welcome to Week 9

Computation and the Brain

Fall 2019

What happened last Wednesday

Today and next three weeks: Language

Today:

- Discussion of **[Friederici 2018 book]** Chapters 1-2
- Questions from HW 7 and 8
- Linguistics overview by Dan Mitropolsky

This and next three weeks: Language

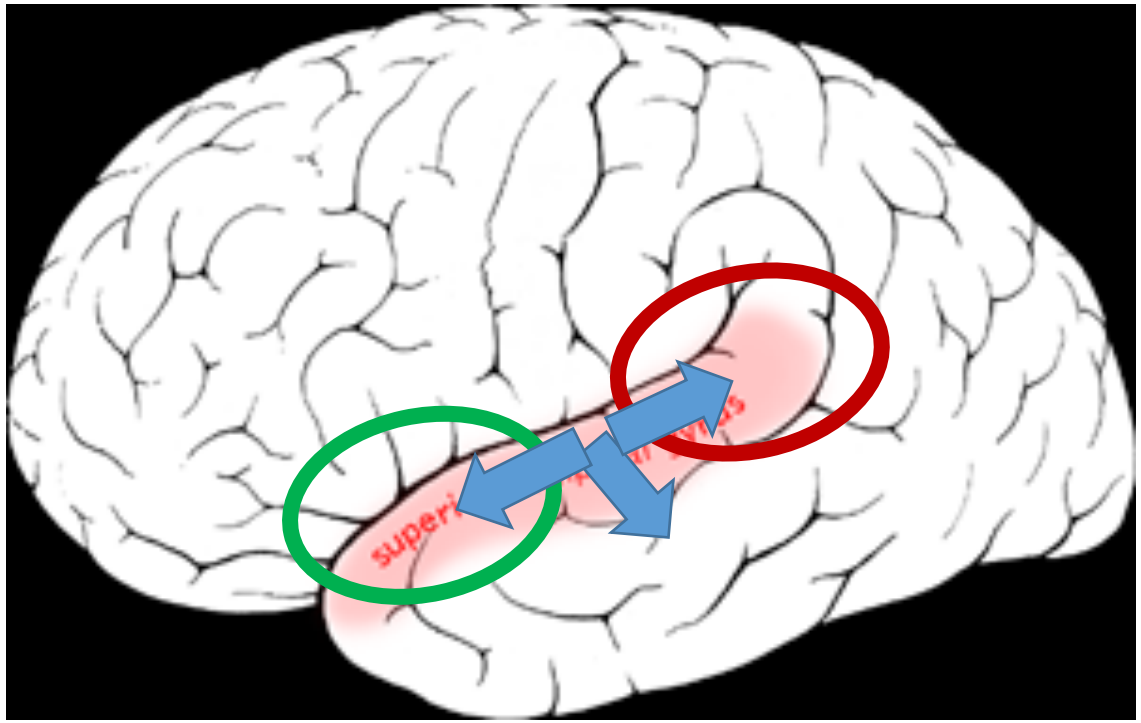
- Next week:
- Our work on assemblies and their operations, and its relation to language
- Week after that:
- wrap up the [Fr2019] book
- Week after that:
- Talk on NLP by Mike Collins!
- …and preliminary project presentations ***(volunteer!!)***

Right off the bat:
"to comprehend an utterance…"

- We are into language ***comprehension***
- (Not generation, for example)
- The basic cognitive model:
- The LH* builds a syntactic model of what is heard
- It builds a "phase structure" ***(= a tree!)***
- Then integrates syntax and semantics
- (The RH processes prosody: intonation, accentuation)

1.2 Acoustic-phonological processes

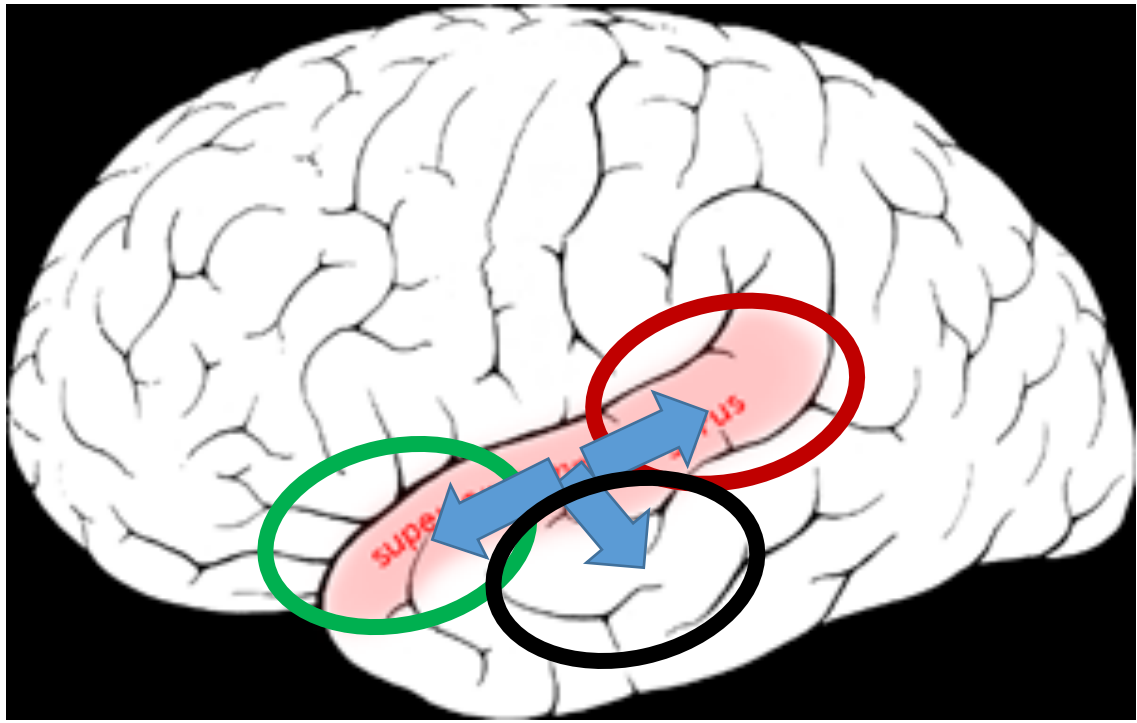
Left auditory cortex treats speech sound differently
Propels it to aSTG and pSTG and MTL



