Proportional and Superlative 'Most' in Visual Verification Tasks

Barbara Tomaszewicz

University of Cologne

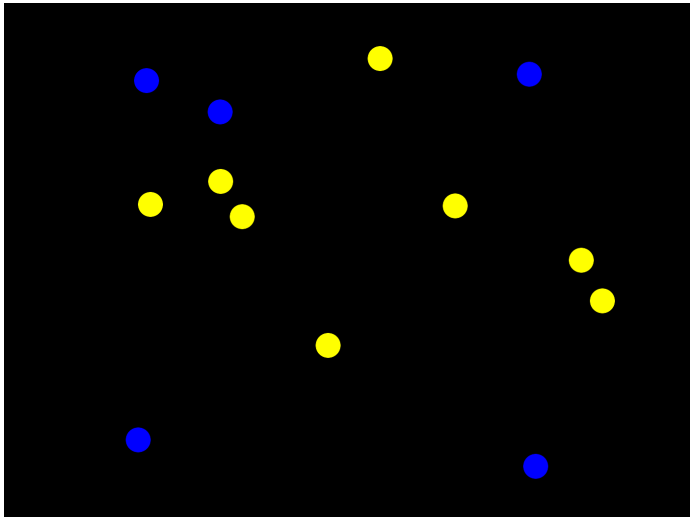
University of Wrocław

btomasze@uni-koeln.de

Outline

- Subtle details in the **semantics of Most** revealed in visual verification tasks:
- 'Proportional Most' vs. 'Superlative Most' in Polish and Bulgarian (Tomaszewicz 2013)
  - **Subtraction verification procedure** vs. **selection procedure** in the estimation of numbers of colored dots
- 'Superlative Most' and Only in Polish
  - **Sentence focus** guides visual inspection of alternatives

Proportional 'Most'



(1) **Most of the dots are yellow.**

(i) |Dot(x) & Yellow(x)| > ½ |Dot(x)|

(ii) |Dot(x) & Yellow (x)| > |Dot(x) & ~Yellow(x)|

(iii) |Dot(x) & Yellow(x)| > |Dot(x)| – |Dot(x) & Yellow(x)|

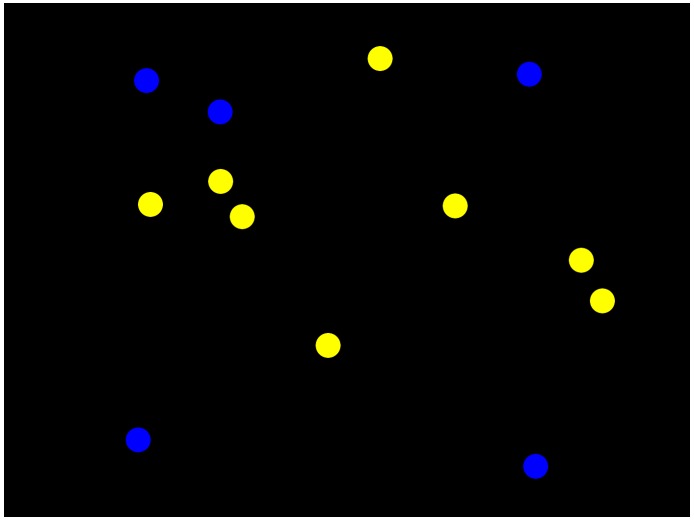
- What do speakers actually do to judge (1) as true/false?

  For any given **truth condition**, there are many distinct **verification procedures** that implement it (Pietroski et al. 2009: Marr's 1982 'level two') → Which procedure do speakers use in specific conditions?

- Lidz et al. 2011: The **meaning of a sentence** is more than just its truth conditions → it carries a "verificational weight", i.e. **biases speakers to use particular verification procedures**

Lidz, J., Pietroski, P., Halberda, J., & Hunter, T. (2011). Interface transparency and the psychosemantics of most. Natural Language Semantics, 19(3), 227-256.

Lidz et al. 2011



(1) Most of the dots are yellow.

Which is the relevant **mental representation** of the "proportional truth conditions" of (1) ?

(ii) |Dot(x) & Yellow (x)| > |Dot(x) & ~Yellow(x)|

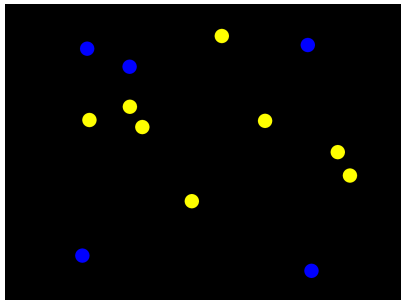
(iii) |Dot(x) & Yellow(x)| > |Dot(x)| – |Dot(x) & Yellow(x)|

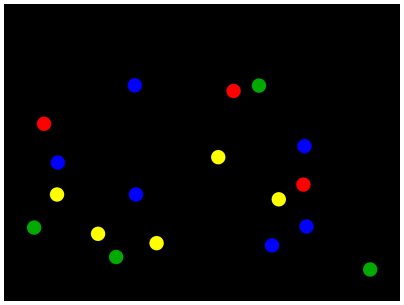
→ The one that can be **transparently mapped** into a **verification procedure**.

Visual verification task allowing only 2 procedures:

- direct **selection** of the non-yellow sets (based on ii)
- **subtraction** to obtain the non-yellow set (based on iii)

Lidz et al. 2011





(1) Most of the dots are yellow.

Visual verification task allowing only 2 procedures:

- direct **selection** vs. **subtraction** to obtain the non-yellow set

→ 150 ms presentation precludes counting (number approximation via ANS)

→ 2-5 color sets, varying ratios. Predictions:

→ Trials with 3-5 colors – **Subtraction** more accurate than **Selection**

A **heterogeneous** set is **not automatically** selectable.

Humans **automatically** compute the **total** number of dots and **two color subsets** (Halberda et al. 2006).

→ Trials with 2 colors – **Selection** more accurate than **Subtraction**

Participants could use the automatically obtained information to directly compare the two sets.

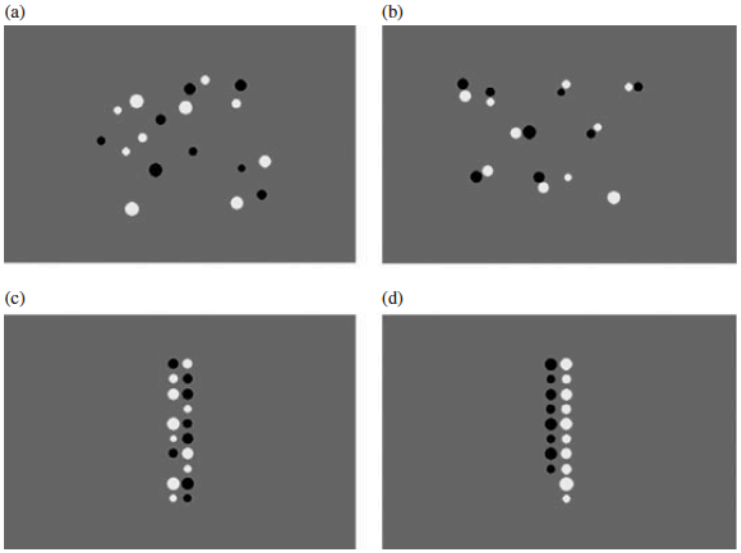
Halberda, J., Sires, S. F., & Feigenson, L. (2006). Multiple spatially overlapping sets can be enumerated in parallel. Psychological science, 17(7), 572-576.

Lidz et al. 2011

Trials with 2 colors:

- Participants could switch to **Selection** on **2 color trials**, because it would be **computationally less costly**.
- The visual system automatically obtains the numerosity of the 2 color sets (and the total) (Halberda 2006: See Appendix).
- In Pietroski et al. 2009, participants **switched** to a more **accurate** strategy on column sorted trials → in this task, different strategies are possible on trial-by-trial basis.

