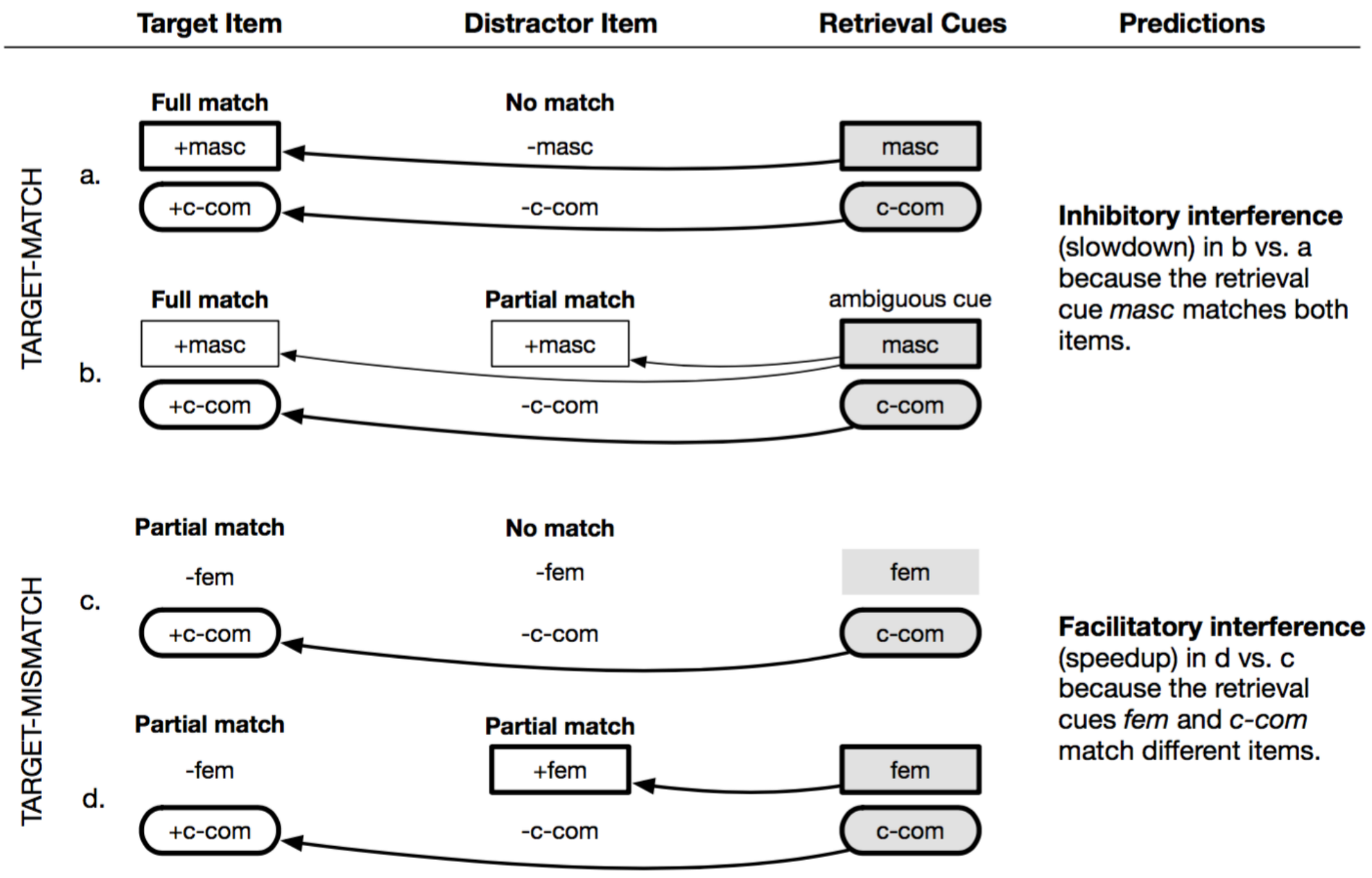
Sentence Comprehension as a Cognitive Process: A computational modeling approach

