

ESSLLI 2023 Monotonicity course



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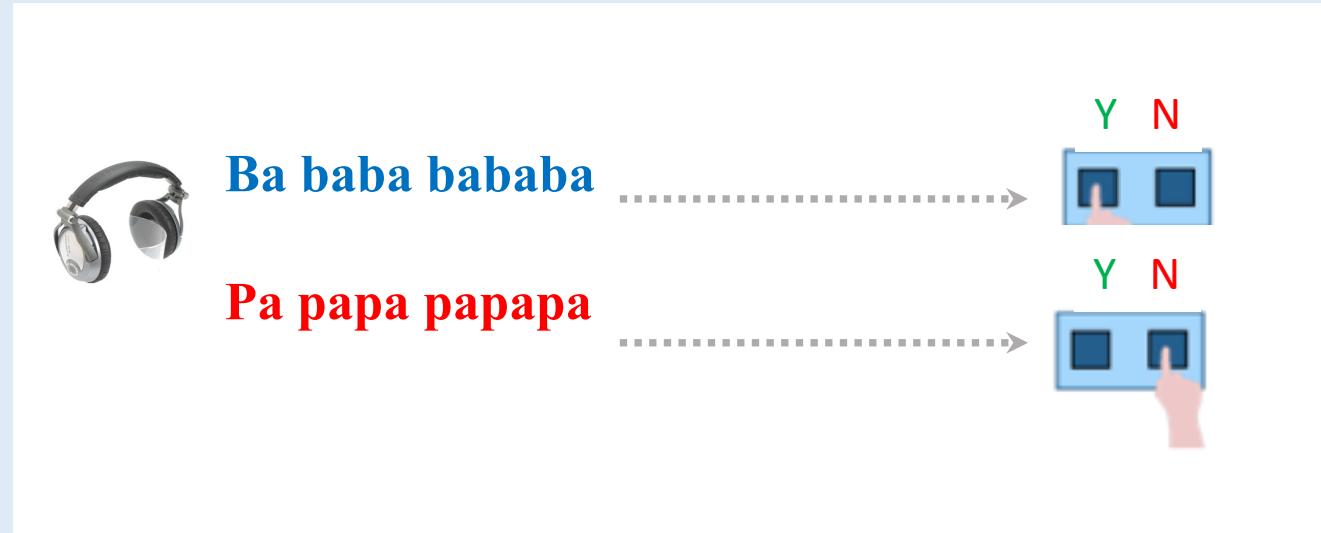
Experimental (neuro)linguistics attempts to...

- 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)

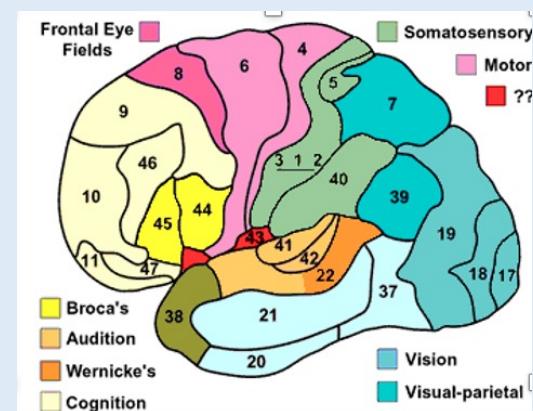
Types of experimental studies



RT

Anatomy

Patients

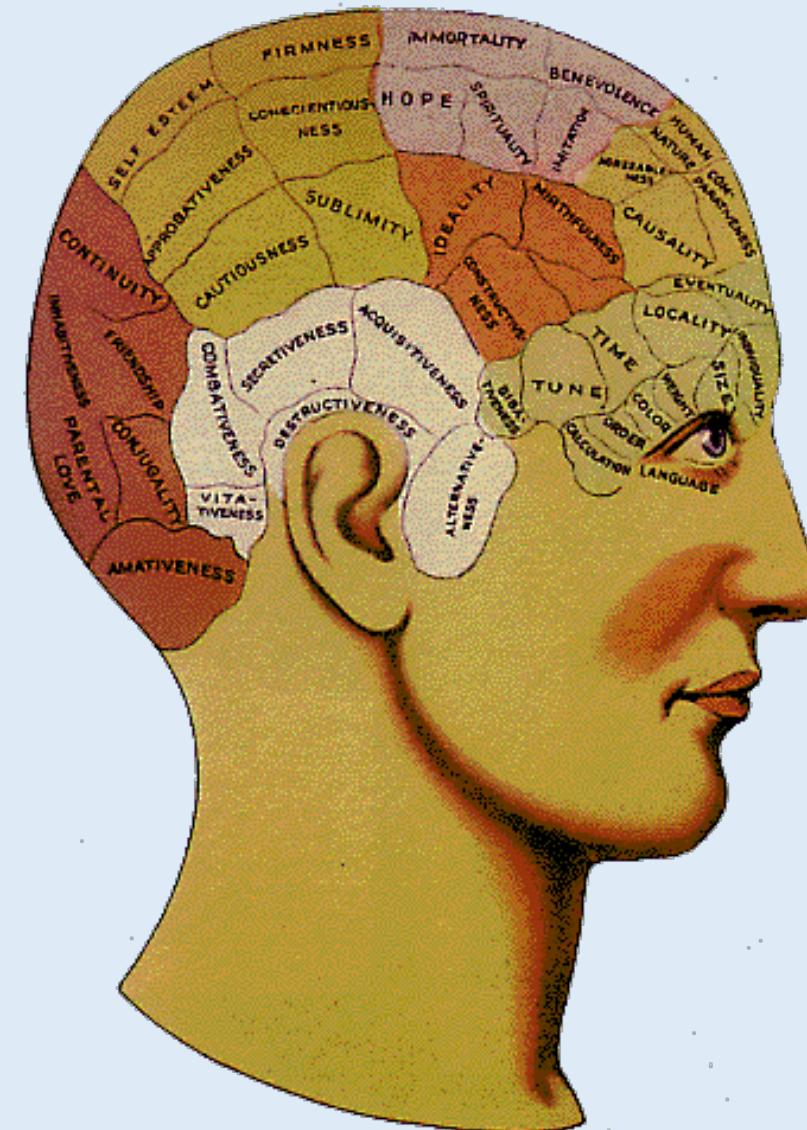


the juice that the child...

fMRI



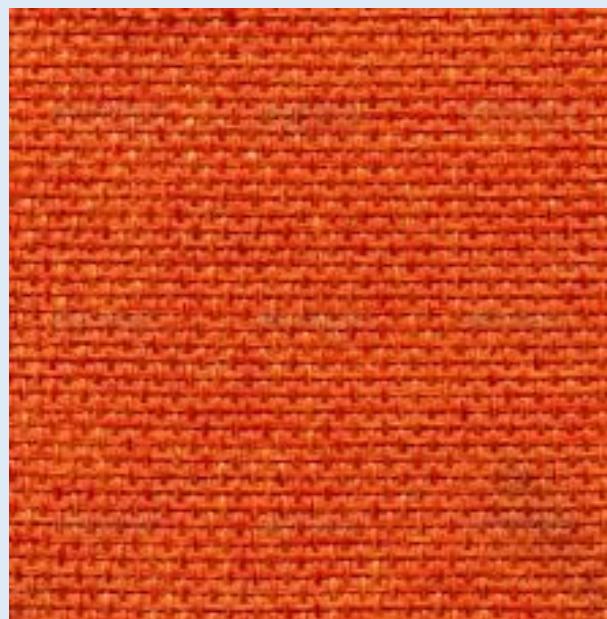
Gall's functional anatomy: borders



Franz Joseph Gall
1758-1828

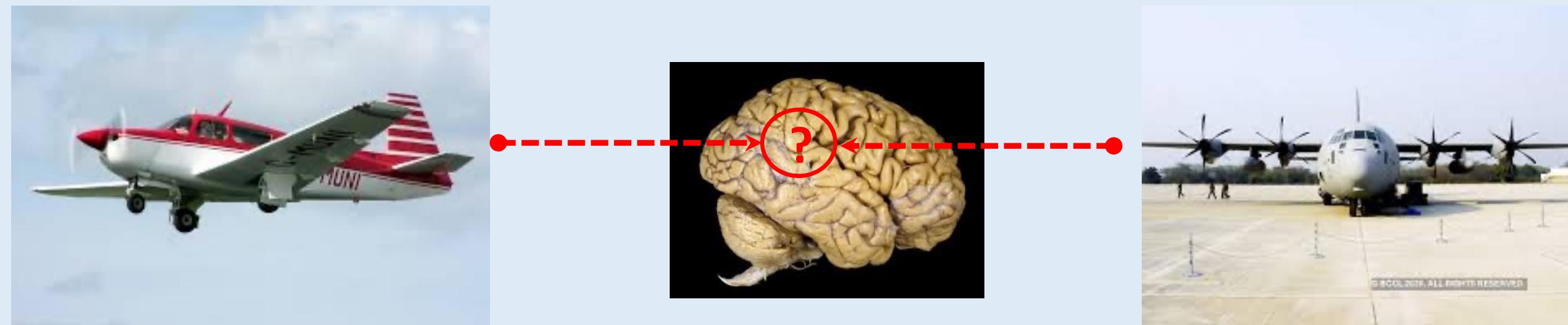
The quilt metaphor

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

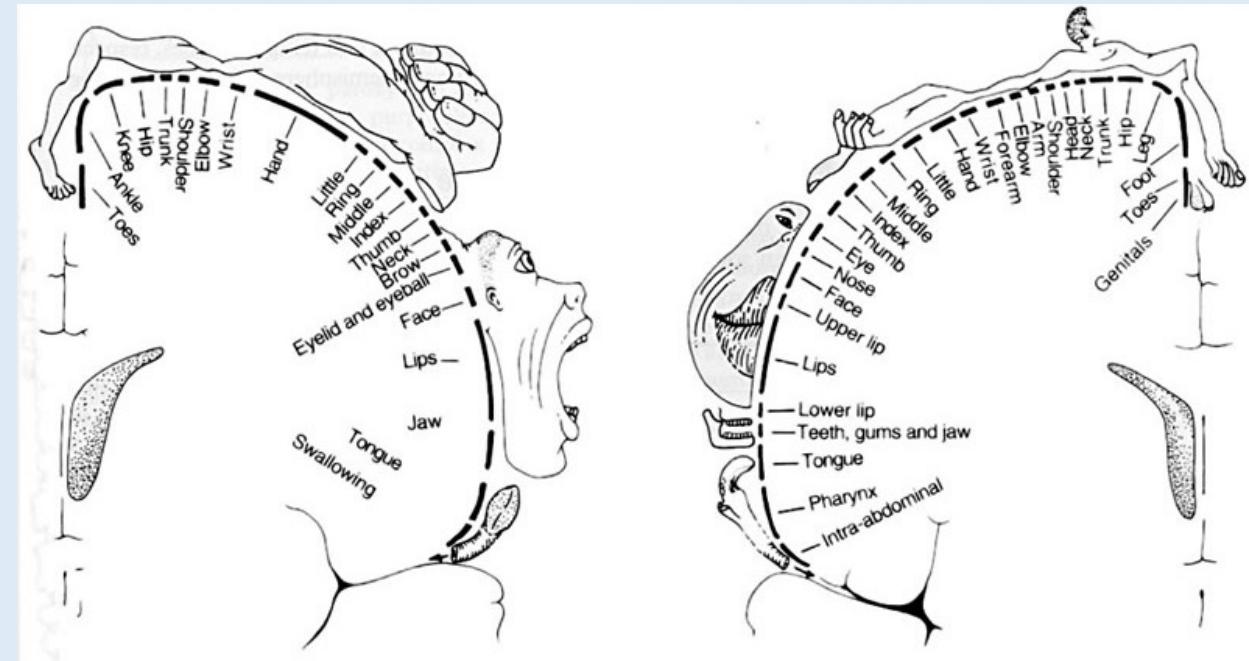


The engine metaphor

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



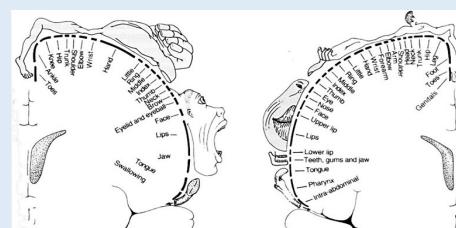
Sensory-motor functional anatomy



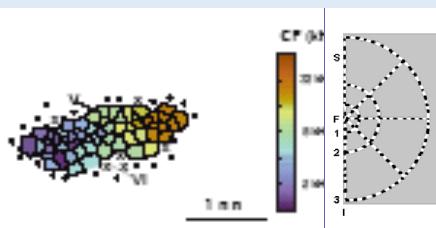
A view of the linguistic brain

Syntactico-Semantic-Topic Conjecture (SSTC)

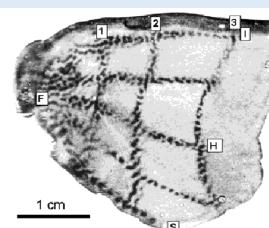
- a. Major syntactic and semantic operations are neurologically individuated
- b. Our current best tool for neurological parcellation is cytoarchitecture



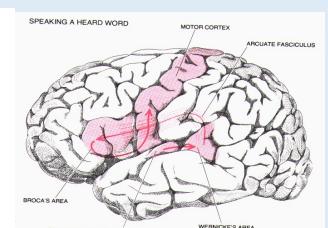
Somatotopy



Tonotopy

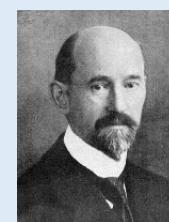


Retinotopy



Syntactotopy?

