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A computational account of bilingual aphasia rehabilitation

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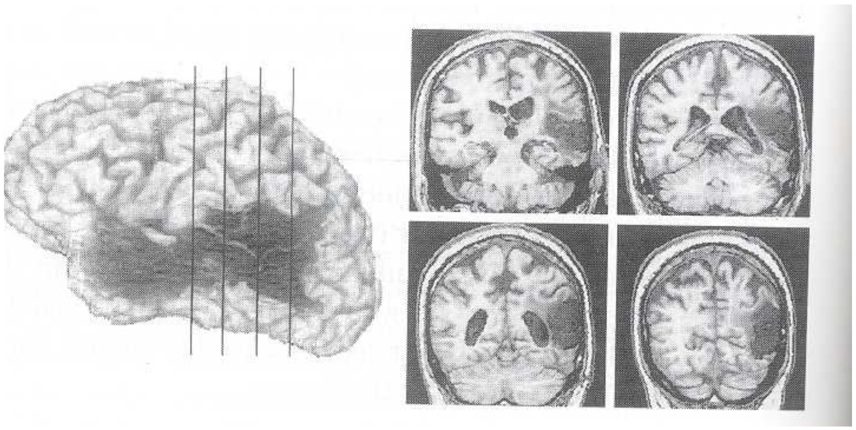
What is aphasia?

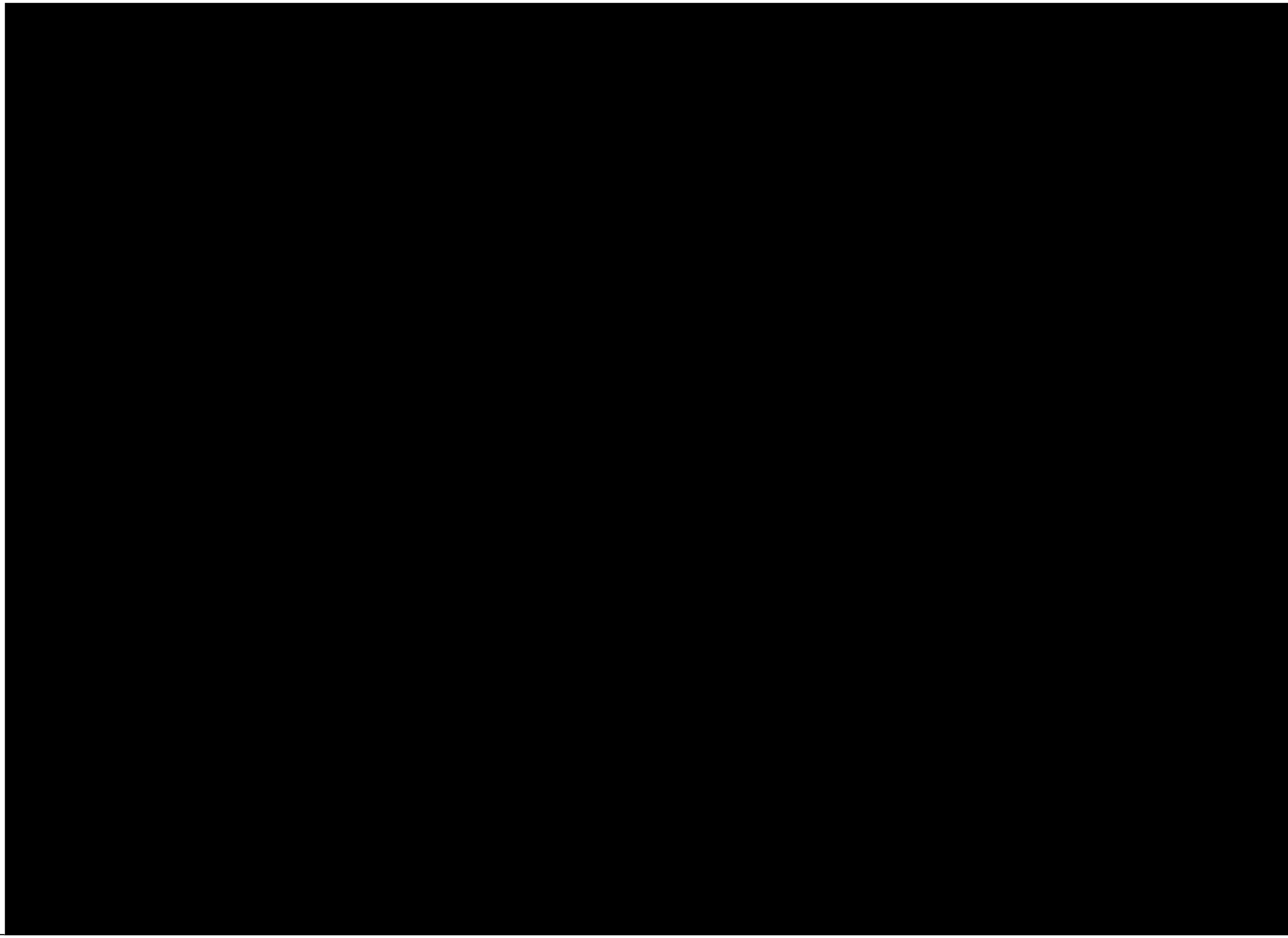
- Aphasia is characterized by language deficits such as problems speaking, understanding people, reading and writing

- Approximately 80,000 people incur aphasia each year

- It is estimated that 60% of the world is bi/multi-lingual



Bilingual Aphasia



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

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Week 1

Week 2

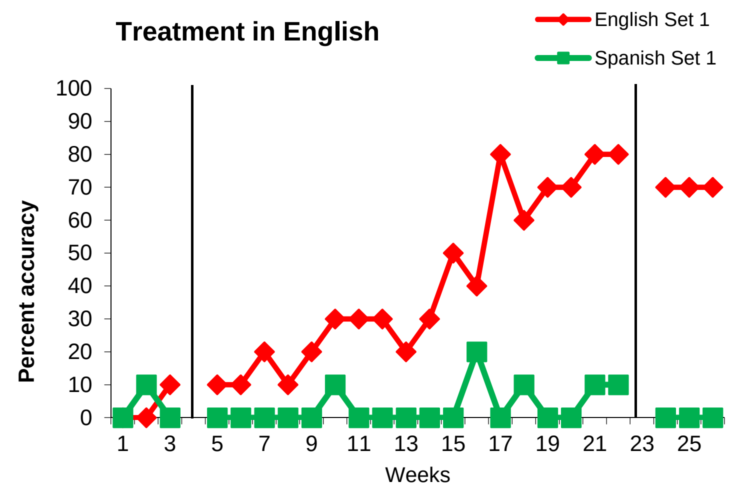
Week 3

Week 4

Session 1: Training
Session 2: Testing & Training

Until 80% accuracy achieved on items trained

Post –treatment assessment:
Standardized language tests



Edmonds & Kiran, (2006) *JSLHR*

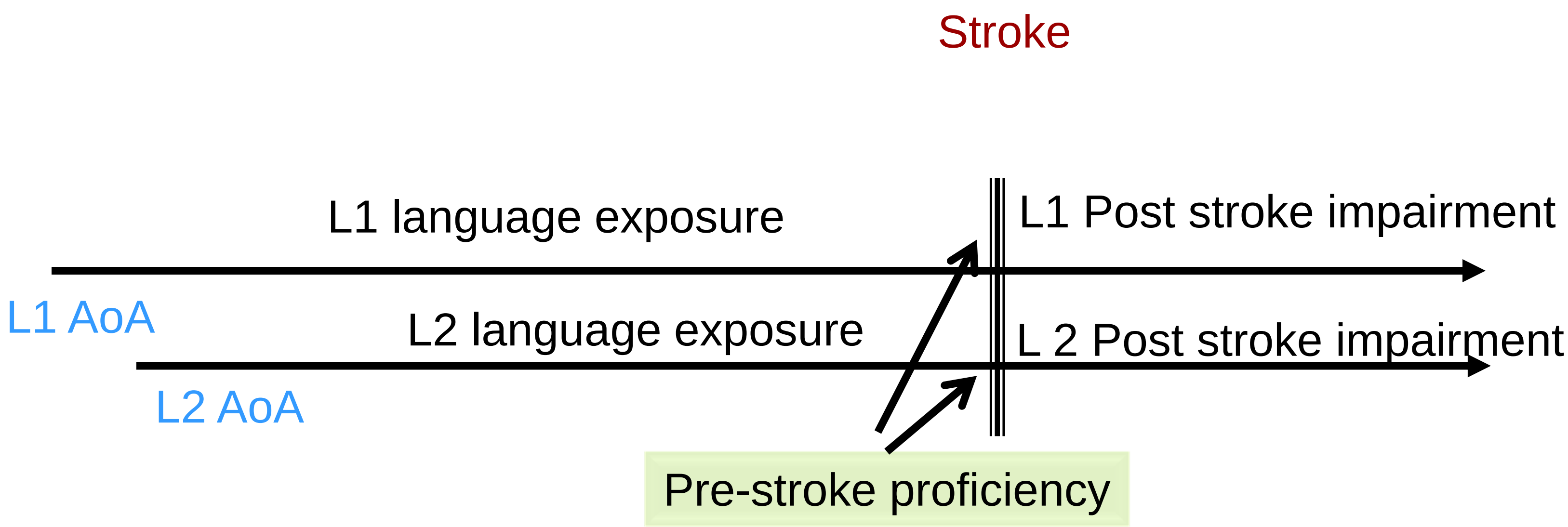
Bilingual Aphasia Rehabilitation

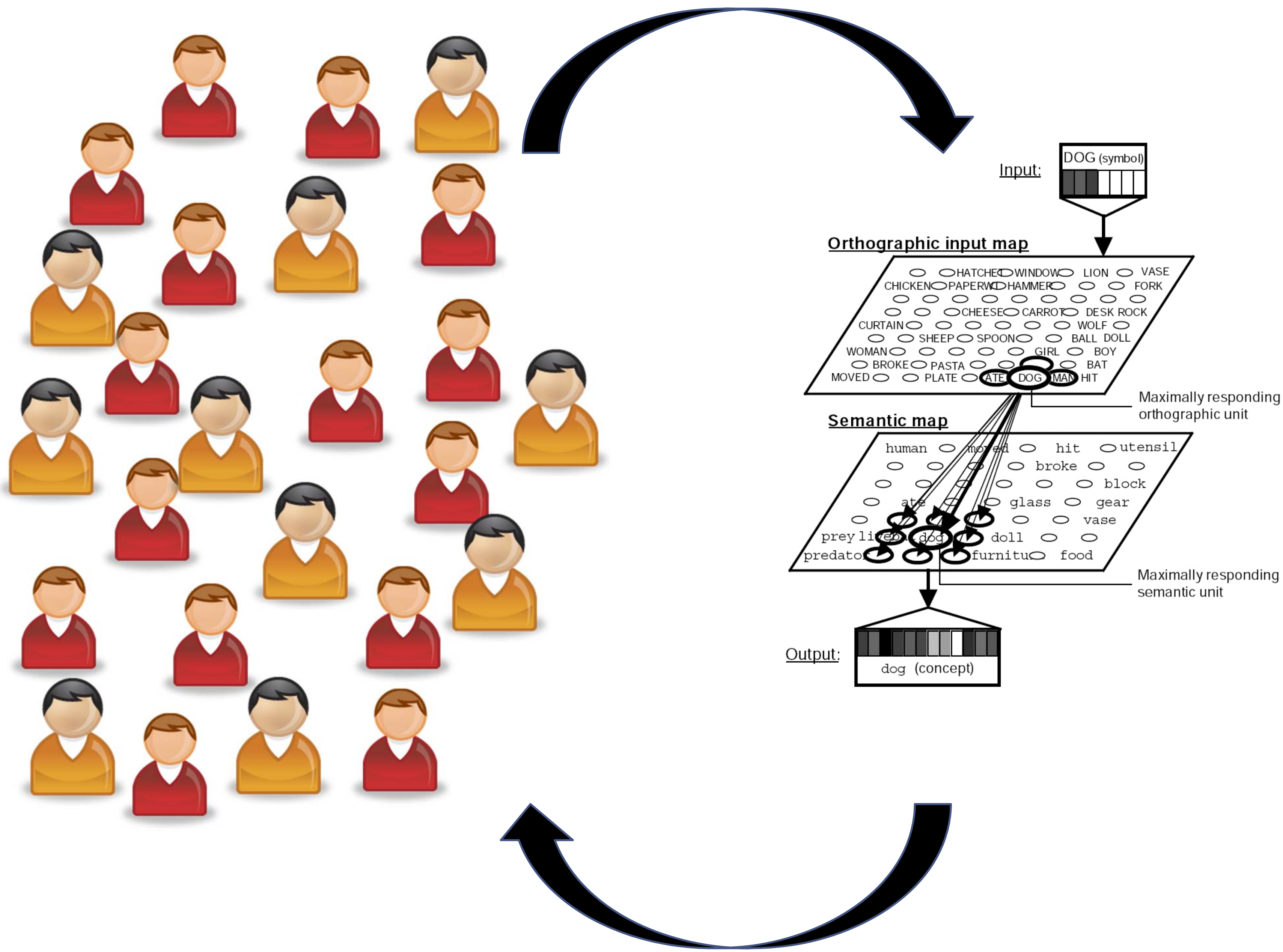
- Obviously, this translates to an increase in clinical need to address bilingual aphasia rehabilitation, but no clear guidelines on how to do so…

