exposure
Spanish: High exposure

Spanish ES: 1.15
English ES: 14.9
UTBA 09:
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 0
English ES: 0
The model can also predicts what treatment outcome may have been if the other language was trained.
UTBA 09:
English: Early
Spanish: Native

English: Moderate exposure
Spanish: Moderate exposure

Spanish ES: 10.97
English ES: 2.07
Summary

- Model can predict rehabilitation outcomes
  - Of the 17 patients, good fit for 12 patients,
  - For patients that do not have a good fit, model overestimates outcomes
    - Education/literacy issues in patients
    - Severe phonological output deficits
    - Severity of language/cognitive issues
- Provides a starting point for understanding why patient did not improve
- Model can also predict what treatment outcome may have been if treatment plan was different that what was followed…
Conclusions

- These results highlight the important interaction between language proficiency, stroke impairment and language recovery.
  - No individual factor can independently predict the amount of treatment recovery.

- Training always improves the trained language but cross language transfer depends on AoA, amount of language exposure pre-stroke and extent of nature of stroke impairment.
  - e.g., in individuals with late AoA, low exposure and high damage, cross-language transfer is less likely to occur.
  - e.g., in individual with early AoA and moderate-high exposure, cross language transfer may be expected.
Conclusions..

- While preliminary, the combination of computational modeling and behavioral treatment provide a promising approach to examining the important issue of recovery of language in bilingual aphasia.
Acknowledgements

- UT Austin
  - Anne Alvarez
  - Ellen Kester
  - Rajani Sebastian

- Boston University
  - Danielle Tsibulsky
  - Fabiana Cabral
  - Lauren Liria