ESSLLI 2023 Monotonicity course

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Experimental (neuro)linguistics attempts to…

- identify natural classes in the functional domain
- identify natural classes in the anatomical domain
- establish correlations between the two domains –
  a precise map of regional specializations.

Our experimental methods:

• Exploring linguistic knowledge in the time domain	(RT experiments)
• Exploring histological structure in brain space	(micro-anatomical studies)
• Exploring deficient linguistic knowledge via errors	(aphasia experiments)
• Exploring linguistic knowledge in brain space	(fMRI)

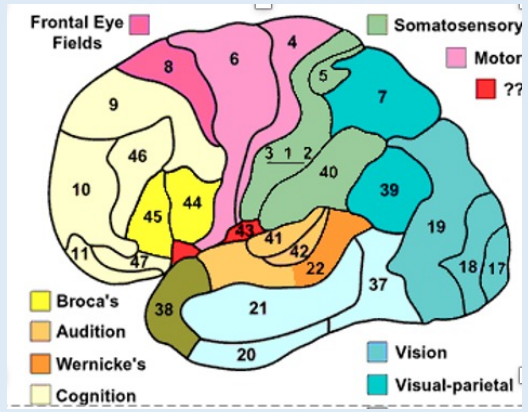
Types of experimental studies

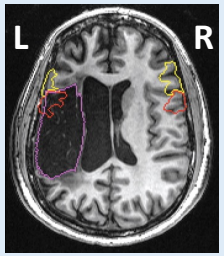
Ba baba bababa

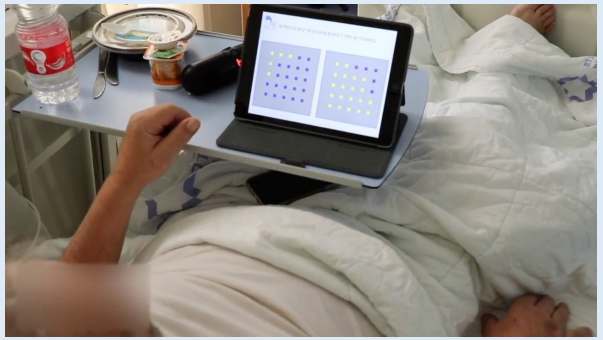
Pa papa papapa

RT

Anatomy





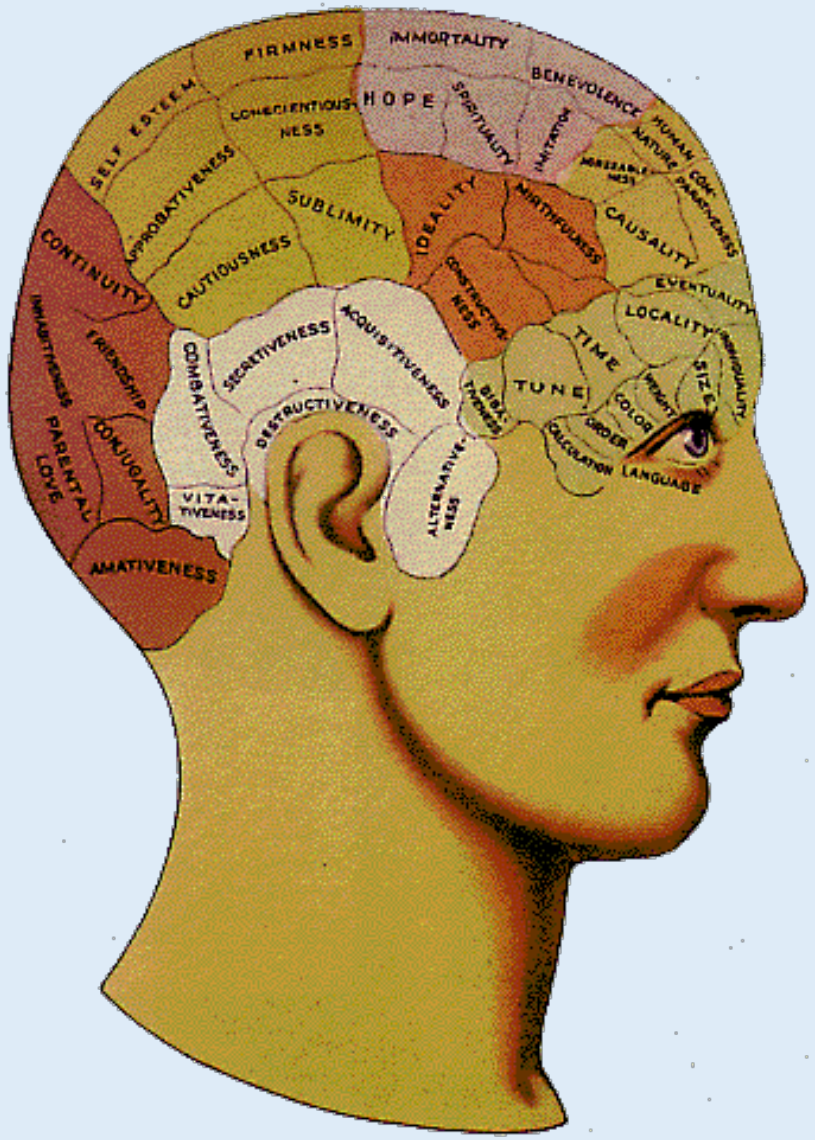


Patients

the juice that the child...

fMRI

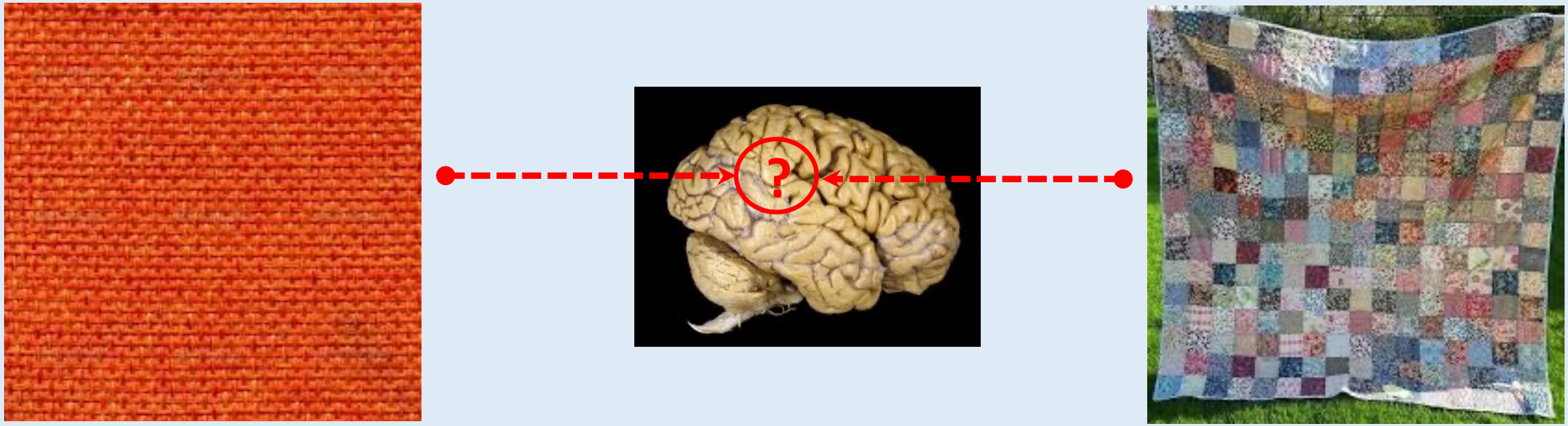
Gall's functional anatomy: borders



Franz Joseph Gall
1958-1828

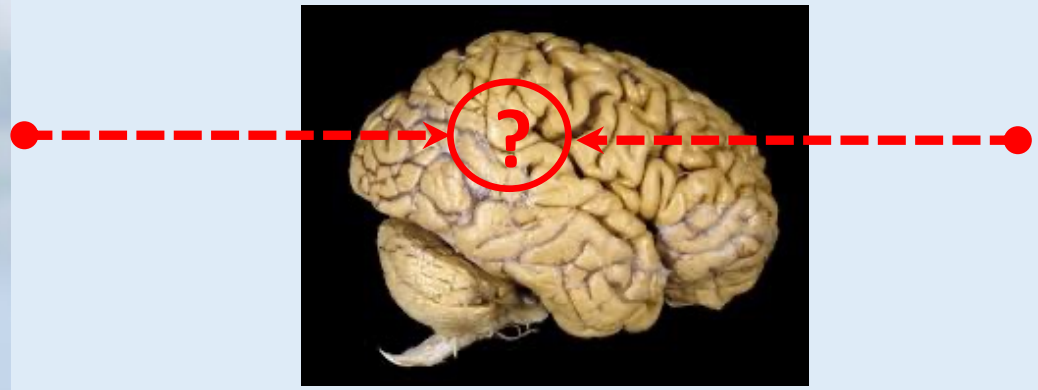
The quilt metaphor

The neuronal makeup of our brain is not of a single fabric.
Rather, there is a patchwork of varied neuronal clusters

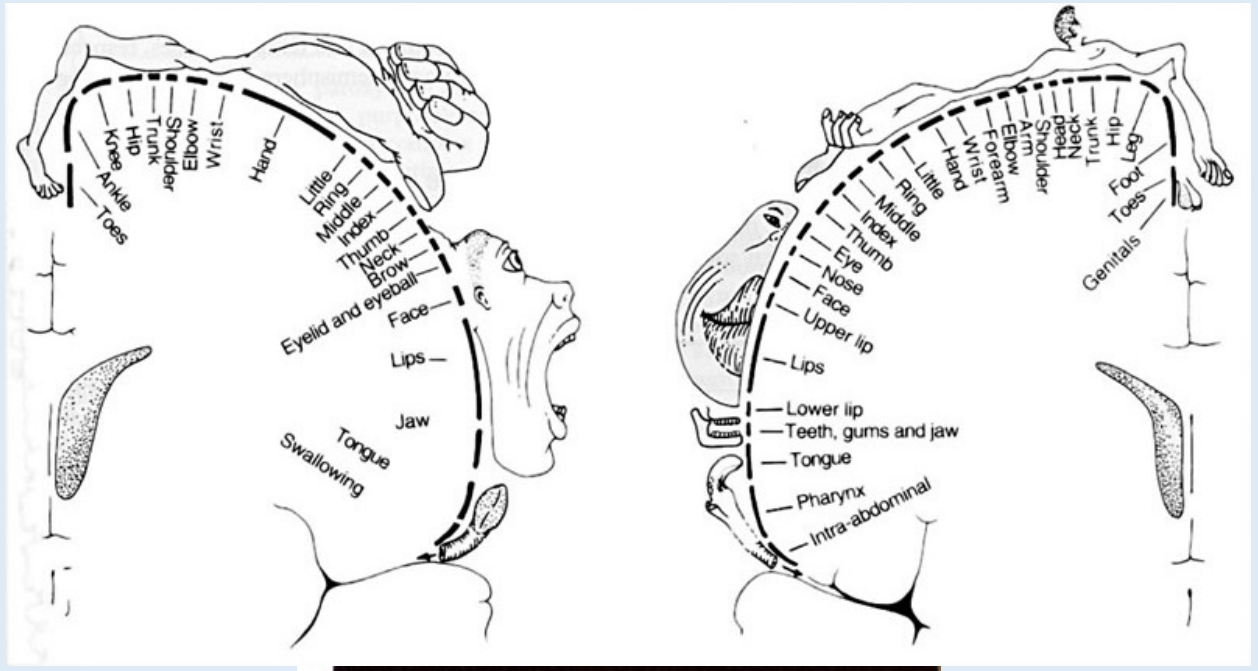


The engine metaphor

Our mental functions are not propelled by one and the same engine.
Rather, there is a multi-engine machine behind our abilities



