

SFB 1102

A5: Distributing referential information across modalities



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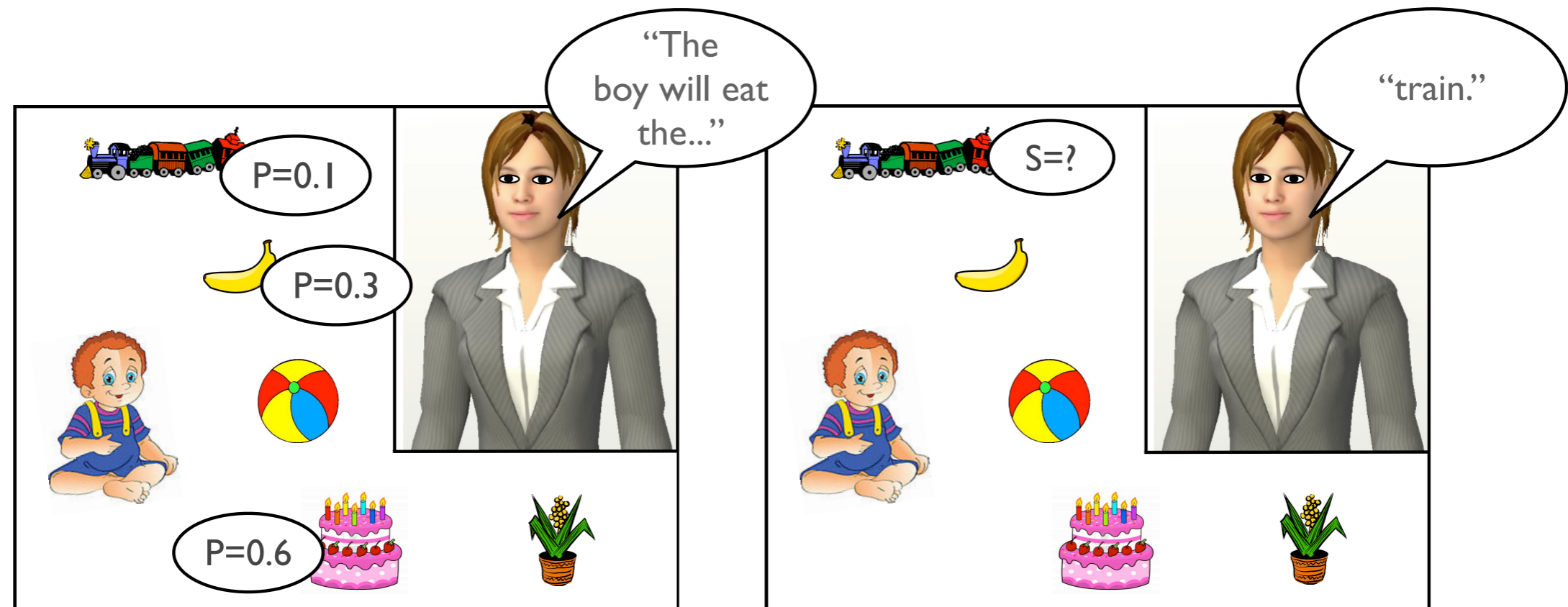


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SS16 - (Embodied) Language Comprehension

Maria Staudte

Prediction & Surprisal



time →

Prediction

Surprisal

Reasoning

- Understanding information -> cognitive load
- Less predictable input -> higher cognitive load
- Surprisal (Hale 2001) reliable linking function between predictability and cognitive load
- But: Readings times (indexing cognitive load) also correlate with Entropy Reduction (Frank 2013)

Sample Stimulus

| | | |
|-------------------------------------|-----------|--|
| | t-Shirt | <i>“plausible”</i> |
| The woman irons soon the | sock | <i>“possible”</i> |
| | arm chair | <i>“anomalous” or “sanity check”</i> |
| | t-Shirt | |
| The woman describes soon the | sock | <i>“possible”</i> |
| | arm chair | |

Classical measures of cognitive load

Plausibility Ratings,
Cloze

Reading
self-paced

Lexical Decision

Reading
eye-tracked

Offline Pre-Tests II

Forced choice cloze task

- **Instructions:** „Im Folgenden findest du unvollständige Sätze. Deine Aufgabe ist es, spontan und ohne zu lange darüber nachzudenken das Objekt aus den Optionen auszuwählen, das dir am passendsten erscheint, um die Lücke zu ersetzen.“

Die Frau bügelt gleich _____*

- die Socke
- den Sessel
- das T-Shirt
- den Käse
- die Fernbedienung
- das Bett

| anomalous | less plausible | plausible |
|-----------|----------------|-----------|
| 0.4% | 13% | 84% |

Self-paced reading: per word

Die | Frau | bügelt | gleich | das | T-shirt | in | der | Washküche. |

- design: 2 (verbs) x 3 (objects)
- 36 experimental sentences; 36 fillers
- each filler sentence illustrated a highly predictable context; followed by a simple yes/no content question
- 30 participants; (7 male); age ranging from 20 to 32 ($M = 24$)
- Button press: Reaction Times

Eye-tracking

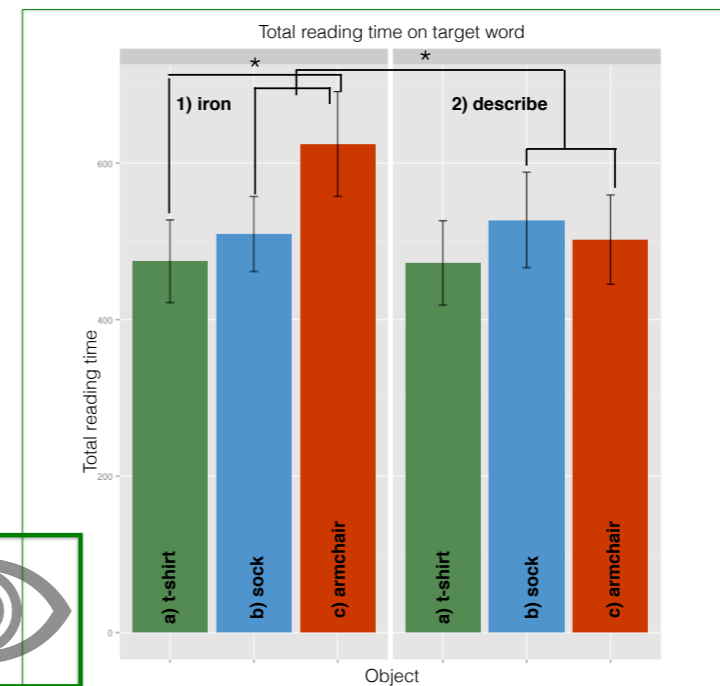
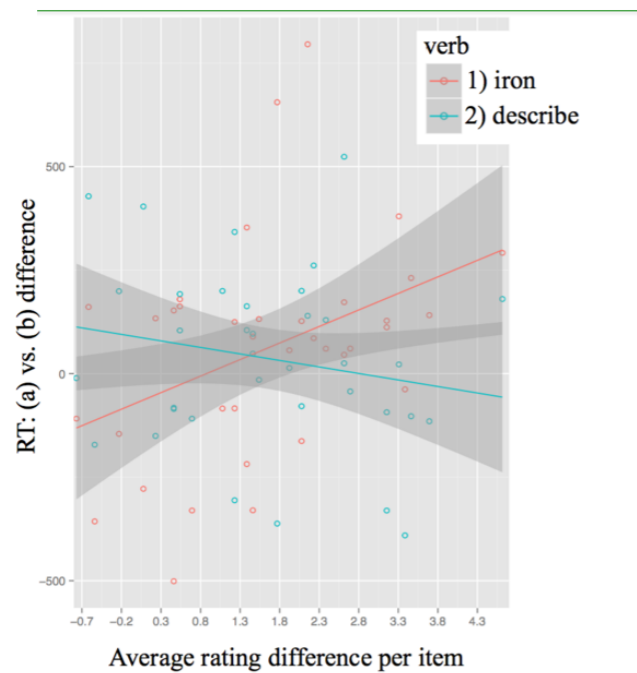
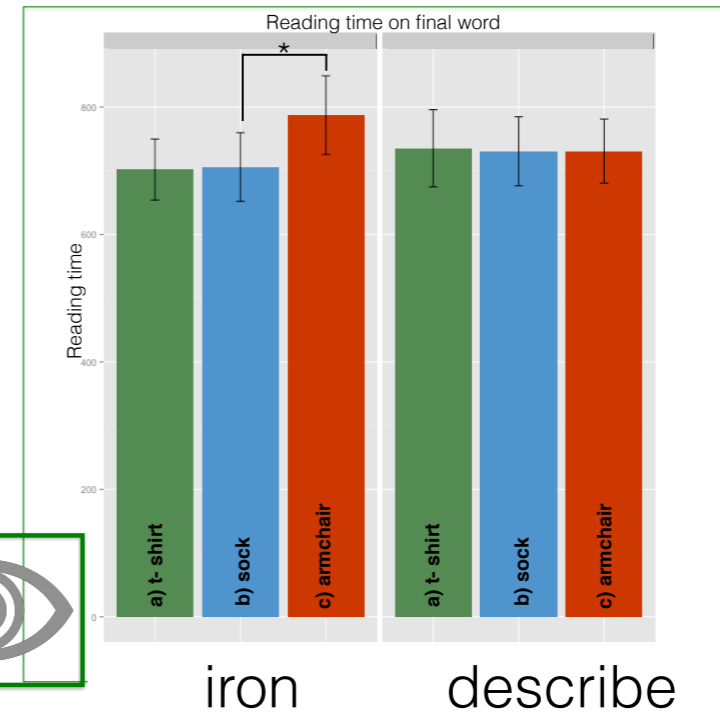
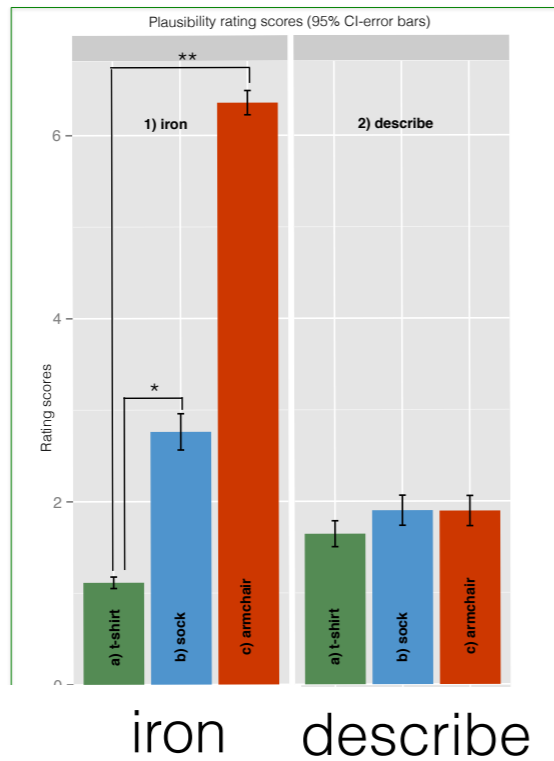
- 25 participants; 8 men; age ranging from 18 to 34 ($M = 23.16$, $SD = 4.49$)
- SR Research EyeLink 1000+
- 35 filler sentences; simple yes/no content questions
- First-pass / total reading times

Auditory Lexical Decision Task

Die Frau bügelt gleich - [500ms] - das T-shirt.

- audio stimuli, LDT on the target word
- 24 participants; 4 male; age ranging from 18 to 36 ($M = 24$, $SD = 4.43$)
- Button press -> reaction time

Classical measures of cognitive load



Sample Item & Pretests

| Item | noun | condition | plausibility <i>M (SD)</i> | cloze probability% <i>M (SD)</i> |
|----------------------------------|-------------|-----------|-------------------------------|-------------------------------------|
| (1) The woman irons soon the | a) t-shirt | plausible | 1.12 (0.68) ↑ | 13.67 (18.06) ↑ |
| | b) sock | possible | 2.76 (2.17) ↑ | 0.16 (00.54) ↑ |
| | c) armchair | anomalous | 6.35 (1.43) | <.01 |
| (2) The woman describes soon the | a) t-shirt | possible | 1.65 (1.50) | NA |
| | b) sock | possible | 1.90 (1.80) | NA |
| | c) armchair | possible | 1.89 (1.78) | NA |

Introducing ICA

Cognitive Load during language processing

describe = iron
iron sock = describe sock

ICA during language processing

ICA during language processing in visual context

Visual Context & CL - Studies:

Aim: quantifying the role of visual context in creating predictions about linguistic items

- Same set of linguistic stimuli (German)
 - 2 Experiments (AUDIO & VIS)
 - Comprehension task

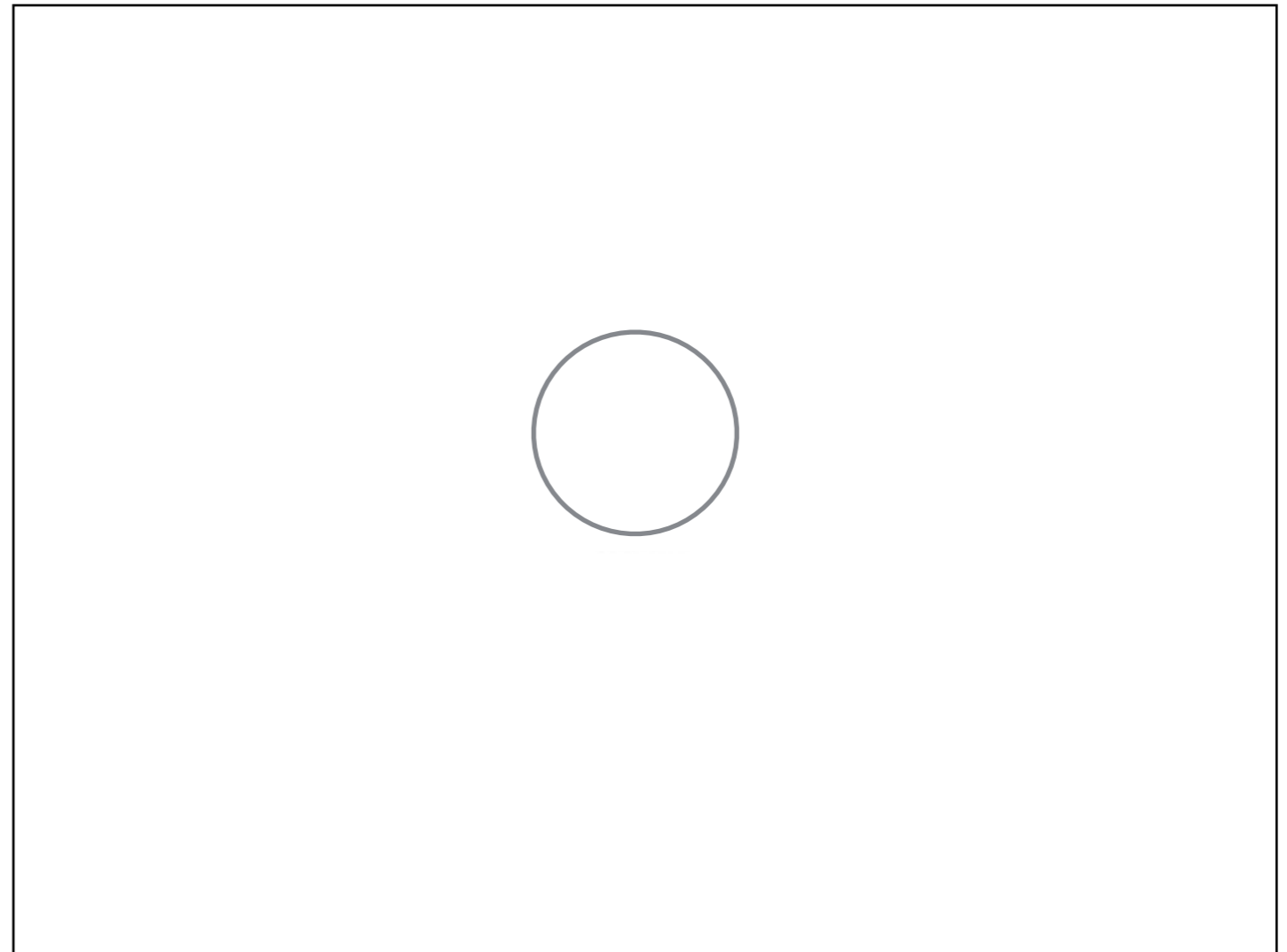


1. Audio ICA study



Method

- Eye Link II, 250 HZ, binocular
- 36 students (20 female)
- aged 19 to 46 years ($M = 24.72$)
- 20 items, 4 conditions
- audio only
- Stimuli presentation: whole sentence + 2000ms break (The woman irons soon the t-shirt _____ 2000ms break.)
- Dependent measure: **ICA events per 100ms from EACH eye**



2. Visual ICA study



Method

- Eye Link II, 250 HZ, binocular
- 36 students -> data from 34
- aged 19 to 38 years ($M = M = 23.25$)
- 20 items, 4 conditions
- audio only
- Stimuli presentation: visual set 1000 ms in advance /whole sentence + 2000ms break (The woman irons soon the t-shirt _____ 2000ms break.)
- Dependent measure: ICA event per 100ms, new inspections



Cloze & “Entropy”

| | | predictability | entropy | | predictability | entropy |
|---------------|----------------|----------------|-------------------------------|-----------------|----------------|-----------------------------|
| | <i>iron</i> | | | <i>describe</i> | | |
| audio | | | | | | |
| | <i>t-shirt</i> | 13.67% | 1/some <u>with</u> | <i>t-shirt</i> | 0% | 1/many <u>no</u> |
| | <i>sock</i> | 0.16% | competitor | <i>sock</i> | 0% | competitor |
| visual | | | | | | |
| | <i>t-shirt</i> | 94.84% | 1/2 | <i>t-shirt</i> | 25% | |
| | <i>sock</i> | 5.16% | 1/2 <u>with</u> competitor | <i>sock</i> | 25% | 1/4 <u>no</u> competitor |
| | <i>d1</i> | 0% | . | <i>d1</i> | 25% | |
| | <i>d2</i> | 0% | . | <i>d2</i> | 25% | |

Audio

Audio study



Audio study

The woman



Audio study

The woman

irons

describes



Audio study

The woman

irons

soon

describes



Audio study

The woman

irons

soon

describes

[iron = describe]

600ms



Audio study

The woman

irons

soon the

t-shirt.

sock.

describes

t-shirt.

sock.