- 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





Input:
DOG (symbol)
Orthographic input map
HATCHET WINDOW LION VASE
CHICKEN PAPER HAMMER FORK
CHEESE CARROT DESK ROCK
CURTAIN WOLF
SHEEP SPOON BALL DOLL
WOMAN GIRL BOY
BROKE PASTA BAT
MOVED PLATE ATE DOG MAN HIT
Maximally responding orthographic unit
Semantic map
human moved hit utensil
broke
block
ate glass gear
vase
prey doll
predator furnitu food
Maximally responding semantic unit
Output:
dog (concept)

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)

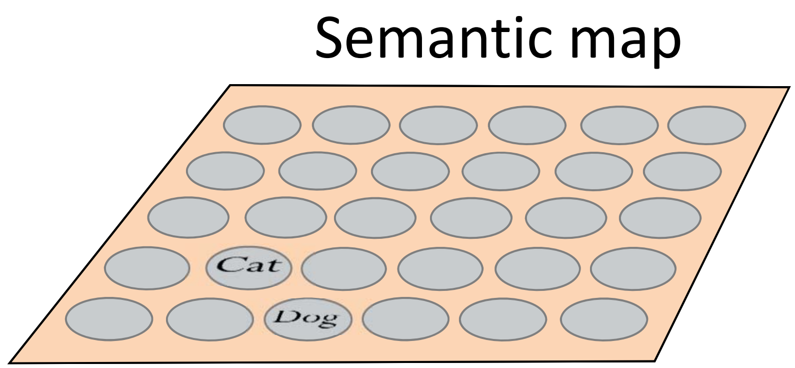
Computational Modeling: SOM

- 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)

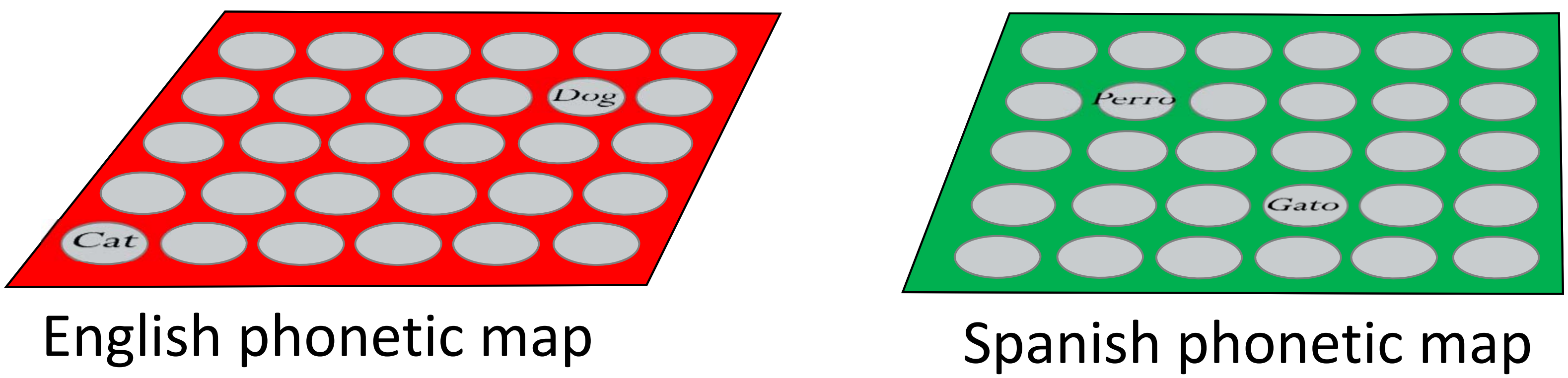
The Bilingual DISLEX Model

Semantic representations
260 hand-coded binary features



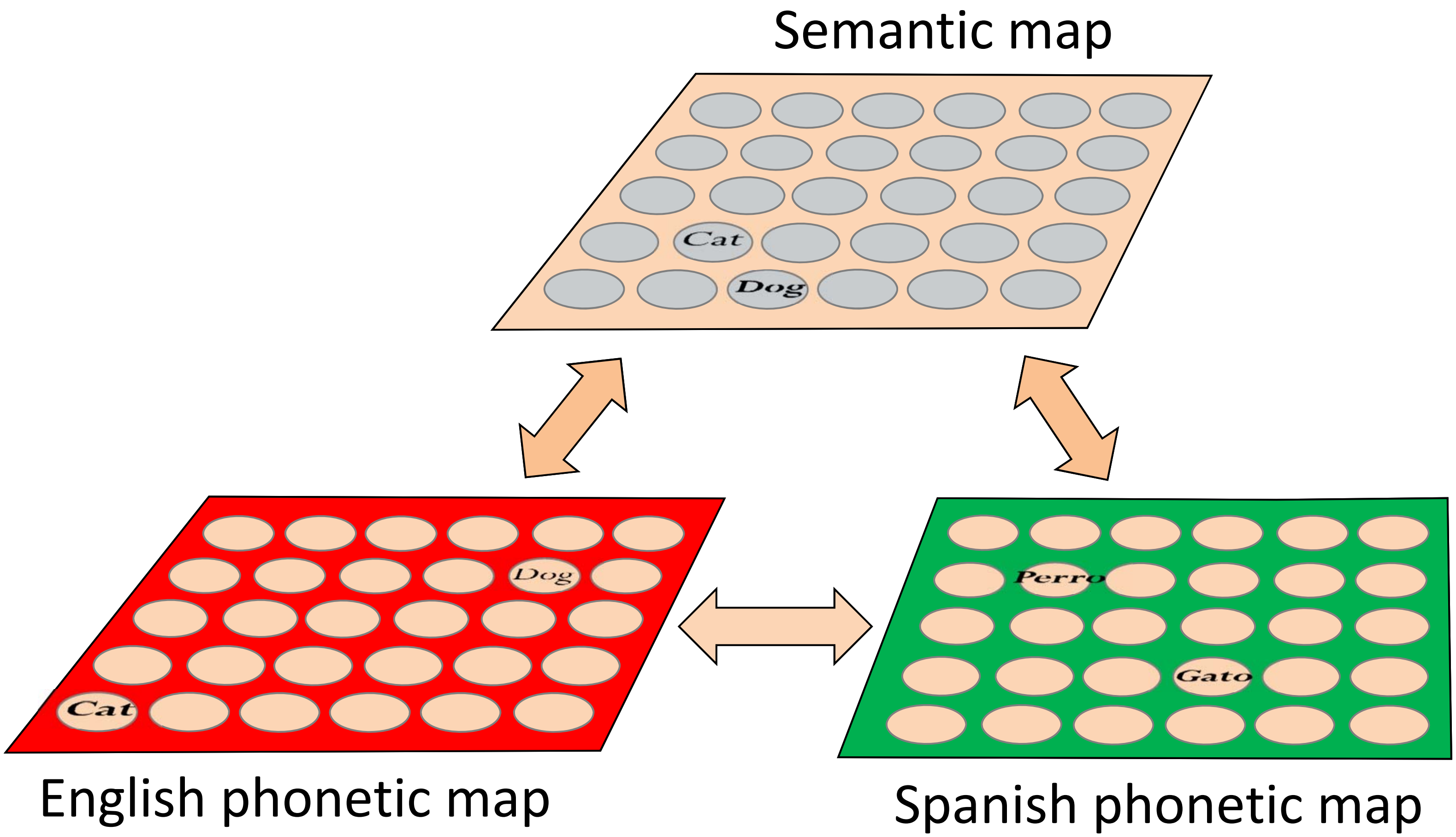
Phonetic representations

- Based on English and Spanish IPA transcriptions
- Numerical representations of phonemes



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

The Bilingual DISLEX Model



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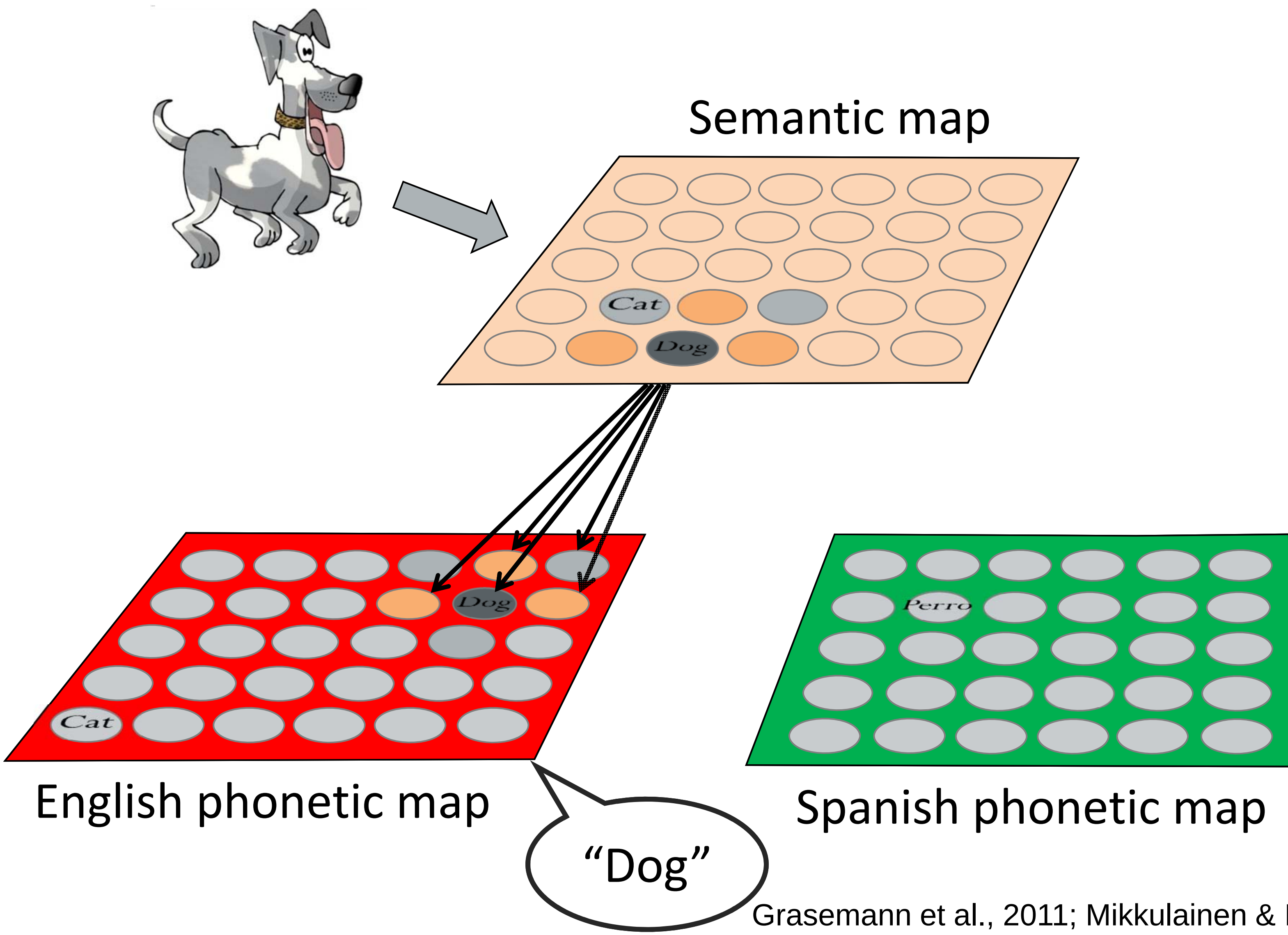
Naming Task in Bilingual DISLEX Model



