Semantic and syntactic processing in the human brain

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The plan of this mini-course again

- *Semantic processing in the brain: how our nervous system deals with the monotonicity of logical operators*

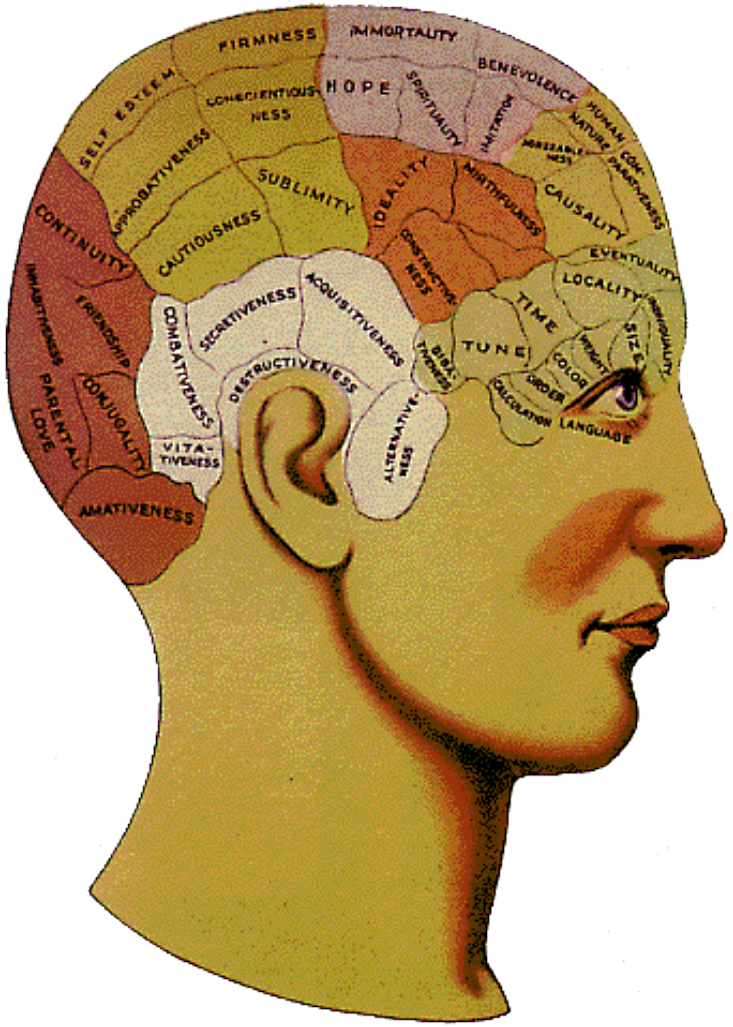
  some logical considerations, followed by multi-modal experimental program with conclusions that might have theoretical implications to compositional semantics

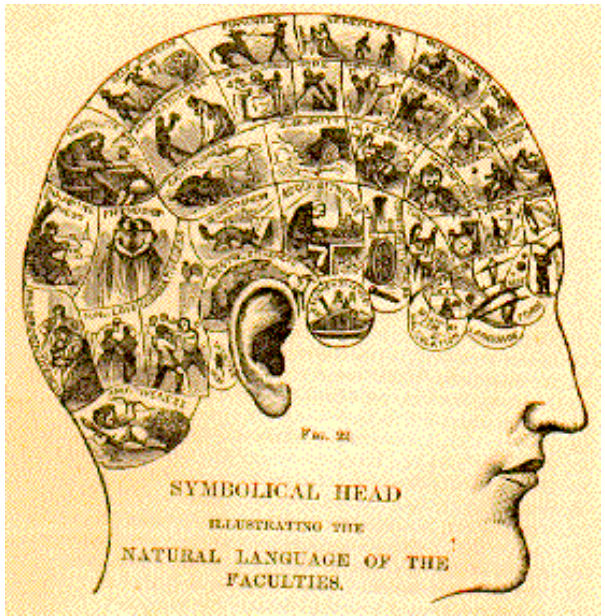
- *Syntactic processing in the brain: the blessing of variability across individual brains and across languages and individuals speakers*

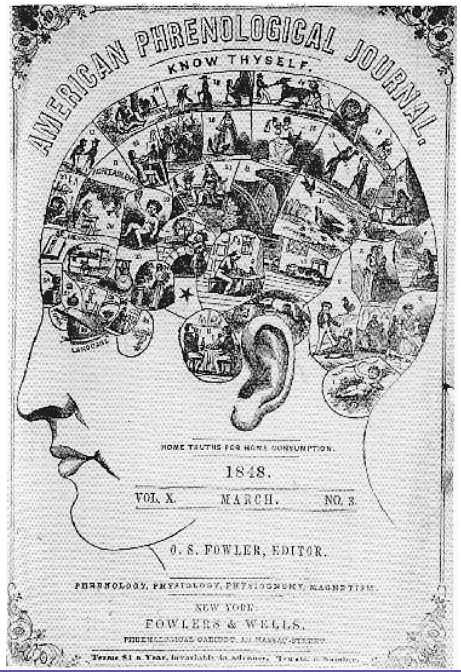
  some anatomical considerations and techniques, with neurolinguistic studies of syntax that focus on variability

Franz Joseph Gall

Pieces of our psychology in brain pieces: Gall's Phrenology and functional localization







Gall's legacy:

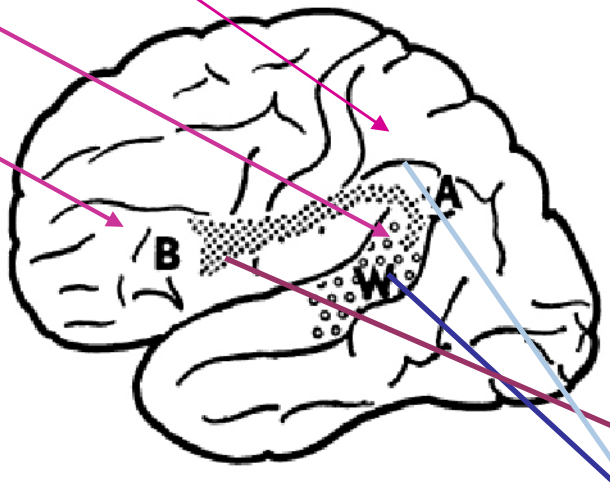
Mapping Principles and their Diagnostic Reflections

production **reception** **naming**

Paul Broca

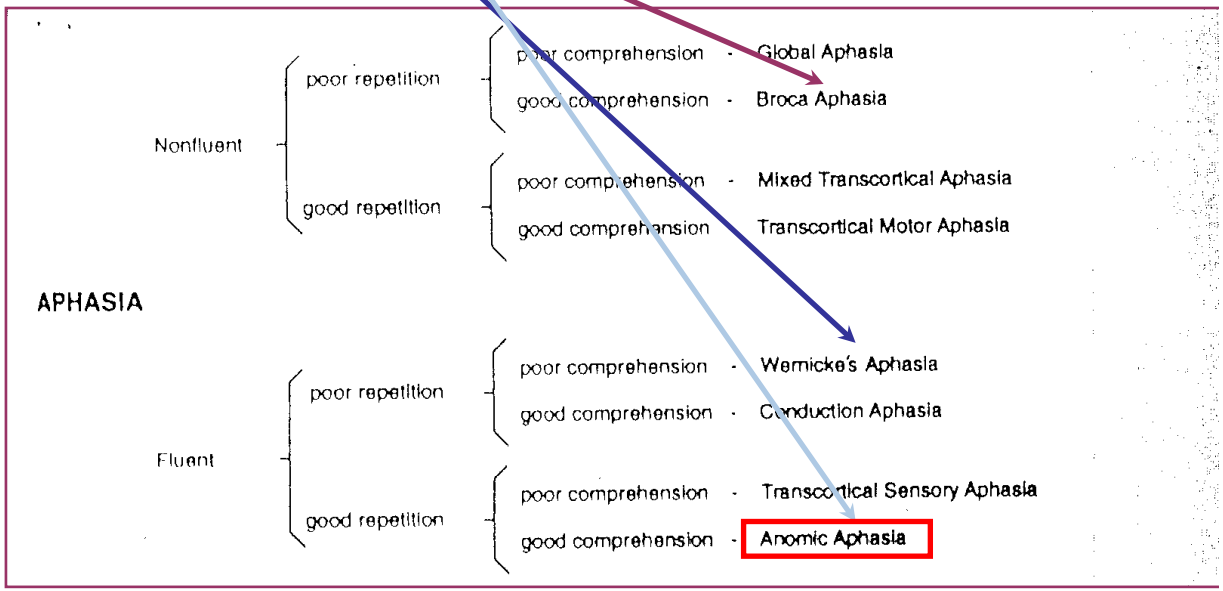
Carl Wernicke

Norman Geschwind



Take 1

Basis: bedside clinical observations, later codified clinical tests (e.g., *BDAE, WAB*)



Geschwind, *Sci.*, 1970; Damasio, *NEJM,* 1992

Is language modularized from other parts of cognition? The Modularism/Holism split in 19th century neurology

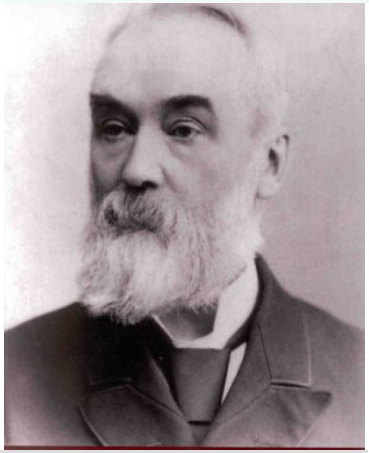
Broca

Broca's Leading ideas:

-Cerebral Representation
-Functional Modularity
-Lateralization

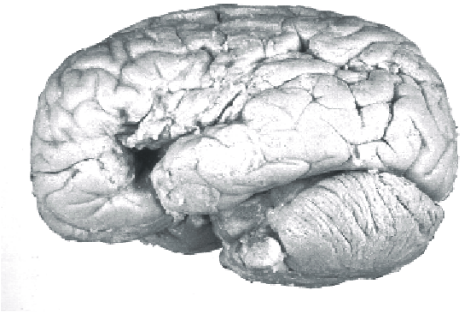
Hughlings-Jackson's Leading ideas:

-To speak is to propositionize
-Aphasia: loss of ability to handle symbols ("asymbolia")
-Aphasia-apraxia-agnosia all have the same hierarchical structure



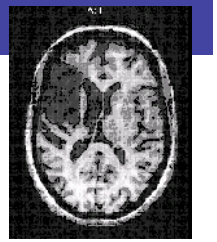
John Hughlings-Jackson

Mr. Tan's brain

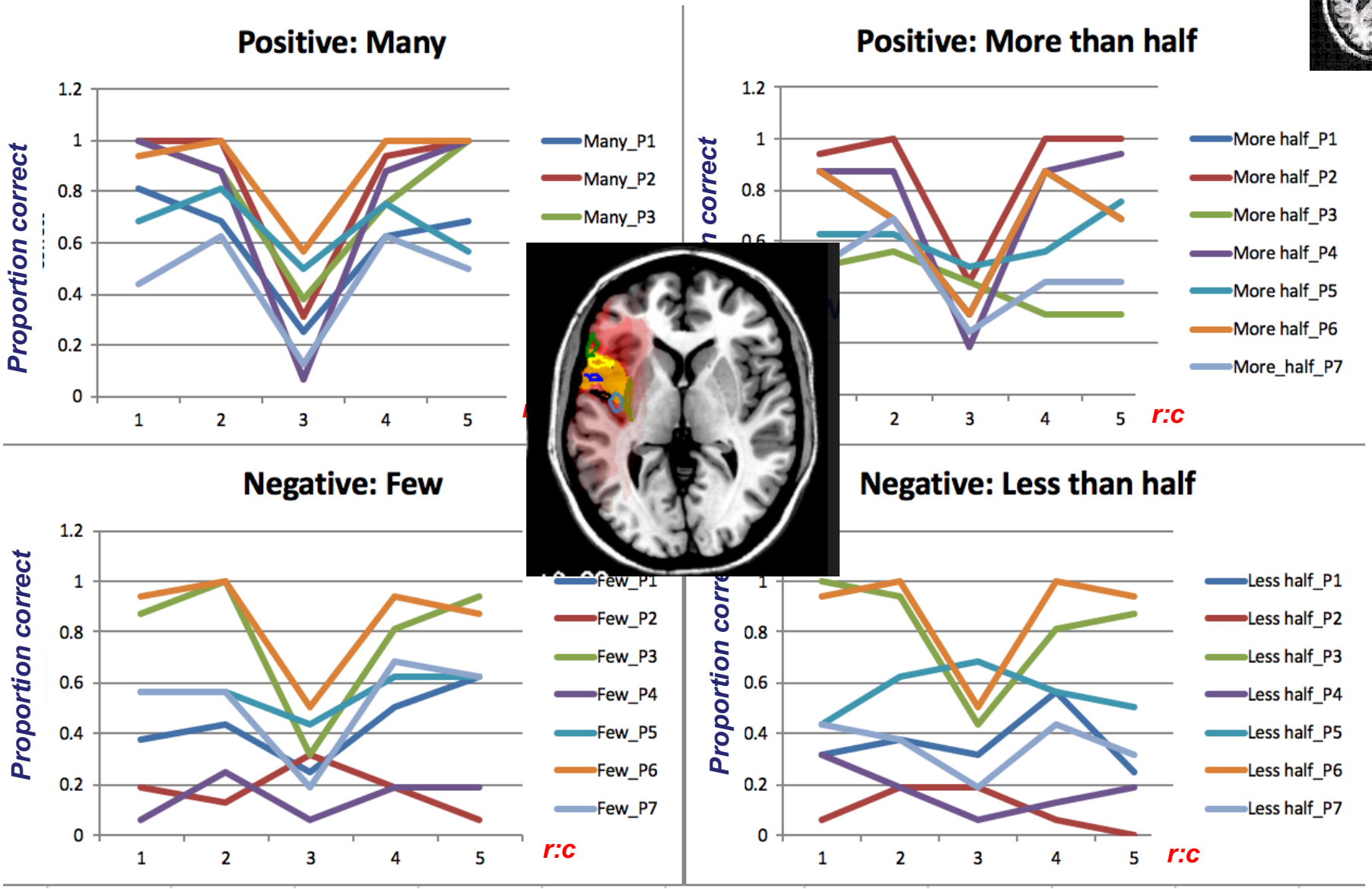


What we did last time

- Polar quantifiers are processed in a selective manner:
  - Reaction Time studies isolate the DE (Downward Entailing) component
  - fMRI likewise localized this computational process in the left anterior insula (LaIns)
  - aphasia points to a DE deficit, and a maximal overlap lesion map points to the LaIns



The PPP in Broca's aphasia



Individual patients' error pattern subsequent to a lesion in Broca's region

Syntactic processing in the brain: the blessing of variability across individual brains and across languages and individuals speakers

What we'll (try to) do in the next 2 classes

- Anatomical variability
  - Brains (like noses and mouths) have different morphological features
  - we'll describe a way to generalize over many brain despite their variable morphology
- Behavioral variability in health and in disease
  - aphasia points
- Structural variability
  - languages differ structurally.
- Anatomico-functional alignment

A strategy for discerning neurocognitive structure:

Syntacto-Topic Conjecture (STC)

a. Major syntactic (and perhaps semantic) operations are neurologically individuated
b. The organization of these operations in brain space is linguistically significant

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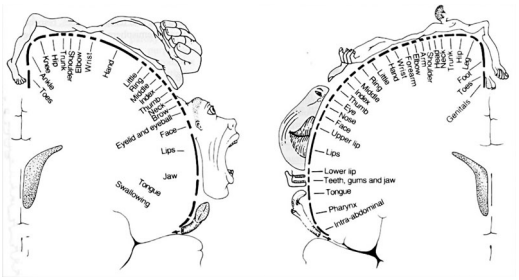
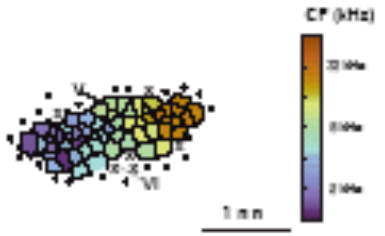
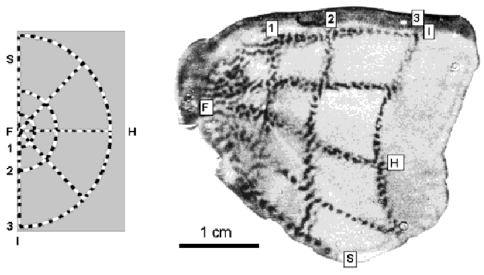


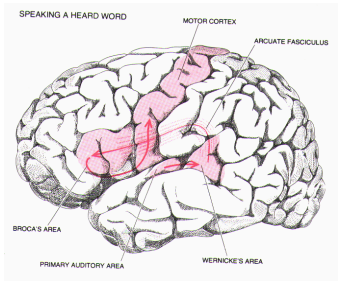
Somatotopy



Tonotopy



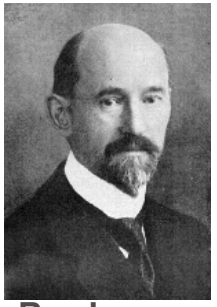
Retinotopy



Syntactotopy?

