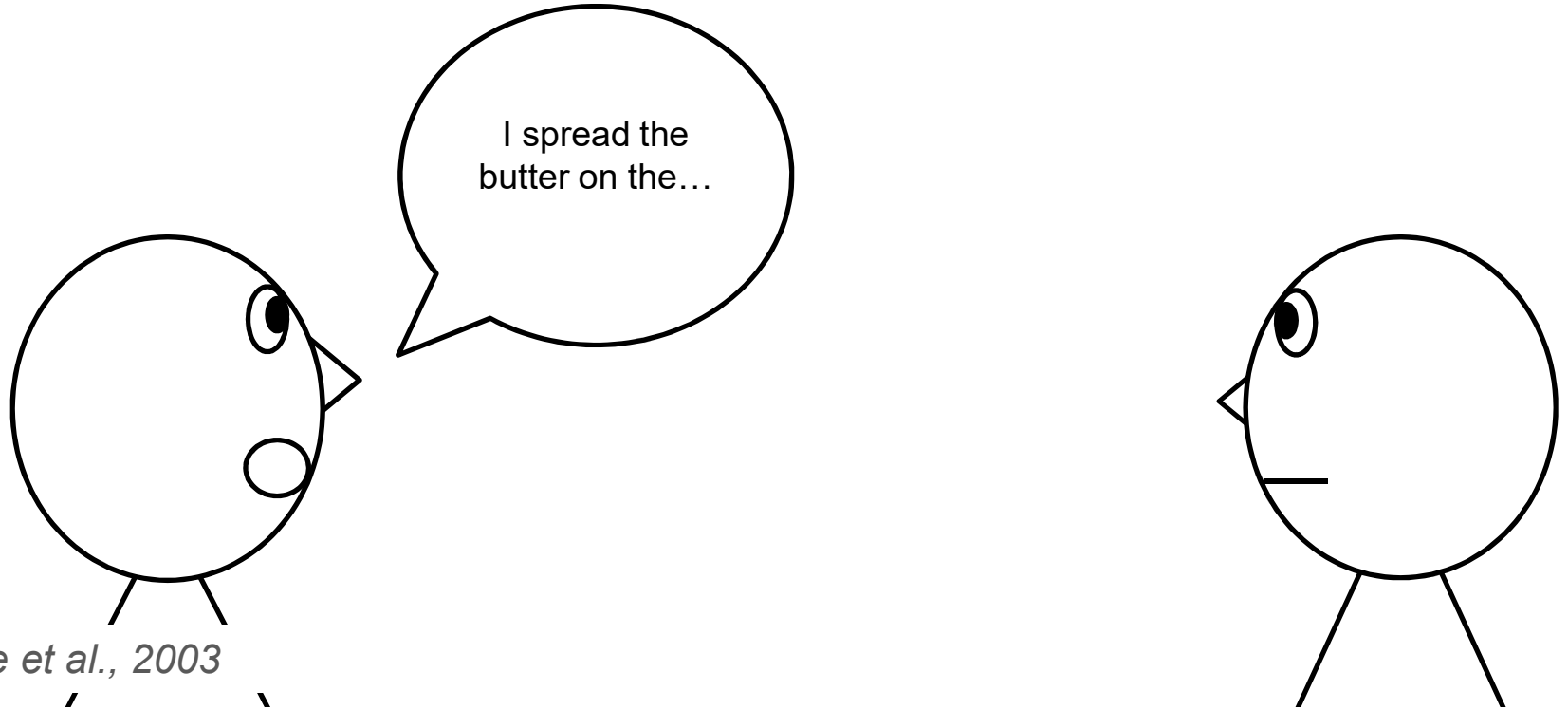
The real-time application of grammatical constraints to prediction: Timecourse evidence from eye tracking

