What's next?

- Language – Today
- Embodiment – Weekend
- Midterm – Next week
- Attention – Next week
- Cognitive Development
- Learning
- Memory
- Reasoning

- Social cognition?...

Term Projects

CMPE489

- Compare:
  - Computational Saliency Models
- Compare:
  - Object recognition models
  - Digit recognition models
- Implement:
  - Neural Network Models

COGS500

- Survey papers:
  - Symbol Emergence
  - Body representation in parietal cortex
  - Multi-sensory integration
  - Category formation in infants
  - Cognitive Approaches to Emotions for Social Robots

Cogs500/CmpE 489: Cognitive Science

Language

Slides adapted from Albert Ali Salah

Readings

- Bermudez, Chapter 1, 1.3: Linguistics and the formal analysis of language
- An Introduction to Language, Chapters 1-2
- Introduction to Psychology, Chapter 2, Asymmetries in the brain

Overview

- What is language?
- Linguistic knowledge
  - Syntax, semantics, (and pragmatics)
  - Generative linguistics
- Brain and language
  - Language disorders
  - Lateralization
- The great past tense debate

What is language? - Symbol System

- A symbol system

- …that allows the construction of infinitely large number of expressions.

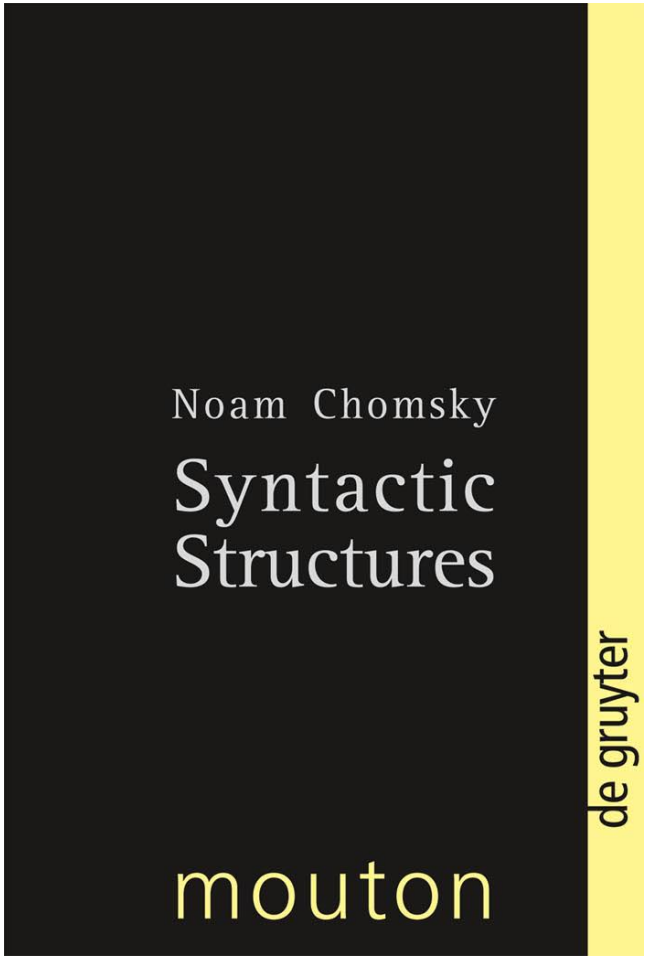
What is “language”?

- Language is made up of several interacting components
  - Phonetics/Phonology (Sound Pattern)
  - Morphology (combination of sounds)
  - Syntax (Structure of Sentences)
  - Semantics (word meaning)
  - Pragmatics (Figuring out when to say what and to whom…)
- Language can be divided into production and comprehension
  - Special speech production system
  - Special auditory perception system

What is language?

"When we study human language, we are approaching what some might call the "human essence," the distinctive qualities of mind that are, so far as we know, unique to man."

Noam Chomsky, *Language and Mind*



Language learning in nonhuman animals

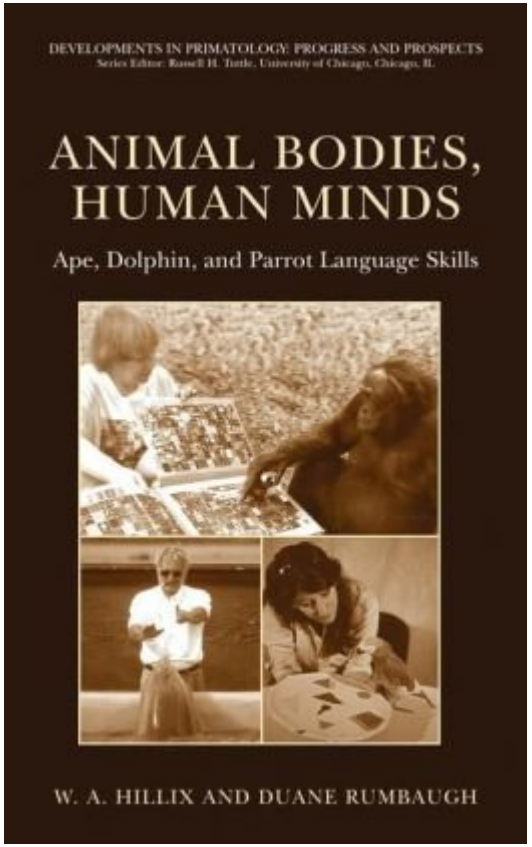
- Two Hypotheses concerning differences between human and non-human communication
  - Human Language must be fundamentally different from any other form of nonhuman animal communication
    - specialized brain circuits that produce a unique form of cognition because of unique genes
  - Human Language is analogous to animal communication
    - it is just that humans are smarter than the rest of the animals
    - so one difference is “intelligence”
    - Another is experience with language
    - other animals may be able to learn some amount of language with sufficient experience

What is language?

- Throughout the history, all efforts to teach speech to animals have failed
- Chimpanzees can learn some ASL
- Lana Project at Emory University:
  - Chimps are able to form novel and meaningful chains

Early attempts at Language Training

- Hillix & Rumbaugh (2004) "Animal bodies, human minds: ape, dolphin, and parrot language skills"
  - covers the history of language training in detail
- Viki: Chimpanzee trained by the Hayes in 1950's
  - Only learned to "speak" a few words
  - Other primates can not make speech sounds
- Washoe: Chimpanzee
  - Trained by Gardners from 1967-1970
  - Continued by Roger Fouts and Deborah Fouts from 1970-2007
  - raised in an environment as close as possible to that of a human child
  - Taught to use sign language
  - approximately 350 signs, simple combinations (if at all)
    - Difficult for other primates to make hand signs



Early attempts at Language Training

- Koko: Gorilla trained by Patterson from 1970's until present
  - Patterson claims comprehension of 100's of signs and novel production for naming objects
    - There is much skepticism about these claims
- Nim Chimpsky: Chimpanzee trained by Terrace in 1970's
  - raised by a family in a home environment
  - could use approximately 100 signs
  - learned to repeat his trainers' signs in appropriate contexts
  - as a means of obtaining an outcome
  - No evidence of syntax
- Lana: Chimpanzee trained by Duane Rumbaugh with lexigram system invented by von Glasersfeld
  - Used the lexigrams in grammatically sequence and make novel utterances
- Kanzi: Bonobo with Sue Savage-Raumbaugh observed lexigram use by his mother Matata
  - Started using the lexigram board spontaneously

Viki

- Catherine Hayes (1951), The Ape in Our House. New York: Harper.