Day 5: Similarity-based interference in parsing

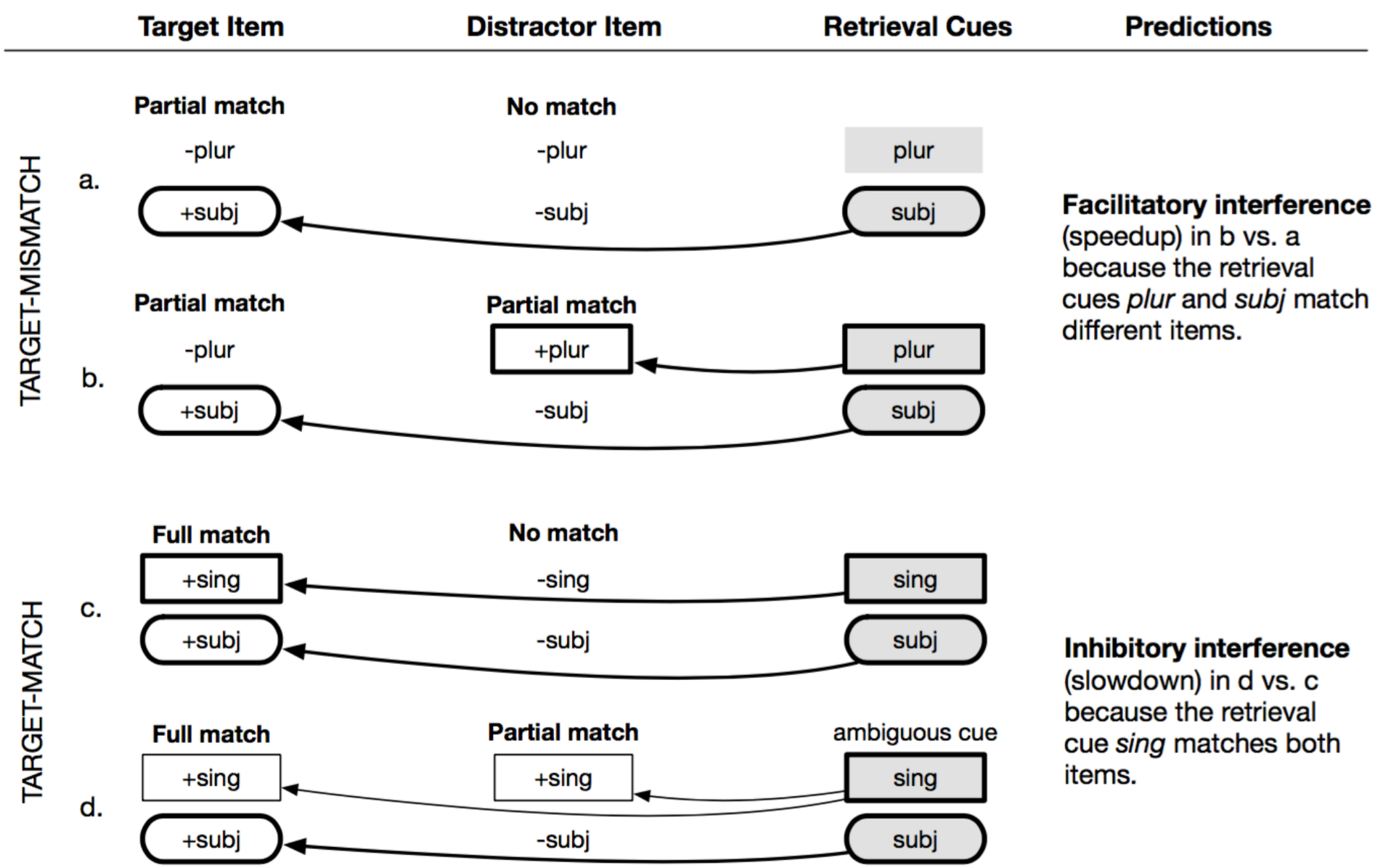
Shravan Vasishth and Felix Engelmann

ESSLLI 2016, Bolzano

Target match vs mismatch configurations (reflexives)



Target match vs mismatch configurations (agreement)



Non-agreement subject-verb dependencies

These have only been investigated for
Target Match conditions (mostly by Julie Van Dyke)

The worker was surprised that the resident who was living near the dangerous *warehouse/neighbor* was complaining about the investigation.

Agreement dependencies

Target Match

a. The key$_{+sing}$ to the cabinet$_{+sing}$ is in the box.

b. The key$_{+sing}$ to the cabinets$_{+plur}$ is in the box.

Target Mismatch

a. * The key$_{+sing}$ to the cabinet$_{+sing}$ are in the box.

b. * The key$_{+sing}$ to the cabinets$_{+plur}$ are in the box.