Kate Stone, Elise Oltrogge, Shravan Vasishth, and Sol Lago

People predict upcoming words



Kamide et al., 2003

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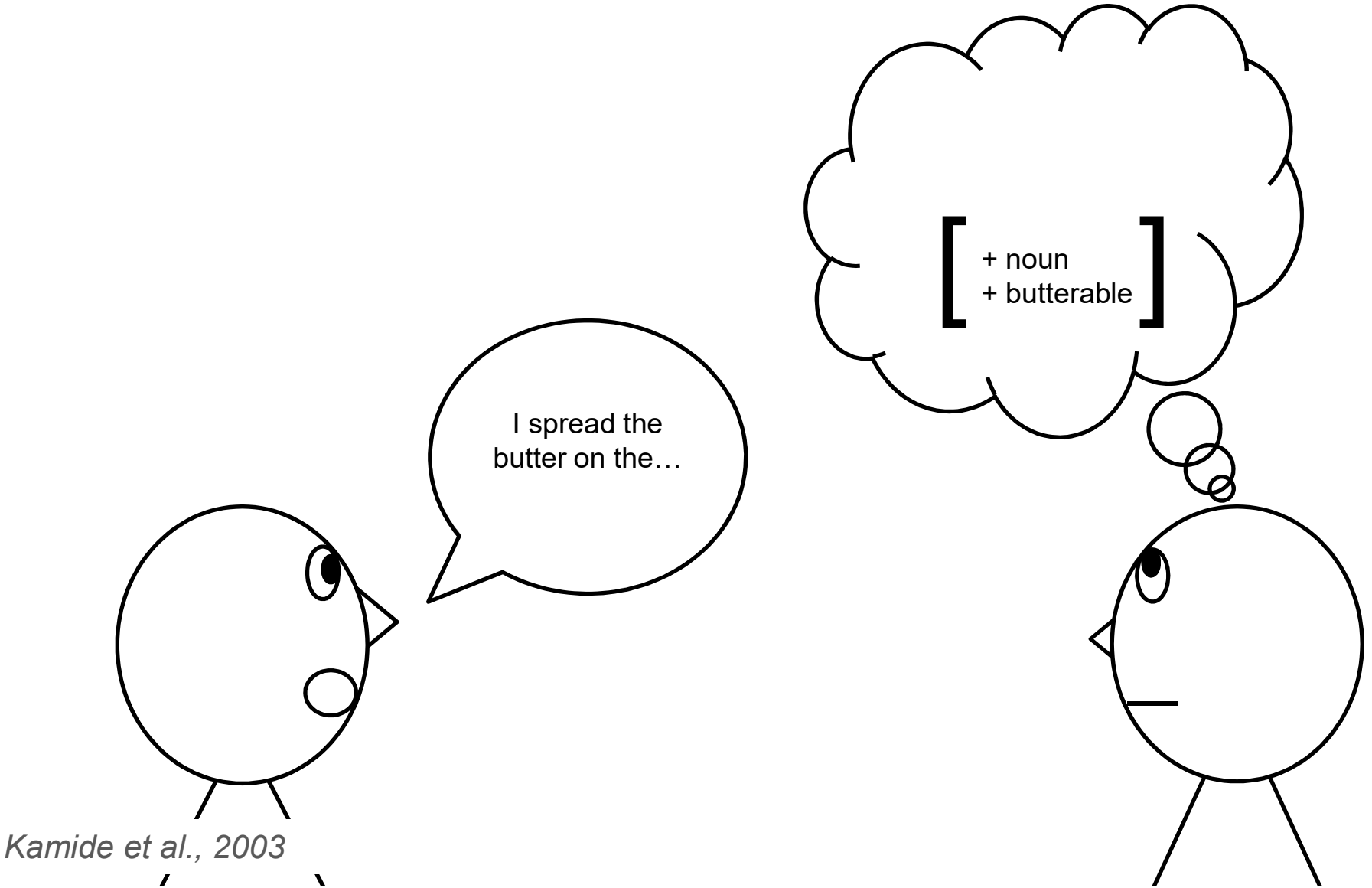

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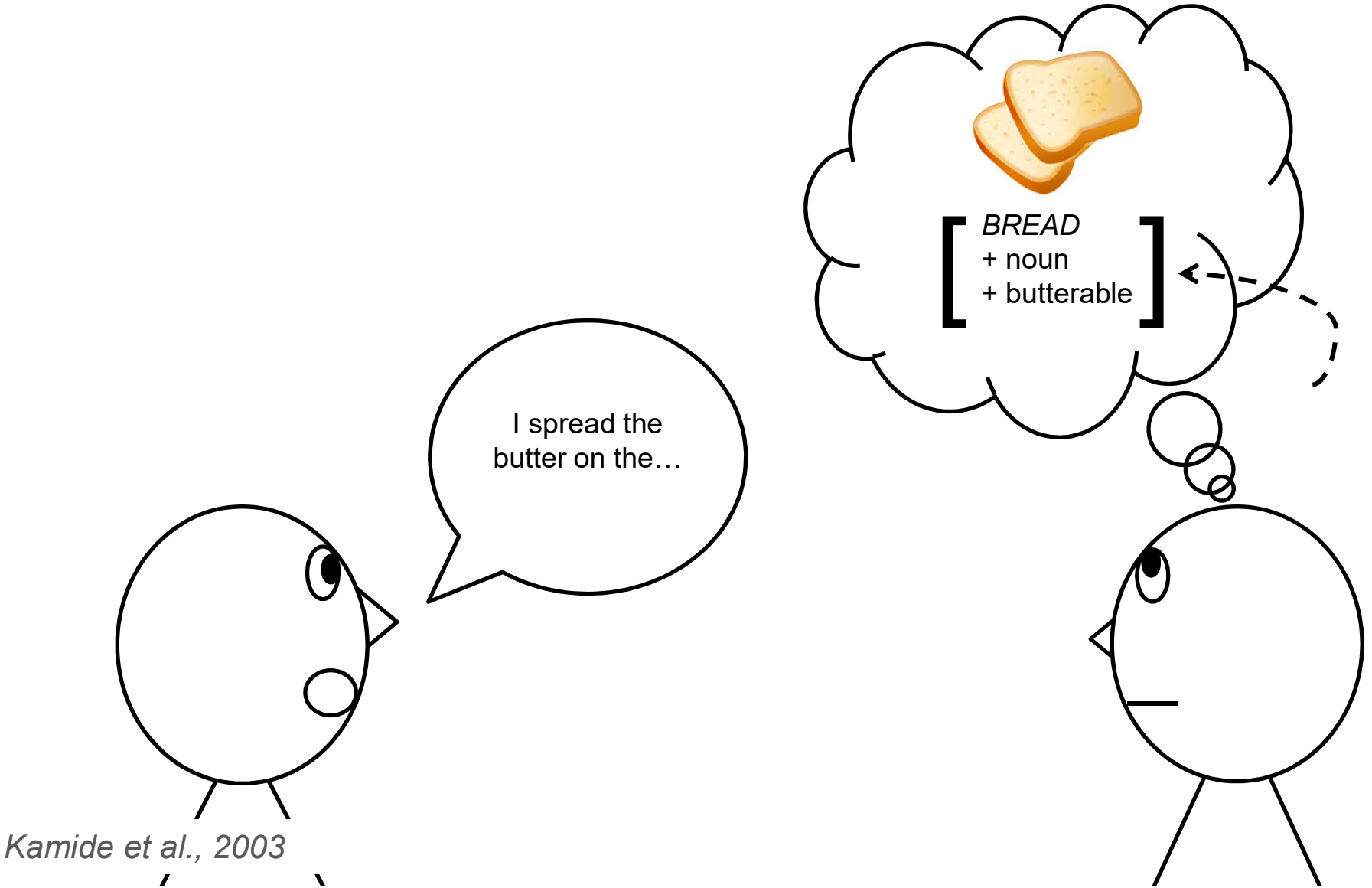

