

# FLST:Cognitive Foundations I









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## What is Cognitive Foundations?

- Language is fundamentally a human phenomena.
  - It originates in, and is processed by the human mind/brain
- The nature of language is shaped by ...
  - communicative pressures and goals
  - the structure of the world: objects, events, ...
  - the processing mechanisms & capacities of the brain
- Experiments help us develop theories of language
- Computational models are necessary to express theories




# The cognitive study of language

-  The **evolution** of the human capacity for language
  -  What are the distinguishing traits that enable human language?
  -  What caused these to emerge?
-  The **acquisition** of our native language
  -  General cognitive learning mechanisms, or domain specific ones?
  -  How does learning take place?
-  The **use** of language
  -  What mechanisms support language encoding and decoding

# Language and thought




## Linguistic Relativity

Sapir, Whorf, Lakoff, Levinson

-  the language that one speaks affects the way they think
-  language adapted to the culturally relevant expression
-  **Evidence:** categorization of color and spatial terms, expression of time

## Linguistic Autonomy

Chomsky, Fodor, Pinker

-  we are all born with knowledge of language
-  separation of language and thought (*mentalese*)
-  **Evidence:** commonalities among languages

# Nature *versus* Nurture

## Nature: Innate Language

Chomsky

- UG constitutes a language specific genetic/biological endowment
- explains why languages have structural commonalities
- **Argument:** successful acquisition despite *poverty of stimulus*

## Nuture: Emergentist

Elman, Bates, Karmiloff-Smith

- linguistic knowledge is derived solely from our experience
- language has adapted to be learnable
- **Argument:** makes fewer assumptions (Occam's razor)

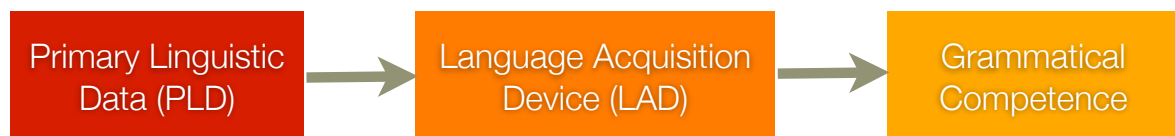
# Universal Grammar

- Domain specific knowledge of language is part of our genetic endowment
  - The structure of possible human languages is “hard-wired”
  - Domain specific innate behaviors are not unusual in animals (e.g. spider webs)
- Consistent with localization of language in the brain
- UG is typically viewed as a “parametrized set of principles”
  - **headedness:** left/right
  - **pro-drop:** yes/no
- Learning of syntax reduces to parameter setting

# Pro Universal Grammar

- ❦ Poverty of stimulus: human language is unlearnable from evidence alone
  - ❦ E. M. Gold showed that any formal language which has hierarchical structure capable of infinite recursion is unlearnable from positive evidence alone
  - ❦ Children do not receive (and if they do, ignore) “labeled” negative evidence
  - ❦ Therefore: they must have some innate knowledge to enable acquisition
- ❦ Empirical support:
  - ❦ Creolization: Hawaiian Creole, Nicaraguan Sign Language
  - ❦ Localization in the brain

# Language Acquisition Device



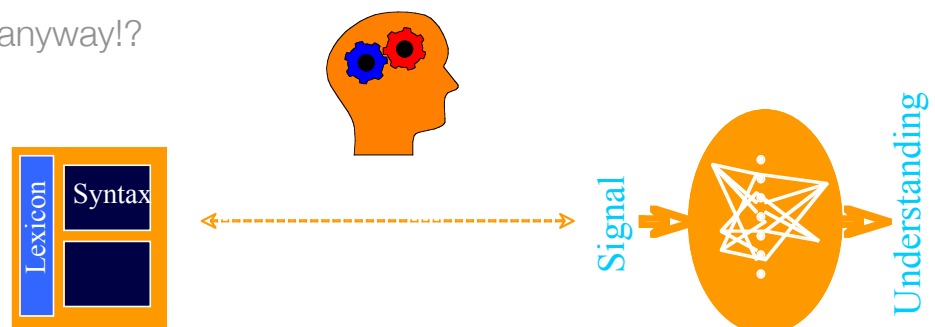
- ❦ The device searches for language structure hypotheses compatible with input signals from the Primary Linguistic Data (PLD).
- ❦ The device then tests the compatibility using the knowledge of implications of each hypothesis for the sentences.
- ❦ One hypothesis or ‘grammar’ is selected as being compatible with the PLD.
- ❦ This grammar provides the device with a method of interpreting sentences