1.3 Words and their information

a search for words takes place

-- only real words activate the MTL



1.3. Information about words: the lexicon

- Initial syllable often starts process
- N400 associated with successful lexical-semantic processing
- Many parallel processes seem to be at work
- Word “engrams” or “entries” in the lexicon are hypothesized to have associated attributes accessible by these processes
- Verbs have their argument structure
- The role of MTL and the hippocampus (new words)
- Representation? Memory association? Sparse coding?

1.4 Initial phrase structure (=Tree) Building

- Syntax-first models
- Word search yields word category "high in the lexical entry since it becomes available fast"
- Early left anterior negativity (ELAN) ***120 – 200ms***
- Seems to signal impossibility of building a tree…
- N400 is about semantic violations

1.4 Initial phrase structure (=Tree) Building

- Left frontal operculum: two-words combinatorics
- Broca's BA44: the initial building of a small tree.
- ***Merge***

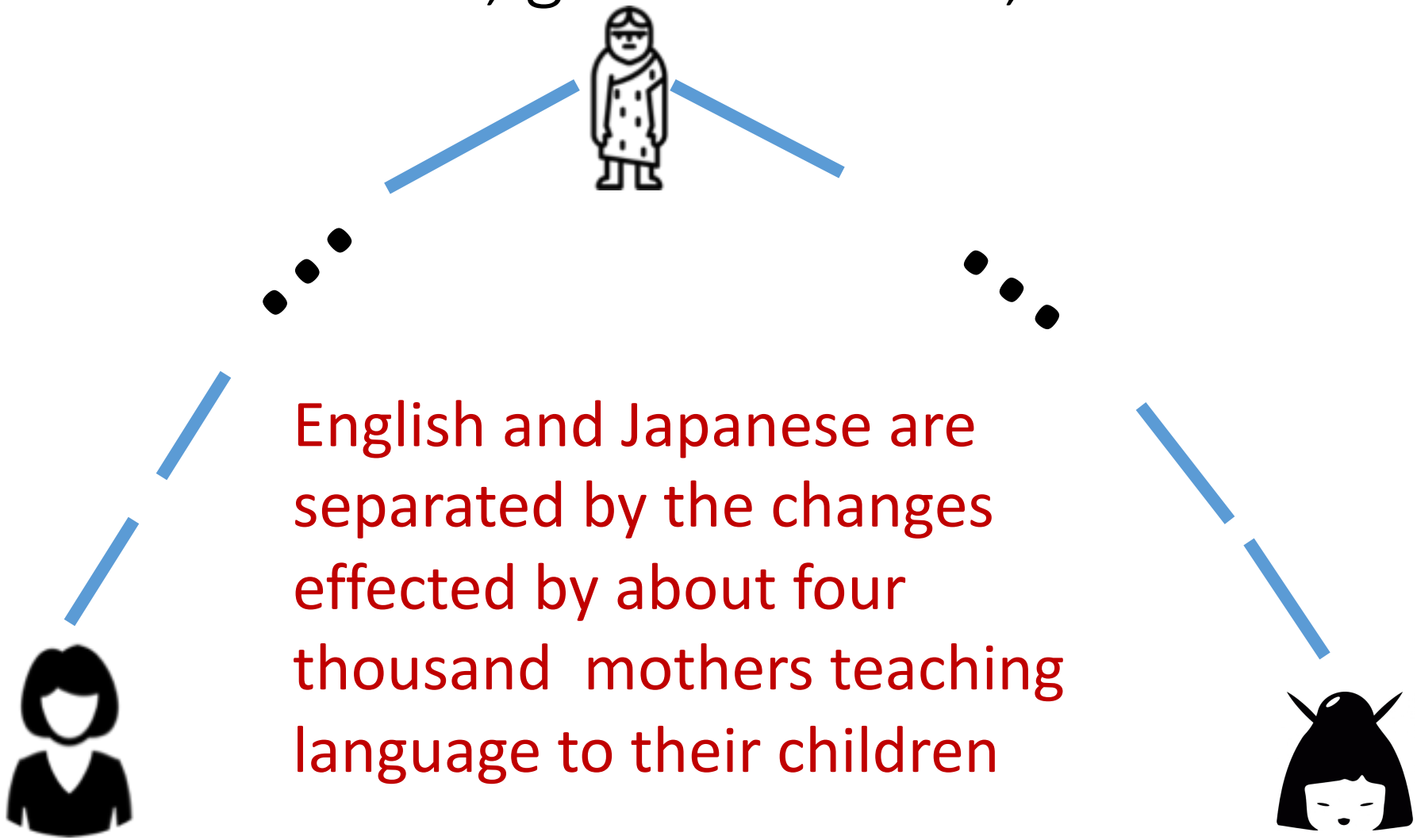
1.5: Syntactic processing

- Syntactic complexity – word order, nesting, movement (??)
- Pseudoword sentences vs sequences: ***Broca!***
- Single Merge ***Broca!***
- ***Also, posterior STG!*** (assigning meaning)
- ***The Poeppel experiment*** (cryptically in [Fr] p. 53 first para, to be explained later today)

How language came about: Speculation

- Was there a cognitive/neural Big Bang?
- Or gradual progress?
- Perhaps we had language (in some weak sense) far before 80 KYBP
- Maybe around 500 or even 800 KYBP
- Perhaps homo sapiens gestured for a very long time
- C Corballis ***The gestural origin of language*** Wiley 2010
- Q: What is the "weak sense"?
- PA: Hierarchically structured thought? Inner language?

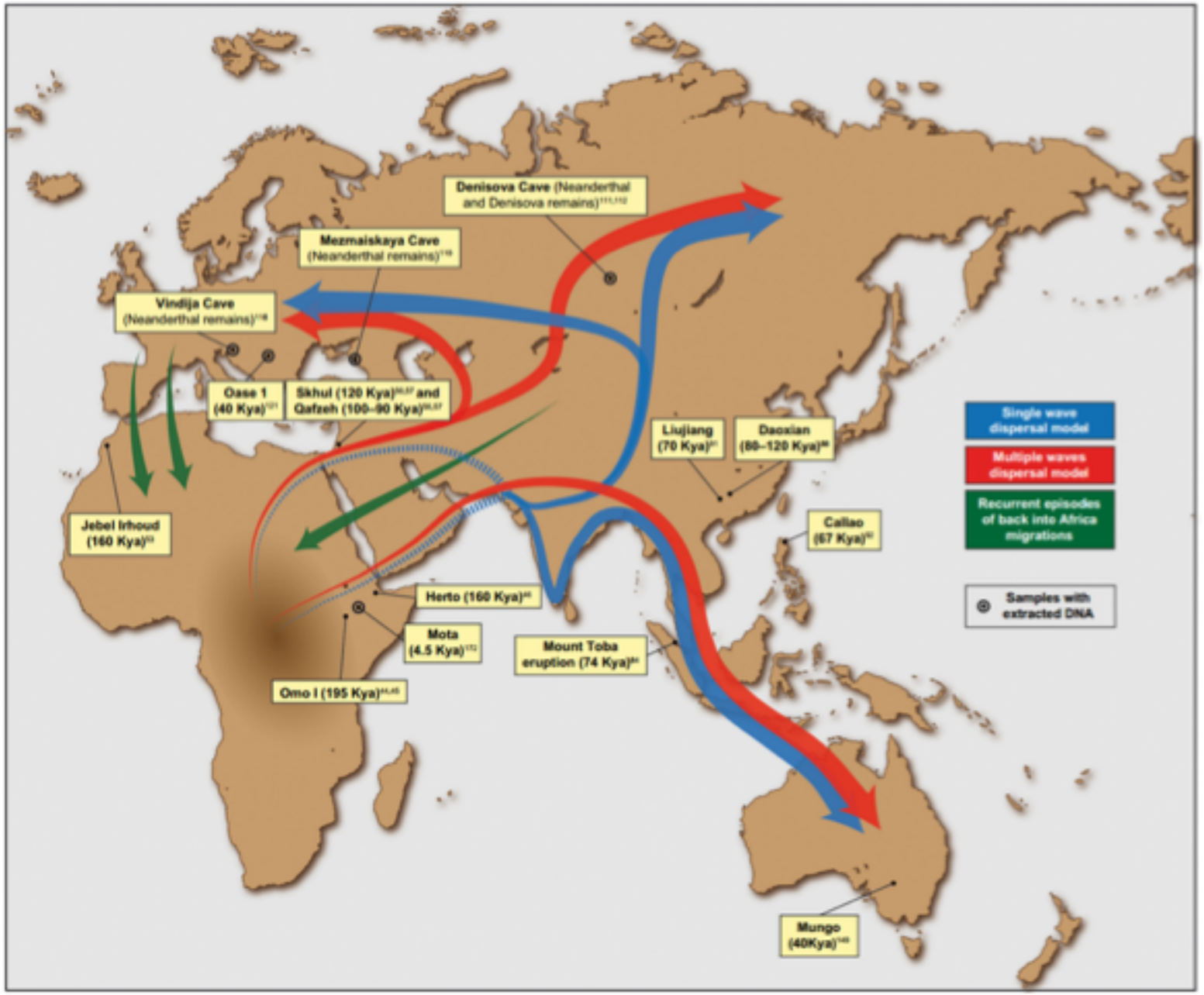
A tale of two island girls
and their mothers, grandmothers, etc.