Washoe: Chimpanzee

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Koko gorilla, 1971

- Patterson simultaneously exposed Koko to spoken English from an early age.
- Koko understands approximately 2,000 words of spoken English, in addition to the signs

Nim Chimpsky: Chimpanzee trained by Terrace in 1970's

- raised by a family in a home environment
- could use approximately 100 signs
- learned to repeat his trainers' signs in appropriate contexts
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LANA project
Lana: Chimpanzee, 1970

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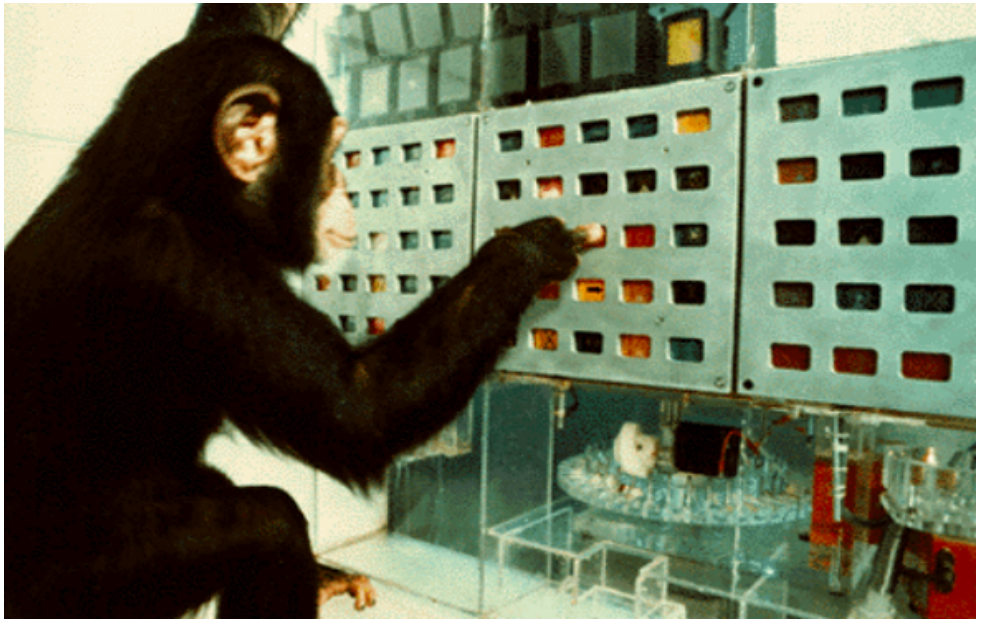
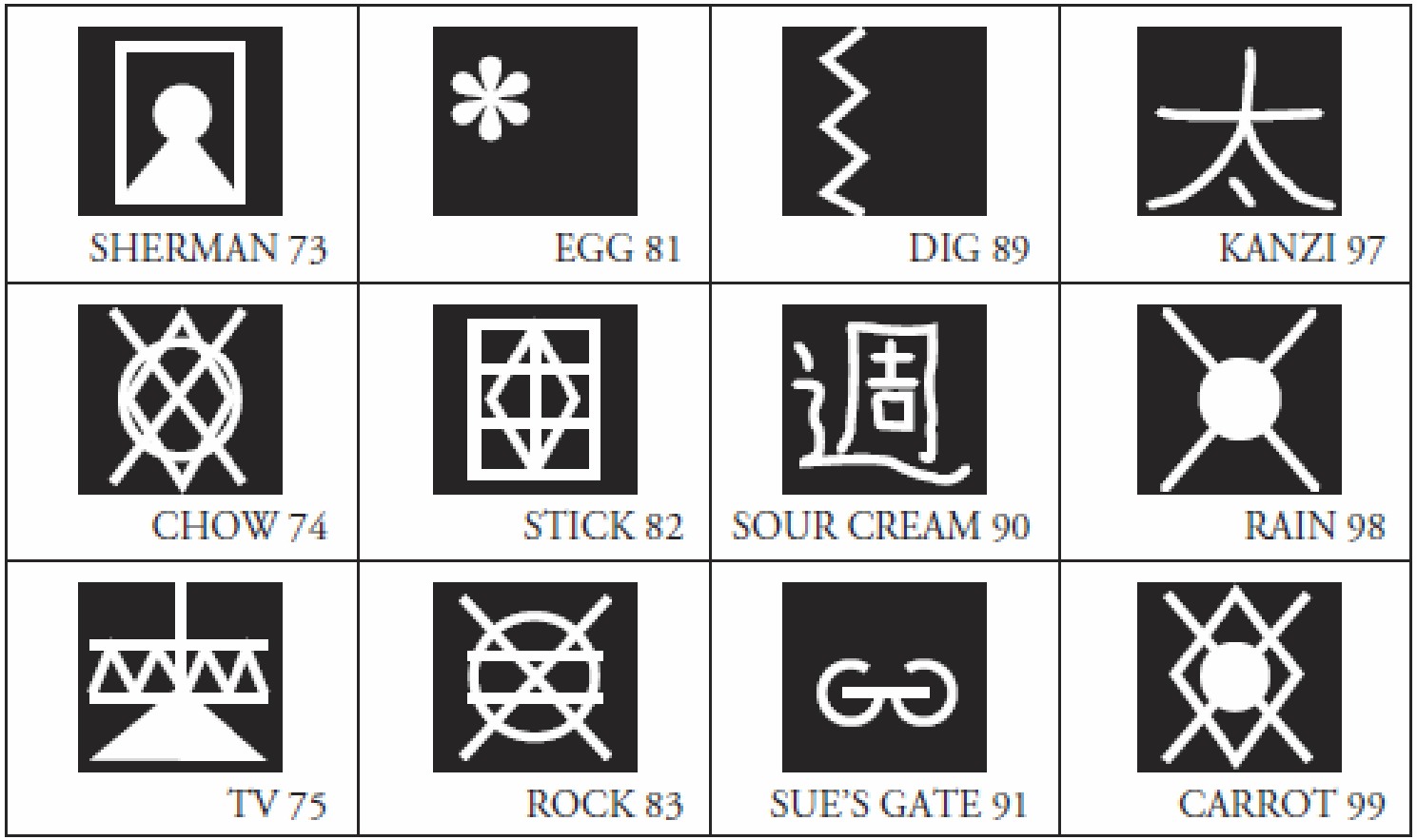


http://www2.gsu.edu/~wwwlrc/Media/Images/LAC/lana.gif

Sue Savage-Rumbaugh (L), Kanzi (R), and his sister Panbinisha (C) working at the portable "keyboard."



Examples of lexigrams used at the Language Research Center of Georgia State University. Courtesy of Duane Rumbaugh, Language Research Center, Georgia State University.

Kanzi, language-reared male bonobo, converses with Sue Savage-Rumbaugh in 2006 using a portable "keyboard" of arbitrary symbols that Kanzi associates with words.

What is language?

- Savage-Rumbaugh believes that
  - Language ability of chimps is underestimated
  - Chimps can understand speech (but can't produce)
  - Language comprehension comes before speech by several million years
  - Intention to communicate is important
- Pinker says "they just don't get it…"

Language Training with Alex: African Grey parrot

- Alex: African Grey parrot was trained by Pepperberg
  - could identify 50 different objects
    - seven colors and five shapes,
  - recognize quantities up to six
  - understand the concepts of "bigger", "smaller", "same" and "different"
  - could describe a key as a key no matter what its size or color, and could determine how the key was different from others.
  - vocabulary of over 100 words

Evidence of "Grammar" in Great Apes

- Learning a vocabulary
  - Associate arbitrary symbols with objects by using lexigram symbols to label and categorize objects
  - Is this the same as naming objects?
- Evidence of Grammar, two-word sequence **production**
  - “water bird” signed by Washoe, meaningful combination or a repetition of symbols?
  - Terrace thought that Nim was just using imitation, not unique production
  - Kanzi used symbol combination that show some evidence of meaning because of the particular combinations.
    - Mostly single word “symbol” production
    - 10-15 % two word combinations
    - Most of the combinations are requests
    - Very few declarative combinations

Comprehension versus Production

- Most research studies the production of language
  - How many symbols or signs are used and in what combination?
- Comprehension precedes production in human language development.
- Work with Kanzi using test sentences with instructions to manipulate familiar objects.
  - "Take the umbrella outdoors"
  - "Take the potato to the bedroom."
  - "Make the doggie bite the snake"
  - "feed you ball some tomato"
- Some Youtube videos about Apes:
  - Kanzi and Novel Sentences
  - Kanzi making a fire
  - Kanzi the Toolmaker
  - Bonobos Cooking
- Other examples of non-human animal comprehension of human language
  - Dogs: Chaser the Border Collie

Do the apes have a Theory of Mind

«Chimpanzees understand others in terms of a perception–goal psychology, as opposed to a full-fledged, human-like belief–desire psychology» Call & Tomasello, 2008

Table 1. Studies on chimpanzees' and human infants' understanding of goals and intentions

Studies	References	
	Chimpanzees	Infants
Getting/finding food		
1. Leave earlier and beg more intensely from an E who is unwilling as opposed to unable to deliver food (behavior similar in the two cases)	[31]	[32]
2. Select the box acted on intentionally versus accidentally (behavior similar in the two cases)	[33]	[33]
3. Leave earlier when E is playing with as opposed to trying to open a box with food (behavior identical in the two cases)	[a]	
Reacting to a partner's actions		
4. Give the object that the E is trying to reach	[34,35]	[34]
5. Take the food that a competitor is trying to reach	[36]	
6. Anticipate where E is going based on potential goals available	[a]	
7. When food is stolen retaliate against thief, not against innocent receiver of stolen food	[37]	
Imitation		
8. Produce target action based on observing a failed attempt	[38,39]	[40]
9. Copy intentional actions more often than accidental actions	[38]	[41]
10. Selectively copy freely chosen acts but not those forced by circumstances	[28]	[29]

[a](D. Buttelmann *et al.*, personal communication).
Gaps in the table indicate no information available.