# Challenging Nativism

- The Poverty of Stimuli evidence is overstated?
- Gold’s results don’t take into account sophisticated probabilistic (including connectionist) learning mechanisms
  - (Simpler) statistics had been previously discredited with behaviourism
- Most researchers actually do believe in some degree of innateness
  - all learning algorithms possess some bias
    - influences what is learned, and how
  - disagreement is more often about the specific UG proposals
- “Logical problem of language acquisition” abstracts from development

# The Modularity Issue

- Is language distinct from other cognitive & perceptual processes?
  - e.g. vision, smell, reasoning ...
- Do distinct modules exist *within* the language processor?
  - e.g. word segmentation, lexical access, syntax ...
- What is a module anyway!?

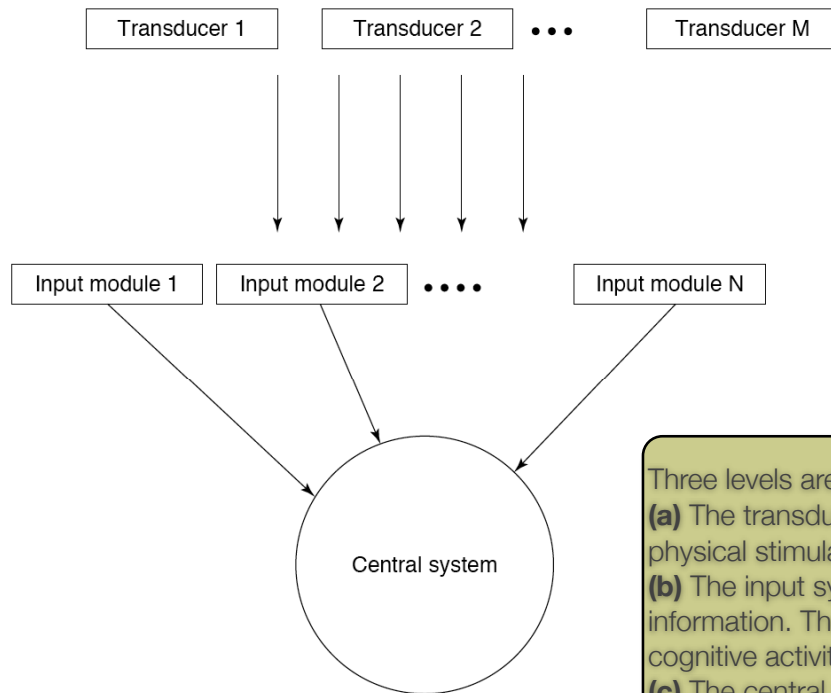


# Architectures and Mechanisms

- ❁ What does “distinct” mean:
  - ❁ Representational autonomy: e.g. phonological versus syntax representations
    - ❁ Possibly interactive processes
  - ❁ Procedural autonomy: e.g. lexical access versus syntax
    - ❁ Possibly shared representations
- ❁ How is the language module organized/interact with other systems?
  - ❁ Does architecture affect possible mechanisms?
  - ❁ Theoretical, computational and empirical arguments concerning modularity?