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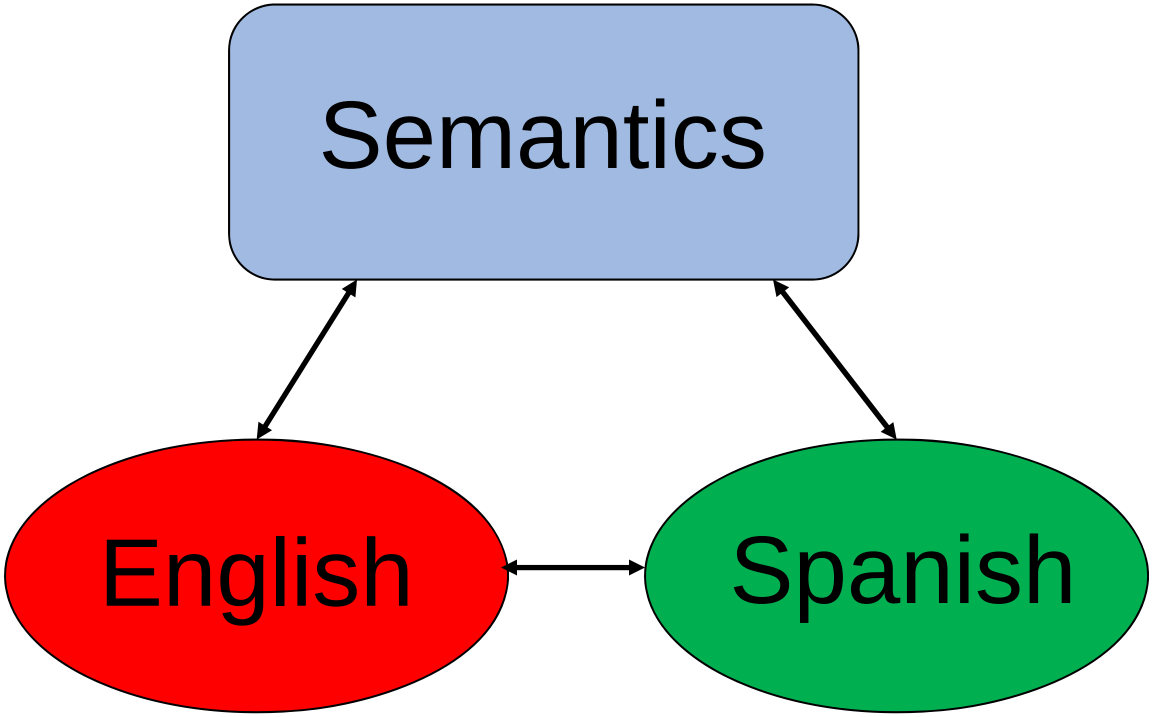
Model of Bilingual Lexical Access



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

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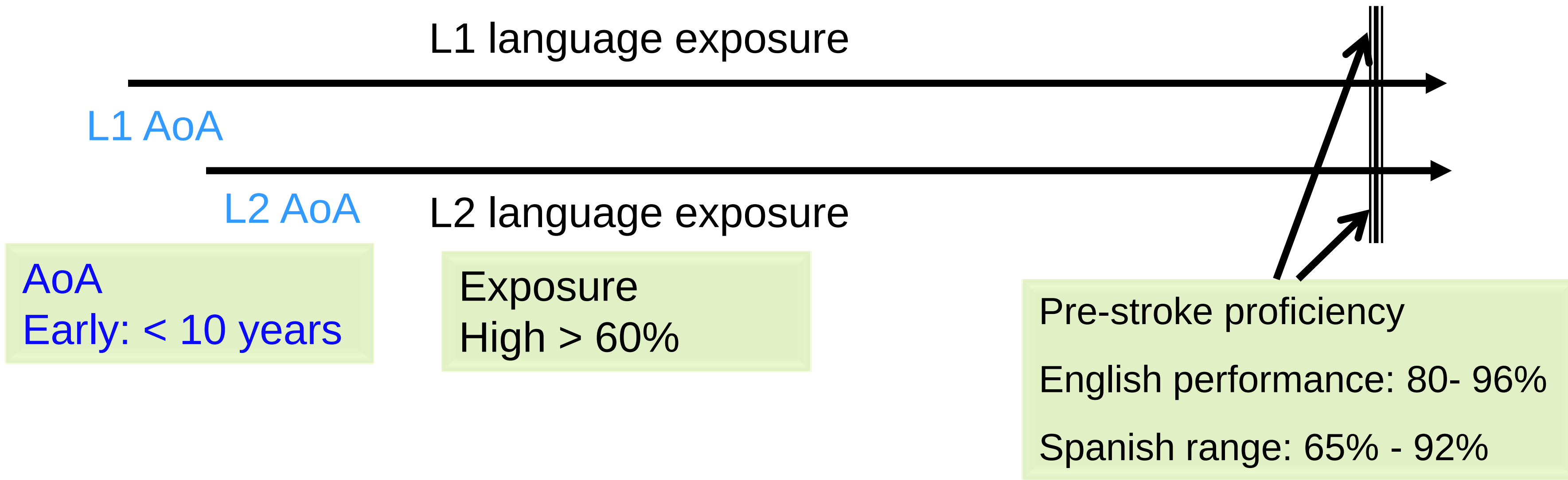
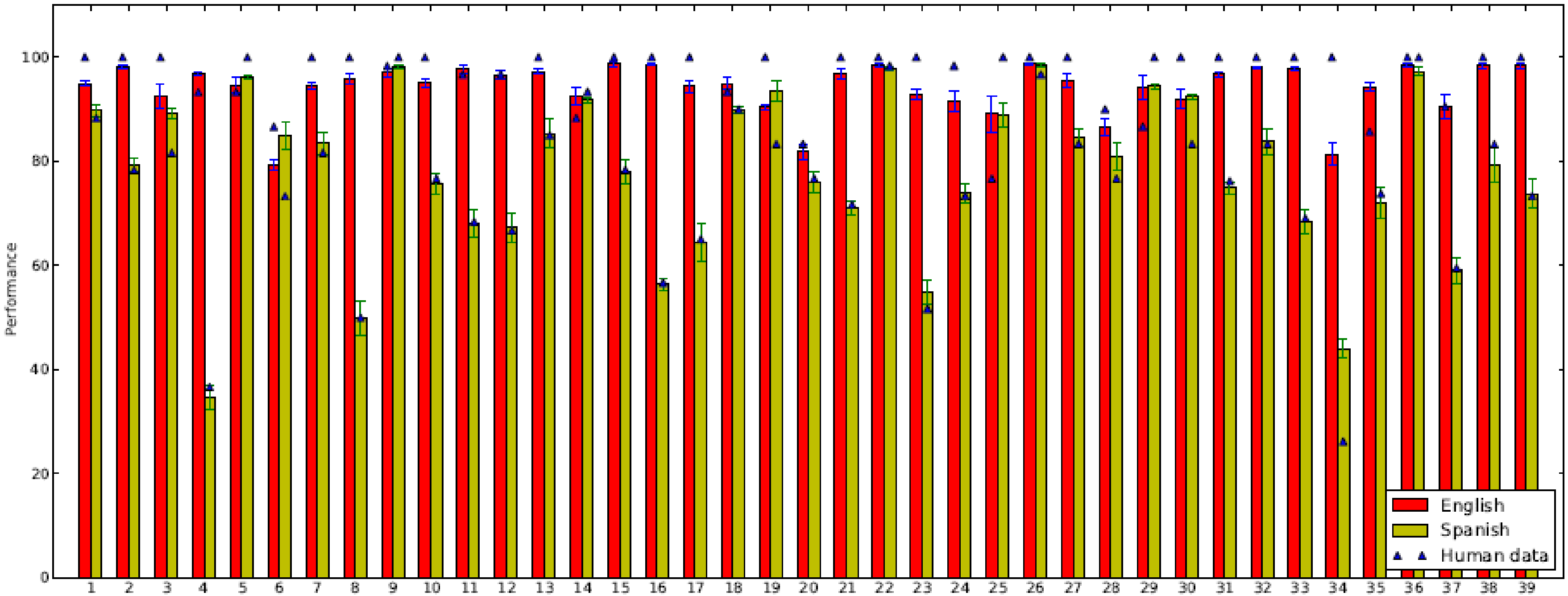
Grasemann et al., 2011; Mikkulainen & Kiran, 2009

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

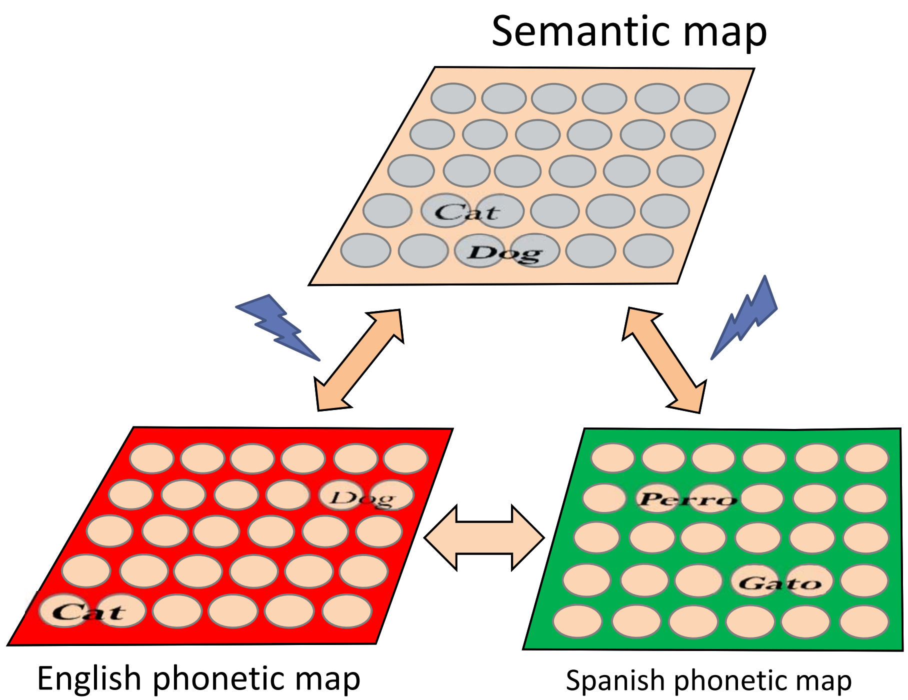
- Simulate damage to the lexicon
  - Distort associative connections with noise
  - DISLEX should be able to model impairment in patients

Simulation of bilingual aphasia-DISLEX Model

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

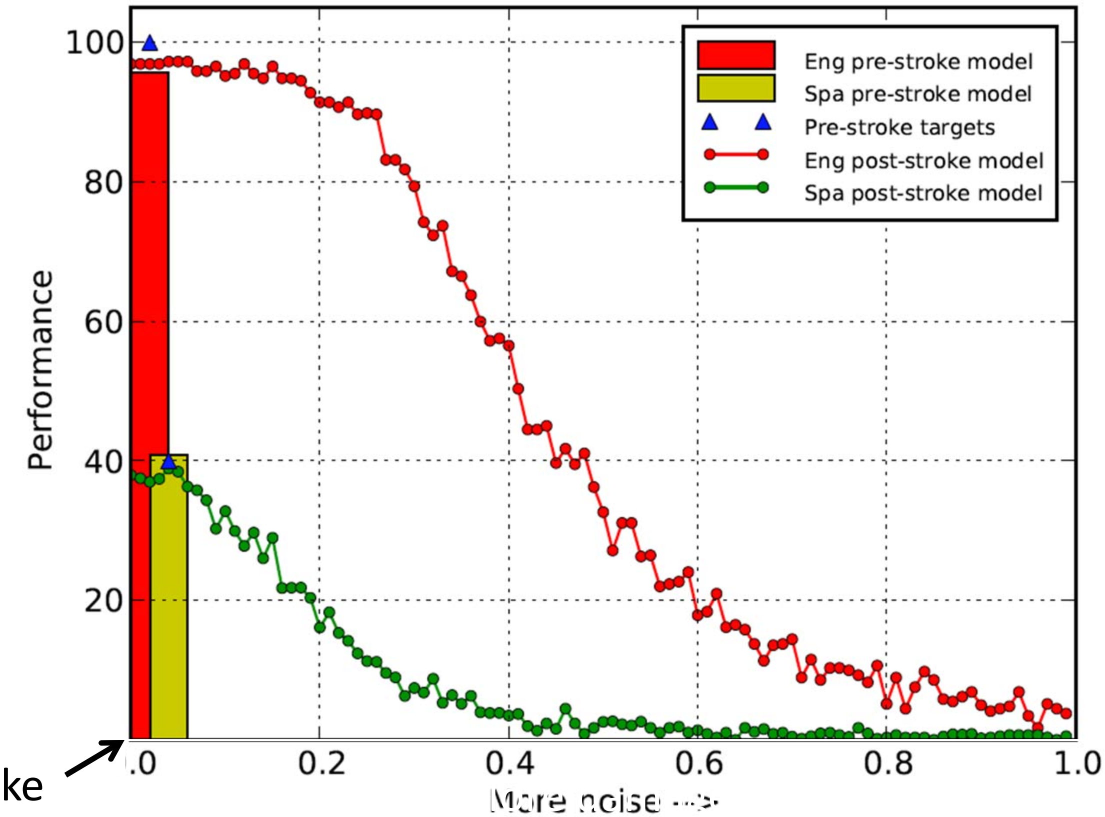
- Adding Gaussian noise with $\mu = 0$ to all these connections.