English and Japanese are separated by the changes effected by about four thousand mothers teaching language to their children

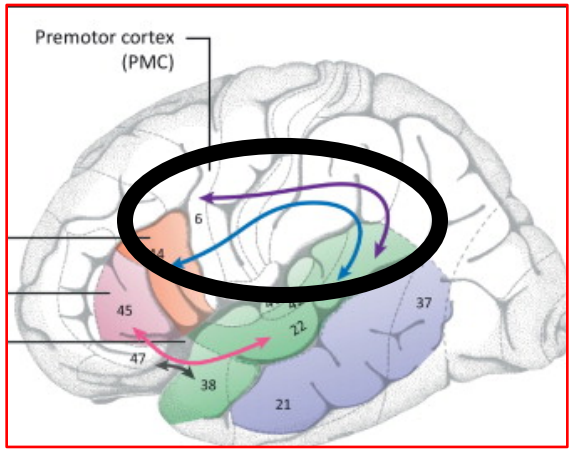
Out of Africa

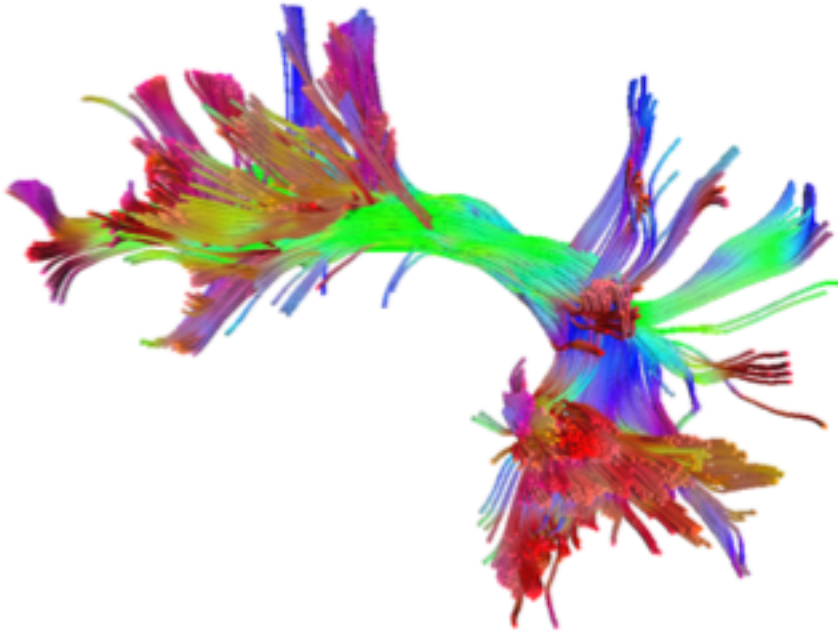
- 80 - 70 KYBP
- Europe: 40 KYBP
- Americas: 20 KYBP
- Arctic: 10 KYBP
- Polynesia: 2 KYBP
- **Single migration?**
- **Or multiple?**