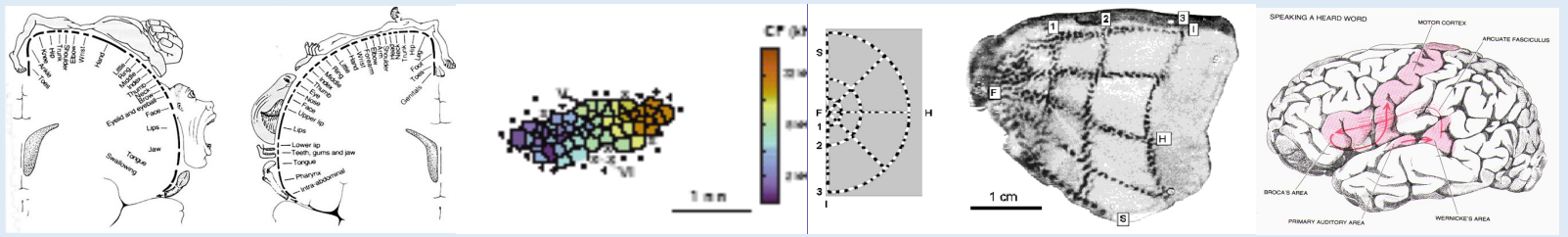
Sensory-motor functional anatomy



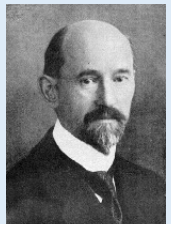
A view of the linguistic brain

Syntactico-Semantic-Topic Conjecture (SSTC)

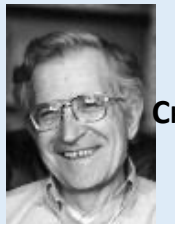
a. Major syntactic and semantic operations are neurologically individuated
b. Our current best tool for neurological parcellation is cytoarchitecture



Somatotopy **Tonotopy** **Retinotopy** **Syntactotopy?**



BRODMANN



CHOMSKY

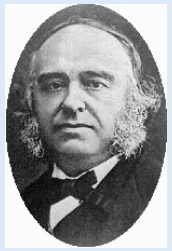
The anatomical pieces are histologically defined

The language pieces are linguistically defined

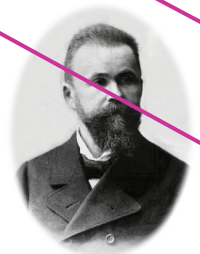
Brodmann, 1909; Amunts & Zilles, 2018; Chomsky, 1980; Fodor, 1983

Gall's legacy: Mapping Principles and their Diagnostic Reflections

production **reception** **naming**

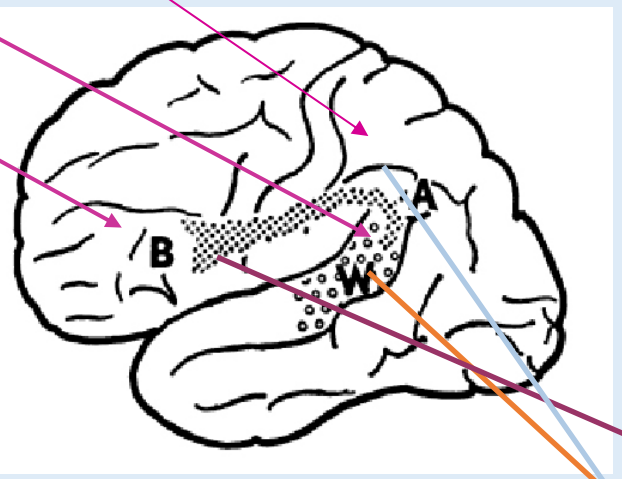


Paul Broca



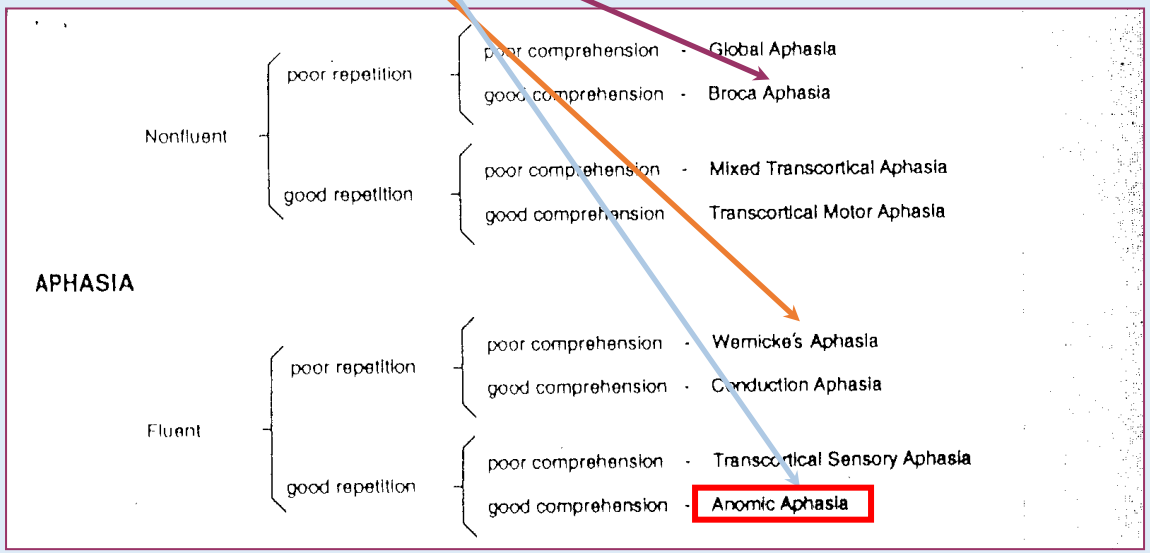
Carl Wernicke

Norman Geschwind



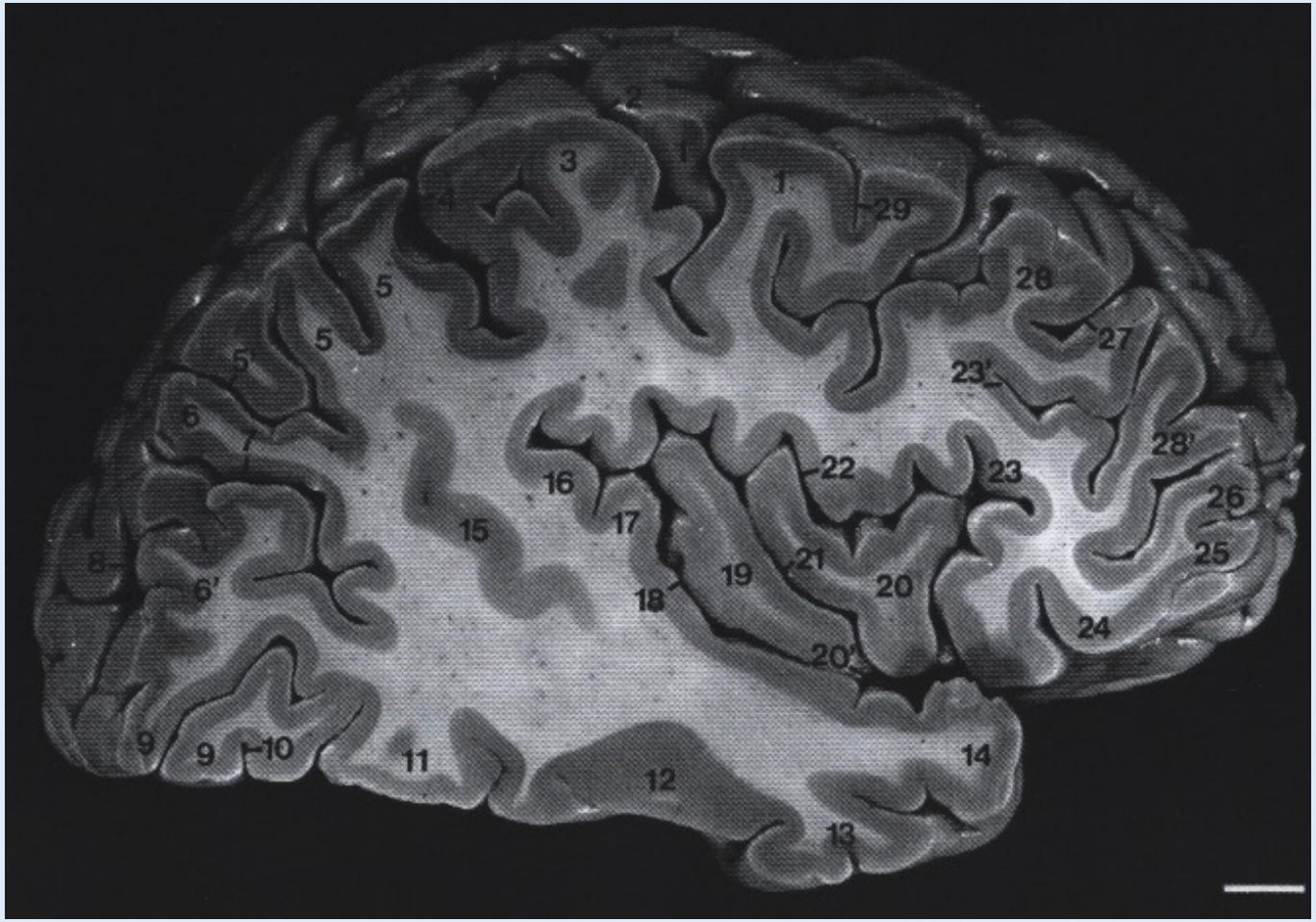
Take 1

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



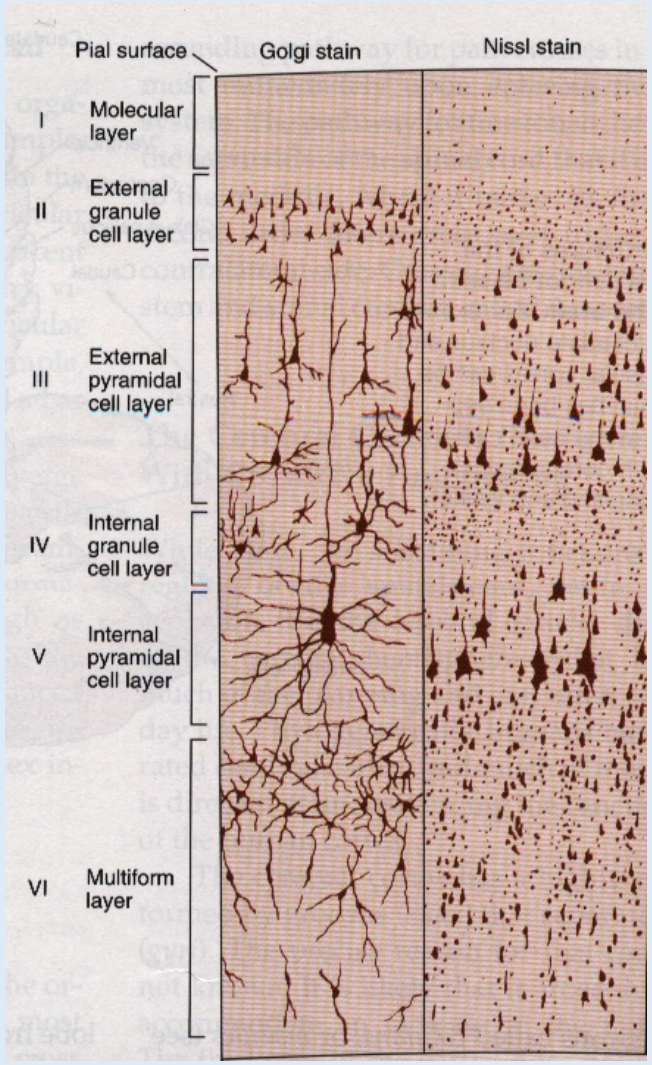
Geschwind, *Sci,* 1970; Damasio, *NEJM,* 1992