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



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

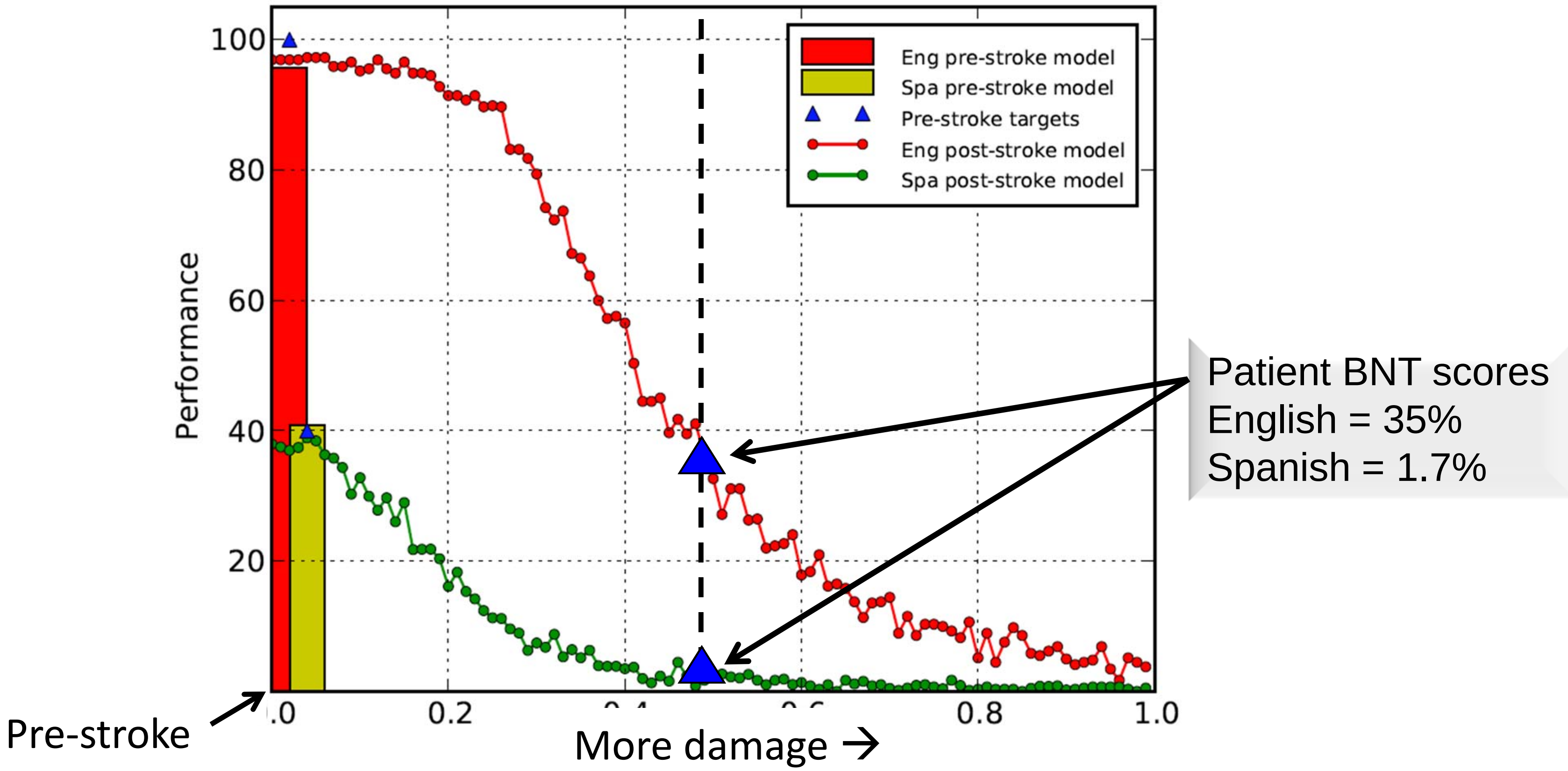
Results from DISLEX Model – Modeling Impairment in one patient



Pre-stroke

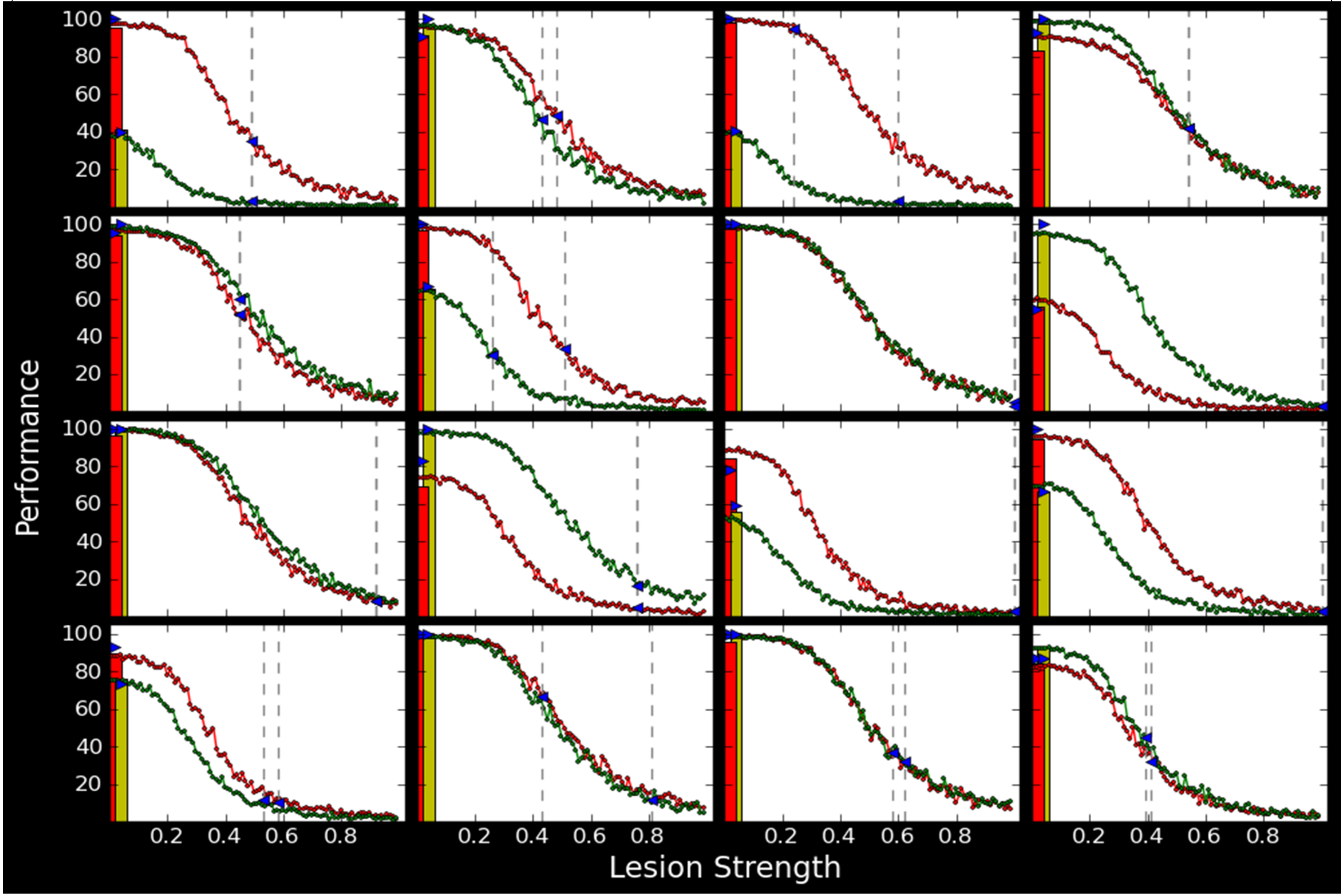
Grasemann et al., 2011; Kiran et al., 2010

Results DISLEX Model– Modeling Impairment in one patient

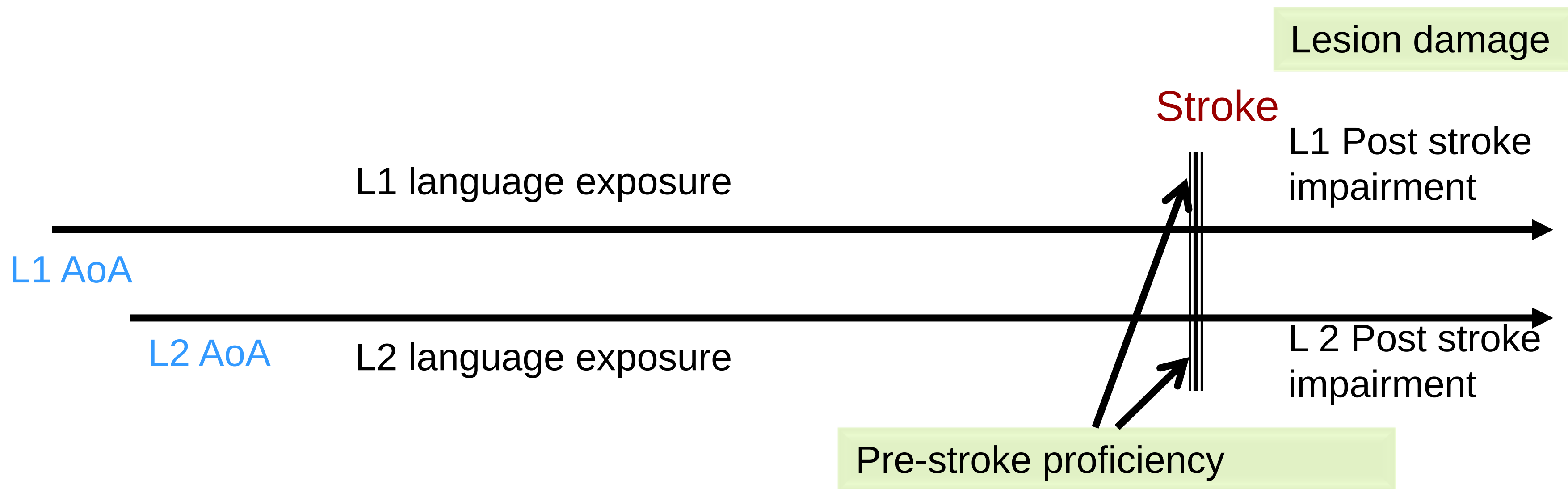


Grasemann et al., 2011; Kiran et al., 2010

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
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Patient Study 3: (N = 17)

	AOA		Lifetime Exposure		Treatment Effect Size	
	English	Spanish	English	Spanish	English	Spanish
UTBA01	Native	native	high	low	12.70	0.58
UTBA02	late	native	low	high	4.95	11.08
UTBA07	native	native	moderate	moderate	3.11	12.41
UTBA09	early	native	moderate	moderate	2.07	10.97
UTBA11	late	native	moderate	high	14.90	1.15
UTBA16	native	native	high	low	6.82	0.83
UTBA17	early	native	high	low	5.32	1.19
UTBA18	late	native	moderate	moderate	1.73	15.17
BUBA01	late	native	low	high	4.92	1.42
BUBA04	early	native	high	low	2.61	16.50
BUBA07	late	native	low	high	2.89	4.08
UTBA19	late	native	low	high	1.44	4.90
UTBA20	late	native	low	high	0	0
UTBA21	early	native			0	0
UTBA22	late	native	low	high	0.13	12.73
UTBA23	early	native	low	high	10.68	13.84
BUBA12	late	native	low	high	8.16	0

Schematic of treatment for each participant

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↓

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↓

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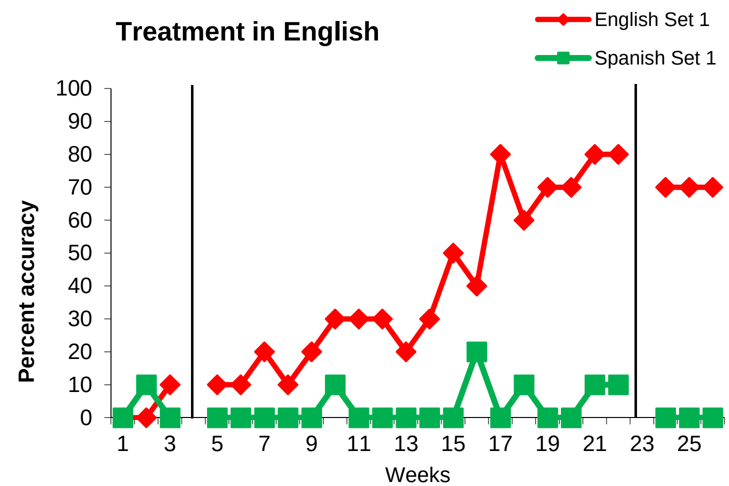
Until 80% accuracy achieved on items trained

