The Analysis of *less*-Comparatives: Evidence from the Processing Cost of Downward Entailingness

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Today's menu

1. Precise measurements of verification time with proportional quantifiers
2. A highly selective Downward Entailingness Cost (DEC) effect
3. A DEC effect in comparatives? A puzzle
4. Paths to a solution:
   a. *ironing a potential experimental wrinkle*
   b. *the detailed analysis of* less-*comparatives*
   c. *tying the DEC to the number of DE operators in an LF*
5. Further issues (LF-complexity, antonyms, truth-value)

Speeded verification with quantifiers: a Parametric Proportion Paradigm (PPP)

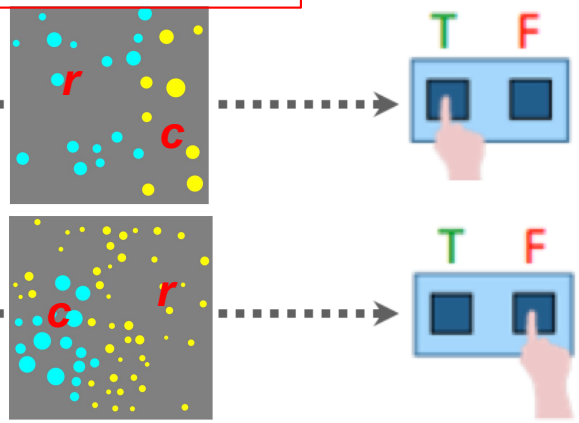
numerosities
***r*=reference**
***c*=comparandum**

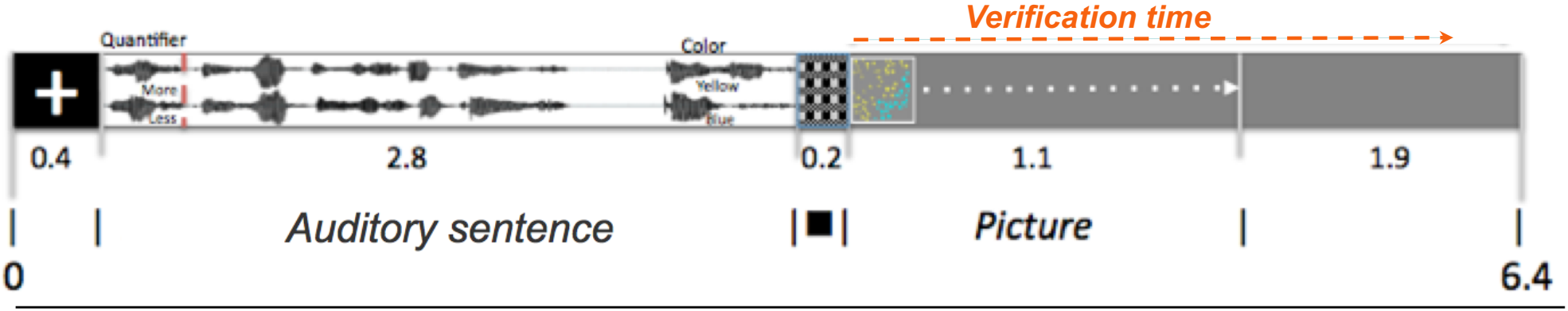
UE

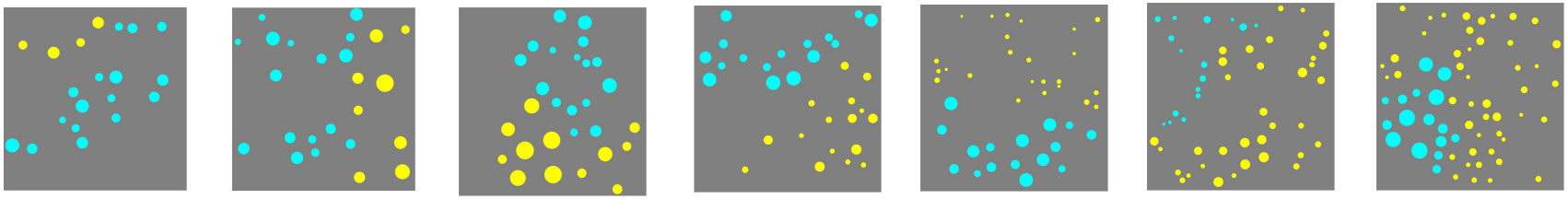
More-than-half of the circles are blue

DE

Less-than-half of the circles are yellow







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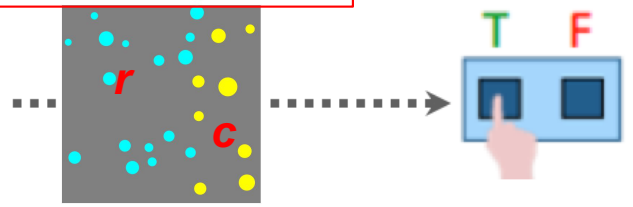
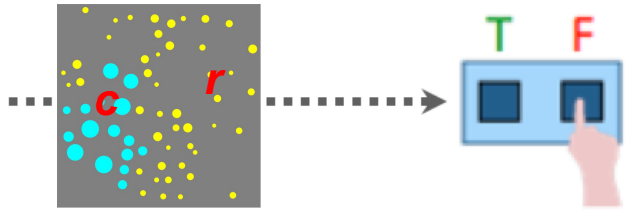
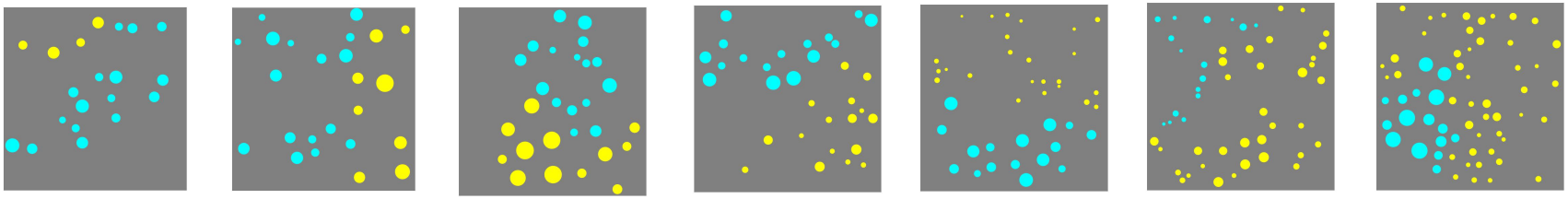