Implication:
The functional pieces of the language map are small and linguistic

***Question*:**
What are the anatomical pieces of the language map?


Brodmann


Chomsky

Phrenological beliefs and hopes in our midst:

The anatomist's:

- ***Anatomic modularity***: the brain can be parsed into pieces with *stable and identifiable borders* (***anatomical modules***)

The linguist's:

- ***Grammatical modularity***: linguistic behavior is structured; the principles governing it can be parsed into pieces (***linguistic modules***)

The neurolinguist's:

- ***Meaningful functional anatomy***: linguistic and anatomical modules align

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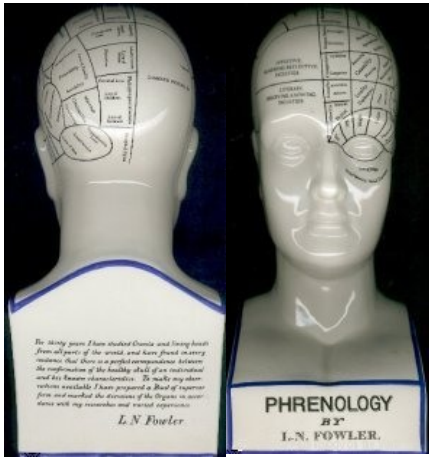
The localizationist research agenda:

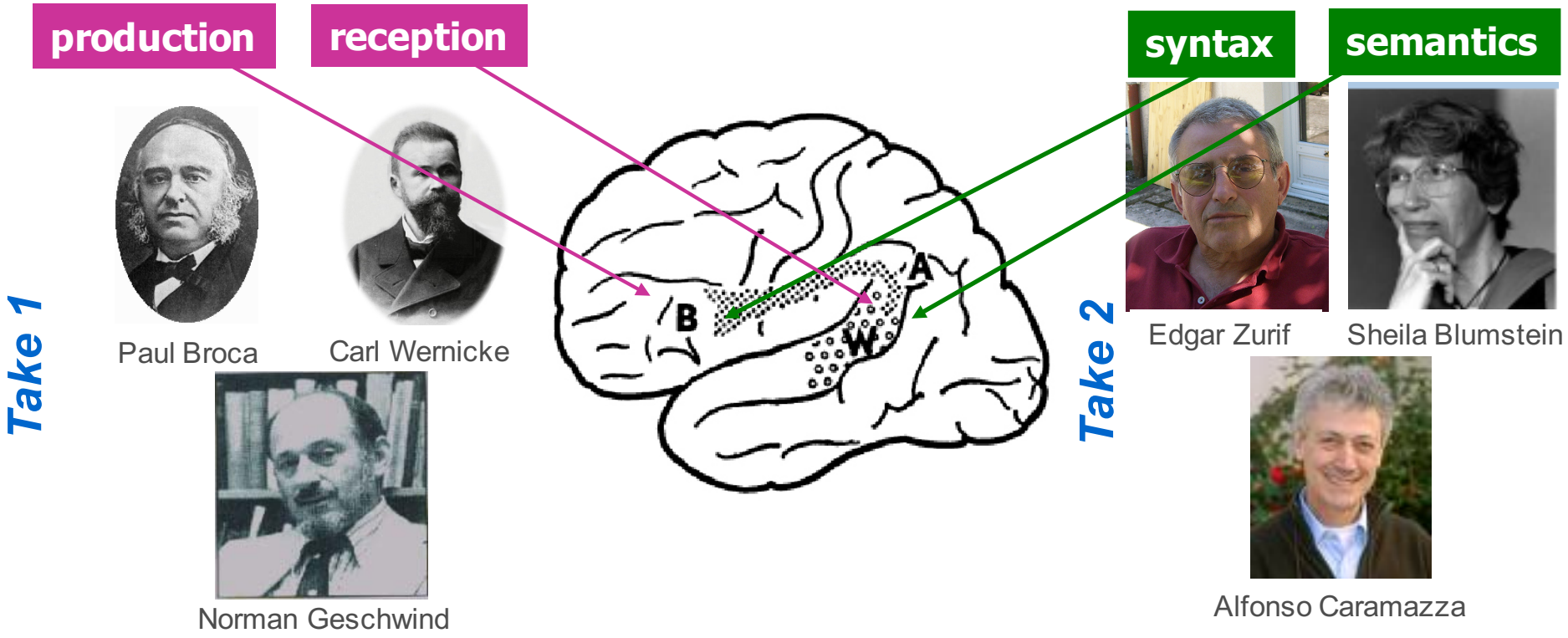
- identify the linguistic modules and anatomical borders
- Seek alignment between the linguistic and the anatomical



The final punch line:

Pieces of linguistic knowledge provide the right functional resolution, aligning with cytoarchitectonic borders.

We are after ***syntax and semantics brain maps***



Take 1: Bedside clinical observations, later codified in The *BDAE, WAB* and related clinical tests

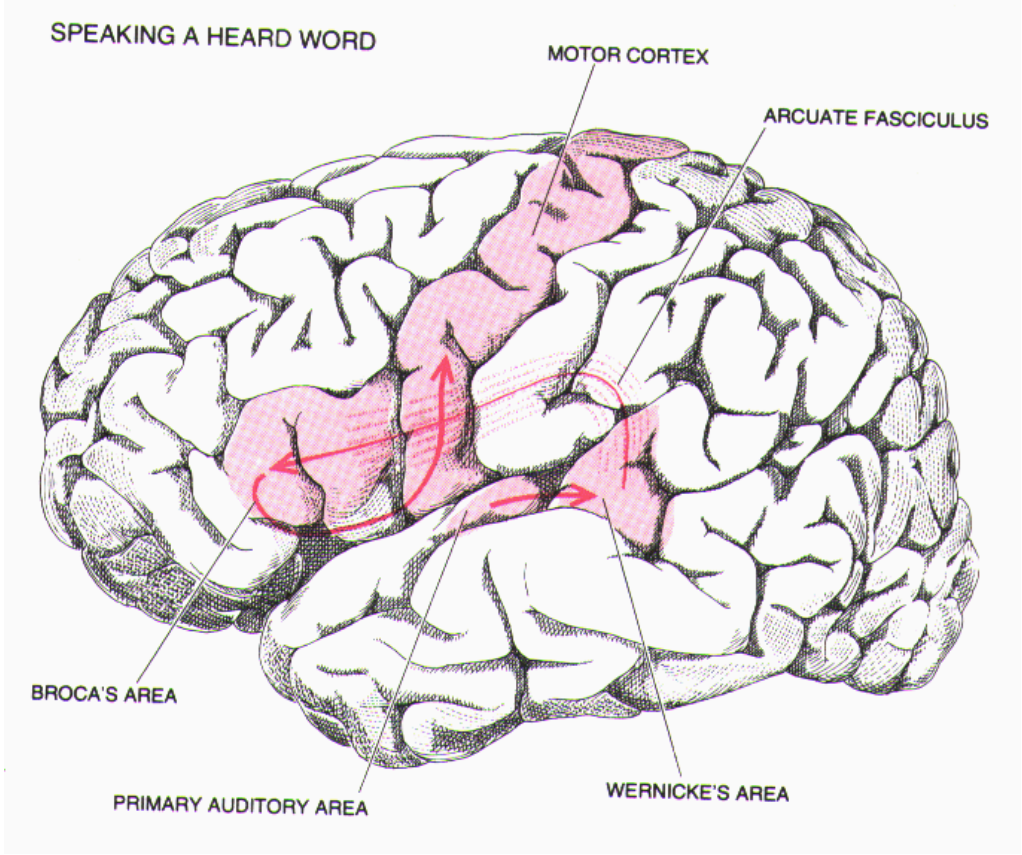
Take 2: Controlled experiments in several modalities; allusion to linguistic concepts.

Characteristic experiments:

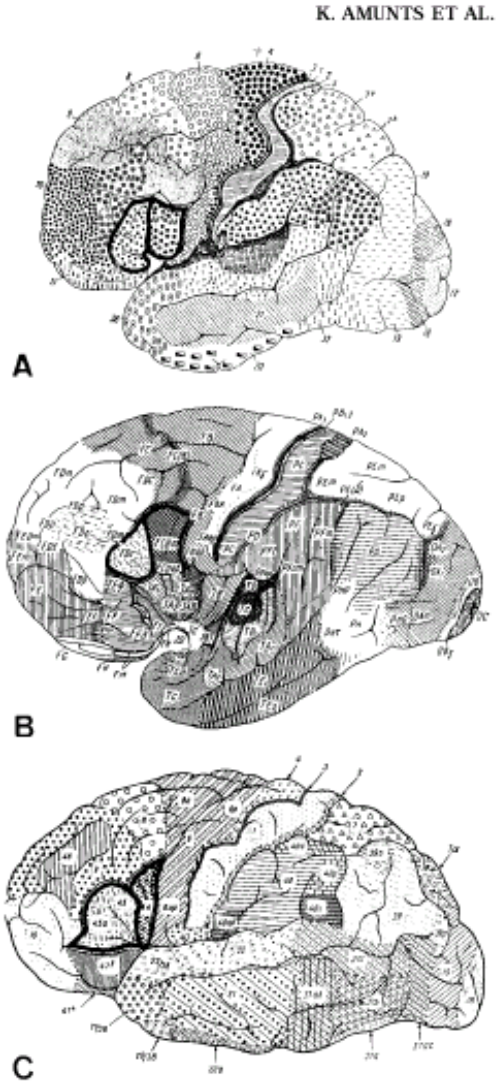
1. Vary properties of stimuli to contrast linguistic "levels" (e.g., "syntax" vs. "semantics")
2. Quantify errors, the dependent measure, allowing for objective tests

Talk 1: how to define anatomical borders in the face of huge variability

Problem 1: how to delineate borders between parts of the brain



Problem II: how to account for individual variation



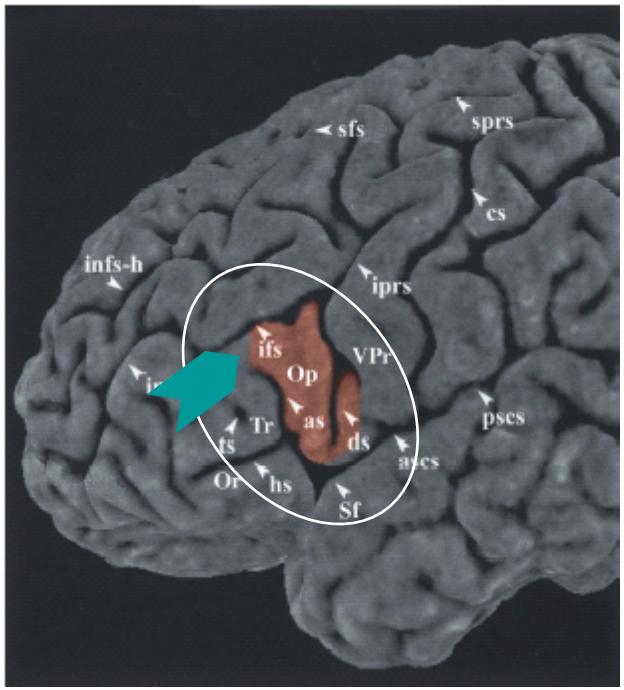
the lateral surface of the human brain

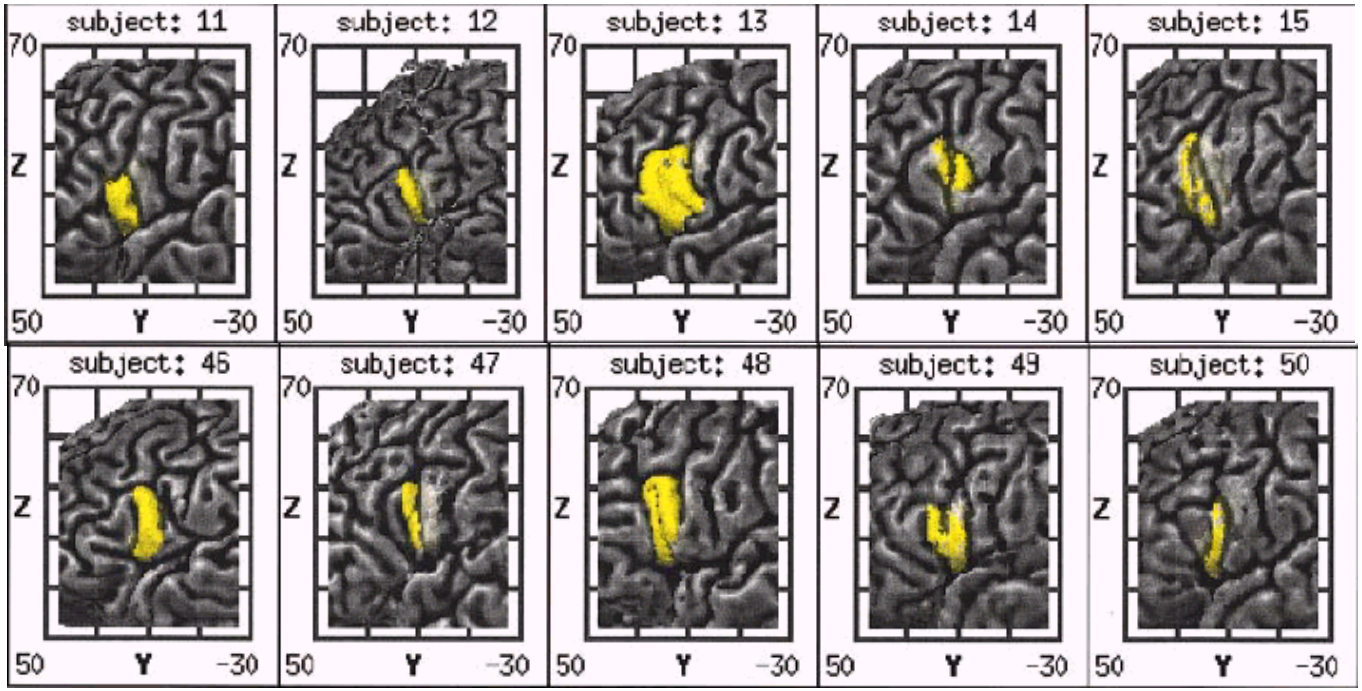
A Brodmann (1909)

B Economo and Koskinas 1925))

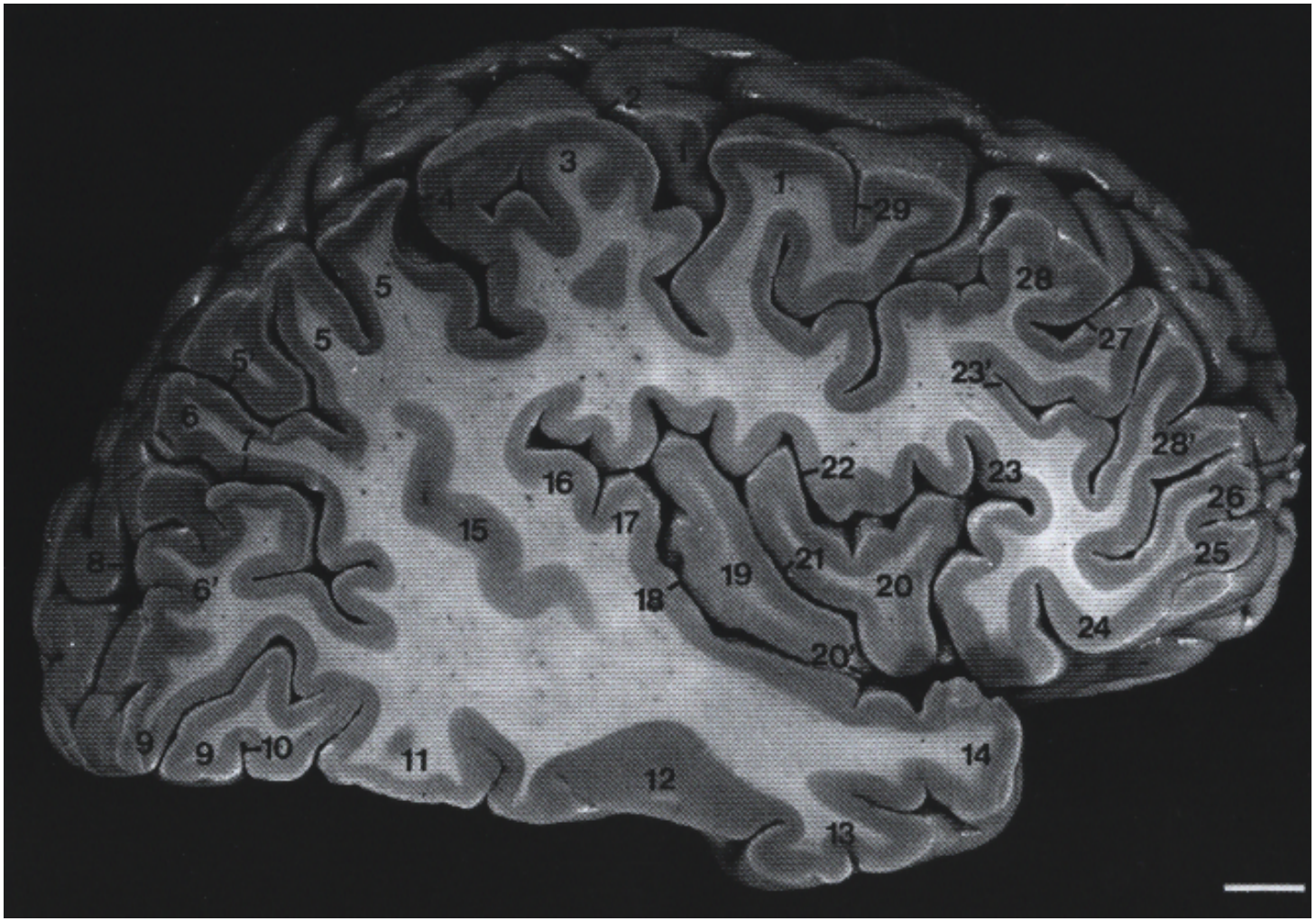
C Sarkisov *et al.* (1949)