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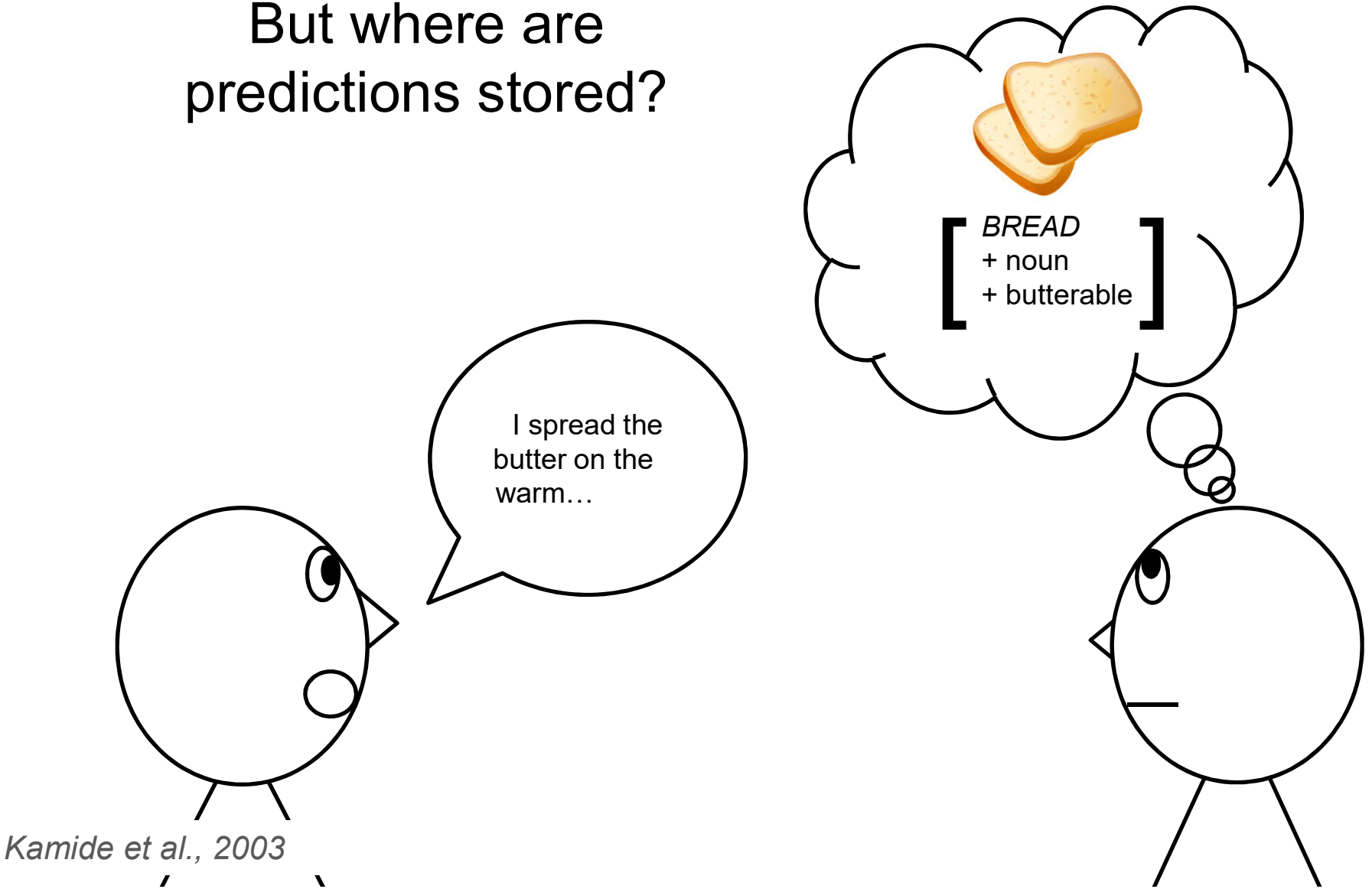
But where are predictions stored?