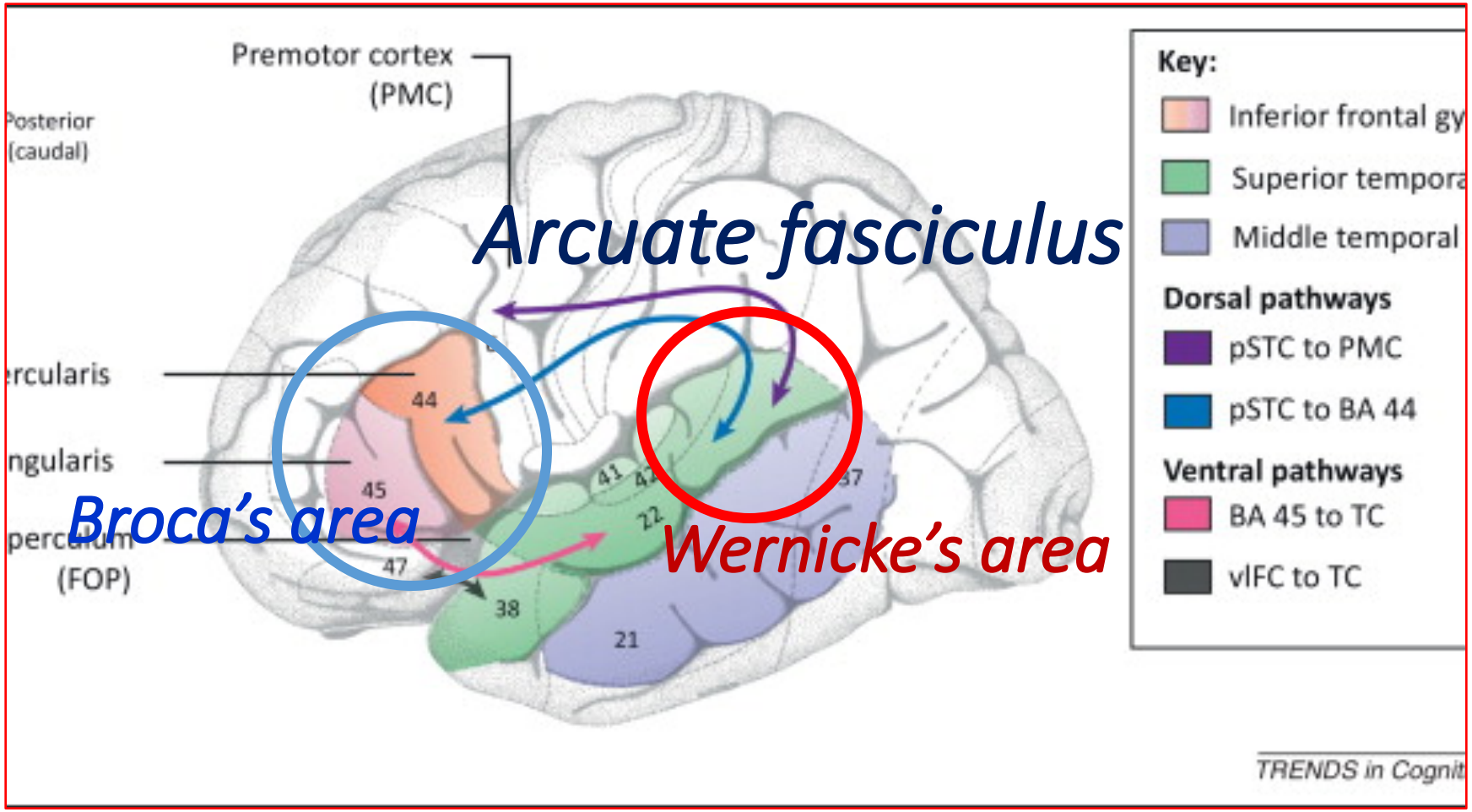
Was there a neural Bing Bang?

- Our left and right hemispheres are anatomically asymmetric
- Seems to be specific to humans
- Main locus of asymmetry: the ***arcuate fasciculus***





The Language hemisphere



Broca aphasia

- poor or absent grammar
- difficulty forming complete sentences
- “Cup, me” instead of “I want the cup”
- more difficulty using verbs than nouns correctly
- difficulty repeating what has been said by others
- trouble with writing sentences, reading
- problems with full comprehension
- difficulty following directions
- frustration

Wernicke aphasia

- string words together to make sentences that don’t make sense
- make up words that have no meaning
- unaware of the mistakes in their speech
- deliver words in a normal melodic line, even though the content may not make any sense
- articulate their words normally
- have difficulty repeating sentences
- add words when trying to repeat someone
- interrupt others and speak rapidly

Conduction aphasia

- Repeat after me:

"I do not suffer from conduction aphasia"

- Lesions in arcuate fasciculus OR Broca OR Wernicke…
- But this is the only symptom of AF lesion!

What does this mean?

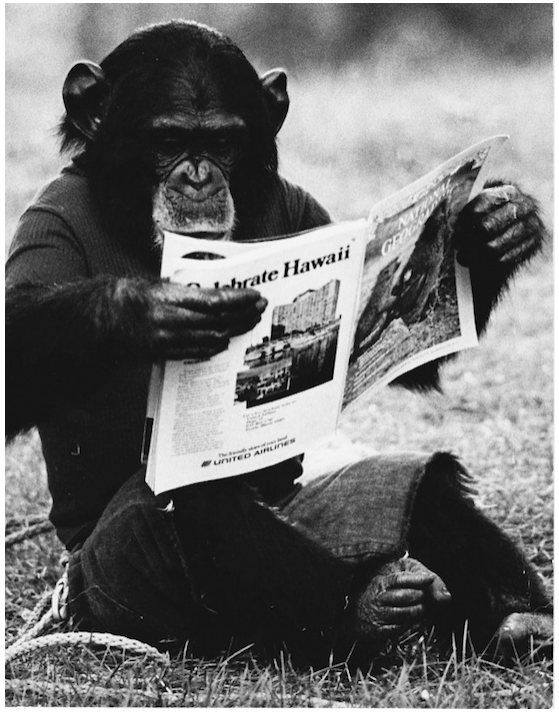
Meanwhile in Cambridge, Mass, ca 1960 : The Skinner – Chomsky debate

Chomsky's theory

- Language is innate
- Enormous gap between stimulus and competence
- Grammar is innate and universal
- Children only have to tune it with "details" (parameters)
- What makes us different: Recursion and infinity
- The minimalist program (1990s): all you need is merge

Besides universality:
how about exclusivity?