BRODMANN



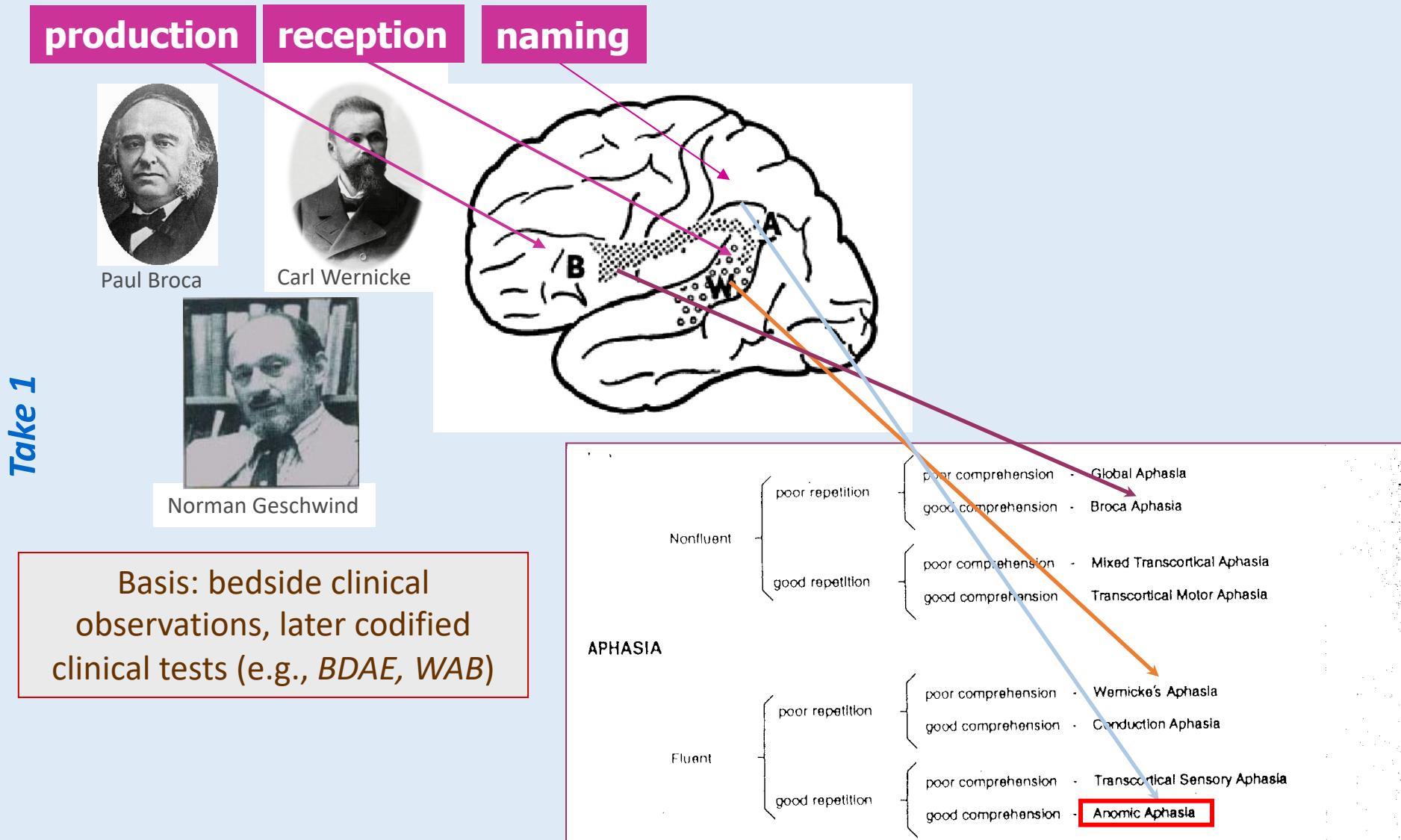
The anatomical pieces
are histologically defined

