PSYC 3640
Psychological Studies of Language
The Hardware of Language Processing

Today’s Outline
• Midterm exam
• Research paper (bonus abstract due next week)
• Final exam: Dec 5 (Wednesday) 2p.m. YH 245
  – 6 short answers
  – 1 essay question
• Lexical network of ‘linguist’
• Brain + Chapter 13 in Altmann’s book
• 10:45 Library workshop

Research Paper
• 10-12 pages, double-spaced
• Choose a topic from the list of lectures (or find your own topic)
• Review recent findings (5-8 recently published articles, 8-10 pages long)
• Suggest a future research direction based on your review (1-2 pages long).
• Research direction can be either theoretical or empirical, i.e., suggest a method
• 150-word BONUS abstract due next week (put your email address on the paper)

Network of ‘Linguist’
What’s in a human brain?

- Two classes of cells: Neurons and glial cells
- All neurons are connected to many others, number of connections can go up to 100,000!
- How many? estimated to be 100 billion
- No regeneration after birth! Neurons are re-organized with experience --> plasticity
- Glial cells play a supporting role for neurons, their general responsibility includes signal transmission and transportation of nutrients.
**Geschwind-Wernicke model**

- From aphasia literature
- **Broca’s area** -- left inferior frontal gyrus (LIFG)
- Leborgne, a.k.a. ‘Tan’
- Responsible for speech production
- **Wernicke’s area** -- posterior part of the superior temporal gyrus (STG)
- Responsible for language comprehension
- The two areas are connected by arcuate fasciculus (a bundle of myelinated neurons -- white matter)

**New Research**

- Dronkers et al., 2007
- Hickok & Poeppel, 2007

- Green – spectrotemporal analysis
- Yellow – phonological analysis
- Pink – lexical interface (links phonological with semantic information)
- Blue – sensorimotor interface and articulatory network
Wiring up a brain

- Connections between neurons reflect experience (or learning, as Altmann has put it)
- Our interpretation of words (meanings) reflects our unique pattern of activity reacting to that word
- Connectionism: constructs a neural network that simulates the one in our brains. Feed input (experience) and compare the output to actual data obtained from behaviour
- computationally-intensive

Three principles

- Neurons send impulses to the connected ones. Rate of firing = strength of signal (activity of a neuron)
- Effects are bi-directional
  - excitatory: increase activity of connected neurons (+)
  - inhibitory: decrease activity of connected neurons (-)
- Connections change:
  - can regenerate
  - can die

Letter-to-sound Network

http://www.gamedev.net/reference/programming/features/vehiclenn/

/\ same procedure
network strength is random
particular pattern at input will result in a particular pattern in output
across time
Elman’s work in the 1980s

- Michael Jordan: Memorize which network was output in experience.
- Elman’s extension:
  - Add copy neurons to the network
  - Each copy neuron is connected to 1 intermediary neuron
  - Duplicate the activation, so next time the same intermediary neuron is activated again, it will receive signal from 2 sources: 1 from the original and 1 from the copy
  - Make prediction based on previous experience

Ability of a Network

- Syntactic categories have unique activation pattern → distinguish nouns from verbs
- Nouns: animate (boy) vs. inanimate (book)
- Verbs: transitive (kick) vs. intransitive (dream)
- Conventional SVO
- Predict the occurrence of a certain syntactic categories

Predictions made by the Network

- Output memory reflects syntactic categories
- Intermediary neurons reflect the syntactic categories of the preceding word to make predictions that “match” the output memory
- The network changes according to the “quality” of previous predictions.
- Pattern of activation ≈ Internal representation

Language Network

- Variation in context gives rise to meaning
- Meaning is encoded by sound in the beginning of development
- Output pattern reflects the “probability” of occurrence of each word → experience-driven
- Our impatience in sentence comprehension is simply a consequence of our prediction-mechanism at work!
Context of Input

- Computational networks do not receive input from different modalities.
- Altmann predicted that the network would be able to predict, not only the subsequent words, but also subsequent phonemes based on learning.

Children as statisticians?

- Calculate the probability of each word’s position in a sentence based on experience
- What’s the denominator?
- Taking into account other words in the sentence
- Calculations become simpler when the network “groups” words into different syntactic categories → assigning a general probability to a category of words

Summary of Today’s lecture

- Language processing involves a network of brain areas: frontal, temporal and parietal.
- The definite interplay of these areas is still a mystery.
- Neural network simulates human language processing to a certain extent, e.g., acquiring vocabulary, meaning and grammatical structures.
- Information is stored so to achieve making predictions.
- Experiential input is VERY limited and the applicability of findings to human development is unknown.