The anatomical landscape: Grey vs White Matter



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

Cortical Layers



I Dendrites of deeper cells

II Small granule cells

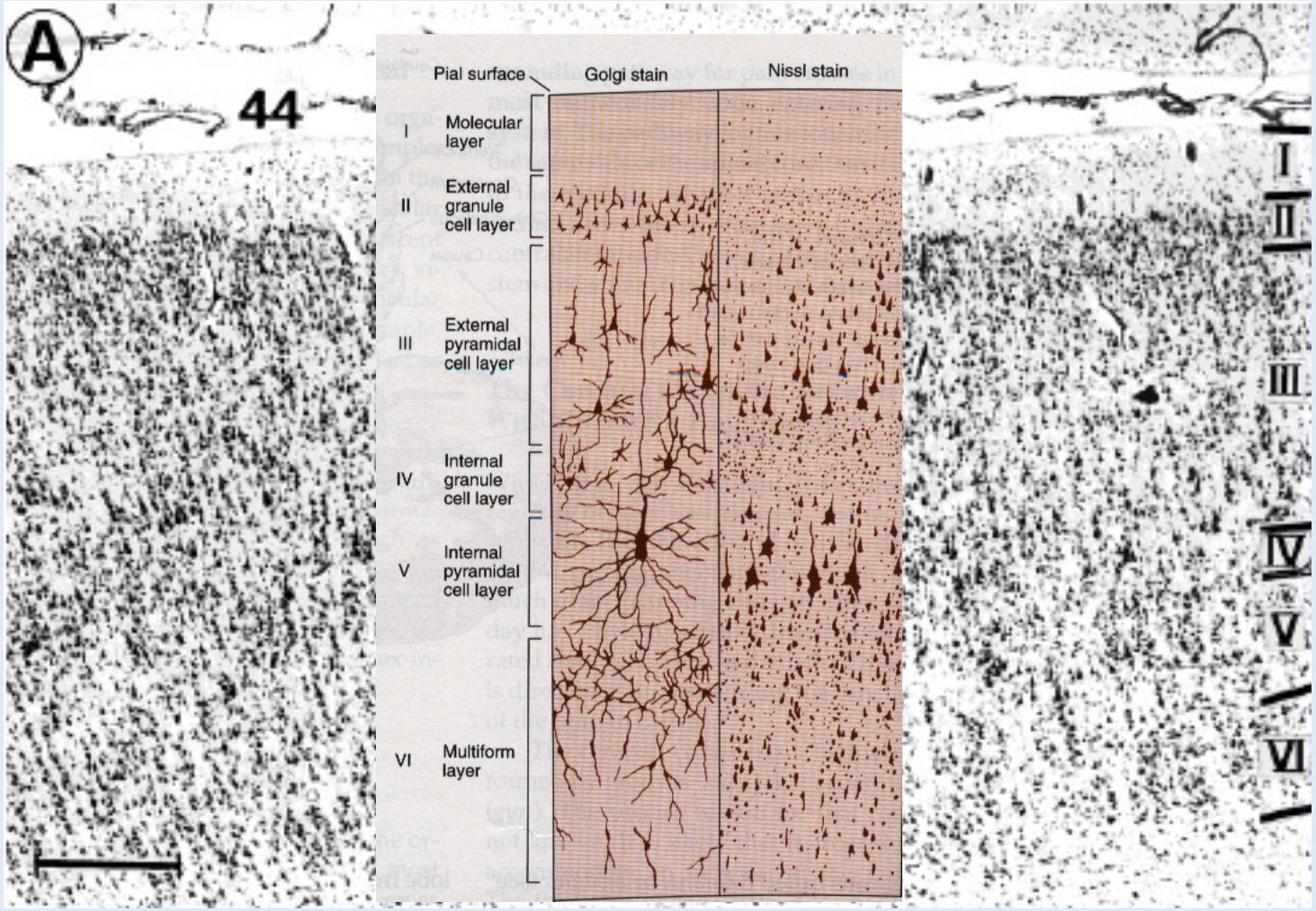
III Variety of cells, many pyramidal in shape

IV Mainly granule cells

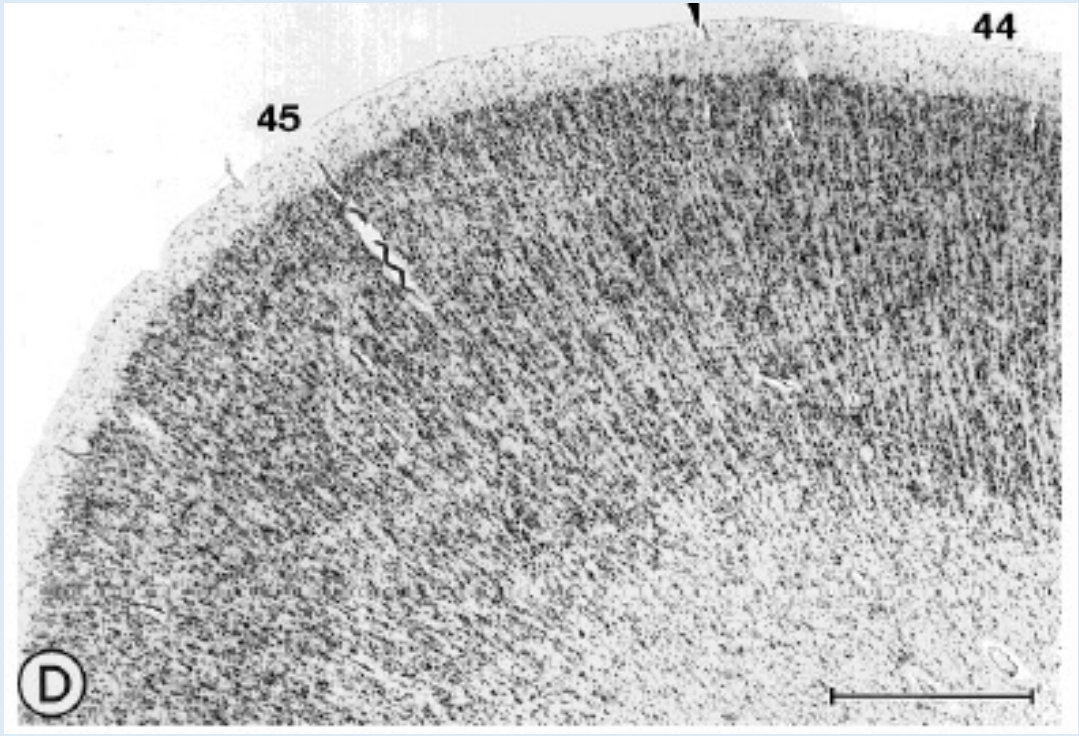
V Pyramidally shaped cells larger than in layer III