The futility of topographic borders





Grey vs White Matter



Gray matter: folded sheet containing cell bodies, dendrites.
White matter: axons

At a higher resolution: Cortical layers

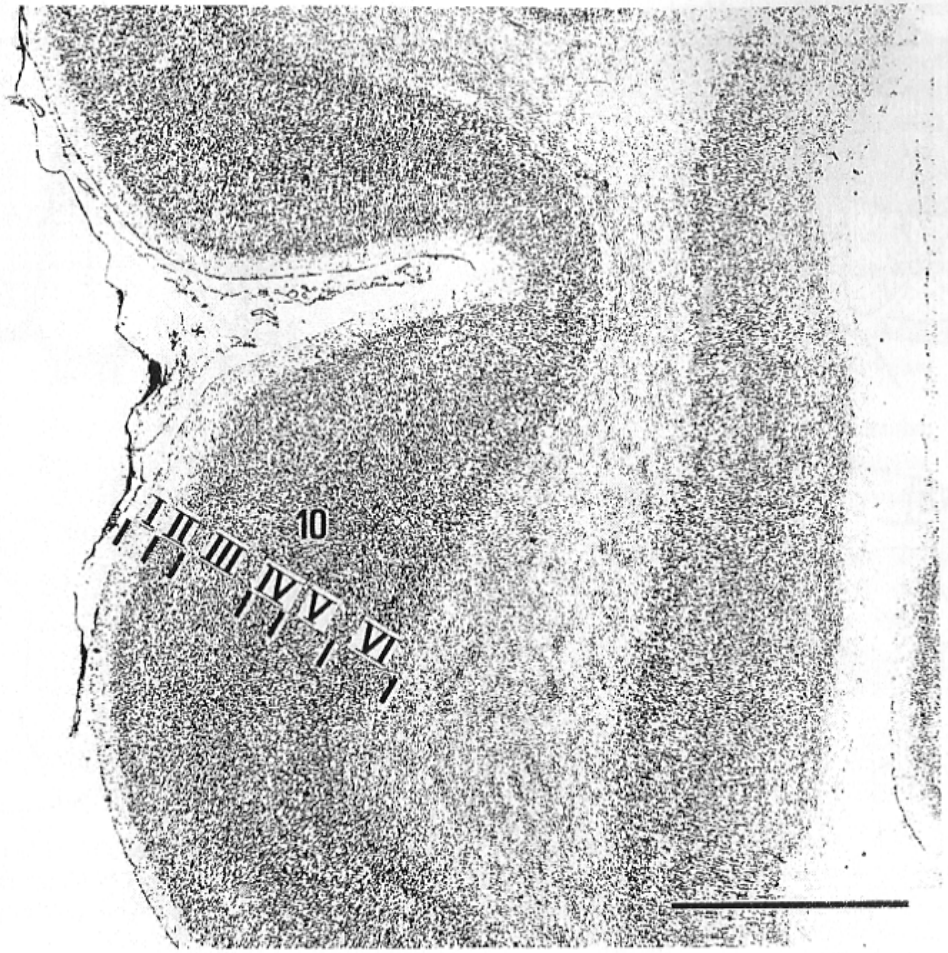
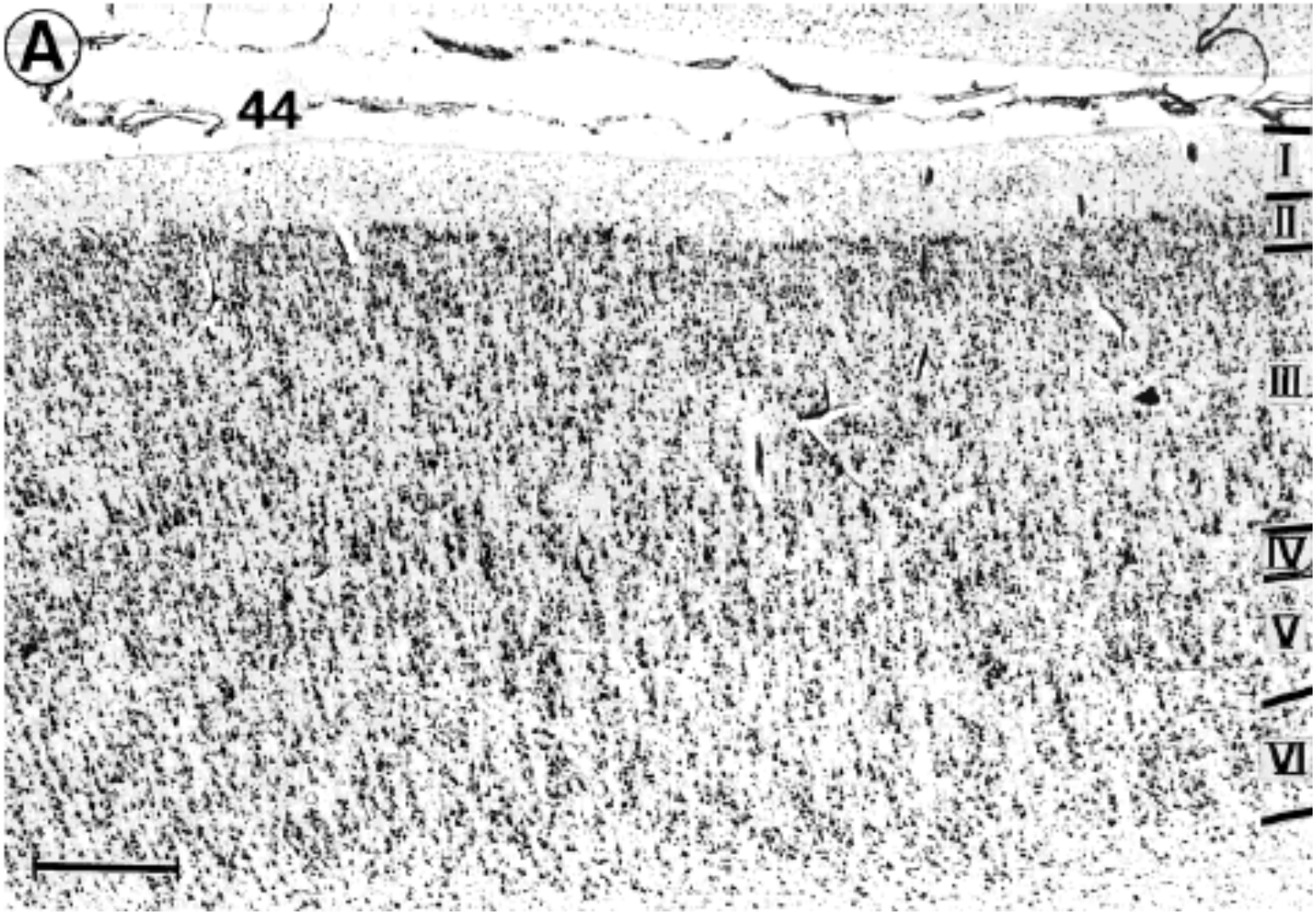
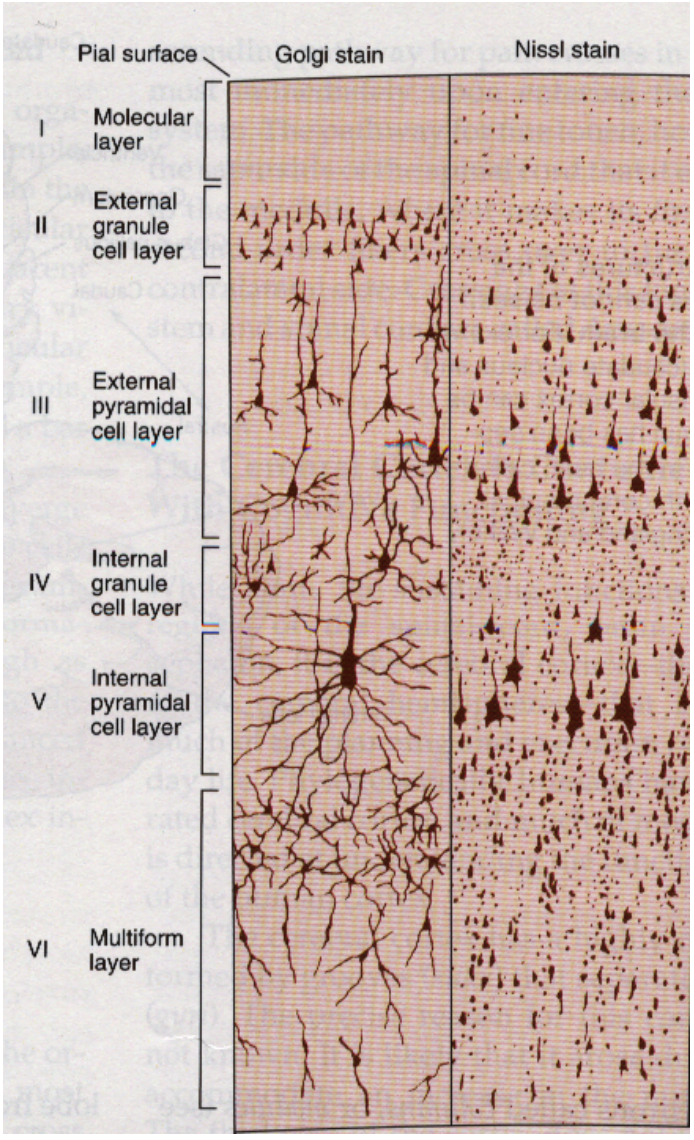


FIGURE 27.7 Horizontal section through Brodmann's (1909) area 10, which belongs to the granular part of the prefrontal cortex. The Roman numerals indicate the six isocortical layers. Bar = 3 mm.

even higher: *A Cortical Slice Stained for Cell Bodies*



a schema: Cortical Layers



I Dendrites of deeper cells

II Small granule cells

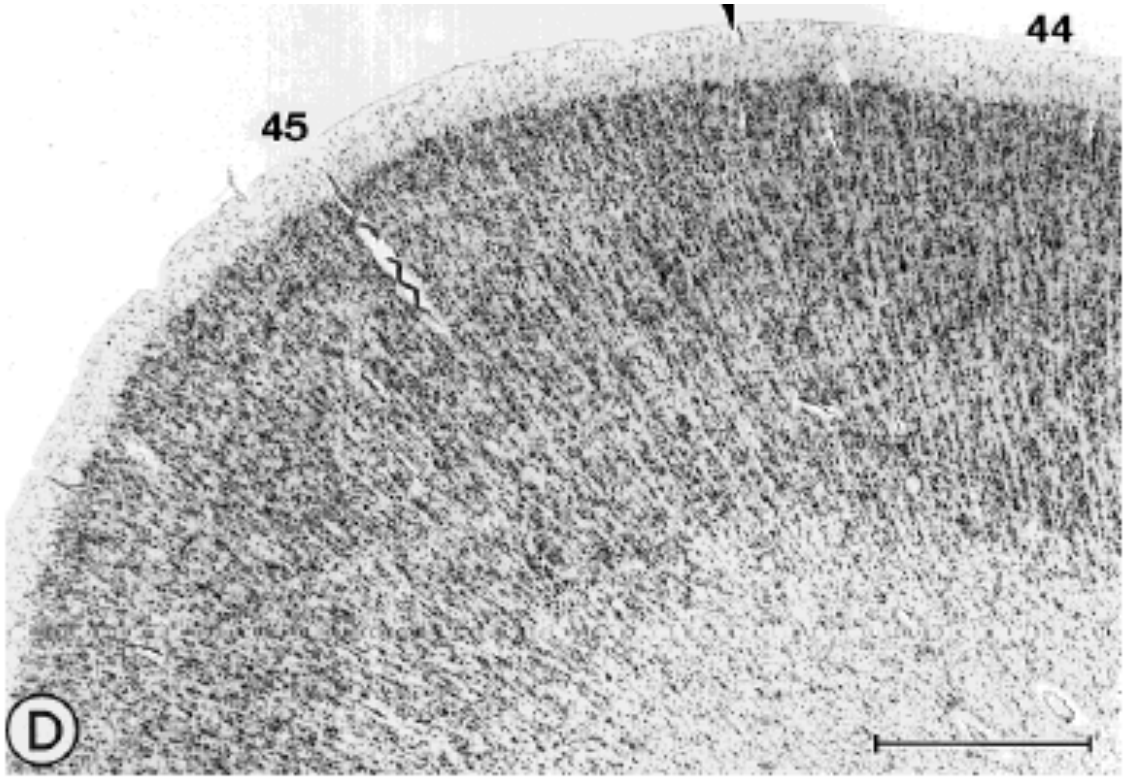
III Variety of cells, many pyramidal in shape

IV Mainly granule cells

V Pyramidally shaped cells larger than in layer III

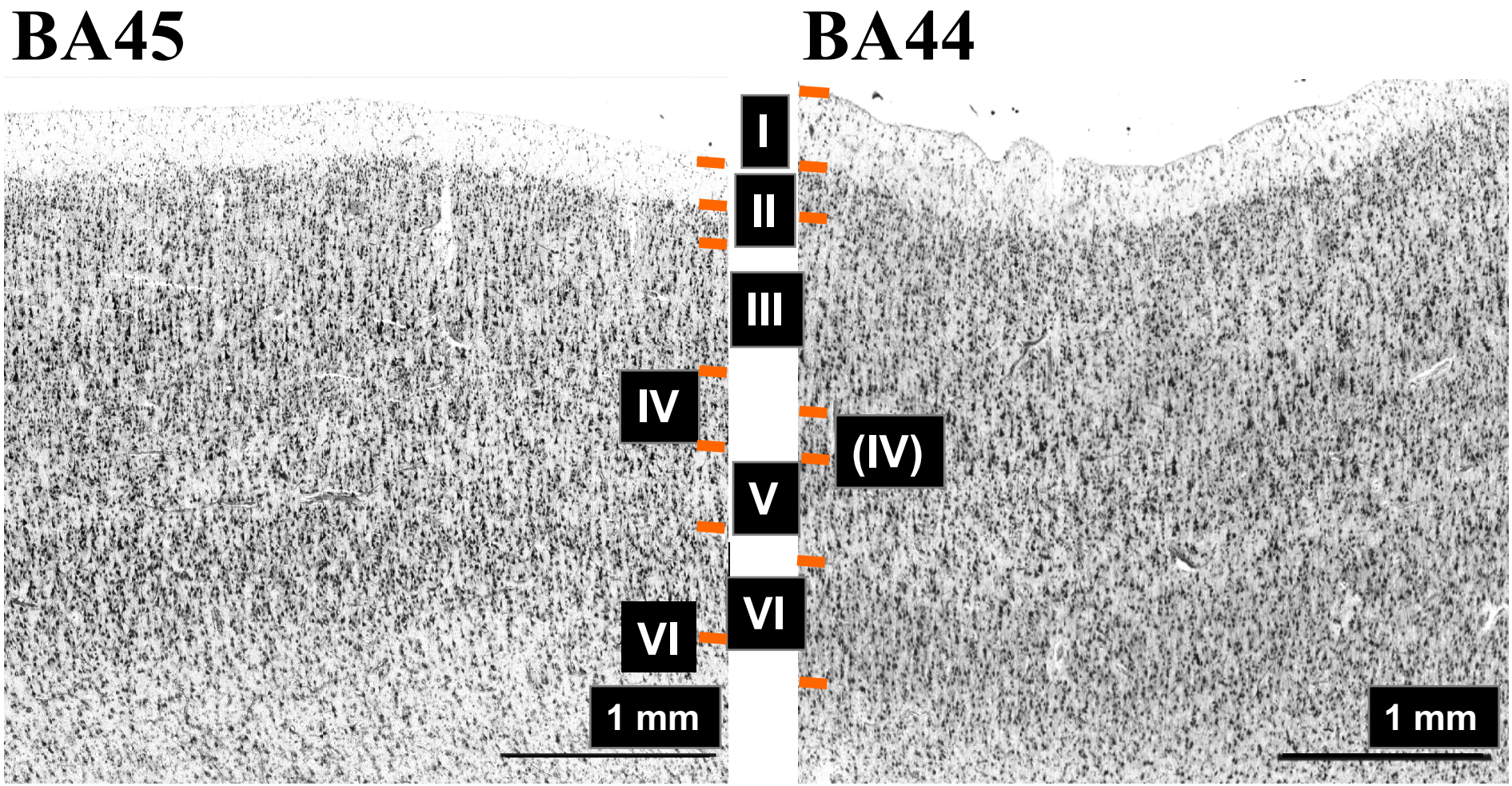
VI Heterogeneous layer of neurons blends into white matter

The idea of Cytoarchitectonic borders

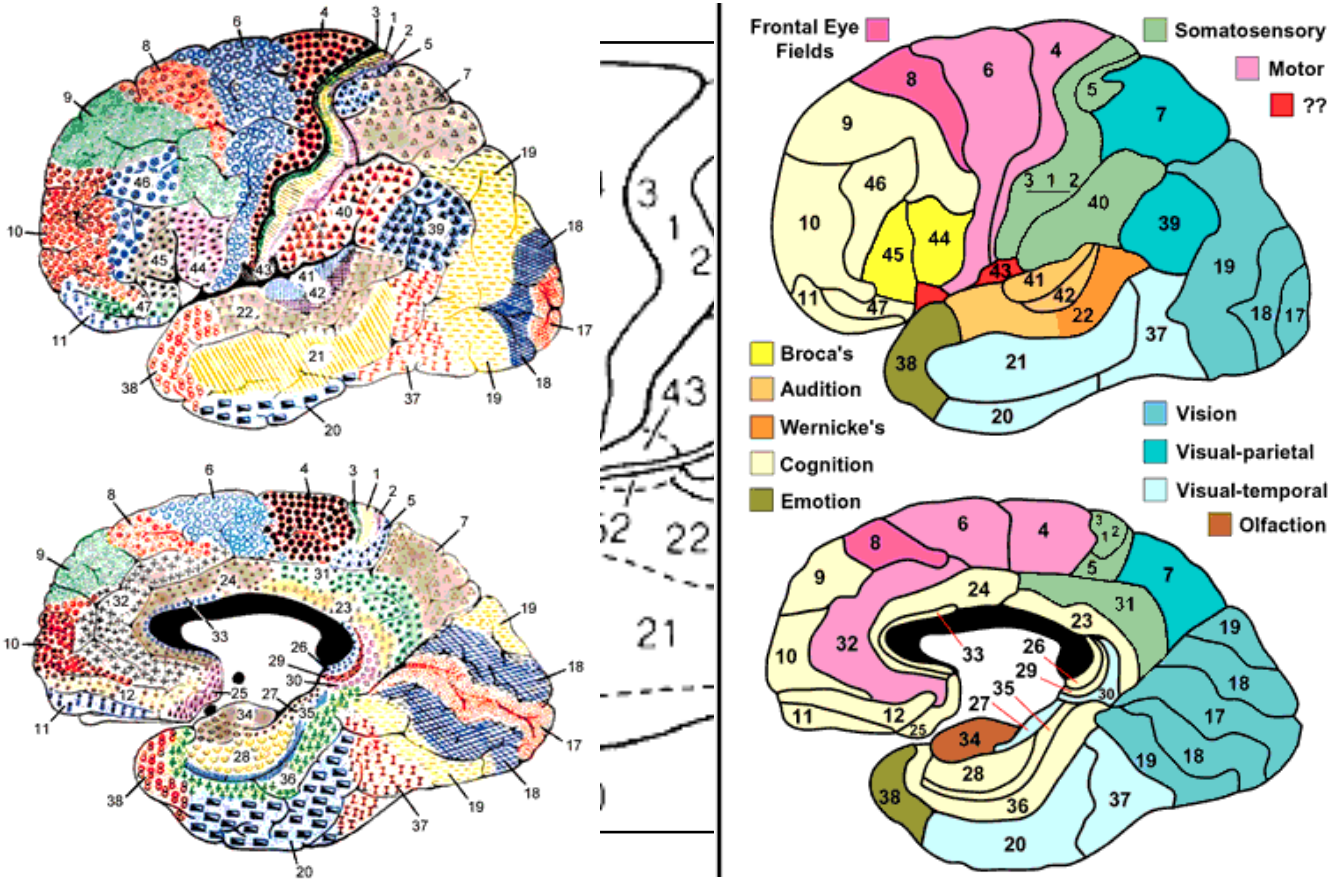


- The cell layers vary throughout Cortex
- Changes in the lamina reflect borders between cytoarchitectonic regions
- Changes in lamina may be in regards to size of layers or the layers' cell size or packing density

Current Cytoarchitectonics: BA 44 & 45 stained for cell bodies (Amunts, Zilles)