[iron = describe]

600ms



Audio study

The woman

irons

soon the

t-shirt.

[sock = t-shirt ?]

sock.

describes

t-shirt.

[sock = t-shirt]

sock.

[iron = describe]

600ms

600ms



Visual

Visual study



Visual study

The woman



Visual study

The woman

irons

describes



Visual study

The woman

irons

soon

describes



Visual study

The woman

irons

soon

describes

[iron = describe?]

600ms



Visual study

The woman

irons

soon the

t-shirt.

sock.

describes

t-shirt.

sock.

[iron = describe?]

600ms



Visual study

The woman

irons

soon the

t-shirt.

[sock > t-shirt]



sock.

describes

t-shirt.

[sock = t-shirt]

sock.

[iron = describe?]

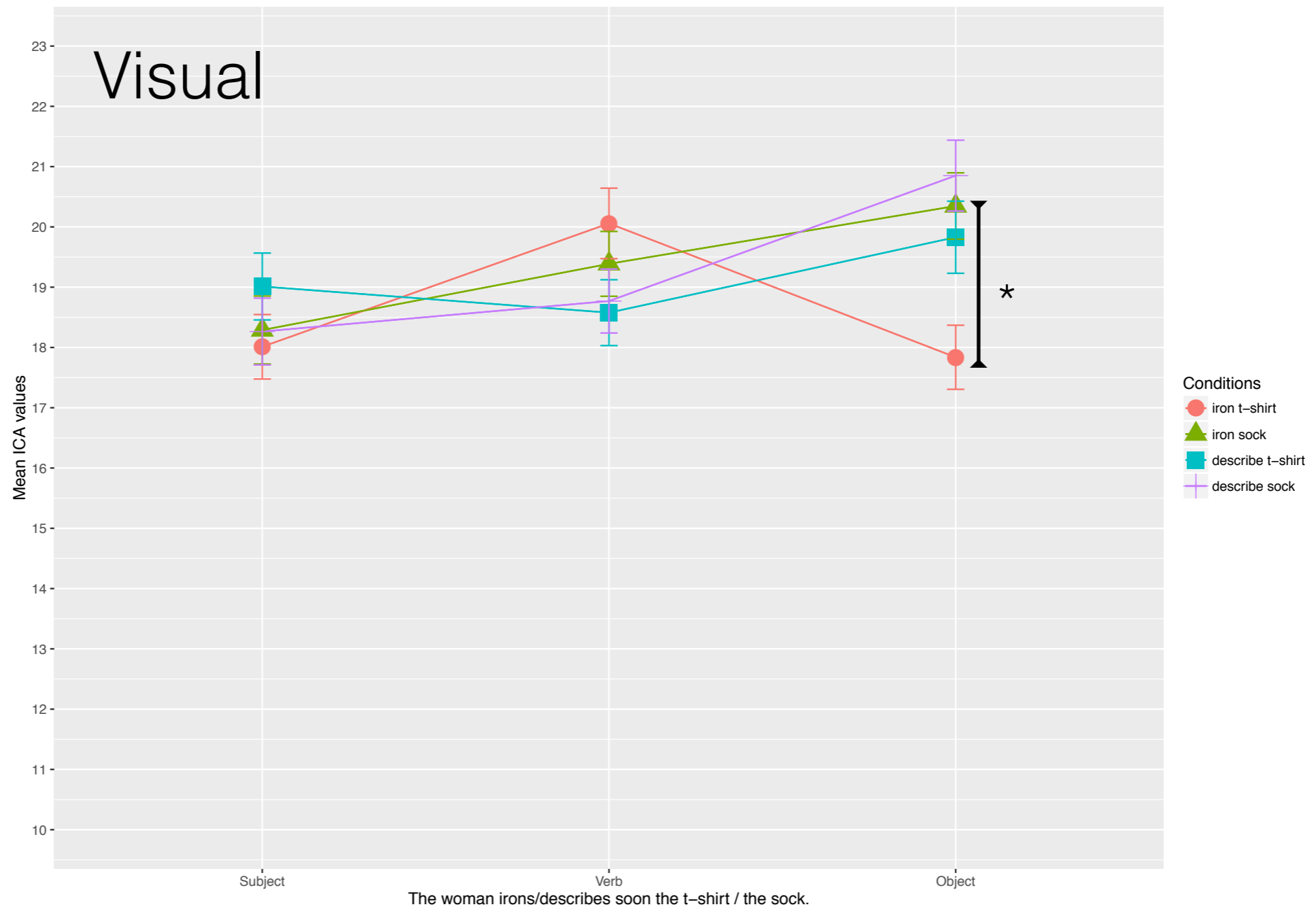
600ms

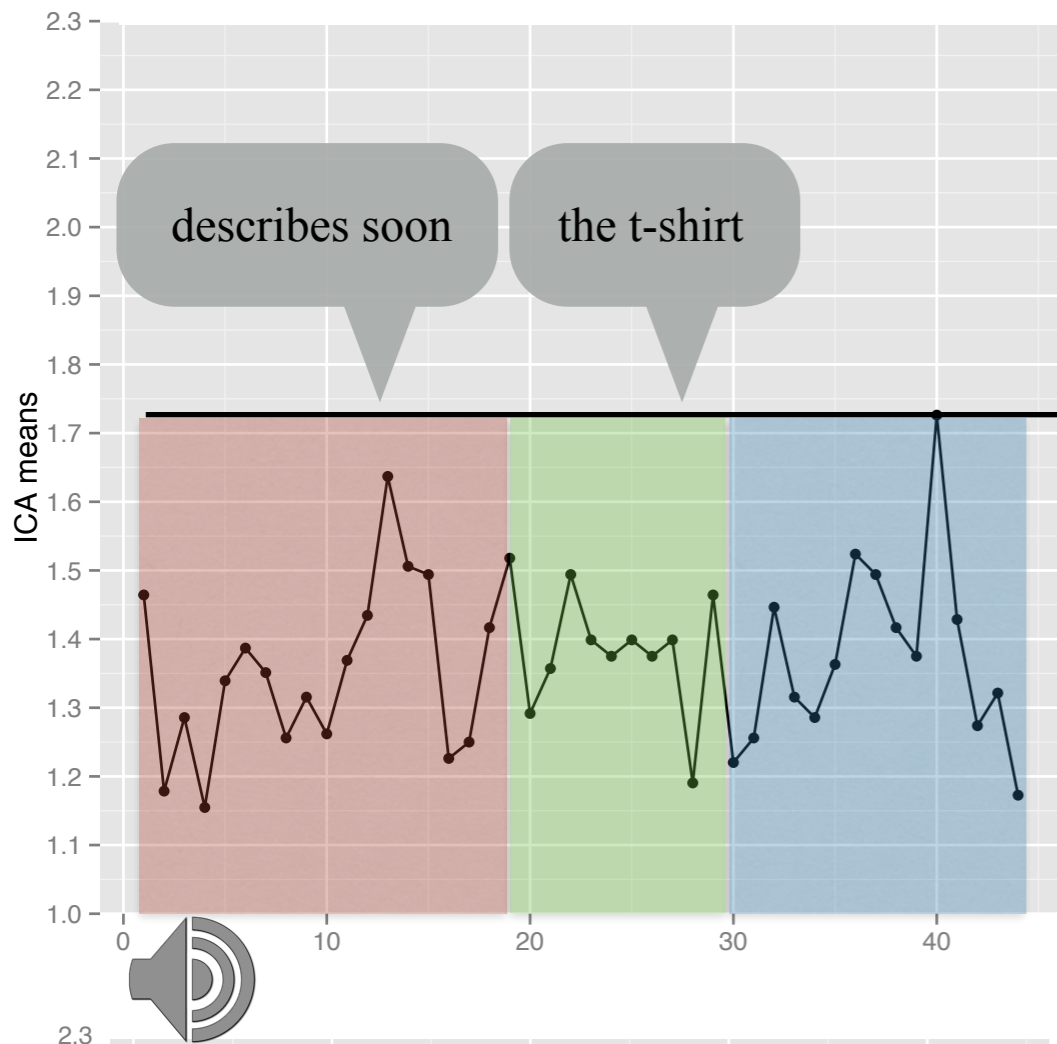
600ms



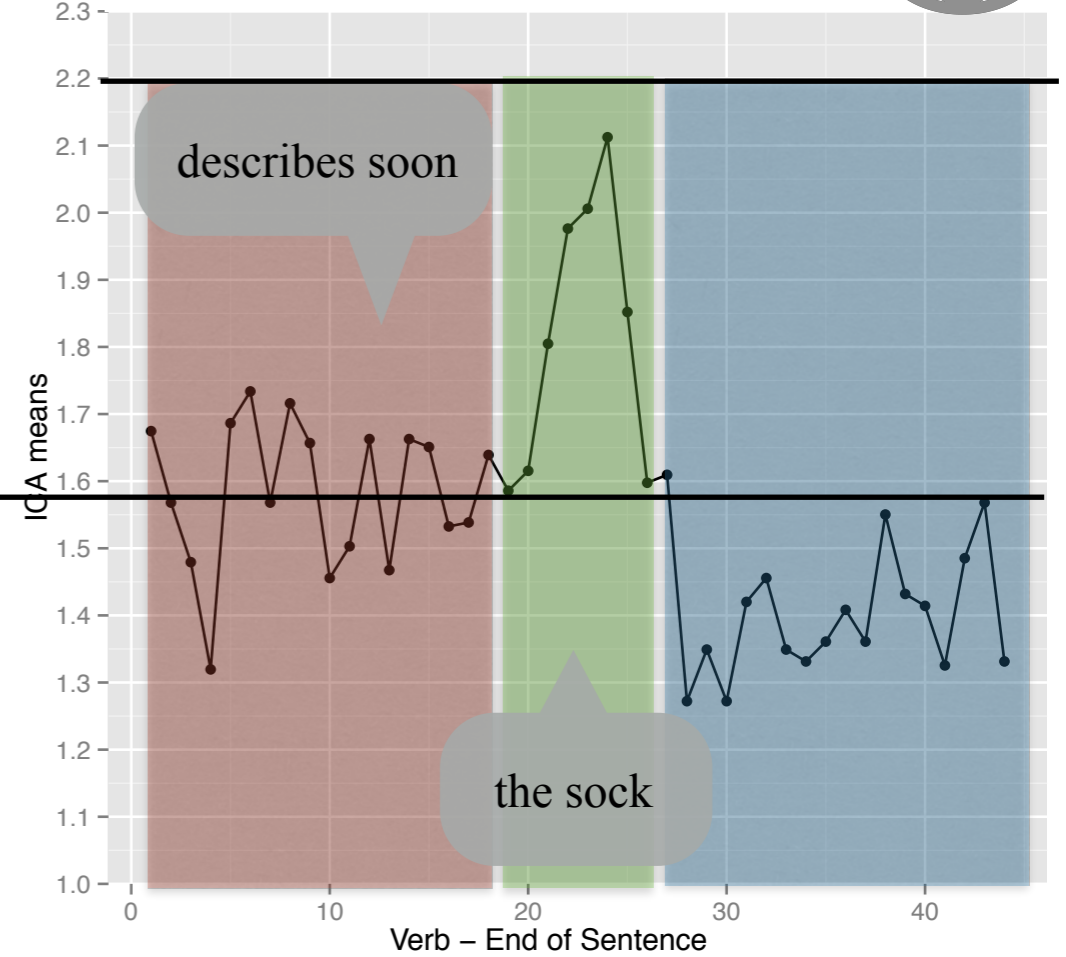
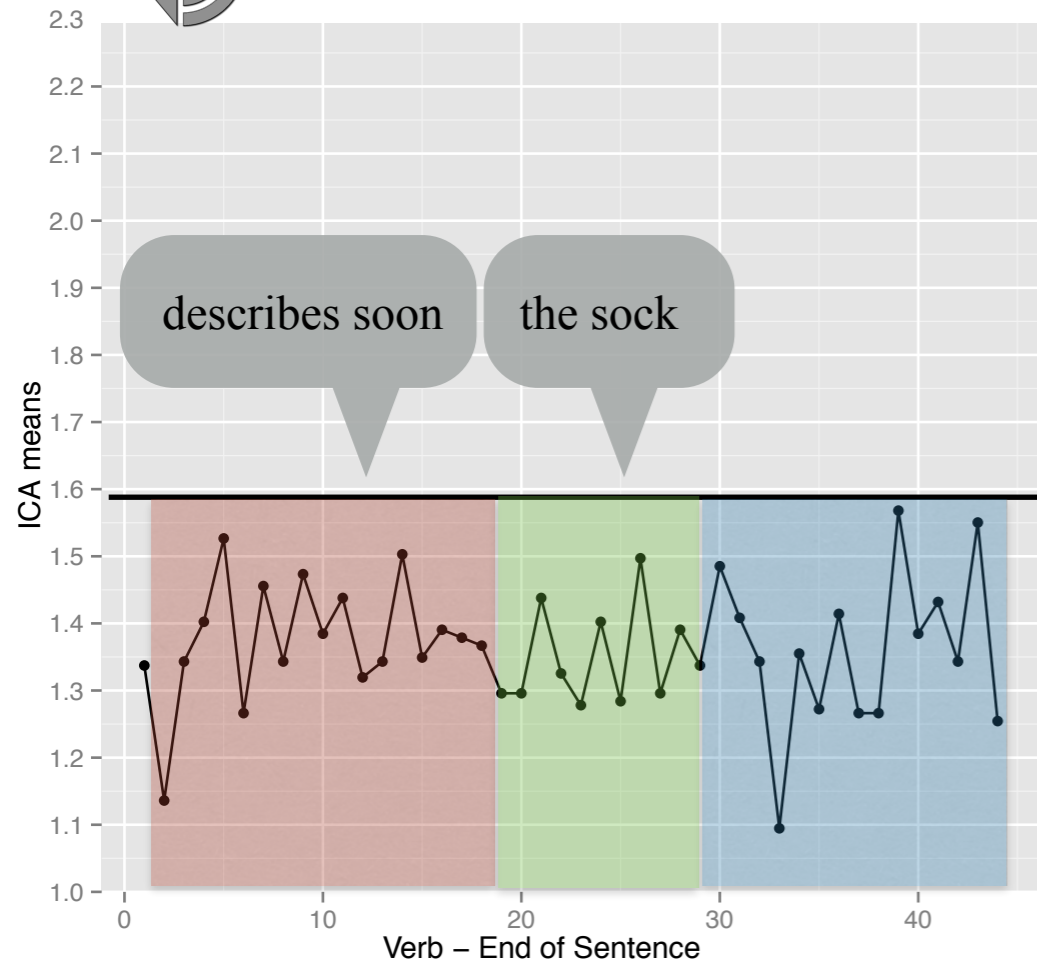
study comparison