# Modularity and Computation

- ❁ The brain is the natural computer, par excellence:
  - ❁ Perception occurs in real time, and is highly strategic
- ❁ Traditional views on human perception: *Cognitivist* and *Behaviourist*
  - ❁ Inferential, unencapsulated: cognitive penetration of perceptual processes
  - ❁ Non-inferential, encapsulated: perception reduces to conditioned reflexes
- ❁ Fodor: inferential but encapsulated
  - ❁ Perception is performed by: “*informationally encapsulated systems which may carry out complex computations*”



Modules are:

- domain specific
- innately specified
- informationally encapsulated
- fast
- hardwired (neurally specific)
- autonomous
- not assembled

Three levels are distinguished:

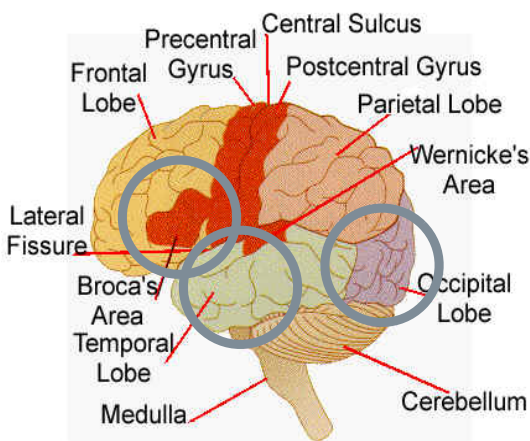
**(a)** The transducers, whose function is to convert physical stimulation into neural signals.

**(b)** The input systems, interpret transduced information. They are responsible for basic cognitive activities and are modular.

**(c)** The central system, is responsible for more complex cognitive activities such as analogical reasoning, and is not modular.

Reference  
 a Fodor, J.A. (1983) *The Modularity of Mind*, MIT Press/Bradford Books

# Language in the Brain



- Frontal lobe: Contains **Broca's Area**
- Damage can lead to **impaired language production**
- Temporal lobe: Contains **Wernicke's area**
- Damage can result in **impaired processing of auditory language**
- Occipital lobe: Visual processing
- Damage can impair processing of written language

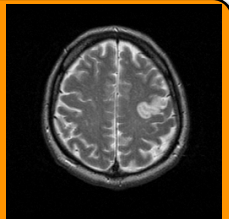
# Proving Modularity

• The best proof of Modularity would be evidence for a “Double Dissociation”:

- #1 Damaged linguistic abilities, but intact general cognition
- #2 Damaged cognitive abilities, but intact language

## #1 Broca's aphasia

- normal IQ
- language comprehension is relatively unimpaired
- language production is non-fluent, few words, short sentences, few function words, no intonation



## #1 Specific Language Impairment

- normal IQ and hearing
- language is meaningful, appropriate
- problem with grammatical morphemes

## #2 Williams Syndrome

(Genetic defect in .001% births)

- low IQ, overly social, poor spatial reasoning
- good language ability, nearly age appropriate

## #2 Senile Dementia

- poor memory and diminished general cognitive function
- language production and comprehension remain intact

# Universal Grammar in the Brain?

• German's were asked to learn a new language (Japanese, Italian)

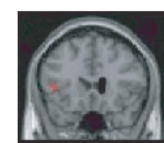
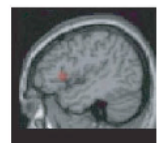
• instructed in the grammar, and given sentence

• Lexical items were the same, but grammar was manipulated

• either linguistically “legal” obeying principles of UG

• or linguistically “illegal” violating UG

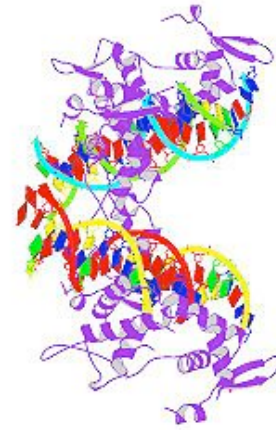
• Activation of Broca's area was only found for the UG language





# The Language Gene?

- ❁ Studies conducted on member of a large family (KE) where about 50% of family members showed
  - ❁ speech disorder, no broader cognitive impairment
  - ❁ difficulty with comprehension
- ❁ All affected family members showed mutation of Foxp2
- ❁ fMRI studies of patients have also shown
  - ❁ underactivation of Broca's area during lexical tasks
  - ❁ functional abnormalities in language-related cortical and basal/ganglia regions