VI Heterogeneous layer of neurons blends into white matter

A Cortical Slice Stained for Cell Bodies

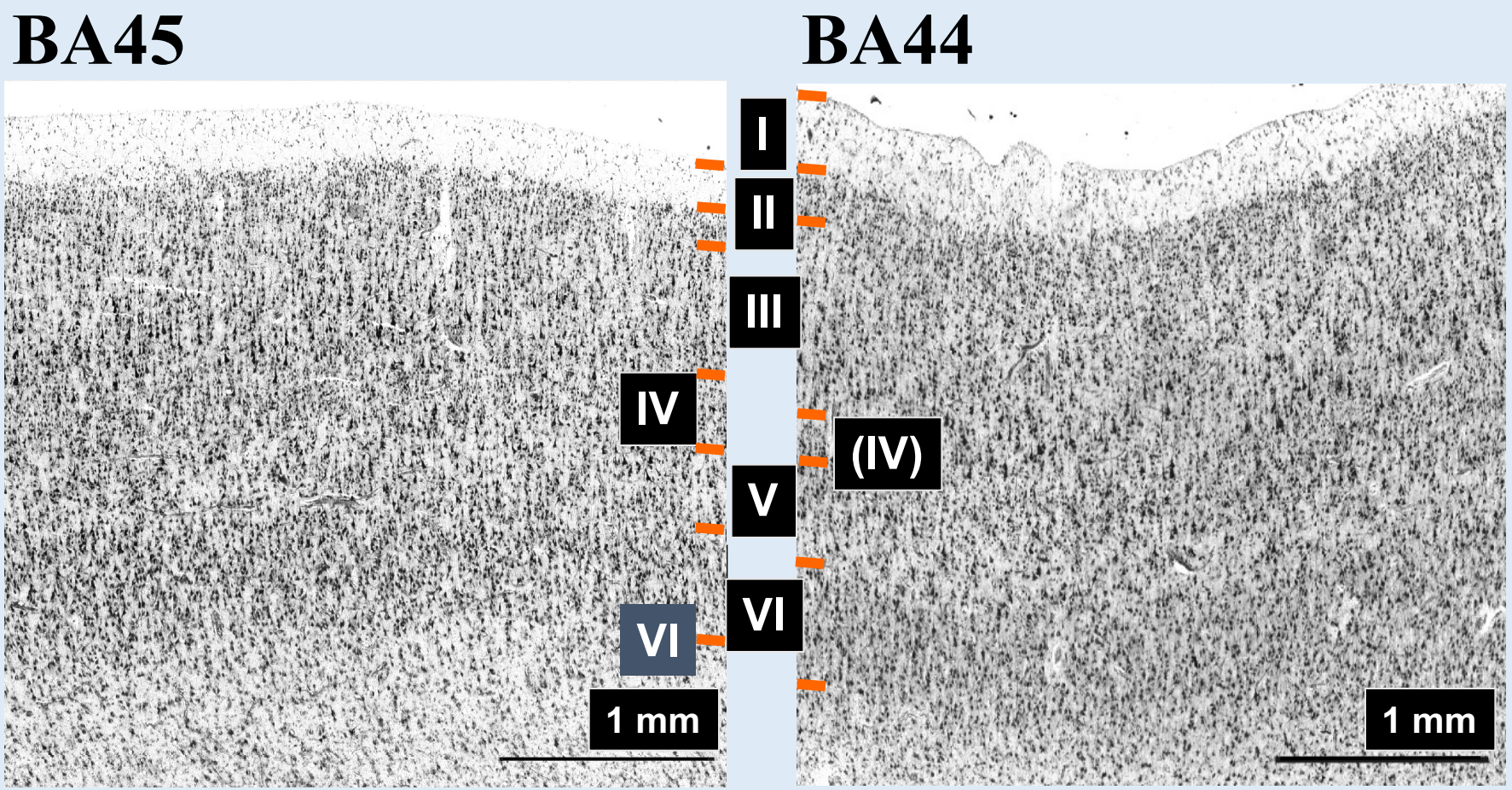


Cytoarchitectonic borders



- 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



Cortical layers again

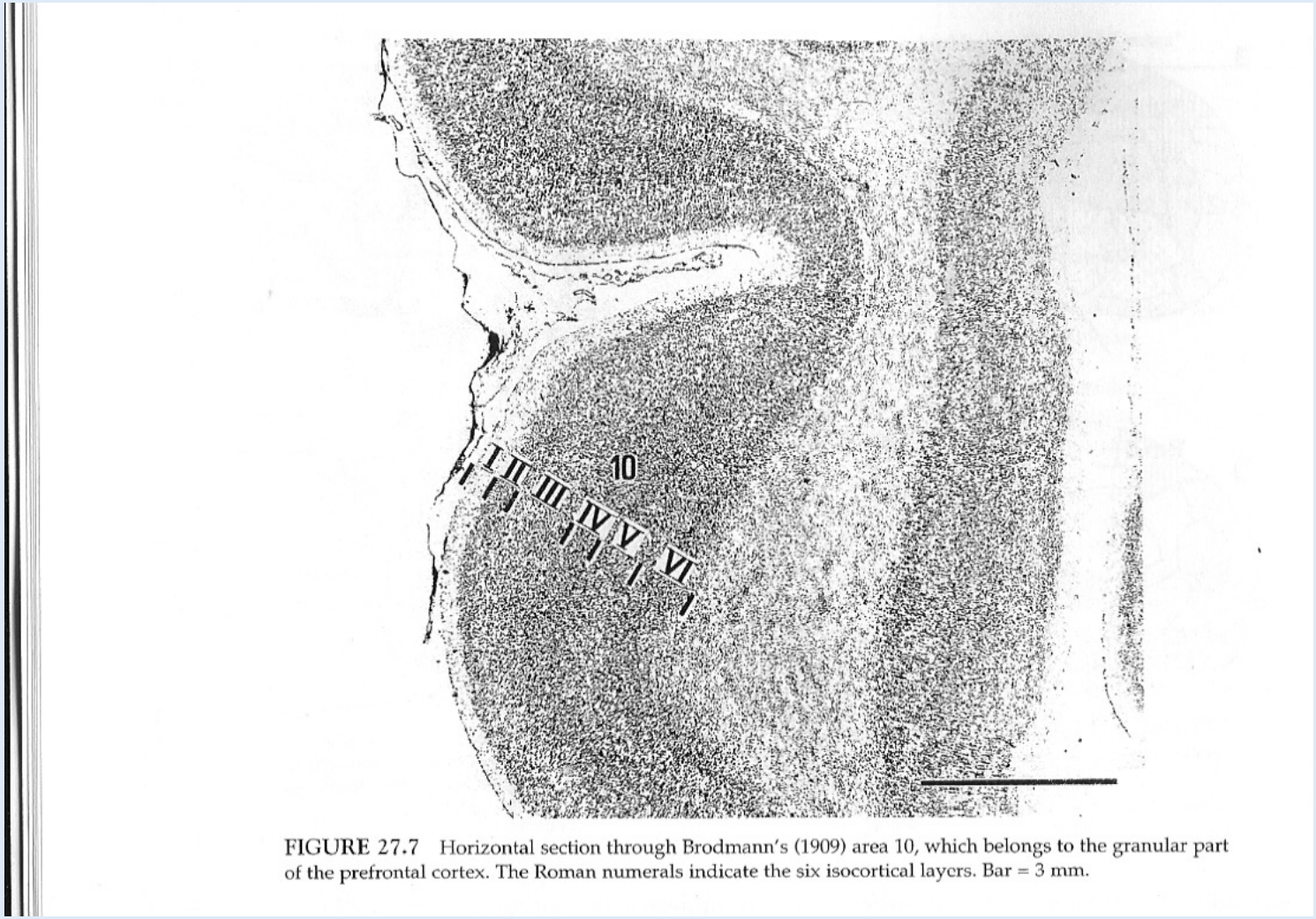
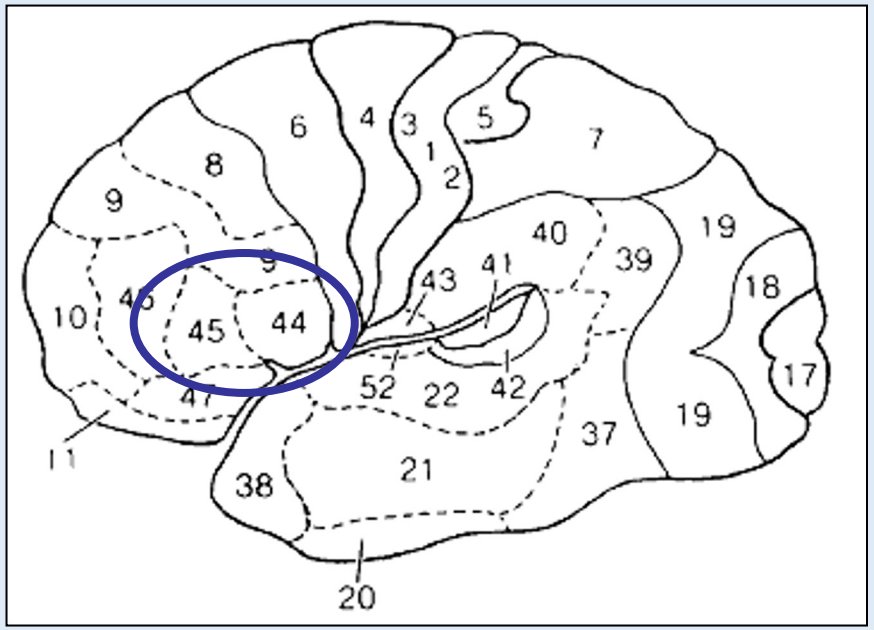
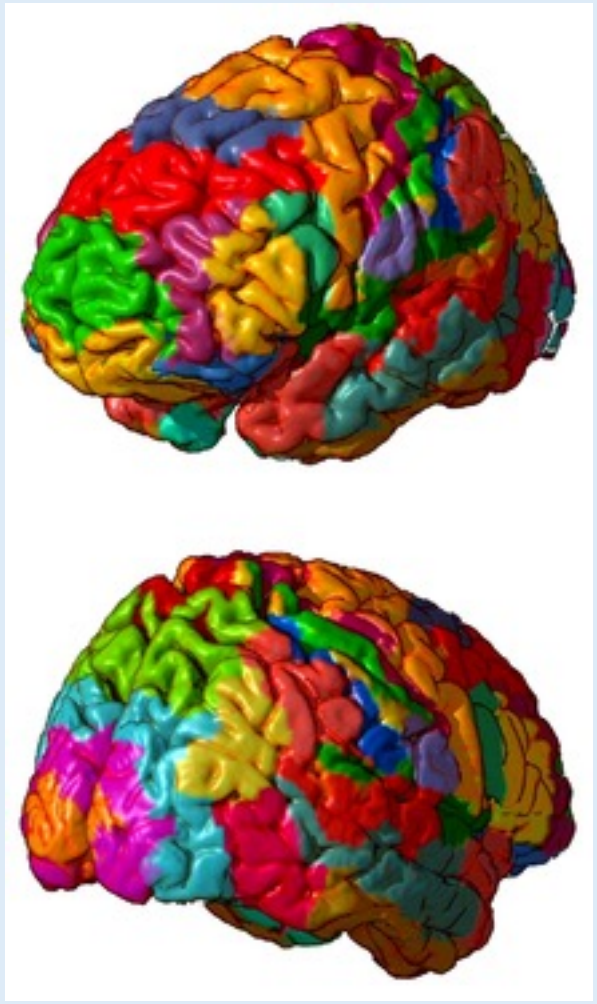


FIGURE 27.7 Horizontal section through Brodmann's (1909) area 10, which belongs to the granular part of the prefrontal cortex. The Roman numerals indicate the six isocortical layers. Bar = 3 mm.

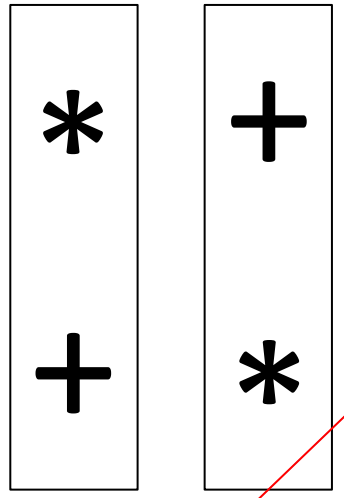
Result: an empirically solid and precise cytoarchitectonic atlas

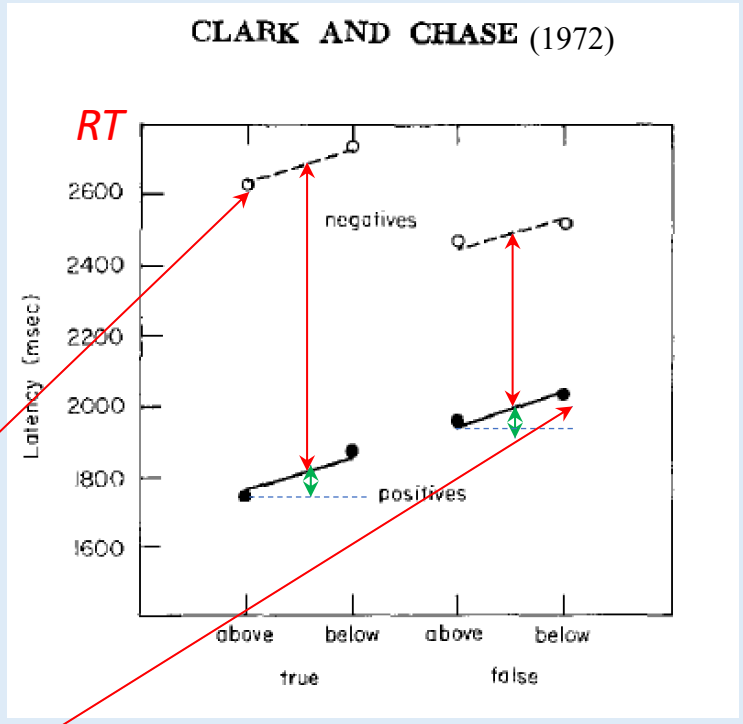




The psycholinguistic landscape: Verification with negation and true-false scenarios

