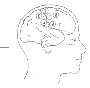
Vocabulary Development in
First and Second Language Acquisition

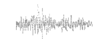
Ping Li
Cognitive Science Lab
Department of Psychology
University of Richmond
Richmond, VA 23173
pli@richmond.edu
http://cogsci.richmond.edu/

Overview of research



How does

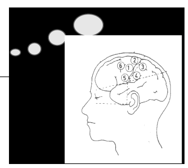
process and organize



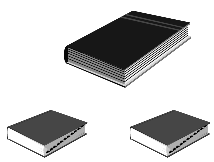
- ***Does it differ in which language we speak?***
  - Crosslinguistic studies of Chinese and English
- ***Does it differ in how many languages we speak?***
  - Bilingual language representation
- ***Does it differ across a developmental trajectory?***
  - Child language acquisition

Approaches:
behavioral, computational, & neural

Outline



- ***The lexicon in acquisition: Major issues***
  - Vocabulary spurt
  - Bilingual lexical representation
  - Age of acquisition/critical periods
- ***Connectionism and development***
- ***Self-organizing neural network models***
  - DevLex, DevLex-II, SOMBiP
- ***Conclusions***

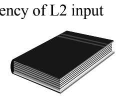


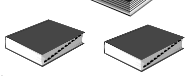
Lexical Development in Monolinguals

- **Lexical development in children: it's fast**
  - 14,000 words by age 6
- **Changes across time: not spread out evenly**
  - 0-18 months: 50 words
  - 18-30 months: 500 words
- **Vocabulary spurt: rapid learning following slow growth**
  - Word-learning intrinsic factors
    - Phonological memory, word retrieval, lexical organization
  - Cognitive and social abilities
    - Naming insight, communicative awakening

Lexical Development in Bilinguals

- **Simultaneous bilingual acquisition**
  - No spurt found for both L1 and L2
  - Individual differences: size, rate, and frequency of L2 input
- **Sequential bilingual acquisition**
  - Shared versus distinct lexical memory
    (one store vs. two stores)





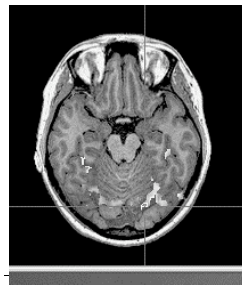
  - Learning **(SLA)** and representation **(Bilingualism)**

A computational perspective

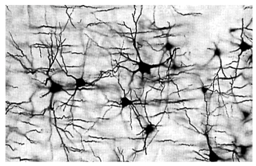
Why computational modeling?

- Flexibility in parameter variation and hypothesis testing
  - e.g., Timing, size, and rate of input
- Computational mechanisms required for lexical acquisition
  - e.g., association, organization, and competition

Localization vs.Organization



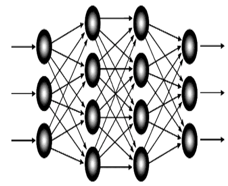
Neurons in the brain connect with one another to form networks



The brain learns by modifying certain connections in response to inputs

Neural Networks

Neurons in the brain connect with one another to form networks



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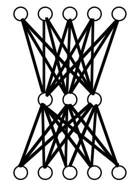
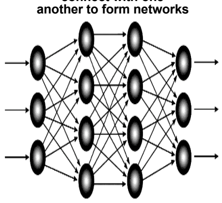


units
connections
activations
weights
learning rule

Neural Networks

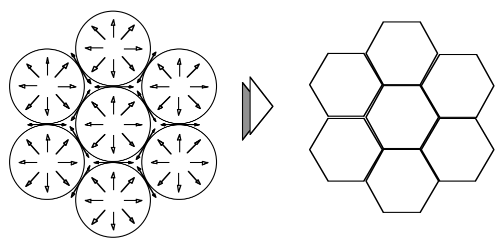
Neurons in the brain connect with one another to form networks



The brain learns by modifying certain connections in response to inputs

- Information is distributed through large groups of connected units
- Knowledge is represented by patterns of activation
- Learning is accomplished by adjustment of the weights that connect the units

Emergent Properties



Connectionist language learning models

Limitation of previous computational models

- Artificial input patterns
- Small size of lexicon
- Supervised learning (e.g., BP network)
- Monolingual learning & representation

Connectionist language learning models

Our Model

- Realistic input (based on parental speech)
- Early child lexicon (500 words based on CDI)
- Unsupervised learning (Self-Organizing Maps)
- Mono-&-bilingual learning and representation

This has been made possible by the availability of large-scale speech corpora online (e.g., CHILDES, CDI, HAL) and the computational tools therein