The FOXP2 gene is located on human chromosome 7

# Foxp2 and Evolution

- ❁ Foxp2 in other species varies



2 amino acids



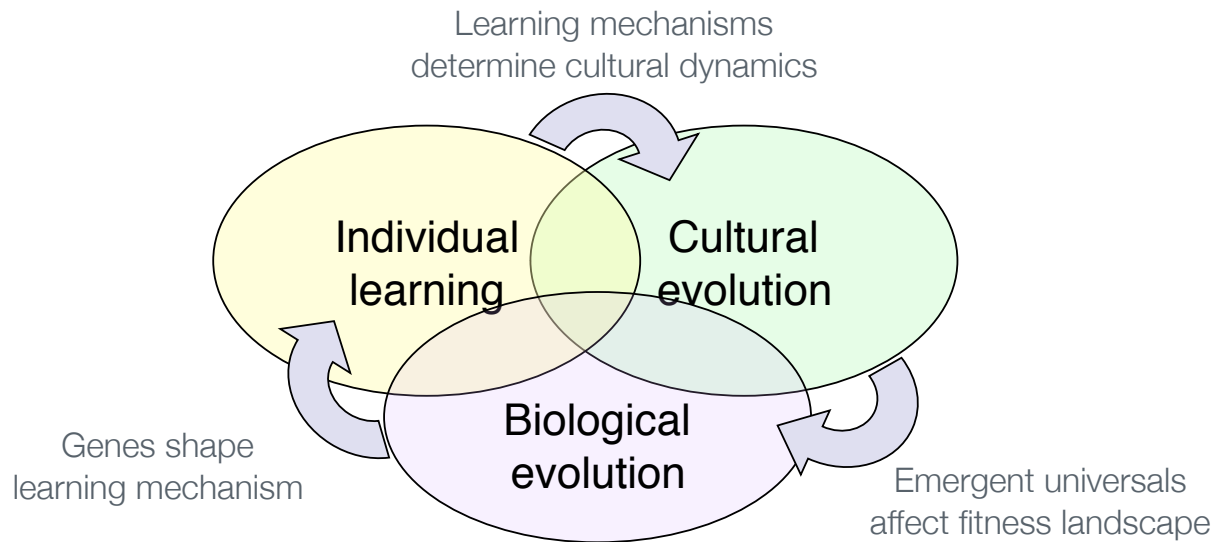
3 amino acids



7 amino acids

- ❁ The gene has also been found in Neanderthals (from which humans split ~300-400K years ago).
- ❁ Foxp2 is almost certainly just one of many genes contributing to language, and may be quite periphery

# The Emergence of Language



From: Kirby *et al*, *PNAS*, 2007

# Language processing

- ❁ Using computational techniques to better understand and model how people produce and comprehend language
  - ❁ Competence: How do utterances relate to underlying meaning?
  - ❁ Performance: How do people establish this relationship during on-line language processing?
- ❁ Psycholinguistics seeks cognitively plausible theories about about both mental rules and representations, and about cognitive processes
- ❁ Computational psycholinguistics seeks to realize such theories as implemented, predictive models of human knowledge and behavior

# Competence & Performance?

- ☘ Sometimes what we do differs from what we know
- ☘ Production: we say things we know
- ☘ Spoonerisms: “Mental lexicon” search
- ☘ Agreement: “The key of the office”
- ☘ Comprehension: we can’t understand
- ☘ Centre embedding: “The mouse that the cat that the dog chased bit fled”
- ☘ Garden paths: “The horse raced past the barn fell”

### More Spoonerisms

- A lack of pies (A pack of lies)
- Wave the sails (Save the whales)
- Plaster man (Master plan)
- Bottle in front of me (Frontal Lobotomy)
- Rental Deceptionist (Dental Receptionist)
- Flock of bats (Block of flats)
- Chewing the doors (Doing the chores)

# Summary of cognitive issues

- ☘ The relation between language and thought
  - ☘ language - culture mutually constraining
  - ☘ autonomy of language vs *mentalese*
- ☘ Linguistic autonomy
  - ☘ Modularity and localization in the brain (these aren’t the same thing)
  - ☘ Innate linguistic (domain specific) language “organ”
- ☘ Distinction between animal “communication” and human language
- ☘ The evolution & emergence of the capacity for human language