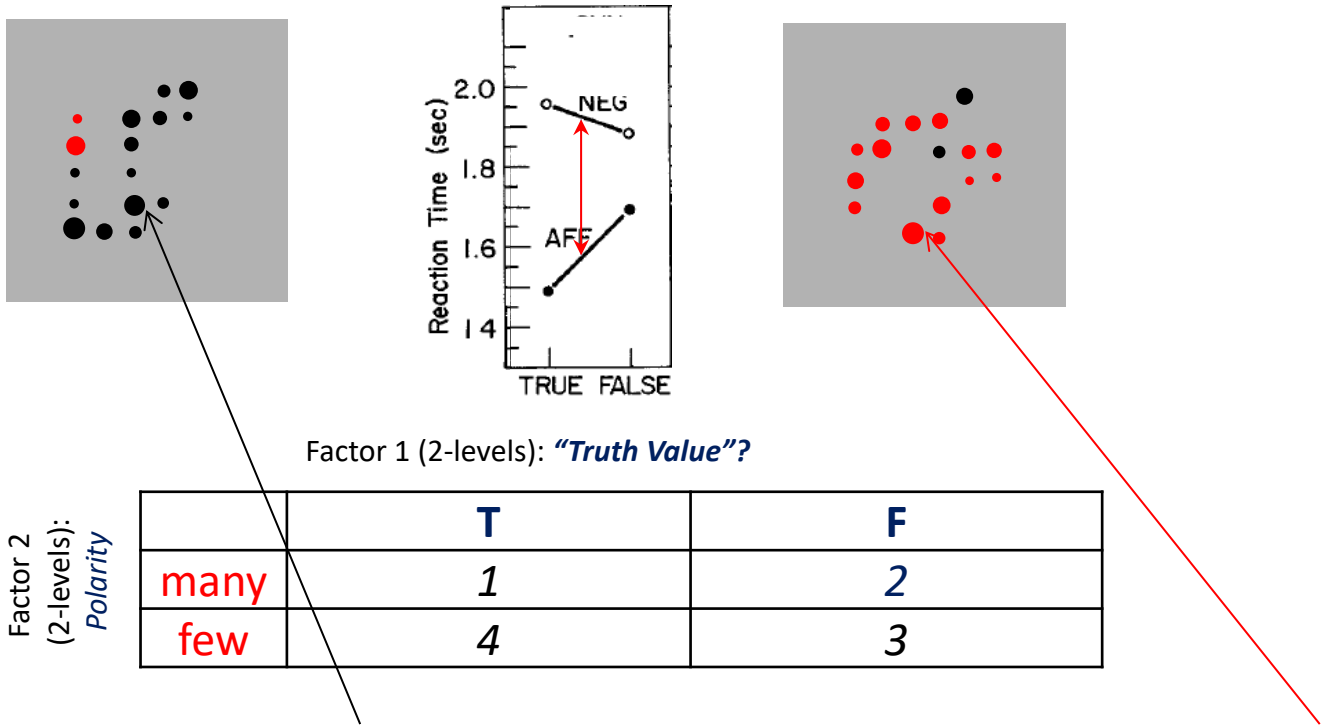
1. a. Star is ***above*** **plus**
   b. Star is**n't** ***above*** **plus**
   c. Star is ***below*** **plus**
   d. Star is**n't** ***below*** **plus**





		Above/below			
		T	F	T	F
-neg		***10a***		***10c***	
		T	F	T	F
+neg		***10b***		***10d***	

First hints: Verification with degree quantifiers



Factor 1 (2-levels): ***"Truth Value"?***

Factor 2 (2-levels): *Polarity*

	T	F
many	*1*	*2*
few	*4*	*3*

11. a. **Many** of the dots are black

b. **Few** of the dots are red

J&C:

- *Decomposition*

  Many dots are red

  Neg(many) dots are red

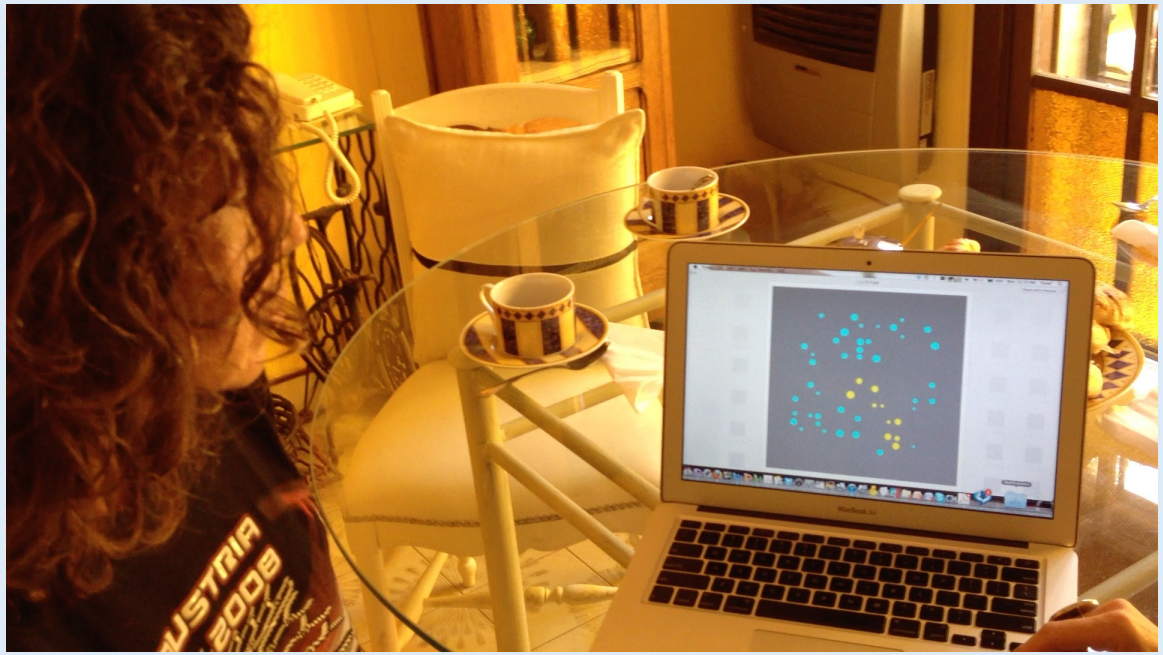
- *Fixed verification strategy*

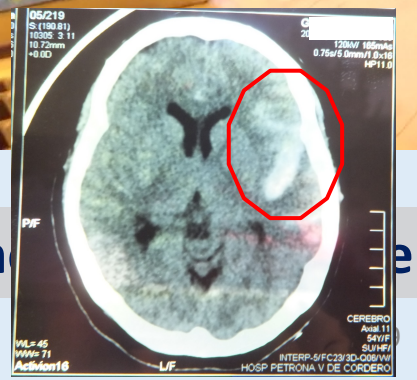
  Focus on larger set of objects in image

  Focus on larger set

Just & Carpenter, 1971

A hint from aphasia: Patient demo (Spanish)





many (*muchos*) of the circles are blue

Few (*pocos*) of th e

Workplan

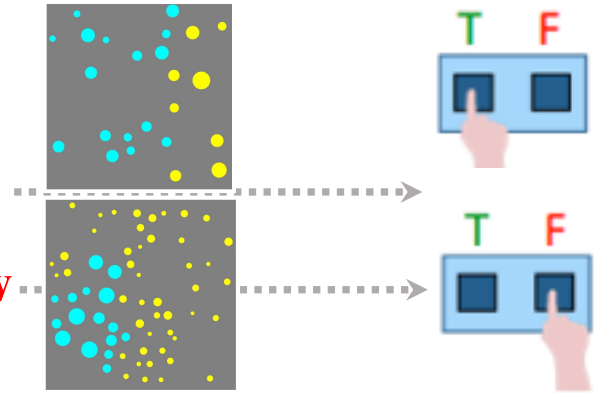
- ❏ Appetizer: monotonicity-related experiments with a single DE operator
  - Some relevant behavioral results
  - Some relevant fMRI results
- ❏ Main course: monotonicity-related experiments with more than one Neg operator
- ❏ Dessert: Deciding between two views of NPI licensing
  - Two different views of NPI licensing, and Flip-flop in French and Hebrew
  - A processing experiment with and without flip-flop environments
  - Ruling out alternative interpretations
- ❏ Implications

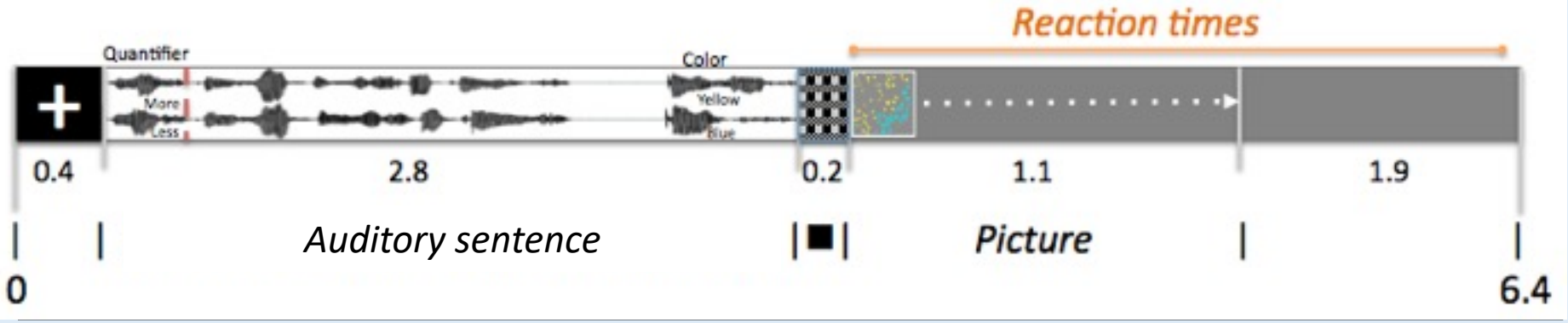
An RT experiment with the Parametric Proportion Paradigm (PPP)

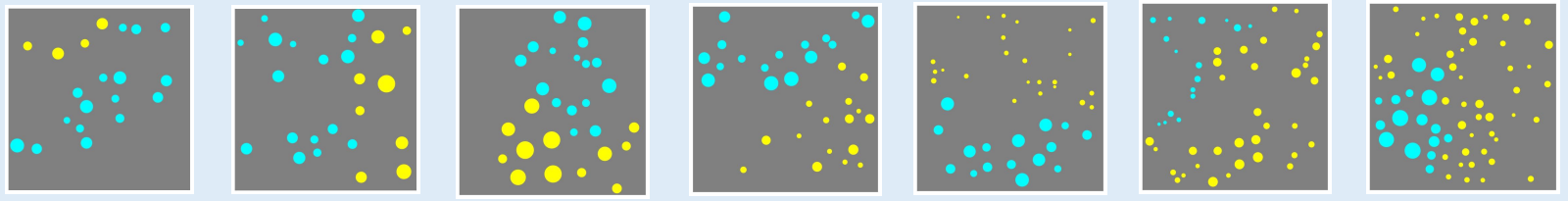
(with Isabelle Deschamps, Galit Agmon & Yonatan Loewenstein)