DE

Less-than-half of the circles are yellow



| ***Composition*** | ***Estimation*** ***Comparison*** |



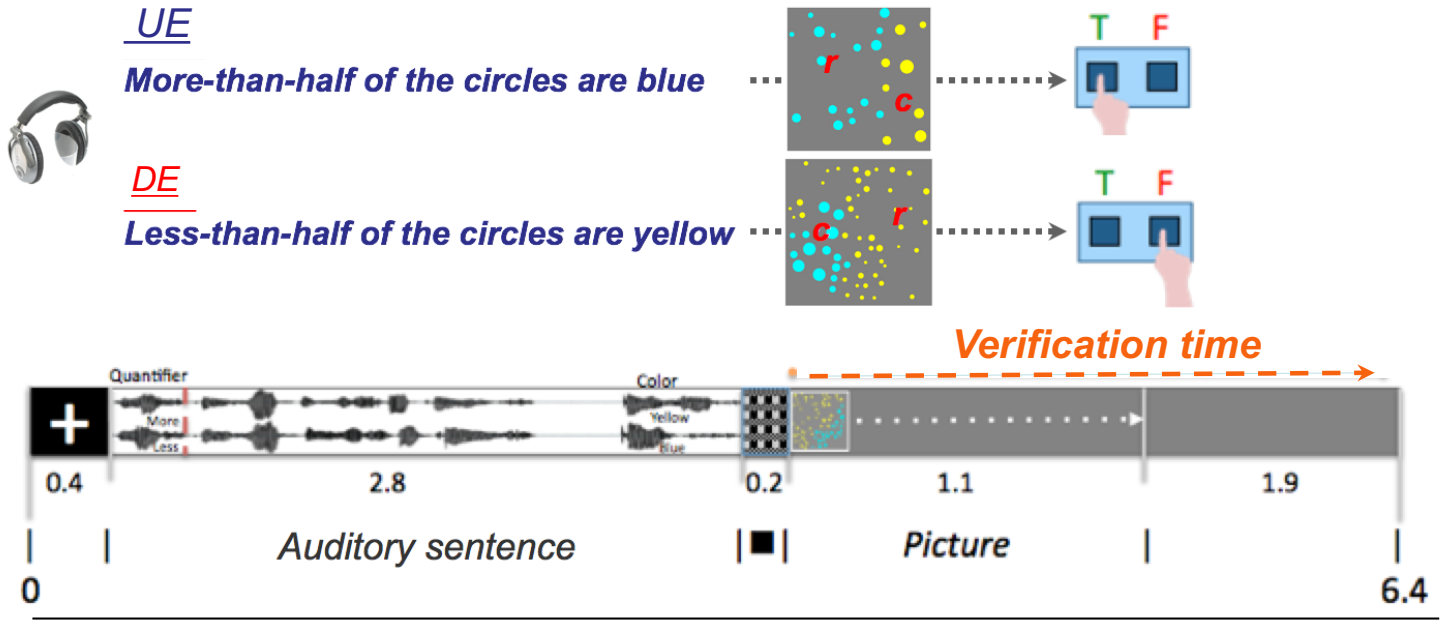
Contributors to the duration of timed sentence verification in the PPP

Building RT from its pieces:

$RT_{composition}$
↑ determined by sentence form and meaning

$RT_{estimation}$
↑ determined by *r,c* (and perceptual principles)

$RT_{comparison}$
↑ determined by *r/c*



Contributors to the duration of timed sentence verification in the PPP

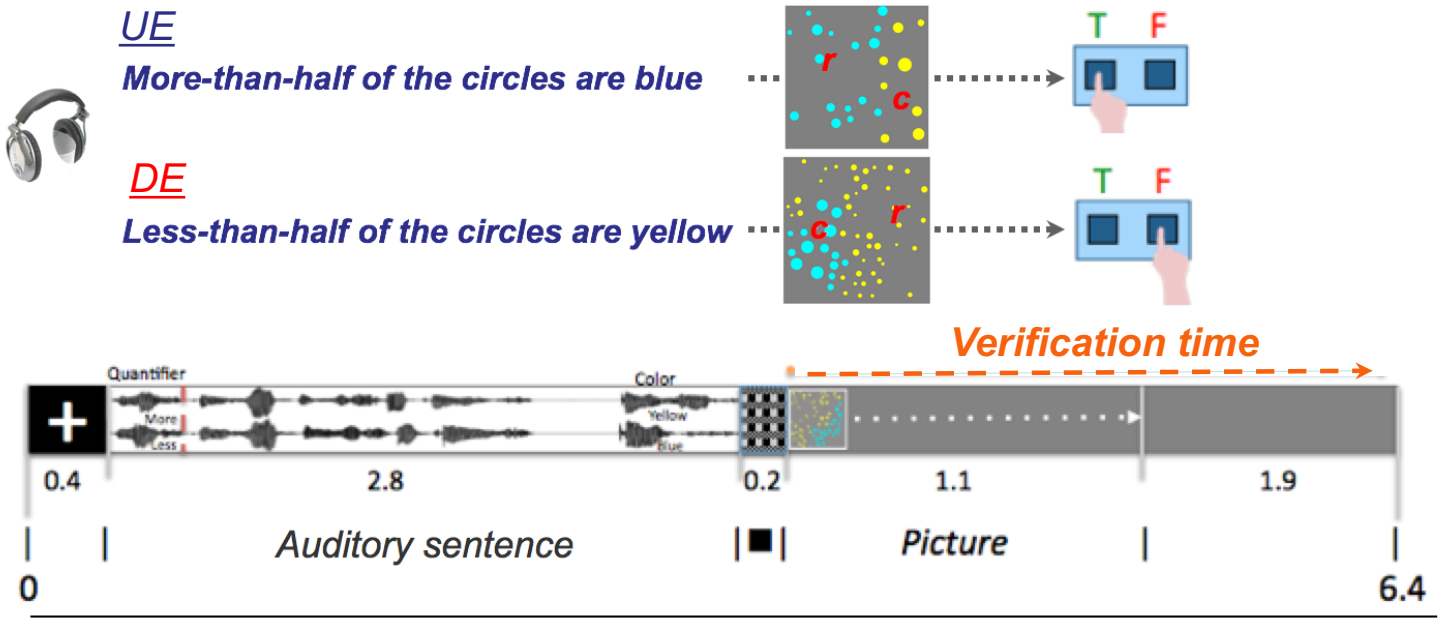
Change in components with experimental manipulation:

$RT_{composition}$

↑ **Grows with contrast "complexity"**

$RT_{estimation}$

$RT_{comparison}$



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Change in components with experimental manipulation:

$RT_{composition}$

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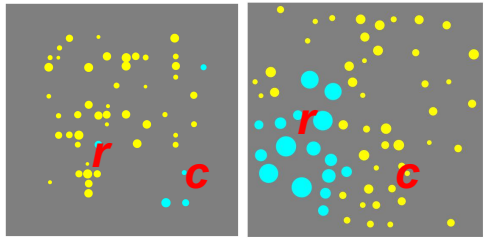


numerosities
***r**=reference*
***c**=comparandum*

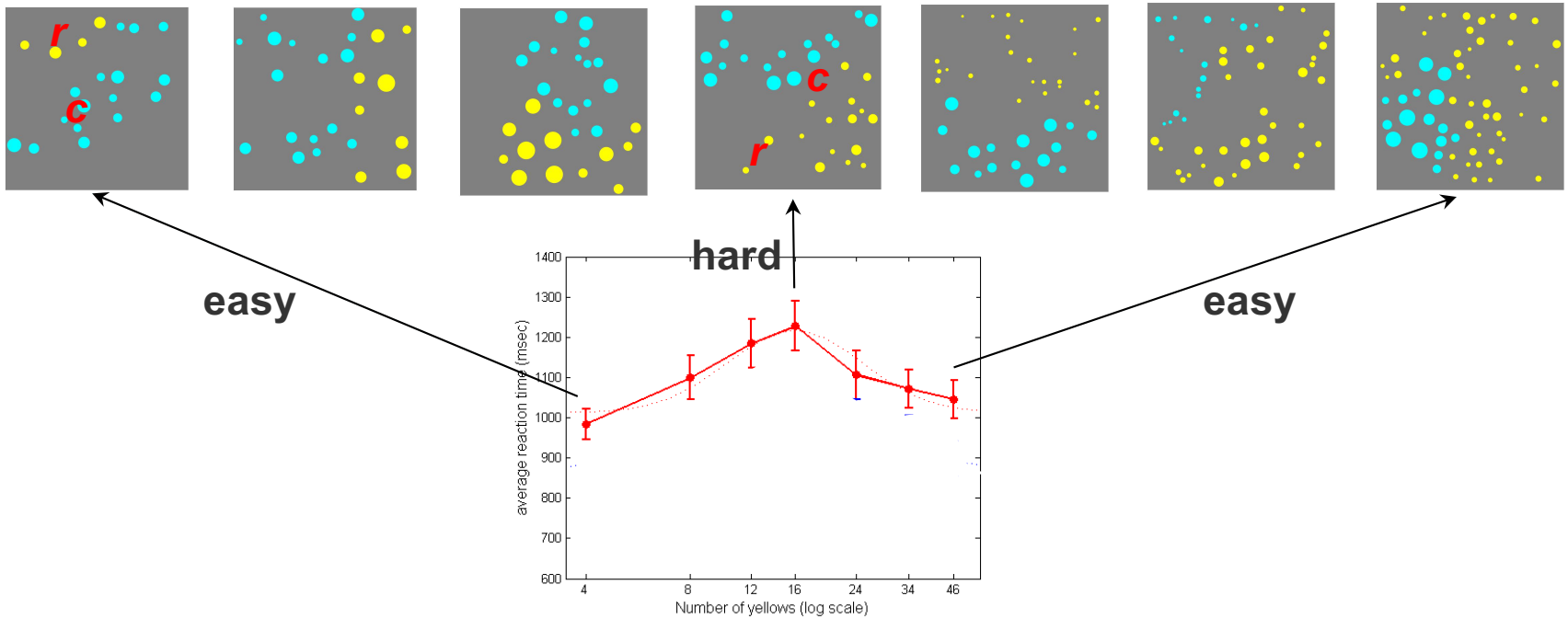
Contributors to the duration of timed sentence verification in the PPP

Change in components with experimental manipulation:

$RT_{composition}$ $RT_{estimation}$

$RT_{comparison}$

grows as
$r/c \rightarrow 1$
(Weber's Law)



Monotonicity in focus

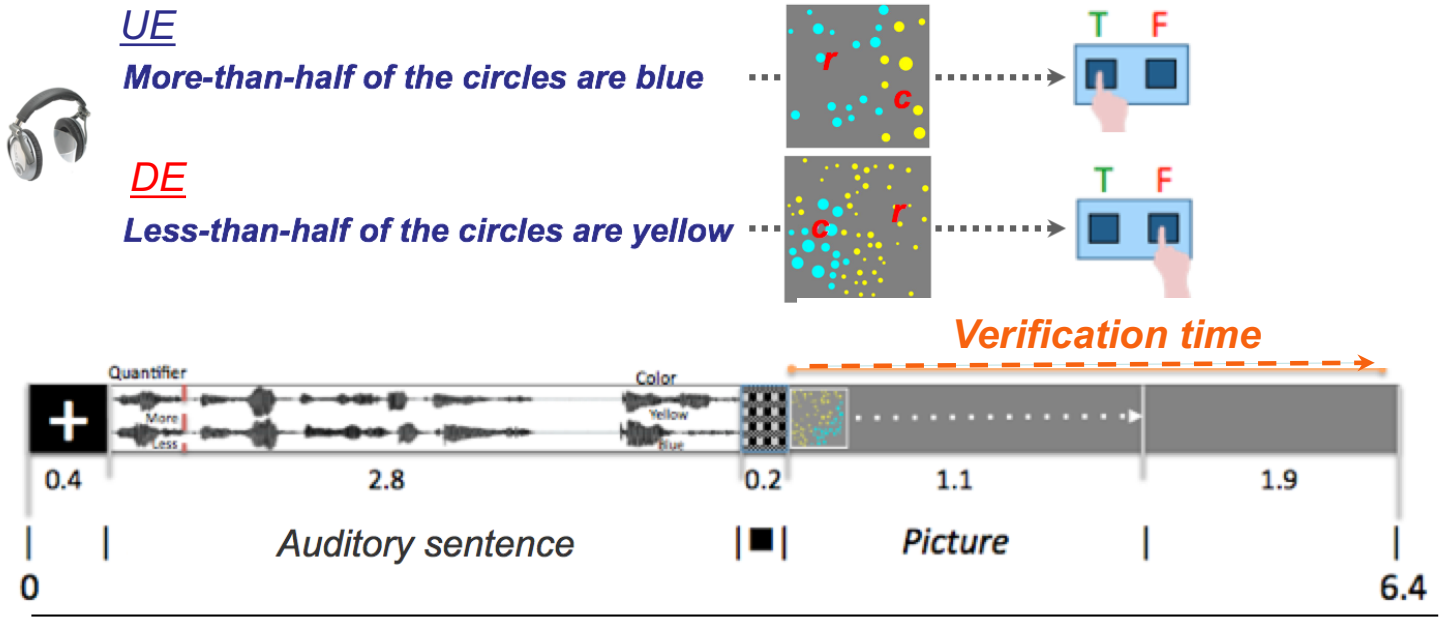
Today, we look at the composition contrast:

$RT_{composition}$

Grows with contrast "complexity"

$RT_{estimation}$

$RT_{comparison}$



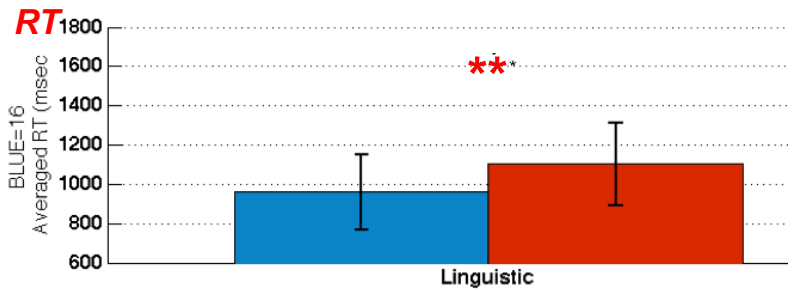
Deschamps et al., *Cognition*, 2015

First PPP result: DE is more costly in RT than UE

(1) *DE*: Less-than-half of the circles are blue

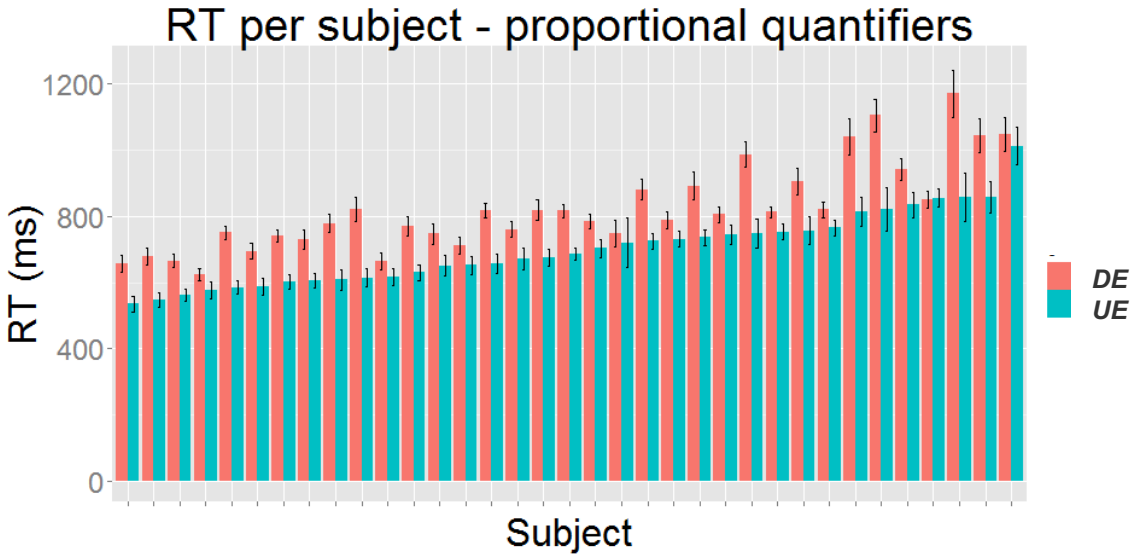
(2) *UE*: More-than-half of the circles are blue

RT: group means (and SEM) across ***r/c***'s

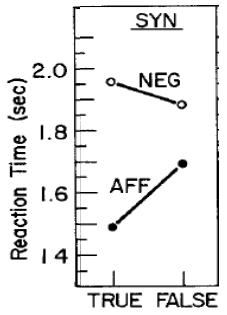


***Result** (more/less, many/few)*:

$\Delta RT (= RT_{(1)} - RT_{(2)}) >^{sig} 0$



DEC_{RT} (DE Cost) effect:
$\Delta RT = RT_{DE} - RT_{UE} >^{sig} 0.$

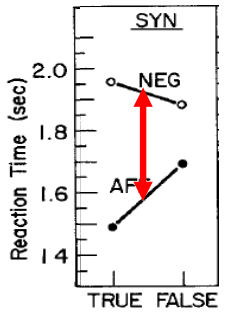


Tribute: Barwise & Cooper on verification and monotonicity

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)



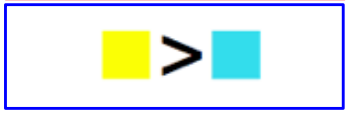
Second PPP result: DEC is specific to linguistic stimuli

(1) ***DE*: Less-than-half of the circles are blue**

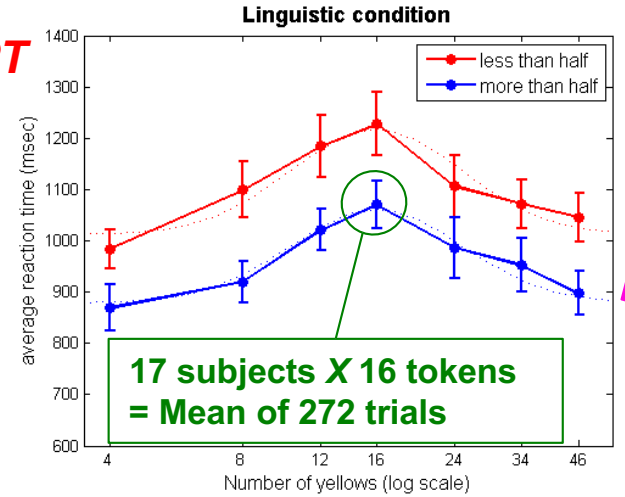
(2) ***UE*: More-than-half of the circles are blue**

(3)

(4)