Cytoarchitectonic modularity: Brodmann's parcellation of cortex

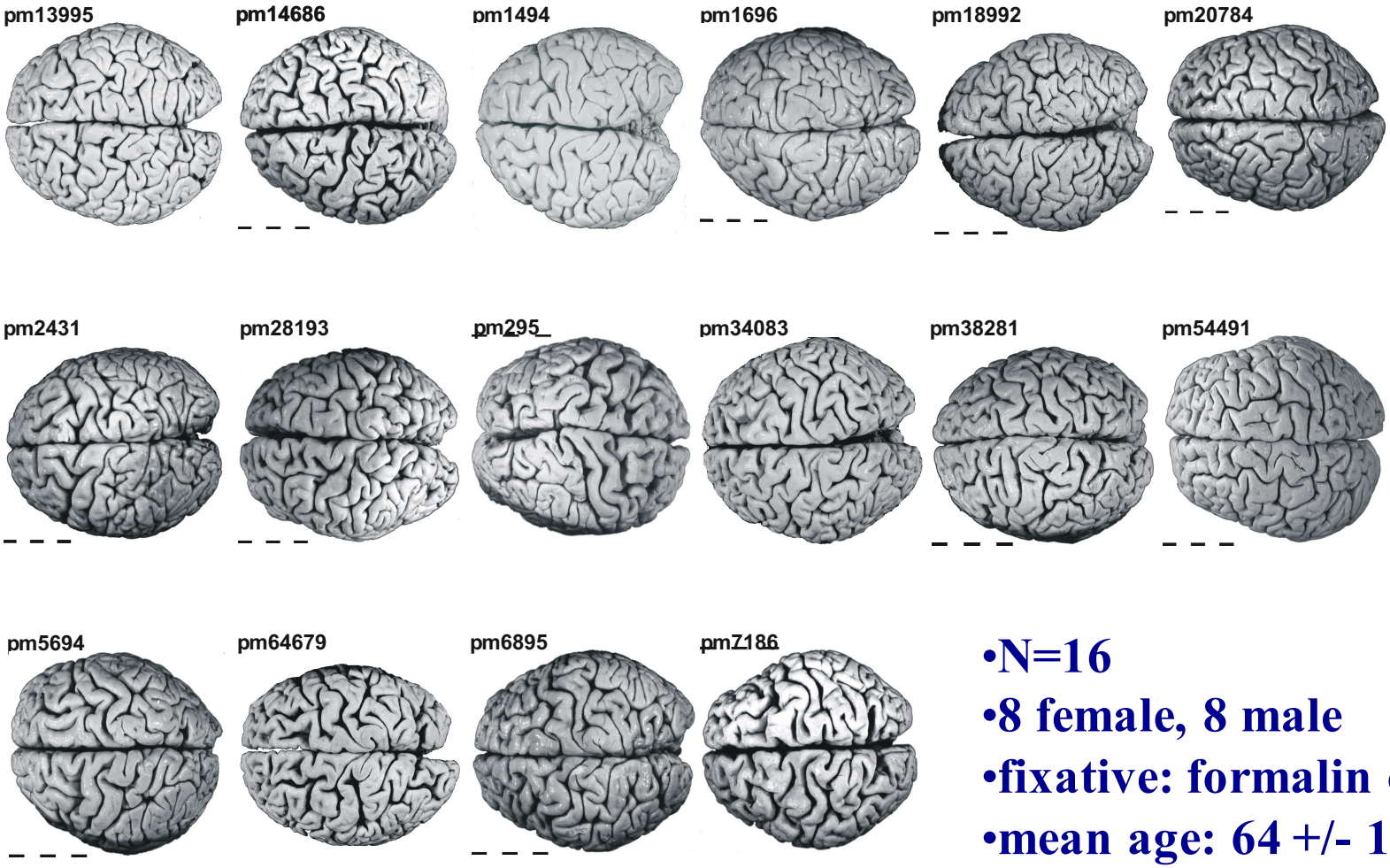


2 questions:

a. Is there a perfect topographic/cytoarchitectonic correspondence?

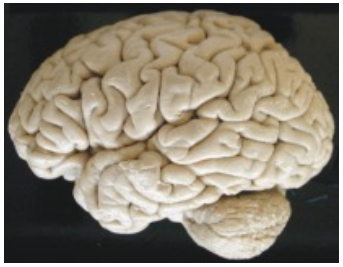
b. If not, which, if any, is the correct unit for functional analysis?

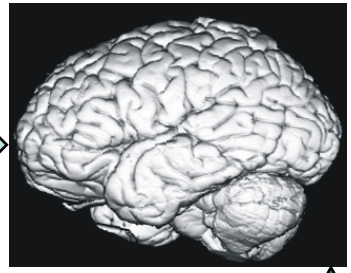
postmortem brains



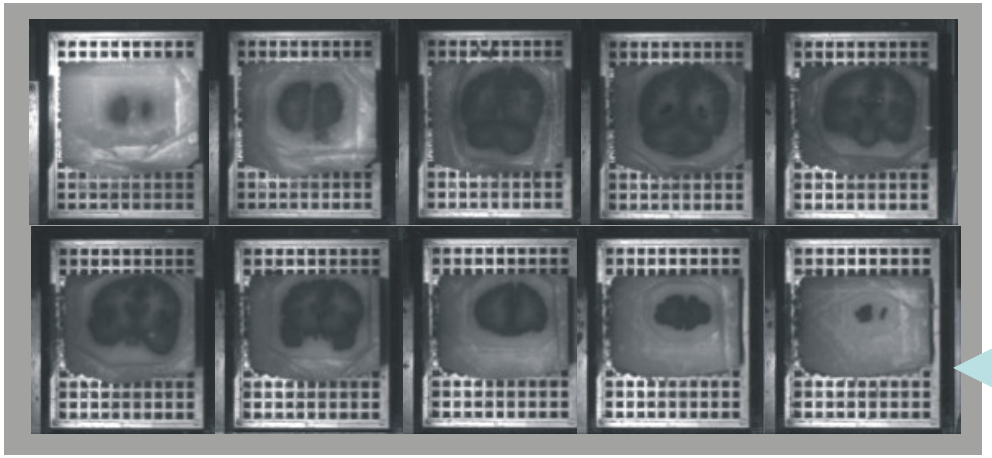
- **N=16**
- **8 female, 8 male**
- **fixative: formalin or Bodian**
- **mean age: 64 +/- 16 y**
- **postmortem delay: 12-24h**

Histological processing

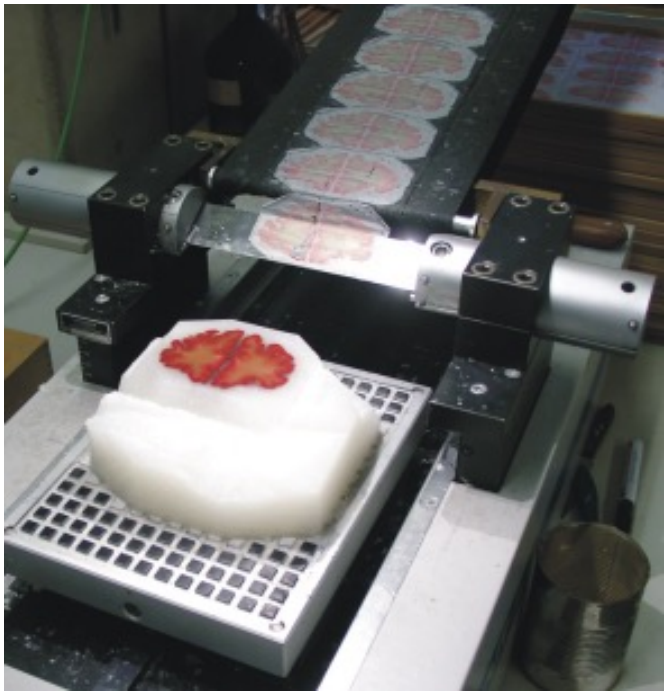




MR

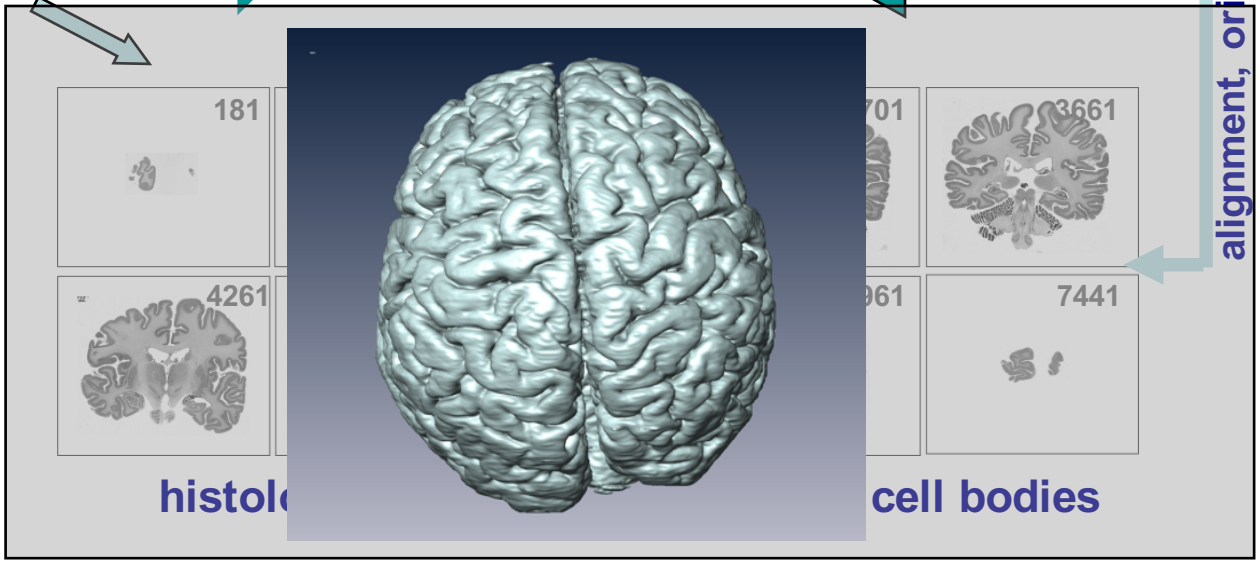


blockface images



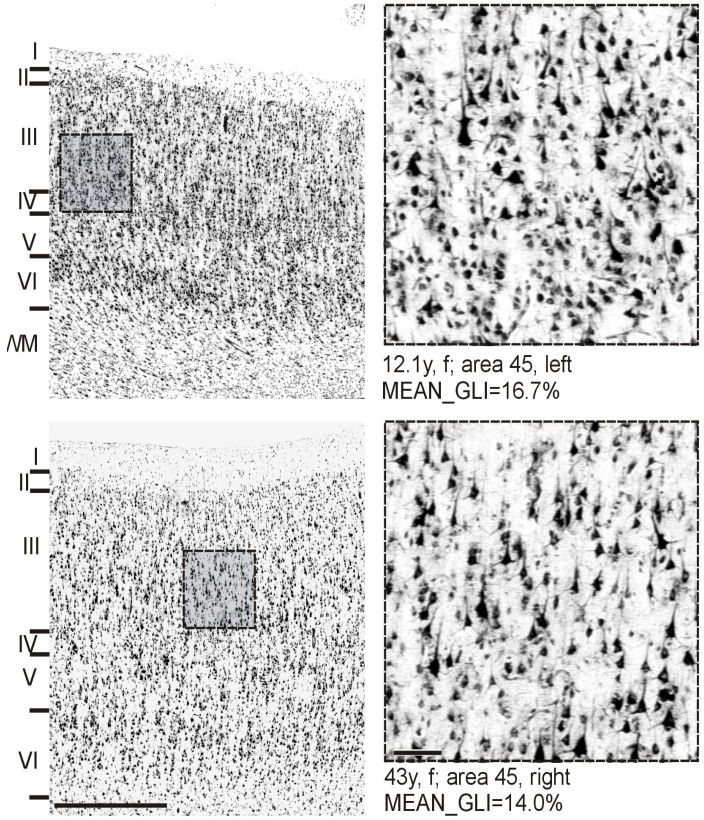
20 μm

Histological volume

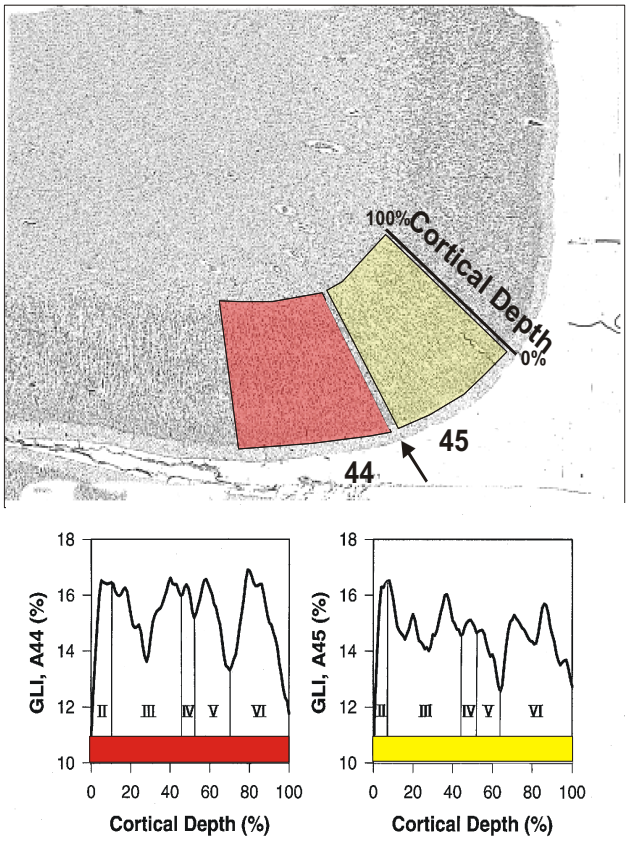


alignment, orientation, scaling

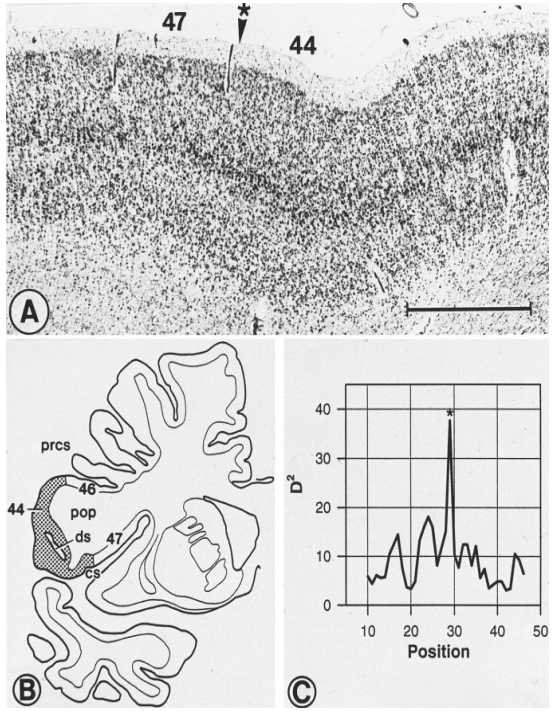
An observer-independent approach to the definition of cytoarchitectonic borders (Zilles, Schleicher, Amunts et al.)



1. Gray Level Index (GLI): an estimate of the volume-fraction of cell bodies



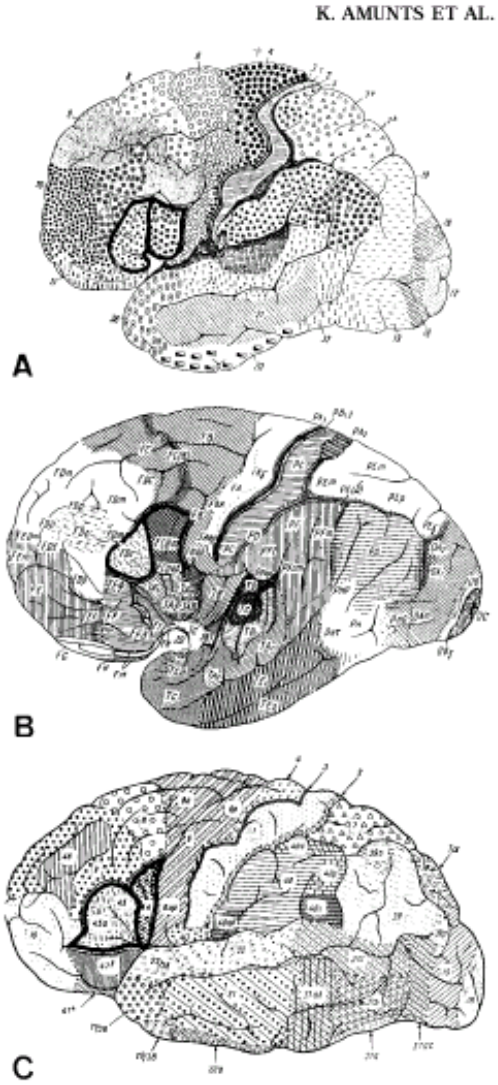
2. Laminar cytoarchitectonic cortical patterns are analyzed via GLI profiles



3. Borders are established where abrupt changes in laminar pattern are detected

Source: Katrin Amunts, FZ Jülich

Problem III: Cytoarchitectonic variability



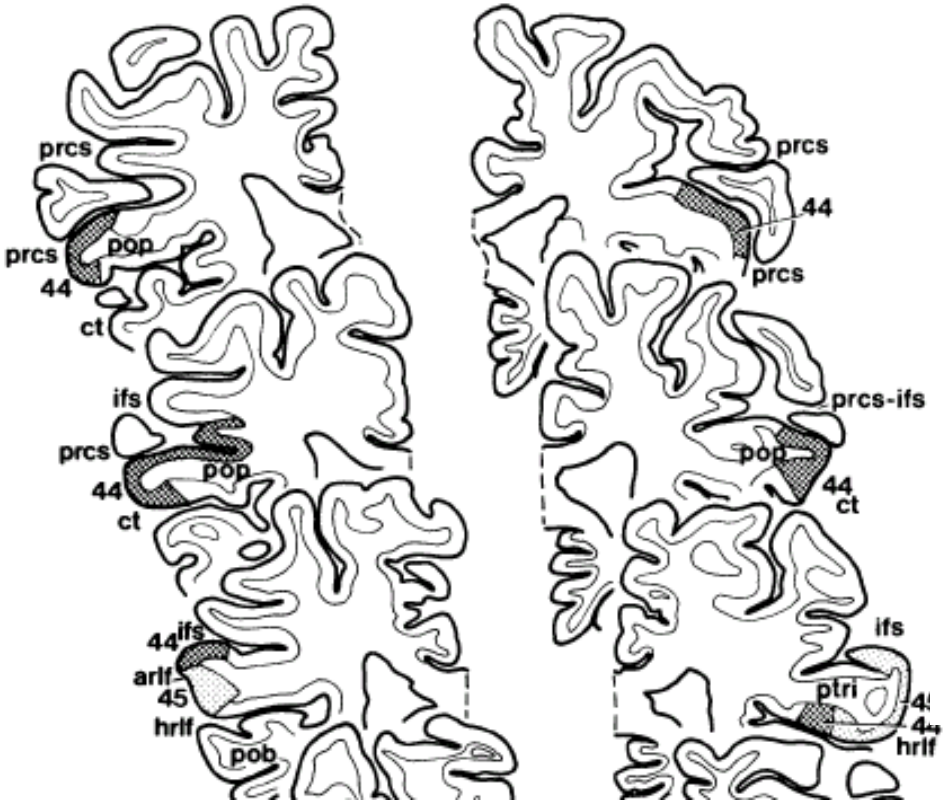
Cytoarchitectonic maps of the lateral surface of human brain