- What does it mean to “know” a language?

Linguistic knowledge

- The capacity to produce sounds that signify certain meanings and to understand or interpret the sounds produced by others.
  - What about children?
  - What about deaf people?

Linguistic knowledge - sound

- The capacity to produce sounds that signify certain meanings and to understand or interpret the sounds produced by others.
  - What about children?
  - What about deaf people?
- Knowledge of the sound system
  - Knowing what sounds are in that language and what sounds are not.
  - Knowing which sounds may start a word, end a word, and follow each other.

Linguistic knowledge – Knowledge of Words

- Knowledge of the meaning of words
  - Knowing that certain sound sequences signify certain concepts or meanings.
  - The relationship between form and meaning of words is arbitrary
  - Few exceptions to arbitrariness: mimetic or iconic signs; onomatopoeic words
- Knowing a language means being able to produce new sentences never spoken before and to understand sentences never heard before.

A person who knows a language has mastered a system of rules that assigns sound and meaning in a definite way for an infinite class of possible sentences.

NOAM CHOMSKY, *Language and Mind*, 1968

Linguistic knowledge

- “Daniel Boone decided to become a pioneer because he dreamed of pigeon-toed giraffes and cross-eyed elephants dancing in pink skirts and green berets on the wind-swept plains of the Midwest”
- There are no limits to the length of a sentence:
  - “This is the dog that chased the cat that killed the rat that ate the malt that lay in the house that Jack built”

Linguistic knowledge - form

- Knowledge of sentences and non-sentences
  - What are drinking and go home?
  - I expect them to arrive a week from next Thursday.
  - I expect a week from next Thursday to arrive them.
  - Linus lost his security blanket.
  - Lost Linus security blanket his.
- Linguistic knowledge includes “rules” for forming sentences and making judgments.

Sapir Whorf hypothesis

- Language usage influences (shapes) thought, and thereby, behavior.
- Also called “linguistic relativity”
- Experiments with color perception: Roger Brown and Eric Lenneberg: whether color perception varies between speakers of languages that classified colors differently.
- universal nature of human language and cognition came into focus
- Berlin and Kay show that color terminology is subject to universal semantic constraints
- There is evidence to show that language influences certain kinds of cognitive processes in non-trivial ways.
  - Lakoff & Johnson: Metaphors of a language reveal cultural ways of thinking.
  - Slobin: Perceptional data and its communication is prone to linguistic relativity.

Design of

- Perception of passage of time / duration perception
- Affected from language use?

Journal of Experimental Psychology: General

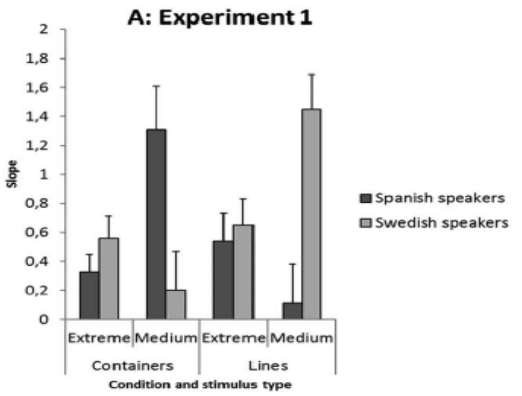
The Whorfian Time Warp: Representing Duration Through the Language Hourglass

Emanuel Bylund and Panos Athanasopoulos

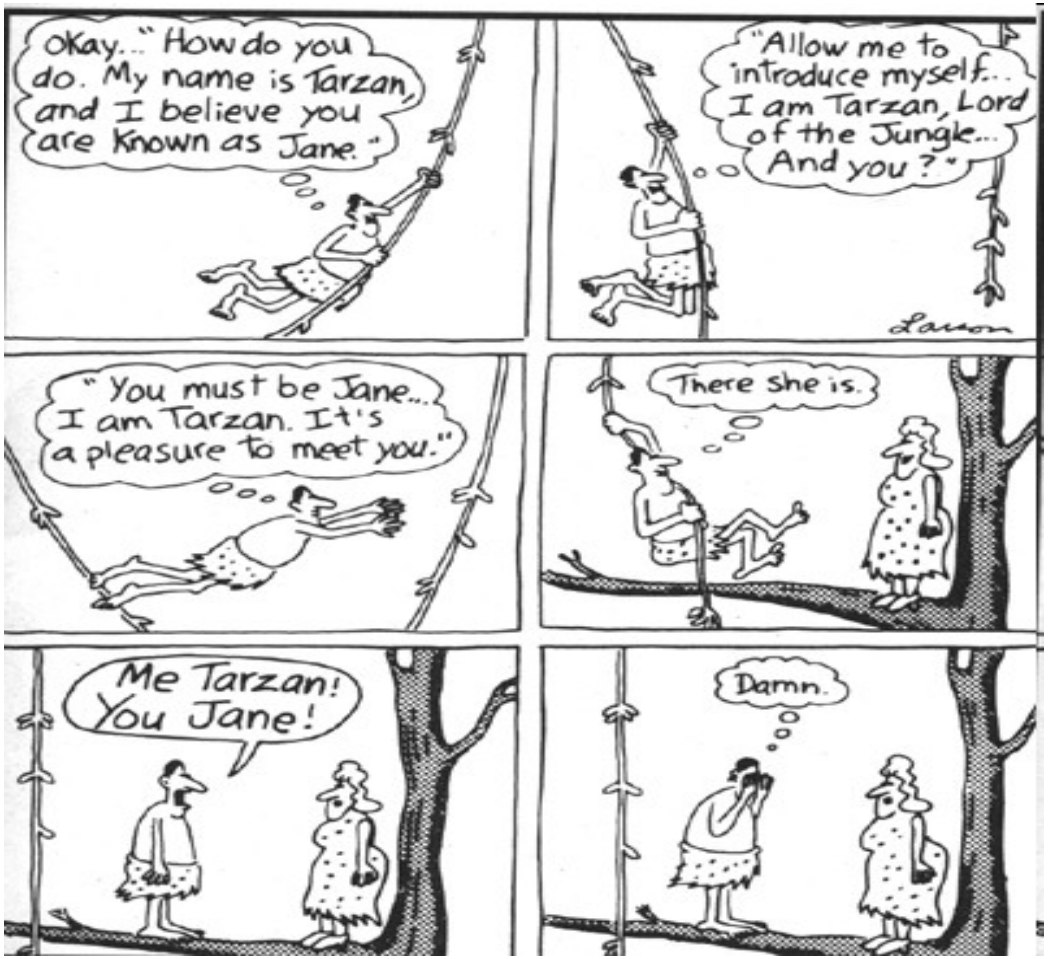
Online First Publication, April 27, 2017. http://dx.doi.org/10.1037/xge0000314

- Construct mental representations of the passage of time?
  - Universalist account claims that abstract concepts like time are universal across humans.
  - Linguistic relativity hypothesis: speakers of different languages represent duration differently
- Language-specific interference in a duration reproduction task, stimulus duration conflicted with its physical growth. When reproducing duration,
  - Swedish speakers were misled by stimulus length,
  - Spanish speakers were misled by stimulus size
- participants either reproduced the duration of computer-generated animations showing
  - either a container that filled gradually with liquid,
  - or a line gradually growing on the screen.

Condition	Medium stimuli	Extreme stimuli
Lines		
Spanish group	390 (256)	235 (167)
Swedish group	412 (276)	310 (282)
Containers		
Spanish group	463 (253)	339 (251)
Swedish group	344 (178)	256 (192)



Linguistic knowledge and performance



G. Larson, Far Side

What is a grammar?

"We use the term "grammar" with a systematic ambiguity. On the one hand, the term refers to the explicit theory constructed by the linguist and proposed as a description of the speaker's competence. On the other hand, [it refers] to this competence itself."