CHOMSKY

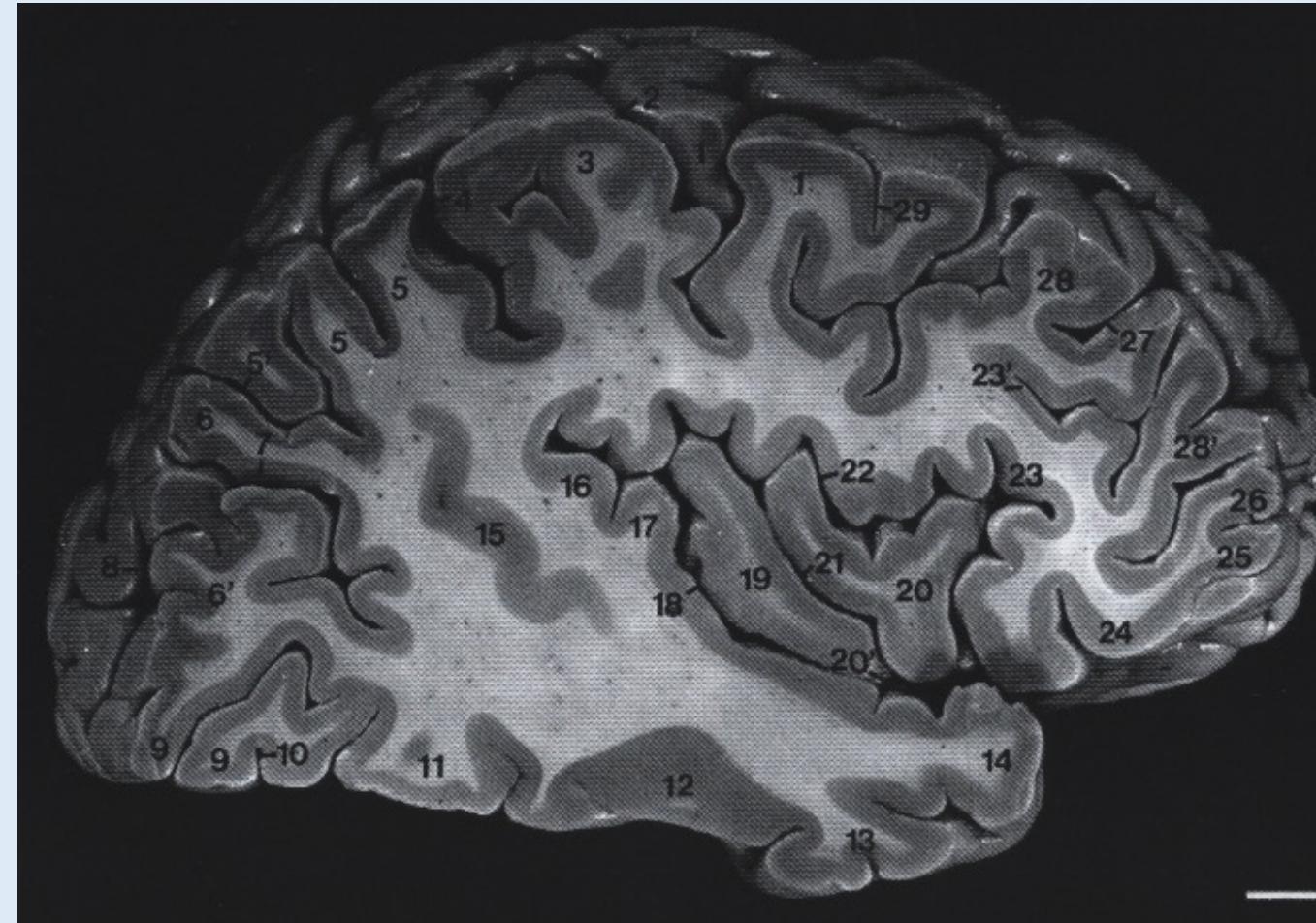


The language pieces
are linguistically defined

Gall's legacy: Mapping Principles and their Diagnostic Reflections

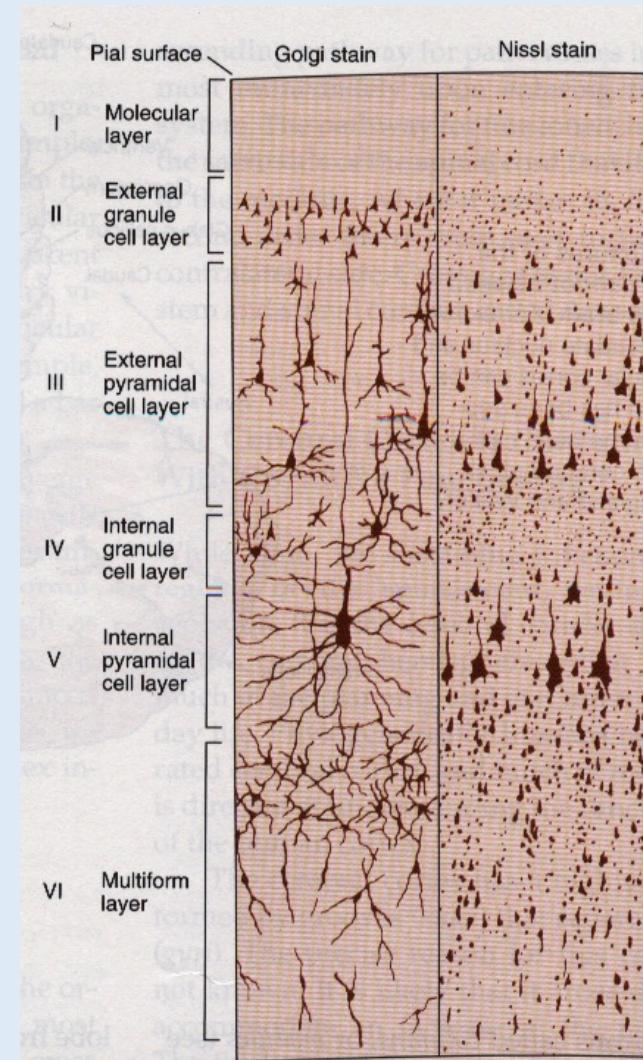


The anatomical landscape: Grey vs White Matter



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

Cortical Layers



White Matter

I Dendrites of deeper cells

II Small granule cells

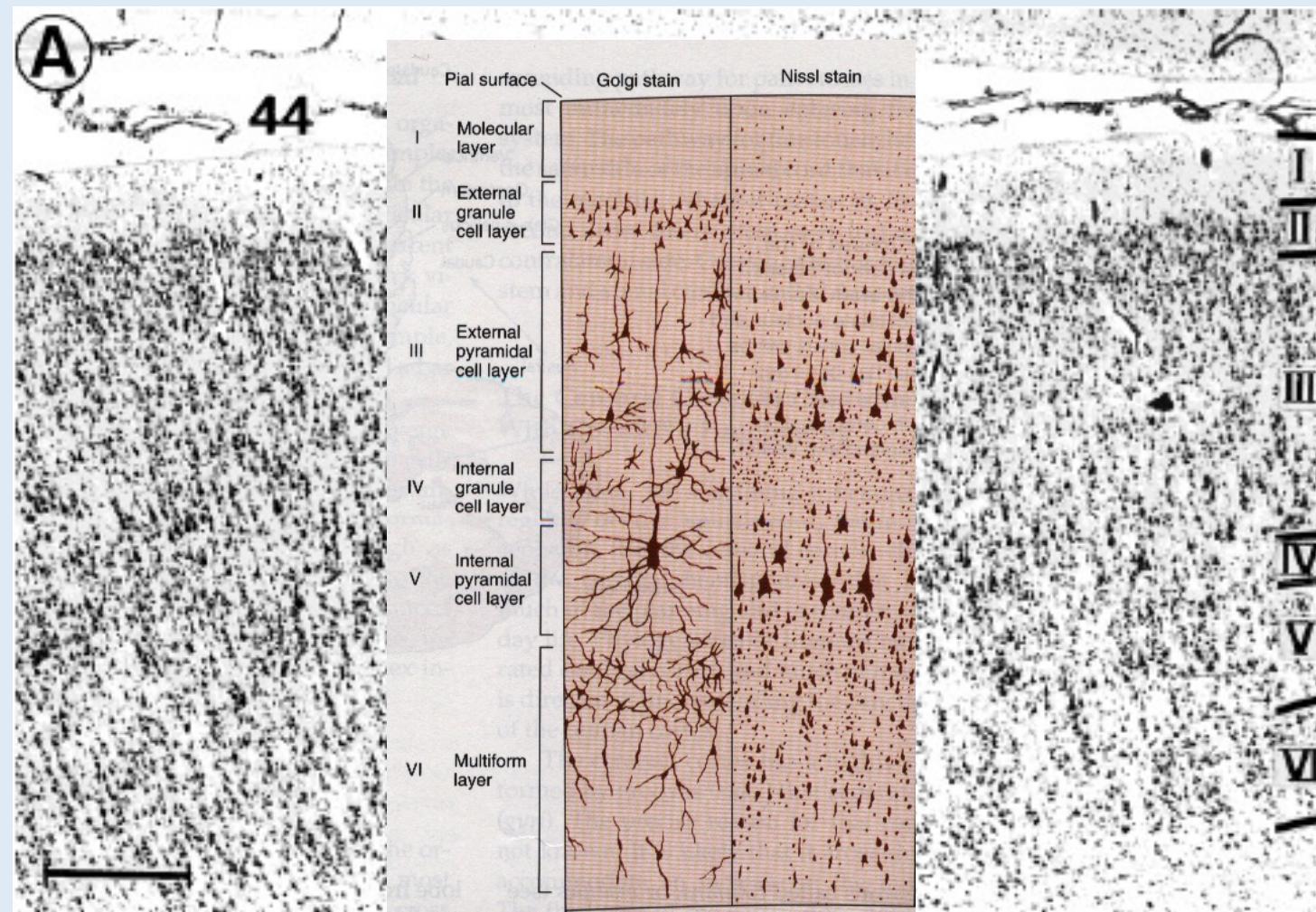
III Variety of cells, many pyramidal in shape

IV Mainly granule cells

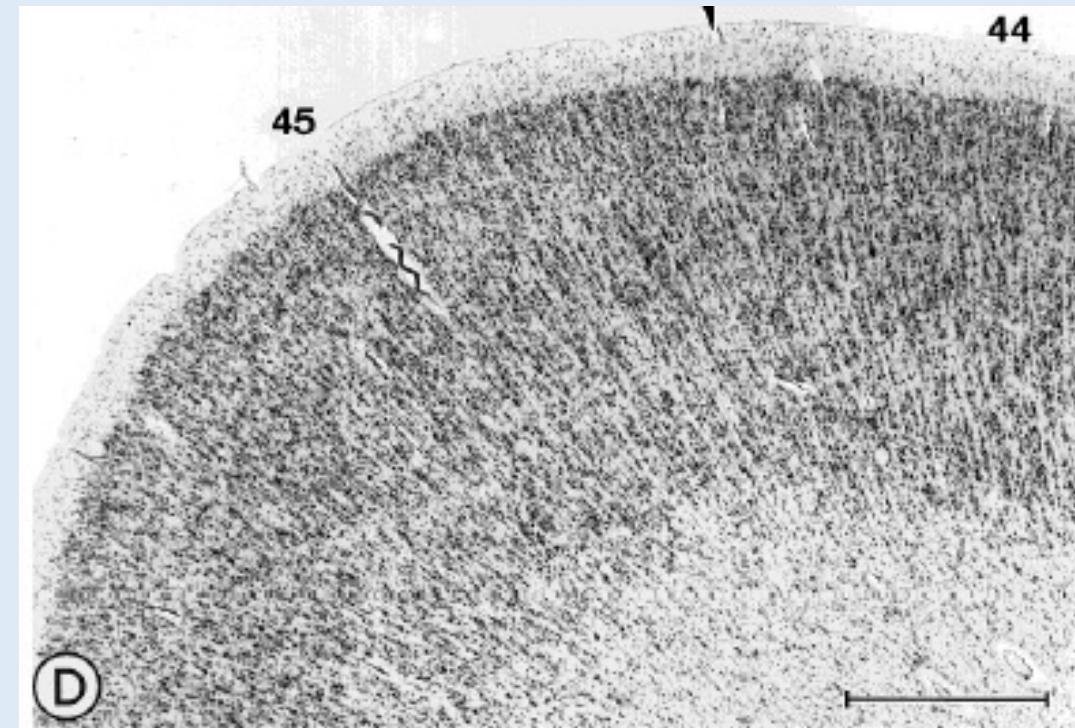
V Pyramidally shaped cells larger than in layer III

VI Heterogeneous layer of neurons blends into white matter

A Cortical Slice Stained for Cell Bodies

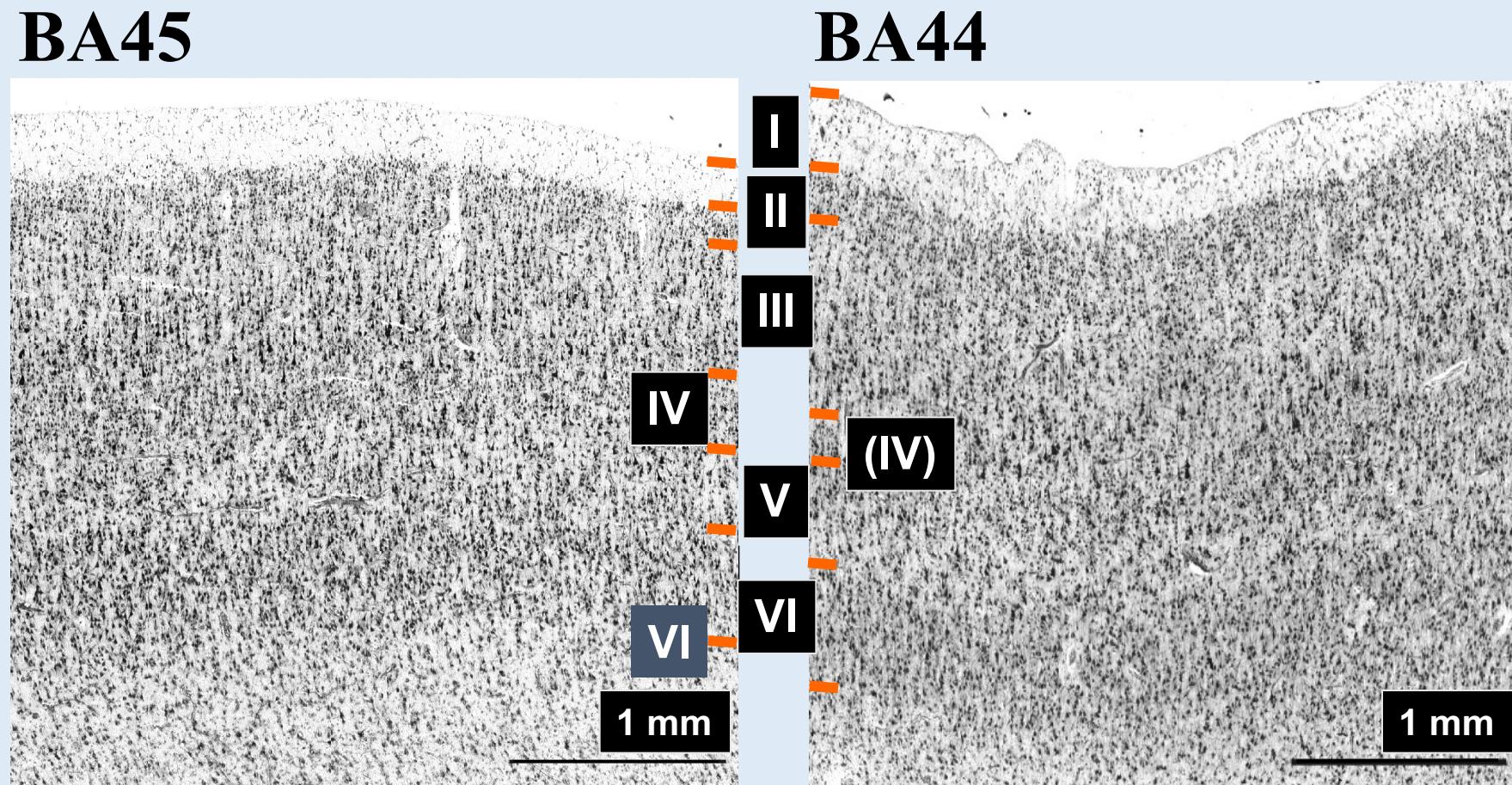


Cytoarchitectonic borders

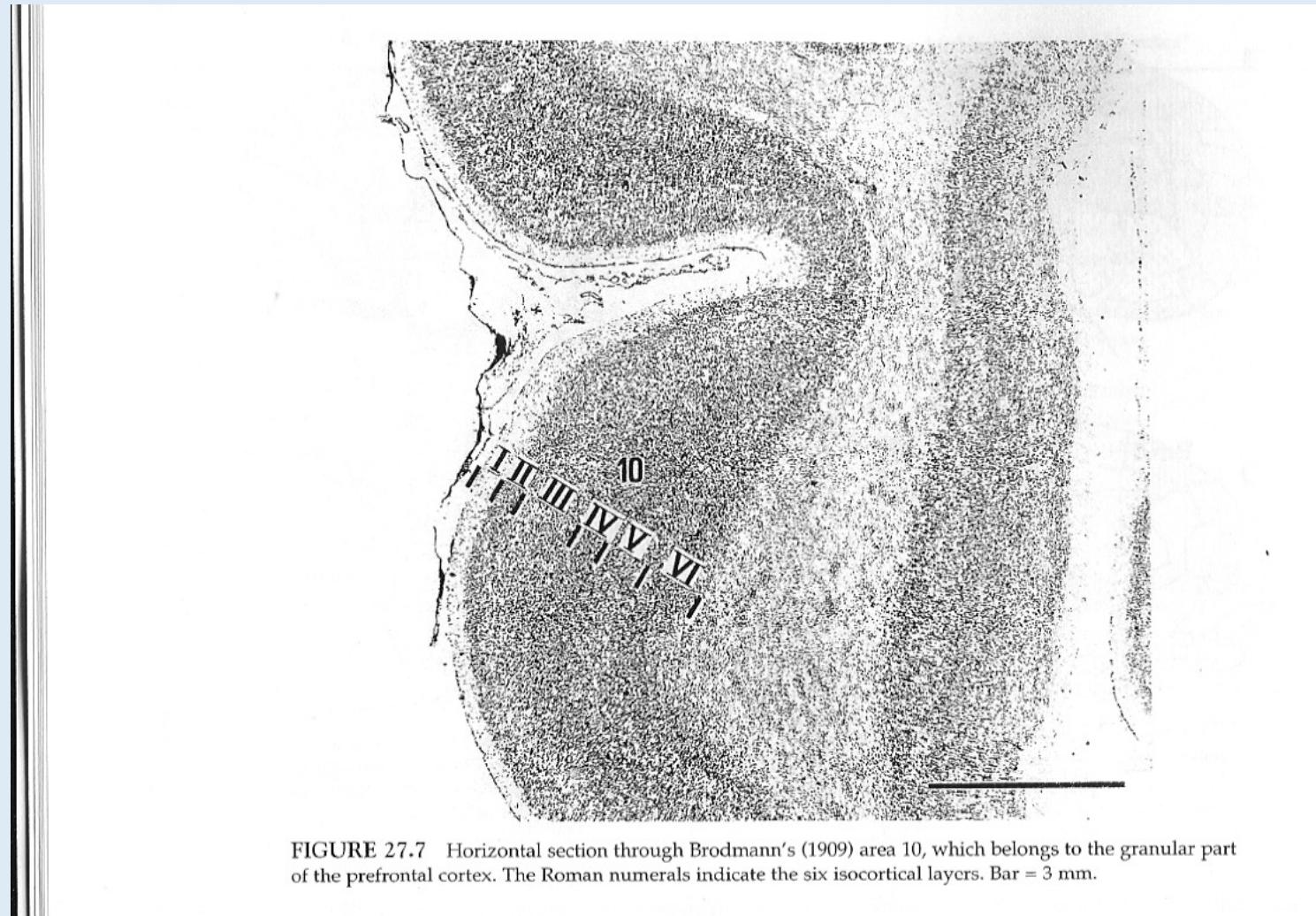


- The cell layers vary throughout Cortex
- Changes in the lamina reflect borders between cytoarchitectonic regions
- Changes in lamina may be in regards to size of layers or the layers' cell size or packing density