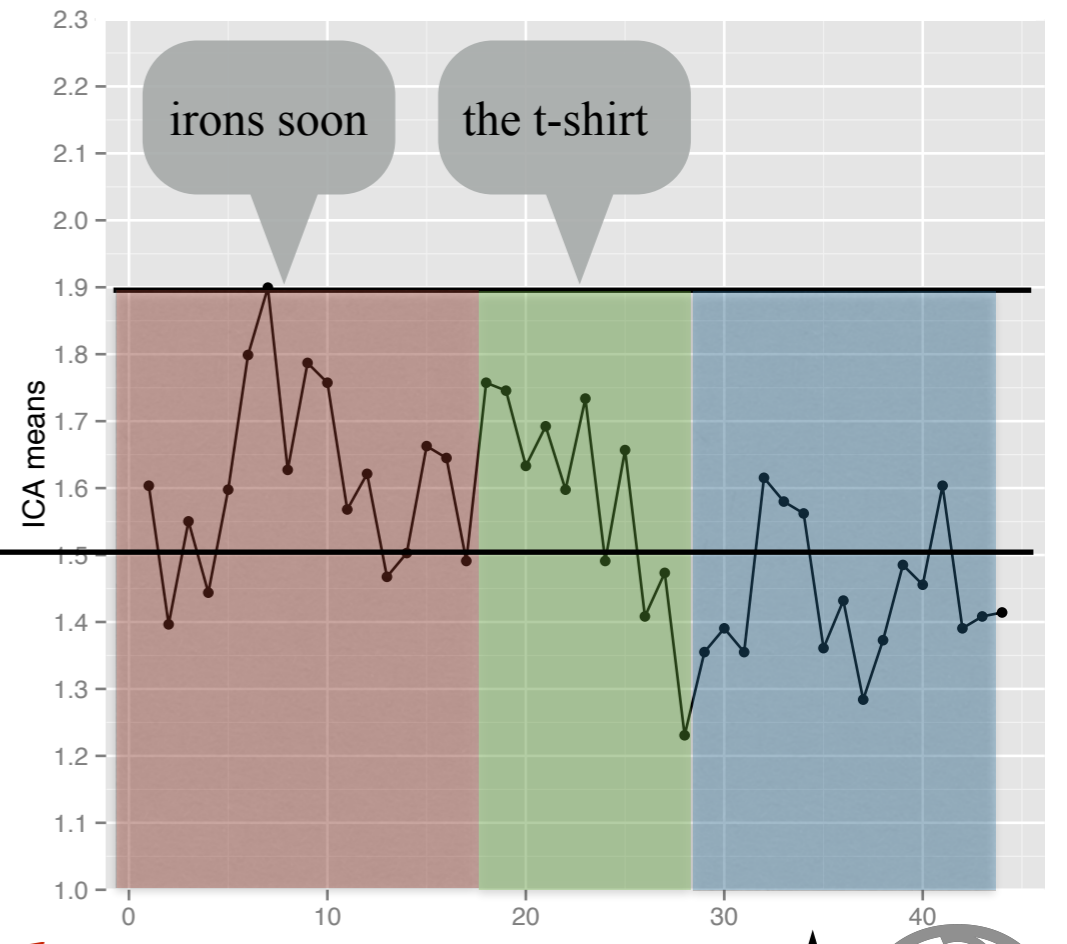
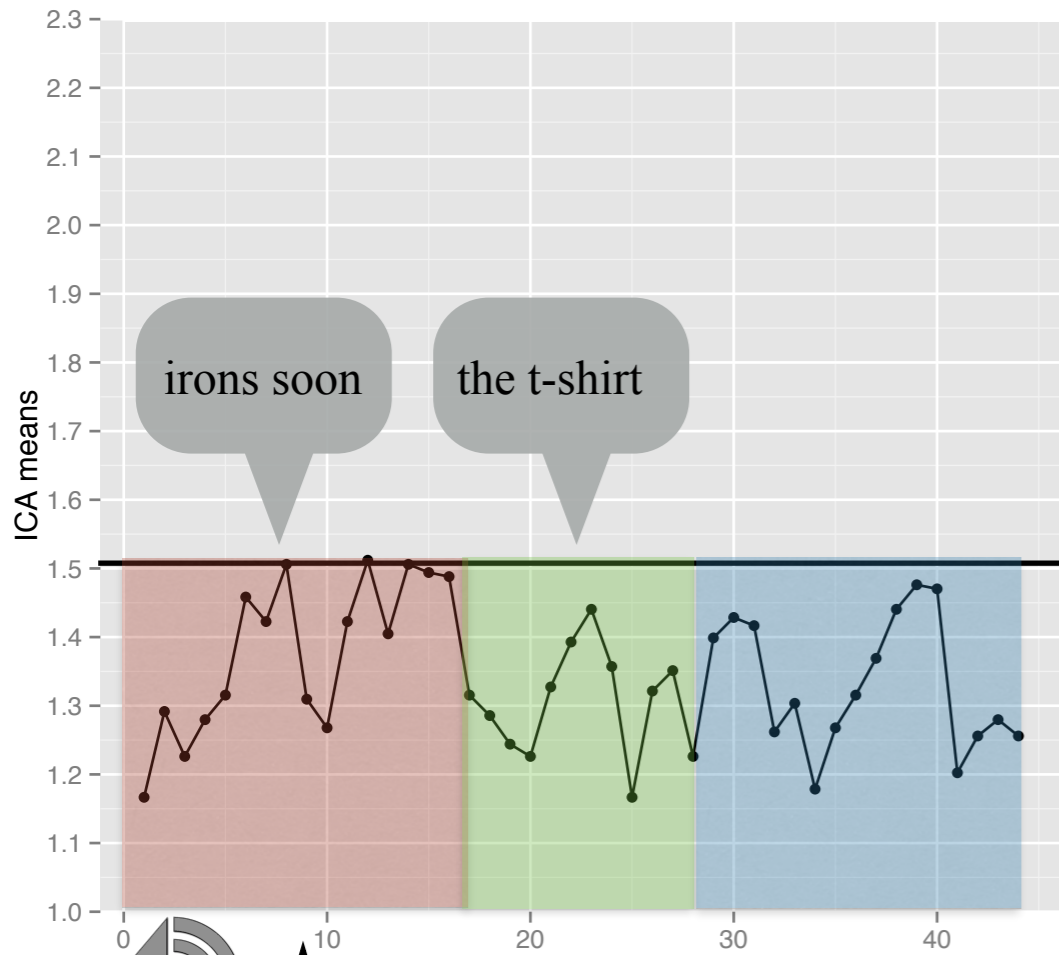
Surprisal (noun)





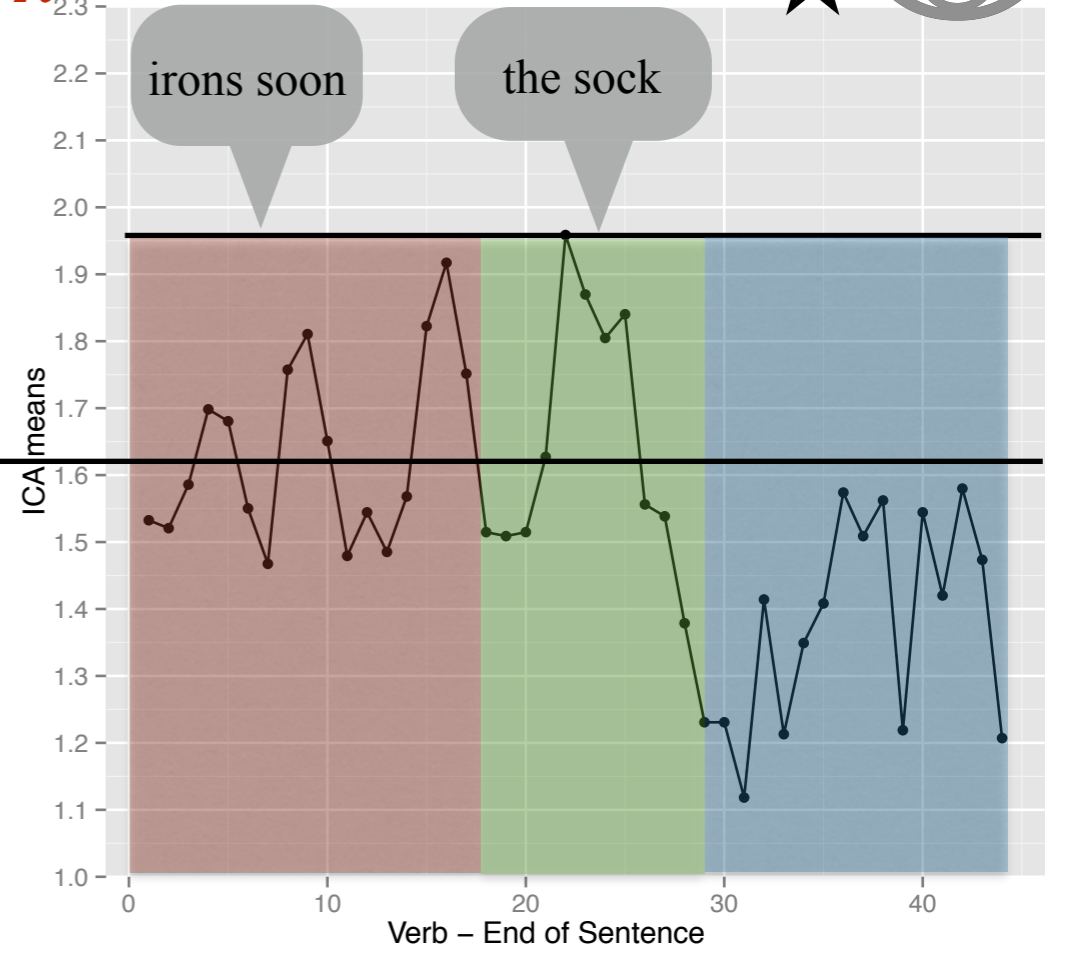
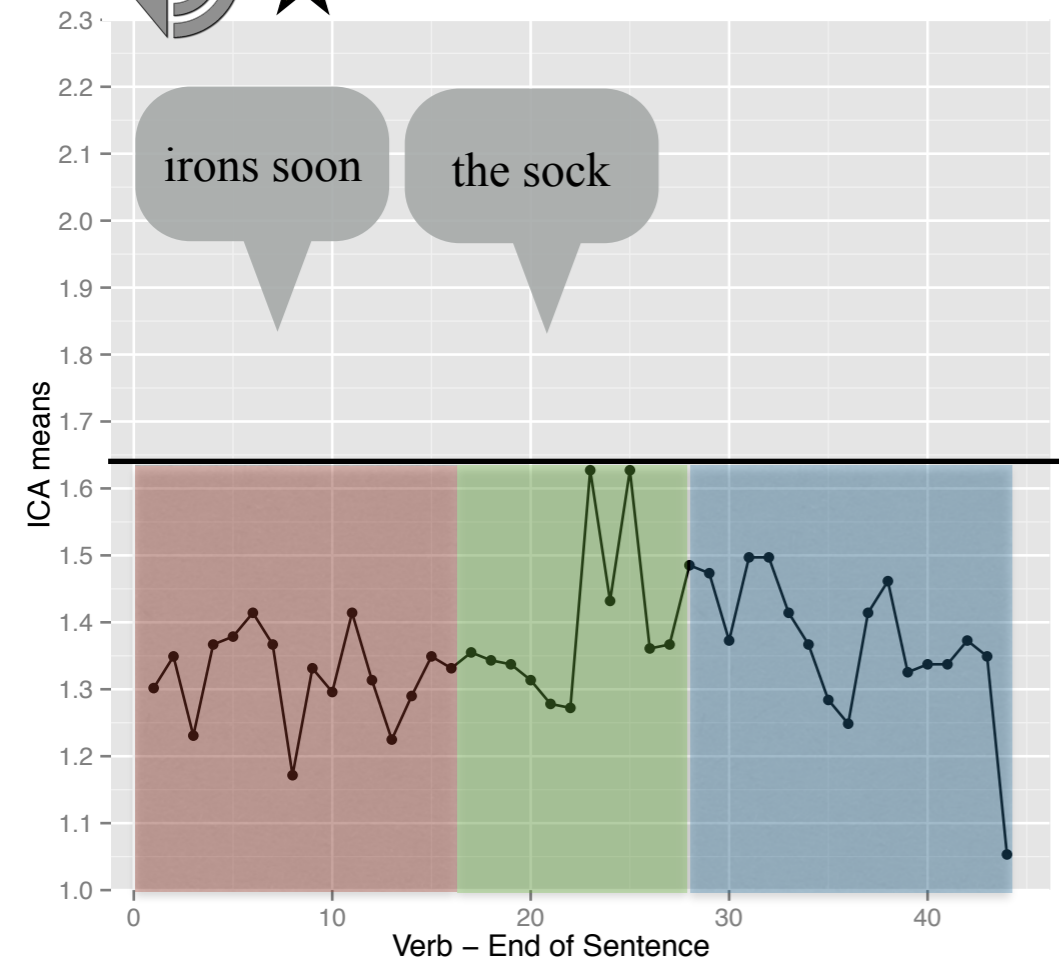
describe
t-shirt = sock