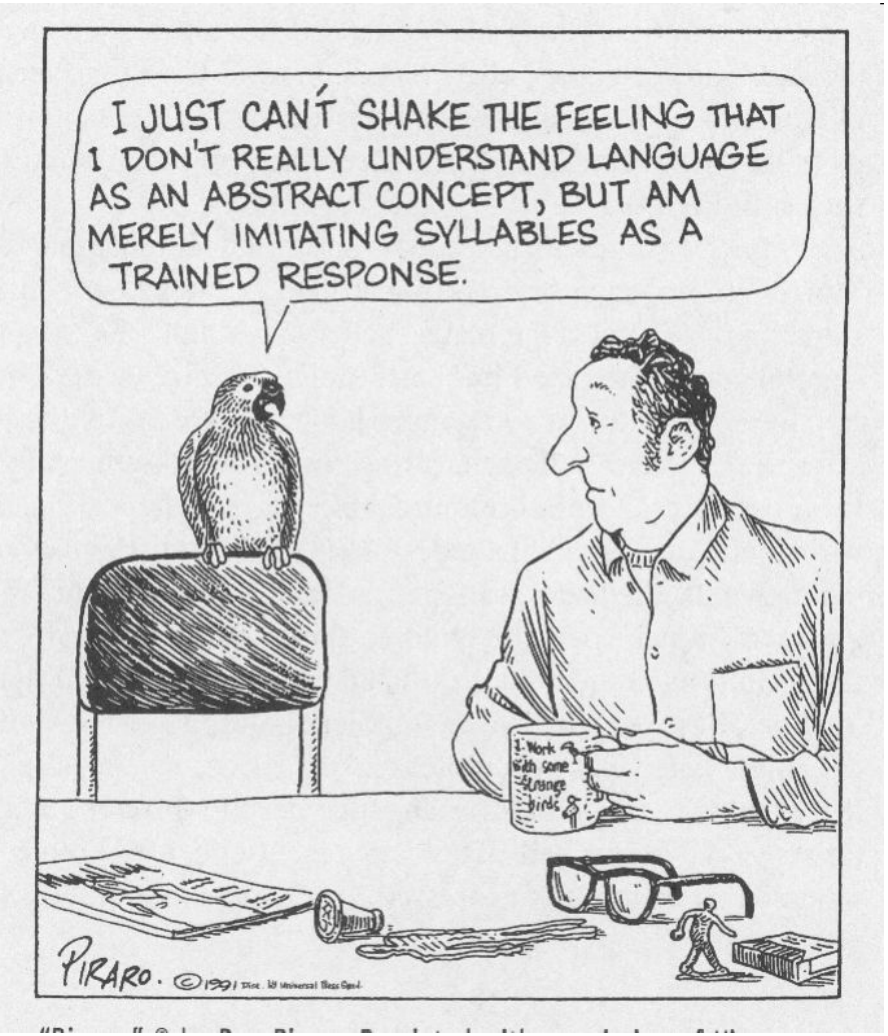
Chomsky and Halle,

The Sound Pattern of English

What is a grammar?

- The sounds and sound patterns, the basic units of meaning, such as words, and the rules to combine them to form new sentences constitute **the grammar**.
  - Sounds into words - phonology (systematic organization of sounds)
  - Rules of word formation – morphology
  - Rules for combining words into phrases and phrases into sentences – syntax
  - Rules for assigning meaning – semantics
- The grammar, together with a mental dictionary (lexicon) that lists the words of the language, represents our linguistic competence.
- Descriptive grammar: The linguist's description of the true model of the speaker's linguistic capacity.
- Prescriptive grammar: The "correct" forms of speaking and writing a language.

What is a grammar?



Universal grammar – Chomsky's view

- Rules/structures that hold in all languages
- All languages have
  - their own set of sounds
  - combine according to certain patterns
  - words themselves recombine to form phrases and sentences
  - Nouns and verbs – universal grammar categories
  - a way of negating, forming questions, issuing commands,
  - referring to past or future time,
- more generally, has a system of rules that will allow her to produce and understand an infinite number of sentences.
- as the blueprint that all languages follow that forms part of the child’s innate capacity for language learning.

Noam Chomsky

https://www.youtube.com/watch?v=E3U6MsdBalg

Noam Chomsky on Mind and Language

https://www.youtube.com/watch?v=nFSsb_N_0as

Generative linguistics

- Chomsky's concept of generative grammar implies a finite set of rules that can be applied to generate sentences, at the same time capable of producing infinite number of strings from the set rules.
- A type of grammar which describes a language by giving a set of rules that can be used to produce other possible sentences in that language.

What is not language

- An essential property of human language not shared by the communication systems of spiders, crabs and other animals is its discreteness. Human languages are not simply made up of a fixed set of invariant signs
- Bird songs - there is no evidence of any internal structure to these songs; they cannot be segmented into discrete meaningful parts and rearranged to encode different messages as can the words, phrases, and sentences of human language
- Honeybee dance: discrete, consist of several parts, might be infinite but.
- **Displacement**: the capacity to talk (or sign) messages that are unrelated to here and now.

Can animals learn language?

- border collie named Chaser is reported to understand the names of 1022 toys!
  - understand the meanings of words?
  - Or just association?
- In their natural habitat, chimpanzees, gorillas, and other nonhuman primates communicate with stereotypical messages
- Early experiments, at home, vocal tracks do not permit, but they can understand some words.
  - Chimpanzee Washoe, gorilla Koko, chimpanzee Nim Chimpsky: Americal Sign Language – strings of two signs.
- Artificial languages: chimpanzees Sarah, Lana, Sherman, Austin, and a male bonobo named Kanzi
  - creative ability is not evidenced by the chimps' use of the artificial languages

Generative linguistics

- Deep vs. surface structure
- Transformational rules
- Universal grammar
  - It is the “innate” (genetically transmitted) aspect of grammatical rules; the ***language instinct*** (Pinker).
  - Allows a human to learn “a” language.
  - Innate does not mean that there is no environmental influence.

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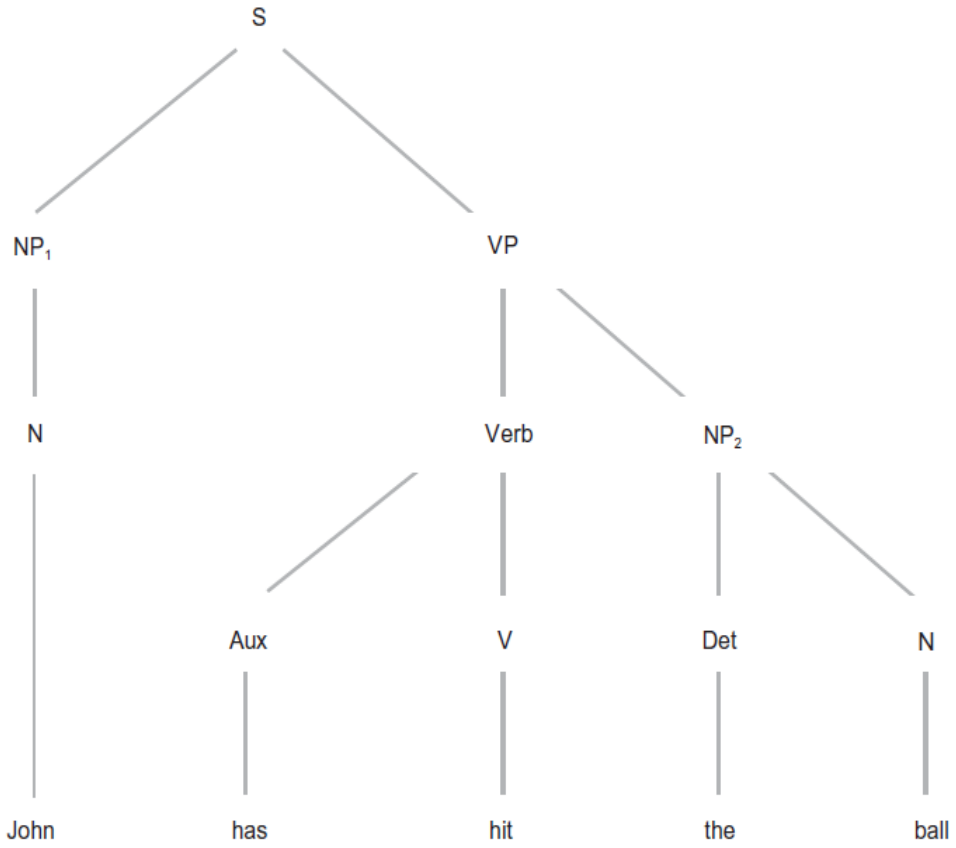
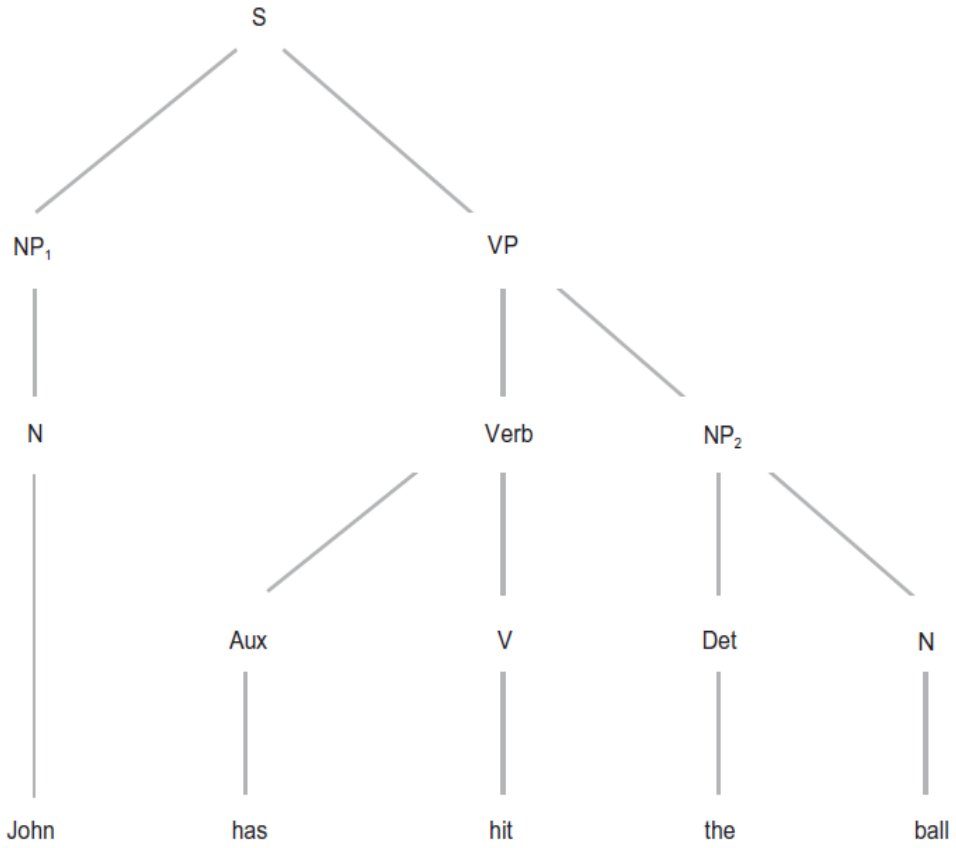