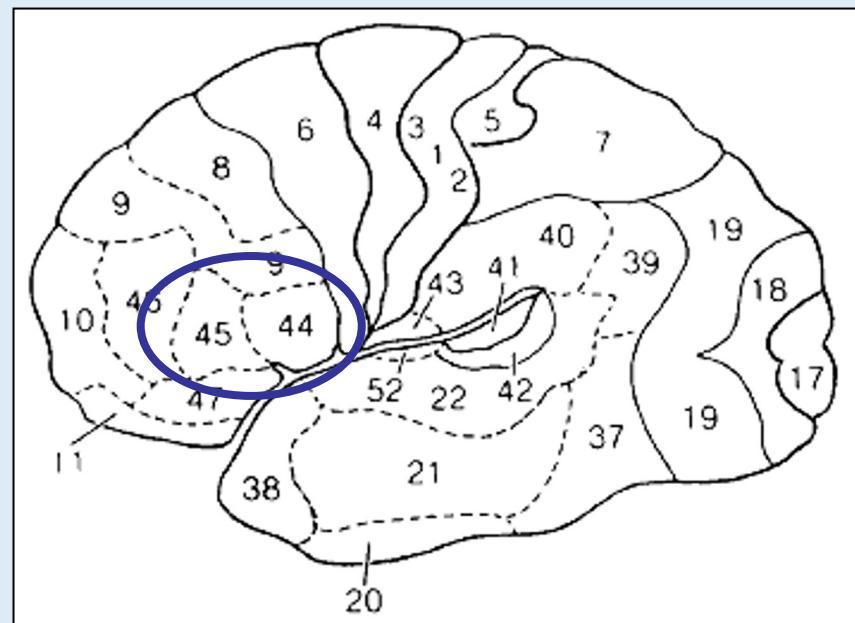
Current Cytoarchitectonics: BA 44 & 45 stained for cell bodies



Cortical layers again

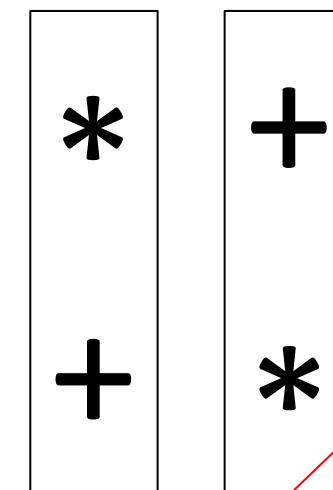


Result: an empirically solid and precise cytoarchitectonic atlas

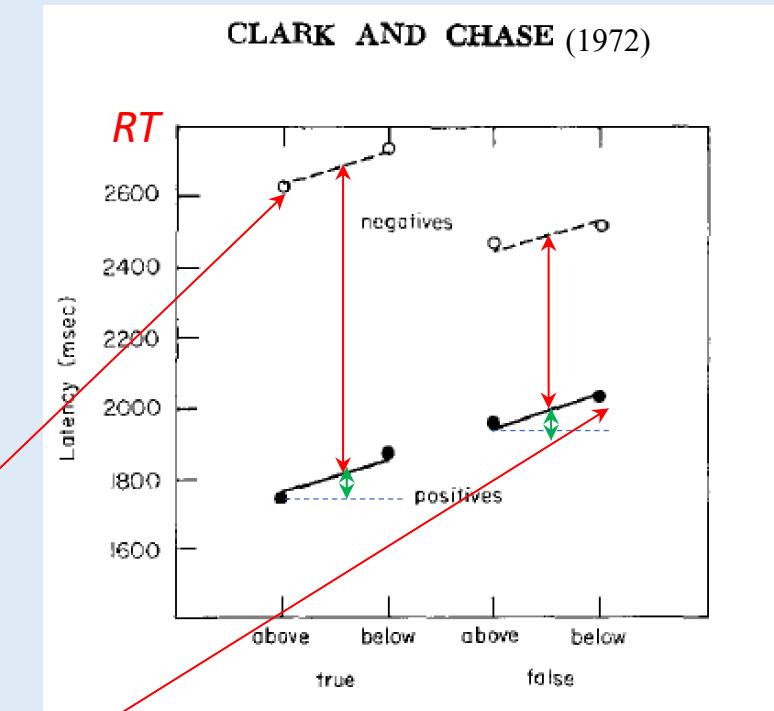


The psycholinguistic landscape: Verification with negation and true-false scenarios

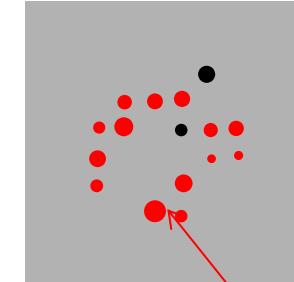
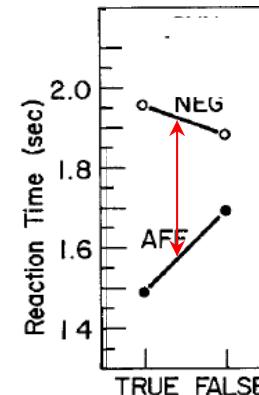
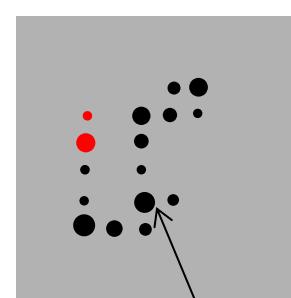
- 1.
- a. Star is *above* plus
 - b. Star is *not above* plus
 - c. Star is *below* plus
 - d. Star is *not below* plus



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



First hints: Verification with degree quantifiers



Factor 2
(2-levels):
Polarity

	T	F
many	1	2
few	4	3

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

J&C:

- *Decomposition*

Many dots are red

- *Fixed verification strategy*

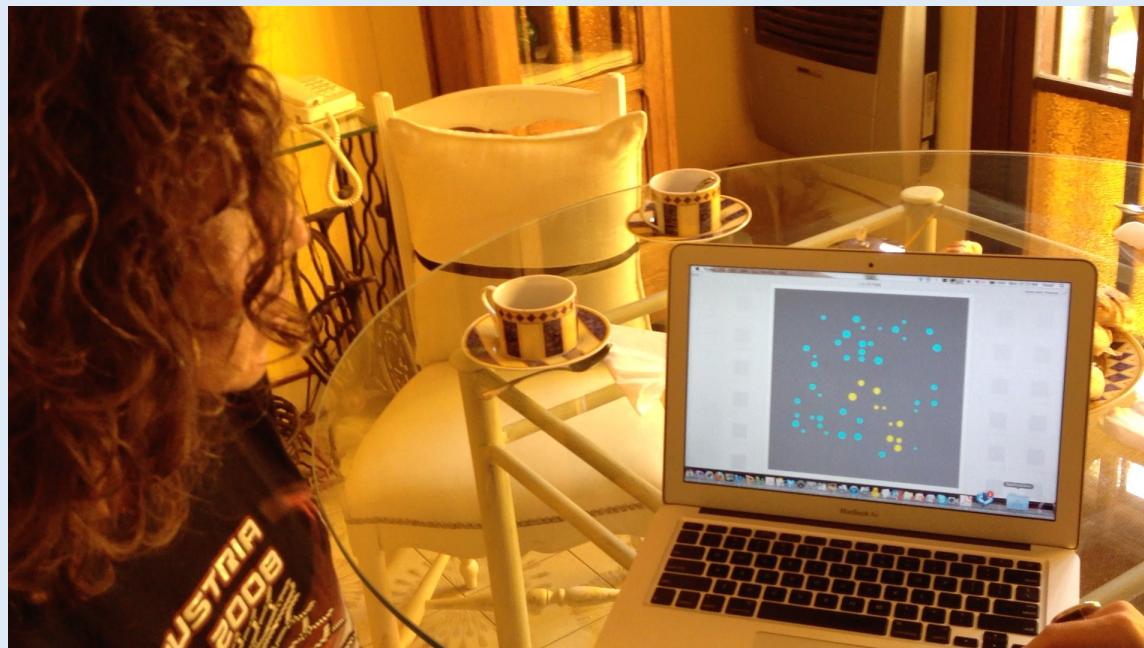
Focus on larger set of objects in image

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

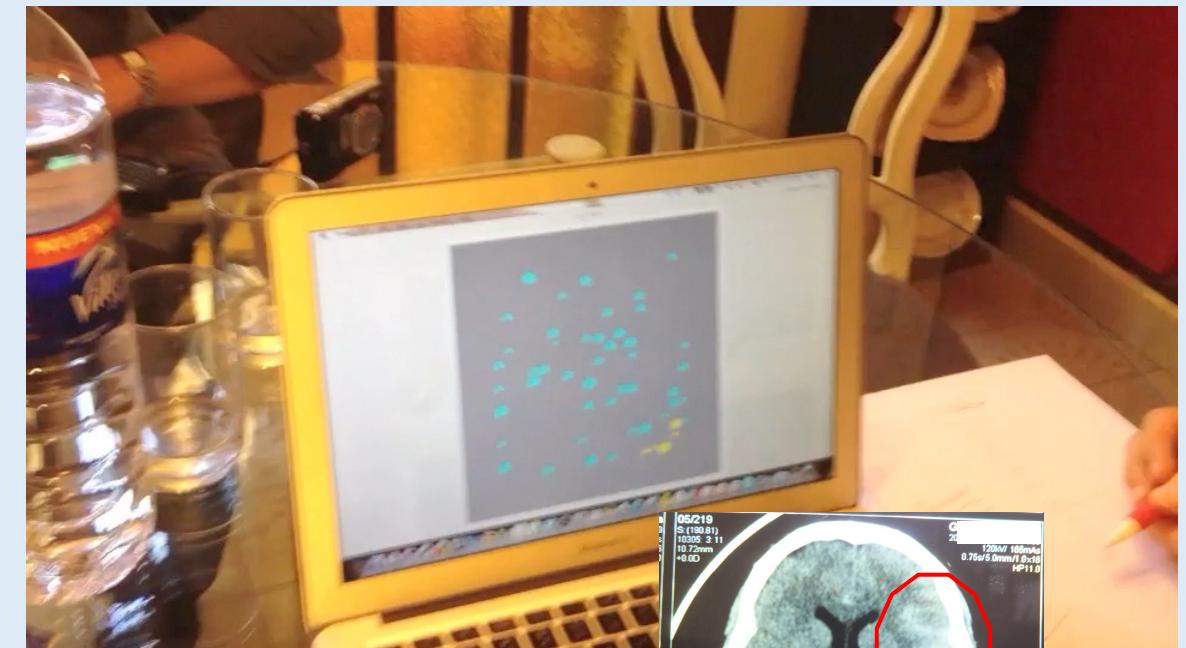
Neg(many) dots are red

Focus on larger set

A hint from aphasia: Patient demo (Spanish)