A Brodmann (1909)

B Economo and Koskinas 1925))

C Sarkisov *et al.* (1949)

Problem IV: no correspondence – Variation in cytoarchitectonic-topographic relations



THE JOURNAL OF COMPARATIVE NEUROLOGY 412:319–341 (1999)

Broca's Region Revisited: Cytoarchitecture and Intersubject Variability

KATRIN AMUNTS,[1]* AXEL SCHLEICHER,[1] ULI BÜRGEL,[1] HARTMUT MOHLBERG,[1] HARRY B.M. UYLINGS,[2] AND KARL ZILLES[1,3]
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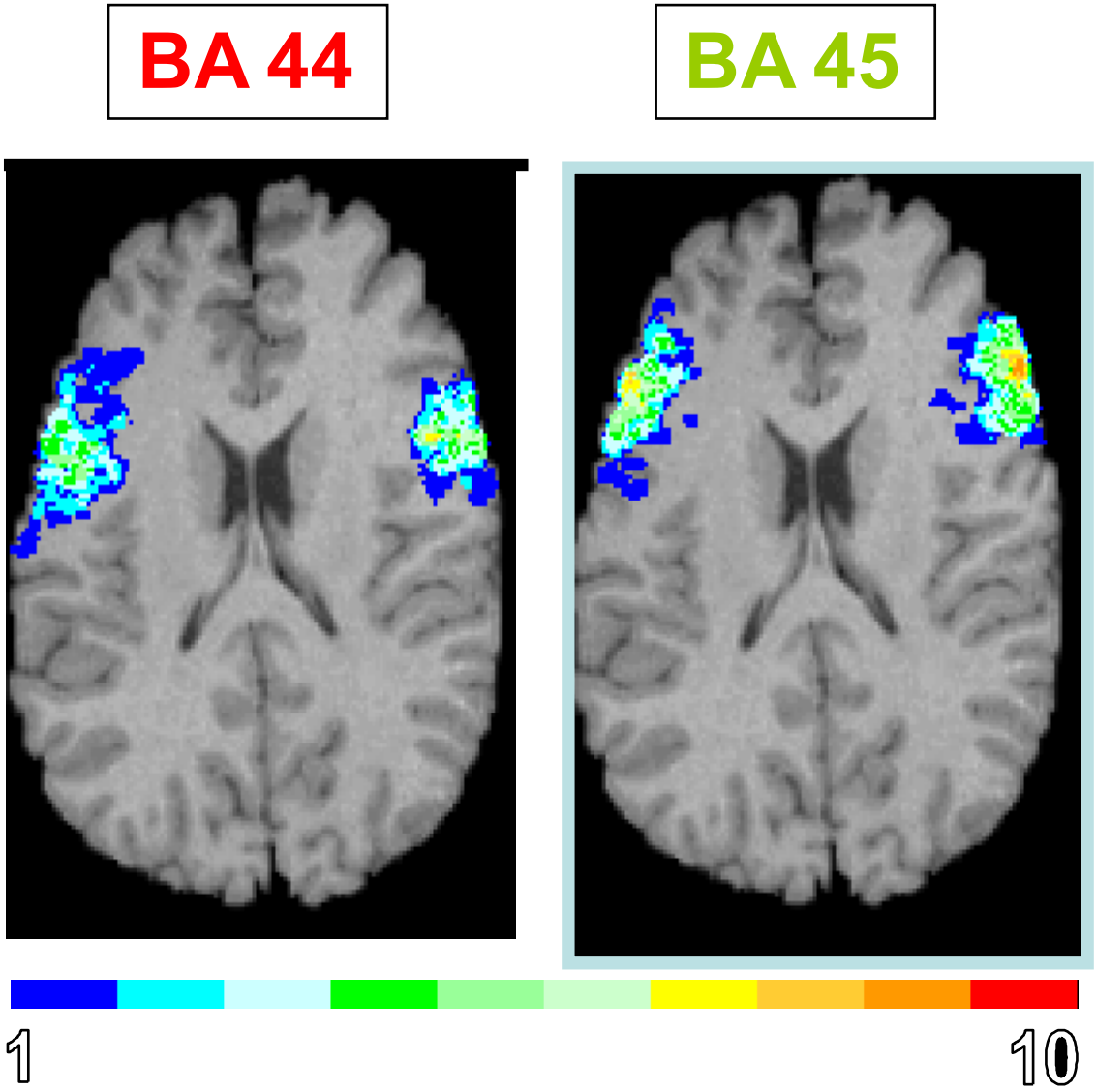
[2]Netherlands Institute for Brain Research, 1105 AZ Amsterdam, The Netherlands
[3]Institute of Medicine, Research Center Jülich, D-52425 Jülich, Germany

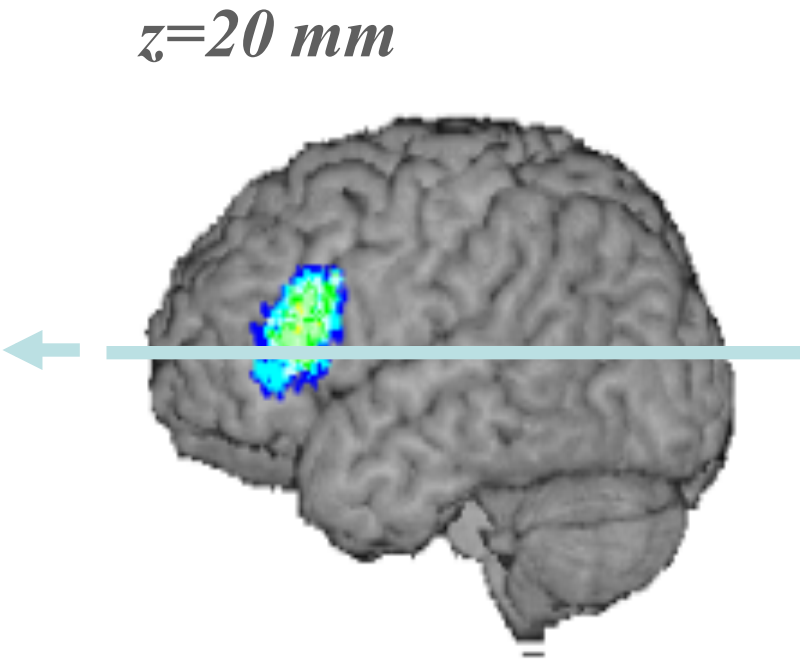
Source: Katrin Amunts, FZ Juelich

Variation summary:

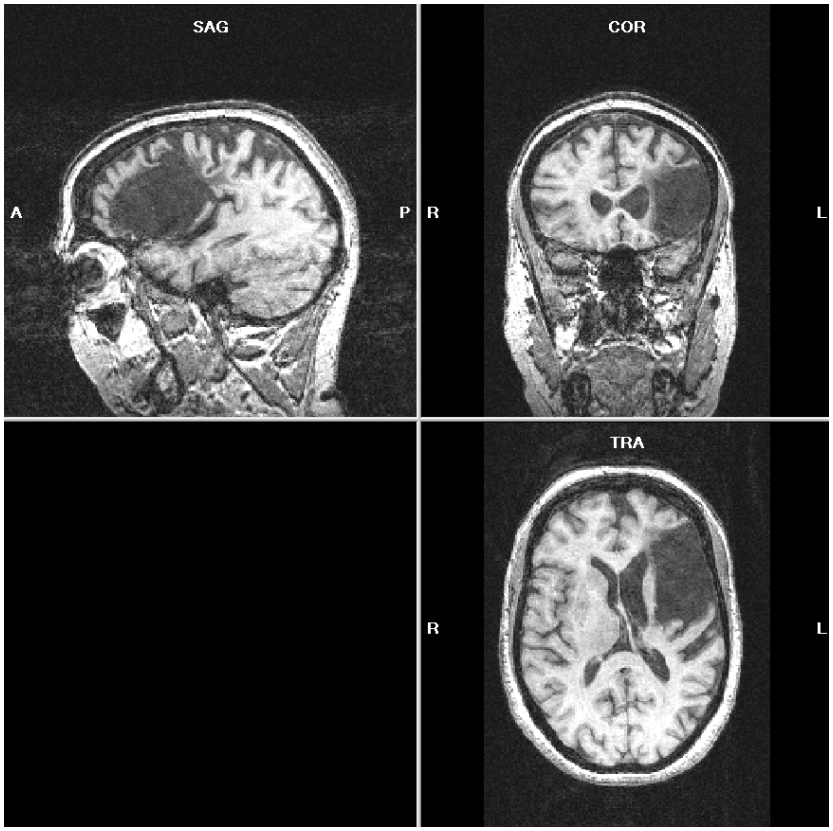
1. There is considerable individual variation in the shape of topographic borders in certain brain regions.
2. There is considerable individual variation in the shape of cytoarchitectonic borders in certain brain regions.
3. The correspondence between the two border types is poor.

Amunts' cytoarchitectonic probability maps of Broca's region (n=10)





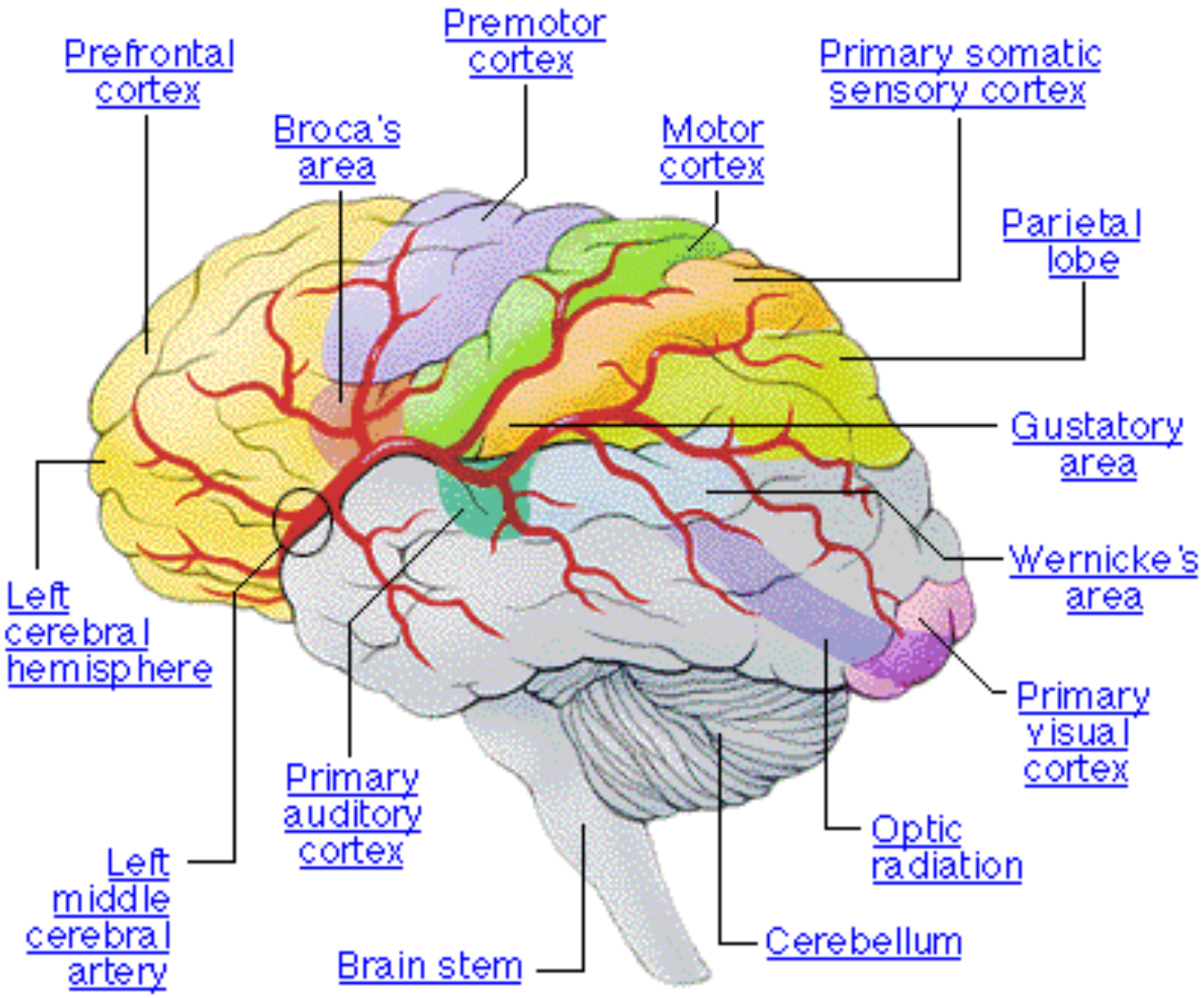
Talk 2: reverse engineering in Broca's aphasia



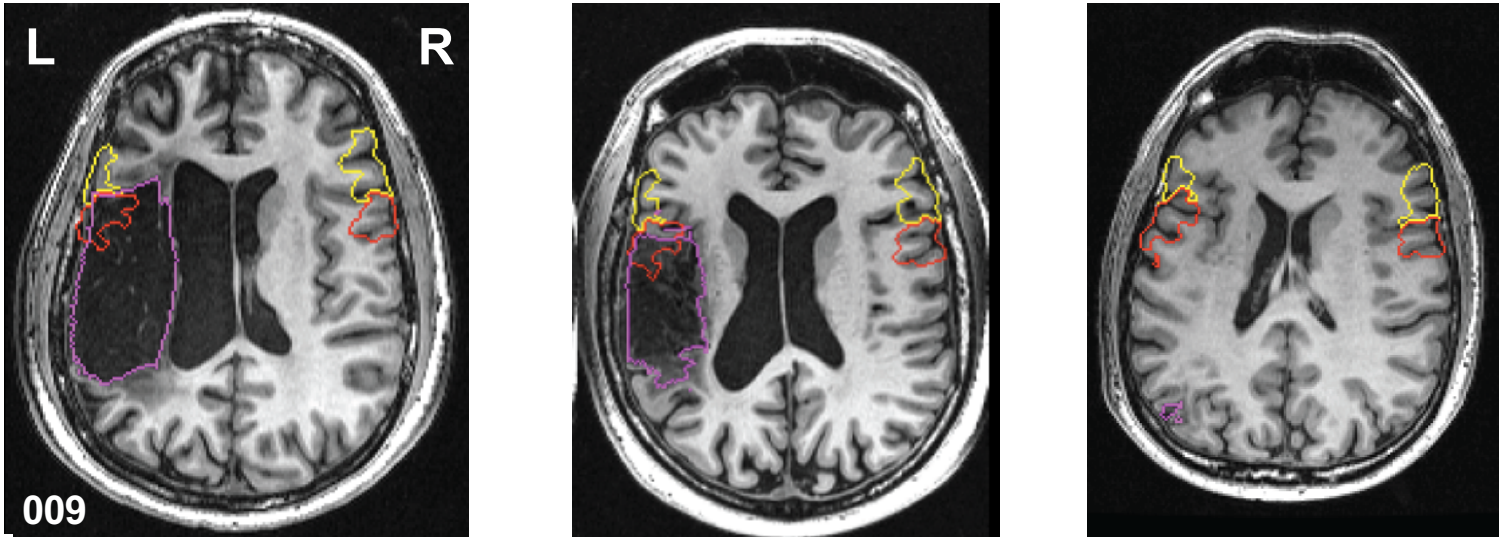
Goals: a. to identify linguistic neurological natural classes through patterns of impairment and sparing in aphasia; b. to get a preliminary glimpse at the linguistic brain map.

Logic of inquiry: Missing pieces of neural tissue that correlate with missing linguistic operations point to the ***critical involvement*** of these brain regions in computation, that are mapped onto these cerebral loci.

Schema of blood vessels in the brain



Applications of p-maps: 2. lesion localization and quantification



BA	***44***		***45***	***44***			***45***	***44***			***45***	
% DESTROYED	**70.2**		**26.7**	**46**		**9.7**	**0**			**0**		

What we did last time

- Methods for anatomical parcellation of the human brain
  - the brain has parts, and one goal of the modular project is to ideitify them (i.e., for aligning brain pieces with pieces of language we must have a clear delineation of the brain pieces)
  - a critical step is in finding a parcellation method
  - a method based on topographic landmarks is not likely to succeed
  - a method based on histologically-determined, "cytoarchitectonic" landmarks is more likely to succeed
  - this method has to grapple with the problem of variability. Probabilistic maps (and atlases) help us to do. The neurolinguistic mapping project uses these atlases as anatomical localizers
- Methods for behavioral parcellation of the human brain
  - "reverse engineering" in aphasia subsequent to focal brain damage: "equate missing piece of brain with missing piece of cognition"

What I (hope to) do today

- Methods for the assessment of the receptive deficit in aphasia
  - the mapping from comprehension scores onto syntactic representation
  - the mapping from grammaticality judgment scores onto syntactic representation
  - a generalization: Trace-Deletion Hypothesis (TDH)
- Problems for the TDH
  - individual variability and tools for handling it
  - cross-linguistic variability and tool for handling it
- Corroborating evidence
  - fMRI results from movement experiments
- Possible relations between the TDH and fMRI results in health

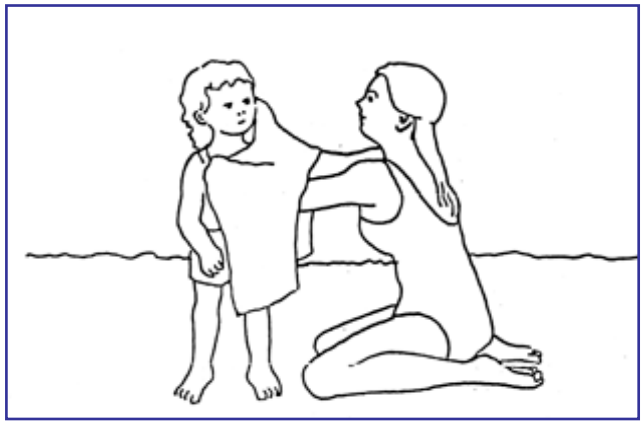
(1) **Performance**

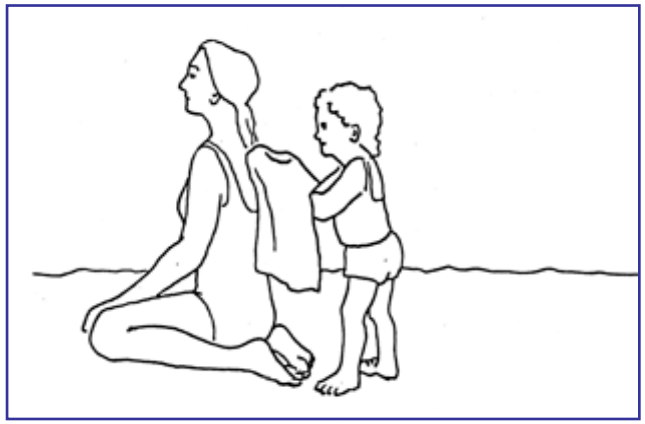
a. ***Semantically "Irreversible"***

The ball that the boy is kicking was red — *High*

b. ***Semantically "Reversible"***

The woman who the girl is drying is thin — *Low*





Caramazza & Zurif's conclusion:

- Broca's aphasics have "asyntactic comprehension."
- As there is a syntactic problem in production, it follows that syntax – harnessed for both productive and receptive tasks – is located in Broca's area.