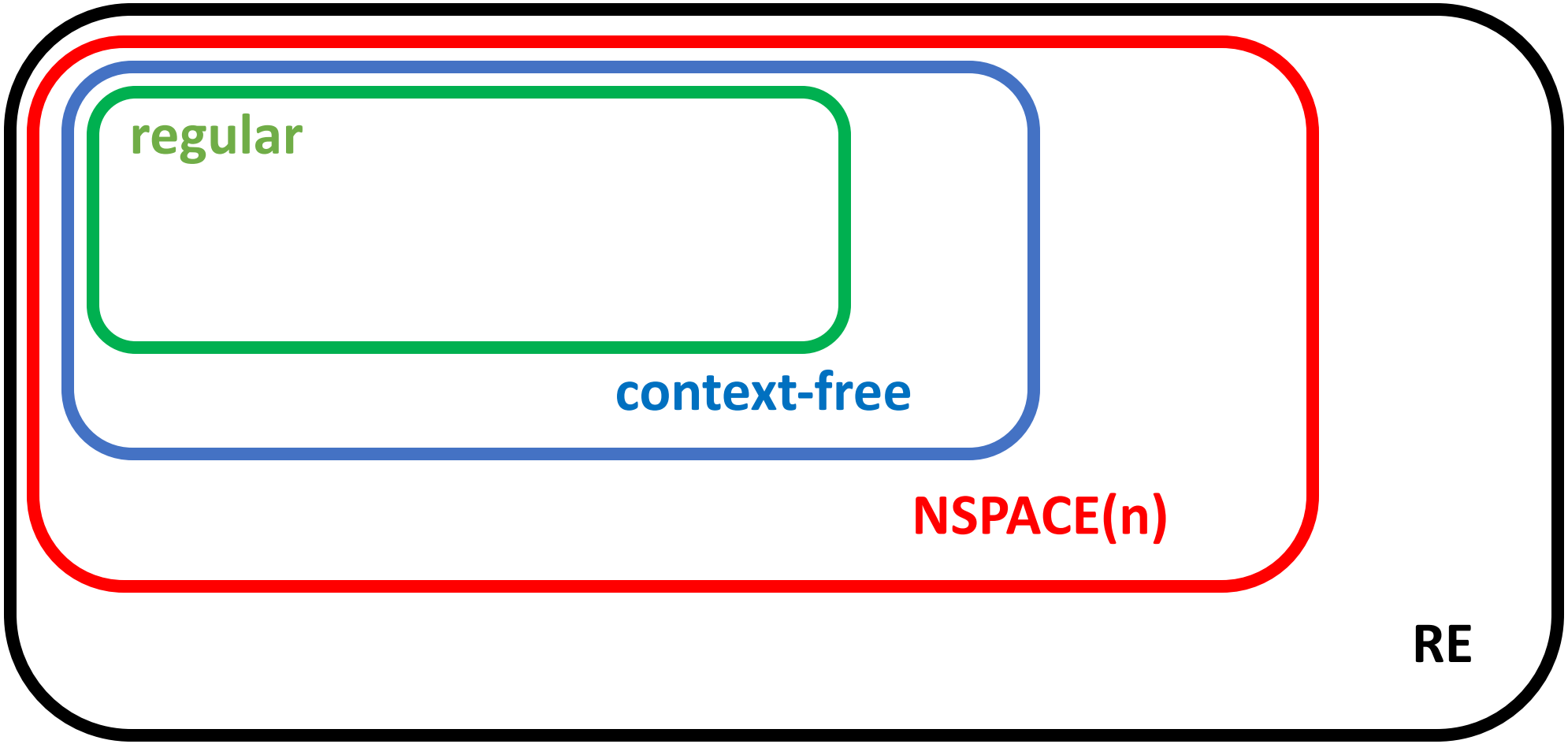
Nim Chimpsky



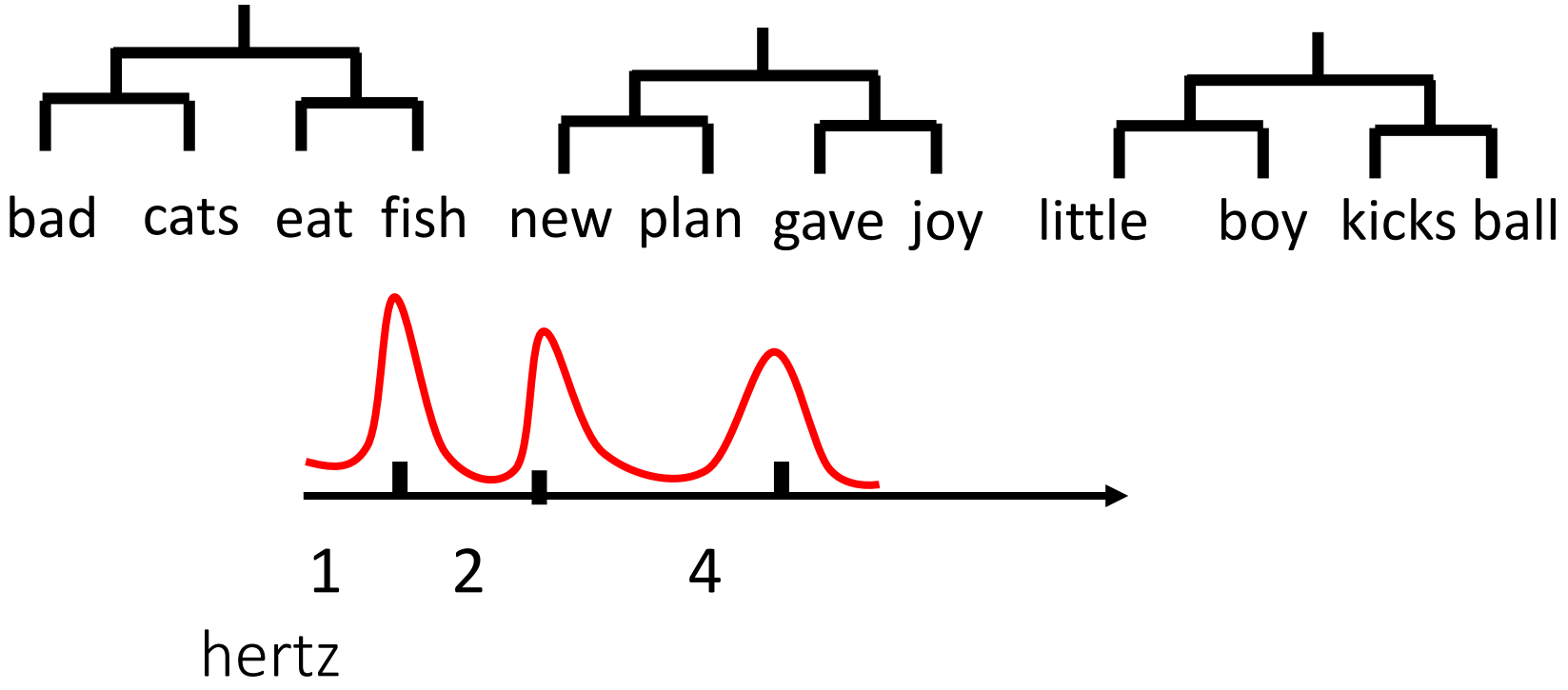
Koko the Gorilla

Song birds

The Chomsky hierarchy



The Poepple experiment, interpretation



[Frankland & Greene PNAS 2015]

"The ball hit the truck"

vs

"The truck hit the ball''

Different areas of the STG responded to "truck" in the two sentences *[Recall relations…]*

The first area also responded to

"The truck was hit by the ball"

But…

- By what mechanism can each tree-building step be carried out by a dozen or so spikes?