Subtraction (irrespective of no. of colors)	**Selection** two colors
1. Estimate **total**.	1. Estimate **yellow** set.
2. Estimate **yellow** set.	2. Estimate **non-yellow** set.
3. **Subtract** yellow from total.	3. **Compare** yellow and non-yellow.
4. **Compare** result with yellow.	



Pietroski, P., Lidz, J., Hunter, T., & Halberda, J. (2009). The meaning of 'most': Semantics, numerosity and psychology. Mind & Language, 24(5), 554-585.

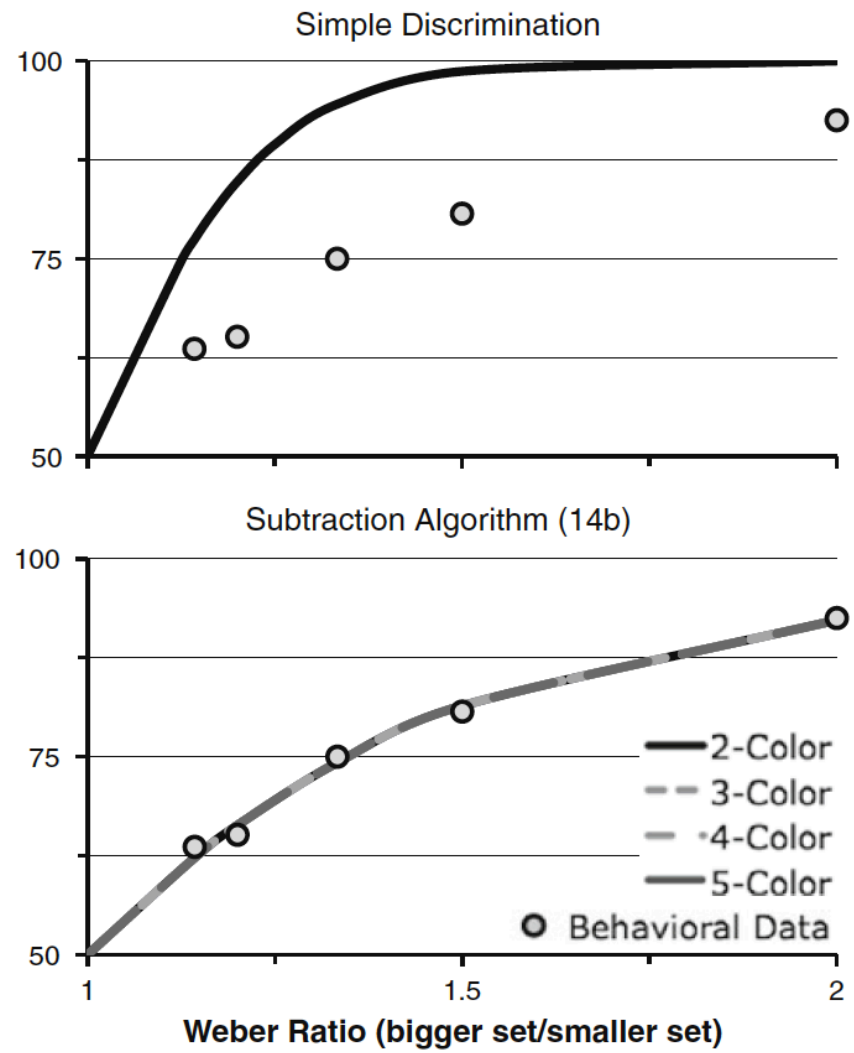
Lidz et al. 2011

Result: **Subtraction** was **always** used for the judgment of (1)

- **No difference in accuracy** as the function of **number of colors** of dots, but only as the function of the ratio (ANS signature).
- Accuracy was lower than predicted by a **psychophysical model** for a discrimination task (*Are there more yellow dots?*) and identical as predicted by the model for subtraction:

→ Participants are biased towards the **subtraction procedure**, because it directly computes the operation in the **mental representation** of (1):

|Dot(x) & Yellow(x)| > |Dot(x)| – |Dot(x) & Yellow(x)|



Tomaszewicz (2013)

- Lidz et al. 2011: "… if the relevant interface system **fails to use certain information that it automatically computes**, when faced with an evaluative task, then it becomes plausible that the **representation of the sentence must be responsible for such a failure** (cf. Kahneman and Tversky 1973)."

→ Find a **minimally different semantic representation** which would **require the use** of the same information!

→ My experiments on Polish and Bulgarian showed that participants use **Selection** on 2 color trials, when the sentence contains **Superlative 'Most'**

Tomaszewicz, B. (2013). Linguistic and visual cognition: Verifying proportional and superlative most in Bulgarian and Polish. Journal of Logic, Language and Information, 22(3), 335-356.

$\textbf{Most}_{\textbf{PROP}}$ and $\textbf{Most}_{\textbf{SUP}}$

(2) **Bulgarian**

a. Povečeto točki sa žəlti.
Most$_{PROP}$ dots.*Pl* are yellow.*Pl*
'**Most** dots are yellow.'

b. Naj-mnogo točki sa žəlti.
Most$_{SUP}$ dots.*Pl* are yellow.*Pl*
'Yellow dots are the **largest subset**.'

(3) **Polish**

a. Większość kropek jest żółta.
Most$_{PROP}$.*Nom.Sg* dots.*Gen.Pl* is yellow.*Nom.Sg*
'**Most** dots are yellow.'

b. Najwięcej jest kropek żółtych.
Most$_{SUP}$ is dots.*Gen.Pl* yellow.*Gen.Pl*
'Yellow dots are the **largest subset**.'

$[\![\text{Most}_{PROP}]\!] = \lambda D.\ \lambda Y.\ \#(D(x)\ \&\ Y(x)) > [\#(D(x)) - \#(D(x)\ \&\ Y(x))]$

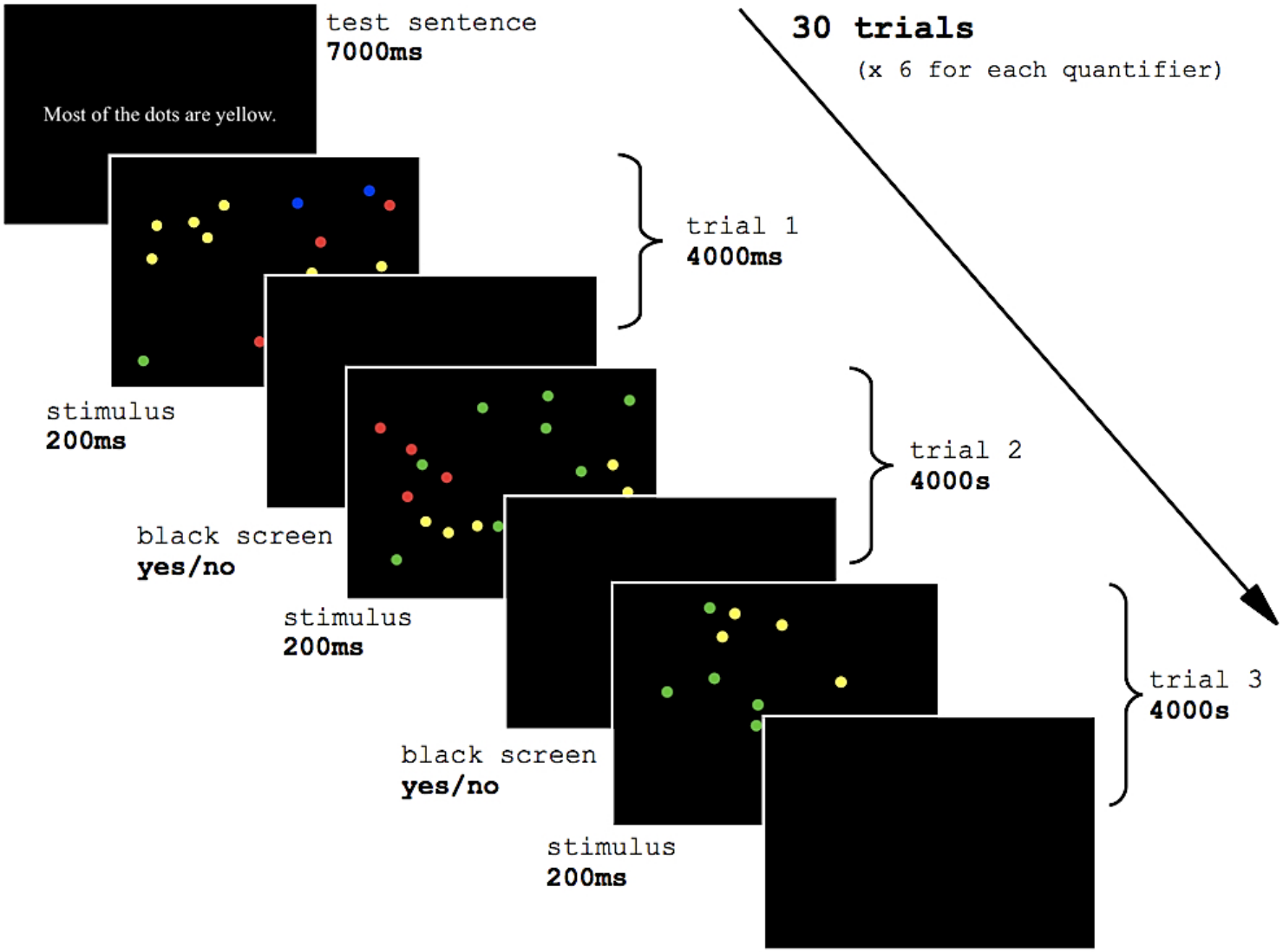
→ compatible with the **Subtraction** strategy