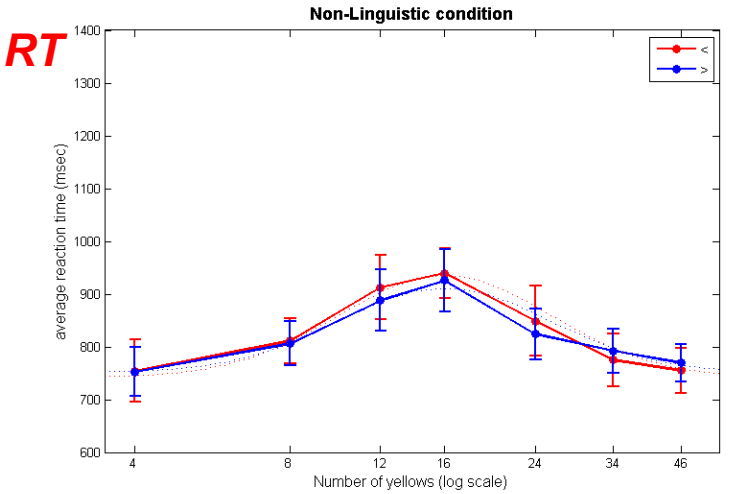


RT

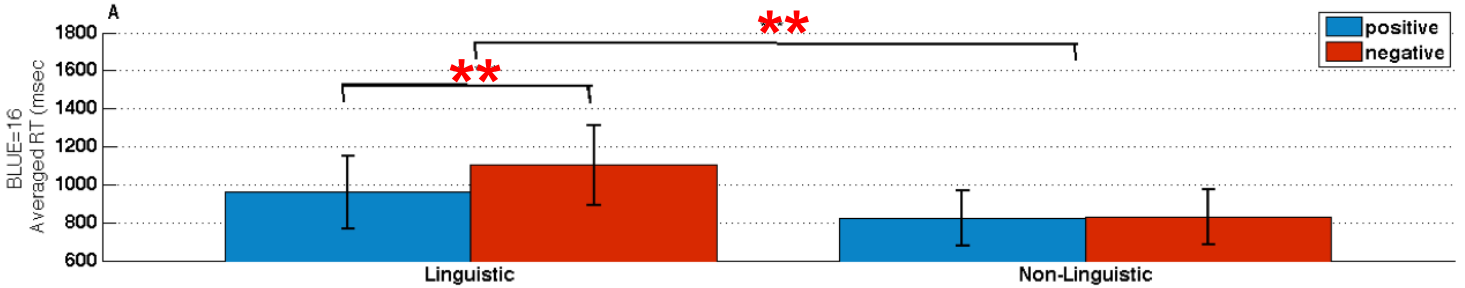


additivity

RT



RT



Net(DEC$_{RT}$) effect :

$\Delta RT_{ling} - \Delta RT_{nonling} >^{sig} 0.$

Third PPP result: DEC has a specific brain locus which is part of an anatomically coherent brain piece

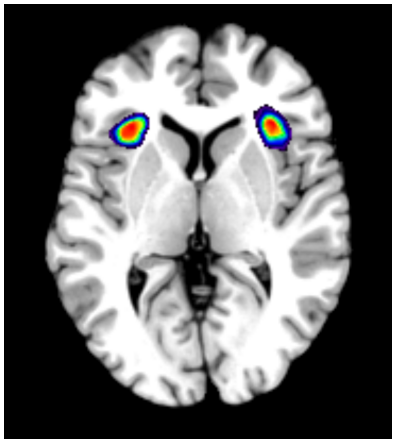
(1) ***DE*: Less-than-half of the circles are blue**

(2) ***UE*: More-than-half of the circles are blue**

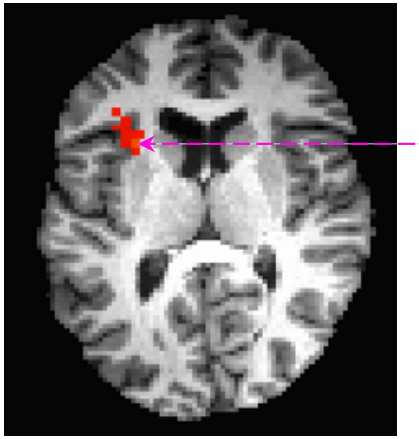
(3)

(4)

Anterior insula



activation by DEC



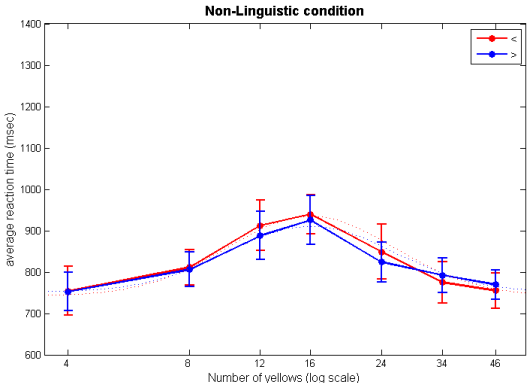
Region in which The Net DEC_{fMRI} effect for Signal Intensity (SI) Is significant

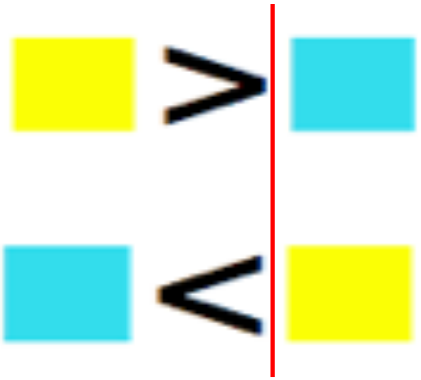
Net(DEC_{fMRI}) effect:

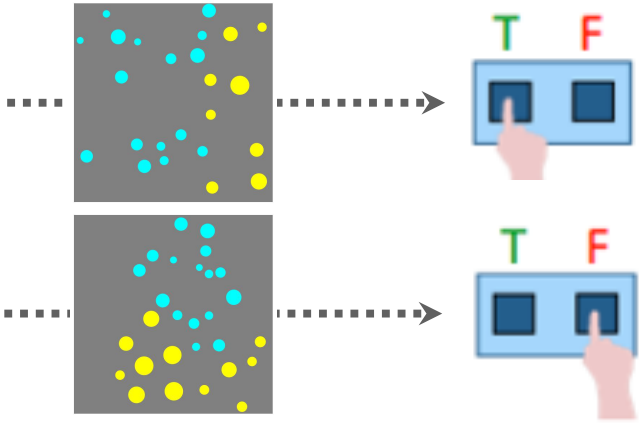
$\Delta SI_{ling} - \Delta SI_{nonling} >^{sig} 0.$