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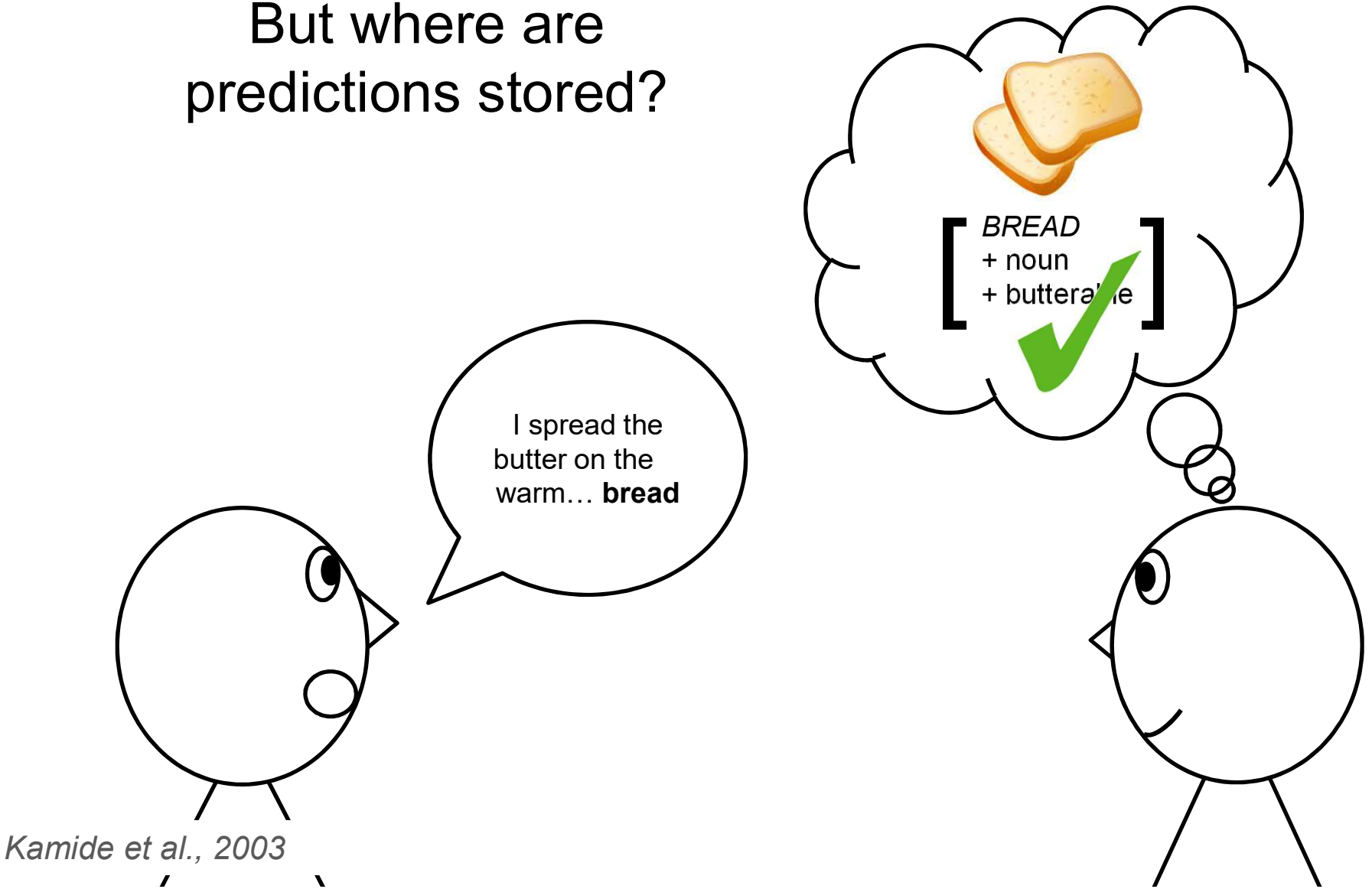

Kamide et al., 2003

Working memory?

- The same system that supports comprehension may also support prediction

  Ness et al., 2018; Lewis & Vasishth, 2005; Lau, Holcomb, & Kuperberg 2013; Gibson 1998; Gibson 2000

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[+ singular
+ c-com]