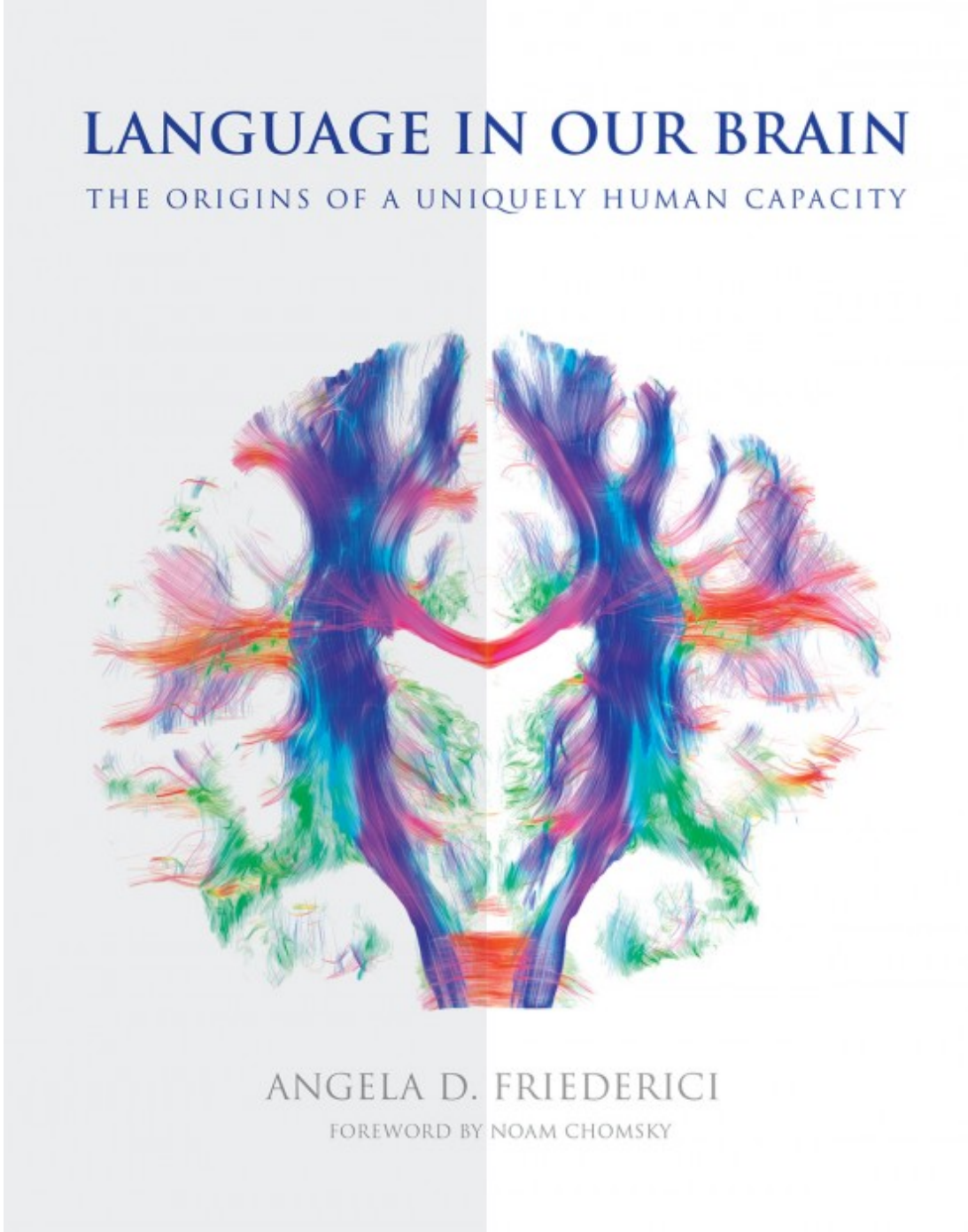
- 12 ~ gamma / theta

We shall come back – and spend a lecture – on this

- **Are language concepts represented like simple and complex cells? As in, could the language pipeline up through the anterior temporal lobe function as a general processing layer, and we build concepts through ands/ors/unions/intersections of concepts? Eg. is Paris something like city + France + capital etc, and we form new dendritic connections btw concepts when we make new associations?**
- **The chapter says that "the processes in language are assumed to run in a partly parallel, but cascadic manner ." How does the brain's neural network handle asynchronous behavior without a clock/flip-flips that make classical computation (and ANNs) work?**
- **The processing pathway of Friederici sounds suspiciously like architecture of human engineered speech processor. How is it possible to know, for example, that phonemes are looked up in a neural word-dictionary when it can't be observed? I would predict that if these postulated modules are incorrect, attempting to localizes them would result in activation in distant parts of the brain.**
- **Matt Botvinick made an interesting connection btw dopaminergic learning in the brain and meta-RL. But why focus on meta-learning as opposed to just learning with delayed rewards? Is RL really necessary for meta-learning?**
- **Due to limited short-term memory, can we put an upper bound on complexity of comprehensible sentences? Anything beyond a certain length is either too complex for comprehension?**
- **The RNN reacts to volatility, and the brain gets a large reaction out of unexpected results. It appears that we get most stimulus from being wrong. In an RNN should positive reward have a different learning rate than error?**

- **Is there any evidence that the prefrontal cortex performs a form of reinforcement learning similar to Meta-RL?**
- **How does memory influence reinforcement/reward-based learning in the brain?**
- **I'm very curious how brain systems for language map onto deaf people interpreting sign. Are there studies about specific streams of interpretation like the ones in this chapter?**
- **How does the human brain reason about discount factors? Is it more appropriate to think of our meta-level learning tasks as finite or infinite horizons? Do we use different discount factors for different tasks?**