*** Food for thought: What picture-pair is given for (1a)? ***

BUT This can't be right because the comprehension deficit doesn't encompass all syntax: when tested in a binary-choice θ-assignment paradigm, patients only fails on sentences with a **Movement** relation.

Alternative Analysis The cognitive building blocks, or modules, that align with neurological pieces are *smaller* than previously supposed

---

Above chance

–Movement

(2) a. The girl dried the woman

b. It was the girl who dried the woman

chance

+Movement

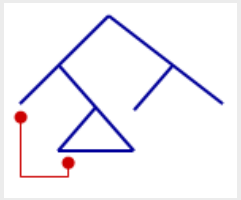
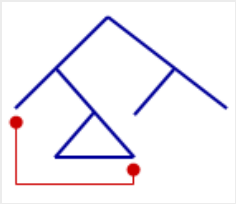
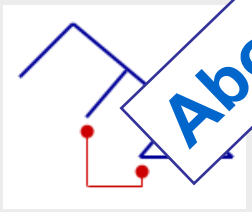
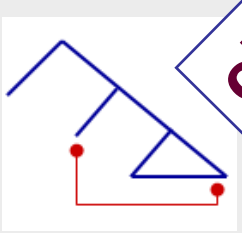
(3) a. **The woman** who the girl dried ◀ was thin

a. It was **the woman** who the girl dried ◀

b. **The woman** was dried ◀ by the girl

A testing session

Complexity a 2x2 factorial design of relative clauses (*Embedding type* X *Movement*) helps focus on the movement deficit:

(4)	Canonical word order (+Movement)	Canonical word order (-Movement)
Center Embedding	I.  The boy [who _ is cha tall girl] is Dan	II.  The boy [who the tall g chasing __] is Dan
Right Branching	III.  Dan is the boy [who __ is chasing the tall girl]	IV.  Dan is the boy [who the tall girl is chasing __]

Above chance

chance

Summary of basic data

(5) Relative clauses — **Performance level**

a. ***Subject***

The woman who dried the girl was thin — *above chance*

b. ***Object***

The woman who the girl dried ◀ was thin — *chance*

(6) Questions

a. ***Subject-questions***

Which woman dried the girl — *above chance*

b. ***Object-questions***

Which girl did the woman dry ◀ ? — *chance*

(7) Active/Passive

a. The woman dried the girl — *above chance*

b. **The girl** was dried ◀ by the woman — *chance*

Query Movement seems relevant, but how can chance performance be derived?

Attempting to understand the observed pattern – Mapping Principles:

P1. Transparency

Error rates must be derived deductively.

(the mapping from representation to error-rate must be explicit)

P2. Restricted Outcomes

The response set determines the range of discernible error types.

(in a binary-choice θ-assignment paradigm, outcomes must be relativized to chance).

P3. Full Interpretation Under Duress

Interpretive forced-choice tasks require that all referential elements have a semantic role.

(when grammatical θ-assignment fails, a θ-less referential element acquires a semantic role via extra-grammatical means)

TDH: trace deletion + default help deduce the pattern

Trace deletion: delete all traces

Default Strategy (S): assign a θ-role to a θ-less NP by linear position

Linear positions: NP1=agent; NP2=theme; NP3=?

Implementation for scores of binary-choice θ-assignment tests

Performance level

Proper compensation in Subject-gap Relative Clauses

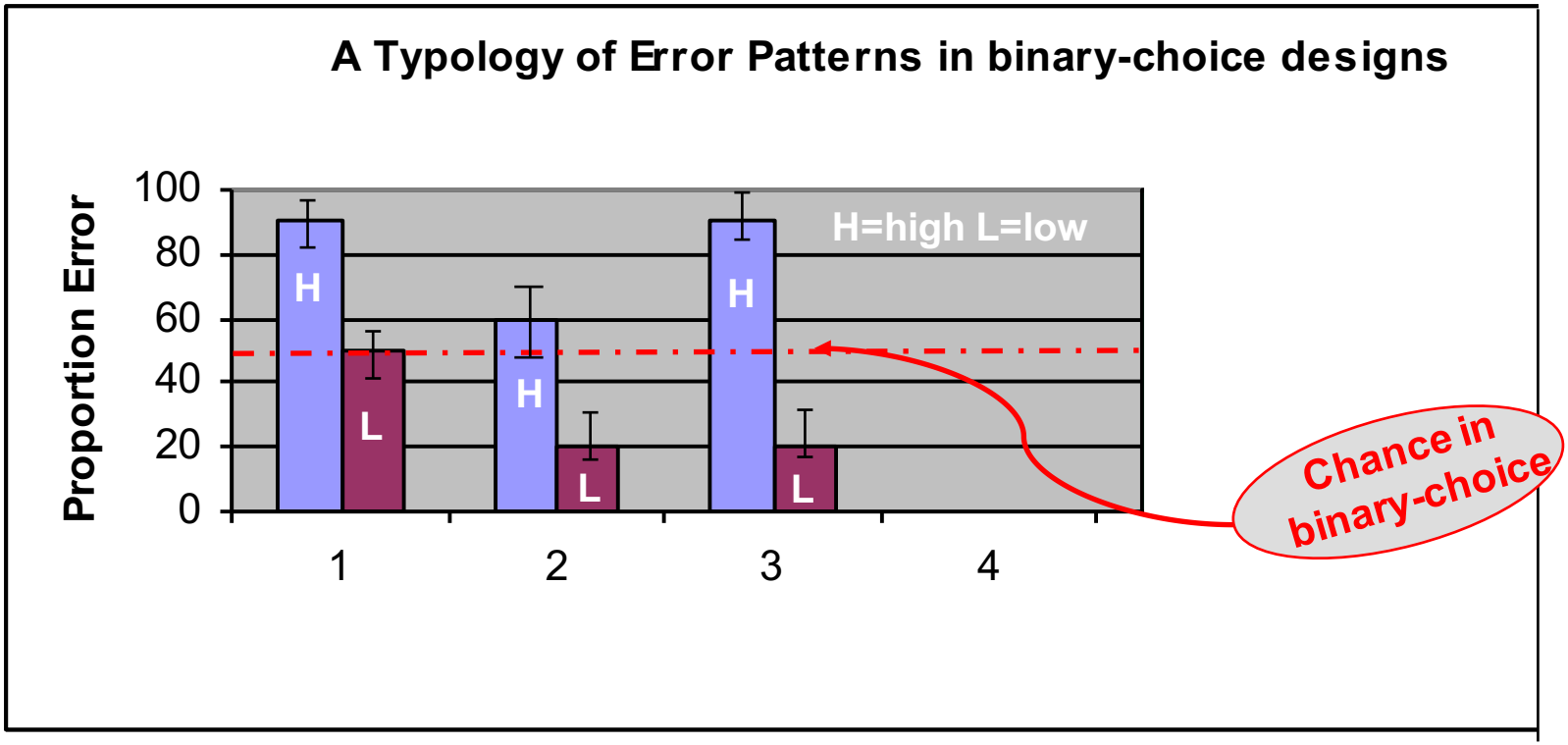
(8) a. *[The woman]$_i$ who$_i$* [* dried the girl] was thin — *above chance*

agent (S) — *theme (G)*

θ-conflict in Object-gap Relative Clauses

b. *[The woman]$_i$ who$_i$* [the girl dried *] was thin — *chance*

agent (S) — *agent (G)*



Dual test pass

1. $H_{ac} > L_c$
2. $H_c > L_{bc}$
3. $H_{ac} > L_{bc}$

Comment: Chance is relativized to the size of the response set. A binary-choice design puts chance at 50%; other designs might entail different levels.

Consequences of the TDH:

- A moved argument may be disconnected from its θ-role
- Representations are exempt from violations of movement constraints
- Processing operations that depend on traces are disrupted.
- Activations in Broca's area would be monitored when traces are linked to their antecedents in the intact brain

XP-Movement-selective impairments in grammaticality judgment

	CONDITION	+Grammatical	-Grammatical
Movement violations	1. Wh-movement/ that-trace	Which woman did David think that John saw? Which woman did David think saw John?	*Which woman did David think that saw John?
Movement violations	2. Superiority	I don't know who said what	*I don't know what who saw
Other violations	3. Place of auxiliary	They could have left town Could they have left town?	*Have they could leave town?
Other violations	4. Negation	John has not left the office John did not sit	*John did not have left the office *John sat not


YES


NO

patient	FC		RD		FA		WF		% error
CONDITION	+G	*-G*	+G	*-G*	+G	*-G*	+G	*-G*	**X'**
1. Wh-movement/that-t	0	***88***	**75**	*25*	0	***100***	33	*38*	44.9
2. Superiority	0	***63***	**63**	*38*	**75**	*0*	**88**	*0*	40.9
3. Place of auxiliary	0	*25*	4	***75***	2	*0*	21	*0*	15.9
4. Negation	0	*13*	6	*25*	0	*19*	38	*6*	13.4

Grodzinsky & Finkel, *J. Cog. Neurosci.*, 1998

Converging evidence II: Cross-Modal Priming failure

Action at-a-distance –
priming at the gap

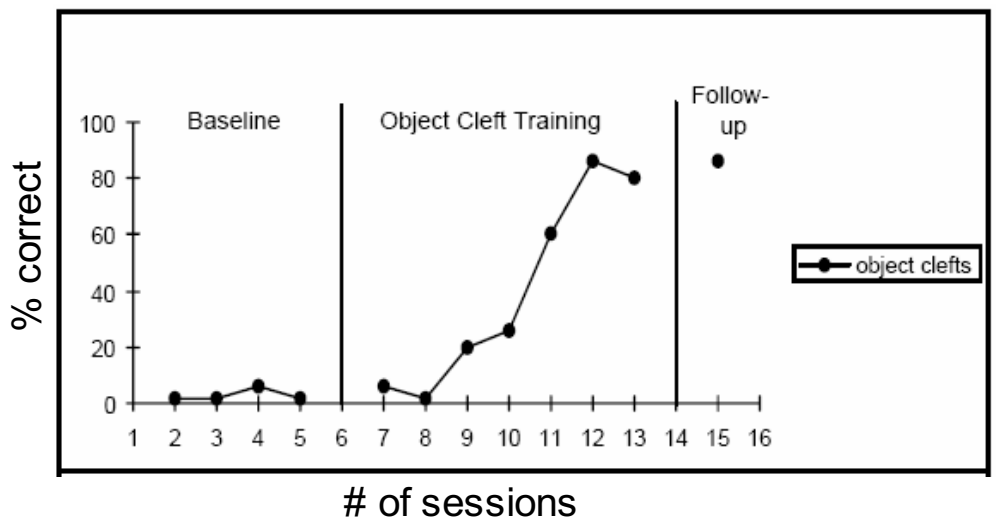
(15) a. The priest enjoyed ***the drink*** *1
[that the caterer was ***2** serving ~~***the drink***~~ ***3**]
to the guests

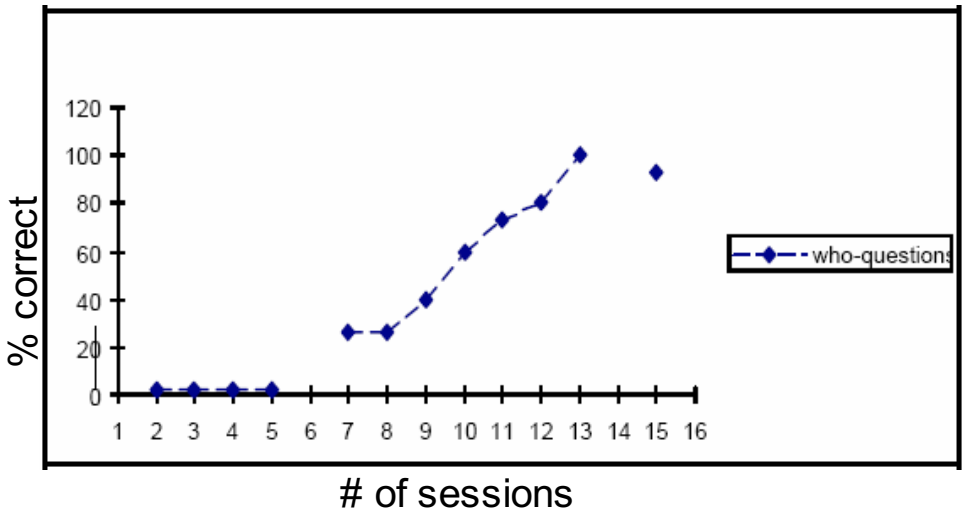
BEER
PEER
TEER

In aphasia, there is priming at *1, but at *3 the antecedent fails to be properly primed, indicating antecedent-gap linking failure

Zurif et al., *Br.Lang.*,1993; Swinney & Zurif, *Br.Lang.*,1995)

Converging evidence III: Movement is a generalization in therapy for aphasic patients





(16) a. It is **the man** that the ◄ boy pushed

b. who did the boy push ◄

Can we conclude that XP-Movement is localized in Broca's area?

Perhaps, but there are some questions that we need to answer first:

I. How great (and significant) is **performance variation** among individual patients? It has been claimed that **variation is boundless**.

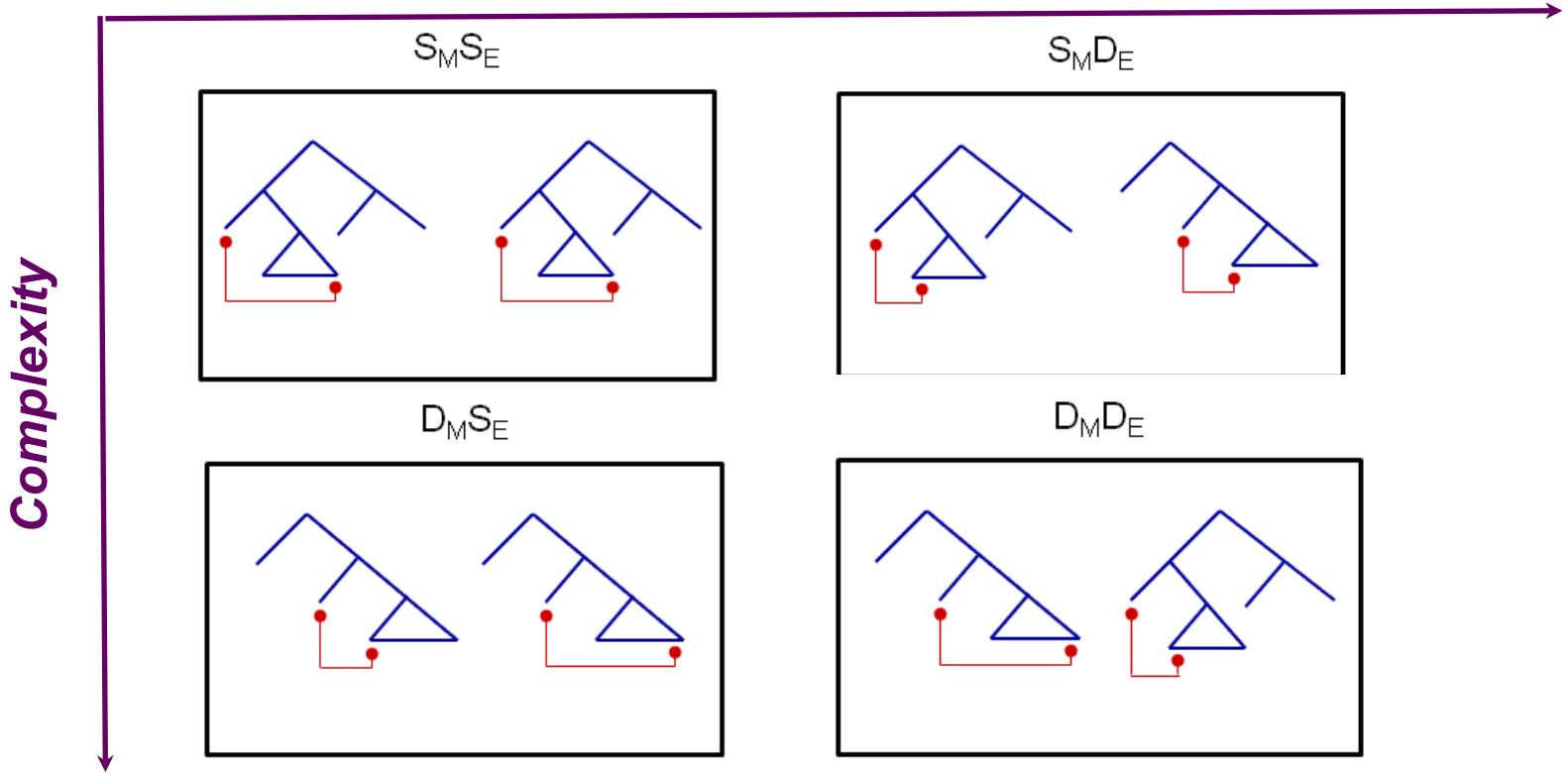
II. How great (and significant) is **cross-linguistic variation**?

III. How precisely can we **localize** the processes **cortically**?

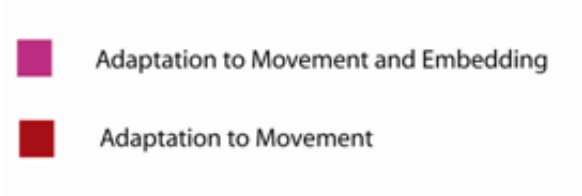
IV. Is the calculation of syntactic Movement during language comprehension neurologically **distinguishable** from other syntactic and/or cognitive operations?

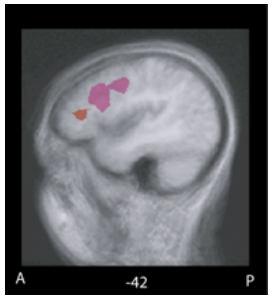
Query If *Movement* is localized in Broca's region, where is the rest of the syntax?