- Different phase structures
  - John has hit the ball
  - The ball has been hit by John
- Similar phase structures
  - Susan is easy to please
  - Susan is eager to please.

- The basic aim of transformational grammar is to explain the connection between sentences of the first type and to explain the differences between sentences of the second type.
- Operate upon a string of symbols to convert it into a different string of symbols



- Different phase structures
  - John has hit the ball
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- Similar phase structures
  - Susan is easy to please
  - Susan is eager to please.

$$NP_1 + Aux + V + NP_2$$
$$\Rightarrow$$
$$NP_2 + Aux + been + V + by + NP_1$$

This transforms the string "John + has + hit + the + ball" into the string "the + ball + has + been + hit + by + John." And it does so in a purely mechanical and algorithmic way.

Creating a Grammar

5 rules:	9 words:
S → NP VP NP → Det N NP → N VP → V NP VP → V	Det: the, four, some N: dogs, cats, slugs V: understood, ate, approached

How many sentences?

Language of Thought

- Jerry Fodor's LOT hypothesis:
  - Thought happens in a special, mental language
  - A representation in LOT has a syntactic structure with appropriate semantics
  - Thinking consists of syntactic operations defined on such representations
- Representational Theory of Thinking
  - Mental processes, thinking in particular, consist of causal sequences of tokenings of mental representations.

Areas of linguistic study

- Syntax: study of the rules that describe what a well-formed or grammatical sentence is
- Semantics: study of the meaning of words and sentences
- Pragmatics: study of what speakers do with language
- Phonology: study of the language as a sound system
- Morphology: study of the rules of word formation
- Lexicon: study of the dictionary of a language

What we know about language

- Wherever humans exist, language exists.
- There are no “primitive” languages – all languages are equally complex and equally capable of expressing any ideas.
- All languages change through time.
- The relationships between the sounds and meanings of spoken languages and between the gestures (signs) and meanings of sign languages are for the most part arbitrary.

What we know about language

- All human languages utilize a finite set of discrete sounds (or gestures) that are combined to form meaningful elements or words, which themselves form an infinite set of possible sentences.
- All grammars contain rules for the formation of words and sentences of a similar kind.
- Every spoken language includes discrete sound segments like p, n, or a, which can be defined by a finite set of sound properties or features. Every spoken language has vowels and consonants.

What we know about language

- Similar grammatical categories (i.e. Verb, noun) are found in all languages.
- Every language has a way of referring to past time, negating, forming questions, issuing commands, and so on.
- Speakers of all languages are capable of producing and comprehending an infinite set of sentences.
- Any child can learn any language.

Sign Language

- Deaf children who are exposed to signed languages acquire them just as hearing children acquire spoken languages, going through the same linguistic stages, including the babbling stage. Deaf children babble with their hands, just as hearing children babble with their vocal tracts. Neurological studies show that signed languages are organized in the brain in the same way as spoken languages, despite their visual modality.

BRAIN AND LANGUAGE

Evolution of brain and language

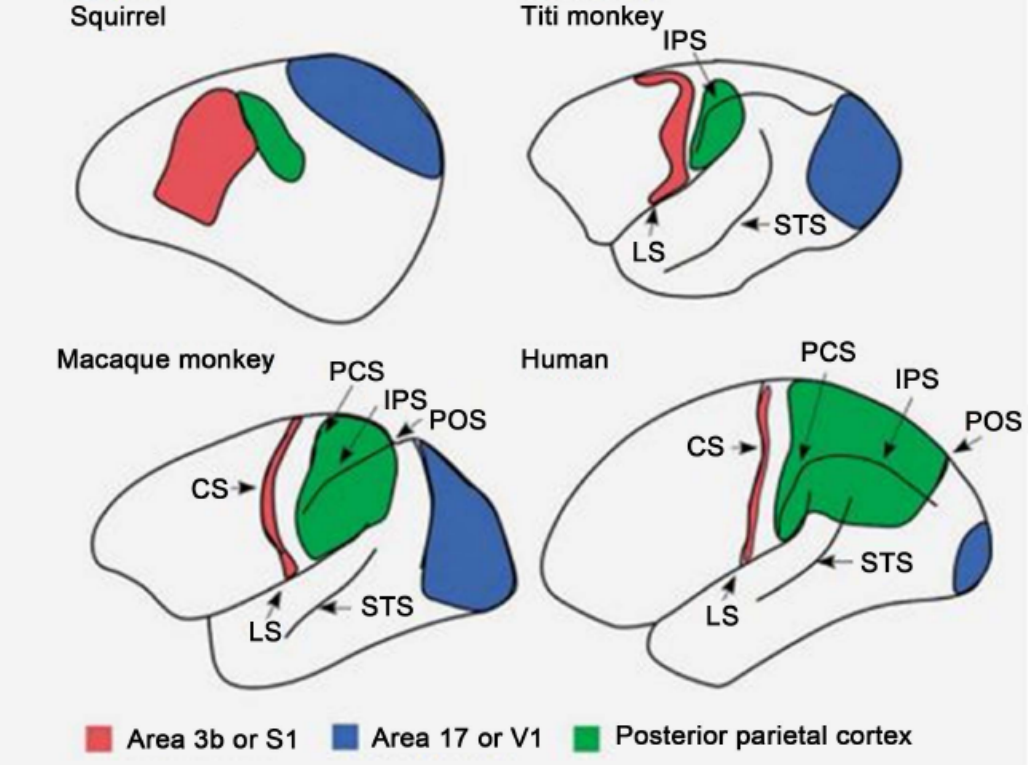
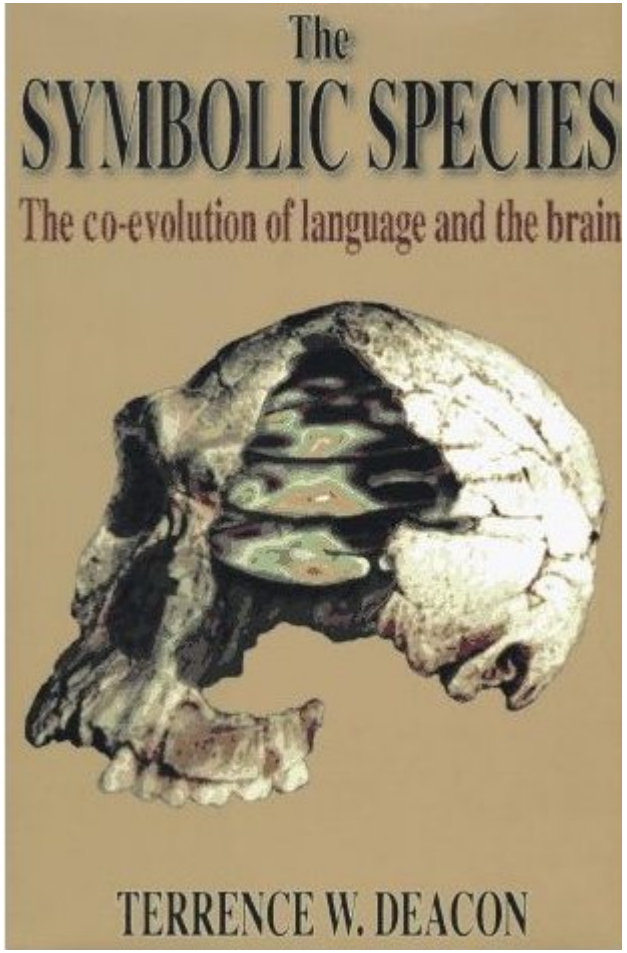