$[\![\text{Most}_{SUP}]\!] = \lambda K.\ \lambda D.\ \lambda Y.\ \forall C \in K\ [C \neq \lambda D.\ \lambda Y.(D(x)\ \&\ Y(x))] \rightarrow [\#(C) < \#(D(x)\ \&\ Y(x))]$

→ requires **Stepwise Selection** (of each color set in K)

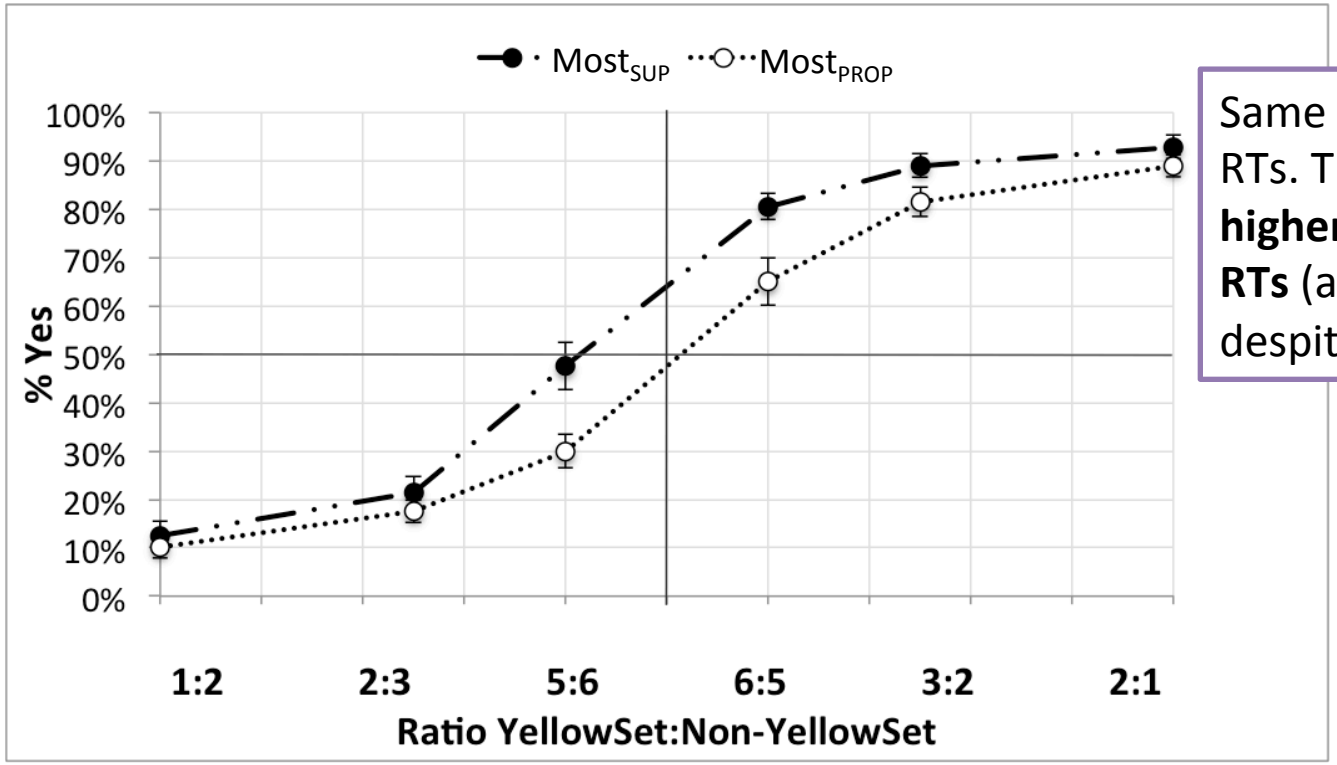
→ number of color sets should affect accuracy

Experimental setup: 2-4 color trials, 3 ratios, 2 separate blocks for each quantifier (in counterbalanced order) with 180 trials each



Trials with 2 colors

- Both Bulgarian and Polish participants were significantly **better with** ***Most***$_{SUP}$ than ***Most***$_{PROP}$ **on true screens**.
- On **false screens** ***Most***$_{PROP}$ significantly **better** than ***Most***$_{SUP}$.

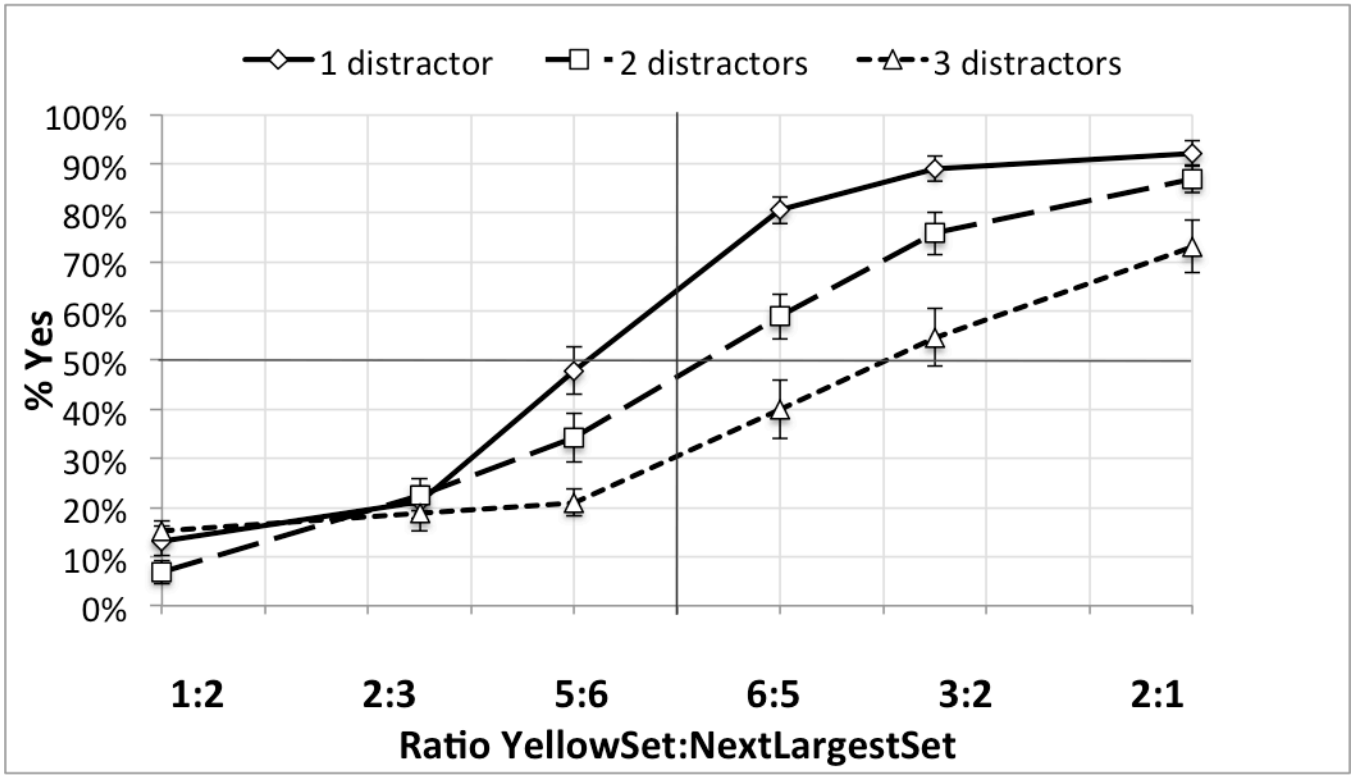


Same behavior wrt. RTs. The **accuracy is higher despite faster RTs** (and lower despite slower RTs)