↓

Post –treatment assessment:
Standardized language tests

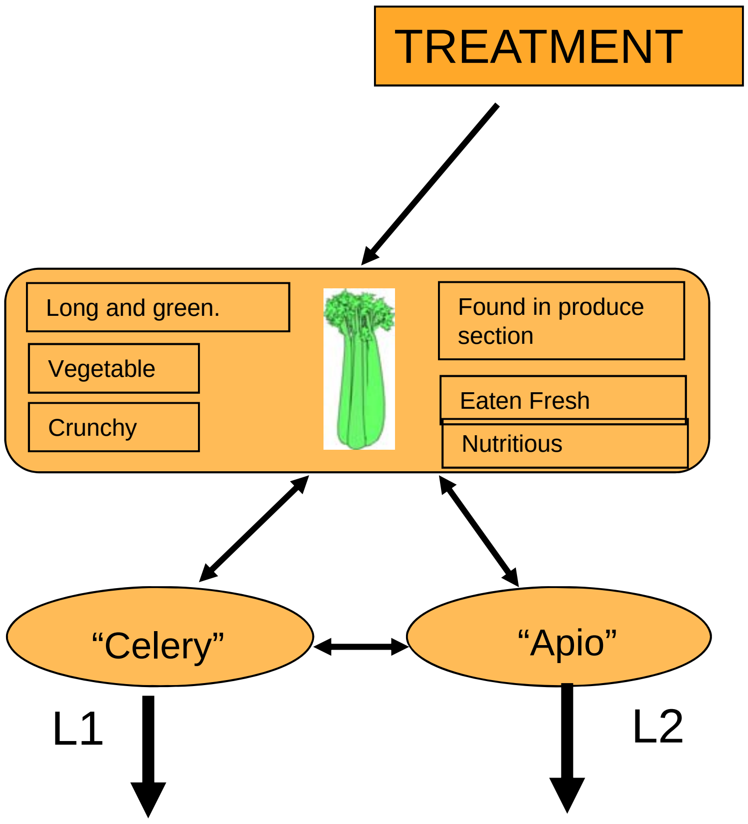


Edmonds & Kiran, (2006) *JSLHR*

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

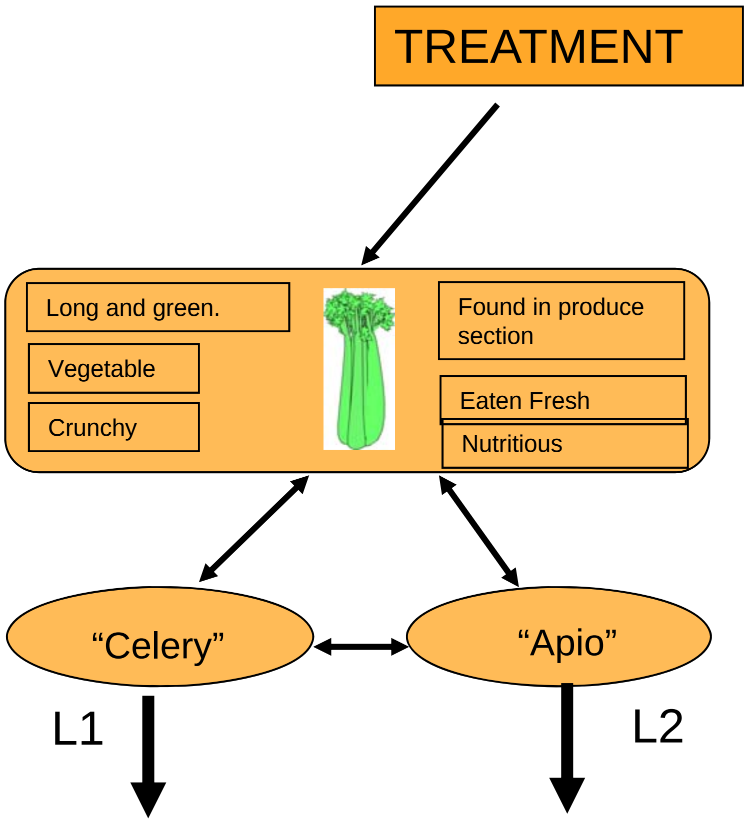
- Treatment always provided only in one language (either English/Spanish) and amount of improvement examined
- Generalization (cross language transfer) examined to untrained language



Edmonds & Kiran, 2006; Kiran & Roberts, 2009

Rehabilitation in the DISLEX Model

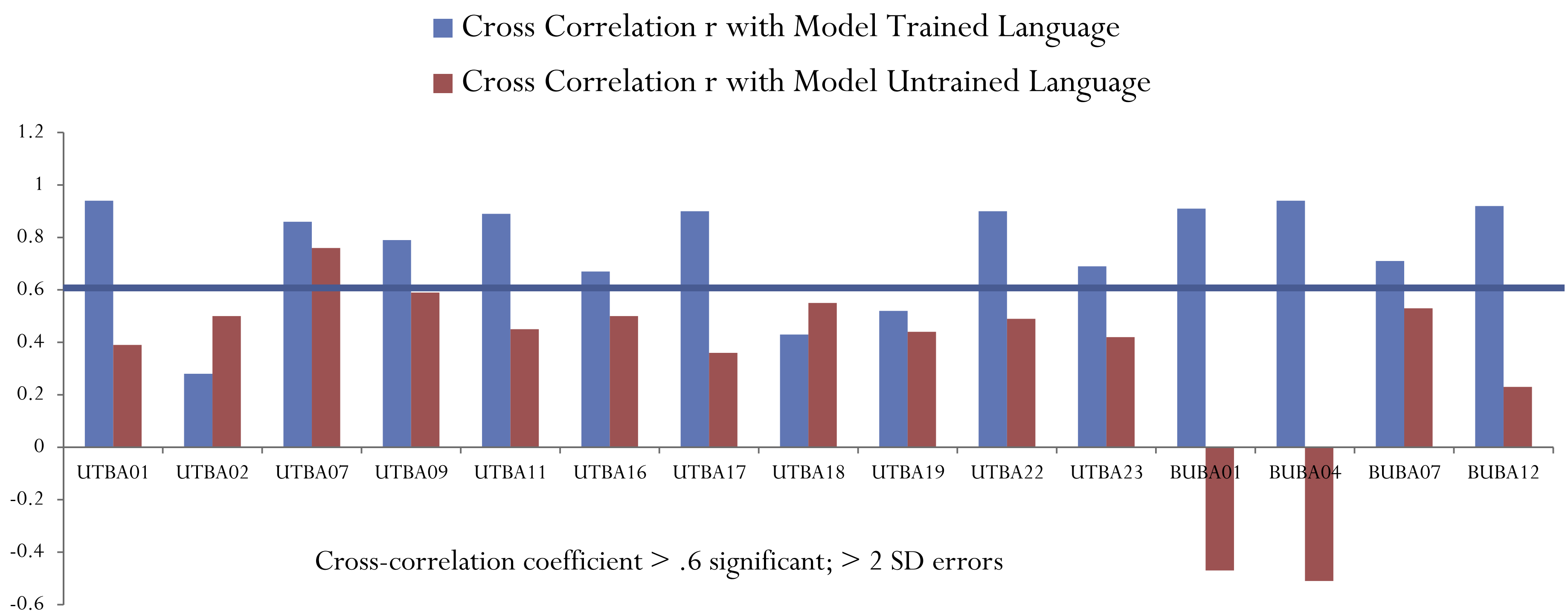
- The starting point was set to either a severe impairment in naming (30% or less accuracy) or mild impairment (70% or high naming accuracy).
- Model retrained trained with different number and schedule of presentations of words in one language
- Treatment always provided only in one language (either English/Spanish) and amount of improvement examined
- Generalization (cross language transfer) examined to untrained language



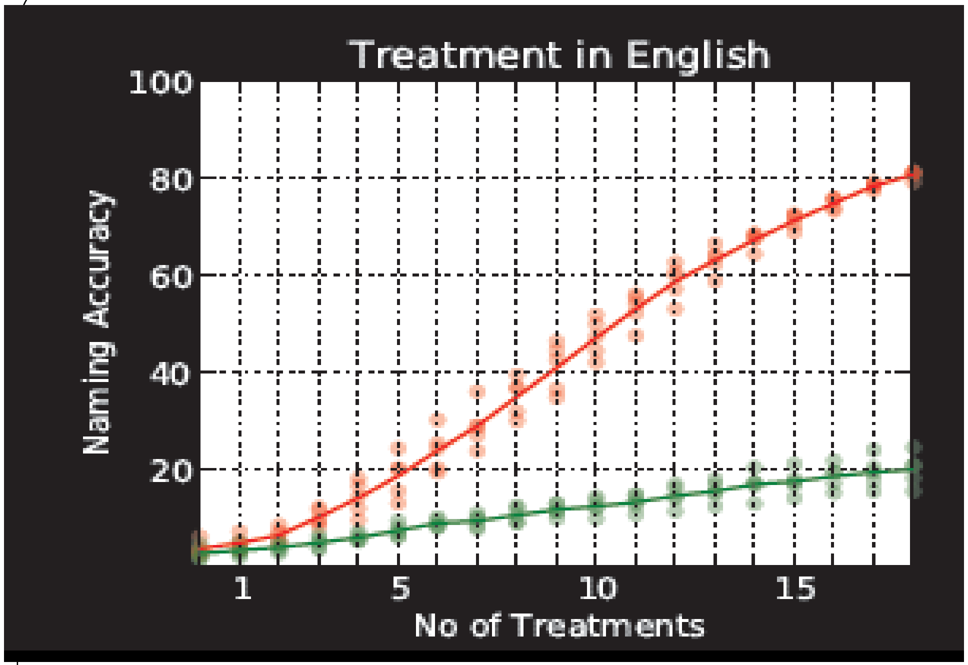
Edmonds & Kiran, 2006; Kiran & Roberts, 2009

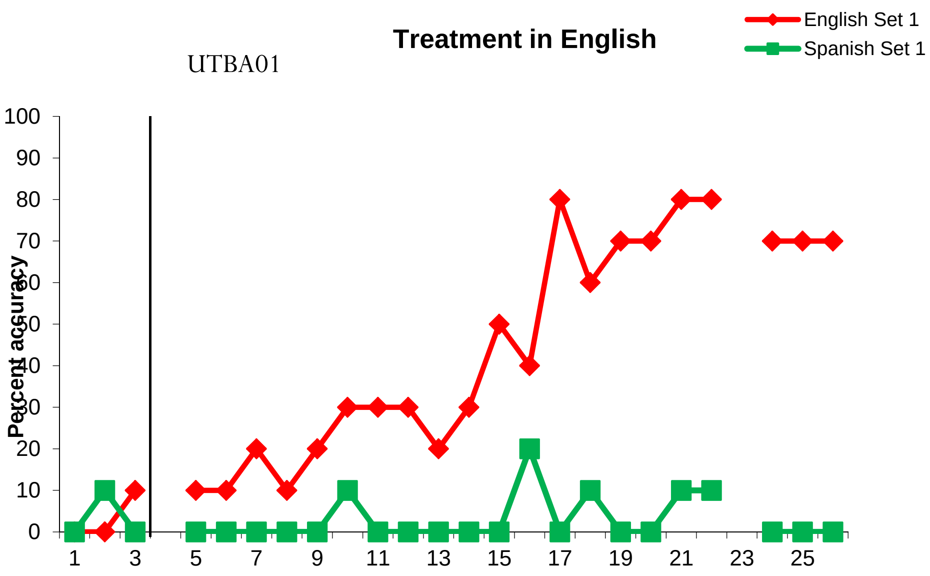
In order to evaluate the model

- 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.