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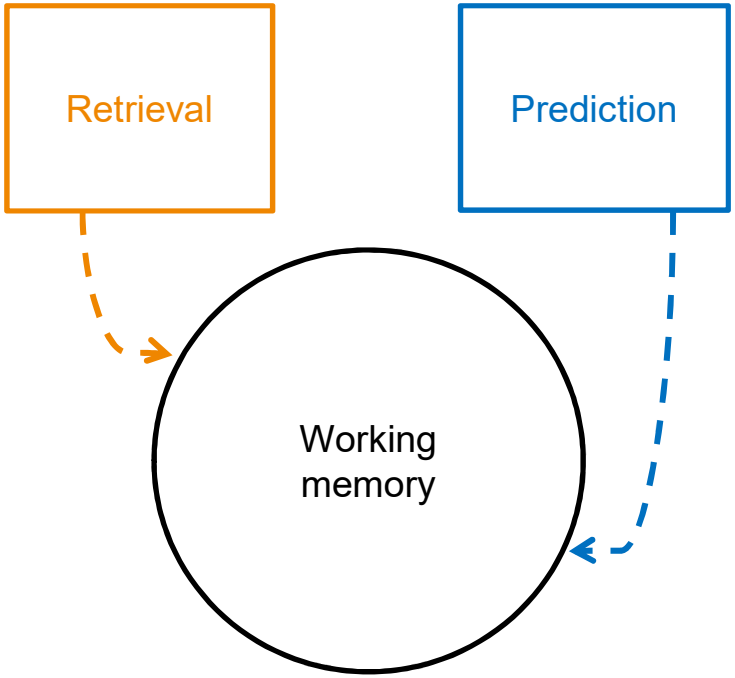
A unified memory store

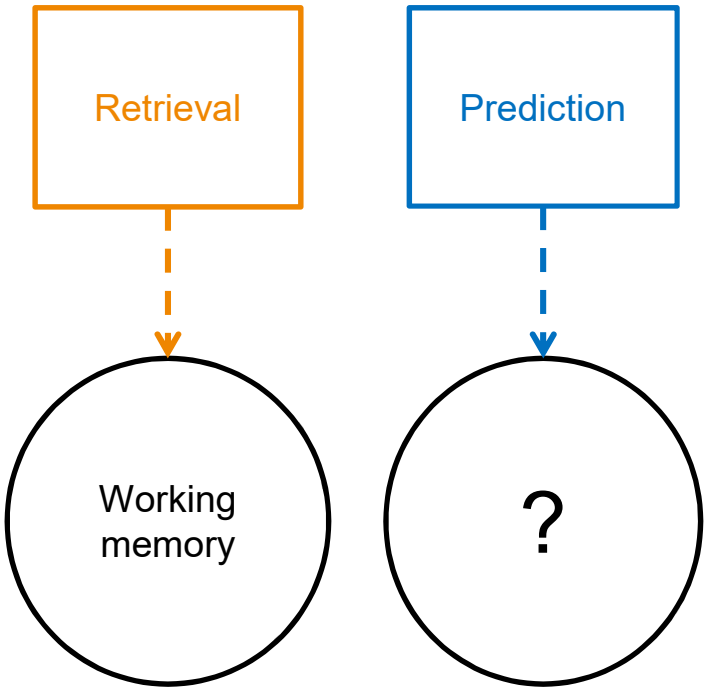


- Previously encountered words and predicted words held in the same memory store
- Consistent with unified models of memory
  - One set of memory representations
  - Activation level determined by recency and frequency of use

Atkinson & Shiffrin, 1971; Anderson, 1983; Cowan, 1988; McElree, 2001; Oberauer, 2002

Multiple memory stores

- Retrieval and predictions have separate memory stores
- Separate unit specialised for each process
- Consistent with models of multiple memory stores



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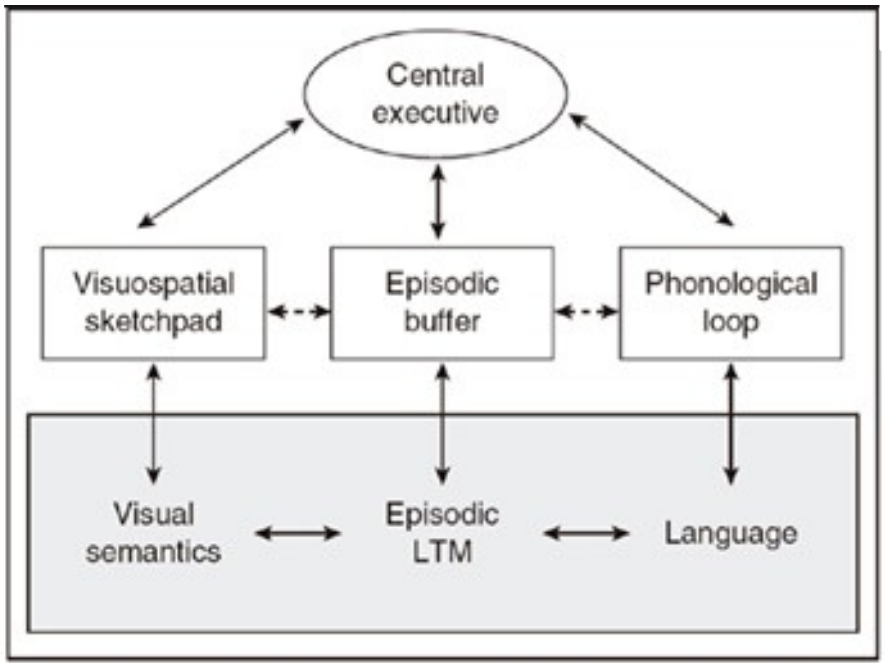
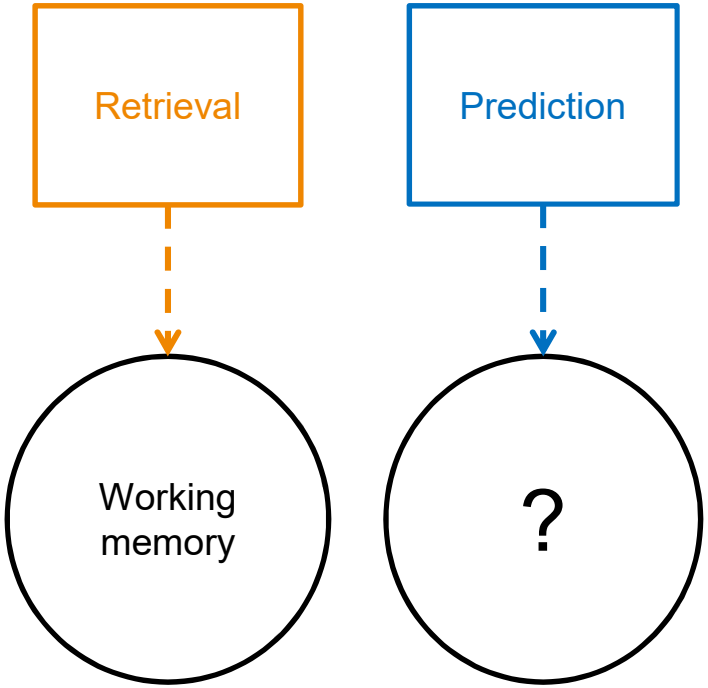