Reflections of this distinction in health:
Andrea Santi's fMRI adaptation study of Embedding (Complexity) vs. Movement:



Expectation: the *Complexity* and *Movement* factors would dissociate anatomically





(12) *Movement*

a. **The mailman and the mother of Jim love the woman who *Kate* burnt**

…NP... NP…NP… The woman…***NP***…

b. **The mother of Jim loves the woman who *the mailman* and *Kate* burnt**

…NP... NP…The woman…***NP*… *NP***…

c. **Kate loves the woman who *the mailman* and *the mother* of *Jim* burnt**

... NP…The woman…***NP*…*NP*…*NP***…

(13) *Binding*

a. **The sister of Kim assumes that Anne loves the mailman who burnt himself**

…NP... NP…NP… the mailman … himself

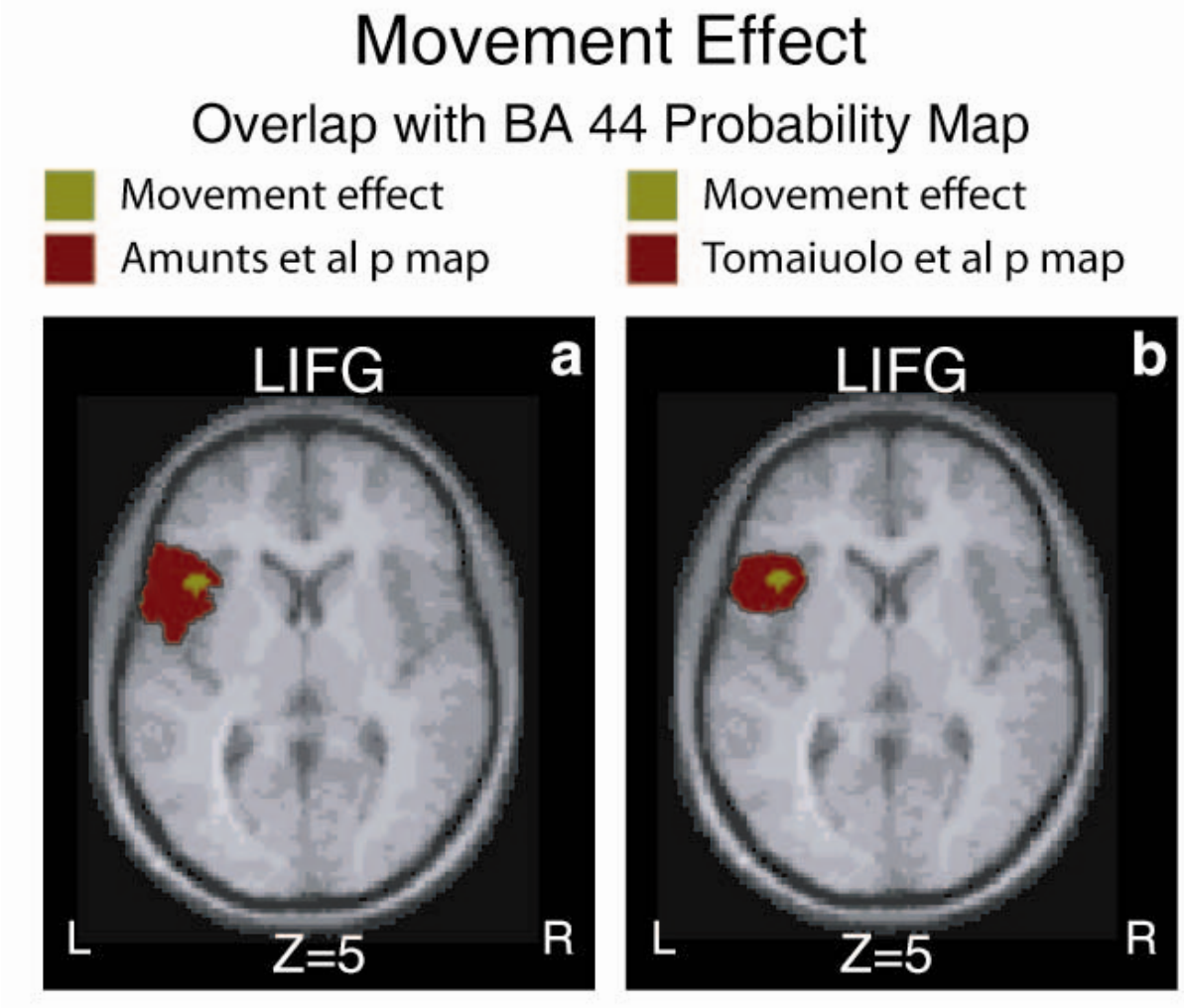
b. **The sister of Kim assumes that the mailman who loves *Anne* burnt himself**

… NP...NP… the mailman …***NP***… himself

c. **Anne assumes that the mailman who loves *the sister* of *Kim* burnt himself**

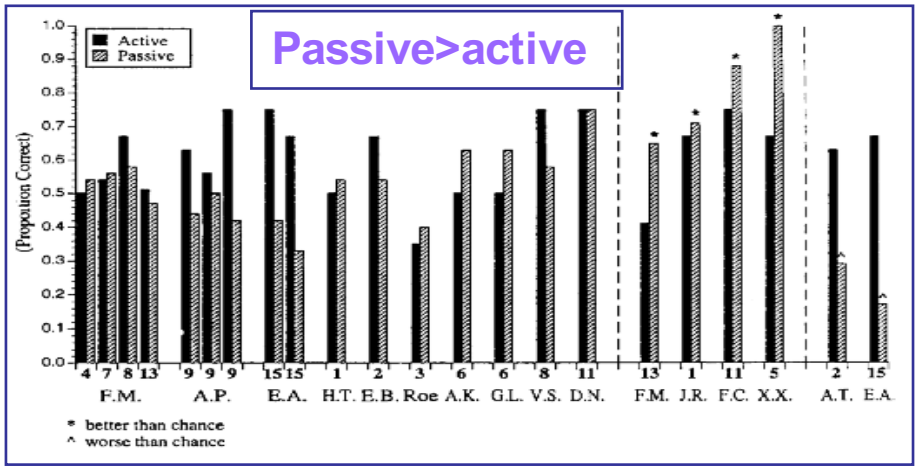
…NP... the mailman… ***NP***… ***NP***… himself

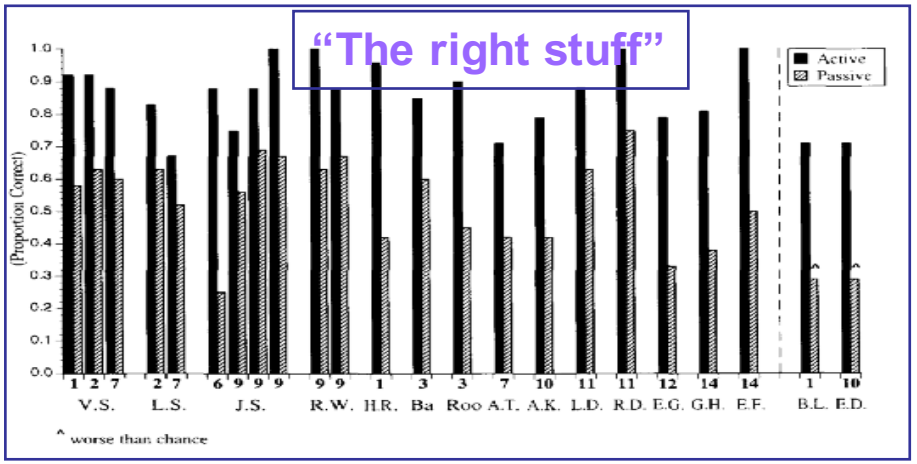
Applications of p-maps: localization of activation clusters in fMRI

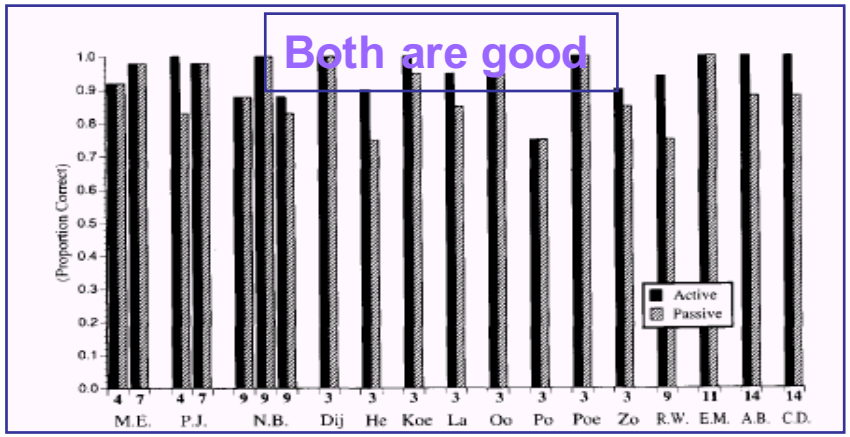


A Reality Check: Huge Individual Variation

active ■ vs. passive ▨



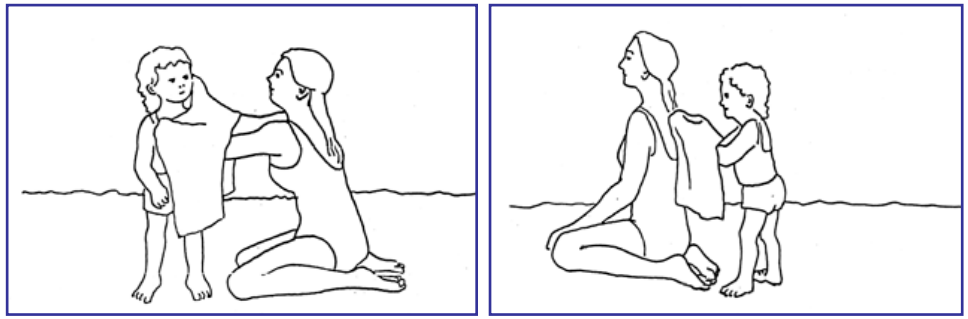




R.S. Berndt et al. / Cognition 58 (1996) 289–308

NB: Histograms represent proportion correct

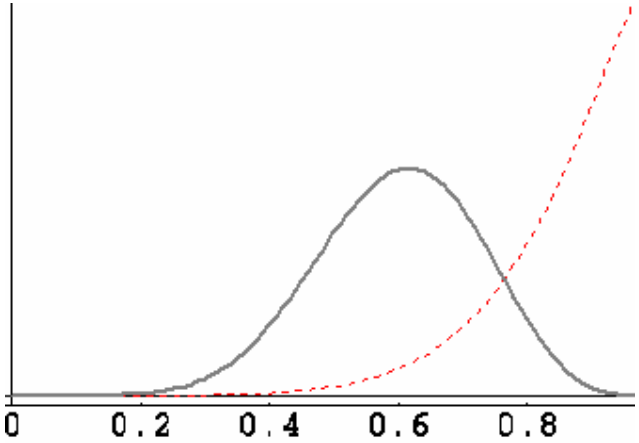
The concept of chance level performance:
When we talk about chance, we expect…



(9) *a. active:* The girl dried the woman *above chance*

b. Passive: ***The girl*** was **dried** ◄ by the woman *chance*

…unimodal distributions, with means right down the middle

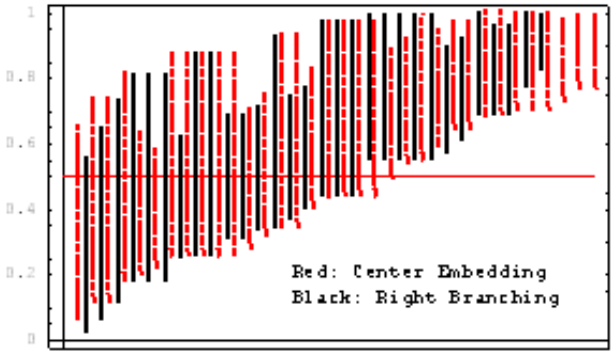


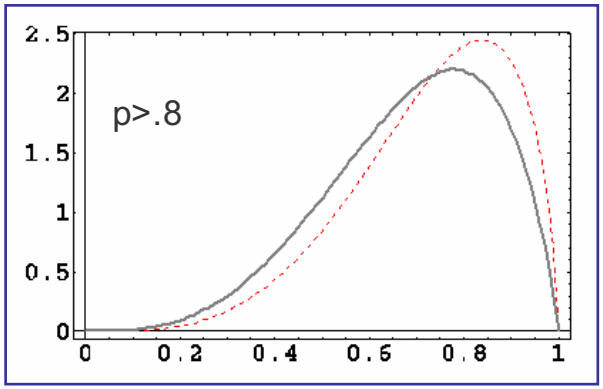
I. measuring "boundless variation" that blurs our vision

Dan Drai's large-scale outlook on relative clause comprehension [n=32]

- *Each individual score is represented as a p<.01 Confidence Interval on a binome*
- *A factorial design*

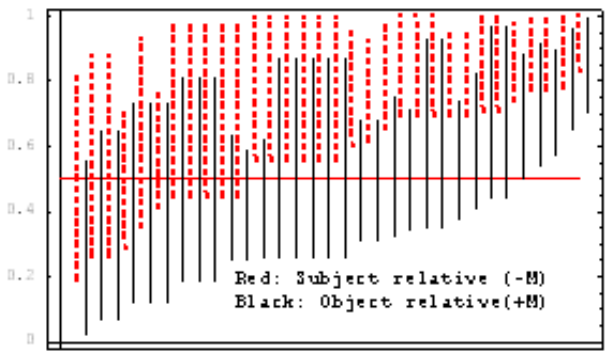
A: analysis by Embedding type (rows)

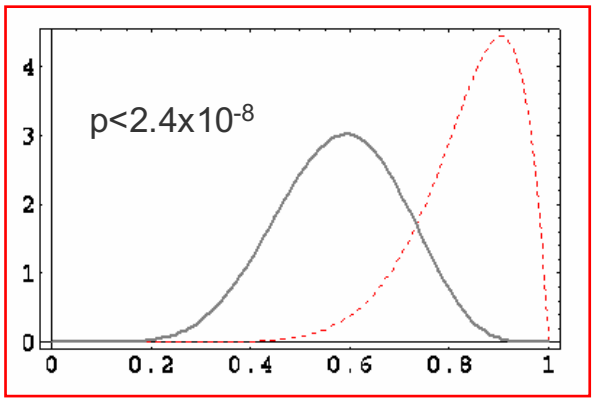




preserved	impaired
I.	II.
III.	IV.

B: analysis by Movement type (columns)

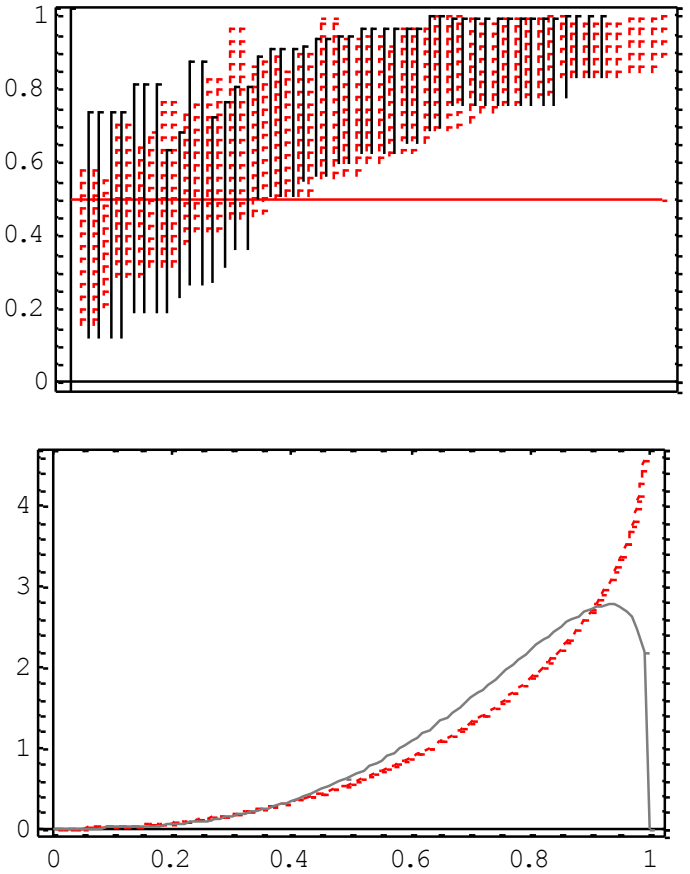




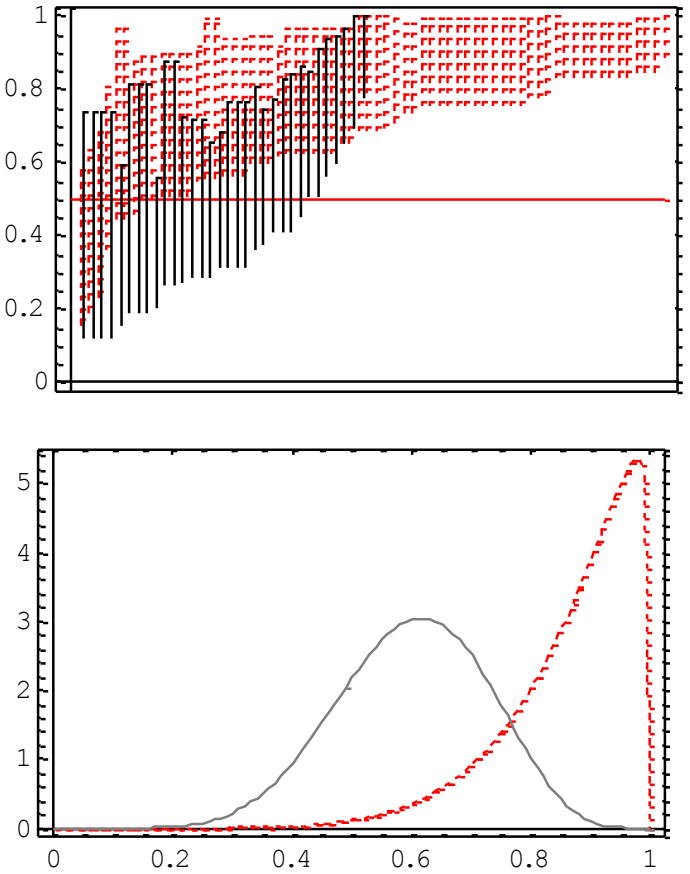
Active/Passive vs. Movement

Mood	Movement: –M	Movement: +M
ACTIVE	a. **Ha-xayal metzayer 'et ha-rofe ha-ze** *The soldier is drawing this doctor*	b. **'Et ha-rofe ha-ze ha-chayal metzayer** ▶ *This doctor, the soldier is drawing*
PASSIVE	c. **door het meisje `wordt` de jongen ◀`gekust`** *by the girl was The boy kissed*	d. **The boy `was seen` ▶ by the girl**