Patient and computational results: Both languages high damage

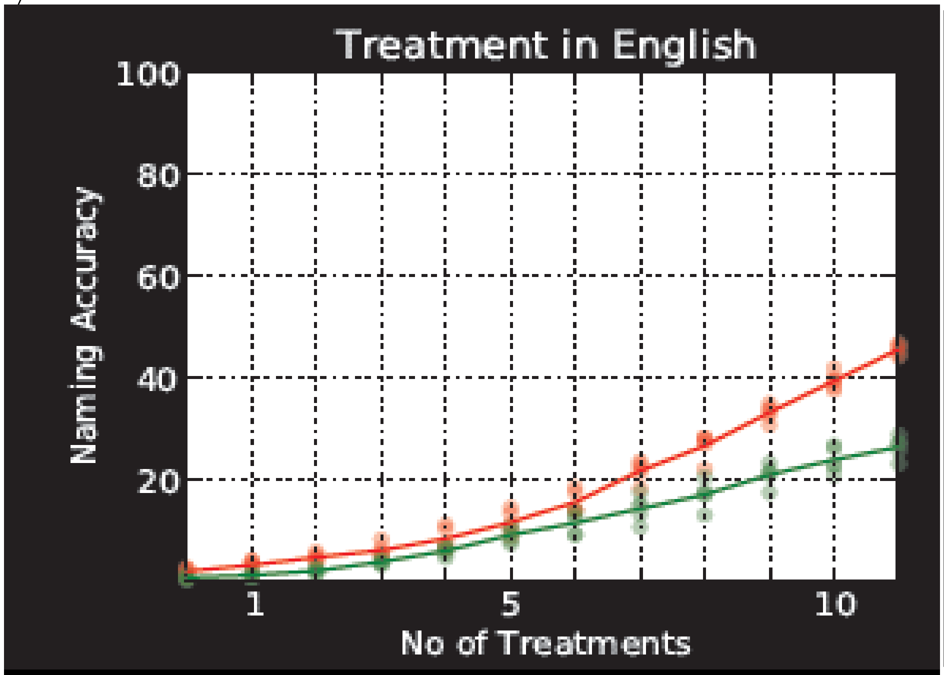


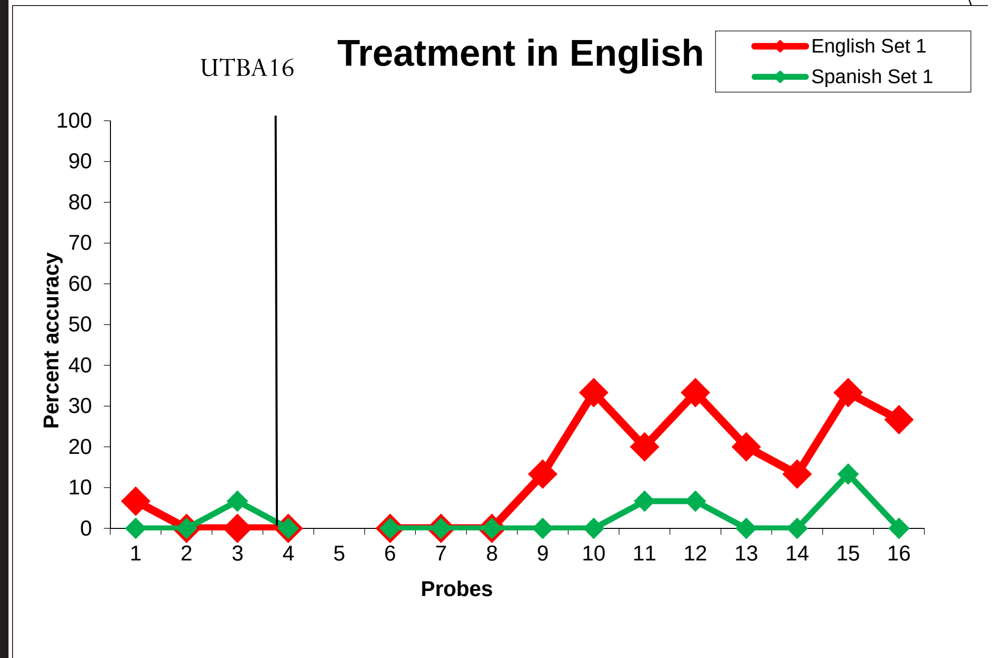


UTBA 01:
English: Early
Spanish: Native

English: High exposure
Spanish: Low exposure

Spanish ES: .58
English ES: 12.7

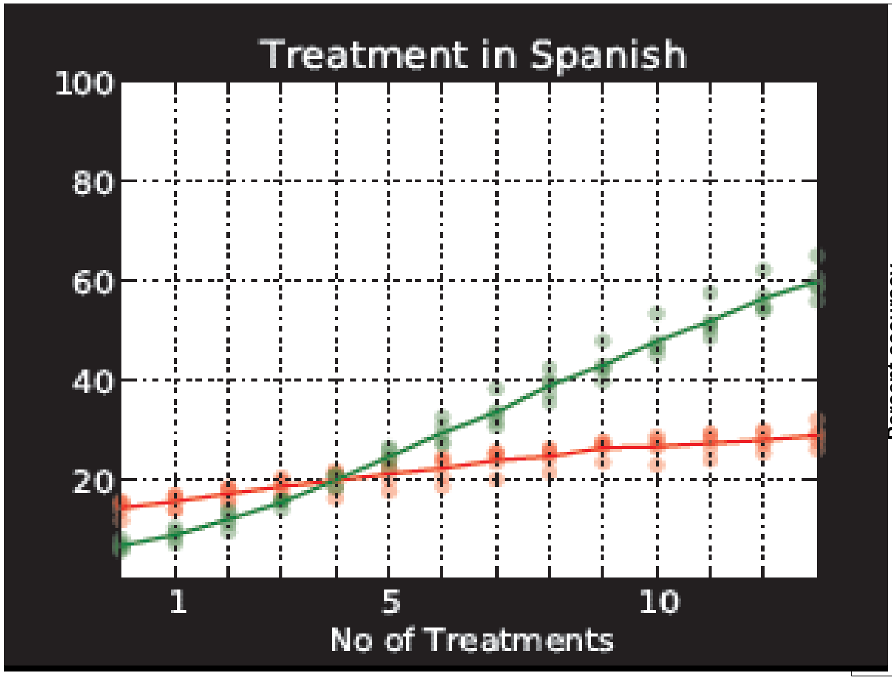


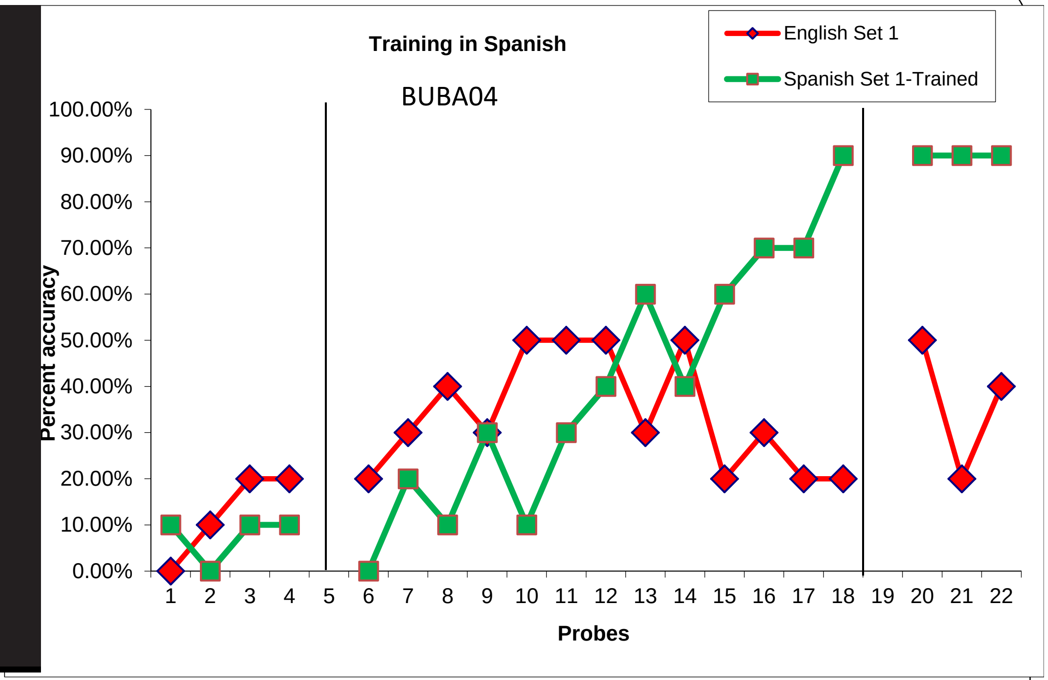


UTBA16:
English: Early
Spanish: Native

English: Moderate exposure
Spanish: Moderate exposure

Spanish ES: .83
English ES: 6.8



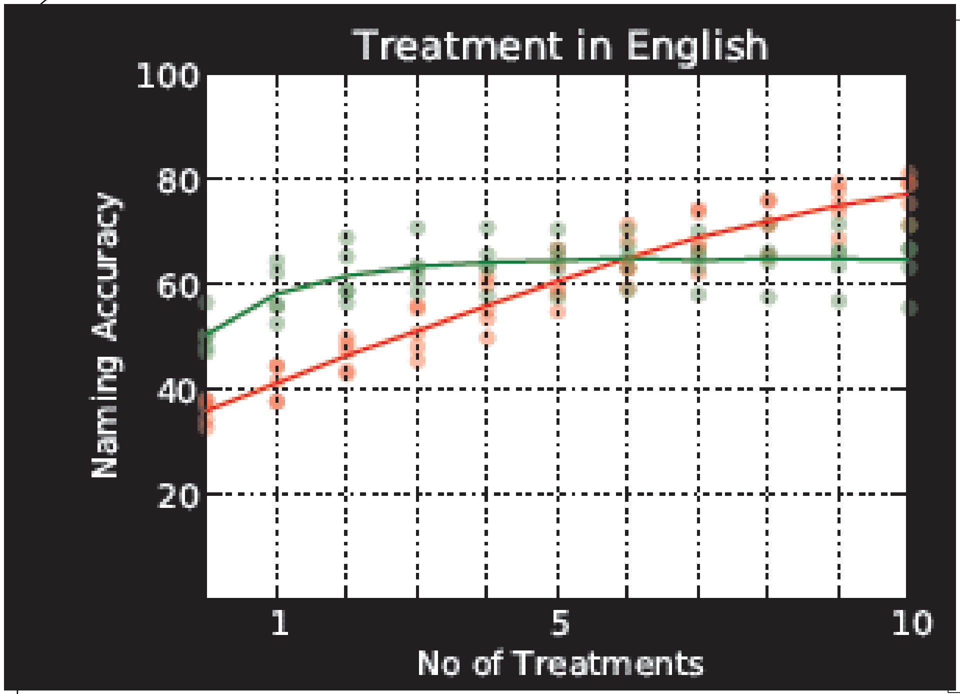


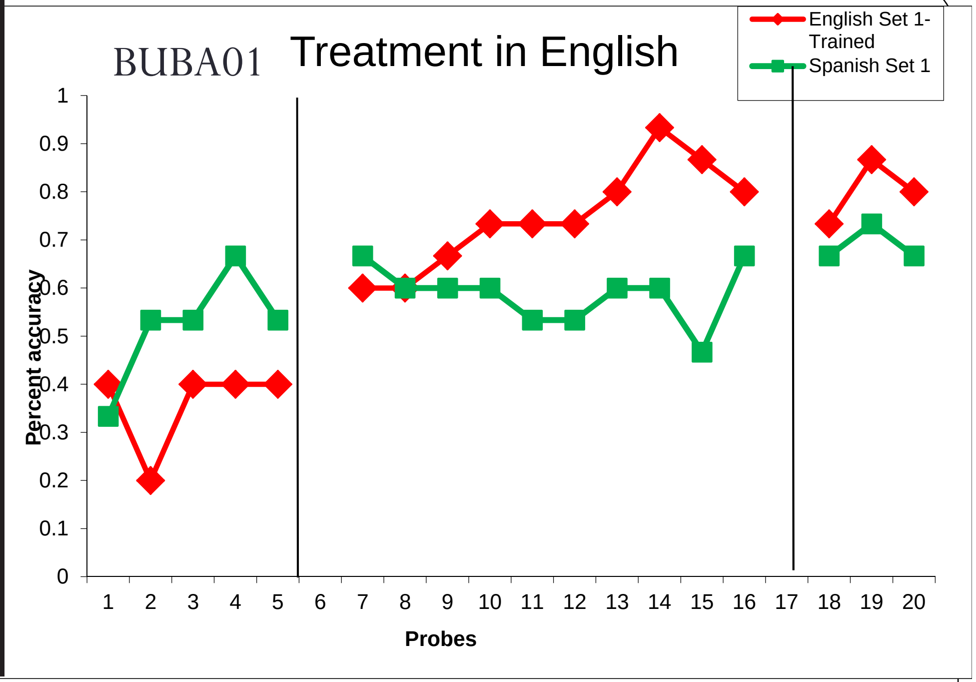
BUBA04:
English: Early
Spanish: Native

English: High exposure
Spanish: Low exposure

Spanish ES: 16.5
English ES: 2.52