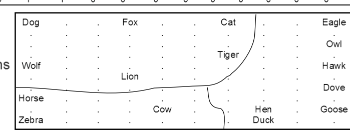
Computational principles of our model

Self-Organizing Map (SOM; Kohonen, 1982, 2001)
- ☐ Unsupervised Learning
- ☐ Topography-preserving
- ☐ Gradual formation of structures with soft boundaries

Forming lexical categories

		Dove	Hen	Duck	Goose	Owl	Hawk	Eagle	Fox	Dog	Wolf	Cat	Tiger	Lion	Horse	Zebra	Cow
is	Small	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0
	Medium	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
	Big	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
has	2 legs	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
	4 legs	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
	Hair	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
	Hooves	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
	Mane	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0
	Feathers	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
likes to	Hunt	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0
	Run	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0
	Fly	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
	Swim	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0

SOM:
10 x 10 neurons after test with animal codes.



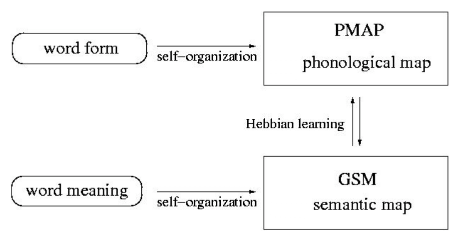
Feature map containing labeled neurons with strongest responses to their respective inputs.

Computational principles of our model

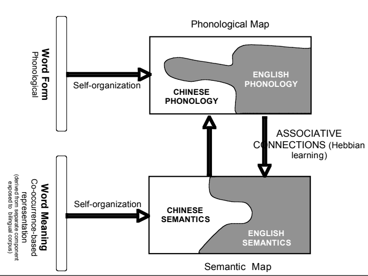
- ☐ **Self-Organizing Map** (SOM; Kohonen, 1982, 2001)
  - Unsupervised Learning
  - Topography-preserving
  - Gradual formation of structures with soft boundaries
- ☐ **Hebbian Learning**
  - Different maps can be connected via Hebbian learning, according to which associative strengths of the corresponding nodes increase through co-activation

Li, P., Farkas, I., & MacWhinney, B. (2004). Early Lexical Development in a Self-Organizing Neural Network. *Neural Networks, 17*, 1345-1362.
Li, P., Zhao, X., & MacWhinney, B. (2007). Dynamic self-organization and early lexical development in children. *Cognitive Science, 31*.

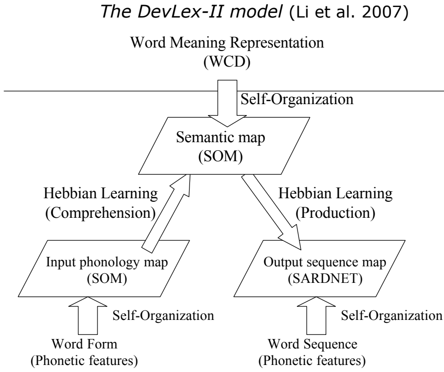
DevLex: a Developmental Lexicon model (Li et al. 2004)



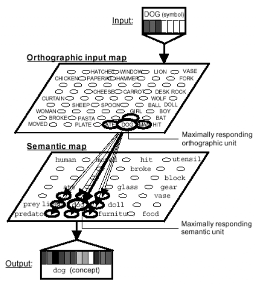
The DevLex Bilingual Model (SOMBiP; Li & Farkas, 2004)



The DevLex-II model (Li et al. 2007)



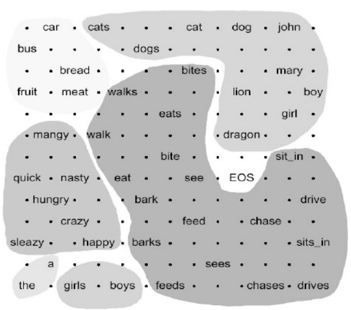
Simulating lexical disorders
(Miikkulainen, 1997; Silberman et al., 2007)



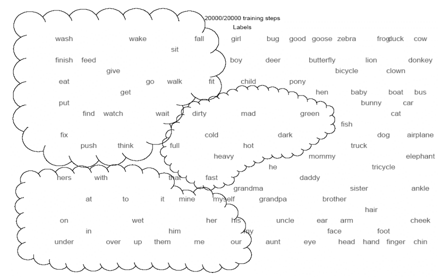
Input Representations

- **Phonological representations**
  - PatPho - a phonological pattern generator (Li & MacWhinney, 2002)
- **Phonemic representations**
  - Articulatory features of phonemes (Ladefoged, 1982)
- **Semantic representations**
  - WCD - a word co-occurrence detector (Farkas & Li, 2002; Li et al., 2004)