Reflexive/reciprocal dependencies

(1)a. *Target-match; distractor-mismatch*

The surgeon$^{+masc}_{+c\text{-}com}$ who treated Jennifer$^{-masc}_{-c\text{-}com}$ had pricked himself$\{^{masc}_{c\text{-}com}\}$...

b. *Target-match; distractor-match*

The surgeon$^{+masc}_{+c\text{-}com}$ who treated Jonathan$^{+masc}_{-c\text{-}com}$ had pricked himself$\{^{masc}_{c\text{-}com}\}$...

c. *Target-mismatch; distractor-mismatch*

The surgeon$^{-fem}_{+c\text{-}com}$ who treated Jonathan$^{-fem}_{-c\text{-}com}$ had pricked herself$\{^{fem}_{c\text{-}com}\}$...

d. *Target-mismatch; distractor-match*

The surgeon$^{-fem}_{+c\text{-}com}$ who treated Jennifer$^{+fem}_{-c\text{-}com}$ had pricked herself$\{^{fem}_{c\text{-}com}\}$...

Target Match

FranckEtAl15E1RC
VanDykeEtal03E4
VanDyke07E1LoSyn
FranckEtAl15
BadeckerEtAl02E4
VanDykeE2LoSyn
BadeckerEtAl02E3
VanDykeEtAl06
VanDyke07E2LoSem
PearlmutterEtAl99E3plu
VanDyke07E3LoSem
DillonEtAl13E1agrmt
JaegerEtAl15E2
VanDyke07E1LoSem
Sturt03E2
LagoEtAl15E1
WagersEtAl09E3RNplu
WagersEtAl09E3RNsing
VanDyke07E3LoSyn
VanDykeEtAl11E2bpro
WagersEtAl09E2
VanDykeEtAl11E1bpro
ChenEtAl12
LagoEtAl15E3a
FelserEtAl09inaccMism
CunningsEtAl13E2HI
FelserEtAl09noccom
BadeckerEtAl02E5
LagoEtAl15E3b
BadeckerEtAl02E6
WagersEtAl09E6
JaegerEtAl15E1
CunningsEtAl14E1
VanDykeEtAl11E1bretro
KushEtAl14
CunningsEtAl13E1HI
LagoEtAl15E2
CunningsEtAl13E1LO
Sturt03E1
DillonEtAl13E1refl
WagersEtAl09E5
VanDykeEtAl11E2bretro
PatilEtAl2016
TuckerEtAl2015
WagersEtAl09E4pp
PearlmutterEtAl99E1
PearlmutterEtAl99E3sing
PearlmutterEtAl99E2
CunningsEtAl13E2LO

Study

−100 −50 0 50 100 150

Observed effect (ms)