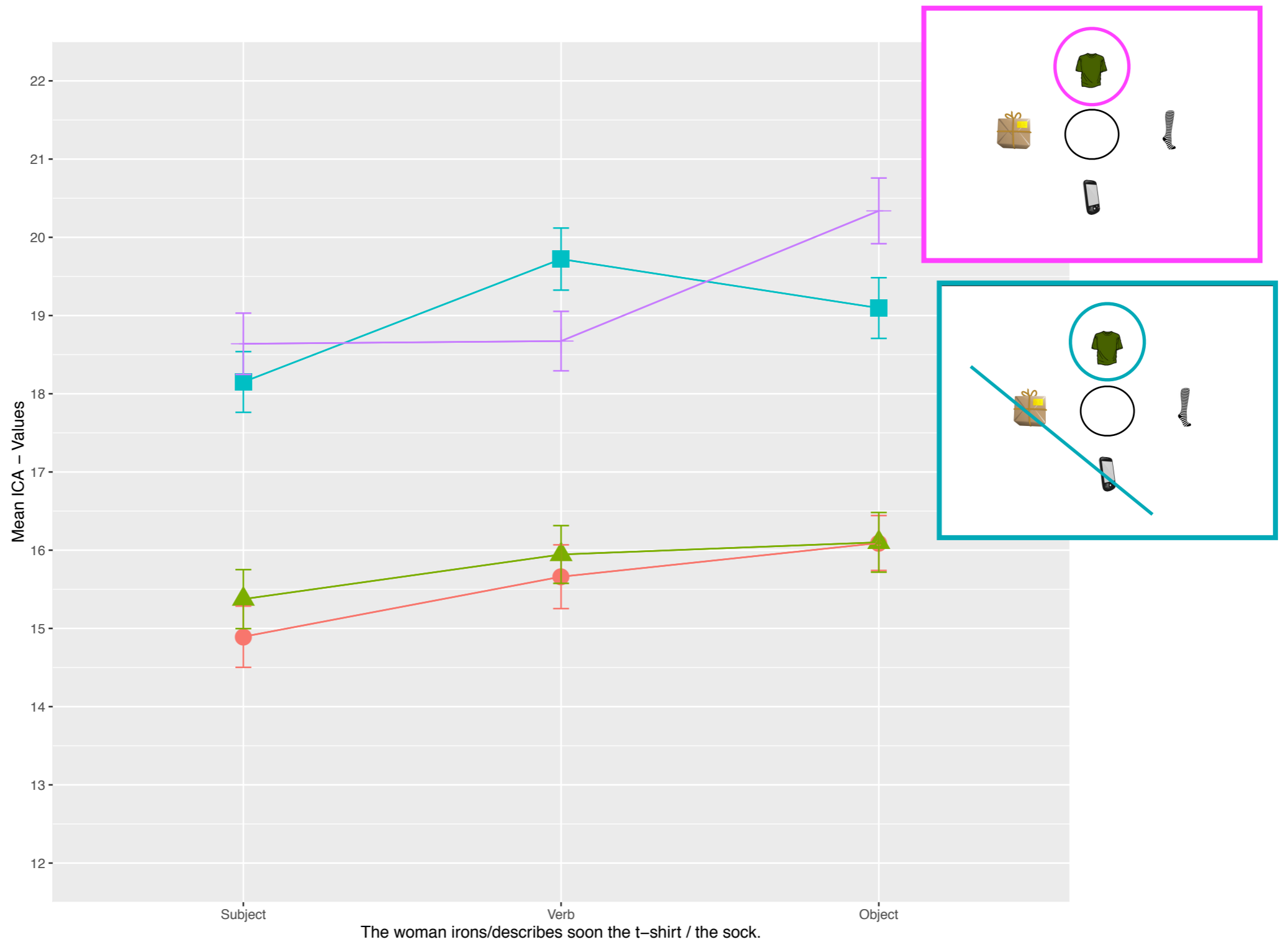


iron

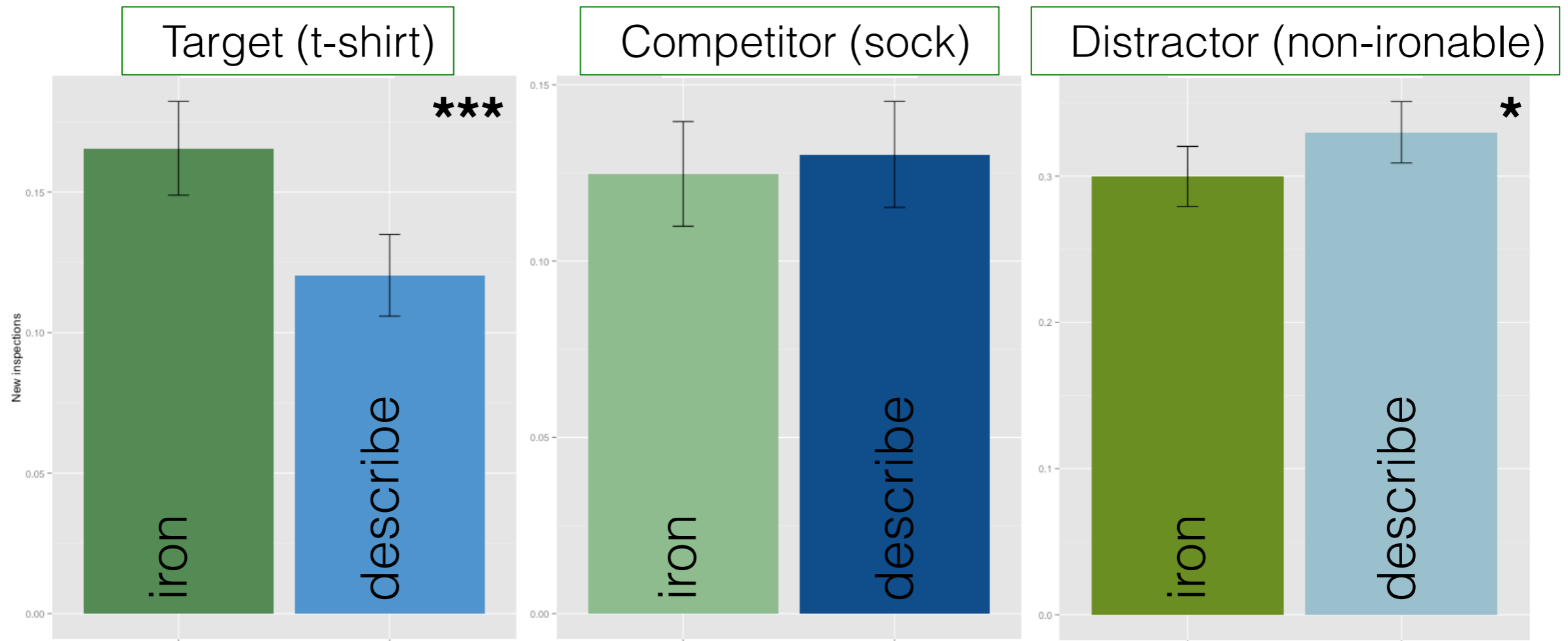
t-shirt < sock



Prediction, Surprisal and UID





Visual Context & CL - Results Eye Movements:



Inspection probability on target, competitor & distractors while hearing the verb

- upon hearing the restrictive verb (iron):
 - less looks to the distractors
 - more looks to the t-shirt

Eye-differences

|  | <u>left eye</u> | <u>right eye</u> |  |
|---|-----------------|---|---|
| <u>verb window</u> Predicting | | | |
| visual > audio ✓ | | | |
| visual: <i>iron > describe</i> | | ? inspection data | |
| verb:study interaction | | | |
| <u>noun window</u> Surprisal | | | |
| visual > audio ✓ | | | |
| visual: <i>t-shirt iron < describe</i> ✓ | | | |
| visual: <i>iron t-shirt < sock</i> | | | |
| | | audio: <i>iron t-shirt < sock</i> | |
| | | <i>sock - verb:study interaction</i> ? | |

Conclusions ICA Audio → ICA Visual

1. ICA Audio:

1. little/no effect of verb for predictions of / surprisal on noun in “language-only”
2. similar to classical measures of cognitive load (CL)

2. ICA Visual:

1. addition of visual context raises CL
2. linguistic predictions sensitive to non-linguistic context:
 - A. lower CL = lower surprisal on more predicted nouns**
 - B. effects of verb constraint + noun-verb plausibility

Prediction as Entropy Reduction

-

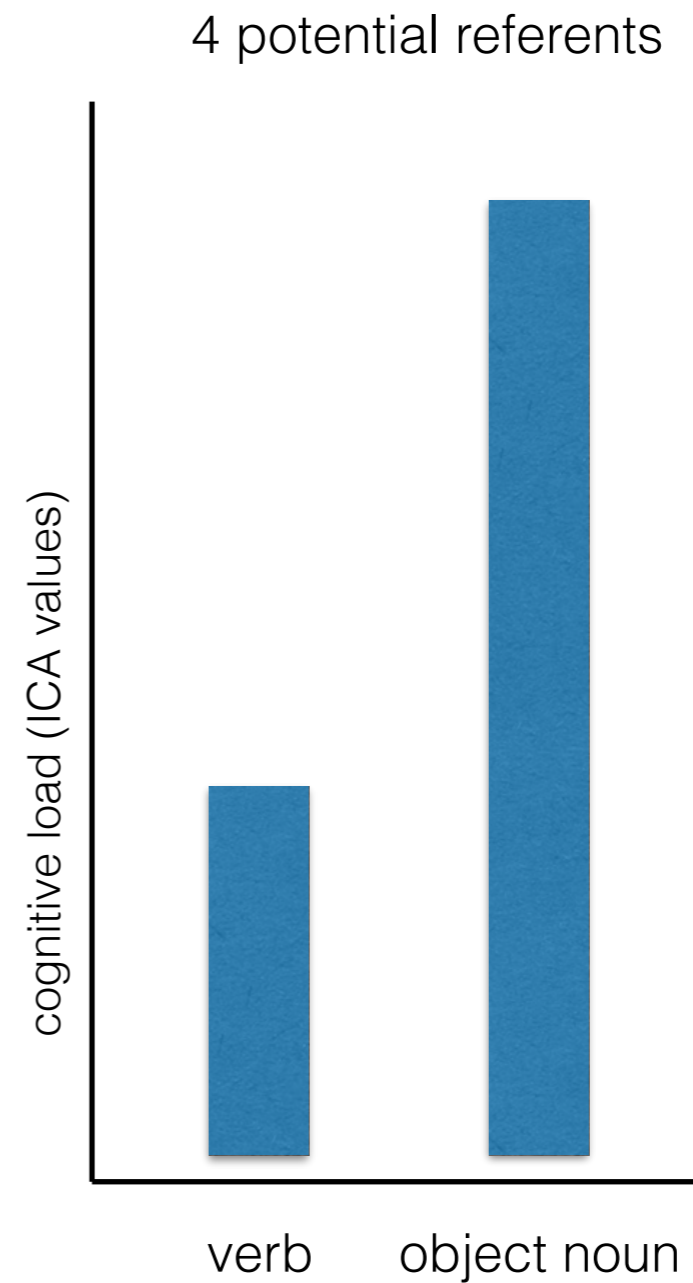
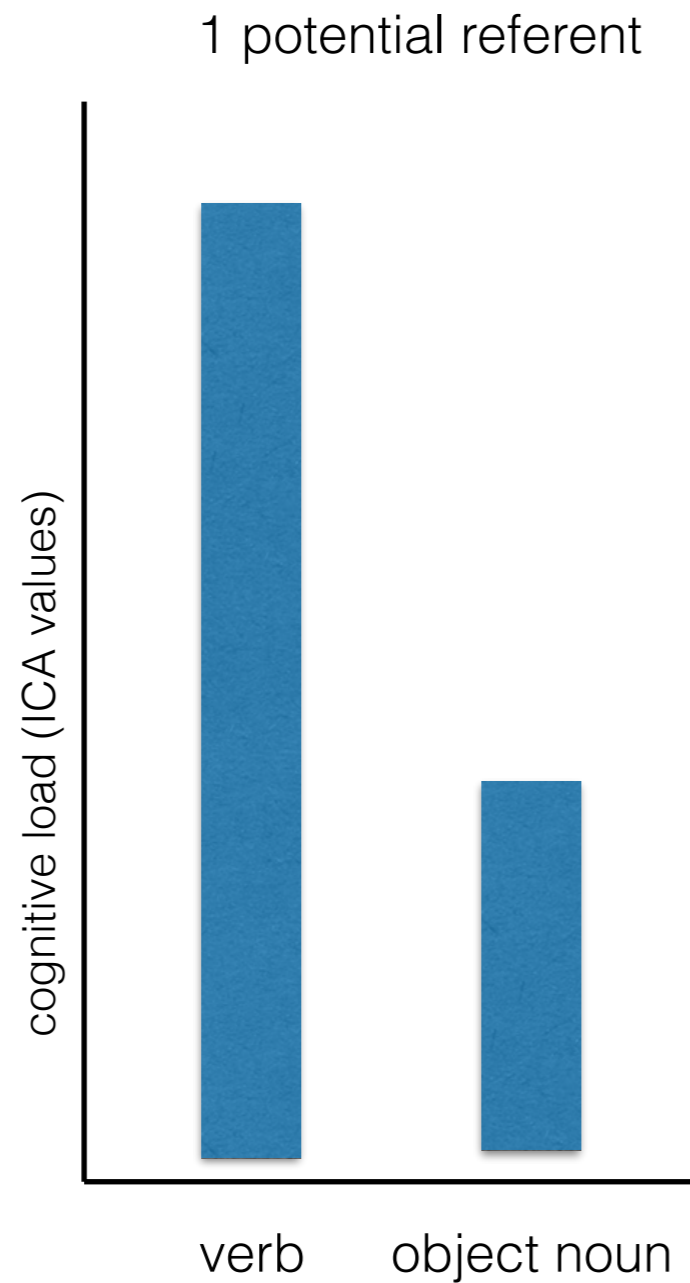
Does CL spread according to UID?

Entropy Reduction in ICA

- Previous: Different verbs/nouns + identical context
- Now: Identical verbs/nouns + different context

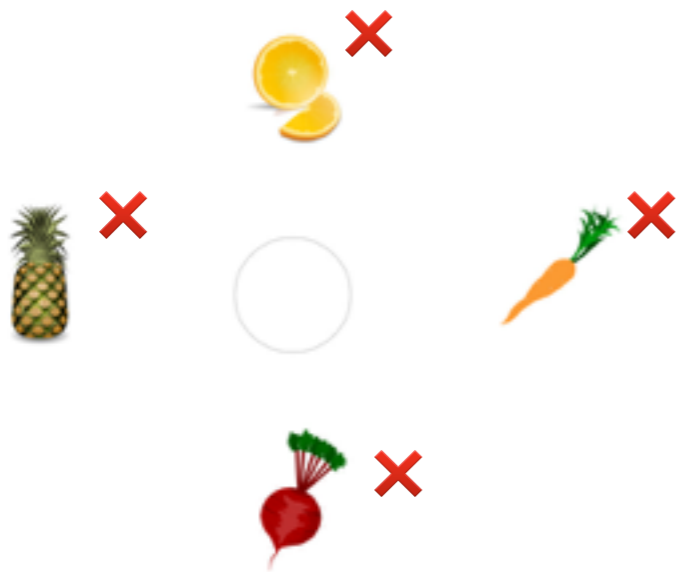
Hypothesis:

According to entropy reduction hypothesis & UID, we assume:

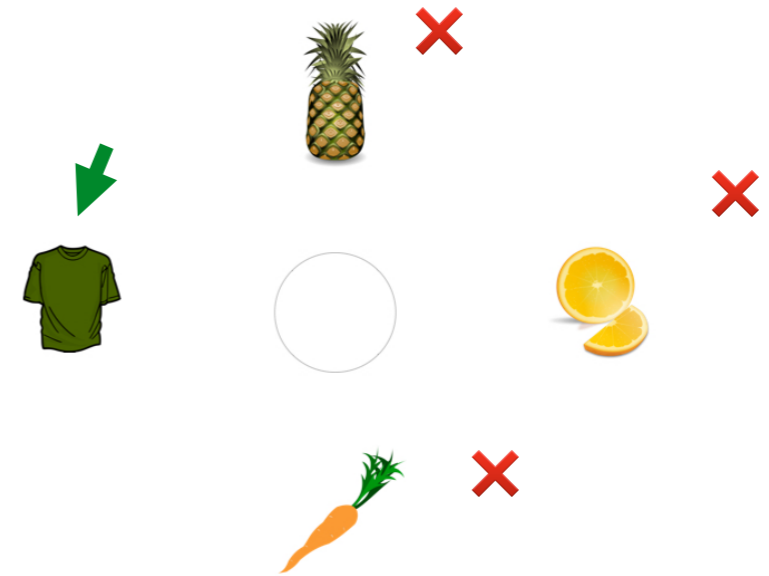




“The woman irons soon the t-shirt”