Figure 1. The brain size has increased over million years of human evolution; the prefrontal cortex has increased in size sixfold according to the dominant theory (along with the increase in the posterior parietal cortex). Krubitzer, L., and Disbrow, E. (2008) The evolution of parietal areas involved in hand use in primates. In: The Senses: A Comprehensive Reference. Volume 6, Somatosensation (Jon Kaas and Ester Gardner eds.) Elsevier, London, pp. 183-214.

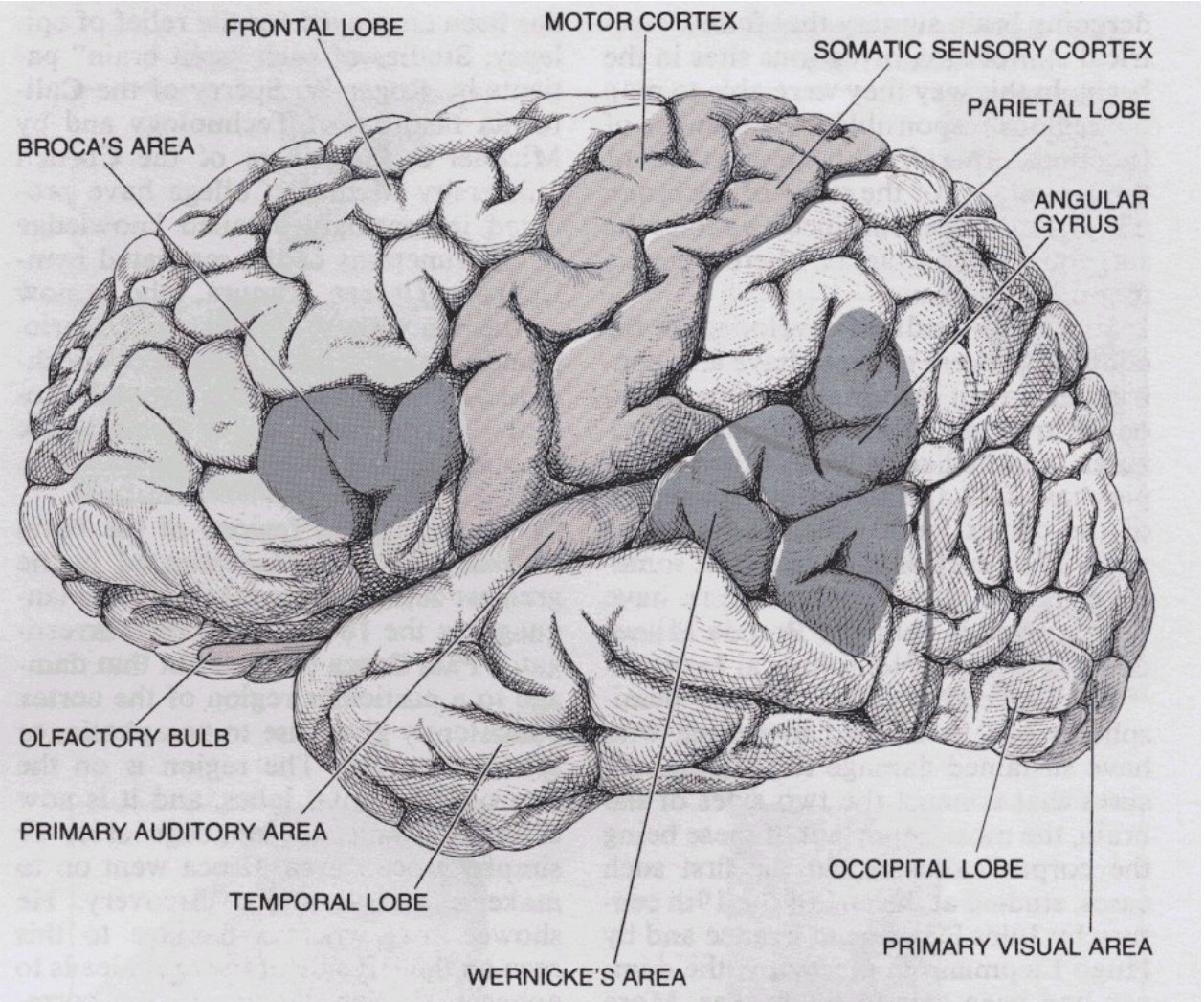
Ko, «Origin of Human Language in an Evolutionary Context: Evolution-Progression Model», Advances in Anthropology, 2015

Evolution of brain and language

- The human brain underwent very rapid growth in recent evolution.
- What was the cause of this "runaway" growth (Wills, 1993)?
- Was expansion of brain size a consequence of the evolution of spoken language and the survival advantage that possessing a language confers?
- The ‘co-evolution hypothesis’ (Deacon, 1997)



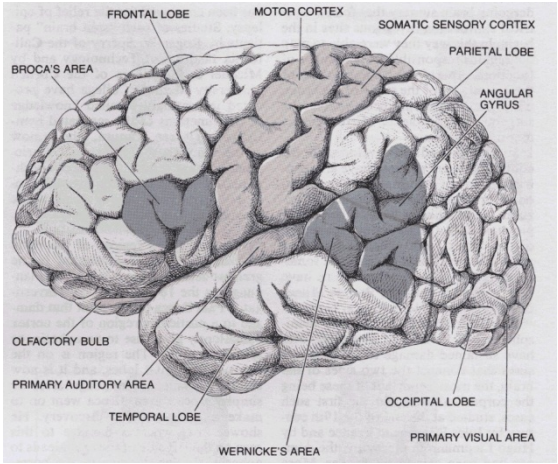
Language areas in the brain



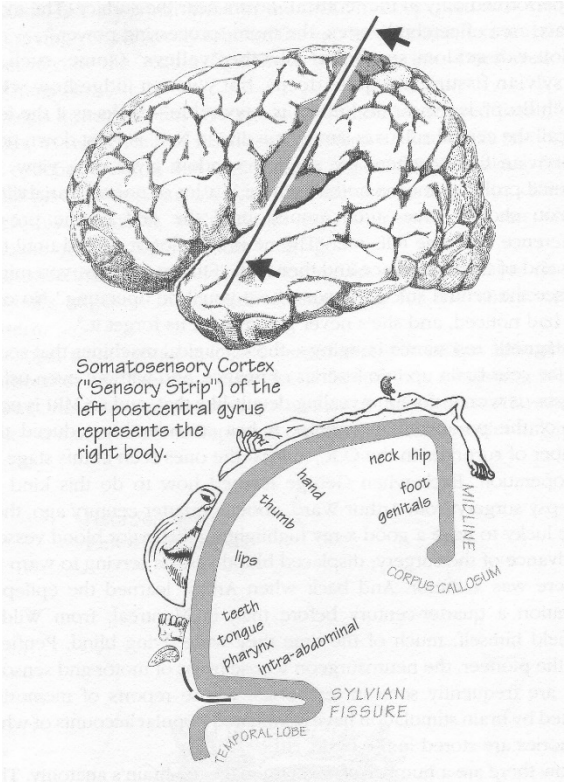
Language Disorders

- Egyptians reported speech loss after blow to head 3000 years ago
- Broca (1861) finds damage to left inferior frontal region (Broca's area) of a language impaired patient, in postmortem analysis

Language areas in the brain



- Language is predominantly lateralized to the left hemisphere.
- How do we know this?
- Why are Broca's and Wernickes areas located where they are?