Do participants respond on partial information: phrasal comparatives

RT

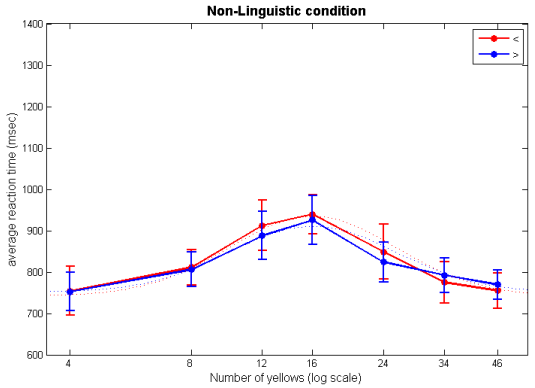






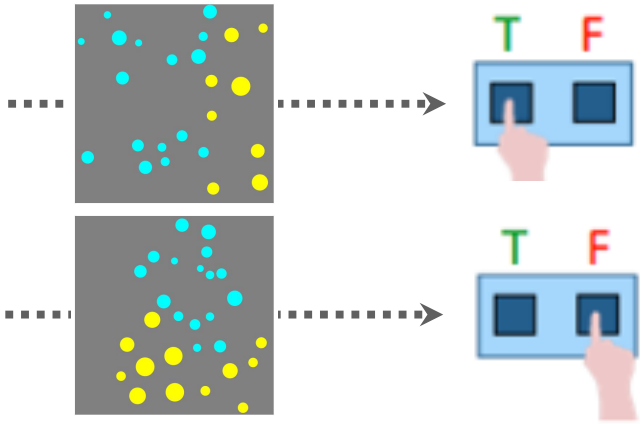
Do participants respond on partial information: phrasal comparatives

RT

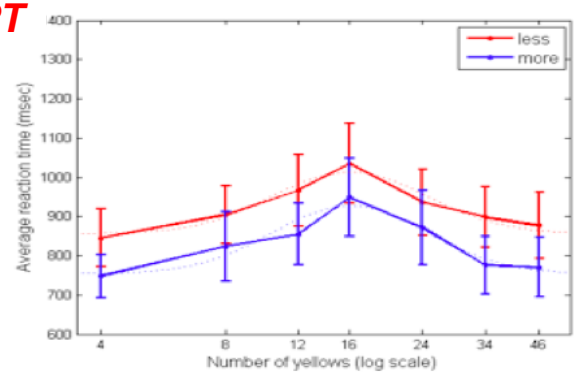


(5) There are fewer blue circles than yellow circles

(6) There are more blue circles than yellow circles



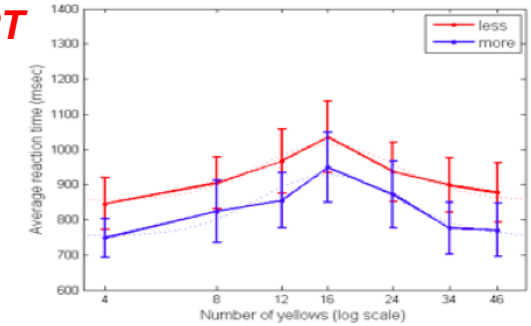
RT



$\Delta RT = RT_{fewer} - RT_{more} >^{sig} 0.$

But wait: do we really expect a "DEC effect" in comparatives?

RT



The monotonicity of (phrasal) comparatives

{cats}⊂{mammals}, {snakes}⊂{reptiles}

(7) a. ***UE***: More cats than snakes died ⇒ More mammals than snakes died

b. ***DE***: More cats than reptiles died ⇒ More cats than snakes died

(8) a. ***DE***: Fewer mammals than snakes live in deserts
⇒ Fewer cats than snakes live in deserts

b. ***UE***: Fewer cats than snakes live in big cities
⇒ Fewer cats than reptiles live in big cities

Comparatives are built from pieces with opposite monotonicities

(9) a. [There are more blue circles]^{UE} [than yellow circles]^{DE}

b. [There are fewer blue circles]^{DE} [than yellow circles]^{UE}

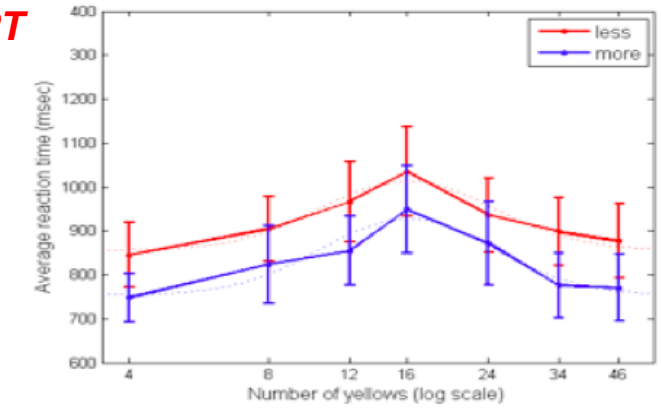
Predicted DEC$_{RT}$ effect (assuming additivity of UE, DE):

$$\Delta RT = RT_{(9b)} - RT_{(9a)} = RT_{DE+UE} - RT_{UE+DE} \approx 0.$$

Observed DEC$_{RT}$ effect:

$$\Delta RT >^{sig} 0.$$

RT



Paths toward a solution

I. **Experimental path**: if sentence is not read to the end, the result follows:

(10) a. UE half: There are more blue circles | than yellow circles

b. DE half: There are fewer blue circles | than yellow circles

If so, then the predicted effect is $\Delta RT = RT_{(10b)} - RT_{(10a)} >^{sig} 0$

Needed: an experiment that would get around this problem.

II. **Theory path**: the representation of monotonicity above is incorrect.

III. **DEC path**: redefine the DEC effect in the face of mixed monotonicity.

The relation between ingredients of the equation

$$\Delta RT = RT_{(9b)} - RT_{(9a)} = RT_{DE+UE} - RT_{UE+DE} \approx 0.$$

need to be reconsidered.