Polish

$Most_{SUP}$

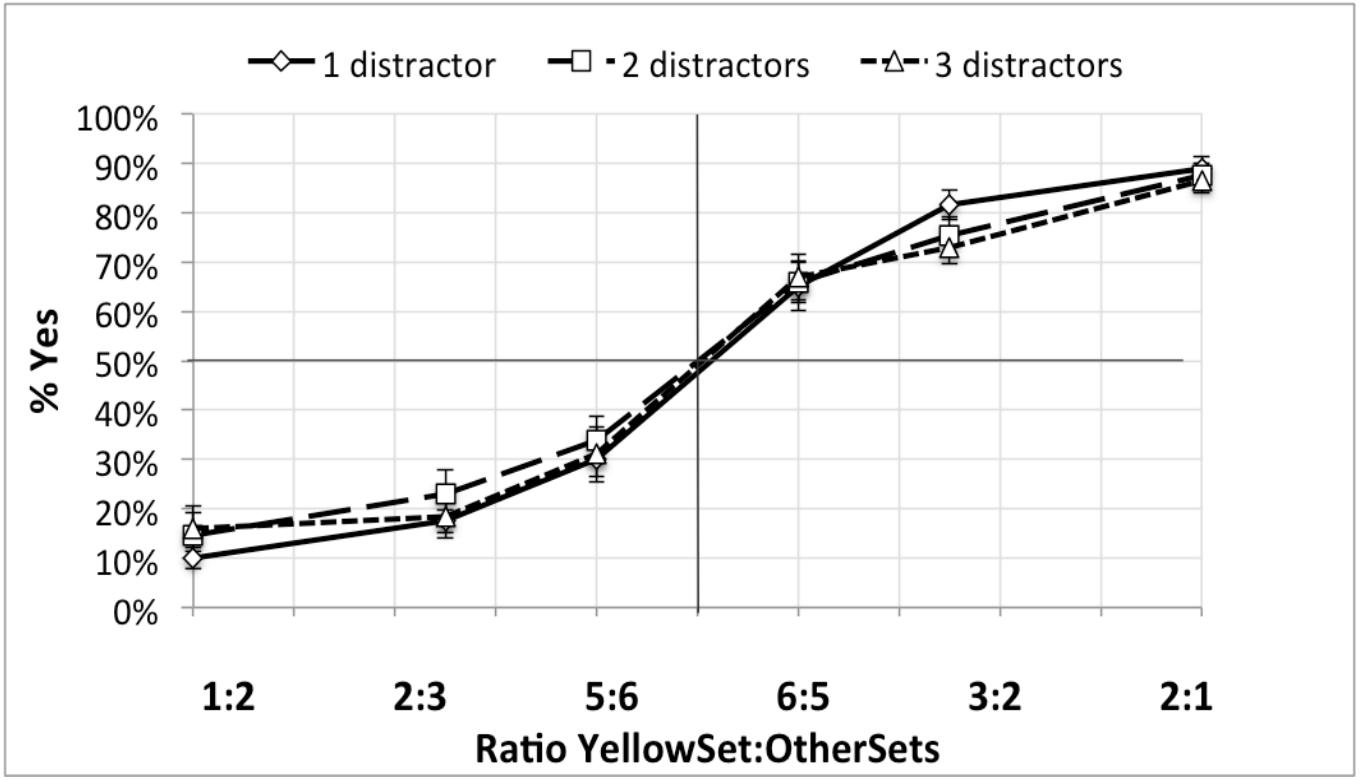
- ***Most***$_{SUP}$ is verified by **Selection**
- **accuracy** rates are significantly affected significantly affected **both** by **ratio** and **number of color sets**



Polish

$\text{Most}_{\text{PROP}}$

- ***Most*$_{\text{PROP}}$** is verified by a **Subtraction** strategy
- **accuracy** rates are affected only by **ratio**, and **not by number of color sets**



Polish

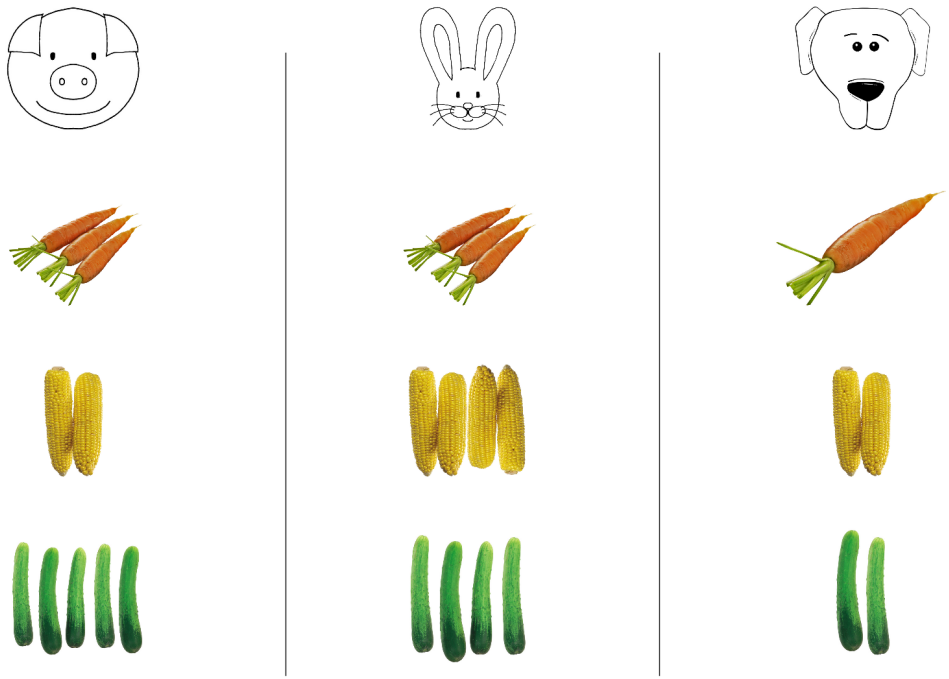
Visual Verification Tasks

- **Context** can favor the most efficient procedure (dot arrangement, Pietroski et al. 2009)
- Available **resources** (Limits on visual search for obtaining the cardinality: time constraints, number of color sets)
- **Linguistic input**

  the motivation for the subconscious switch in procedures is not to maximize efficiency, but to **obtain the information** from the visual scene **as instructed by the semantics of the quantifier**

The **semantics of Most$_{SUP}$** require a comparison set: its contents are determined by the **scope** of Most$_{SUP}$ and **focus association** → experimental evidence

Most$_{SUP}$ and selection of alternatives



(4) **The piglet ate the most cucumbers**.

'The piglet ate more cucumbers <u>than anybody else</u>.'

Polish:

(5) **Prosiaczek zjadł najwięcej ogórków**

piglet ate most$_{SUP}$ cucumbers

➡ 'The piglet ate more cucumbers <u>than anybody else</u>.'