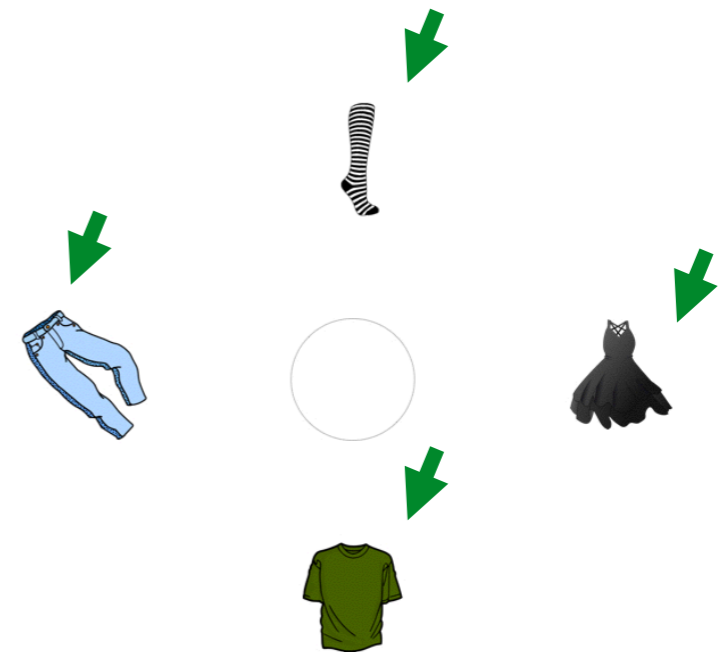
0 possible targets



1 possible target



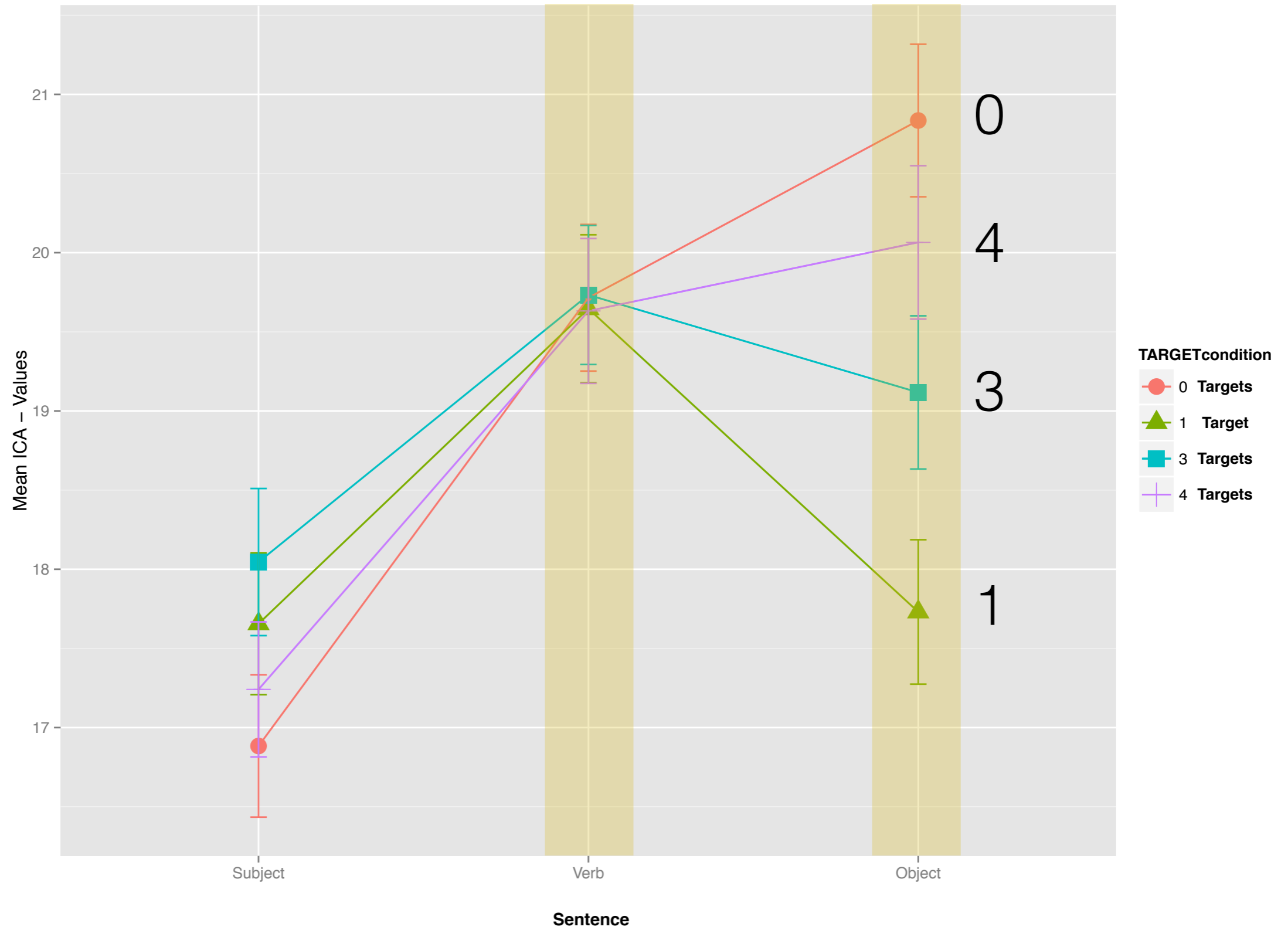
3 possible targets



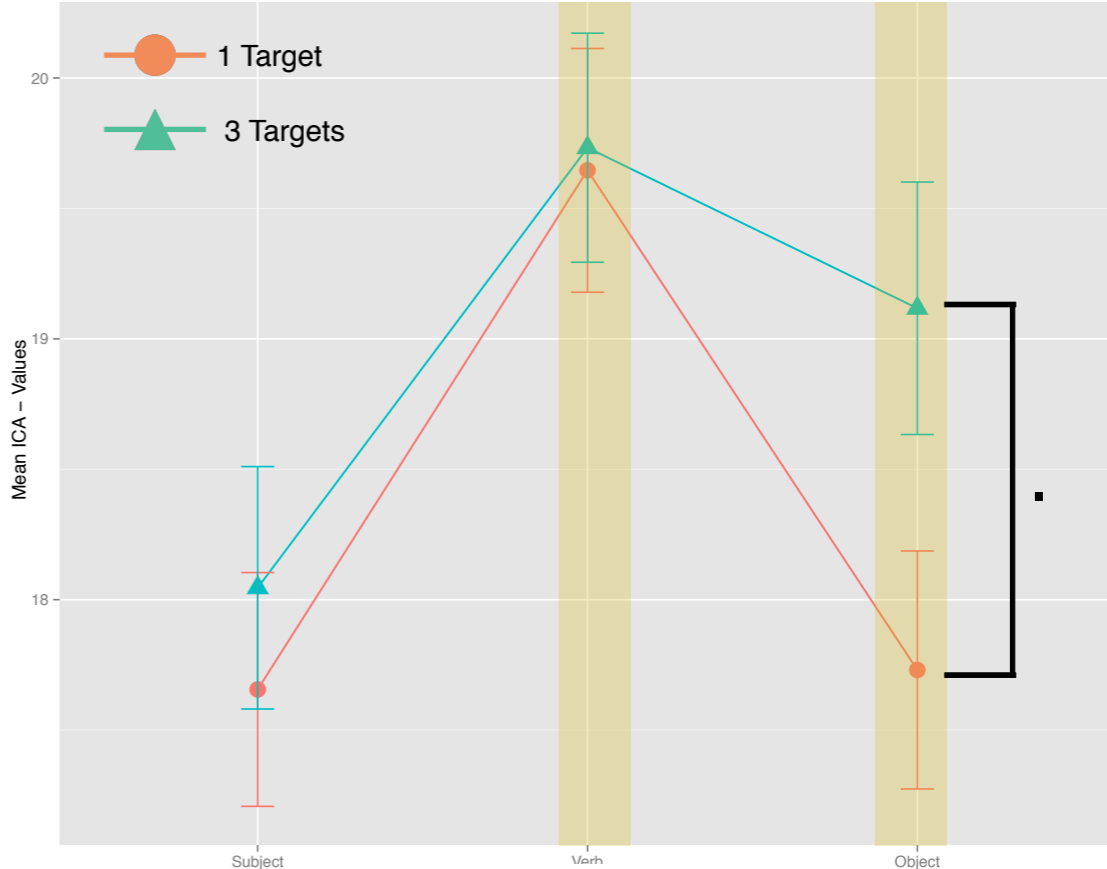
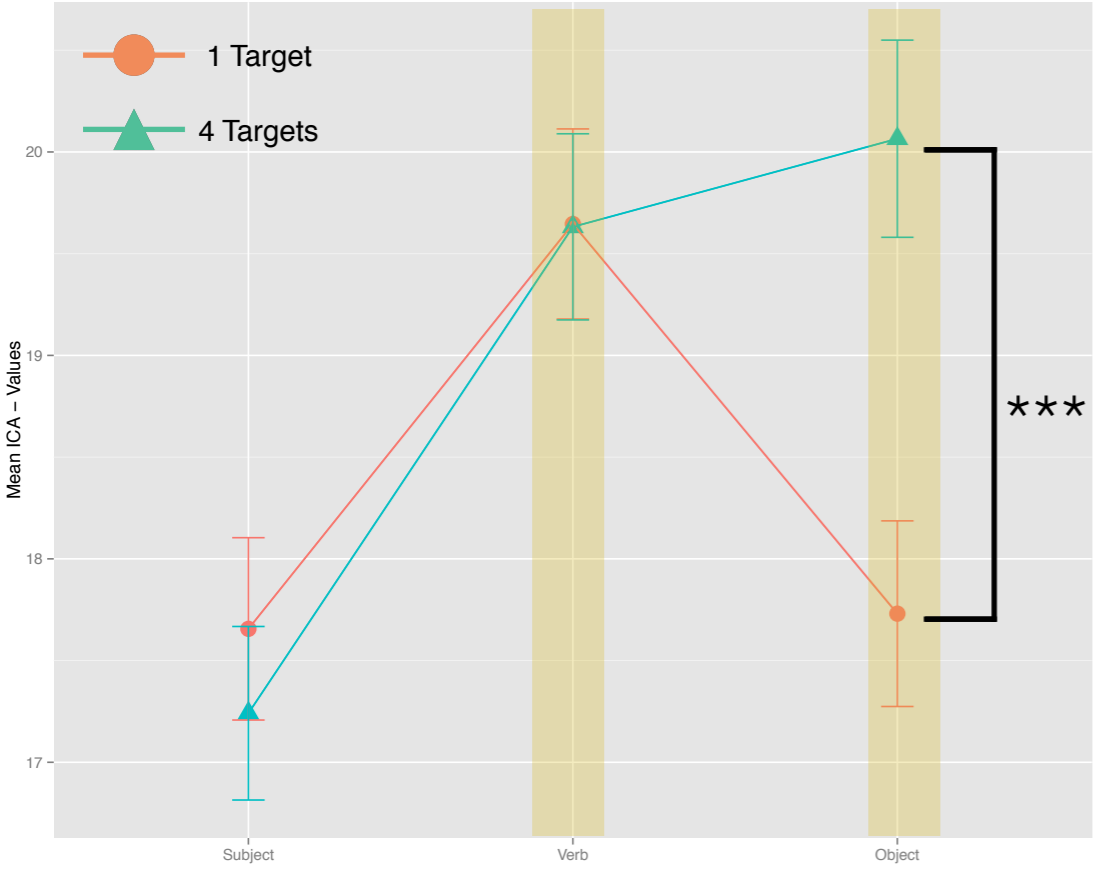
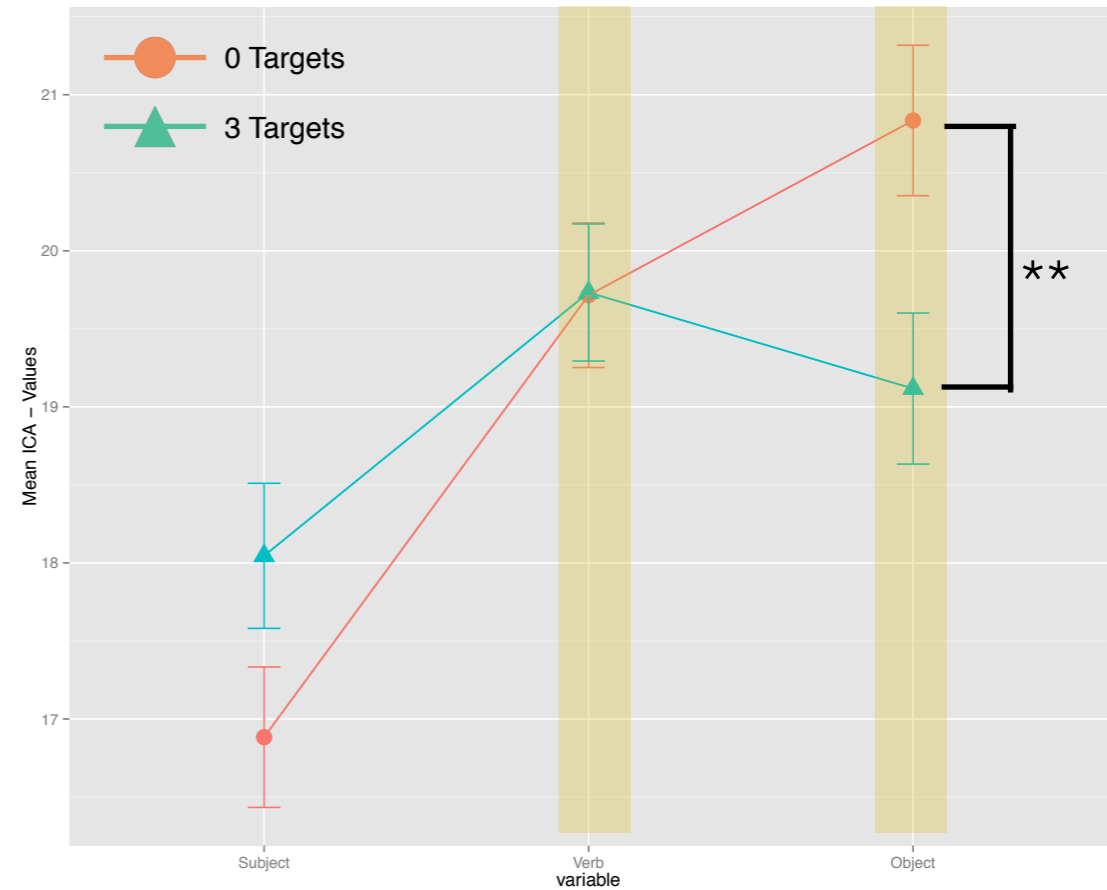
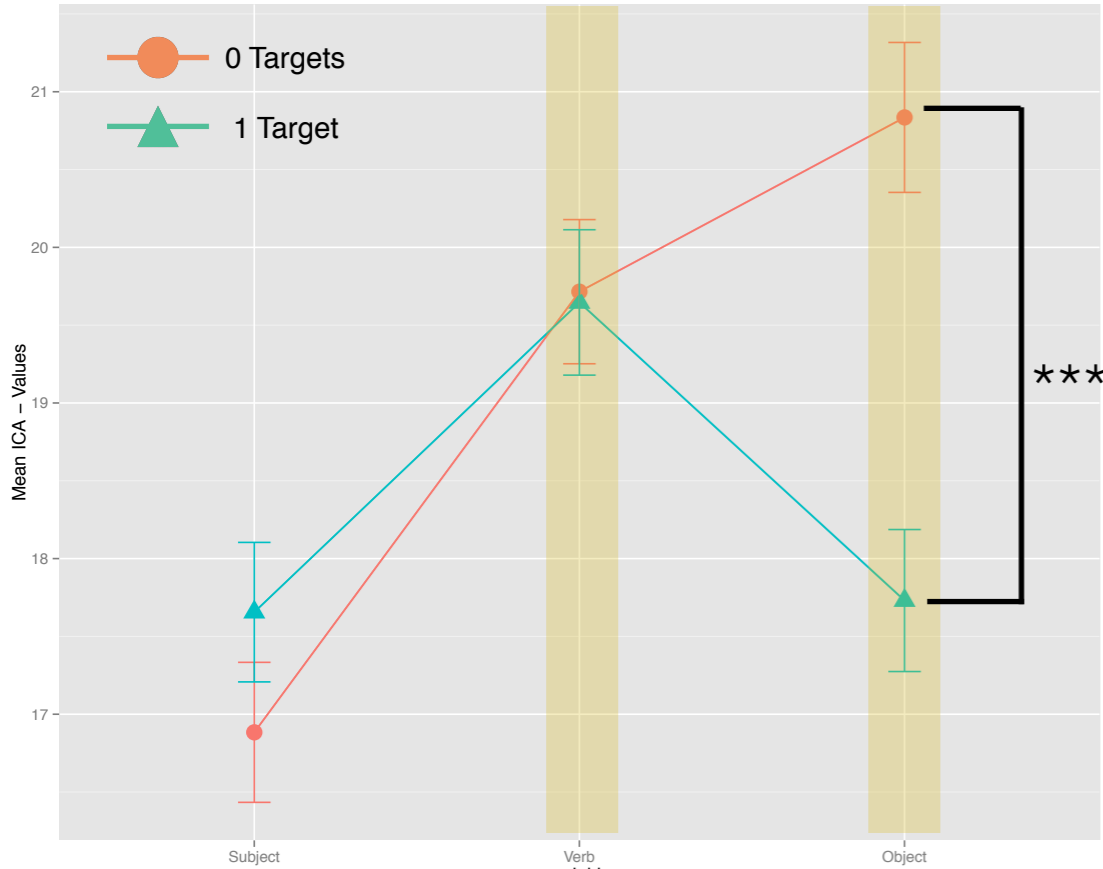
4 possible targets

Prediction/ER

Surprisal

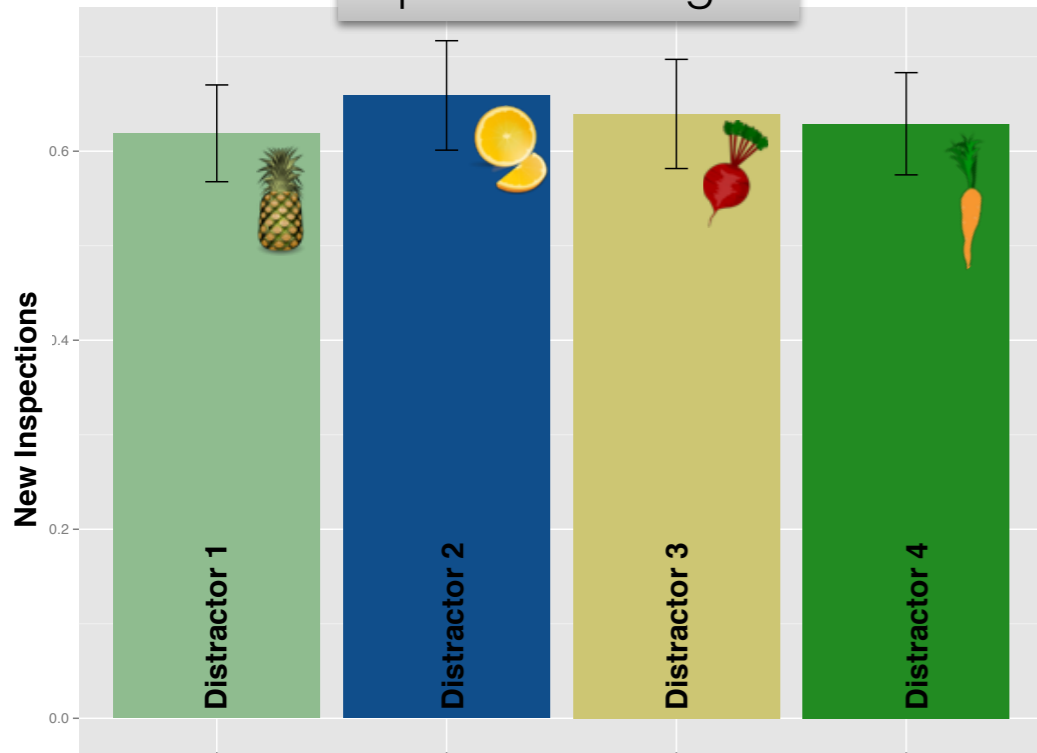


Results (single condition comparisons):