data
posterior

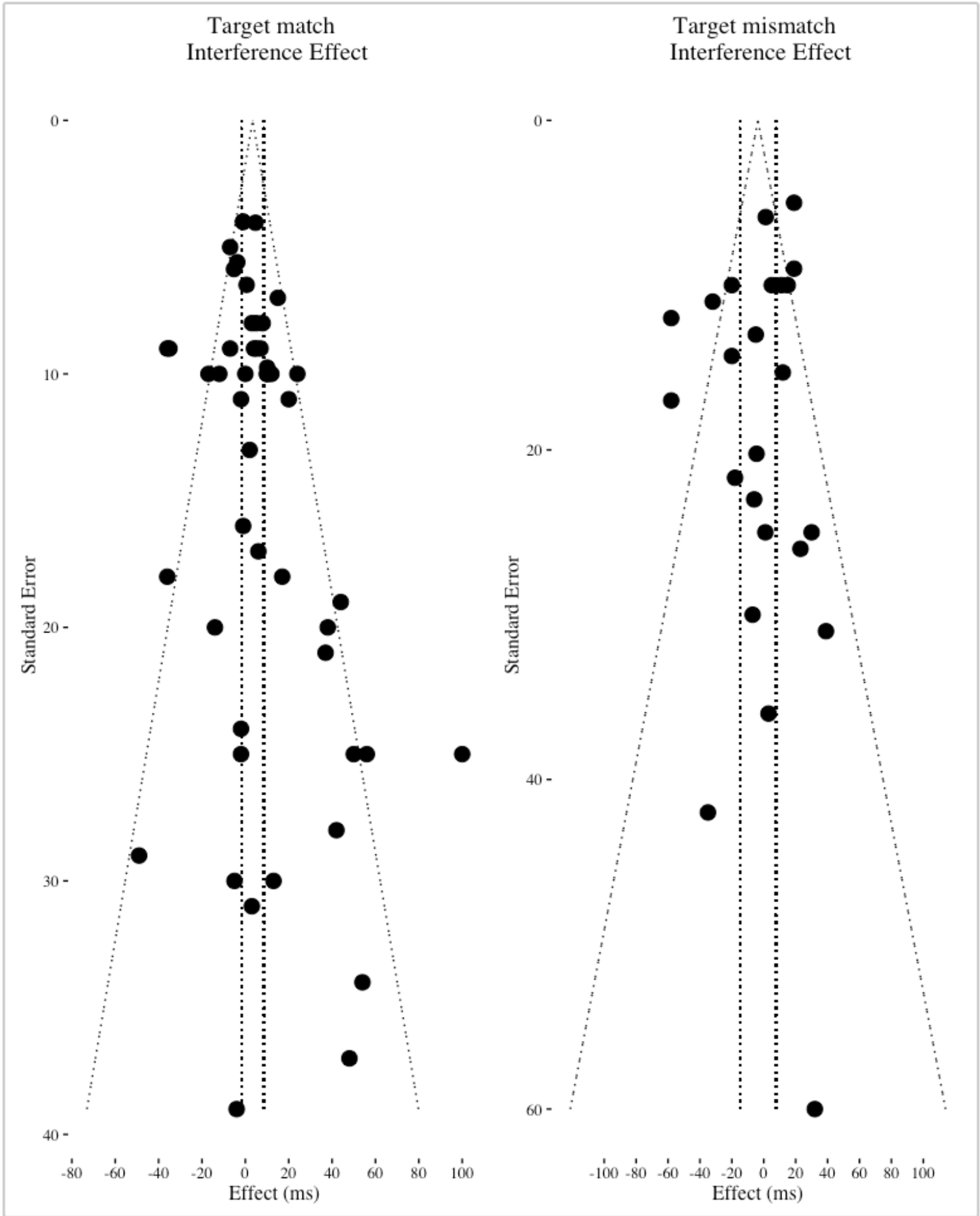
Target Mismatch

CunningsEtAl14E1
CunningsEtAl13E1LO
KushEtAl14
CunningsEtAl13E2LO
PearlmutterEtAl99E1
JaegerEtAl15E1
Sturt03E2
LagoEtAl15E3a
PatilEtAl2016
WagersEtAl09E3RNplu
CunningsEtAl13E2HI
DillonEtAl13E1refl
CunningsEtAl13E1HI
LagoEtAl15E3b
PearlmutterEtAl99E2
DillonEtAl13E1agrmt
Sturt03E1
LagoEtAl15E1
WagersEtAl09E3RNsing
LagoEtAl15E2
WagersEtAl09E4pp
TuckerEtAl2015
WagersEtAl09E5
WagersEtAl09E2

Study

−100 0 100

Observed effect (ms)


Target match
Interference Effect
Target mismatch
Interference Effect
Standard Error
0
10
20
30
40
-80
-60
-40
-20
0
20
40
60
80
100
Effect (ms)
Standard Error
0
20
40
60
-100
-80
-60
-40
-20
0
20
40
60
80
100
Effect (ms)

Publication bias

- There is clear evidence for publication bias in Target Match data (see the missing data in the lower left part of the funnel plot).

- In Target Mismatch, we see quite a few extreme effects being observed.

- These are probably instances of Type S and M errors, and are due to the fact that we run relatively low powered studies in psycholinguistics (See SV's ESSLLI 2015 course: http://bit.ly/esslli15vasishth).