- **I am wondering whether they can generalize the experiment result to the setting with more than 3 arms (rather than 2). Will RL outperform well-developed algorithms like UCB / Thompsons samplings? On the other hand, how about comparing with humans? Does RL still share similarity with the human learning process?**
- **Is there any difference in the brain to process a native language vs a foreign language? Since we care more about grammar when learning a foreign language, will it affect the way our brain parses it?**
- **What are the MLE/MAP perspectives to the RL derivations?**

Chapters 1 and 2.
what have we learned?



1.6 Semantics in the brain

- Semantics seems to involve a circle of areas around STG (counterclockwise):
- MTL (lexicon) AG (combinatorial semantics, integration) BA44 (sentences? Join?) BA 45/47 and aIFG (Semantics? Two-word phrases?) and ATC (combinatorial semantics?)
- N400 seems to signify “semantic effort”
- ***Q: 400 after what?***

1.7 Thematic role assignment

- (but this is syntax!?!)
- ***The verb is the queen of the sentence***
- How can you tell if a noun is the subject? (parsing…)
- Position or Nominative morphology or help words?
- Analytic vs Synthetic languages
- A propos the position: **SVO, SOV, VSO, OSV, OVS, VOS**

1.7 Thematic role assignment (cont.)

- The argument structure of a verb
- A subject/actor (always, even if implied)
- An object/patient (often but not always, intransitive verbs)
- Second object?
- ***“I gave George his book”***
- Third object?

1.7 Thematic role assignment (cont.)

- LAN effect and disagreement
- Gender, plural, meaning
- e.g., ”hire a guide” vs ”hire a goat” vs “hire a lake”
- And remember the Frankland and Green experiment “the ball hit the truck vs the truck hit the ball”

1.8 Prosody

- Very important in all languages (and not just tonal ones like Chinese)
- Two kinds: frequency vs emphasis
- Also, pauses
- Mostly RH, but also LH when function calls
- Interaction with syntax and semantics
- Emotional prosody: RH lesions result in comprehension deficits

MUSIC!

Chapter 2: Language generation

- Common knowledge base
- And common neural correlates?
- Imho, generation is more basic
- (Why?)
- Experiments with production from pictures
- Lexical (MTL) precedes grammatical (Broca's area) processing
- Pragmatics and gestures