many (*muchos*) of the circles are blue



Few (*pocos*) of the circles are blue

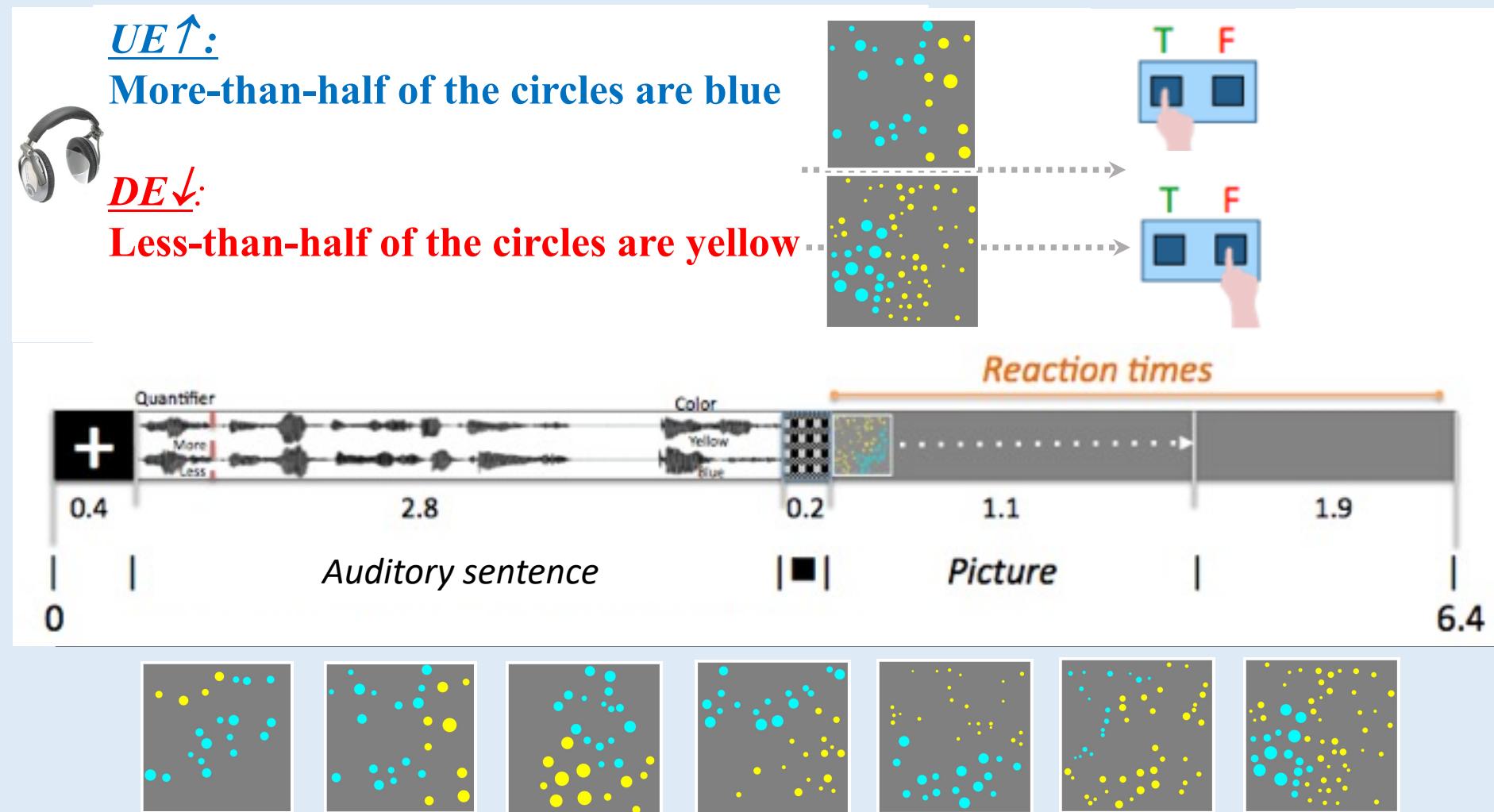


Workplan

- ❑ 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

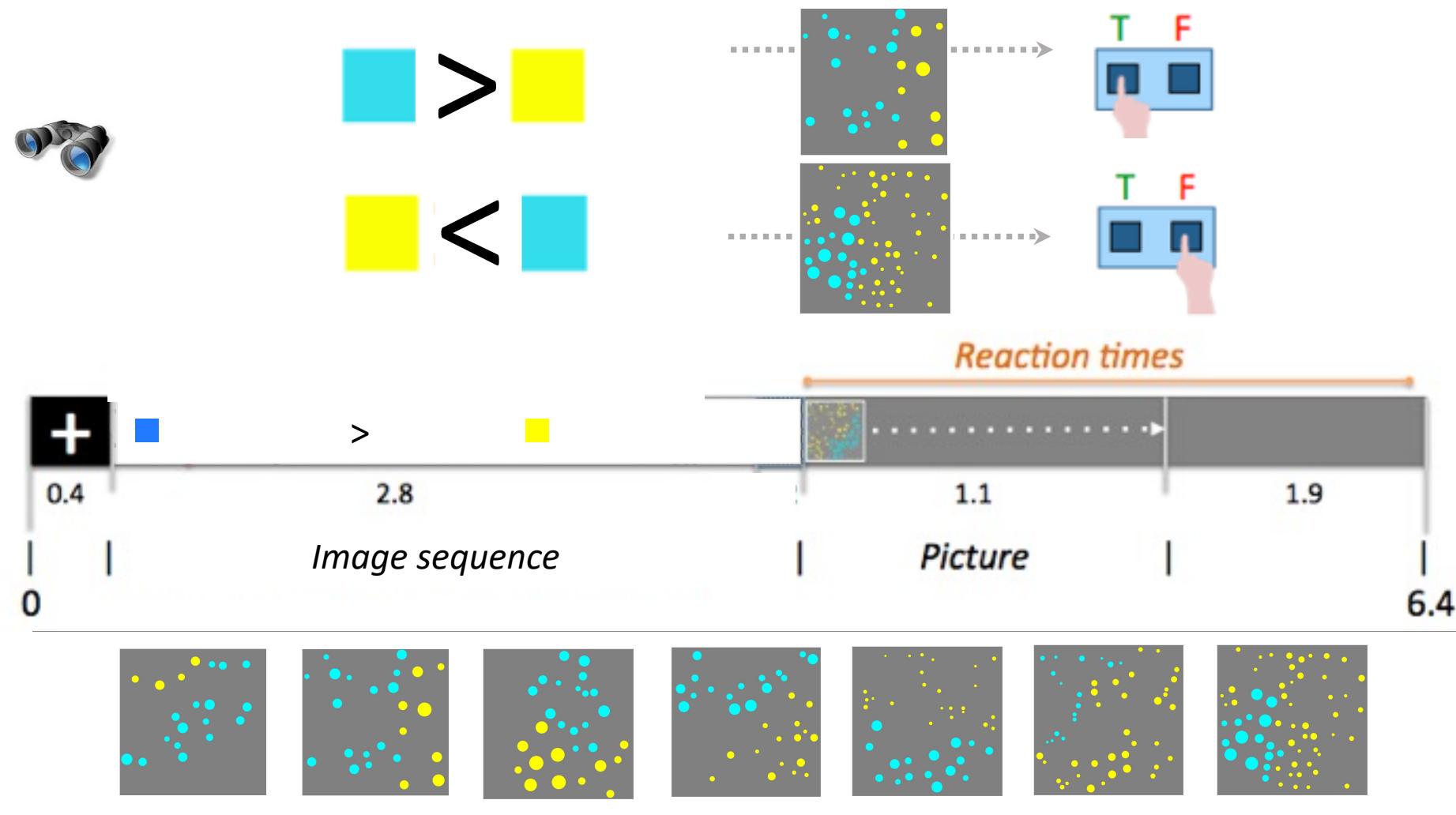
An RT experiment with the Parametric Proportion Paradigm (PPP)

(with Isabelle Deschamps, Galit Agmon & Yonatan Loewenstein)



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

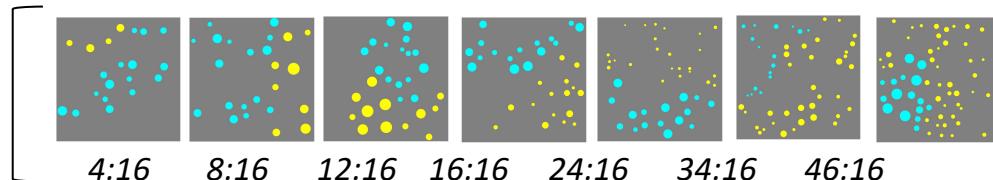
Fixed standard
Degree

POS: **More-than-half of the circles are blue**
NEG: **Less-than-half of the circles are yellow**

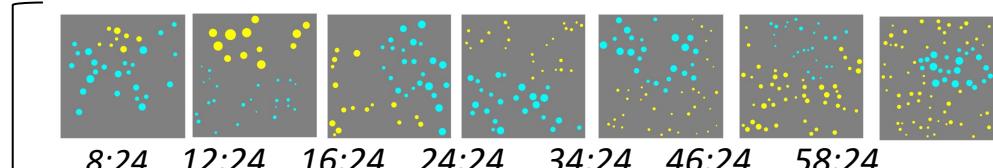
POS: **Many of the circles are blue**
NEG: **Few of the circles are yellow**