Broca’s aphasia

- Paul Broca (1861) was the first to provide convincing evidence that language is localized to a particular region of the brain.
- What language impairments are found in Broca's aphasia?
  - effortful, non-fluent speech,
  - absence of function words and inflectional morphology,
  - short utterances,
  - relatively intact comprehension,
  - awareness of deficit.

Speech production in Broca's aphasia

- What brought you to hospital?
  - Yes... ah... Monday... ah... Dad and Peter Hogan, and Dad... ah... hospital... and ah... Wednesday... Wednesday nine o'clock and ah Thursday... ten o'clock ah doctors... two... two... an doctors and... ah... teeth... yah... And a doctor an girl... and gums, an I.

Wernicke's Aphasia

- The language symptoms of Wernicke's aphasia are **complementary** to those of Broca's aphasia.
  - fluent but empty speech,
  - grammatical inflections, normal prosody
  - utterances of normal length
  - poor comprehension
  - unaware of deficit.

Speech in Wernicke's aphasia

- What brings you to hospital?
  - Boy, I'm sweating, I'm awful nervous, you know, once in a while I get caught up, I can't mention the tarripoi, a month ago, quite a little, I've done a lot well, I impose a lot, while, on the other hand, you know what I mean, I have to run around, look it over, trebbin and all that sort of stuff.

Wernicke-Geschwind model (Geschwind, 1979)

- Broca's area stores articulatory codes,
- these codes are transmitted to the motor area
- Wernicke's area is where auditory codes and the meanings of words are stored.
- For a word to be spoken, its auditory code must be activated in Wernicke's area and transmitted to Broca's area.
- Spoken word → Wernicke's area → match with auditory code → activate meaning
- Written word → angular gyrus → visual form of the word with its auditory code in Wernicke's area

Some phonological errors typical of fluent (Wernincke's) aphasia

- *tarripoi, trebbin* neologisms,
- *tying [trying]* omissions
- *repuceration [recuperation]* transpositions
- The speech which is produced is phonetically well formed and conforms to the sound-sequencing rules of English.
- By contrast, the Broca's aphasic has manifest difficulties with speech production.

Broca and Wernicke aphasics

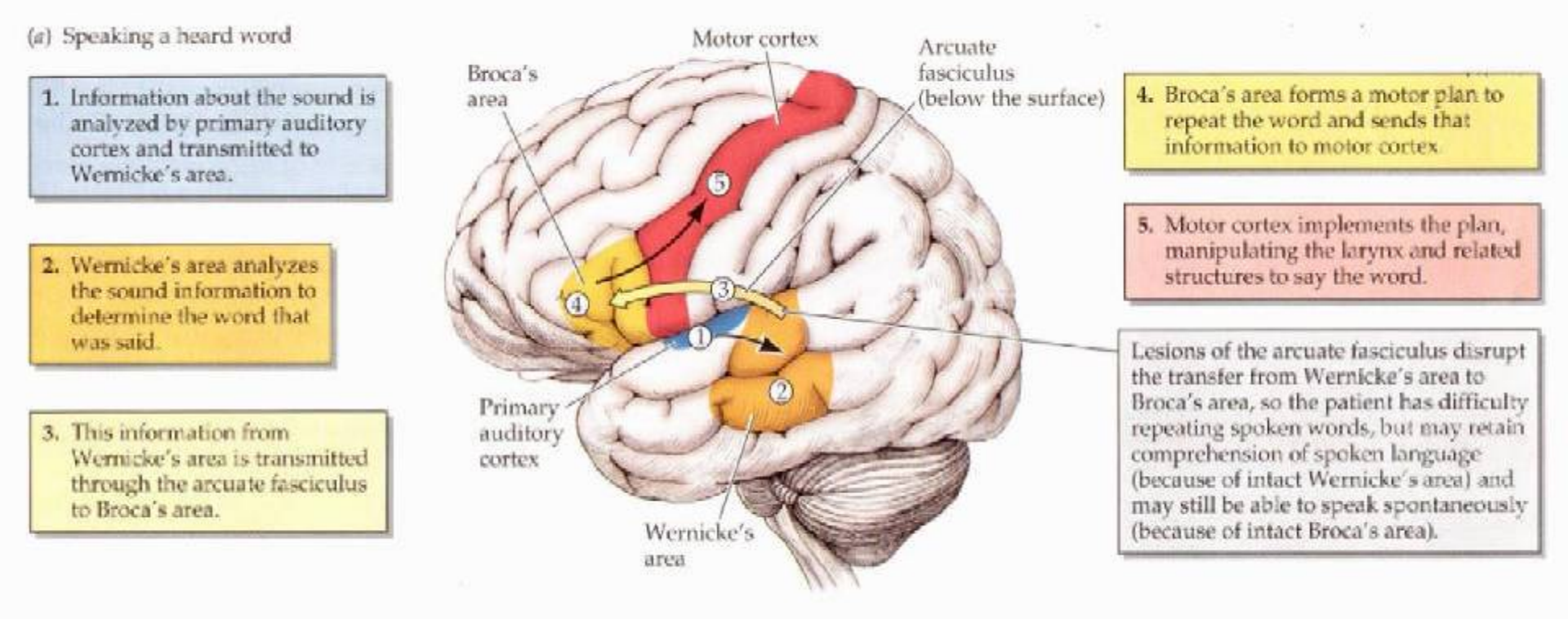
- Neurologists (like Luria) often use the label **receptive** aphasia for Wernicke's aphasia.
- Although comprehension of language appears to be largely intact in Broca's aphasia, there is often a specific deficit in the comprehension of syntax.
- The term **agrammatism** is used to describe the a-syntactic, telegraphic speech, with its absence of function words, grammatical inflections and verb forms.
- There is a corresponding comprehension deficit associated with these forms.

Sign aphasia

- There is evidence from a deaf speaker, who suffered a stroke and damage to Broca’s area, and has expressive difficulties in sign language production.
- This suggests that Broca’s area is specialized not for *speech*, but *for language* production.
- Damage to Broca's area results in slow signing where most grammatical inflections are omitted.
- Damage to Wernicke's area leaves signers signing fluently and rapidly, but making little sense, and experiencing great difficulty understanding others' signs.