Down the experimental path

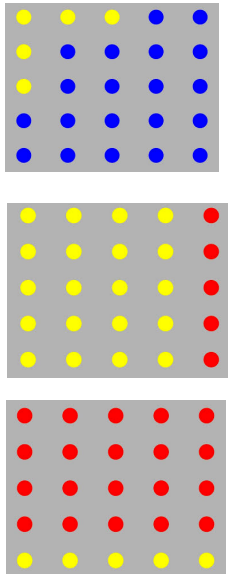
Goal: force participants to read instruction sentence to the end.
Trick: add a color. Inform participants that there may be a sentence-image color mismatch. Add a 3rd response button (MM)

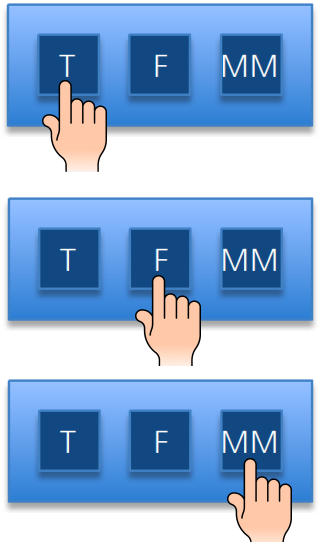
(11)

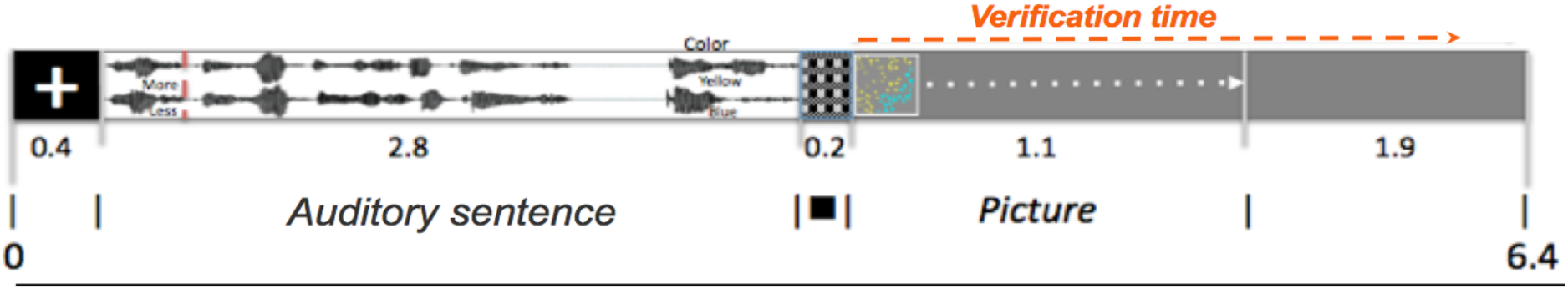
a. There are more blue circles than yellow circles.

b. There are fewer yellow circles than red circles.

c. There are more red circles than blue circles.

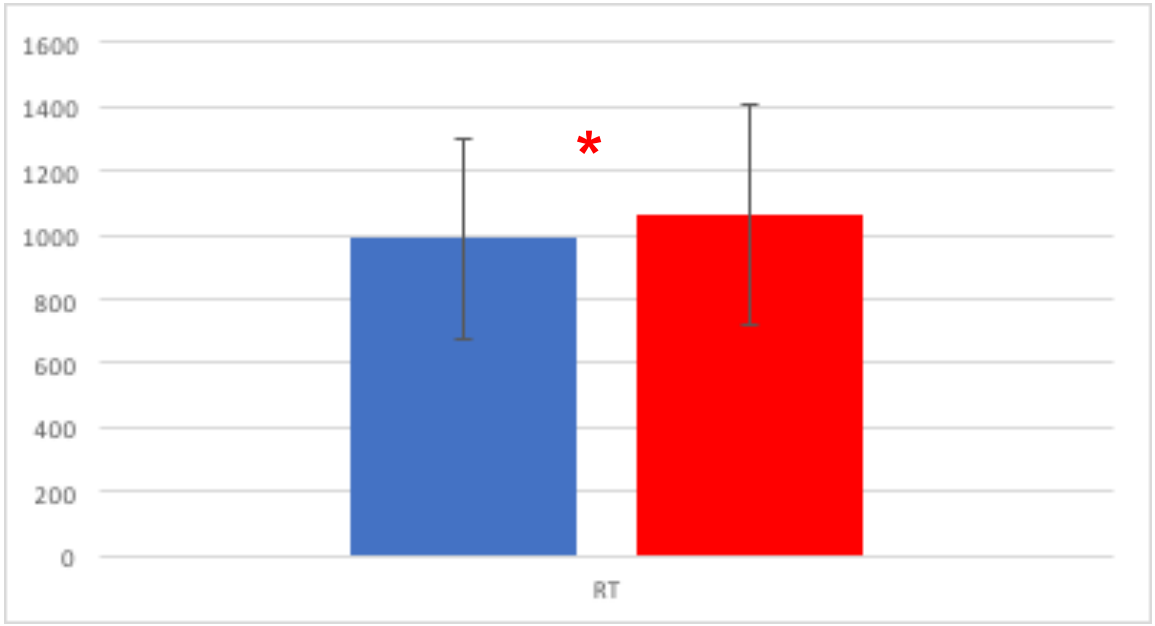






Results and Status

RT



More **fewer**

Note: results only include correct T/F responses (MM excluded); error rates are very low.

Conclusion: The experimental path doesn't get us out of the puzzle.

The Seuren/Rullman puzzle

Expected: NPIs are licensed only in the "DE part" of the more-comparative

(12) a. there are **more** students than (there are) **profs I've *ever*$_{NPI}$ met**

b. *there are **more students I've *ever*$_{NPI}$ met** than (there are) profs

Expected: NPI licensing in the "DE part" *of* less-*comparatives*:

(13) there are **fewer students I've *ever*$_{NPI}$ met** than (there are) profs

***Unexpected**: NPI licensing in the "UE* part" *of* less-*comparatives*:

(14) there are **fewer** students than (there are) **profs I've *ever*$_{NPI}$ met**

Rullman: This pattern follows if there are two DE operators in the comparative clause:

(15) a. More [(there are) blue circles]^{UE} [than yellow circles]^{DE}

b. Fewer [(there are) blue circles]^{DE} [than yellow circles]$^{DE*DE(=UE)}$

Getting there: Heim (2006) as an example

(16) a. *fewer=little* + *many* + *–er*

b. *Little* is a negation

c. *–er* denotes a comparison between degree intervals, contains a negation

d. Elided parts of the *than*-part are copied from the matrix at LF

Sketchy LFs:

(17)

a. **More**:

[*–er* [than ∃d'/d'-many yellow circles][∃d/d-many blue circles]]

b. **Fewer**:

[*–er* [than *little* ∃d'/d'-many [yellow circles][*little* ∃d/d-many [blue circles]]

counting DE operators

(18)

a. **More**:

[–*er*^{DE} [than ∃d'/d'-many yellow circles][∃d/d-many blue circles]] ***=1*DE***

b. **Fewer**:

[–*er*^{DE} [than *little*^{DE} ∃d'/d'-many [yellow circles][*little*^{DE} ∃d/d-many [blue circles]]

=3*DE

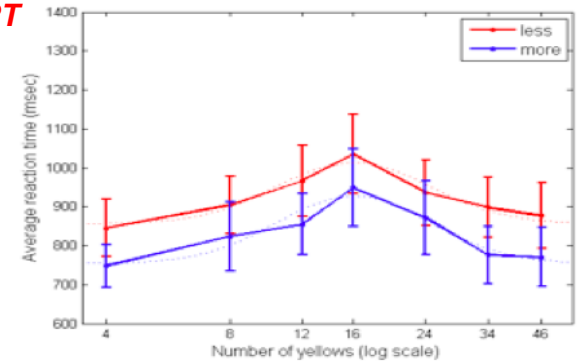
Reformulating the DEC effect

1. Assume that each DE operator contributes equally to processing cost. DEC is determined by *the number of DE-operators, n_{DE}, in a given LF*:

> ***DEC_{RT} effect (final):***
> $n_{DE}(LF_2) > n_{DE}(LF_1) \Rightarrow RT(LF_2) >^{sig} RT(LF_1)$.