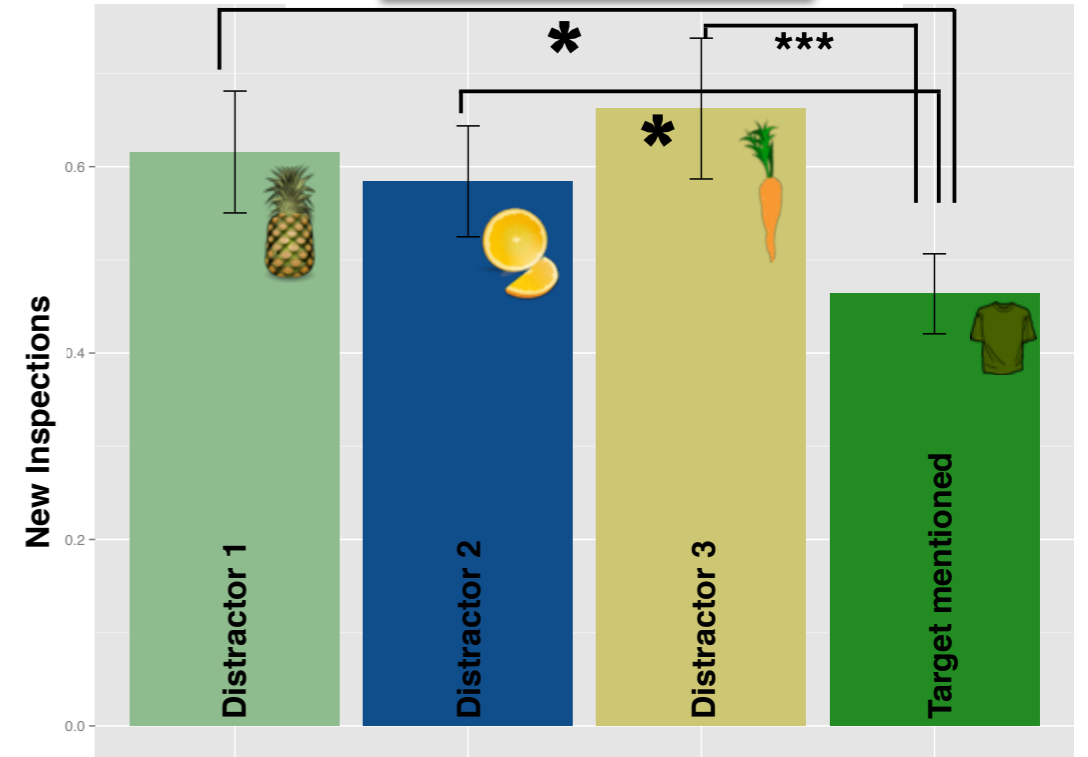


Entropy Reduction - Results Eye Movements:

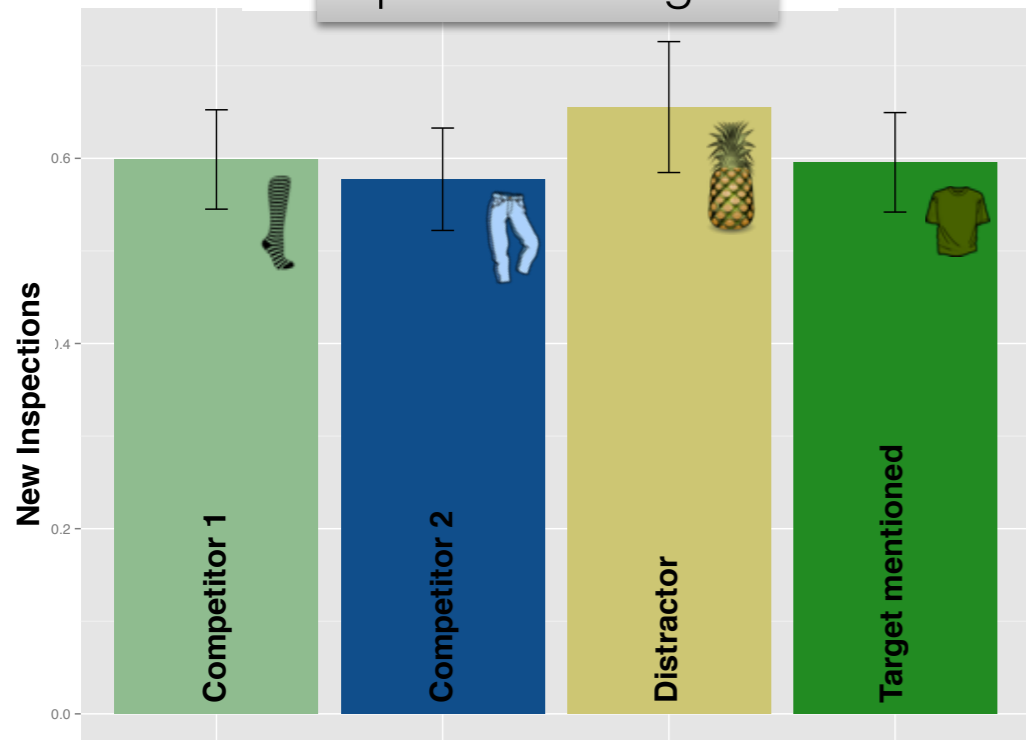
0 possible Targets



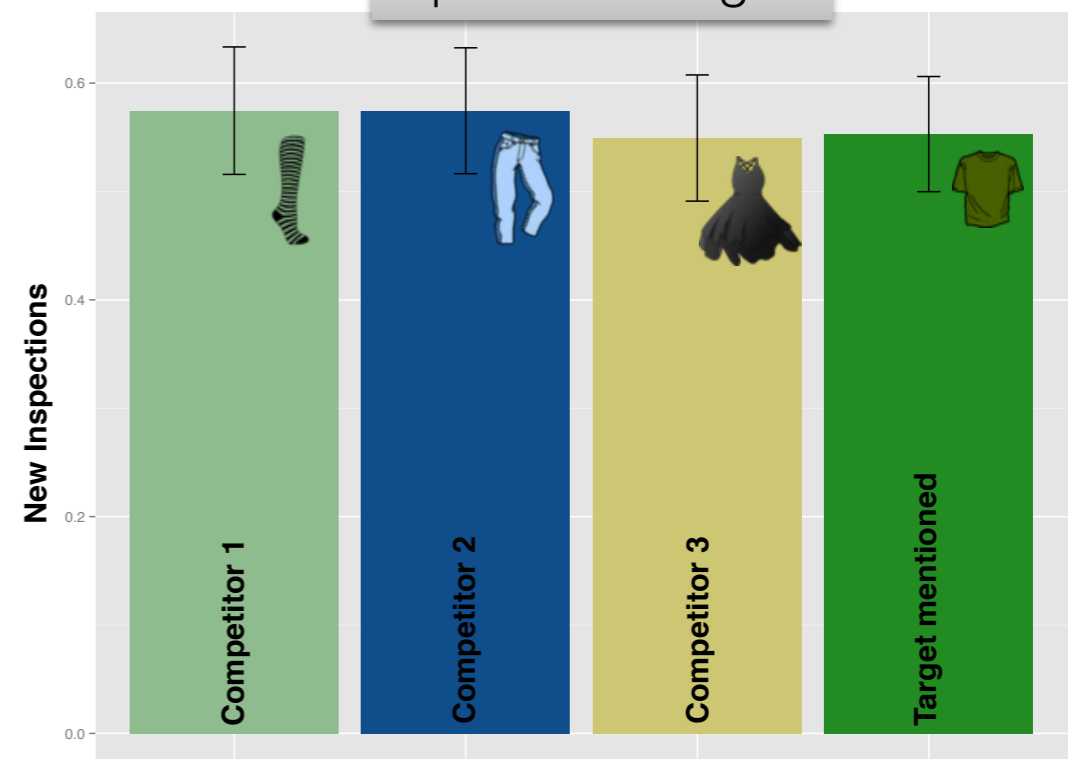
1 possible Target



3 possible Targets



4 possible Targets



Results

- Verb:
 - Fewer inspections to predicted objects (1,3)
 - No effect on ICA
 - Noun:
 - Inspections of mentioned object
 - Clear ICA/surprisal effect of no. of predicted objects
- ➔ No Cog. Load for Entropy Reduction → no UID ?
- ➔ Different type of Cog. Load, not ICA-relevant ?

Visual Context + Gaze

Why gaze?



- Speakers look at entities shortly before mentioning them. (Griffin & Bock, 2000; Meyer et al., 1998)
- Listeners rapidly inspect objects as they are mentioned. (Tanenhaus et al., 1995)
- Situated communication: gaze cue an inseparable part of the visual context
- Linguistic and visual context aid prediction of the upcoming contents. Can gaze cue adopt the same function?

Distribution of CL across gaze and linguistic cues

- Is gaze cue part of the context for the spoken referent?
- Is there surprisal on the gaze cue?
 - Is there a distribution of surprisal between the gaze and the referent?

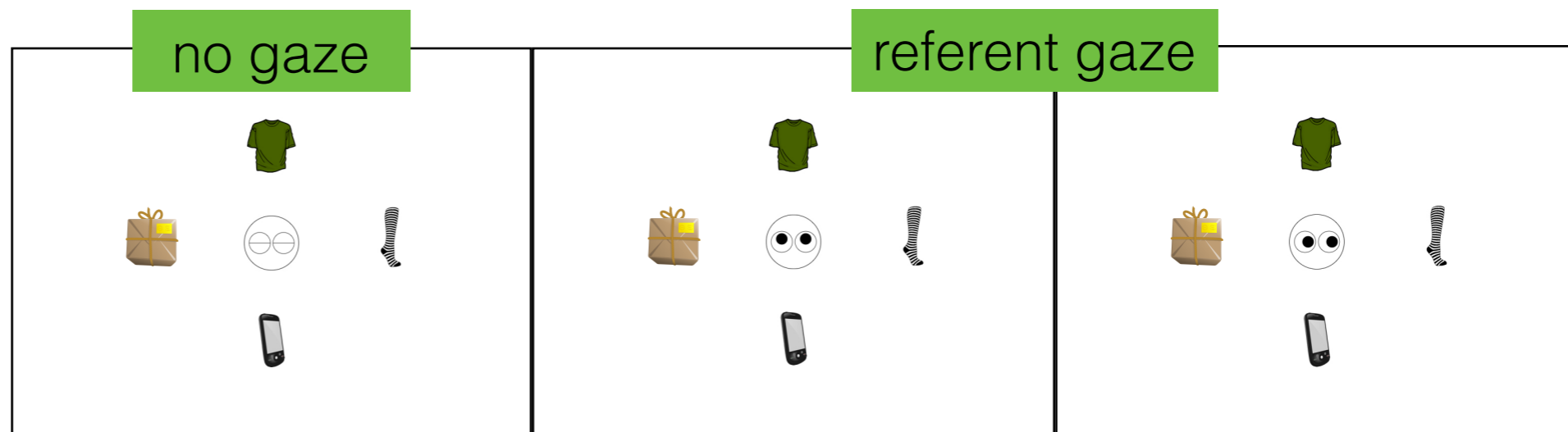
1. linguistic context

| | | | |
|-----------------|-------------------|---------------|---------------------|
| Die Frau | bügelt | gleich | das T-Shirt. |
| The woman | irons | soon | the t-shirt |
| | beschreibt | | die Socke. |
| | describes | | the sock |

2. visual context



3. gaze cue





1000ms



“Die Frau bügelt”

300ms



“gleich”

100ms

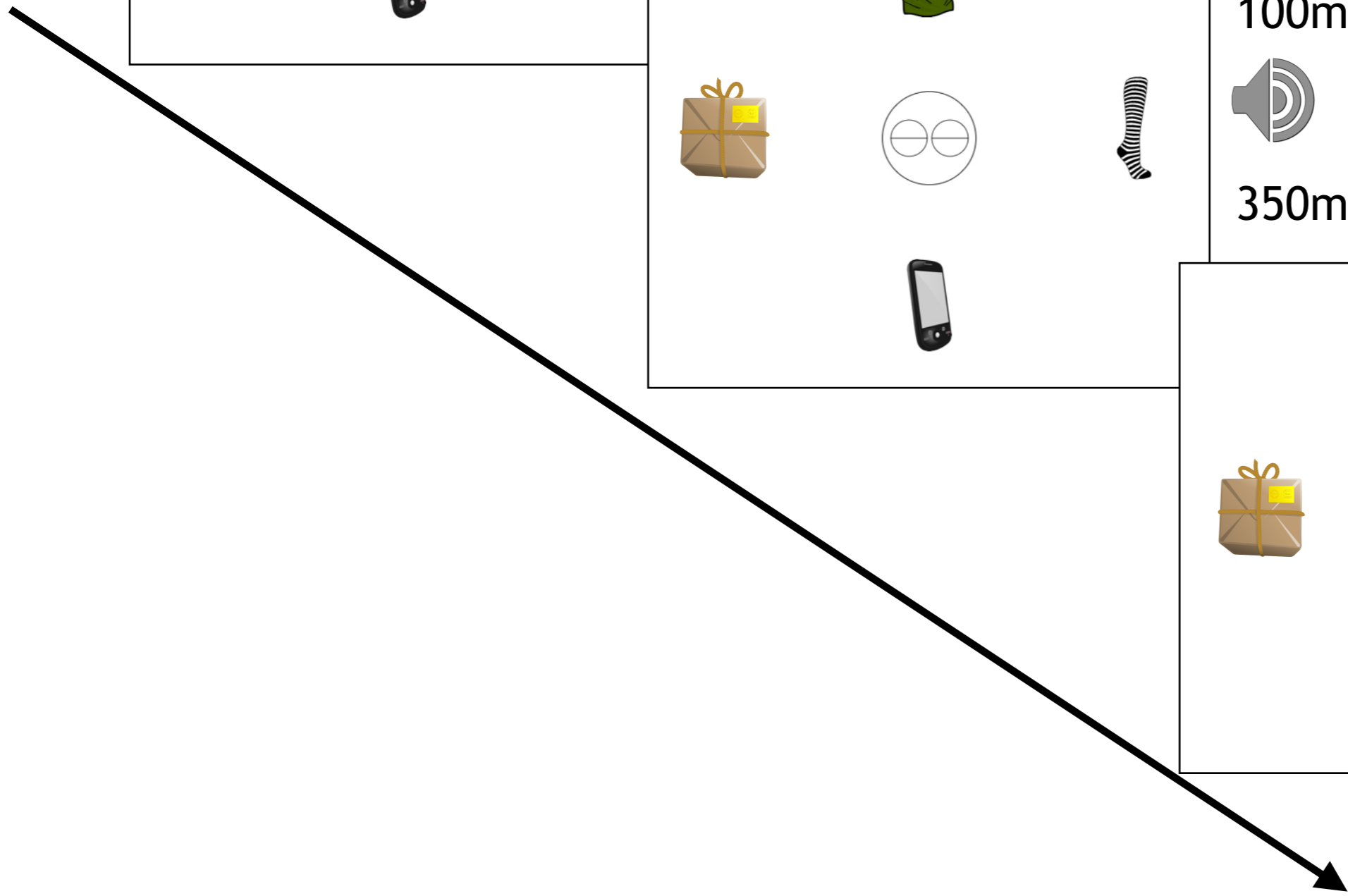


“das T-Shirt.”