- Proportion and Numerosity

$r=16$

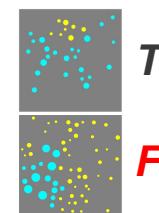


$r=24$



- Truth-value

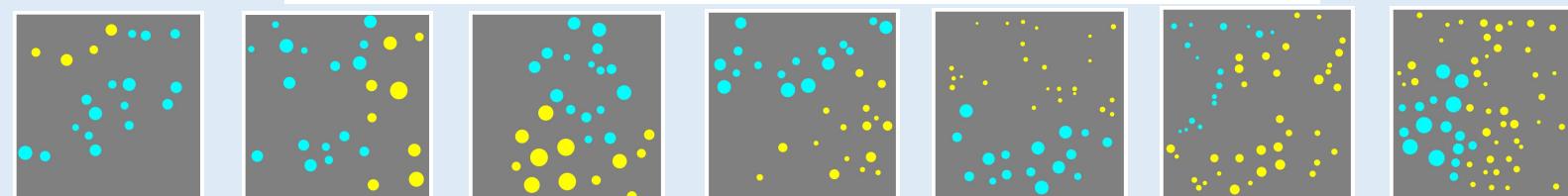
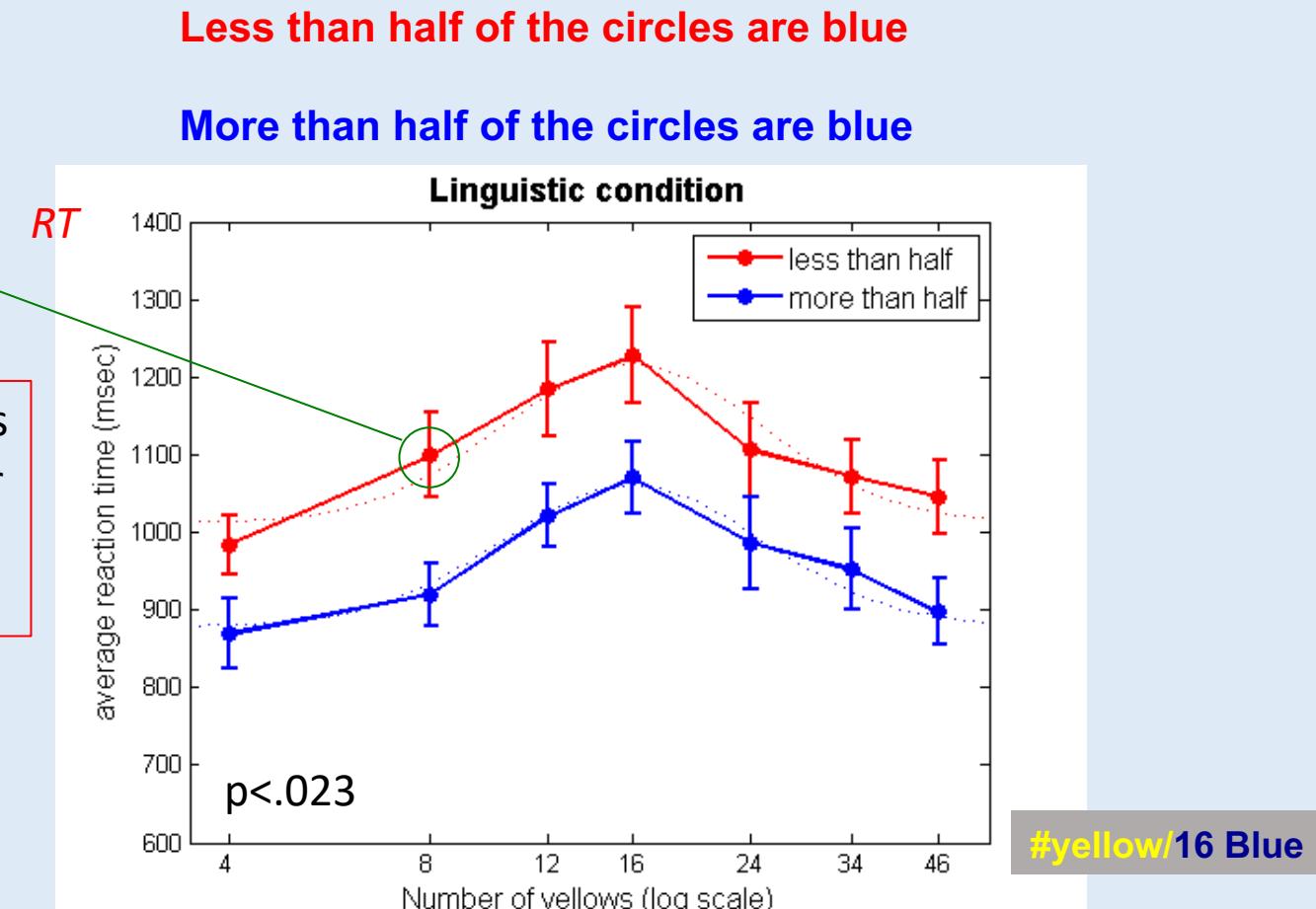
More-than-half of the circles are blue



First PPP result: Polarity matters – RT functions

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

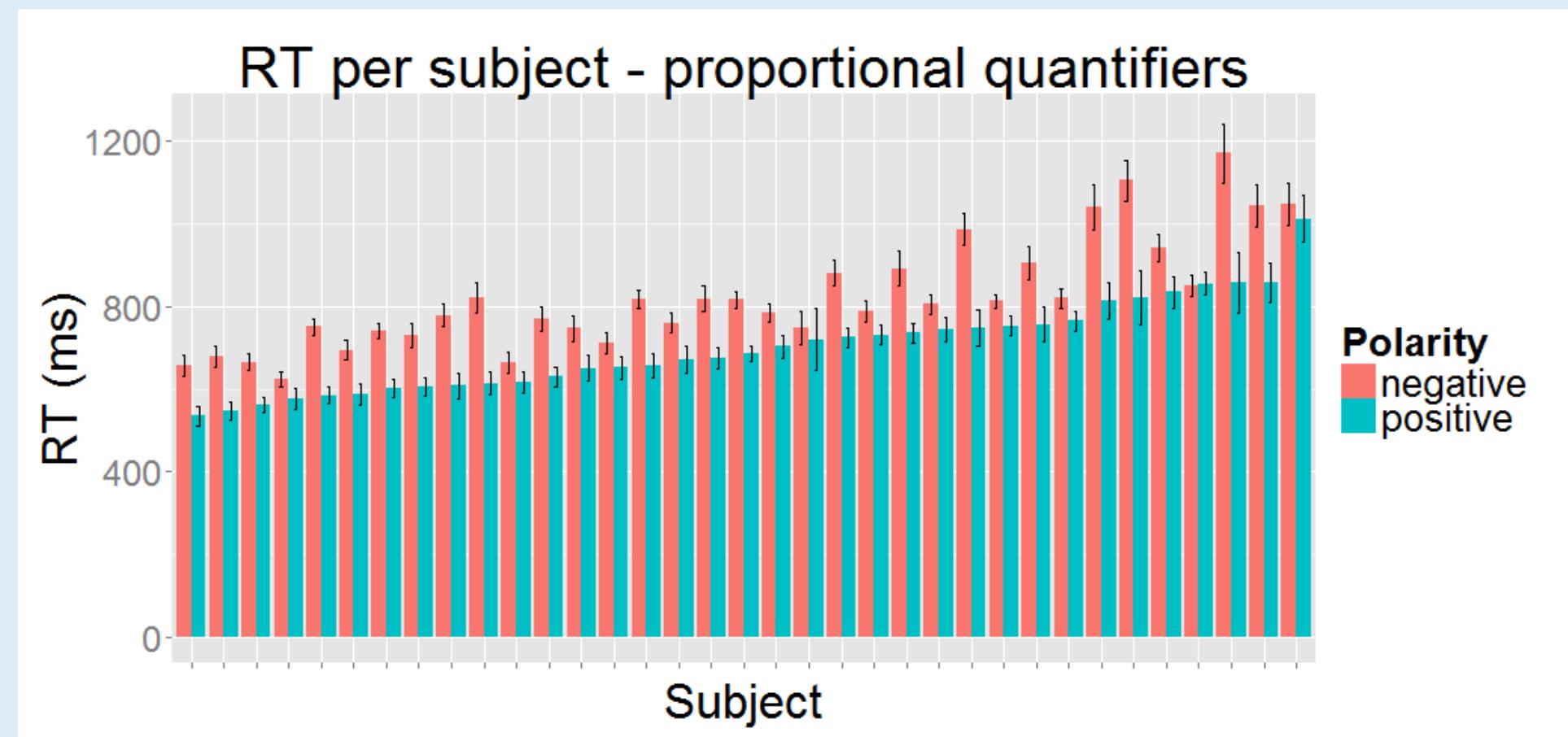
NB: same results
for $r=24$, and for
the *many/few*
contrast



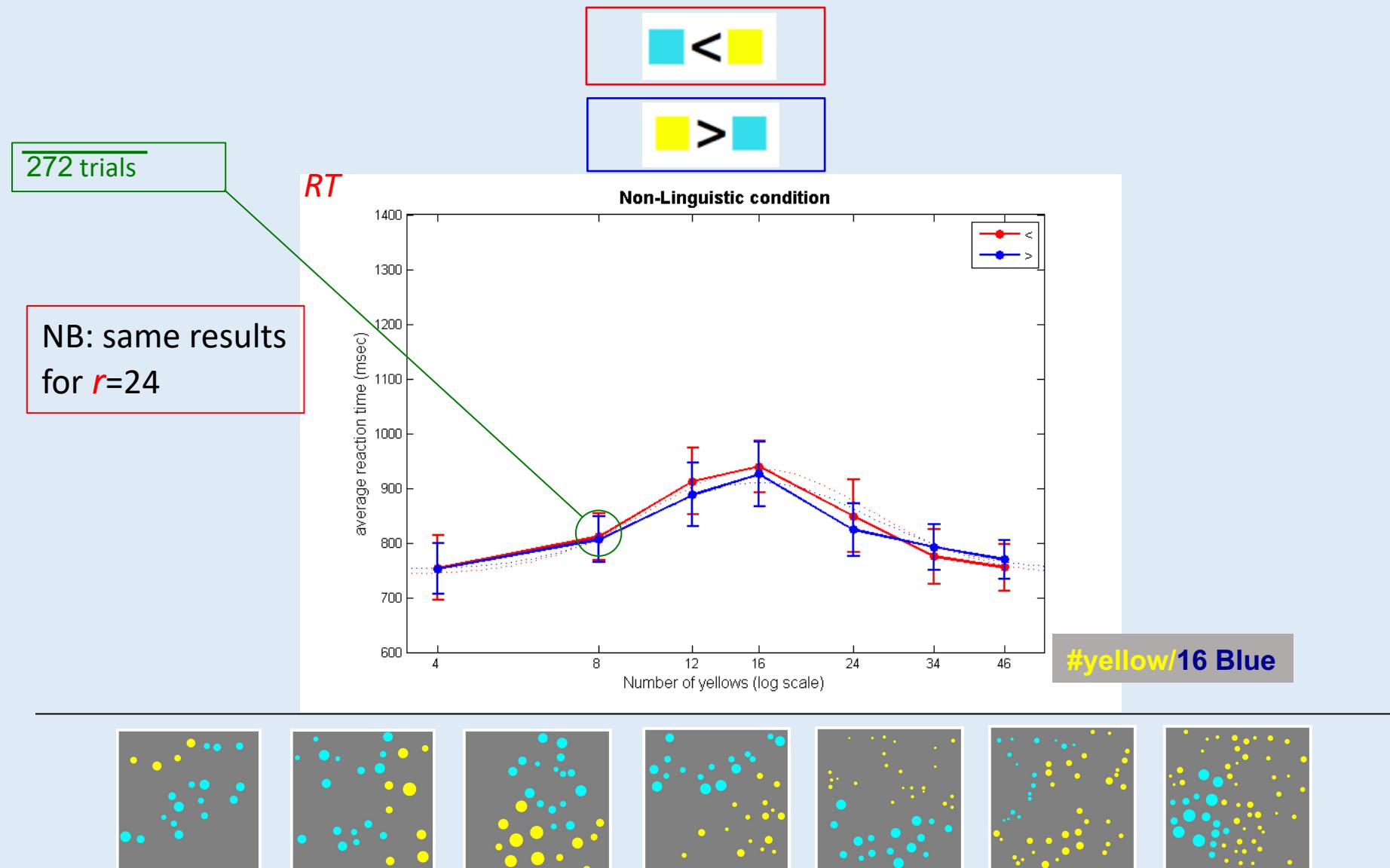
Second PPP result: Polarity difference at the single subject level!

Less-than-half of the circles are blue

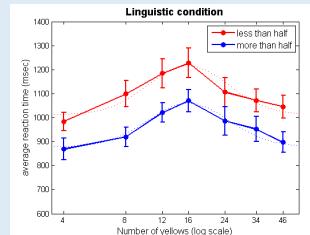
More-than-half of the circles are blue



Third PPP result: verification with analogous symbols



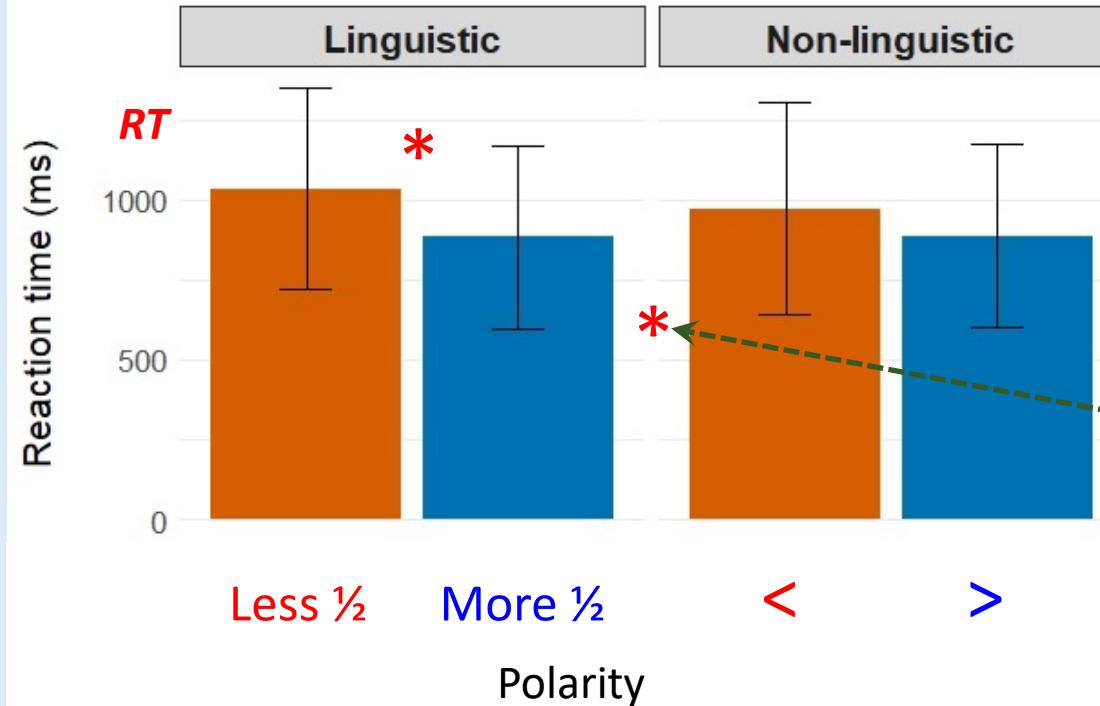
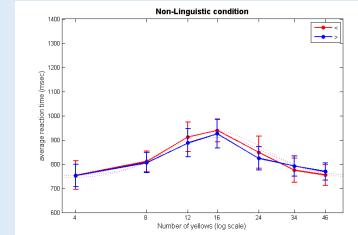
Fourth PPP result: Polarity \times ±linguistic interaction