➡ 'The piglet ate more cucumbers <u>than anything else</u>.'

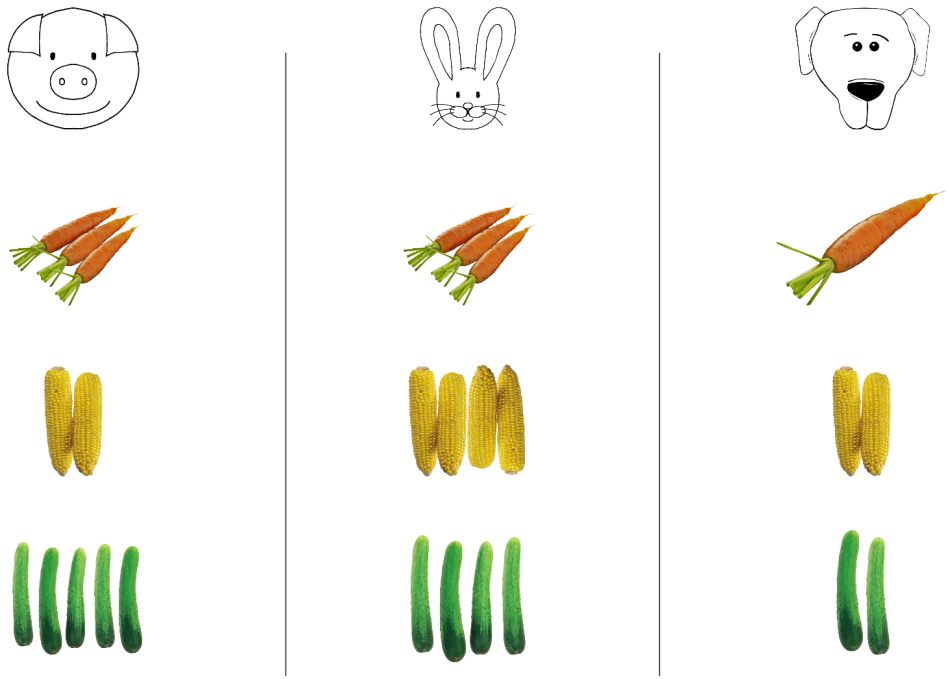
Focus determines the set of alternatives (Tomaszewicz 2015)

Most$_{SUP}$ and selection of alternatives

(6) **I only gave cucumbers to the piglet.**

➡ 'I gave cucumbers to the piglet <u>and nobody else</u>.'

➡ 'I gave piglet cucumbers <u>and nothing else</u>.'



Polish:

(5) **Prosiaczek zjadł najwięcej ogórków**

piglet ate most$_{SUP}$ cucumbers

➡ 'The piglet ate more cucumbers <u>than anybody else</u>.'

➡ 'The piglet ate more cucumbers <u>than anything else</u>.'

Focus determines the set of alternatives (Tomaszewicz 2015)

Focus alternatives in visual verification

Tomaszewicz 2015: In the absence of the definite determiner **Most$_{SUP}$ associates with focus** for the derivation of each reading of (5).

→ In a visual verification task, the identification of alternatives should proceed exactly parallel in the sentences with **Most$_{SUP}$** and ***Only***.

(single difference: number estimation)

Joint work with **Andreas Brocher** (University of Cologne). Funding: **Polish National Science** (NCN) OPUS 5 - HS2: Psycholinguistic investigations into number and quantification in natural language

Focus alternatives in visual verification

MATERIALS

In Polish, syntactic focus disambiguates (sentence final constituent receives the nuclear stress):

(7) **Najwięcej** ogórków zjadł [prosiaczek]$_F$.
most$_{SUP}$ *cucumbers ate piglet*
'The piglet ate more cucumbers than anybody else.'

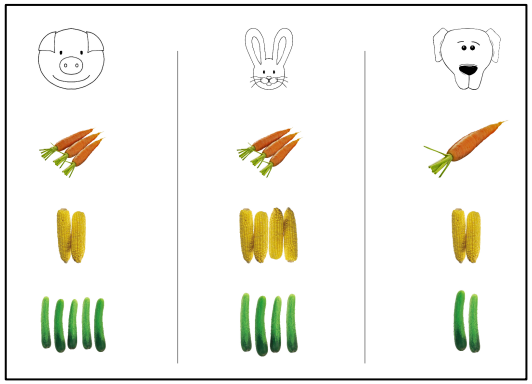
(8) **Najwiecej** prosiaczek zjadl [ogórków]$_F$.
most$_{SUP}$ *piglet ate cucumbers*
'The piglet ate more cucumbers than other veggies.'

(9) Ogórki zjadł **nie tylko** [prosiaczek]$_F$.
cucumbers ate ***not only*** *piglet*
'Not only the piglet ate cucumbers.'

(10) Prosiaczek zjadł **nie tylko** [ogórki]$_F$.
piglet ate ***not only*** *cucumbers*
'The piglet ate not only cucumbers.'

PRESENTATION

Sentence reading



(up to 10s)

Yes/No judgement

Syntactic complexity

Evidence for
focus association
= facilitation with
"special" (implicit)
prosody

MATERIALS

In Polish, syntactic focus disambiguates (sentence final constituent receives the nuclear stress, Appendix):

(7) **Najwięcej** ogórków zjadł [prosiaczek]$_F$.
most$_{SUP}$ *cucumbers* *ate* *piglet*
'The piglet ate more cucumbers than anybody else.'

Right Dislocation
special prosody

(8) Najwiecej prosiaczek zjadl [[ogórków]$_F$]$_{DP}$.
most$_{SUP}$ *piglet* *ate* *cucumbers*
'The piglet ate more cucumbers than other veggies.'

Left Branch Extraction
special prosody

(9) Ogórki zjadł **nie tylko** [prosiaczek]$_F$.
cucumbers *ate* ***not only*** *piglet*
'Not only the piglet ate cucumbers.'

Right Dislocation
special prosody

(10) Prosiaczek zjadł **nie tylko** [ogórki]$_F$.
piglet *ate* ***not only*** *cucumbers*
'The piglet ate not only cucumbers.'

Basic Word Order
neutral prosody

Predictions for RTs

Evidence for "focus association"

Option 1

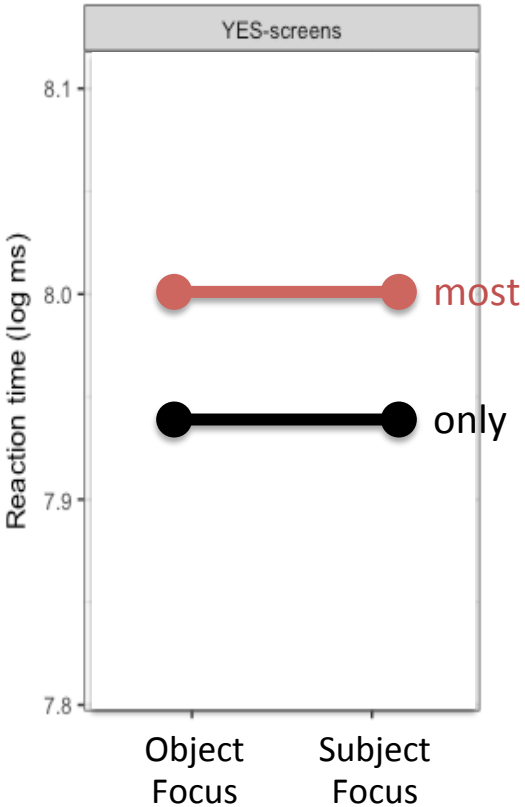
- No difference btw. **subject** and **object focus**.
- Number estimation takes longer.