Wernicke-Geschwind Model

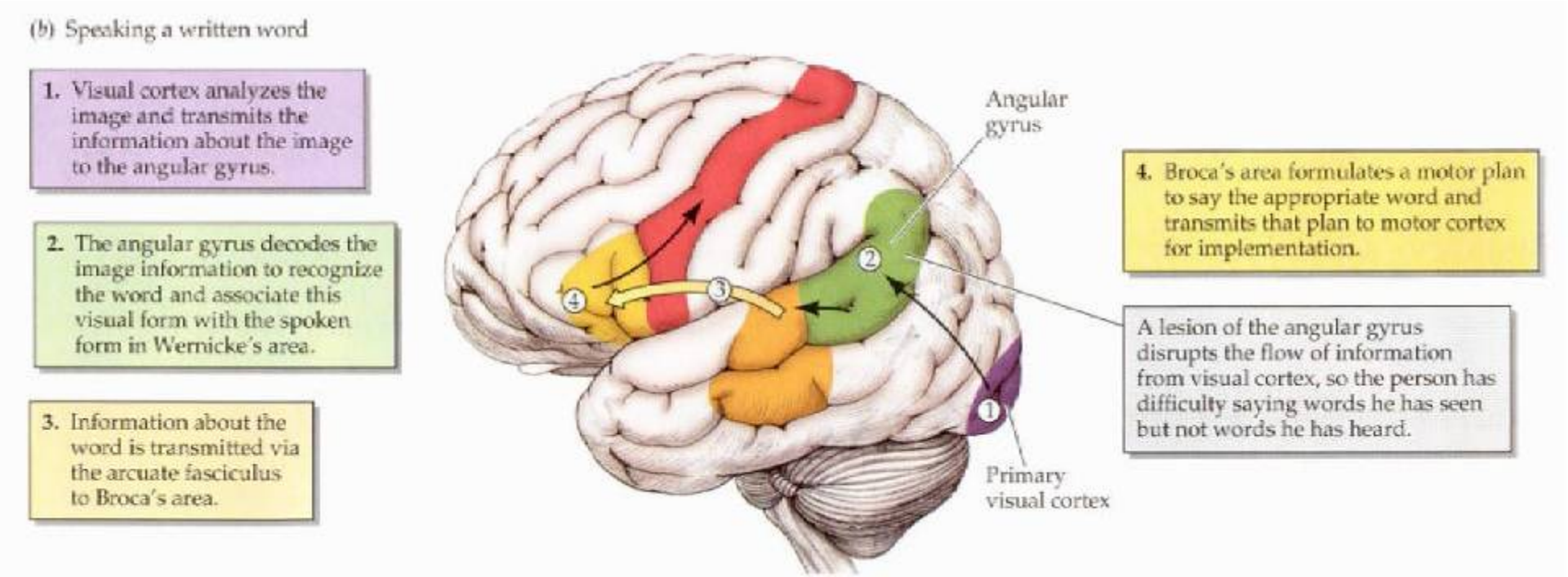
1. Repeating a spoken word



- Arcuate fasciculus is the bridge from the Wernicke's area to the Broca's area

Wernicke-Geschwind Model

2. Repeating a written word



- Angular gyrus is the gateway from visual cortex to Wernicke's area
- This is an oversimplification of the issue:
  - not all patients show such predicted behavior (Howard, 1997)

Some conclusions

- There are functional centers in the brain for different aspects of language function.
- Lesion studies reveal the broad outline of mechanisms to process language in the brain.
- These studies do not tell us whether there are grammatical rules implemented in the brain, or what the precise representation of words and concepts are.

THE GREAT PAST TENSE DEBATE

The critical age for language learning

- For human babies, the brain is very flexible, and the left hemisphere is not dominant. By the Critical Age, the left hemisphere is dominant and Broca's area and Wernicke's area become less adaptable to new language stimuli.

(Heny 649)

- "The critical-age hypothesis assumes that language is biologically based and states that the ability to learn a native language develops within a fixed period, from birth to middle childhood."

(Fromkin, Rodman, Hyams [2007] 53)

Learning the past tense

- In English, most regular verbs have past tense formation via adding an /–ed/:
  - added, carried, climbed...
- Children learning past tense sometimes apply this rule to non-regular verbs:
  - holded, goed, hitted
- There are different types of irregular verbs:
  - go/went (arbitrary change)
  - hit/hit (no change)
  - see/saw (vowel change)
  - sleep/slept (blending)

Stages of past tense acquisition in children

Stage 1 (1-2 years)

Past tense of a few specific verbs, some regular (e.g. looked, needed), most irregular (came, got, went, took, gave). Children initially memorize forms

Stage 2 (2-5 years)

Evidence of general rule for past-tense, i.e. add *ed* to stem of verb. Children often overgeneralise irregulars, e.g. *camed* or *comed* instead of *came*. Ability to generate past tense for an *invented* word, e.g. *rick*. Subjects say *ricked* when using the 'word' in the past-tense

Stage 3

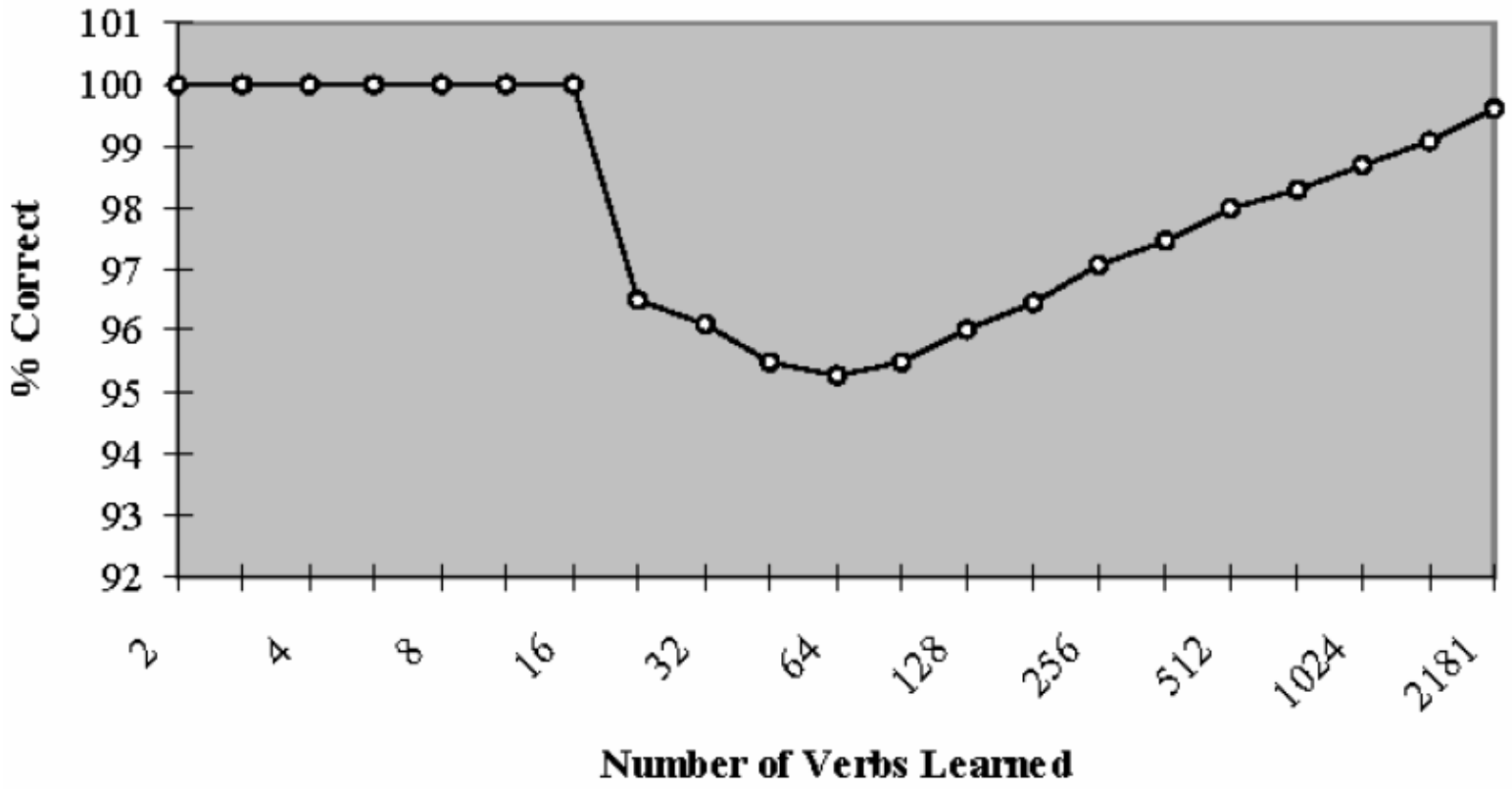
Children produce correct forms for both regular and irregular verbs.

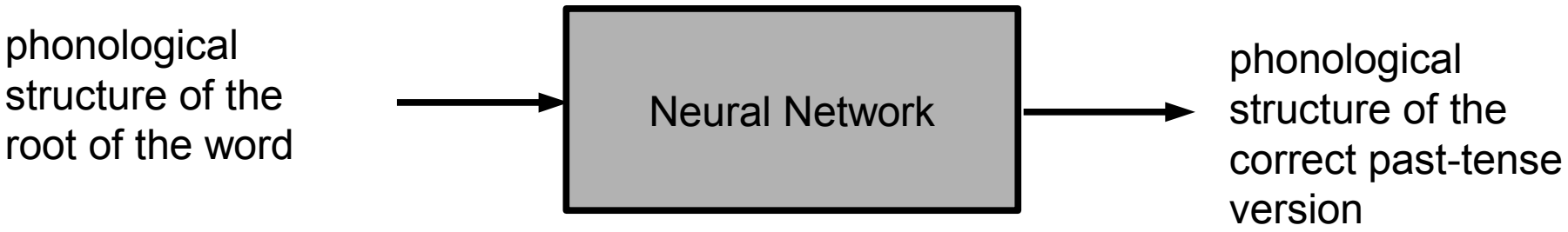
The U shaped learning curve

Slightly older child: *Daddy came home* Stage 1

Older child: *Daddy comed/camed home* Stage 2

Even older child: *Daddy came home* Stage 3




phonological structure of the root of the word
Neural Network
phonological structure of the correct past-tense version

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