UE↑:
More-than-half of the circles are blue

DE↓:
Less-than-half of the circles are yellow



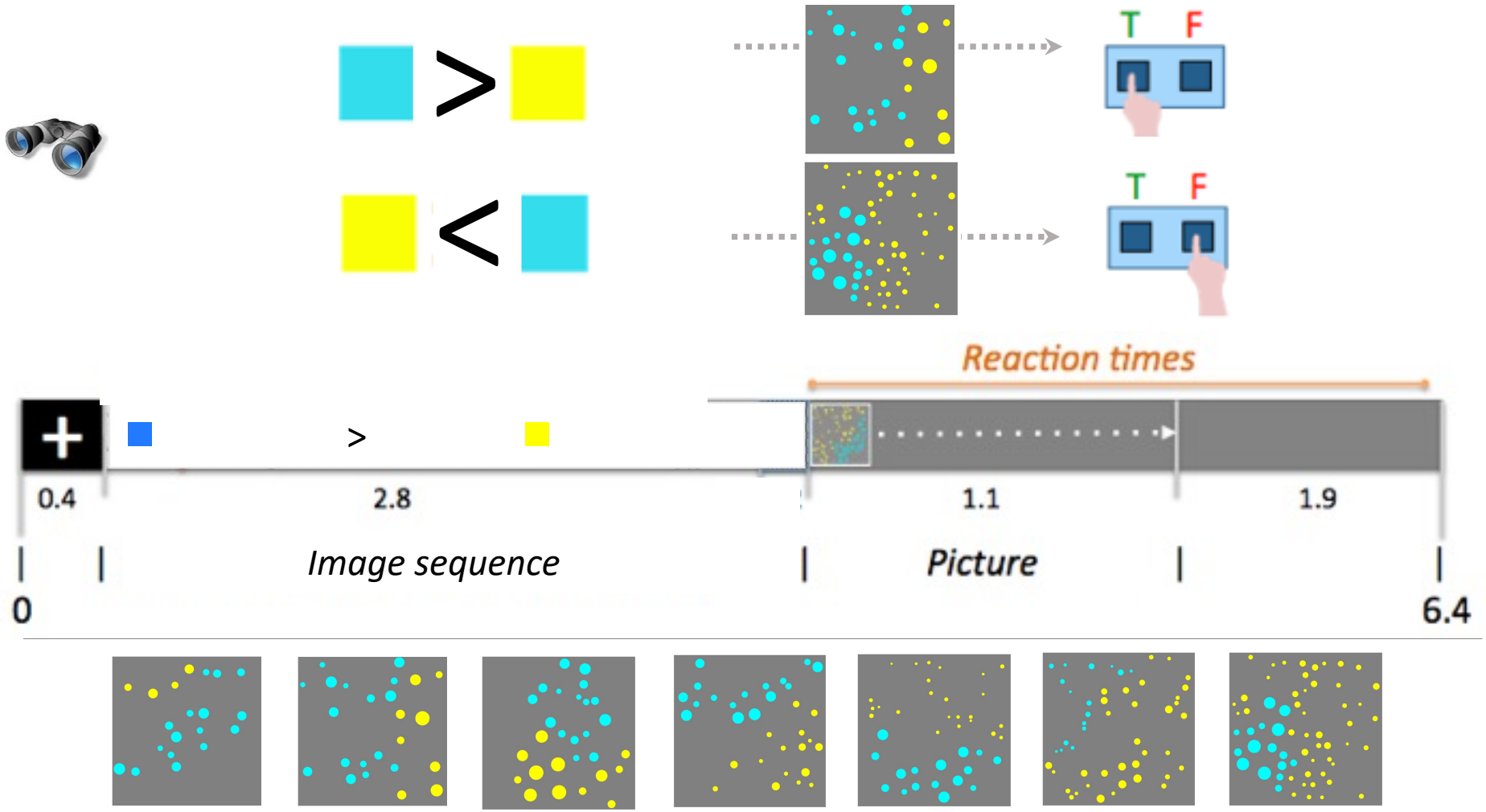




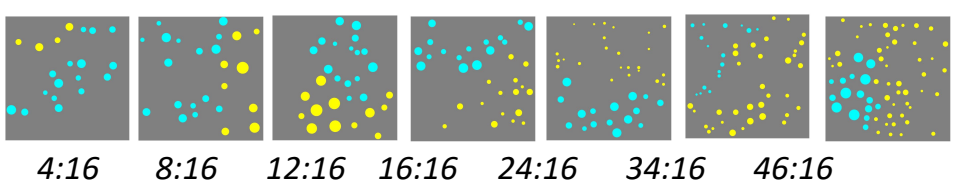
Deschamps et al., *Cog.*, 2015

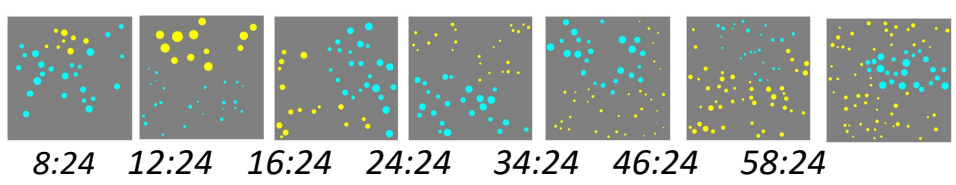
A non-verbal PPP: verification with symbols

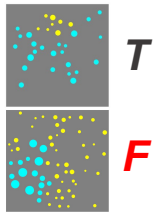
"Your task is to determine whether the instruction matches the scenario in the image, and do so as quickly as you can"



Factors in this design

- Expression type
  - Non-linguistic: 
  - Linguistic: Q of the circles are blue
- Quantifier Type and Monotonicity
  - Fixed standard
    - POS: More-than-half of the circles are blue
    - NEG: Less-than-half of the circles are yellow
  - Degree
    - POS: Many of the circles are blue
    - NEG: Few of the circles are yellow
- Proportion and Numerosity
  - r=16 

  - r=24 

- Truth-value
  - More-than-half of the circles are blue 

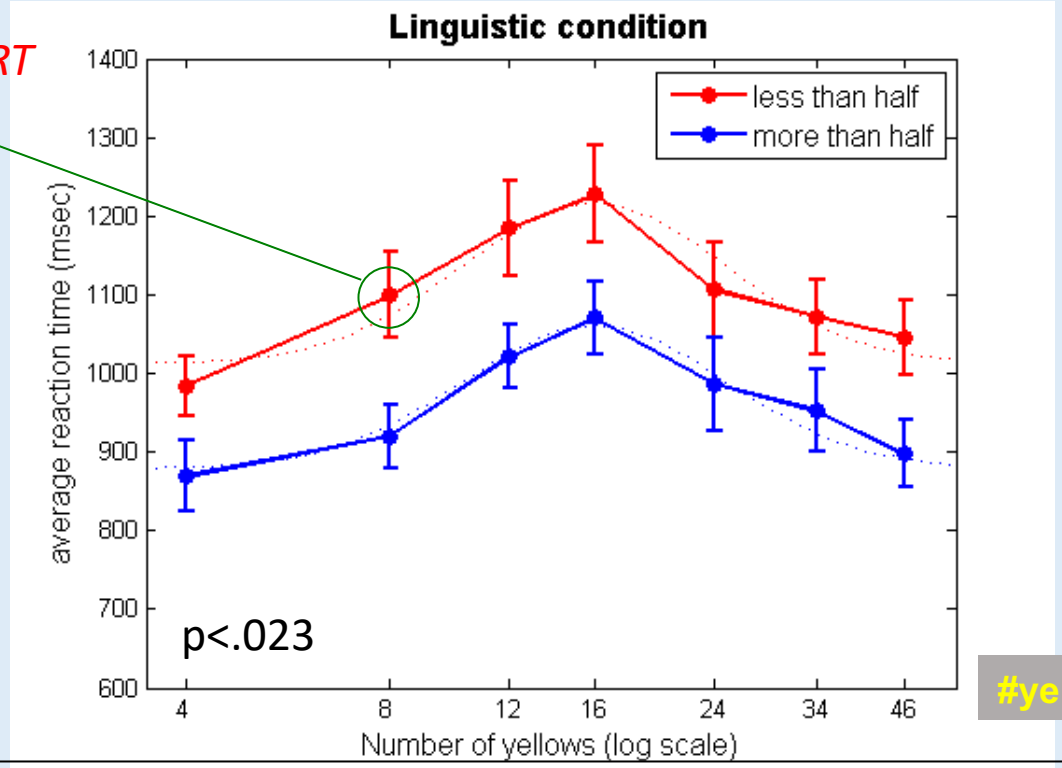
First PPP result: Polarity matters – RT functions

Splitting the previous graph:
17 subjects *X* 2 quantifiers *X* 16 T/F
272= trials

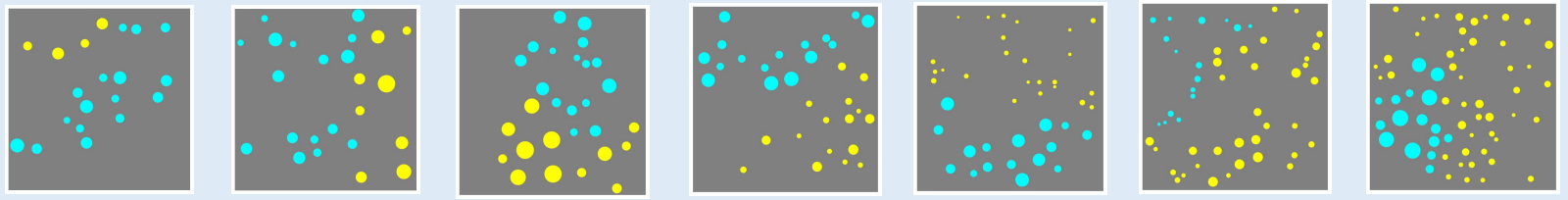
NB: same results for *r*=24, and for the *many*/*few* contrast