Active vs. passive

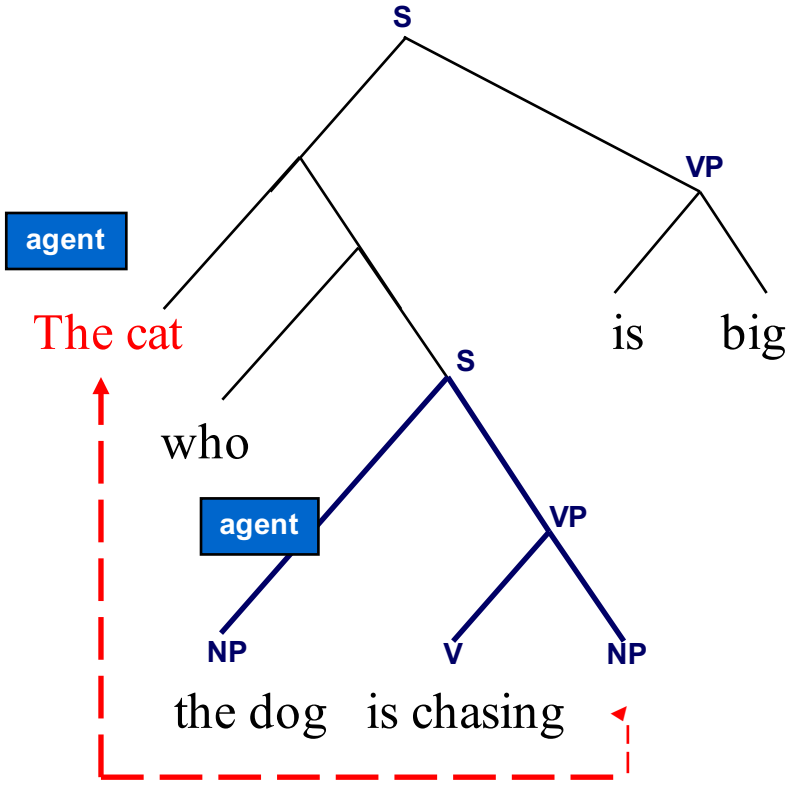


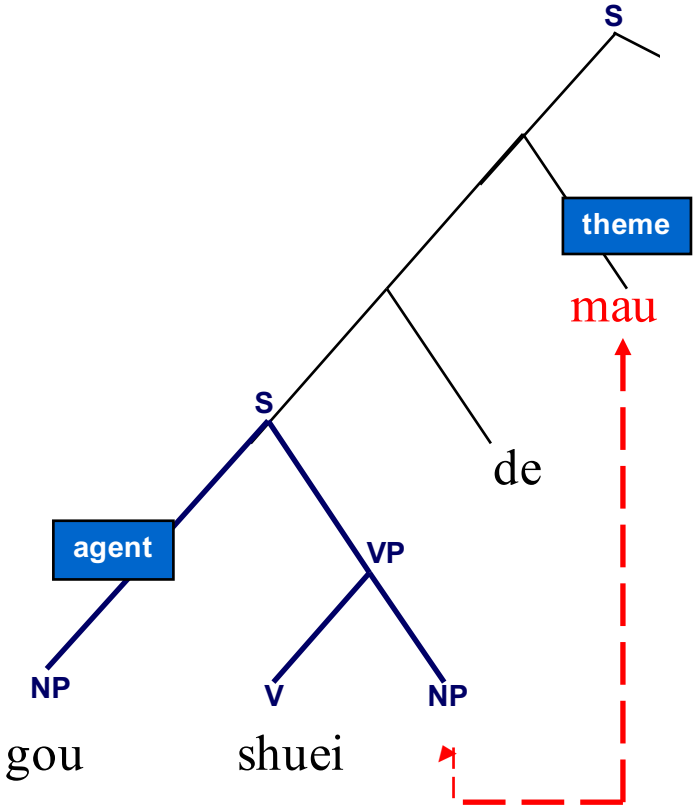
+Movement vs. -Movement



II. Cross-linguistic variation that sharpens our vision:
English vs. Chinese relative clauses

(10)	*English*
a. *The cat* *who* ***is big*** *[is chasing the dog]*	***Above chance***
b. *The cat* *who* ***is big*** *[the dog is chasing ◂]*	***Chance***





More cross-linguistic variation that sharpens our vision:
English vs. German/Dutch passive

(11) *English*

a. active: The girl dried the woman

b. Passive: ***The woman*** was **dried** ◄ by the girl

(12) *Dutch/German*

a. active: De man redt de vrouw

The man saves the woman

b. Passive: ***De vrouw*** *wordt door de man* ◄ ***gered***

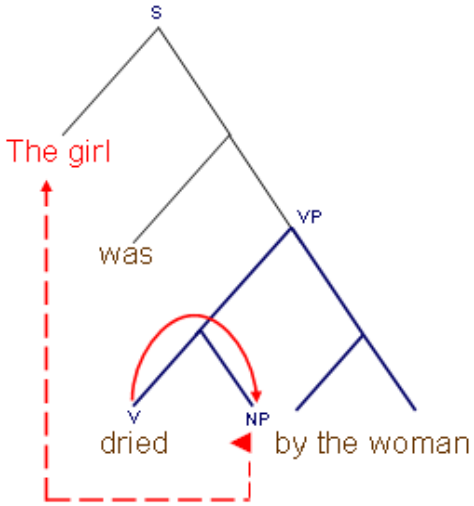
Above chance

Chance

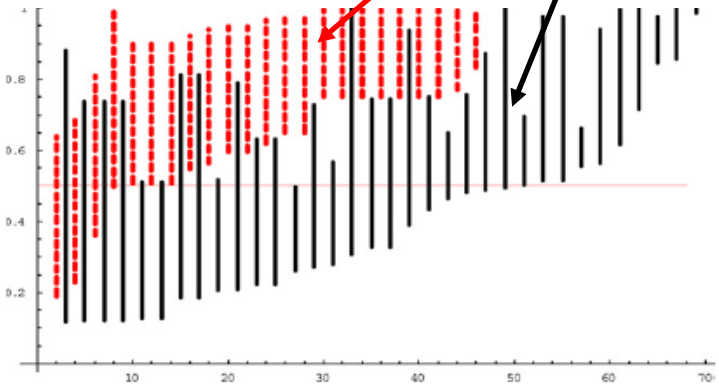
Above chance

Above chance

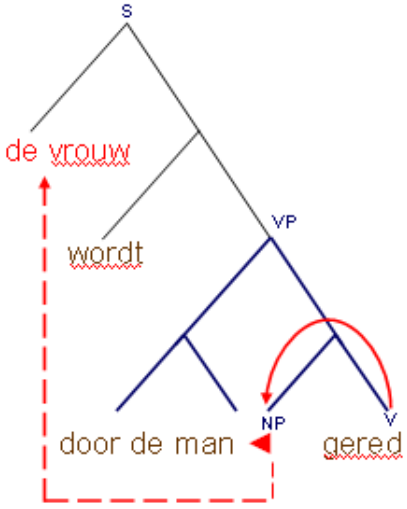
English (chance)



Dutch/German (n=18) vs. English (n=34) passive



Dutch (above chance)



Kolk, *Cog. Neuro.* 1985; Friederici & Graetz, *Br. Lang.*, 1987; Drai & Grodzinsky, *Br. Lang.*, 2006b

"Bridging"

English

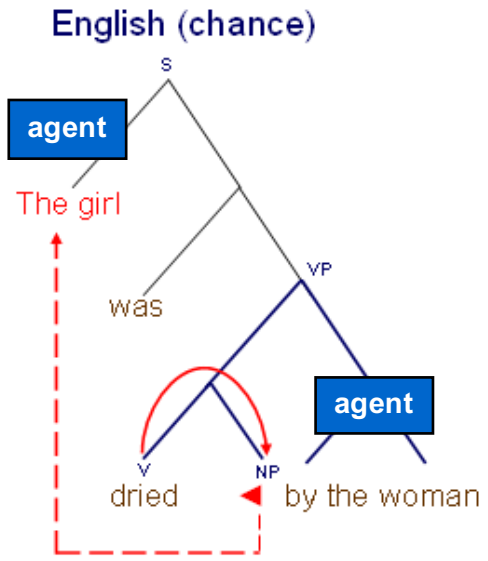
(13) **The woman** was dried ***t*** [by the girl] — *chance*

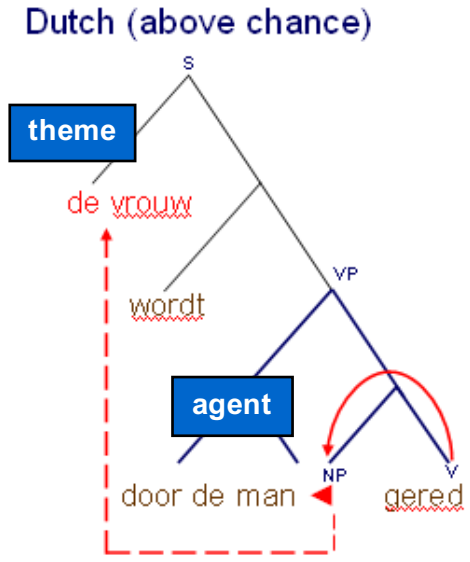
Dutch

(14) **De vrouw** wordt [door de man] ***t*** gered — *above chance*

German

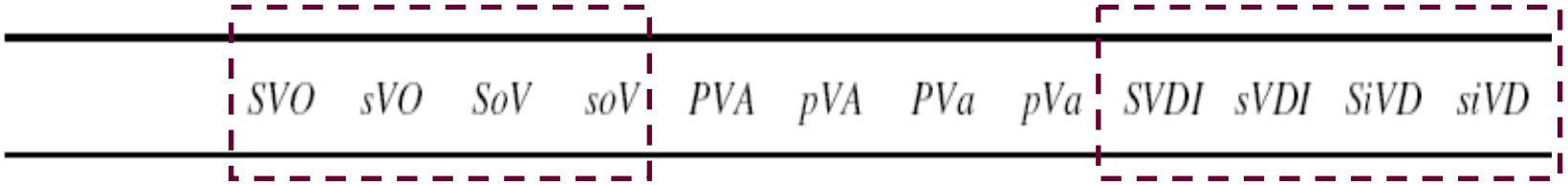
(15) **Der Gaul** wird [vom Esel] ***t*** getretten — *above chance*





NB This analysis predicts comprehension failure only if the moved element crosses its θ-assigner. This has consequences to θ-assignment to VP-internal subjects.

3 cross-linguistic puzzles
1. Italian clitics



(16) ***Cliticized Direct Objects in transitive sentences***

a. Mario cerca Flora

Mario seeks Flora

S V O

b. Mario **la$_i$** cerca **t$_i$**

Mario *her* seeks *t*

S *cl*$_i$ V t$_i$

(17) ***Cliticized Indirect Objects in ditransitive sentences***

a. Mario da un regalo a Flora

Mario gives a present to Flora

S V DO IO

b. Mario **le$_i$** da un regalo **t$_i$**

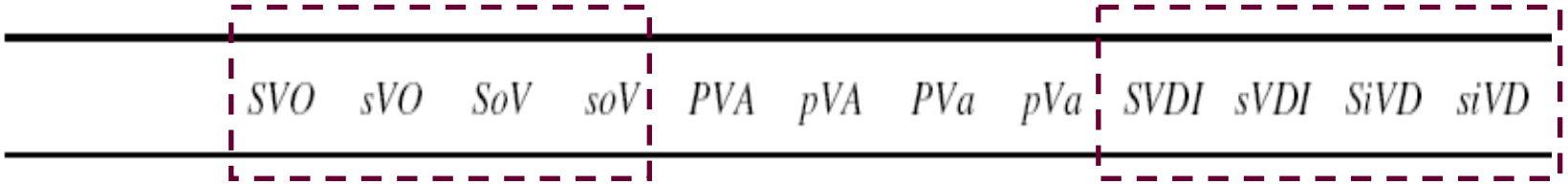
Mario *her* gives a present *t*

S *cl*$_{IO}$ V DO t$_{IO}$

Raw patient scores (# correct out of 10 trials)

	SVO	sVO	SoV	soV	SVDI	sVDI	SiVD	siVD
A.D.	8	6	6	7	7	5	1	4
D.R.	5	3	5	2	8	3	2	2
L.Z.	7	10	8	9	8	8	4	7
M.B.	10	9	8	8	8	7	6	5
M.G.	7	6	8	5	8	7	6	3
P.Gh.	8	7	9	6	10	10	5	7
P.Gi.	7	7	7	5	9	9	5	1
R.O.	8	7	2	5	5	8	1	5

Results



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a. Mario cerca Flora

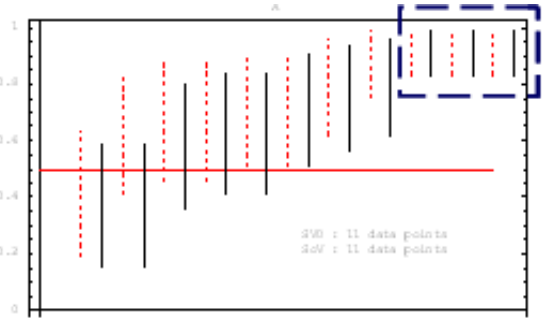
Mario seeks Flora

S V O

b. Mario **la**$_i$ cerca **t**$_i$

Mario *her* seeks *t*

S *cl*$_i$ V t$_i$



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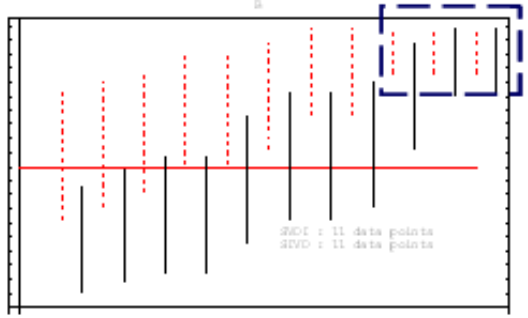
S V DO IO

b. Mario **le**$_i$ da un regalo **t**$_i$

Mario *her* gives a presen

S *cl*$_{IO}$ V DO t$_{IO}$



Can these asymmetries be deduced from the TDH?

(16)' ***Cliticized Direct Objects in transitive sentences***

a. **Mario$_1$ t$_1$** cerca Flora

S * V O

| |

agent(G) theme(G)

b. **Mario$_1$ t$_1$ la$_2$** cerca **t$_2$**

S * *cl* V *

| |

agent(S) theme(S)

(17)' ***Cliticized Indirect Objects in ditransitive sentences***

a. **Mario$_1$ t$_1$** da un regalo a Flora

S * V DO IO

| | |

agent(S) theme(G) goal(G)

b. **Mario$_1$ t$_2$ le$_i$** da un regalo **t$_i$**

S * *cl* V *DO* *

| | |

agent(S) theme(S) theme(G)

NB - Chance performance in (17b) is derived via a theme-theme conflict that brings about a thematically incoherent representation, but it all seems to work only if we drop the "bridging" assumption

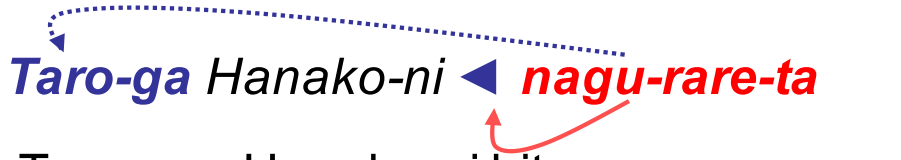
2. Another Complication from Japanese and Korean: An unexpected difference within SOV Languages

(18) a. *Dutch Passive*

De vrouw *wordt door de man* ◀ ***gered*** *above chance*

The woman was by the man saved

b. *Japanese Passive*



Taro-ga *Hanako-ni* ◀ ***nagu-rare-ta*** *chance*

Taro-**NOM** Hanako-ni hit-**PASS-PAST**

2 cross-linguistic differences that may be relevant:

I. Unlike Dutch/German, Japanese has no auxiliary in passive

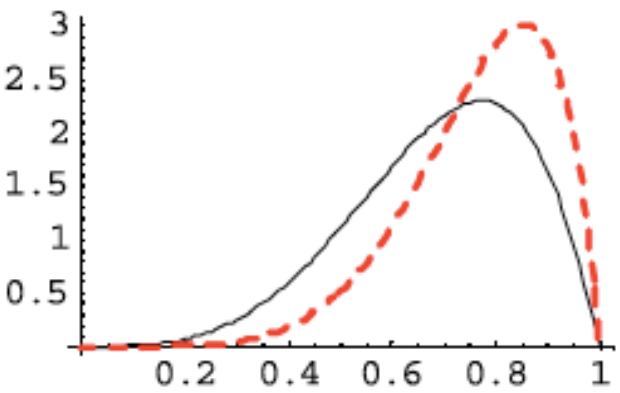
II. *-ni* is a Dative case, and is not exactly like *by, door* or *vom*.

3. A quantitative mystery: Murky Italian Contrasts

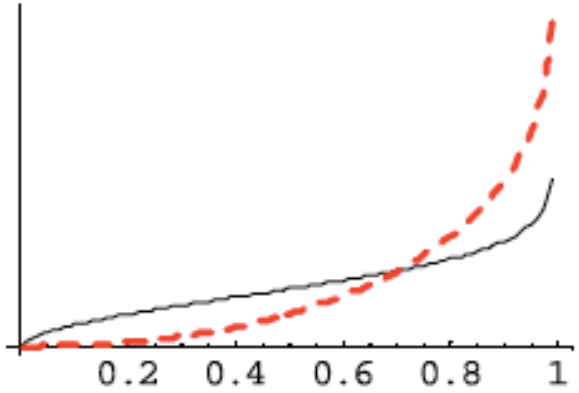
(19) *a. active:* *Il ragazzo abbraccia la ragazza* — *slightly above chance*

The boy hugs the girl

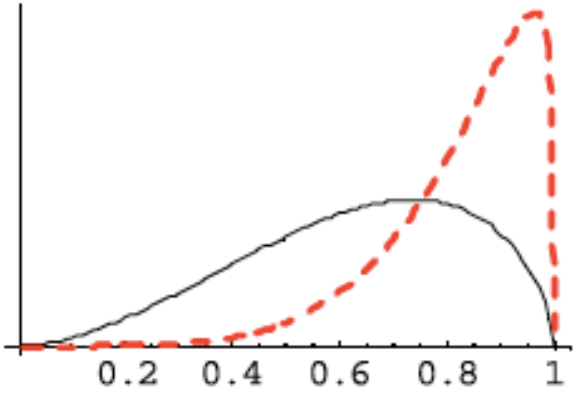
b. Passive: ***La ragazza*** *è* ***abbracciata*** ◄ *dal ragazzo* — *almost at chance*



Caramazza *et al.* (n=38)



Luzzatti *et al*. (n=11)



Drai & Grodzinsky (n=27)

Caramazza, A. et al.,. *Br. Lang,* 2005; Luzzatti *et al.*. *Aphas;* 2001

extensions

- **Generality**

I. Can we find independent evidence for this pattern of selectivity?
II. Do all patients perform in the same way?
III. Is the deficit equally manifested in languages other than English, and if so, how do we think about it?
IV. What are there implications to the normal brain?

- **Specificity**
- V. What are the bounds of the pattern of selectivity?
- VI. Do only Broca's patients exhibit this pattern?
- VII. Is there a regular relation between lesion and performance type?

the end

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