2. The DEC effect can now be used to compare the number of DE operators (all else equal).

RT



3. The DEC effect might help us uncover hidden DE operators through RT patterns (e.g., where 2*n**DE =*n*UE).

4. In such cases, NPIs would be licensed in environments that appear UE due to an even number of DE operators.

DEC_{RT} effect (final):

$n_{DE}(LF_2) > n_{DE}(LF_1) \Rightarrow RT(LF_2) >^{sig} RT(LF_1)$.

- The DEC effect indexes the complexity of LF representations
- DEC is a complexity metric on LF representations metric quite unlike past metrics (e.g., DTC and related metrics)
- In the present case, DEC might help us uncover hidden DE operators through RT
  patterns (e.g., where 2*n**DE =*n*UE).
- In such cases, NPIs would be licensed in environments that appear UE due to an even number of DE operators.
- The present formulation is weak. It rank-orders LFs. On evidence, it could be strengthened, perhaps generalized to include other logical operators.

Coda: do "negative" antonyms evince a DEC effect?

A well-known problem concerns "negative" adjectives, which evince the same ambiguity, but not in every instance (a, b, may be true where c is false):

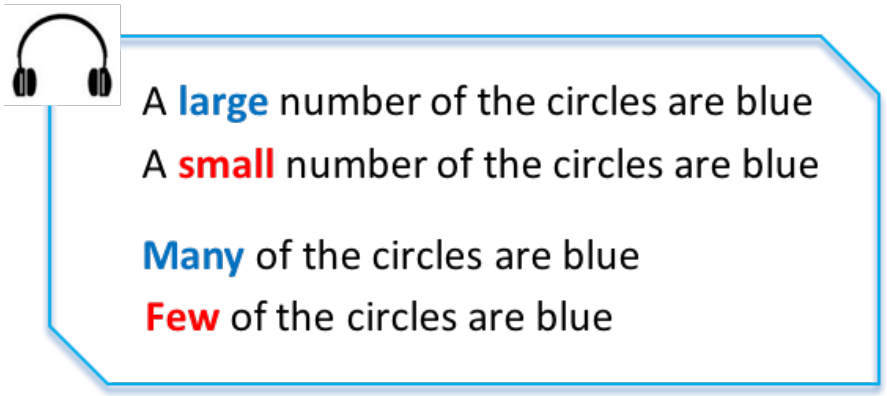
(19) a. Mary needs to drive slower than John needs to drive.

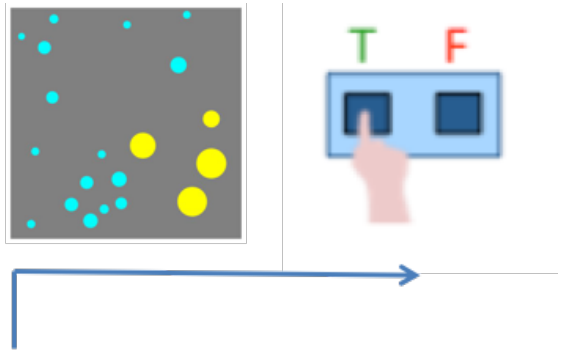
b. John needs to drive less fast than Mary needs to drive.

c. John needs to drive more slowly than Mary needs to drive.

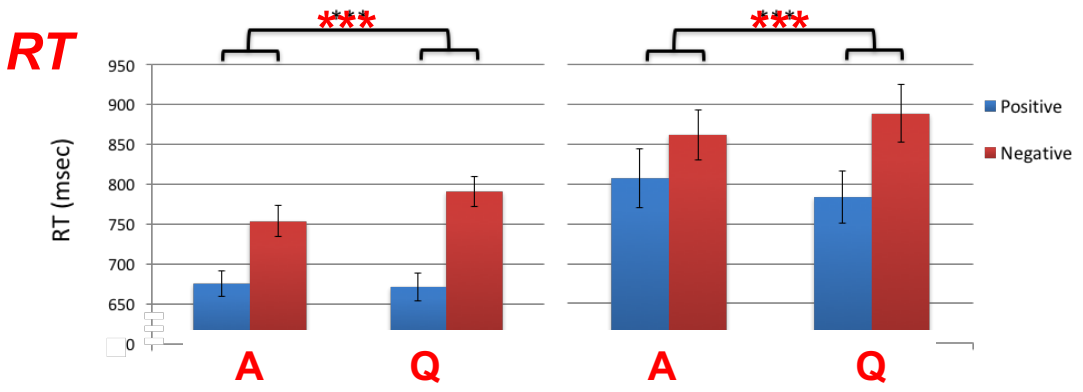
Judgments are difficult, but RT studies may offer a way to discern negative adjectives from DE quantifiers

A verification experiment with polar antonyms and quantifiers





				Polarity	
				Positive	Negative
Standard	Proportional comparison	Type	Quantifier	*More than half*	*Less than half*
			Adjective	*A high proportion*	*A low proportion*
	Cardinal comparison	Type	Quantifier	*Many*	*Few*
			Adjective	*A large number*	*A small number*



English
(cardinal comparison, auditory, time-limited response, N=32)

Hebrew
(cardinal comparison, auditory, non-time-limited response, N=30)

Summary: what we did and didn't tell you

We talked about

1. Verification with proportional quantifiers and proportions (PPP)
2. The DEC effect – a new LF complexity metric
3. Comparatives and hidden operators
4. The DEC effect as a way to uncover hidden DE operators
5. Possible differences between DE operator types

We did not talk about

1. Possible reasons for a DEC effect and the nature of verification
2. Possible connections between DE-ness and truth value

Difference in RT patterns when data is split by truth-value