Less than half of the circles are blue

More than half of the circles are blue



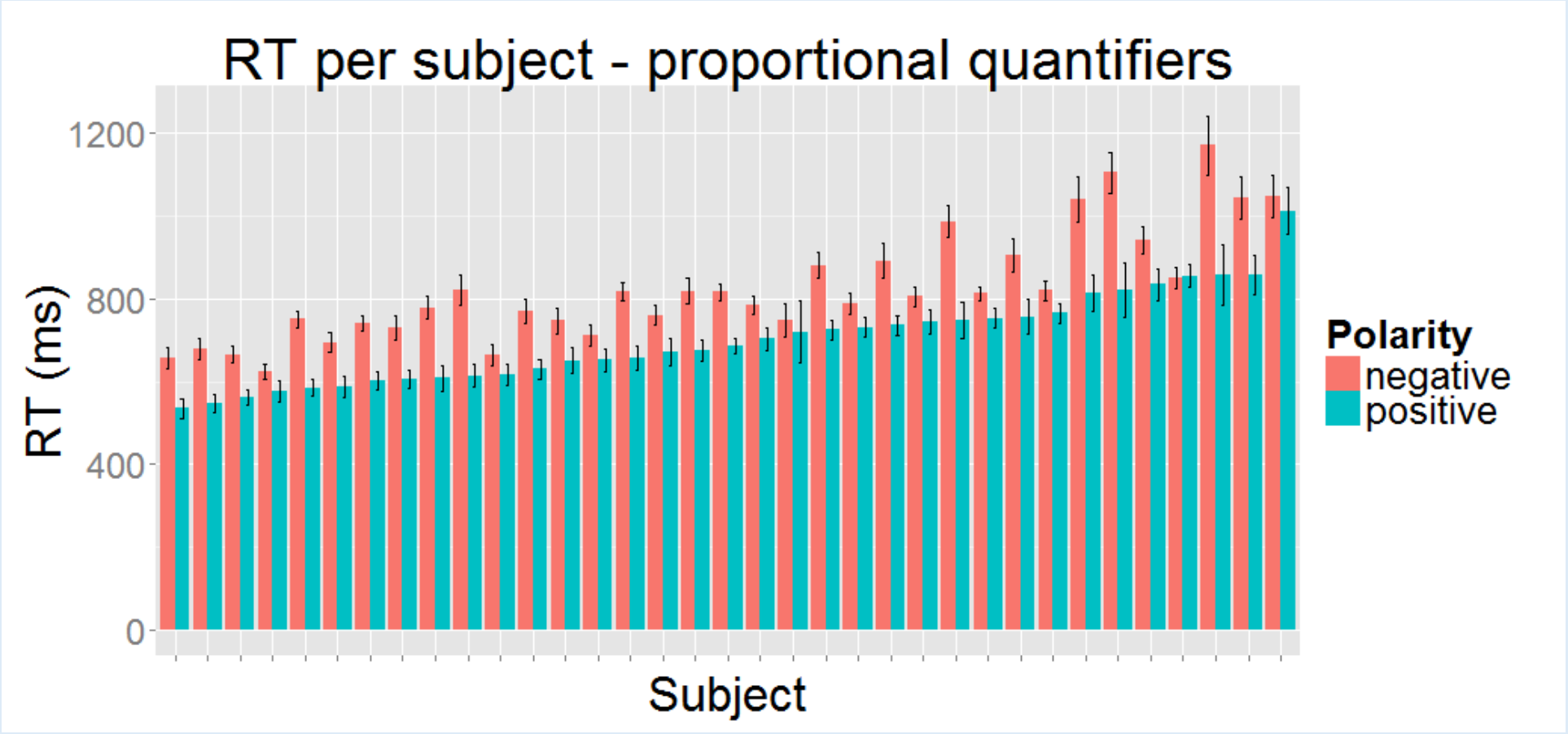
#yellow/16 Blue



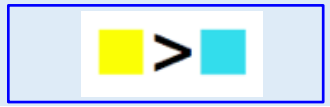
Second PPP result: Polarity difference at the single subject level!

Less-than-half of the circles are blue

More-than-half of the circles are blue



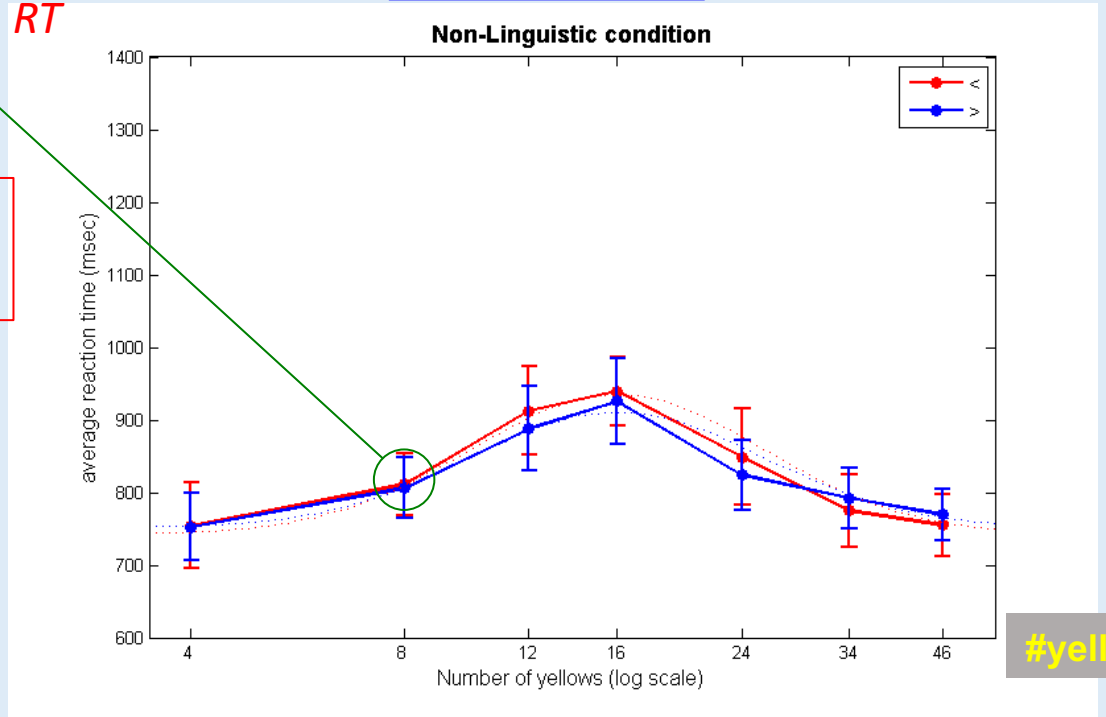
Third PPP result: verification with analogous symbols



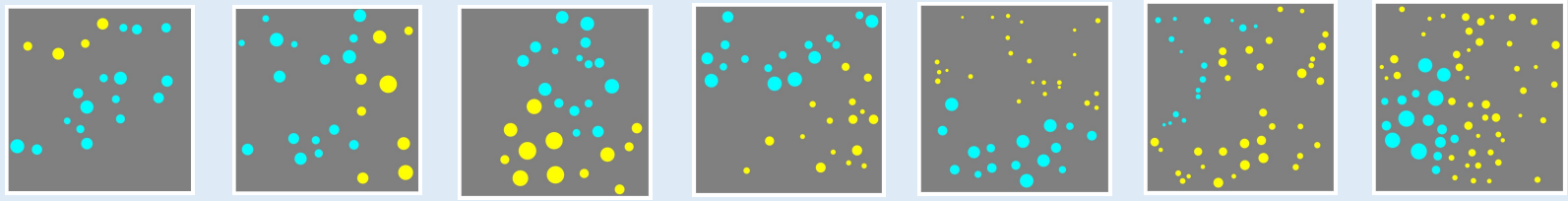
272 trials

NB: same results for *r*=24

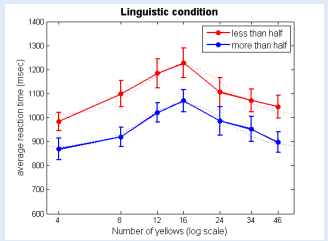
RT



#yellow/16 Blue

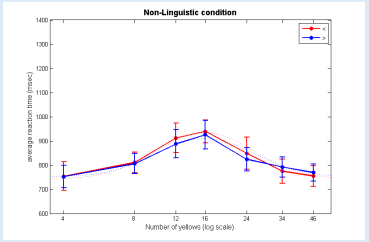


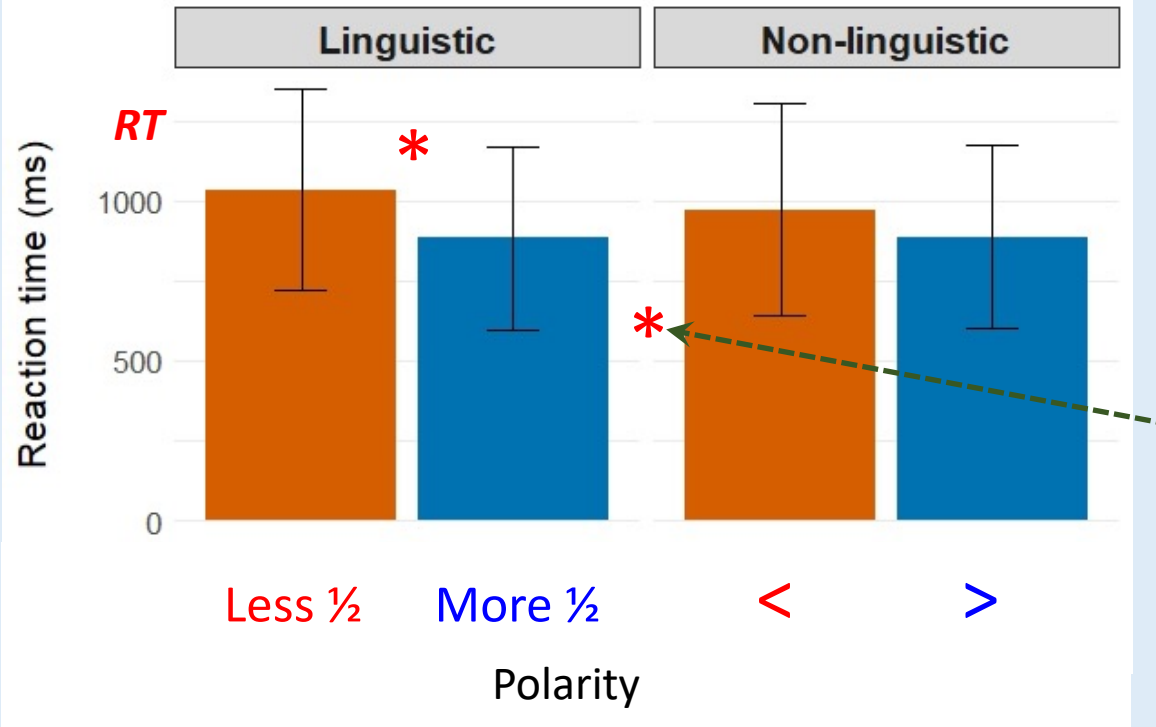
Fourth PPP result: Polarity X ±linguistic interaction



