Simulating bilingual aphasia rehabilitation: Evidence from a computational model

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Funding support from NIH/NIDCD: R21 DC009446; ASHF-Clinical Research Grant, ASHF New Investigator Grant
Bilingual Aphasia

L1 language exposure  L1 Post stroke impairment
L1 AoA

L2 language exposure
L2 AoA

Pre-stroke proficiency

Stroke
Factors influencing language recovery and rehabilitation

Factors

- Age of acquisition
  - Learning history
- Exposure
- Language use
  - Education
- Impairment
  - Site/size of lesion
  - Impairment severity

Hernandez & Li, 2007; Li, Zhao, & McWhinney, 2007; Abutalebi, 2008

Fabbro, 2001a; Lorenzen & Murray, 2009; Mechelli, Crinion, et al., 2004
Bilingual Aphasia Rehabilitation

• 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)

• For instance…
English dominant patient
Trained in English

Equally proficient patient
Trained in Spanish

English dominant patient
Trained in Spanish

Edmonds & Kiran, 2006
English dominant patient
More impaired in Spanish
Trained in Spanish

Equally proficient
Trained in English

Kiran & Roberts, 2009
Goal of this project

- Develop a computational simulation of bilingual aphasic naming deficits and rehabilitation of bilingual aphasia.
  - Similar to predicting rehabilitation of naming deficits (Plaut, 1996)

- Self Organizing Maps (Kohonen, 1995) is a type of artificial neural network that is based on unsupervised learning.

- SOMs 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)
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
300 words, including those used for treatment

Semantic representations

- 260 hand-coded binary features
- E.g. “can fly”, “is a container”, “can be used as a weapon”

Phonetic representations

- Based on English and Spanish IPA transcriptions
- Numerical representations of phonemes
- E.g. frontness, openness, roundedness for vowels
The Bilingual DISLEX Model

Semantic map

English phonetic map

Spanish phonetic map
The Bilingual DISLEX Model
The Bilingual DISLEX Model

Semantic map

English phonetic map

Spanish phonetic map
Naming Task

Semantic map

English phonetic map

Spanish phonetic map

“Dog”
Model of Bilingual Lexical Access

Semantics

L1 \quad \rightarrow \quad \leftarrow \quad L2

Asymmetrical Model
(Kroll & Stewart, 1994)
Kroll et al., 2010)

(de Groot, 1992, 1994)
Model of Bilingual Lexical Access

(de Groot, 1992, 1994)

Asymmetrical Model
(Kroll & Stewart, 1994
Kroll et al., 2010)
Model of Bilingual Lexical Access

(de Groot, 1992, 1994)

Asymmetrical Model
(Kroll & Stewart, 1994
Kroll et al., 2010)
Approach

L1 language exposure

L1 AoA

L2 AoA

L2 language exposure

AoA

Early: < 10 years

Exposure

High > 60%

Pre-stroke proficiency

English performance: 80-96%

Spanish range: 65% - 92%

Information about AoA, Language exposure, proficiency obtained from a language use question – Kiran et al. (2010, submitted)
Simulate normal bilingual performance
• 39 normal bilinguals
• 19 patients with bilingual aphasia

(Grasemann et al., 2010; Grasemann et al., 2011; Kiran et al., 2010)
Results of simulation of normal bilingual individuals

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

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

- 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.

- Then, individual models of premorbid patient performance were used to investigate how damage to the model’s lexicon matched actual bilingual aphasia patient naming patterns.

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

Grasemann et al., 2011; Kiran et al., 2010
Results – Modeling Impairment

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

Different pre-stroke proficiency, different level of impairment

Patient BNT scores
English = 35%
Spanish = 1.7%
Modeling impairment for 16 patients with aphasia
Step 3

- Use the model to predict treatment outcomes
- Examine improvements in trained language and cross language transfer
Approach

L1 language exposure

L1 AoA

L2 AoA

L2 language exposure

L1 Post stroke impairment

L2 Post stroke impairment

Stroke

Lesion damage
High < 30%
Low > 70%

Pre-stroke proficiency
English performance: 80-96%
Spanish range: 65% - 92%

AoA
Early: < 10 years

Exposure
High > 60%
Approach

- 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.
## Patient Parameters

<table>
<thead>
<tr>
<th></th>
<th>Spanish AoA</th>
<th>Spanish exposure</th>
<th>Spanish Damage</th>
<th>English AoA</th>
<th>Spanish exposure</th>
<th>Spanish Damage</th>
<th>Trained Language</th>
<th>Trained Effect size</th>
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UTBA 09:
Spanish ES: 10.97
English ES: 2.07
UTBA 17:
Spanish ES: 5.32
English ES: 1.19
UTBA 01:
Spanish ES: .58
English ES: 12.7
UTBA 22:
Spanish ES: 12.7
English ES: 1.89
SPA: native, high exp, med-low dmg; ENG: late, low exp, med-high dmg

**Treatment in English**

<table>
<thead>
<tr>
<th>Probes</th>
<th>English Set 1-Trained</th>
<th>Spanish Set 1</th>
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BUBA01
Spanish ES: 1.42
English ES: 4.92
UTBA16:
Spanish ES: .83
English ES: 6.8
SPA: native, high exp, high dmg; ENG: late, low exp, high dmg

Treatment in English

No of Treatments

Naming Accuracy

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

0 1 2 3 4 5

BUBA07
Spanish ES: 4.08
English ES: 2.8
Summary

- Model can predict rehabilitation outcomes
  - Of the 16 patients, good fit for 11 patients,
  - For patients that do not have a good fit 5/16, model overestimates outcomes for 3 of them
  - Provides a starting point for understanding why patient did not improve

- Curve fitting analysis ongoing-can evaluate the extent of match.

- Model can also predict what treatment outcome may have been if treatment plan was different that what was followed…
Conclusions and future directions

• While preliminary, results from this project allows a direct comparison of outcomes using two parallel yet complementary scientific approaches.

• The combination of computational modeling and behavioral treatment provide a promising approach to examining the important issue of recovery of language in bilingual aphasia.

• In future, we are refining our ability to describe our own patients in terms of exposure, proficiency and impairment- which in of itself can help us better understand bilingual aphasia.
UT Austin
- Anne Alvarez
- Ellen Kester
- Rajani Sebastian

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

Acknowledgements
Results – Modeling Impairment in a different patient

More damage

Pre-stroke Similar pre-stroke proficiency, different level of impairment

Grasemann et al., 2011; Kiran et al., 2010
Results – Modeling Impairment in a third patient

Similar pre-stroke proficiency, same level of impairment

Impairment of 12/15 patients modeled well with symmetric damage