Baddeley, 2000



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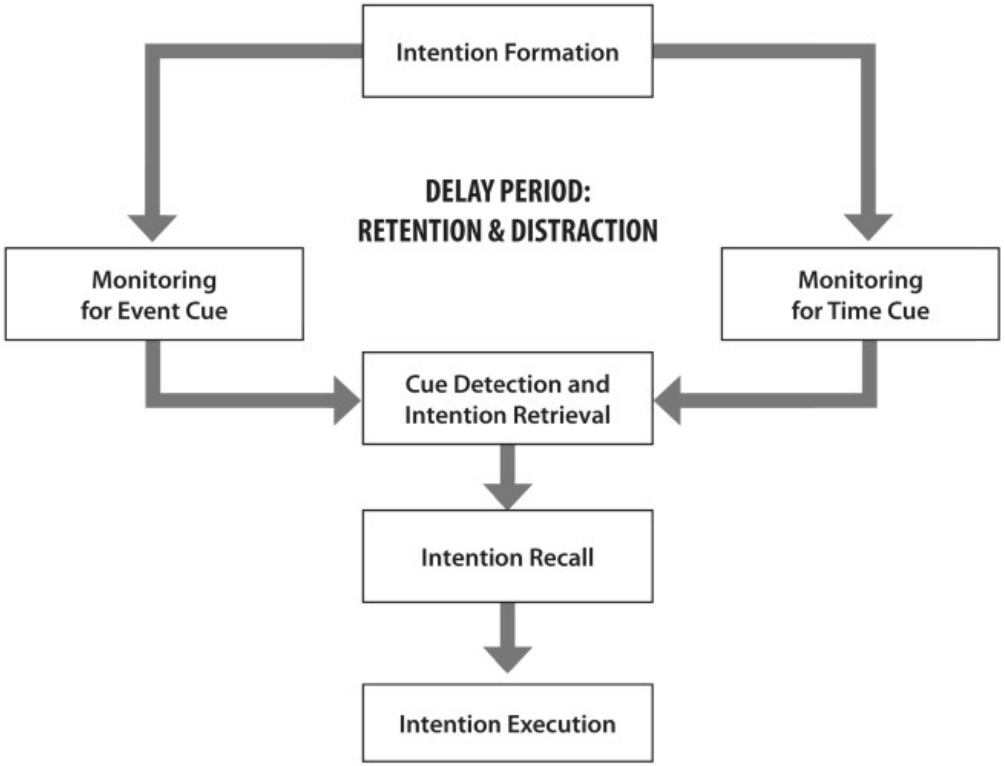
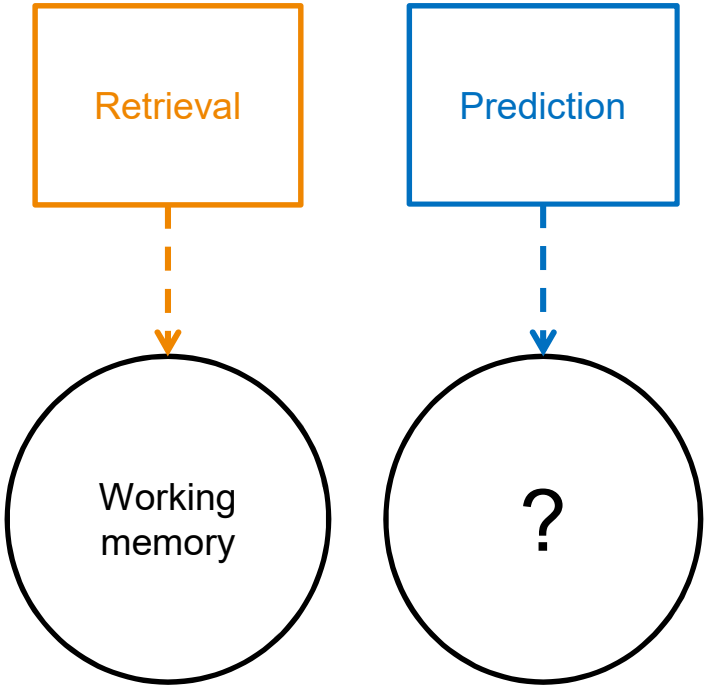
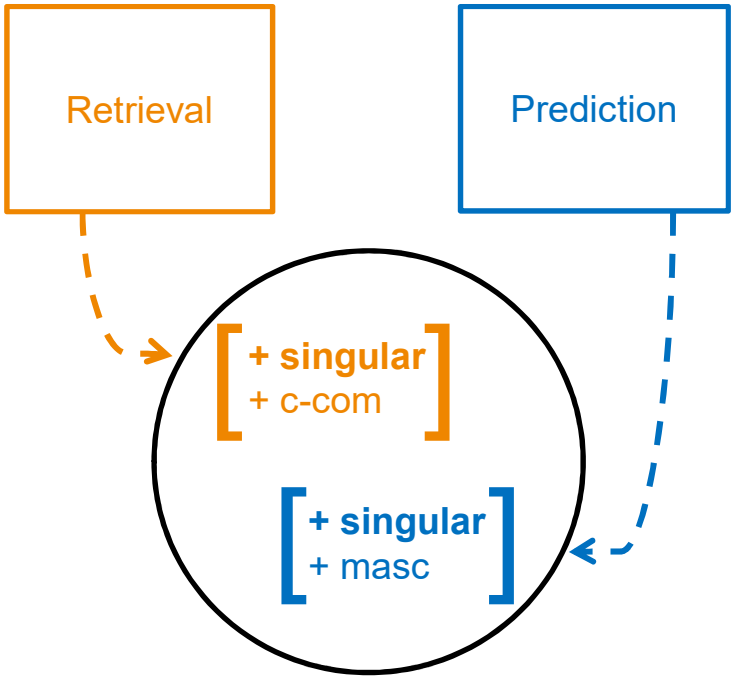