350ms



1000ms



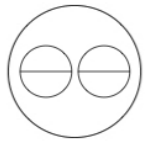








ICA Results

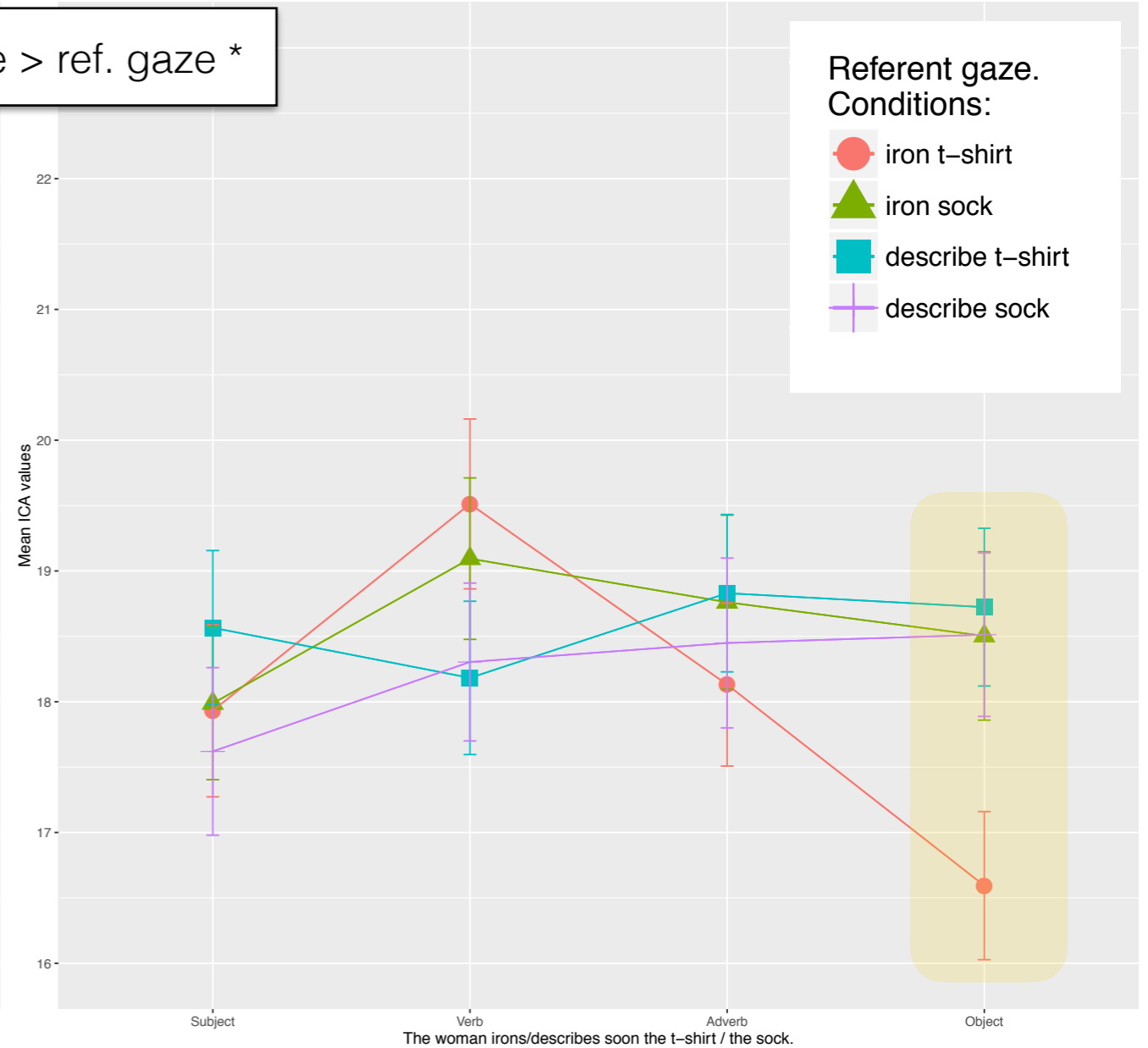
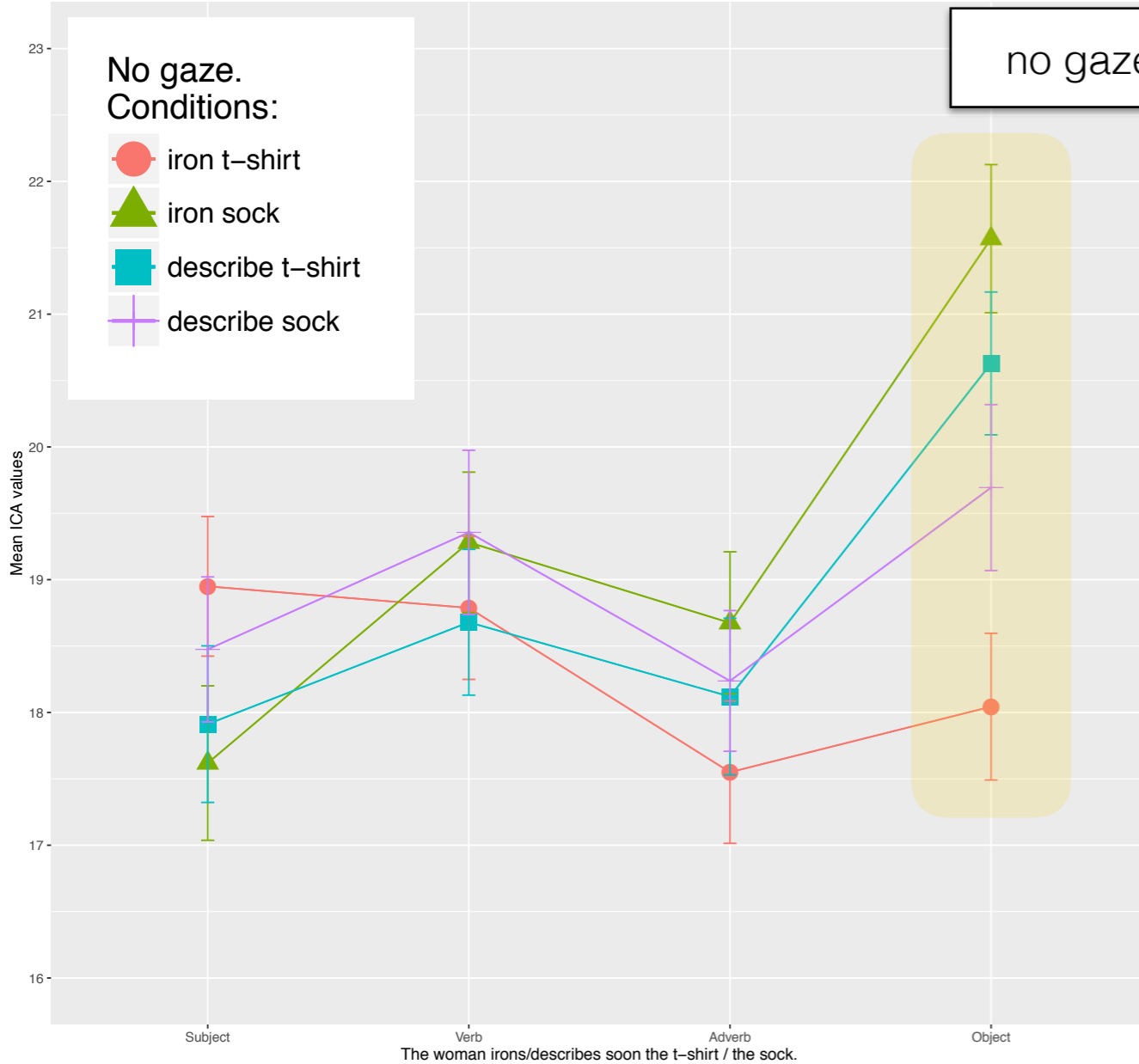


iron: t-shirt < sock *** t-shirt: iron < describe **
 describe: t-shirt = sock sock: iron > describe **

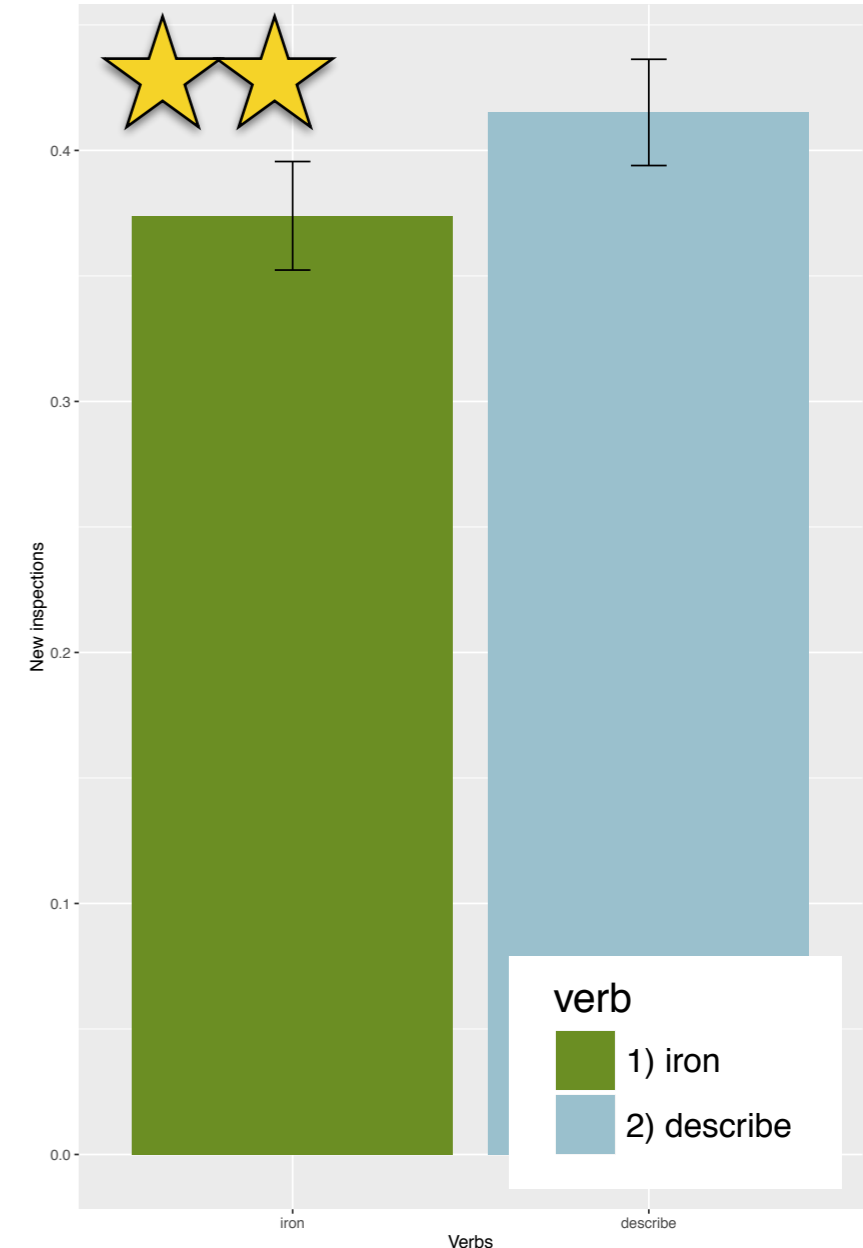
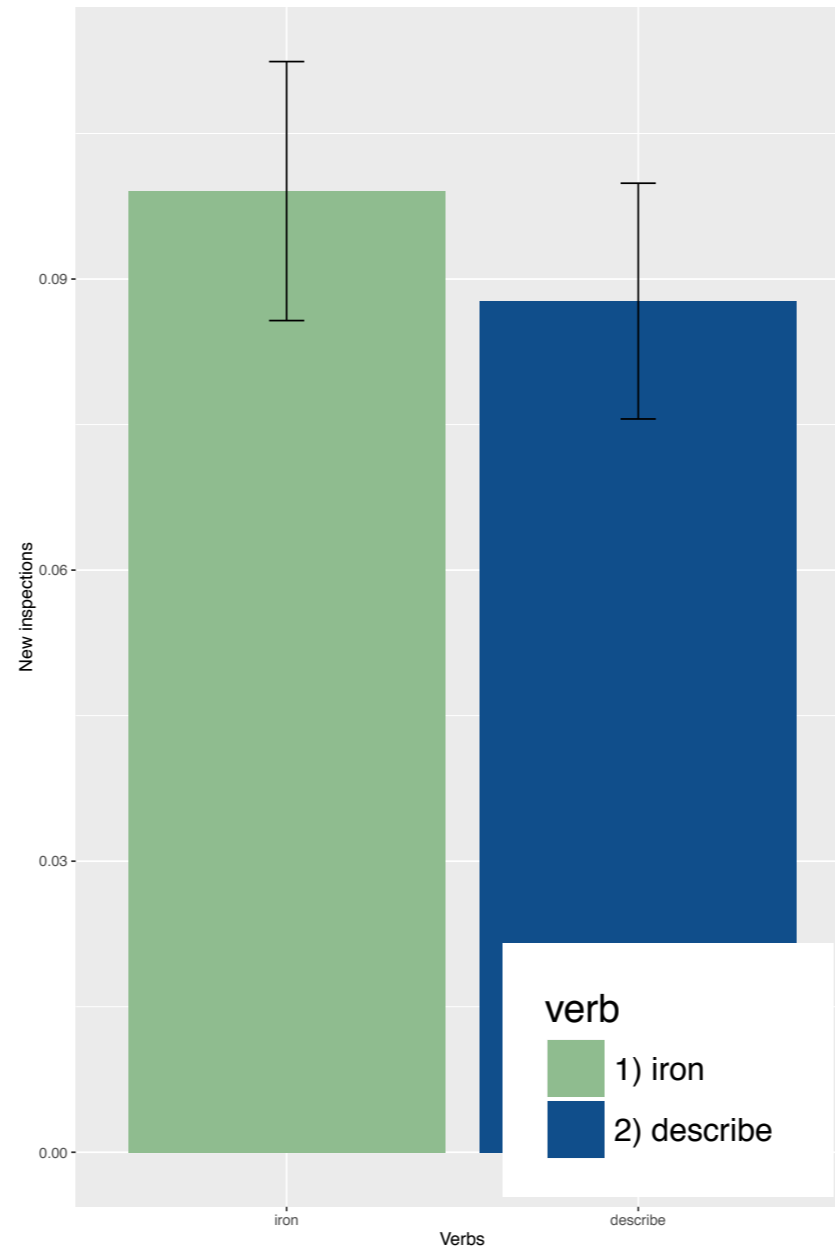
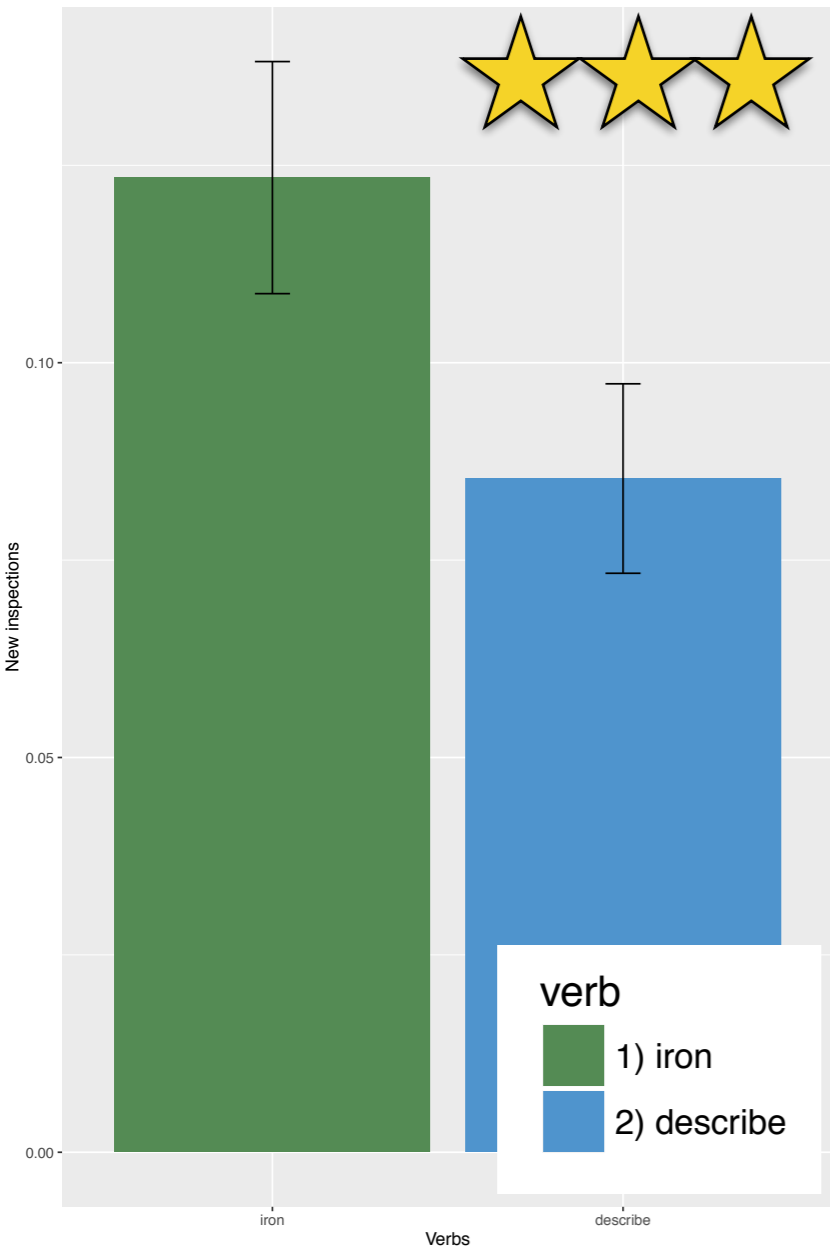