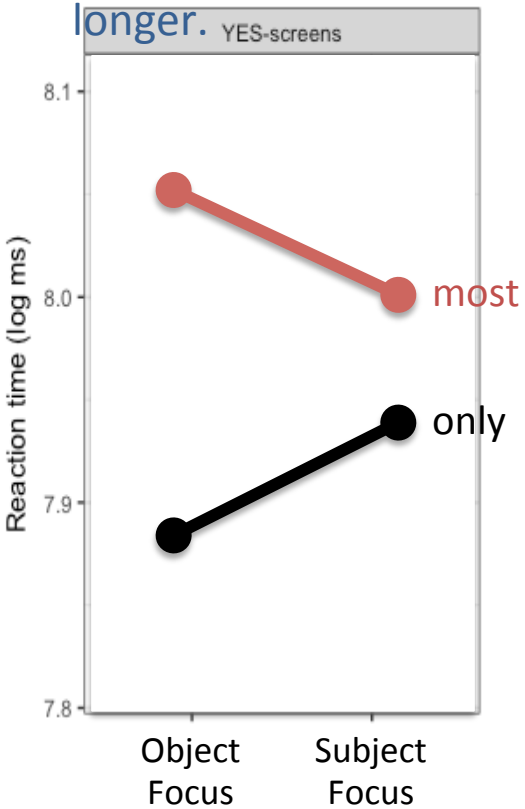
Option 2

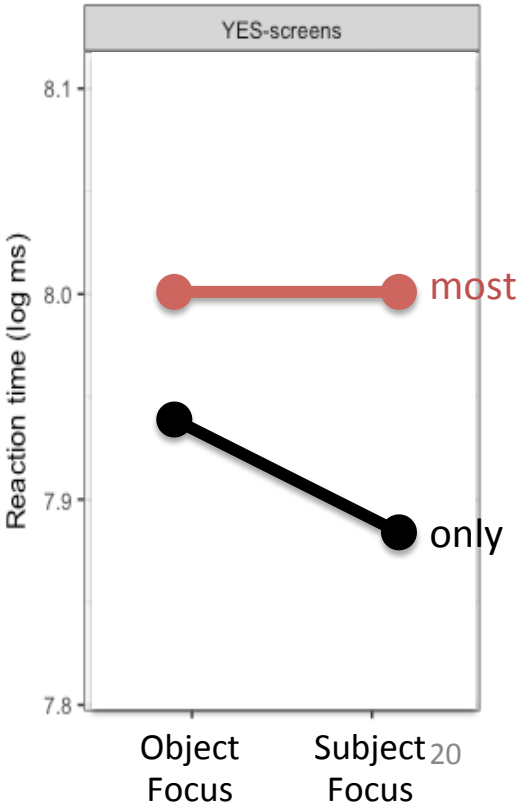
- Effect of **Syntactic complexity** (Left Branch Extraction > Right Dislocation > Basic Word Order)
- Number estimation takes longer.

Option 3

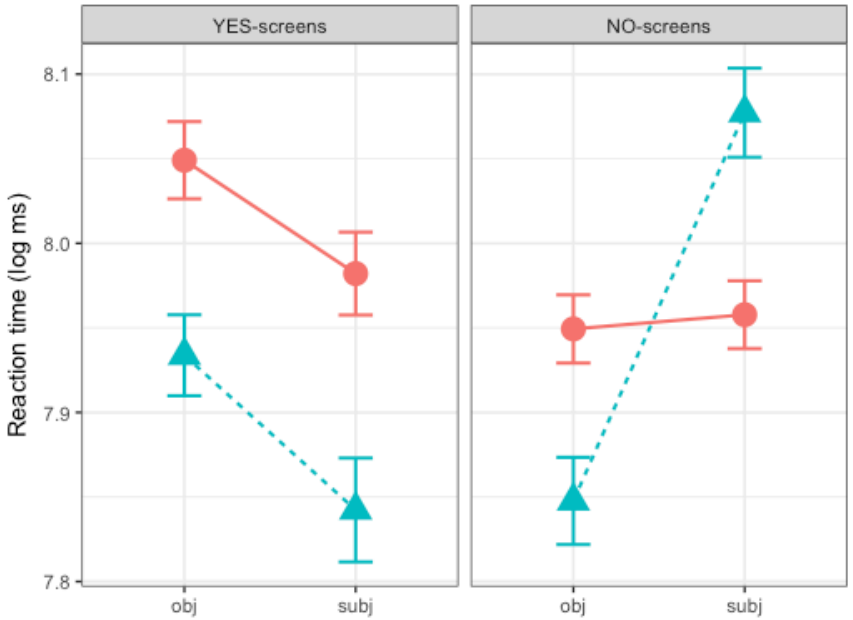
- **Dislocated focus** facilitates.
- Number estimation takes longer.

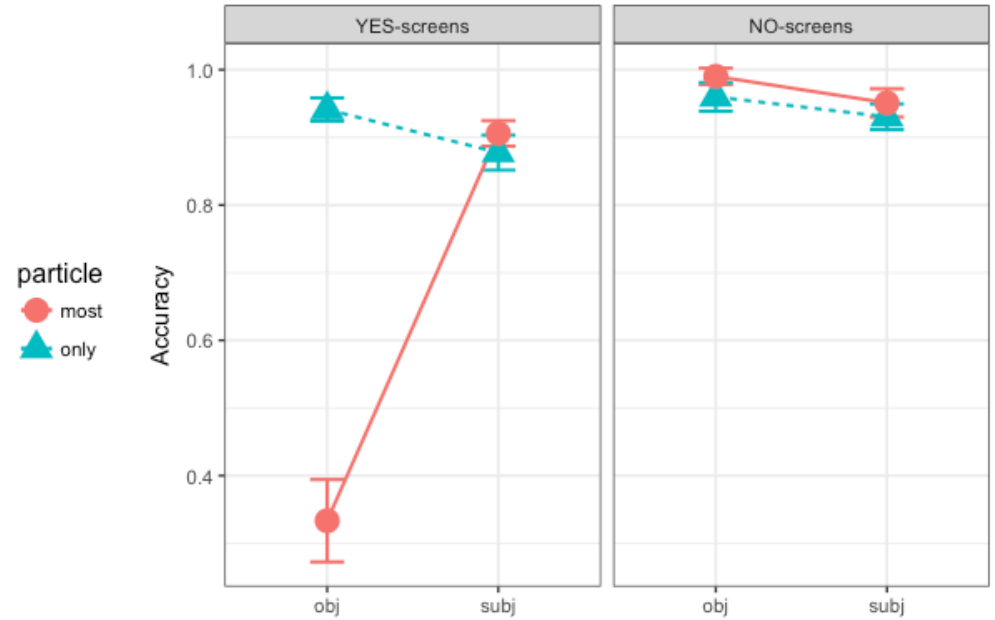






Results





YES-screens were the same for **Most** and **Only**

Only: Dislocated subject focus facilitates

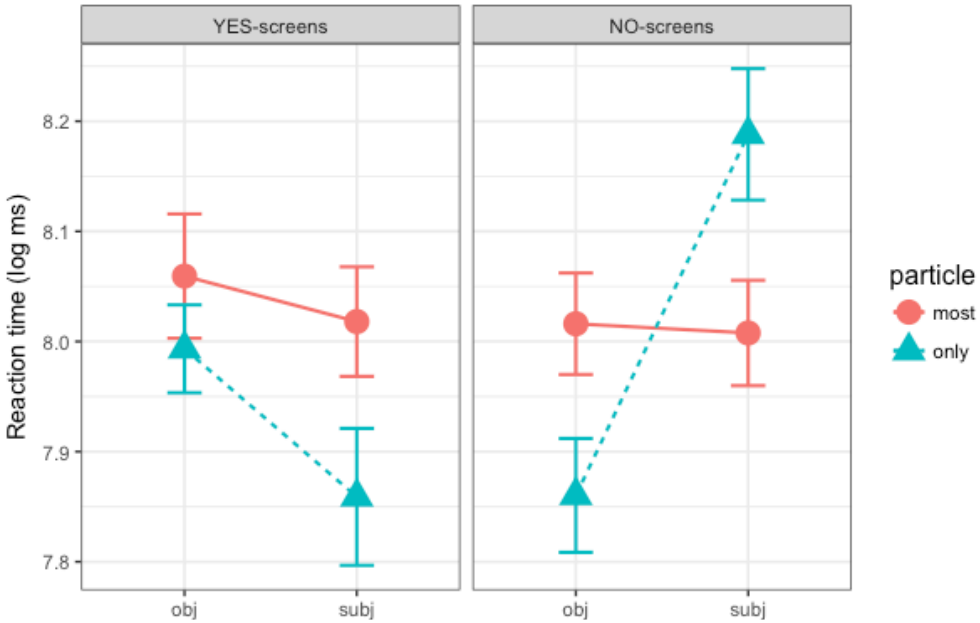
→ **advantage of syntactic focus marking** over syntactic complexity.