Zogg et al., 2012

Two possible scenarios

Unified memory store



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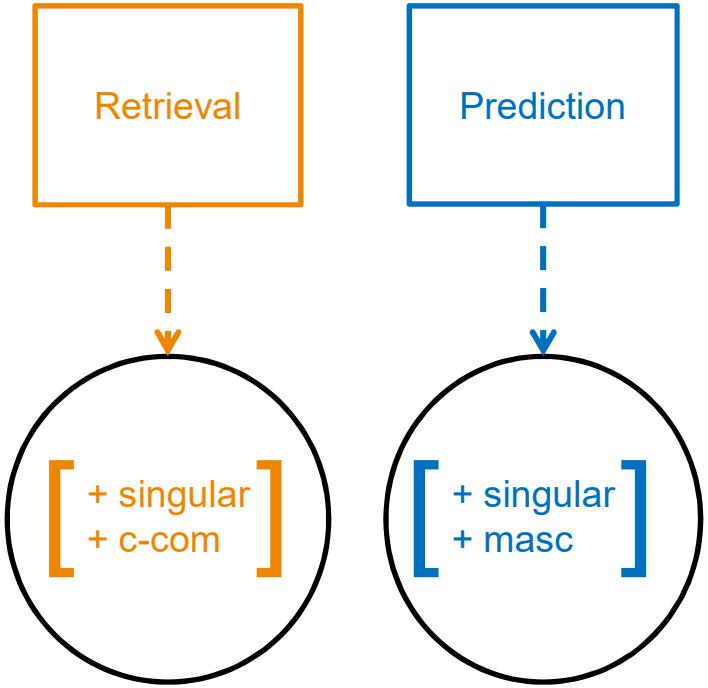
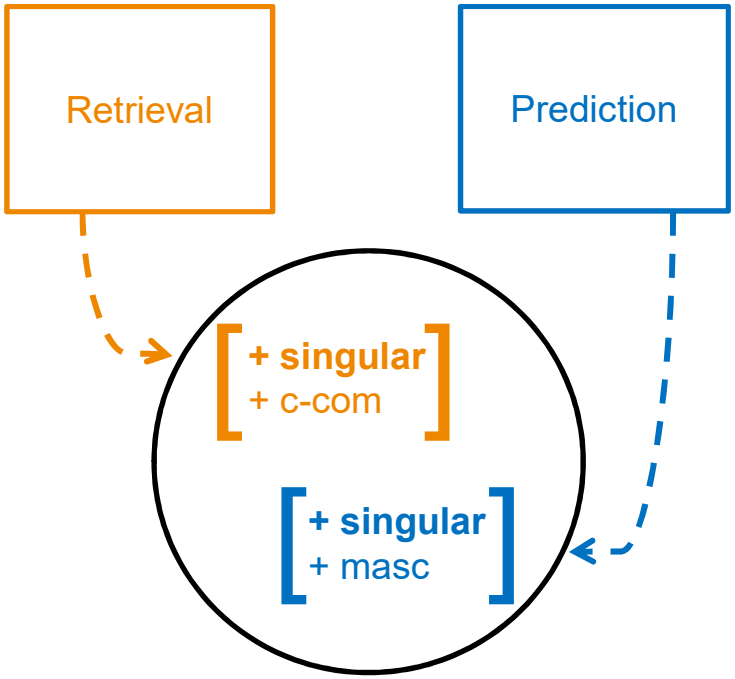