iron: t-shirt < sock * t-shirt: iron < describe **
 describe: t-shirt = sock sock: iron = describe

no gaze > ref. gaze *



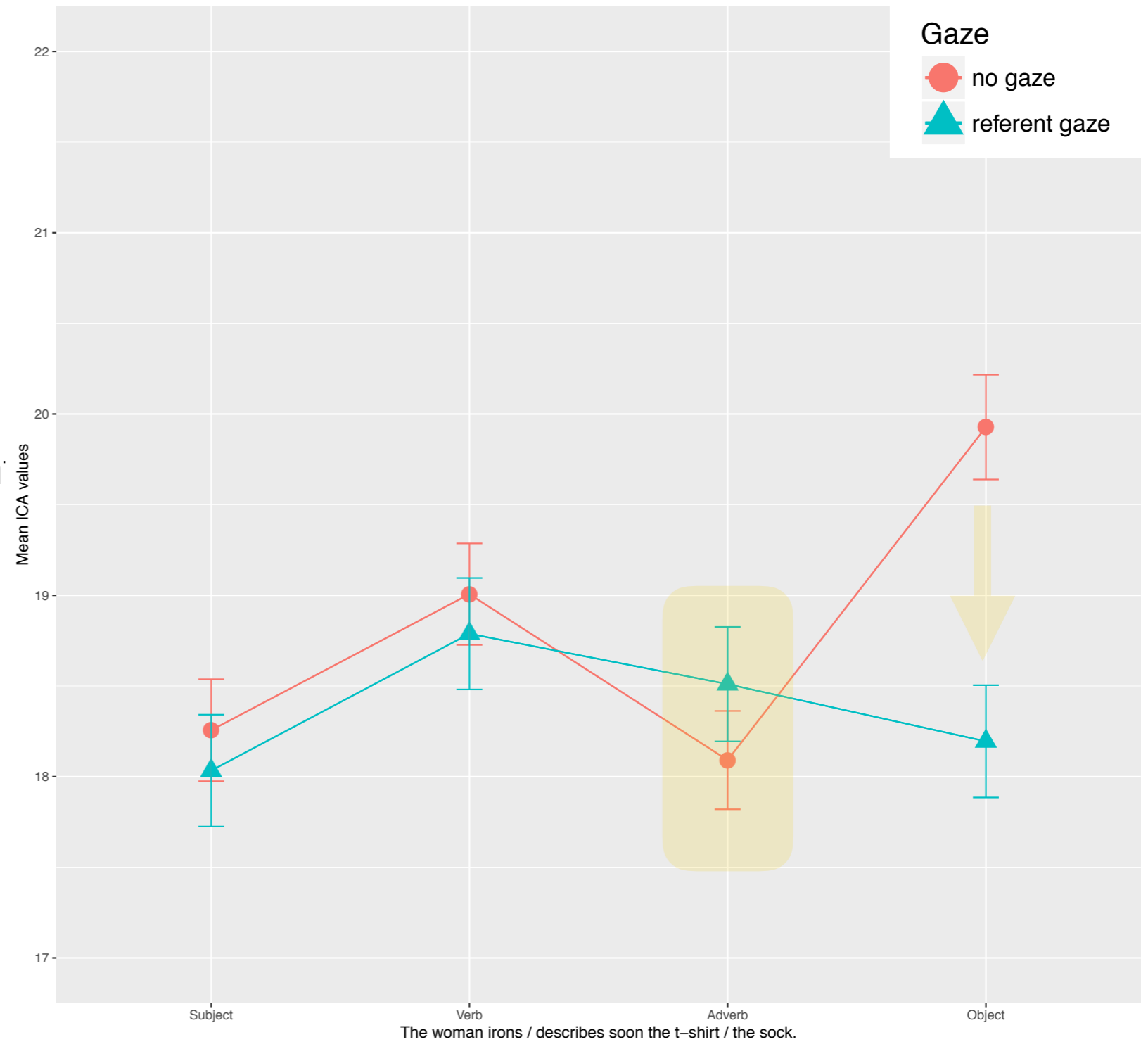
Eye-movements. New inspections during the verb.



Conclusions

1. Is gaze cue part of

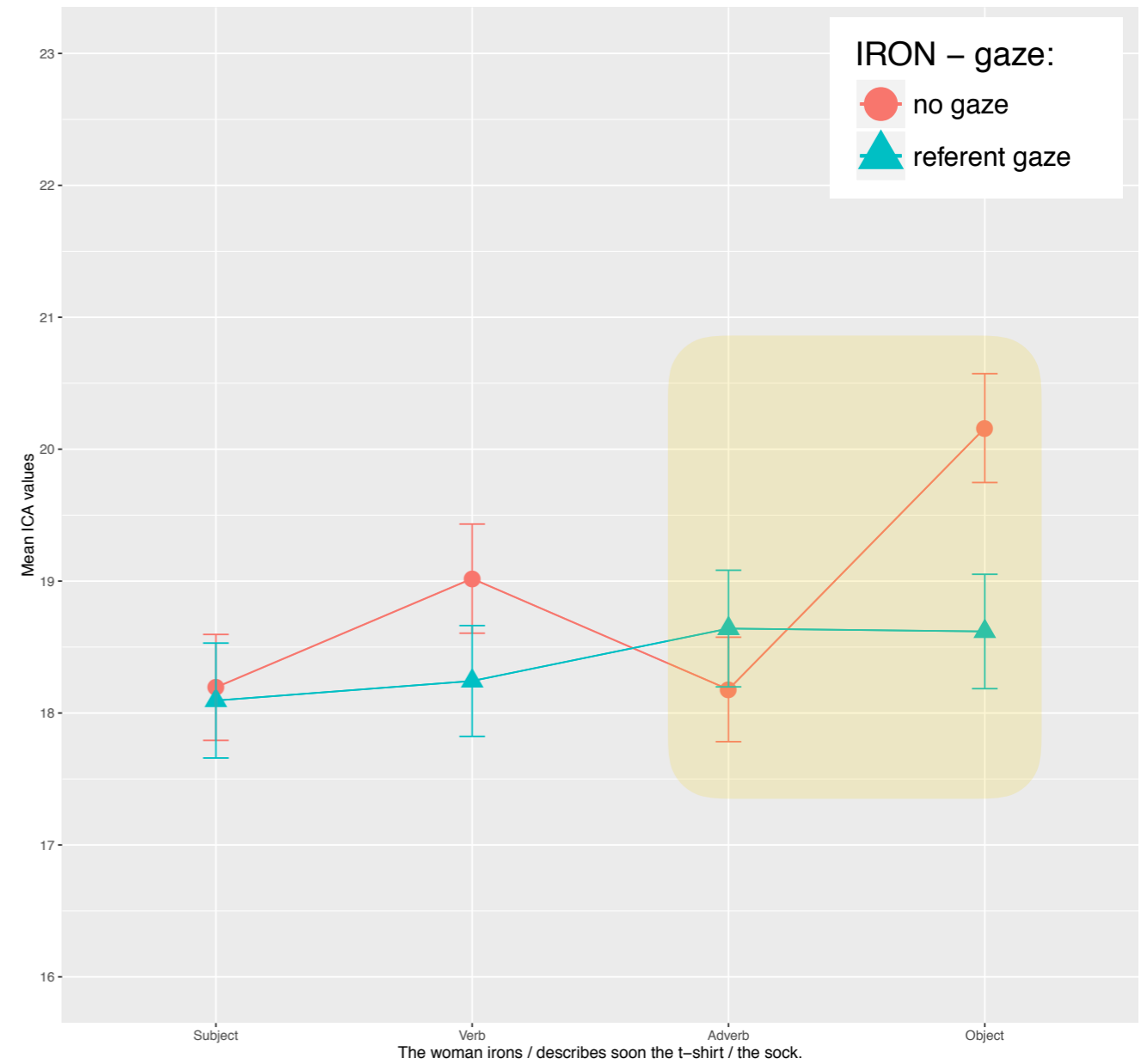
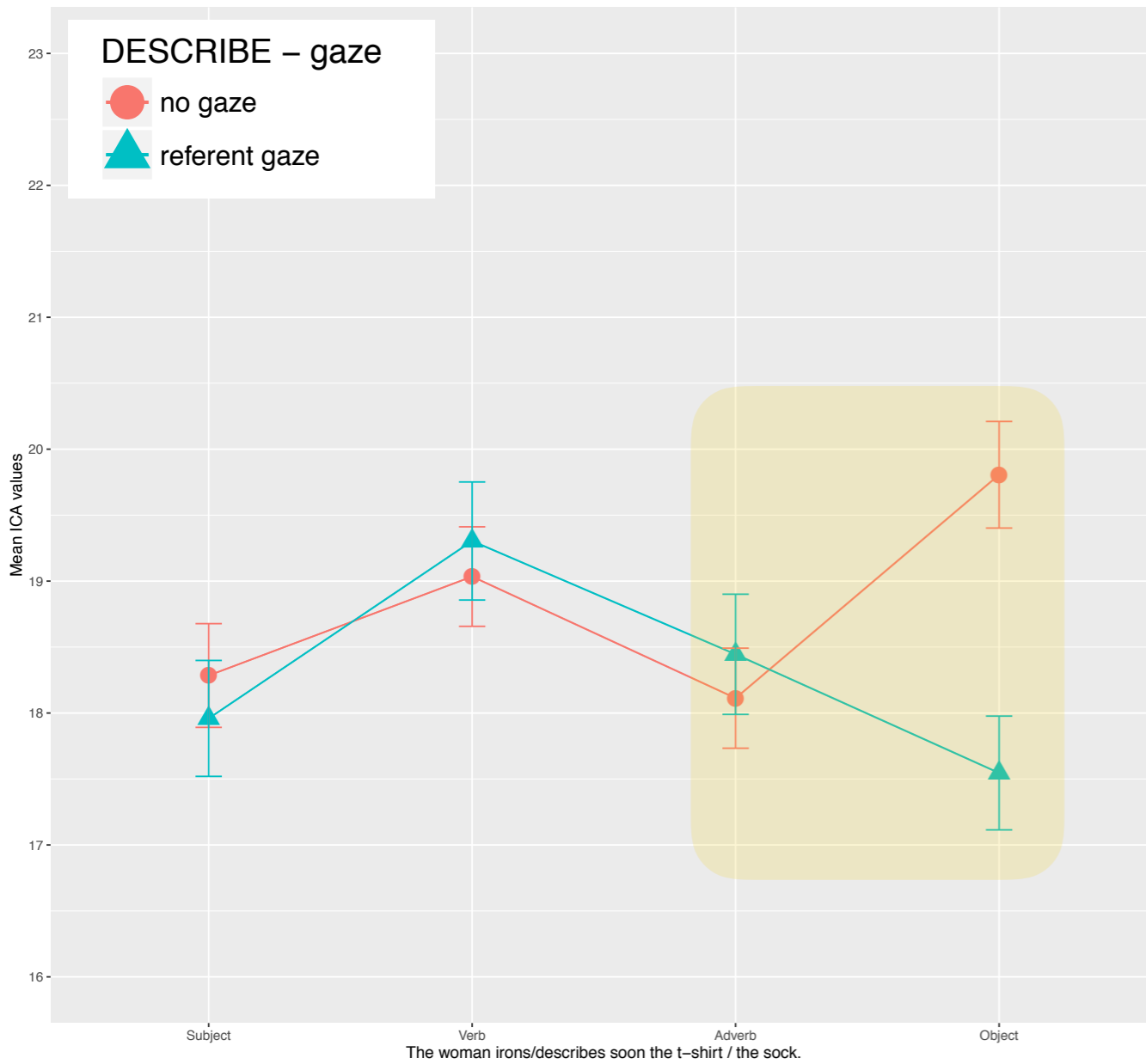
2. If so, how does it in



Conclusions

1. Is gaze cue part of the context for the spoken referent?
 - Gaze cue is considered as part of the context for the spoken referent.
2. If so, how does it influence the surprisal on the referent?
 - (Reliable congruent) gaze cue contributes to the reduction of surprisal on the linguistic referent.

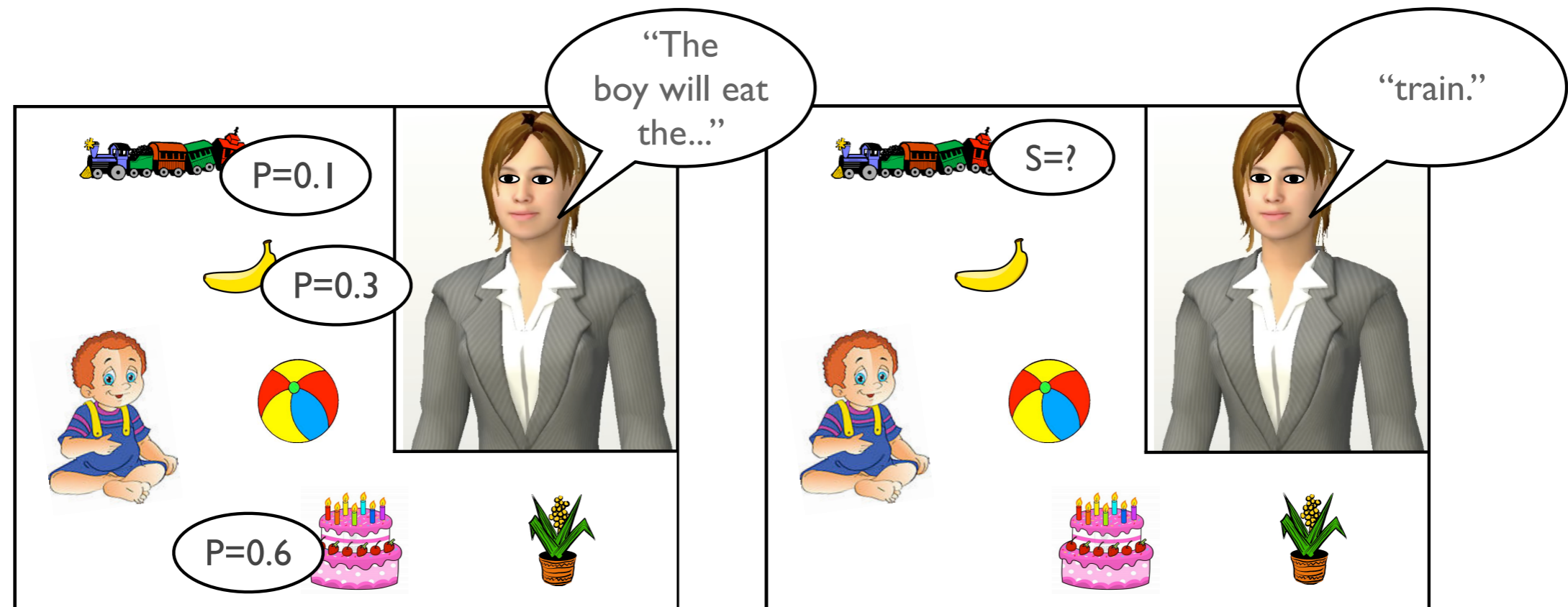
Conclusions



Gaze & Surprisal

- Gaze cue **is** part of the context for the spoken referent.
- (Reliable congruent) gaze cues contribute to reduction of surprisal on linguistic referent
- **No** surprisal on gaze cue itself
 - ➔ So far no evidence for distribution of surprisal between gaze cue and referent

Prediction & Surprisal



time →

Prediction

Surprisal

Entropy Reduction \neq CL

Wrap-Up

- Embodiment (1 + 2)
- Situated & embodied language learning (3 + 4)
- Situated adult language comprehension (& production) (5 + 6)
- Language in Interaction (7 - 9)
 - Taking another person into account
 - Sending and perceiving bodily signals
 - Applications
- Context effects on workload during language processing (10)

Questions?

References

- Hale, John (2001). A probabilistic early parser as a psycholinguistic model. Proceedings of the North American association of computational linguistics.
- Frank, Stefan (2013). “Uncertainty reduction as a measure of cognitive load in sentence comprehension”. Topics in Cognitive Science, 5, 475-494.
- Marshall, Sandra P. (2002). The index of cognitive activity: Measuring cognitive workload. In: Proceedings of the conference on Human factors and power plants. IEEE; 7–5.
- Demberg, V., & Sayeed, A. (2016). The Frequency of Rapid Pupil Dilations as a Measure of Linguistic Processing Difficulty. PloS one, 11(1).