Patient and computational results: Both languages low damage



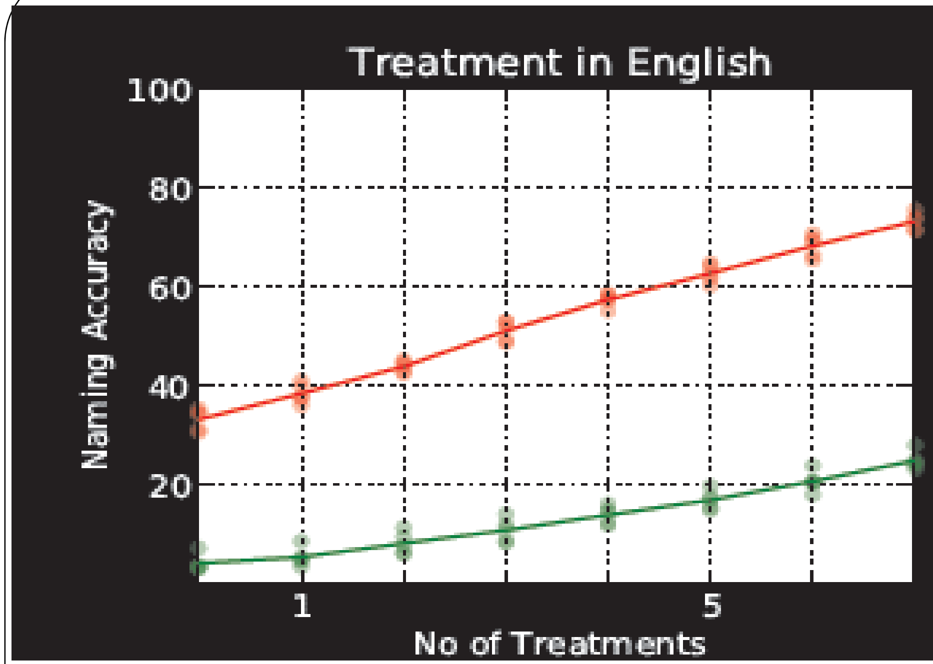


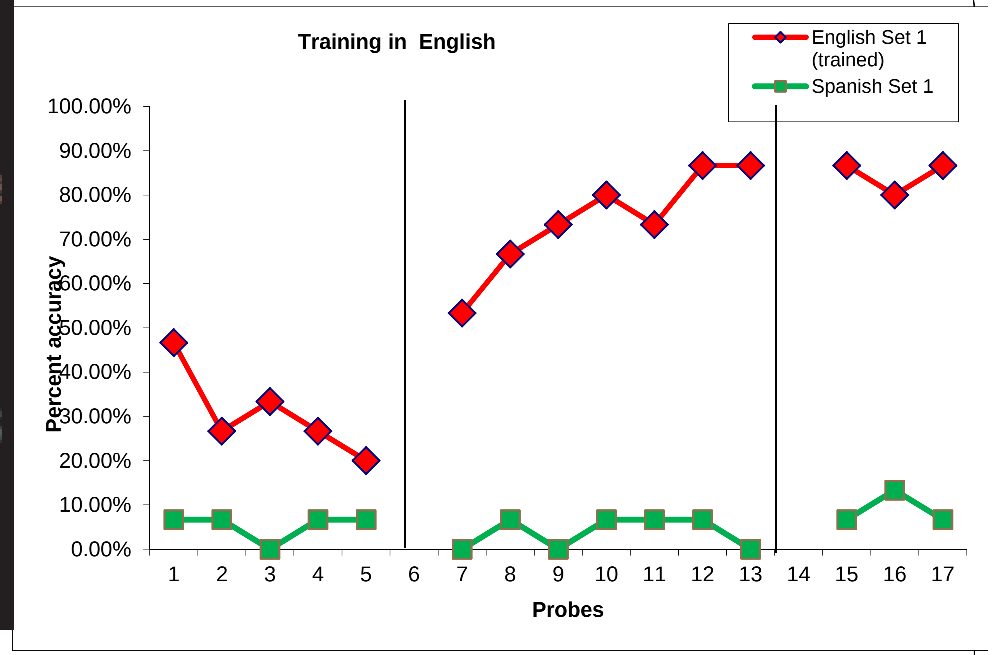
BUBA01
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 1.42
English ES: 4.92

Patient and computational results: Both languages differential damage



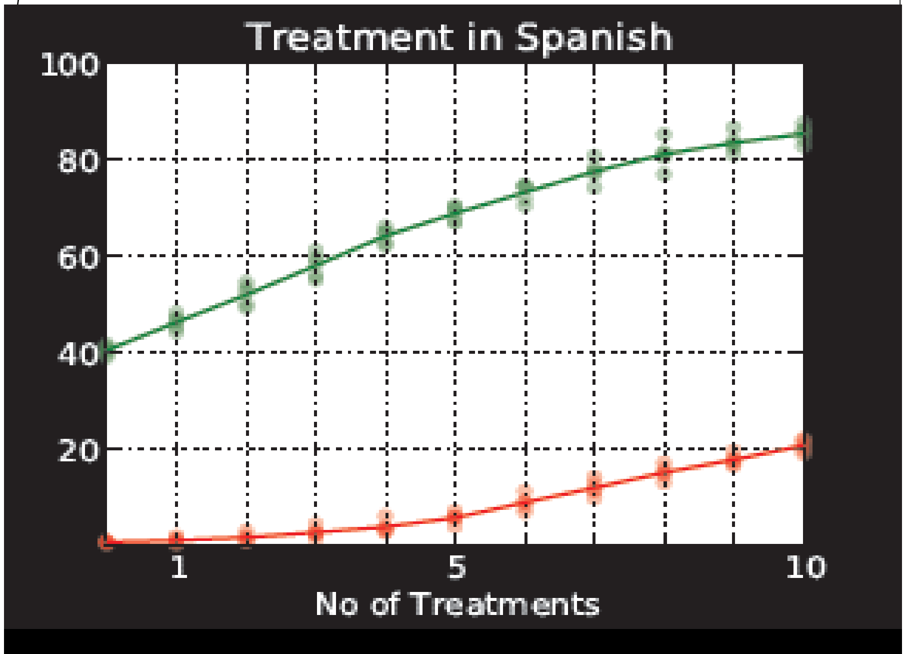


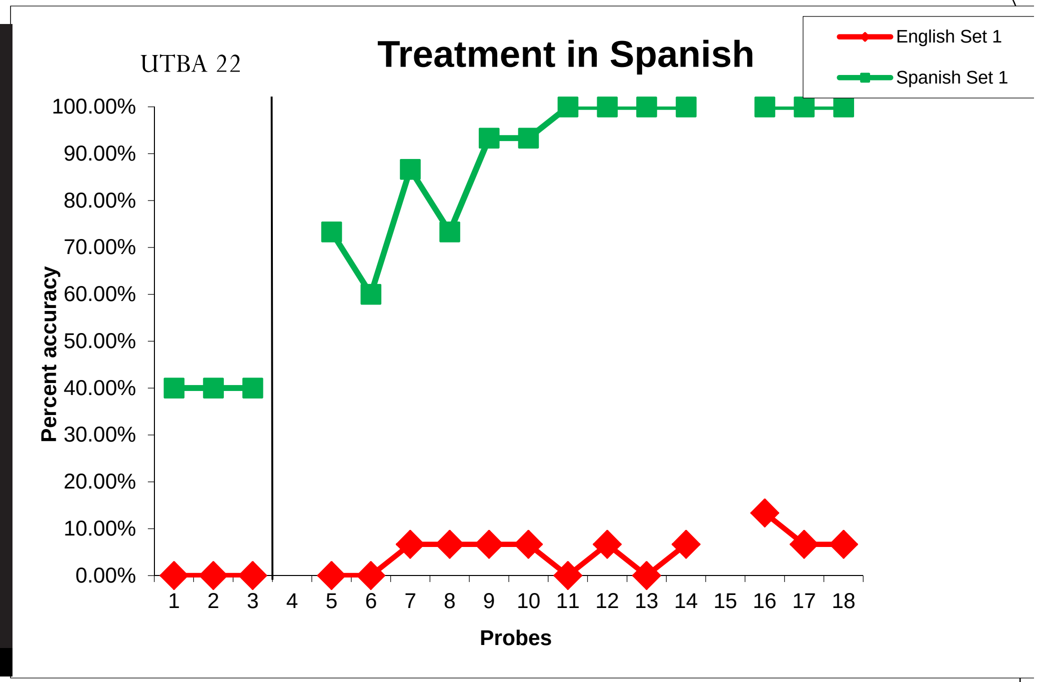
UTBA 17:

English: Early
Spanish: Native

English: Moderate exposure
Spanish: Moderate exposure

Spanish ES: 5.32
English ES: 1.19



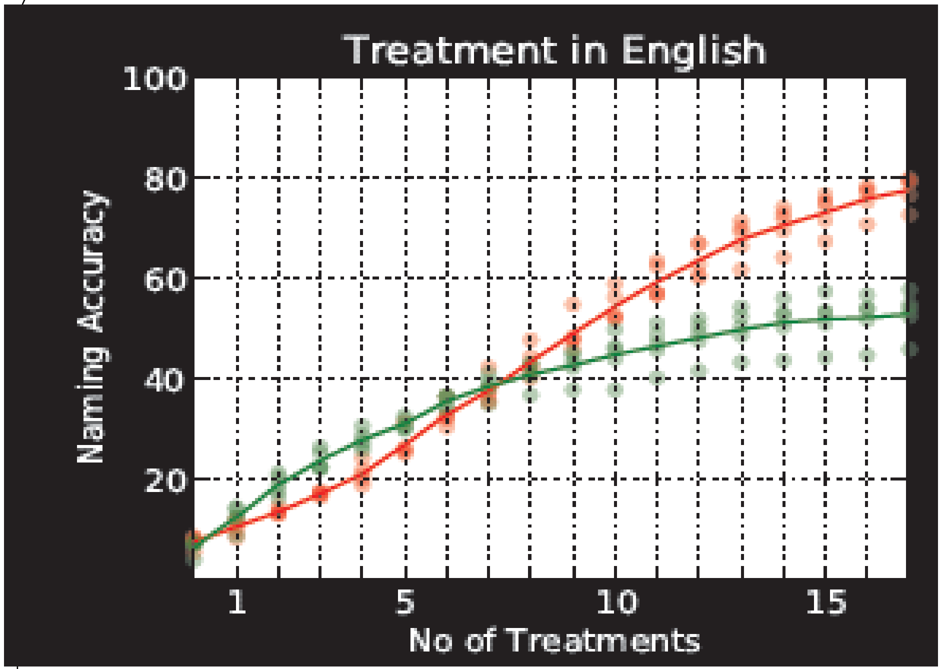


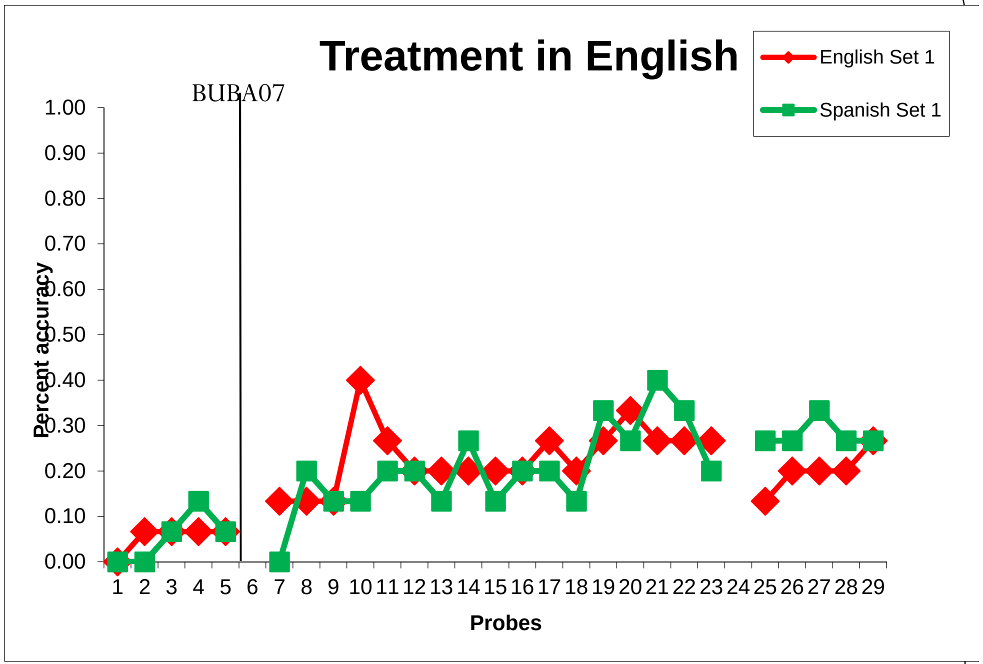
UTBA 22:
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 12.7
English ES: 1.89