More than half of the circles are blue ■ > ■

Less than half of the circles are blue ■ < ■

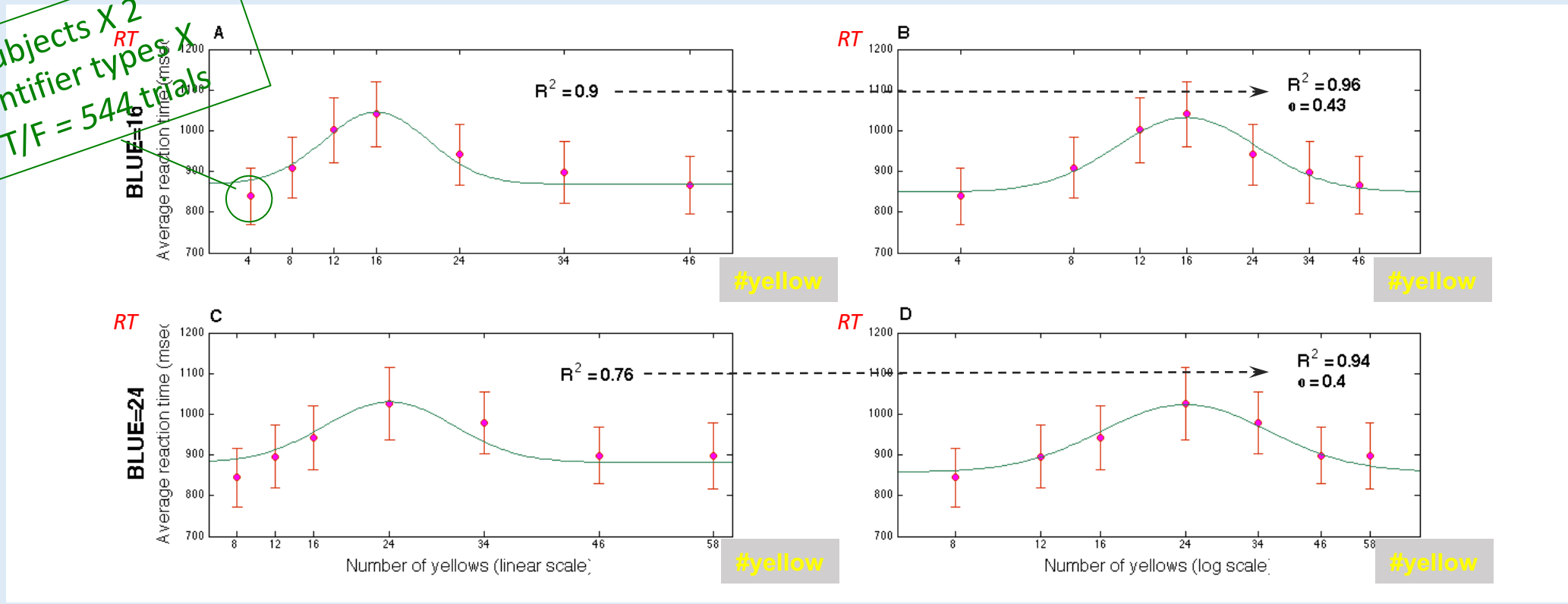




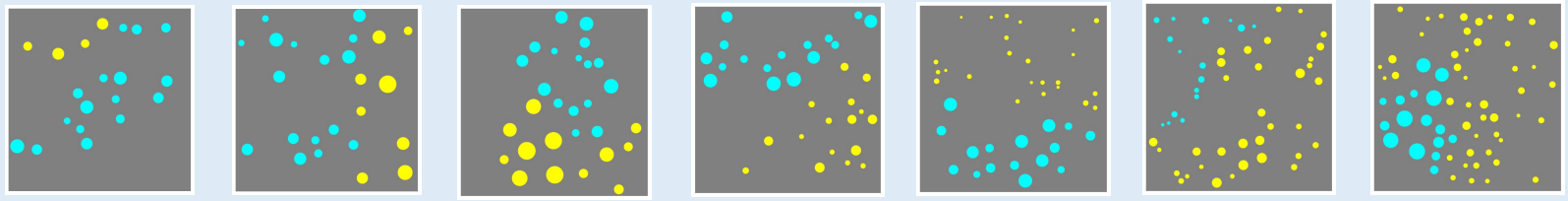
Net Negation effect

Fifth PPP result: RTs abide by Weber's Law

17 subjects X 2 quantifier types X 16 T/F = 544 trials



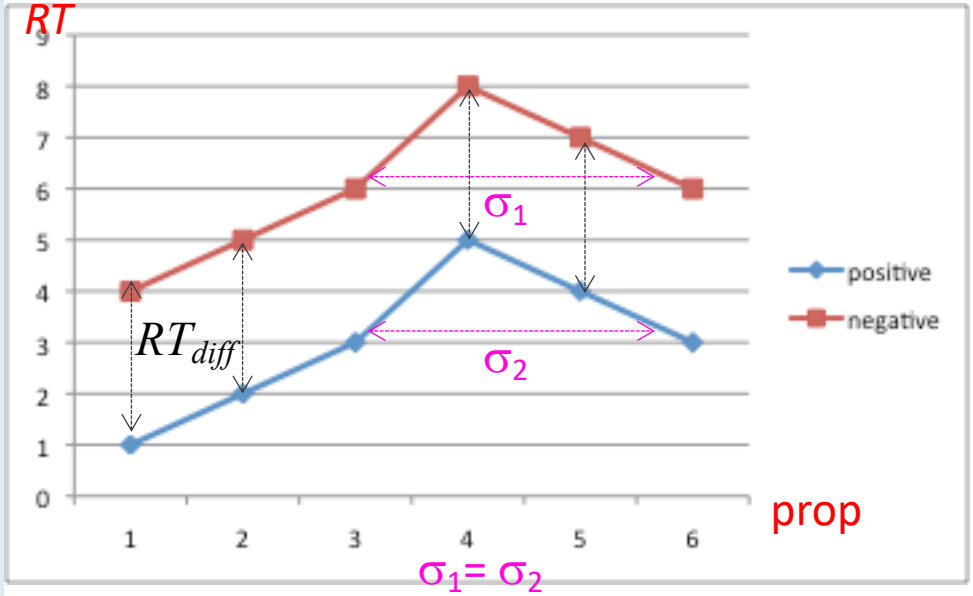
Improvement of gaussian fit to mean RT fit on log compression (across all sentence types)



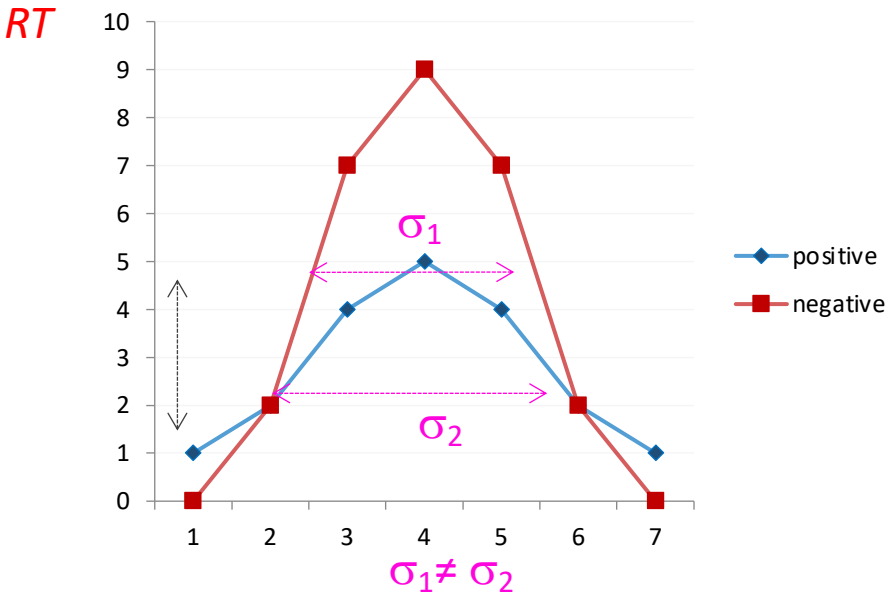
Sixth PPP result: the Polarity effect is additive

Possible relations between curves

Additive: Polarity effect
is independent from proportion



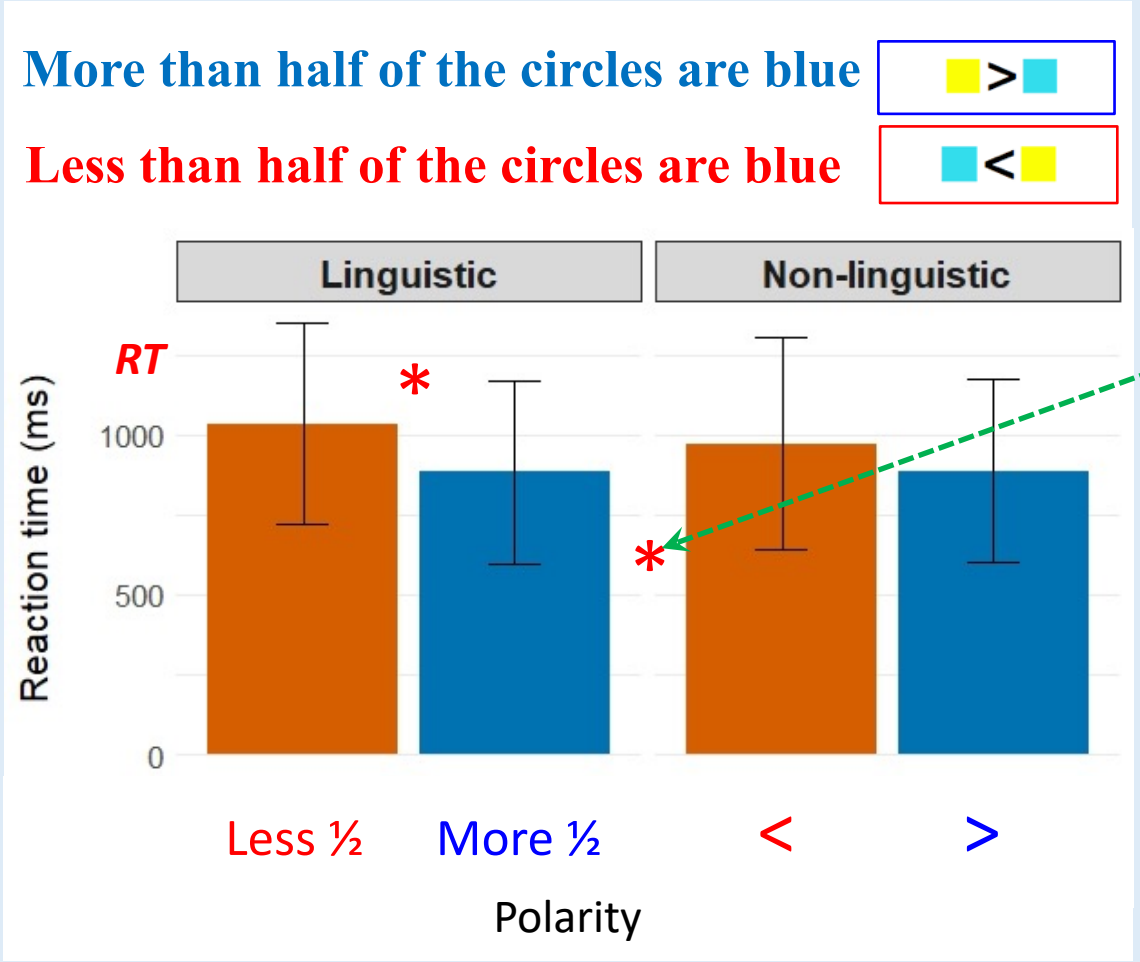
Non-additive: Polarity effect
is *not* independent from proportion



Permutation tests indicate that the effect is additive. RT_{diff} is independent of r/c.

⇒ *Verification is unaffected by proportion; contrary to the focus-on-the-larger set strategy*

Lead result: Polarity X ±linguistic interaction



Net Negation effect