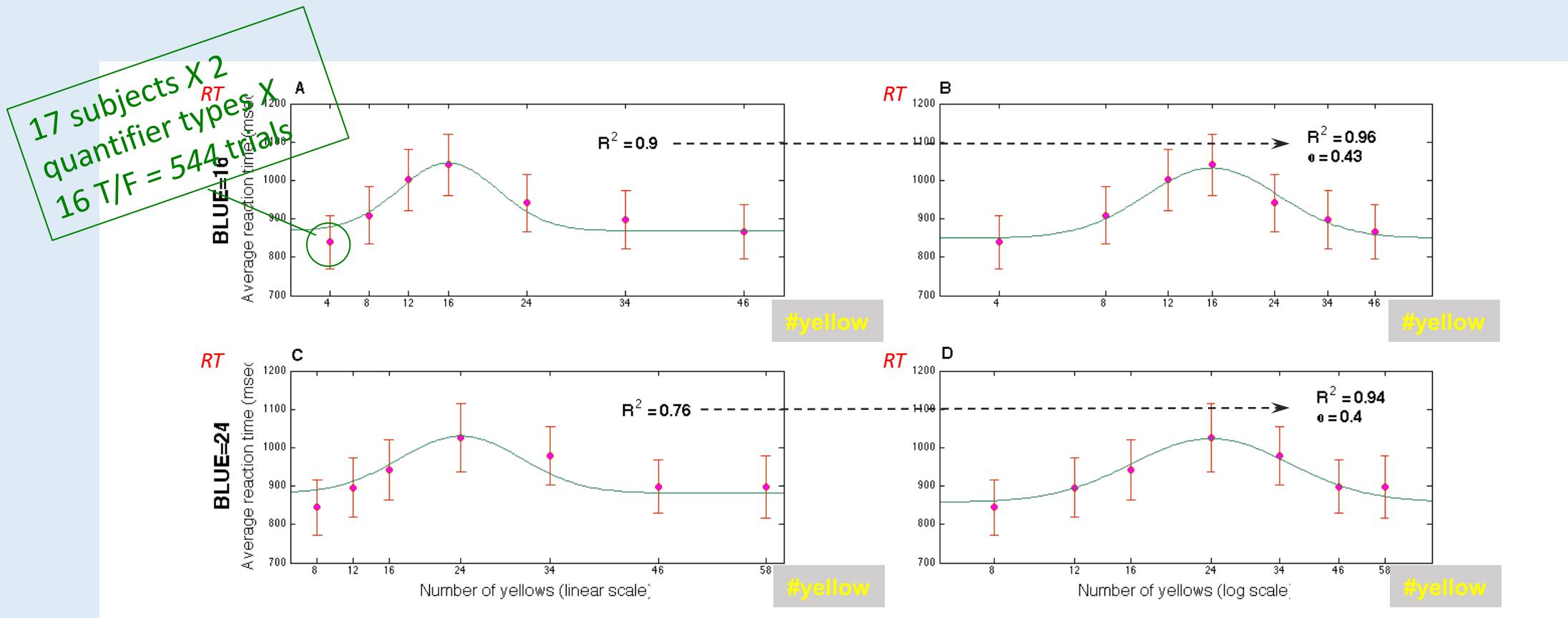
More than half of the circles are blue



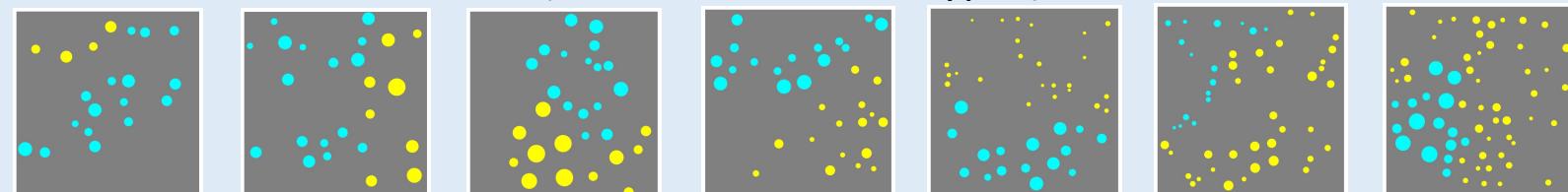
Less than half of the circles are blue



Fifth PPP result: RTs abide by Weber's Law



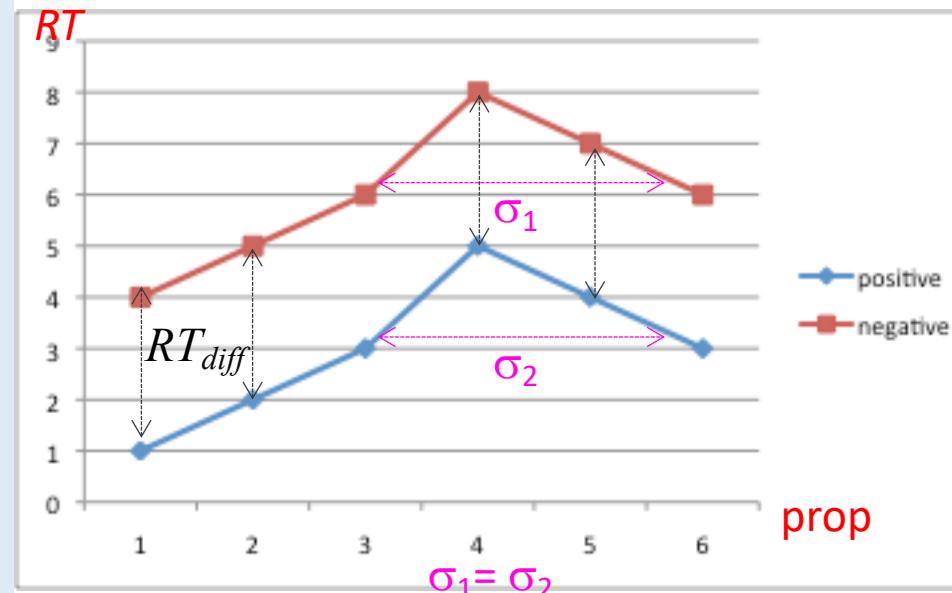
Improvement of gaussian fit to mean RT fit on log compression
(across all sentence types)



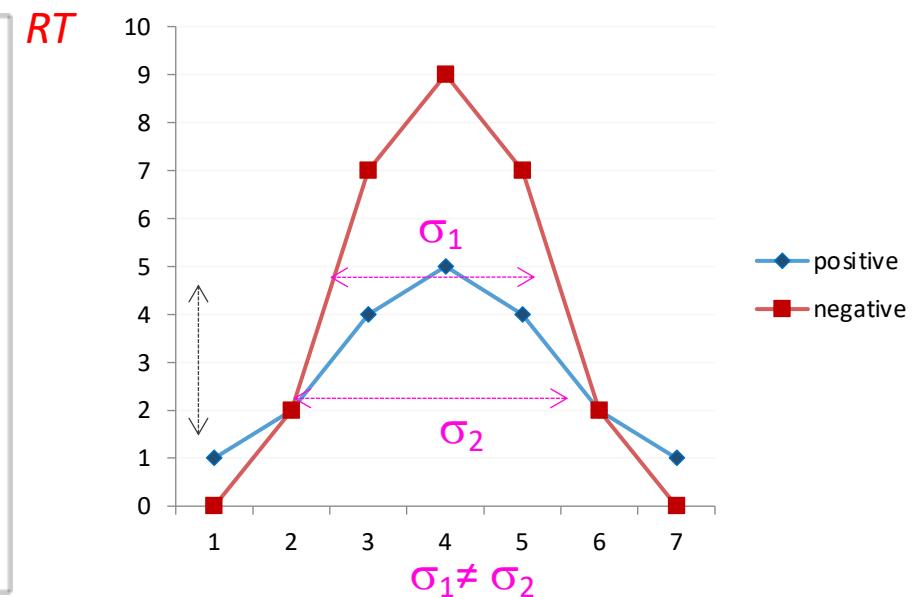
Sixth PPP result: the Polarity effect is additive

Possible relations between curves

Additive: Polarity effect
is independent from proportion



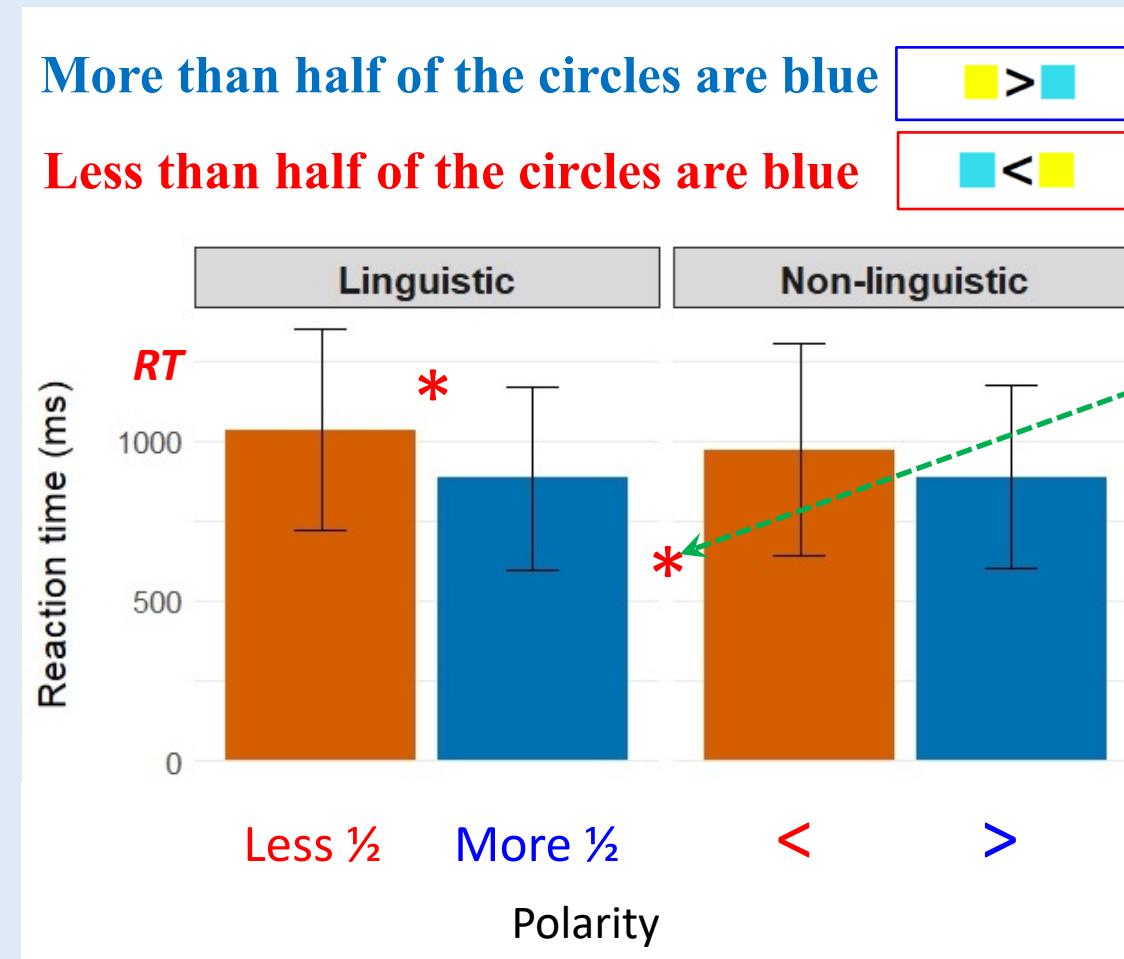
Non-additive: Polarity effect
is *not* independent from proportion