The model also does not always predict correct performance

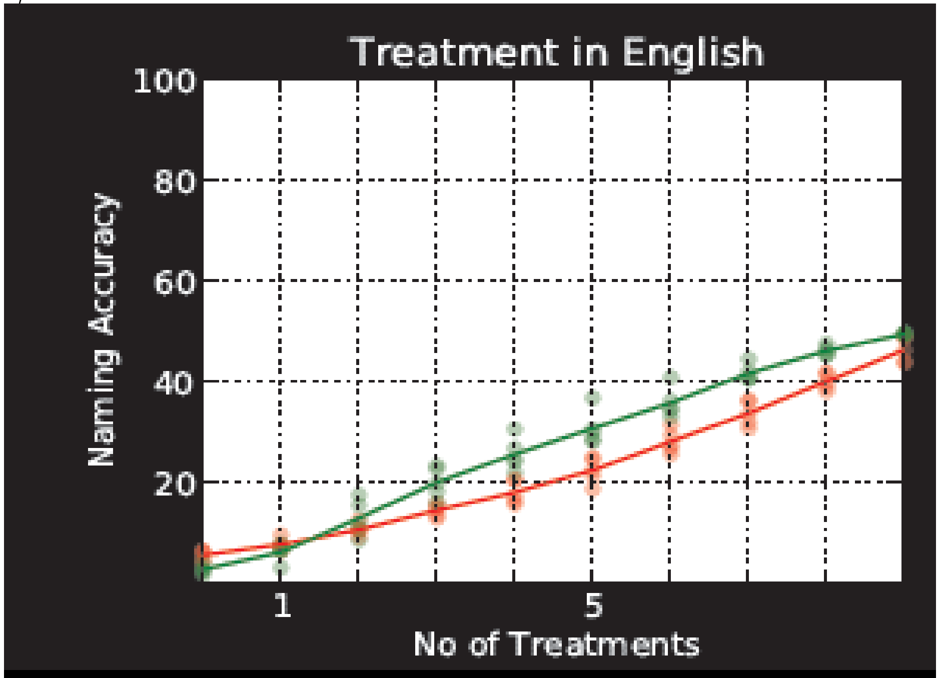


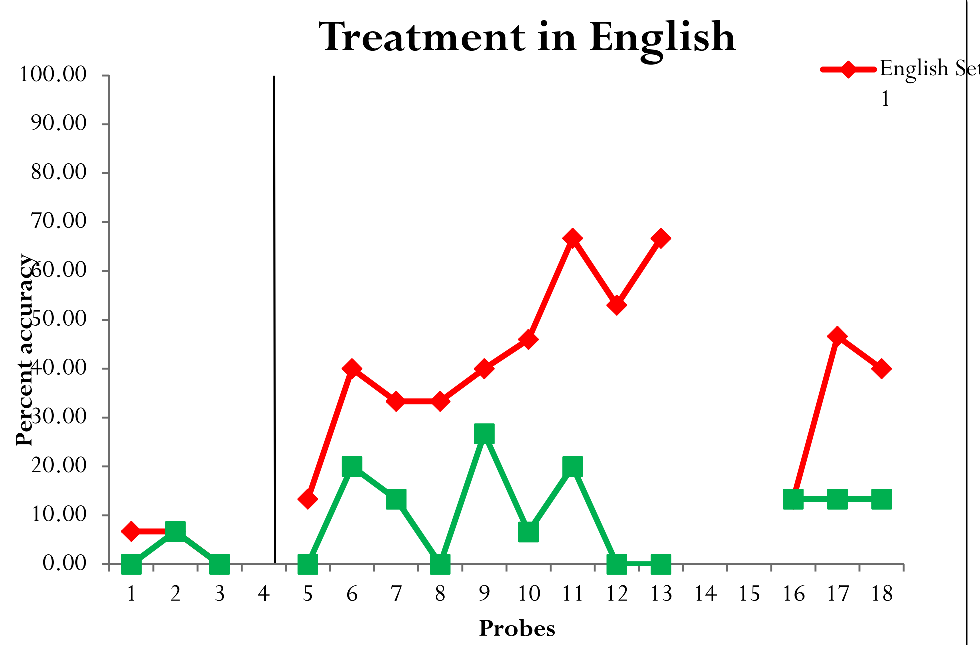


BUBA07
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 4.08
English ES: 2.8

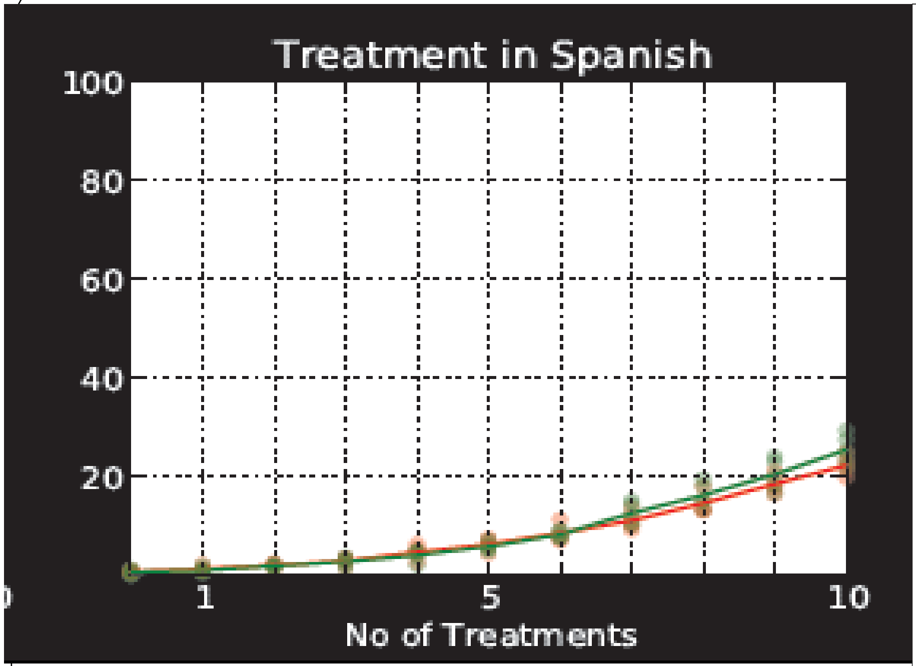


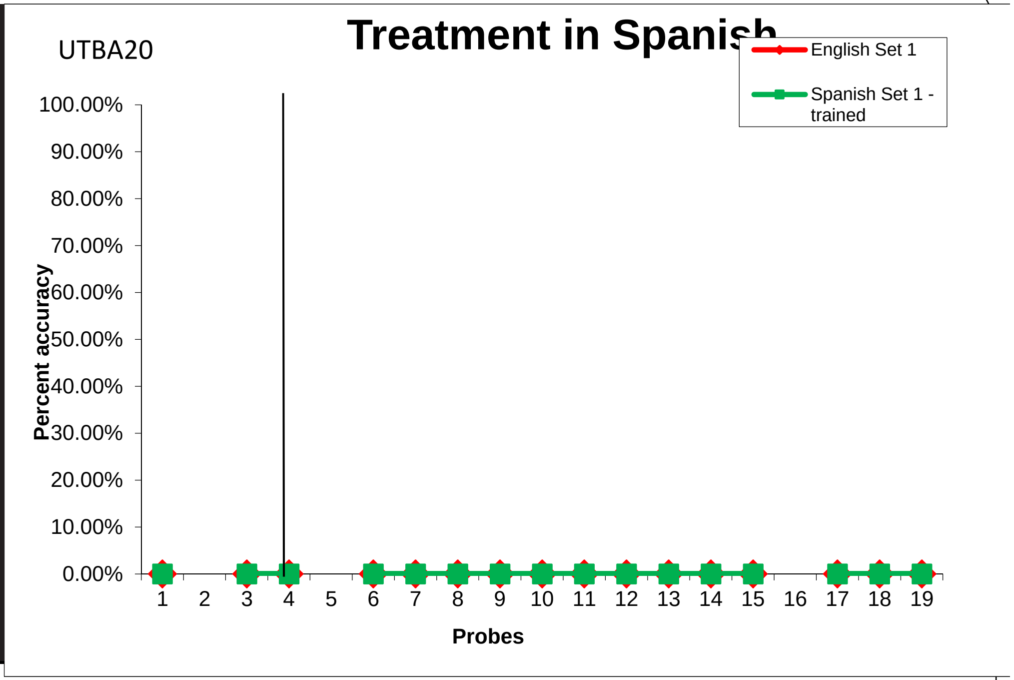


UTBA11
English: Late
Spanish: Native

English: High exposure
Spanish: High exposure

Spanish ES: 1.15
English ES: 14.9



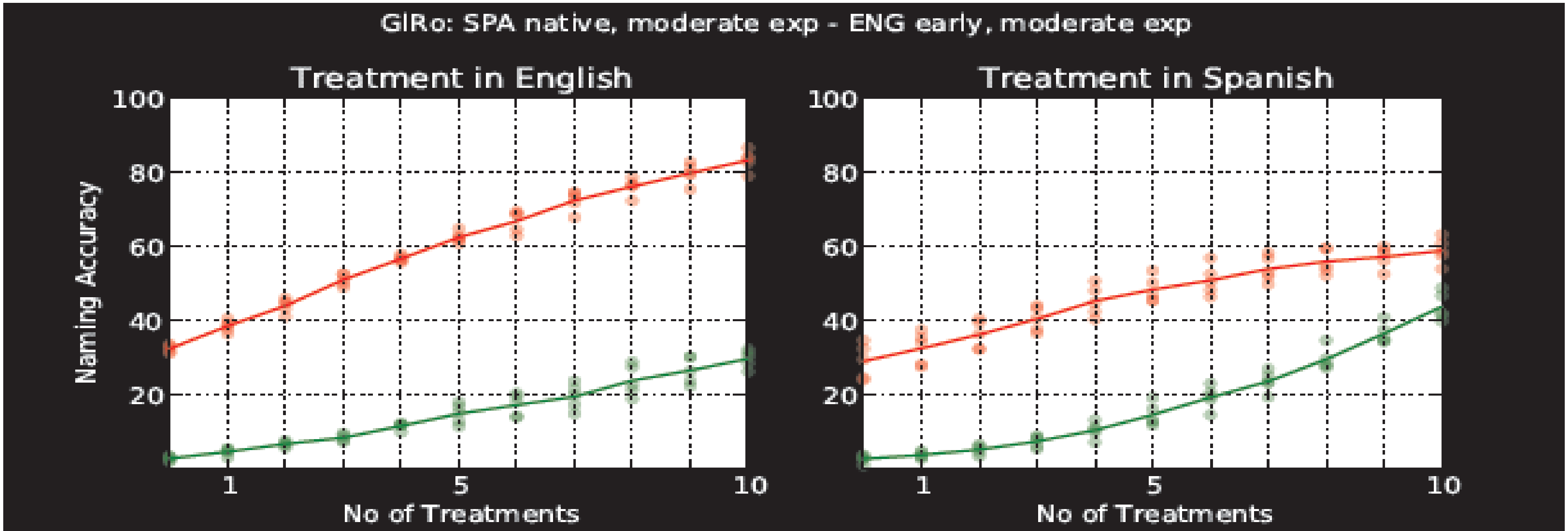


UTBA 09:
English: Late
Spanish: Native

English: Low exposure
Spanish: High exposure

Spanish ES: 0
English ES: 0

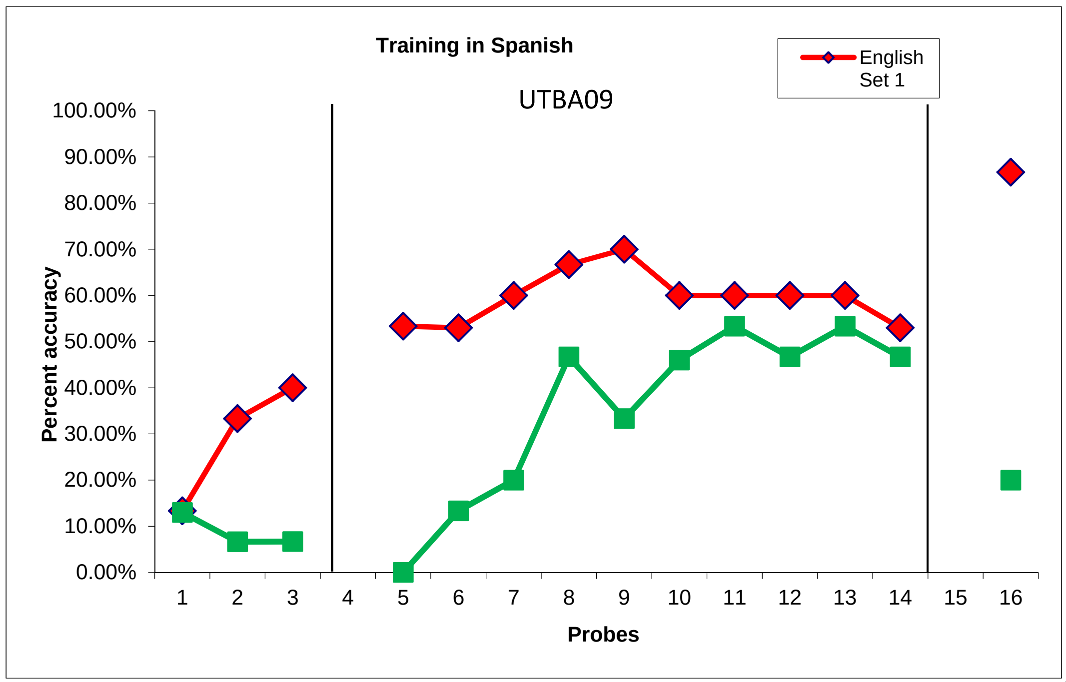
The model can also predicts what treatment outcome may have been if the other language was trained



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

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