Most: Object focus with Left-Branch Extraction is difficult

→ **syntactic complexity despite unambiguous focus marking?**

The increase in RTs is simply due to wrong responses.

Results



Responses of participants who were correct on Object Focus Most screens (7 out of 34)

Only: Same as everyone else: Dislocated subject focus facilitates

→ **advantage of syntactic focus marking** over syntactic complexity.

Most: Object focus with Left-Branch Extraction is no more difficult than subject focus

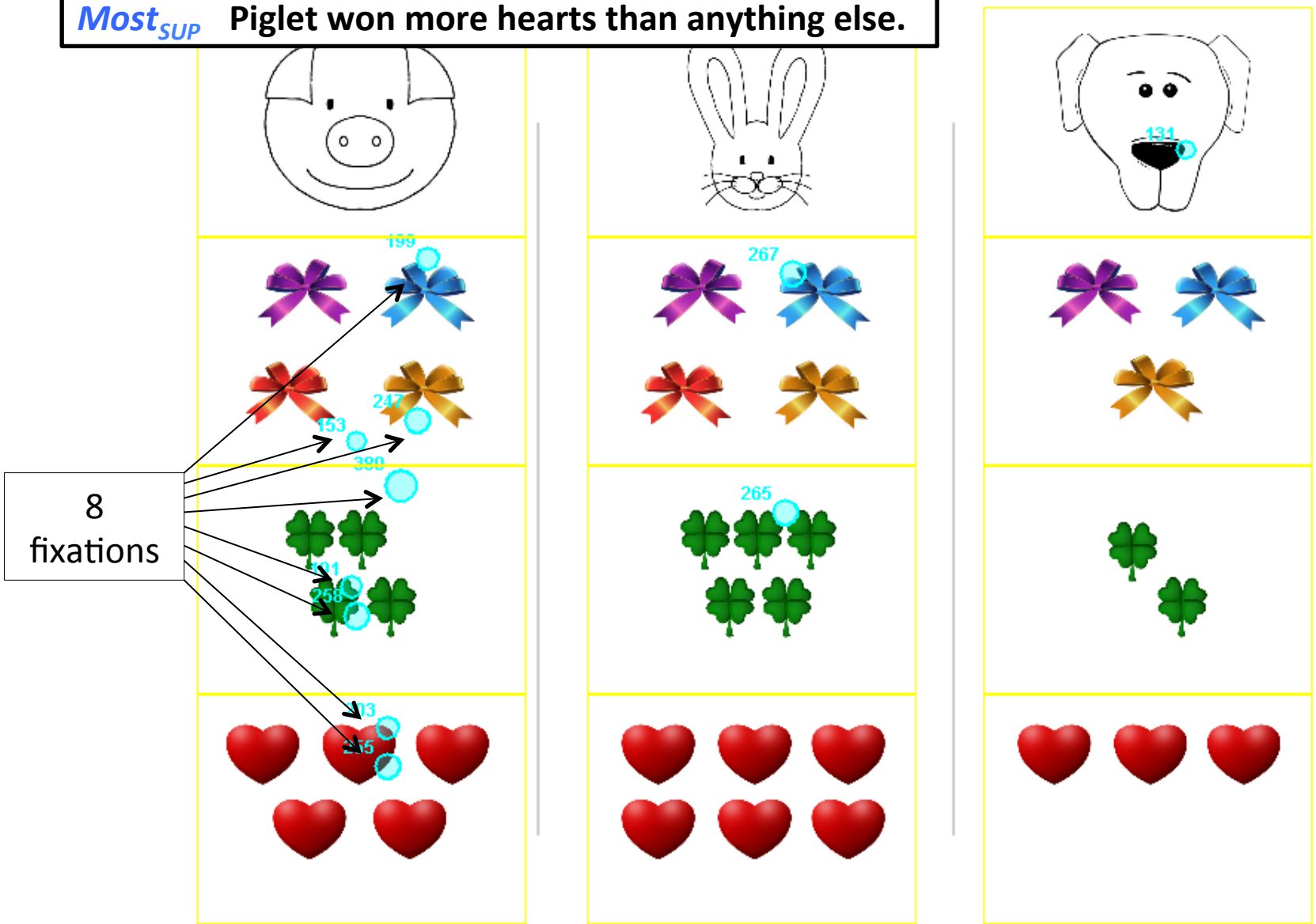
→ **advantage of syntactic focus marking** over syntactic complexity

→ **Evidence for number estimation with Most? Eye-movement patterns?**

Work in Progress

Signature for number estimation?

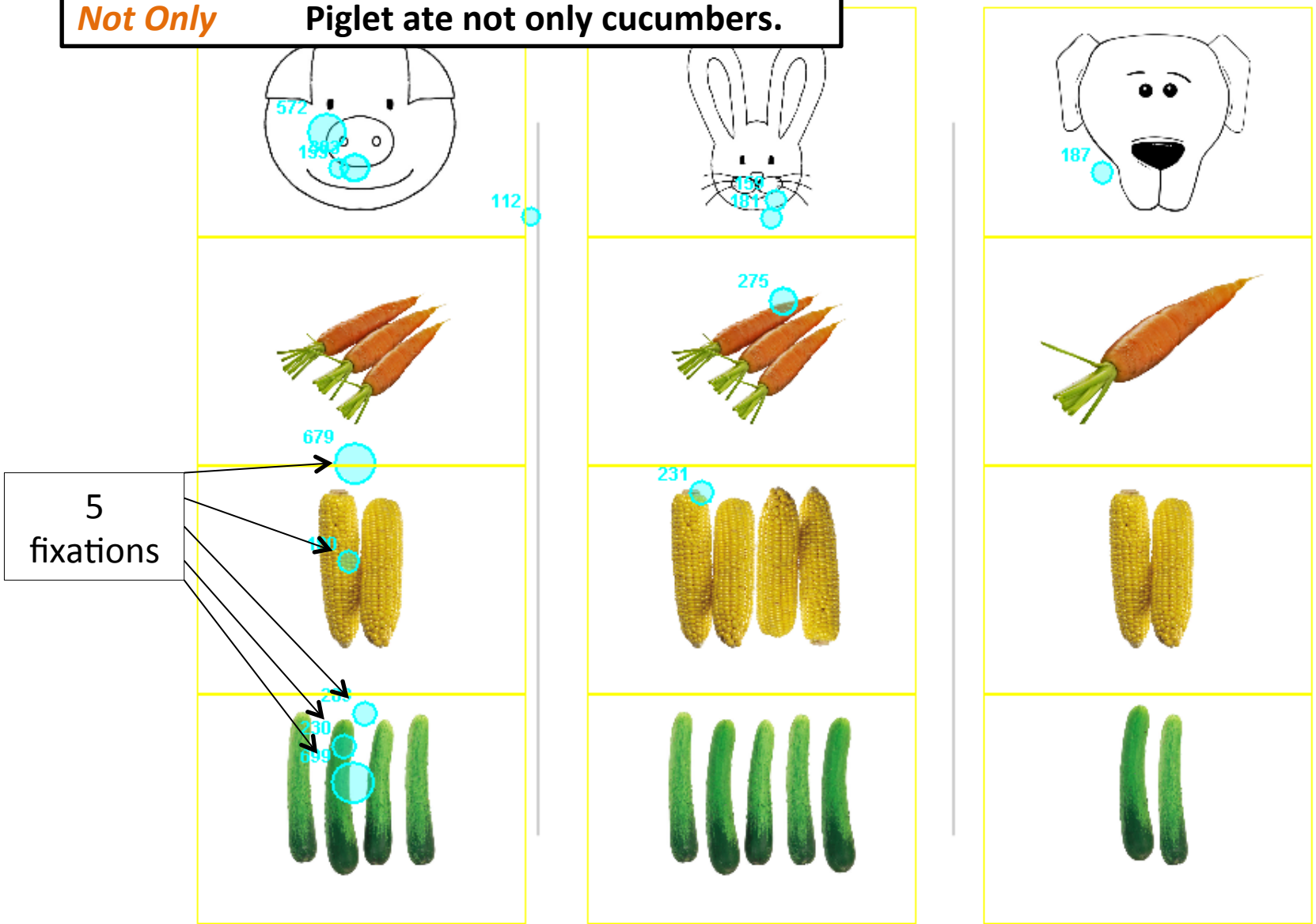
Most$_{SUP}$ **Piglet won more hearts than anything else.**



Work in Progress

Signature for number estimation?