Emergence of Lexical Categories in DevLex



Emergence of structured semantic representations



SOM 14-Nov-2006

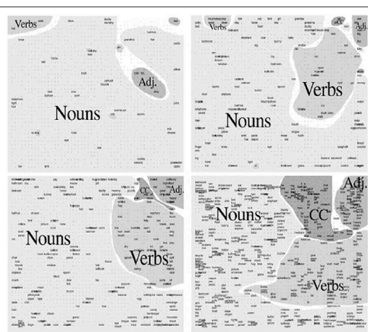
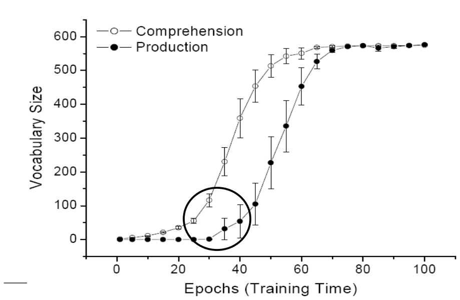


Figure 1. Snapshots of the DevLex model across stages of lexical development: Stage 1 (upper left) 50 words; Stage 3 (upper right) 150 words; Stage 5 (lower left) 2 and Stage 10 (lower right) all 500 words. The self-organizing map separates the four major categories – Nouns, Verbs, Adjectives, and closed class words (CC towards the final stage. (The labels for individual words are not legible because of the large number of words represented.)

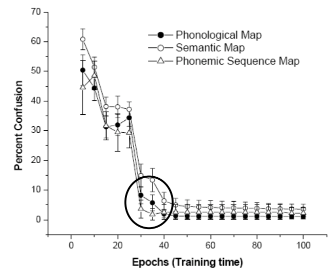
Rapid learning in early vocabulary



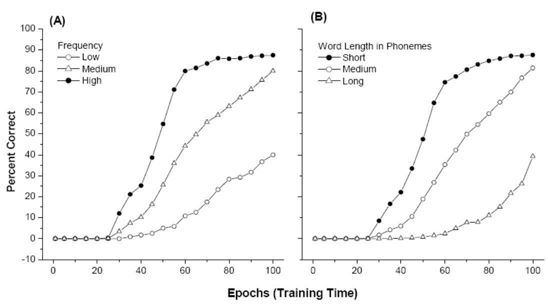
Rapid learning and lexical organization

- **Vocabulary spurt occurs when**
  - Structured representations in word meaning and phonological shape are established
  - Associative mapping is consolidated
  - “Setting up the basic framework”

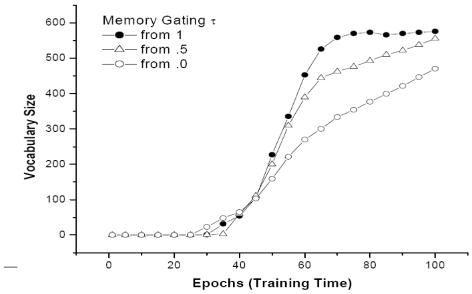
Word confusion rates across time



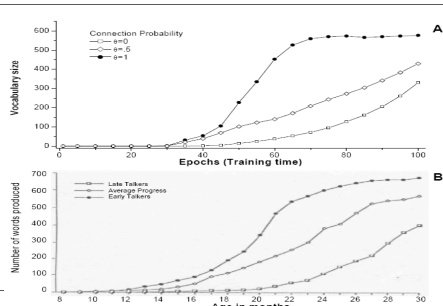
Effects of word frequency and length



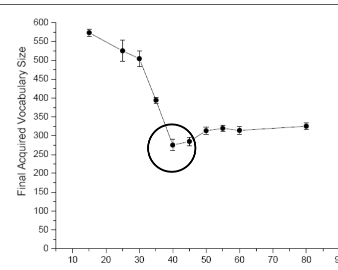
Effects of phonological working memory



Effects of associative capacity



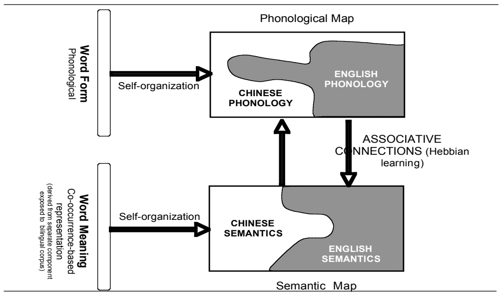
Effects of simulated lesion



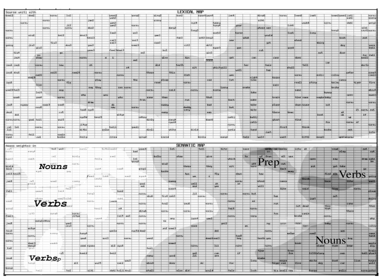
Summary of DevLex Results for L1

- Developmental changes in word learning are modulated by lexical organization; Lexical organization is reflected in the development of structured representation
- Individual differences with respect to the shape and function of early vocabulary are explained by the interaction between several parameters, including phonological short-term memory and associative capacity
- Learning itself can determine the shape of change, and discontinuous patterns of development can emerge from the same underlying mechanisms