Bayesian Meta-regression (Jäger, Engelmann, Vasishth 2016)

$$y_i \mid \theta_i, \beta, \sigma_i^2 \sim N(\theta_i + \beta \times \text{predictor}_i, \sigma_i^2) \quad i = 1, \ldots, n$$

$$\theta_i \mid \theta, \tau^2 \sim N(\theta, \tau^2),$$

$$\theta \sim N(0, 100^2),$$

$$\beta \sim N(0, 100^2),$$

$$\tau \sim N(0, 100^2) T(0,) (\text{truncated normal})$$

Meta-regression

In the data, the distractor was either:

- Subject AND Topic
- Subject OR Topic
- Neither subject nor topic

We investigated whether the prominence of the distractor has an effect

Meta-regression

In the data, the distractor was in a configuration such that interference was:

- proactive
- retroactive

We investigated whether the prominence of the distractor has an effect

Meta-regression

So the predictors were:

- AND vs OR (contrast coding: +1,-1)
- Or vs Other (contrast coding +1, -1)
- Pro vs retroactive interference (+1, -1)

The meta analysis model is shown in the next slide:

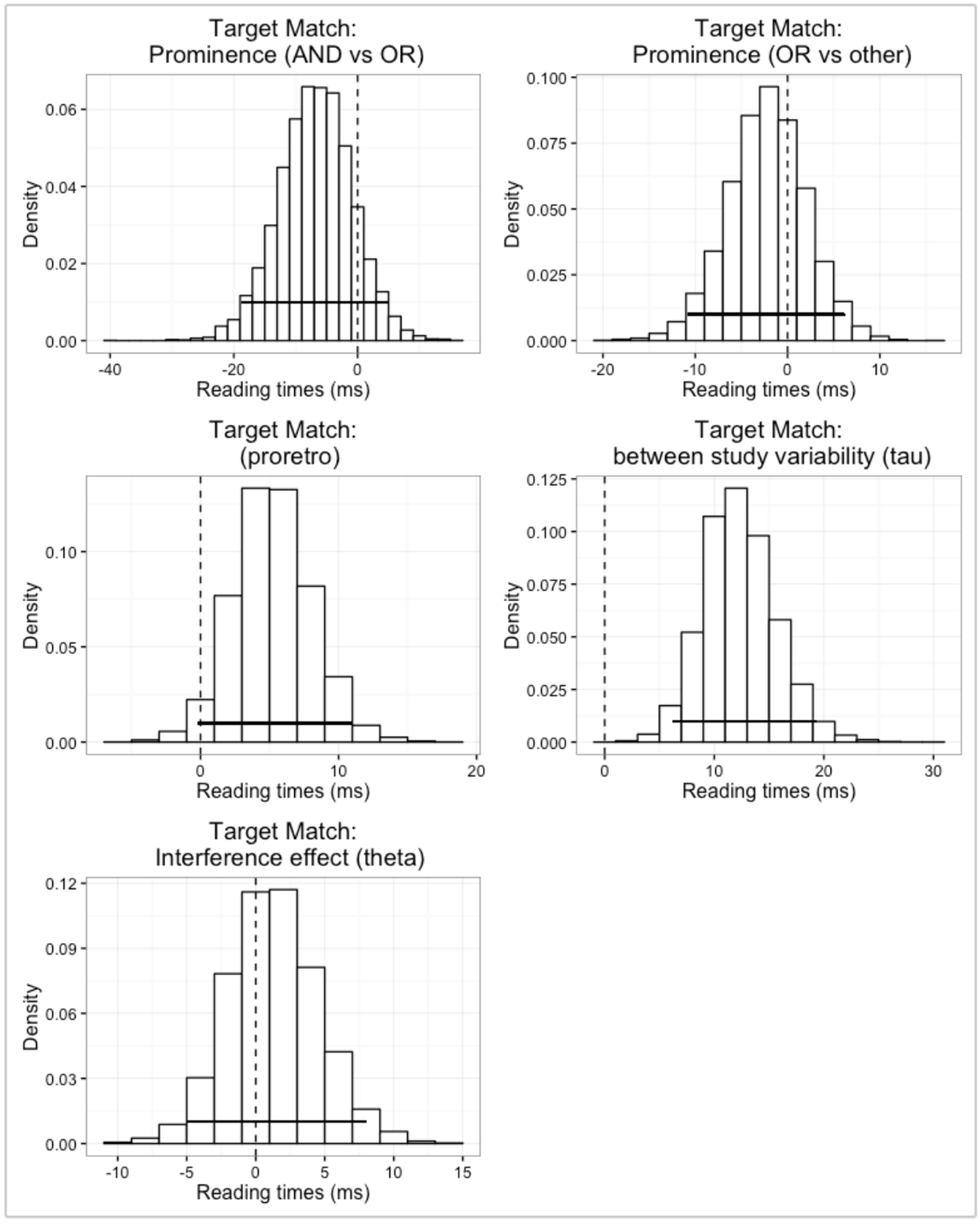
Meta-regression

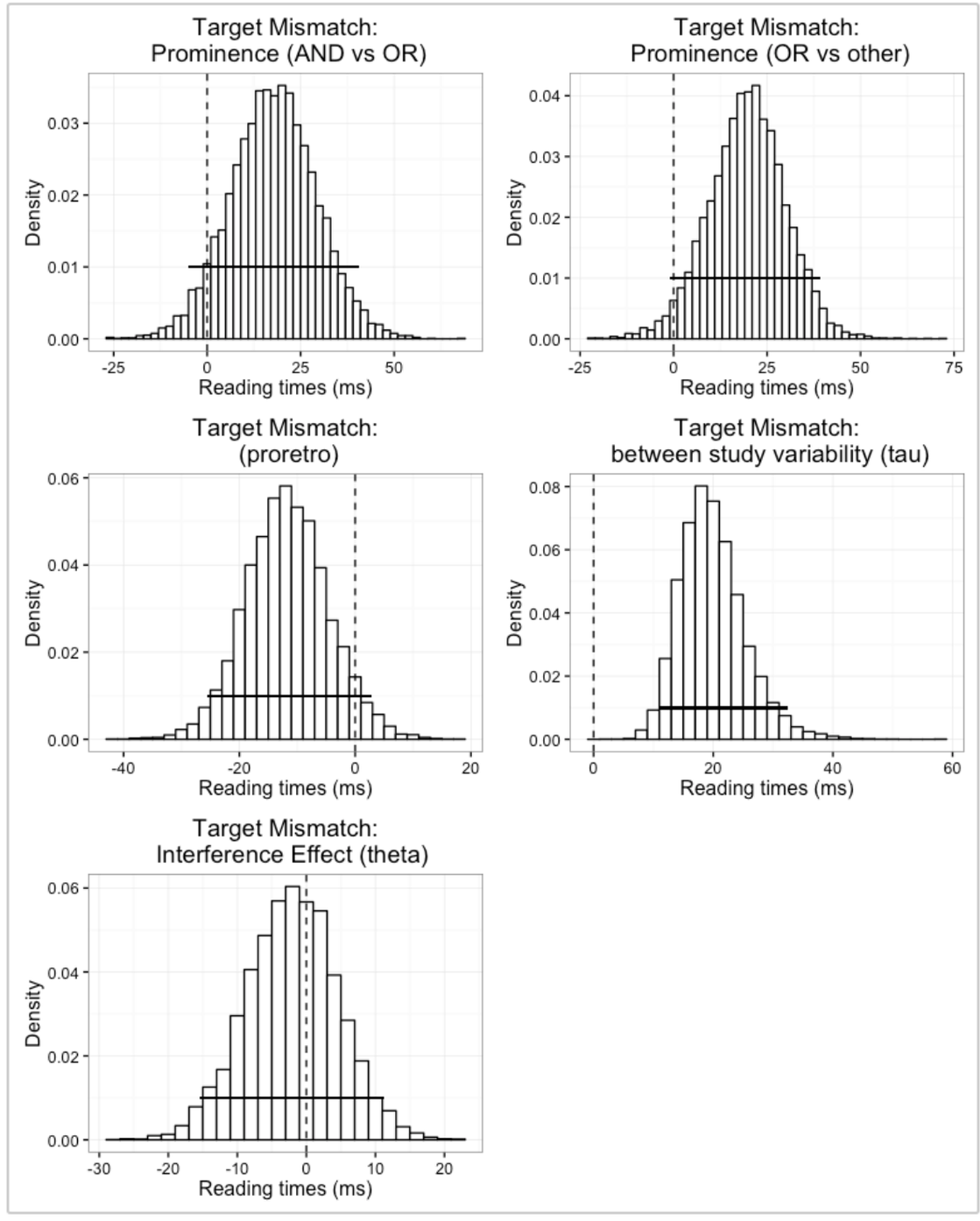
$$
\begin{aligned}
y_i \mid \theta_i, \beta_{AND}, \beta_{OR}, \beta_{PR}, \sigma_i^2 &\sim N(\theta_i + \beta_{AND}\text{ANDOR}_i + \beta_{OR}\text{ORother}_i + \beta_{PR}\text{proretro}, \sigma_i^2) \quad i = 1, \ldots, n \\
\theta_i \mid \theta, \tau^2 &\sim N(\theta, \tau^2), \\
\theta &\sim N(0, 100^2), \\
\beta &\sim N(0, 100^2), \\
\tau &\sim N(0, 100^2)T(0,)(\text{truncated normal})
\end{aligned}
$$

We can track the posterior distributions of

- The three beta parameters
- The between study variability tau
- The “true effect” theta.