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

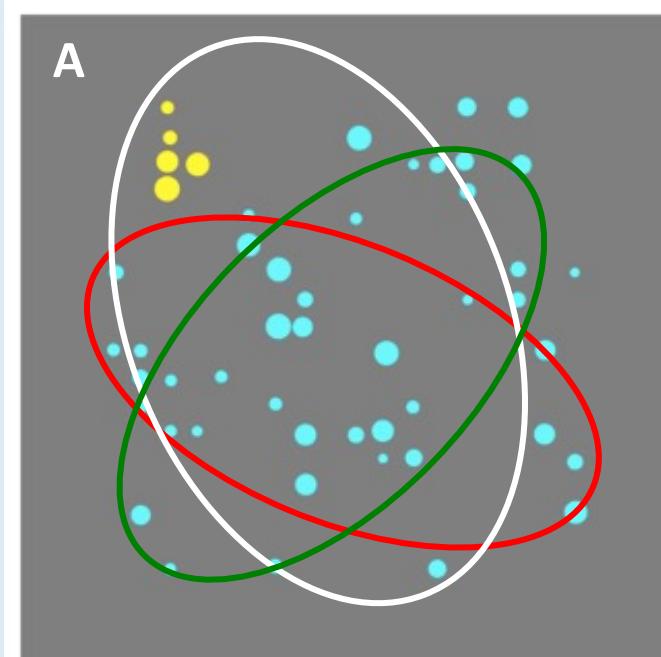
Barwise & Cooper on verification and monotonicity

Verification strategies are determined by monotonicity (“witness set”)

In truth determination by repeated sampling, verification of a proposition that contains a UE function requires less steps than one with a DE function

“we predict that response latencies for verification tasks involving decreasing quantifiers would be somewhat greater than for increasing quantifiers...These predictions are based on the complexity of the checking procedure we have suggested” (1981, p. 192)

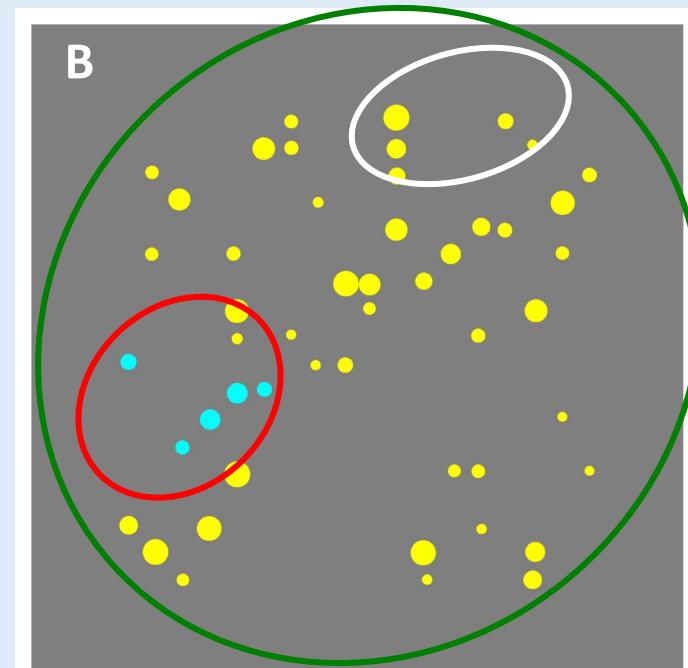
Semantics: B & C's "witness set" verification algorithm



more-than-half of the circles are blue:

- (i) find the sets that contain each $>\frac{1}{2}$ of the circles (e.g., {WHITE}, {RED}).
- (ii) find a set w whose members are all blue. If it is found (e.g., {RED}, but not {WHITE}), indicate "True".

The presence of other sets that satisfy the requirements ({GREEN}) does not affect truth value.



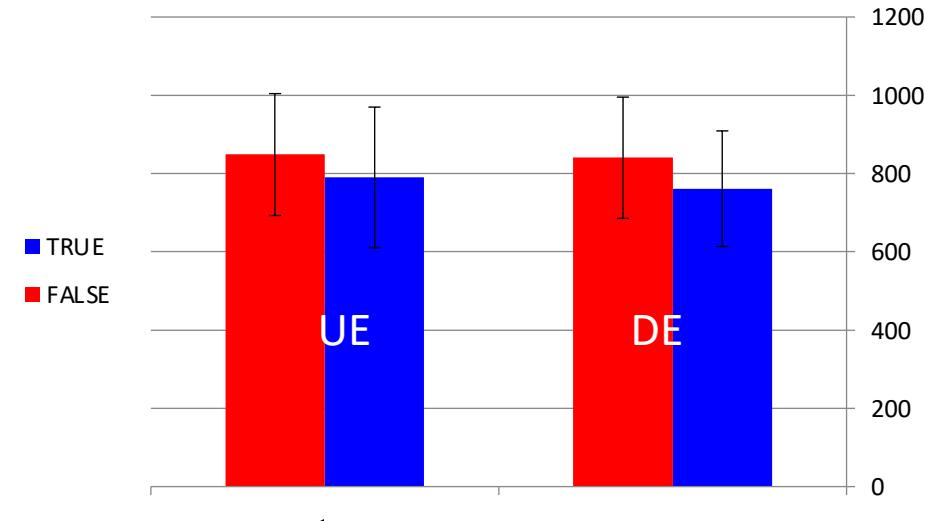
less-than-half of the circles are blue: (i)

- find the sets that contain yellow circles (e.g., {GREEN}).
- (ii) find the family of sets w that contain $<\frac{1}{2}$ of the circles (e.g., {WHITE}, {RED}). (iii) if {GREEN} $\in w$, indicate "True". This is the case here, hence "True".

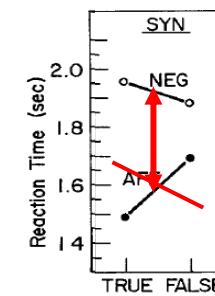
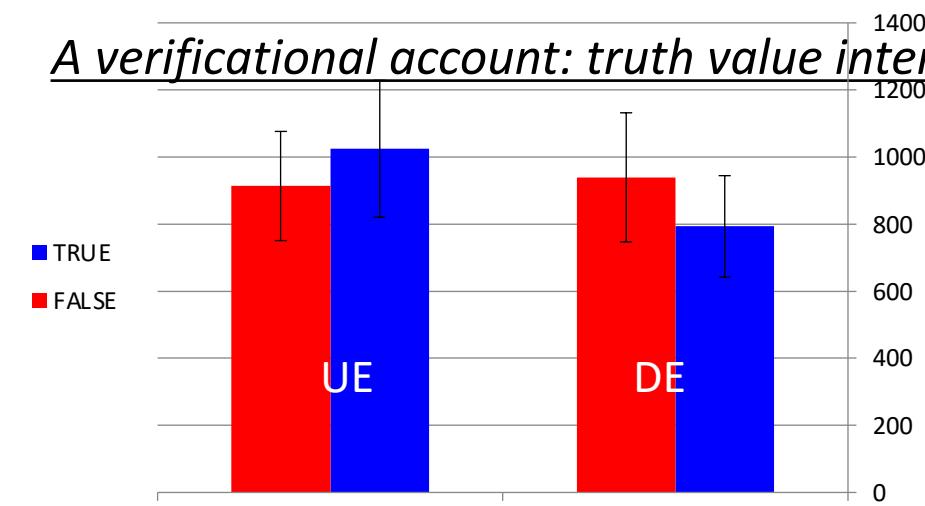
This search must ensure that no set of blue circles contains $\frac{1}{2}$ or more circles

Possible outcomes

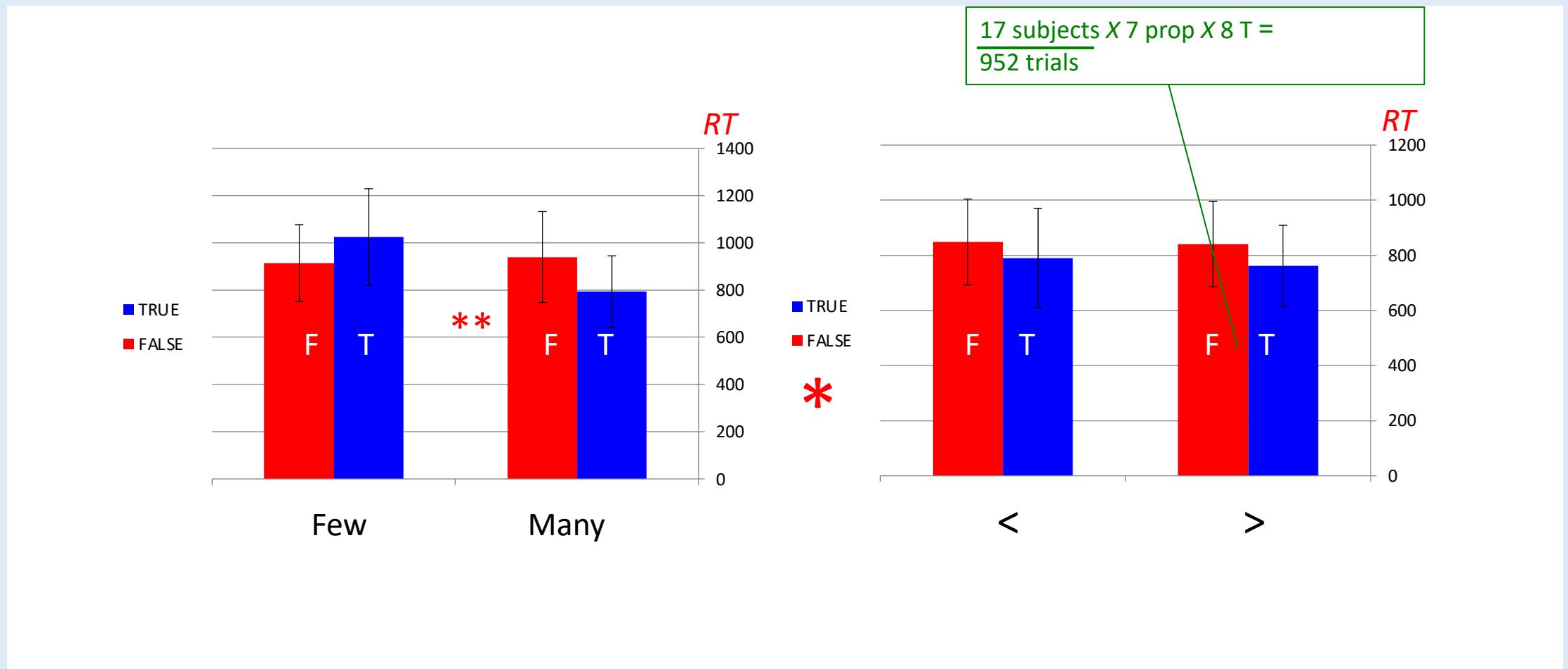
A non-verificational account: truth value is orthogonal to RT



A verificational account: truth value interacts with RT



Degree quantifiers show the pattern predicted by the semantic account
($r=24$, across all 7 proportions)



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The neural cost of implicit negation

(with Isabelle Deschamps, Peter Pieperhoff, Francesca Iannilli, Galit Agmon, Yonatan Loewenstein & Katrin Amunts)