Not Only **Piglet ate not only cucumbers.**



Conclusions

The results of visual verification experiments can add the kind of detail to semantic analyses that cannot be obtained using solely theoretical diagnostics.

- Experiments on **$Most_{PROP}$** and **$Most_{SUP}$** indicated that the way participants obtain **information from a visual scene** is driven by the **semantics of the quantifier**.

  (On the same 2 color screens participants use Selection with $Most_{SUP}$ and Subtraction with $Most_{PROP}$)

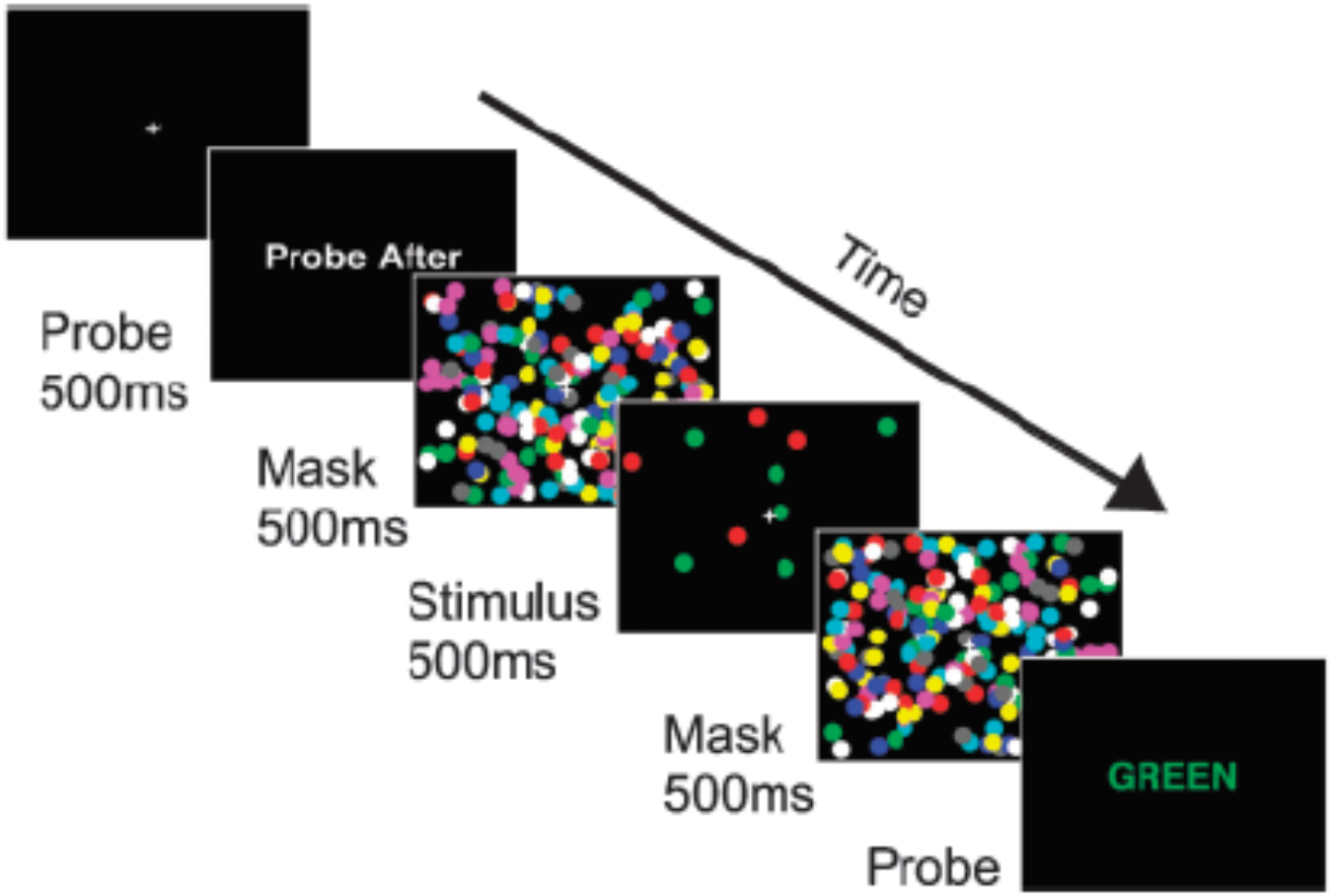
- Experiment on **$Most_{SUP}$** and **Only** provided evidence for **focus association** – focus facilitates identification of the alternative set in the display.

  (Implicit focus prosody due to syntactic displacement with Most and Only + Subject Focus, but not Only + Object Focus where no displacement)

Thank you!

Appendix Halberda et al. 2006

"human adults can select and enumerate items on the basis of shared color and can enumerate approximately **three color subsets** from a single glance" + the total set



Halberda, J., Sires, S. F., & Feigenson, L. (2006). Multiple spatially overlapping sets can be enumerated in parallel. Psychological science, 17(7), 572-576.

Appendix

Syntactic complexity & Focus projection

Evidence for
focus association
= facilitation with
"special" (implicit) prosody

MATERIALS

In Polish, syntactic focus disambiguates (sentence final constituent receives the nuclear stress):

(7) t_1 **Najwięcej** ogórków zjadł [prosiaczek$_1$]$_F$.
most$_{SUP}$ cucumbers ate piglet
'The piglet ate more cucumbers than anybody else.'

Right Dislocation
special prosody

(8) **Najwiecej$_1$** prosiaczek zjadl [$_{DP}$ t_1 [ogórków]$_F$].
most$_{SUP}$ piglet ate cucumbers
'The piglet ate more cucumbers than other veggies.'

Left Branch Extraction
special prosody

(9) t_1 Ogórki zjadł **nie tylko** [prosiaczek$_1$]$_F$.
*cucumbers ate **not only** piglet*
'Not only the piglet ate cucumbers.'

Right Dislocation
special prosody

(10) Prosiaczek zjadł **nie tylko** [ogórki]$_F$.
*piglet ate **not only** cucumbers*
'The piglet ate not only cucumbers.'

Basic Word Order
neutral prosody

Appendix
Syntactic complexity & Focus projection

Focus projection possible only in (10)

(7) **Najwięcej** ogórków zjadł [prosiaczek]$_F$.
most$_{SUP}$ *cucumbers ate piglet*
'The piglet ate more cucumbers than anybody else.'

Right Dislocation
special prosody

(8) **Najwiecej** prosiaczek zjadl [$_{DP}$ [ogórków]$_F$].
most$_{SUP}$ *piglet ate cucumbers*
'The piglet ate more cucumbers than other veggies.'

Left Branch Extraction
special prosody

(9) Ogórki zjadł **nie tylko** [prosiaczek]$_F$.
cucumbers ate ***not only*** *piglet*
'Not only the piglet ate cucumbers.'

Right Dislocation
special prosody

(10) [$_{CP}$Prosiaczek [$_{VP}$ zjadł [$_{DP}$**nie tylko** [$_{NP}$ogórki]$_{F1}$]$_{F2}$]$_{F3}$]$_{F4}$.
piglet ate ***not only*** *cucumbers*
'The piglet ate not only cucumbers.'

Basic Word Order
neutral prosody