Target Match and Mismatch studies (Meta-regression)





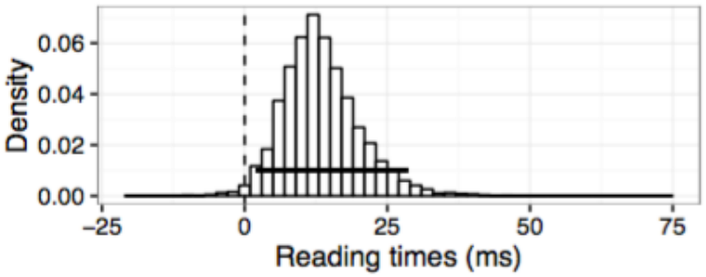
Sub-group analyses (by dependency type)

- Subject-verb dependencies (non-agreement, non-reflexive/reciprocal), all are Target Match

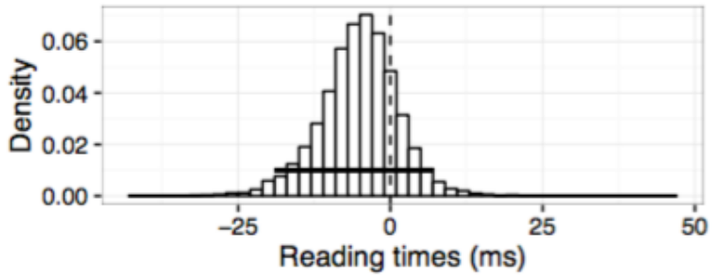
- Agreement subject-verb dependencies (Target Match and Mismatch)

- Reflexive/reciprocal dependencies (Target Match and Mismatch)

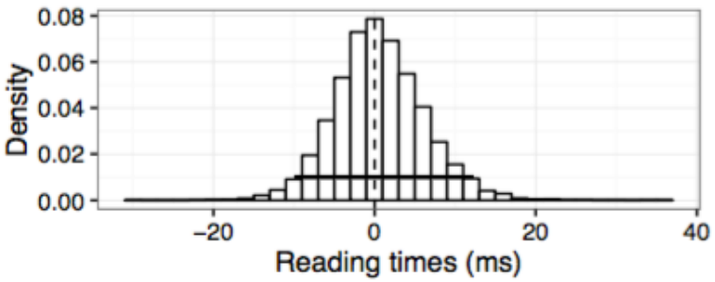
Target Match (Non−agreement, non−Reci): theta



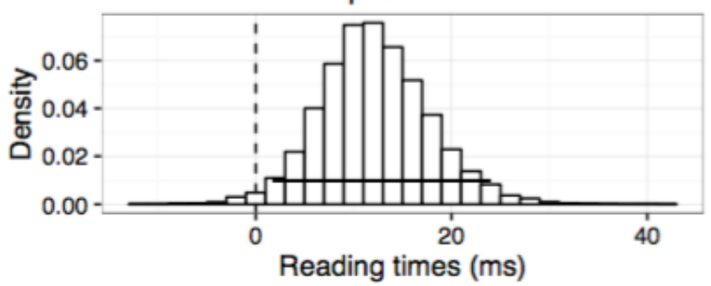
Target Match (Non−agreement, non−Reci): proretro