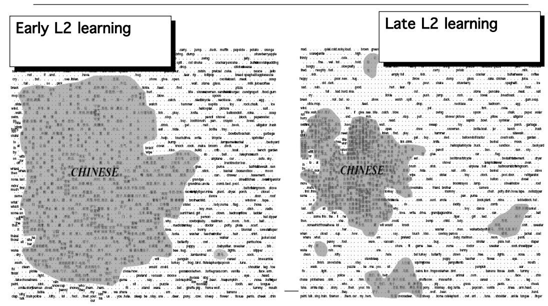
Emergence of lexical representations based on bilingual input



Emergence of lexical representations (Simultaneous Learning)



Effects of age of learning



Effects of age of learning

Table 1: Size of lexical space and rate of confusion for Chinese (L2) vs. English (L1) on the semantic map

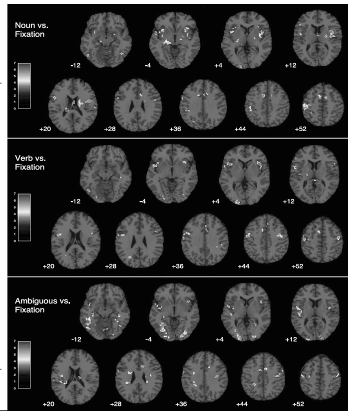
		Lexical space	Confusion rate
Simultaneous learning	Chinese	2038	12.8%
	English	2162	12.8%
	L2:L1	0.94:1	1:1
Early L2 learning	Chinese	1803	20.6%
	English	2397	11%
	L2:L1	0.75:1	1.87:1
Late L2 Learning	Chinese	956	64%
	English	3244	2%
	L2:L1	0.3:1	32:1

Summary of DevLex Results for L2

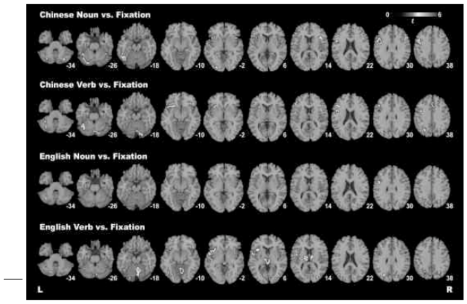
- When the learning of L2 is early relative to that of L1, functionally distinct representations of the two lexicons may be established.
- When the learning of L2 is delayed relative to that of L1, the structural consolidation of L1 will significantly (sometimes dramatically) impact on the representation of L2 (e.g., resulting in parasitic L2).
- Plasticity and competition: The network' ability to reorganize its structure decreases as the structure of L1 has consolidated

Li, et al. 2004

Neural correlates of nouns and verbs in Chinese



Neural correlates of nouns and verbs in early bilinguals
Chan, et al. (2006)



ERP signatures of subject-verb agreement in L2 learning
Chen, et al. (2006)

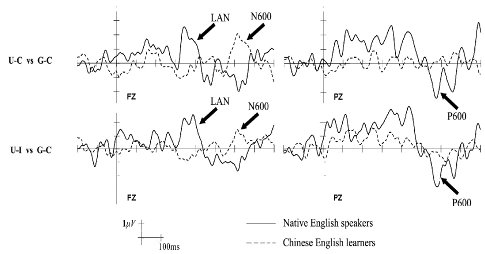


Figure 5. Difference waveforms: native speakers versus L2 learners

Conclusions

- DevLex is a developmentally plausible and computationally realistic model designed to account for the dynamic self-organization in lexical learning and representation
- The model captures important mechanisms underlying developmental phenomena (e.g., early plasticity, competition, and experience-dependent structural changes; Bates, 1999).
- Our model projects lexical development at a dynamical systems level, in which phonological and semantic representations of words continuously interact and evolve.
- New research in language acquisition point to directions beyond the nature-nurture debate (e.g., infant studies; cf. Kuhl; Saffran), and our research exemplifies such directions.

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