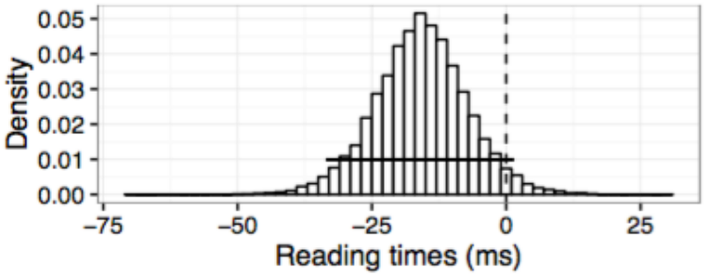
Target Match Agrmt: theta



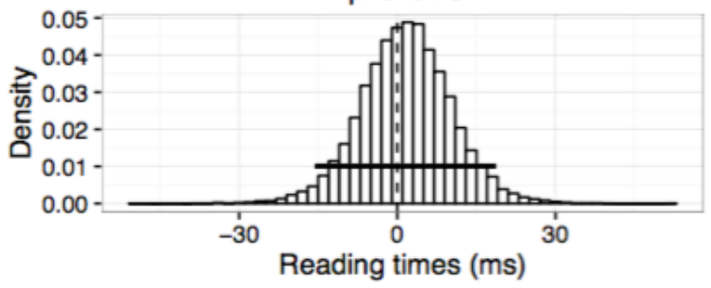
Target Match Agrmt: proretro



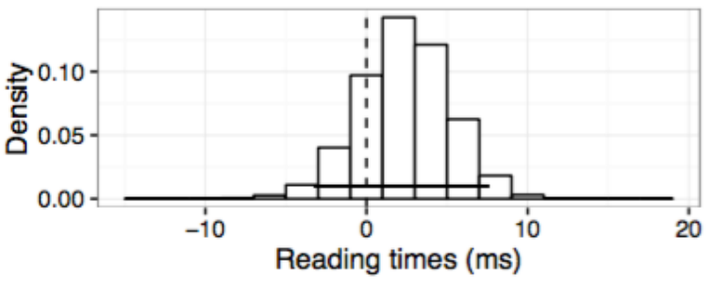
Target Mismatch Agrmt: theta



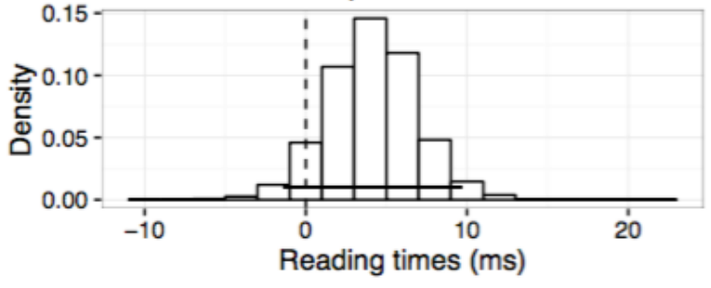
Target Mismatch Agrmt: proretro



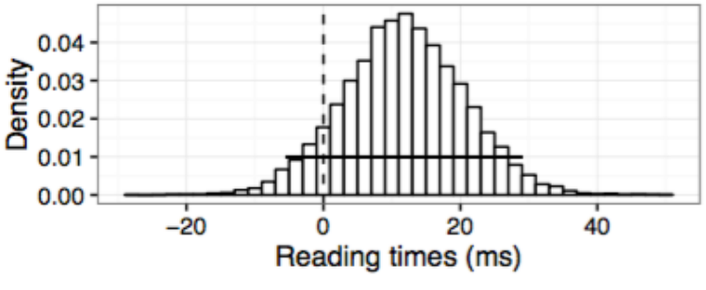
Target Match Refl: theta



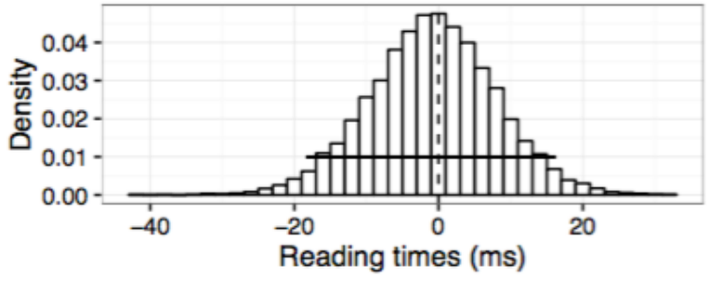
Target Match Refl: proretro



Target Mismatch Refl: theta



Target Mismatch Refl: proretro



Conclusions from meta-analysis

- Dependency type affects the pro/retro interference effect: proactive interference is strong only in agreement Match and reflexive Match data.
- Subject-verb dependencies and reflexives (Mismatch) show a slowdown in the interference effect.
- Agreement mismatch shows a speedup in the interference effect.
- The magnitude of the interference effect is rather small (in reading).
- The 2005 version of the ACT-R model fails to explain some of the studies:
  - Studies showing facilitation in Target Match.
  - Studies showing inhibition in Target Mismatch.