Two possible scenarios

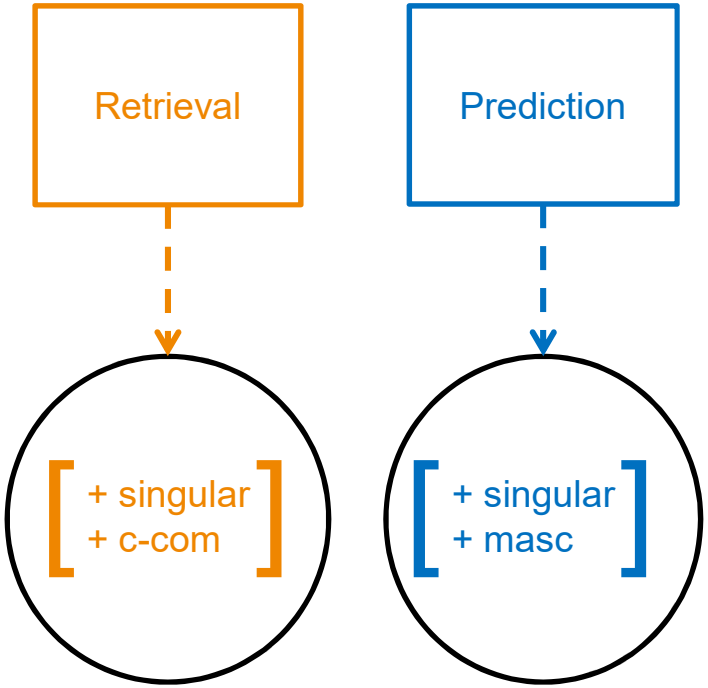
Unified memory store

INTERACTION



Multiple memory stores

NO INTERACTION



Does antecedent retrieval interact with word prediction?

Possessive pronouns

English: Martin asks Sarah to sew **his** button on.

Possessive pronouns

English: Martin asks Sarah to sew **his** button on.

[+ masc]

Possessive pronouns

Possessive pronouns

German: Martin bittet Sarah, **seinen** Knopf anzunähen.

Possessive pronouns

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Possessive pronouns

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Possessive pronouns

Does noun prediction interact with antecedent retrieval in German?

German possessive pronouns:

A visual world experiment

Martin and Sarah have to clean up the house before their parents get home

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A visual world experiment

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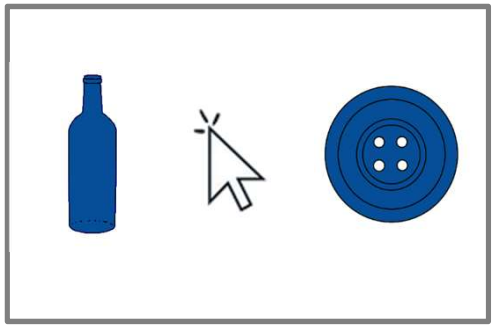
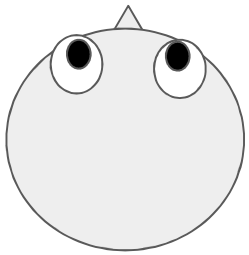
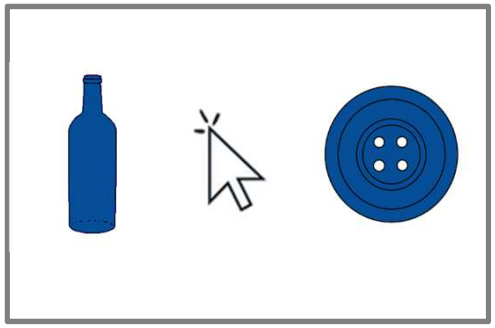


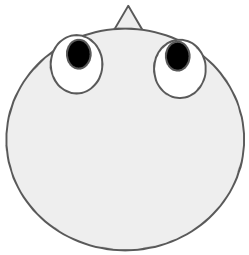


Martin and Sarah have to clean up the house before their parents get home

“Click on his blue button”

“Klicke auf sein**en** blauen Knopf”





Martin and Sarah have to clean up the house before their parents get home

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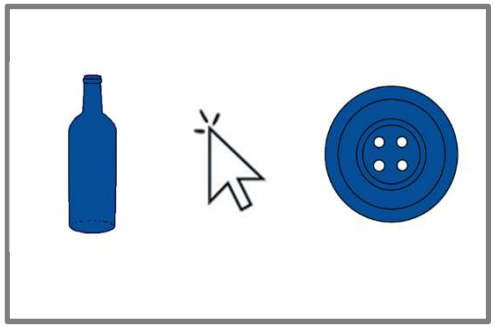
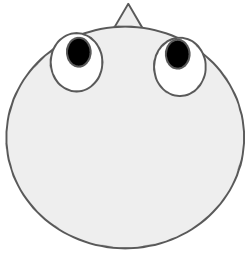
die Flasche.fem
COMPETITOR



der Knopf.masc
TARGET

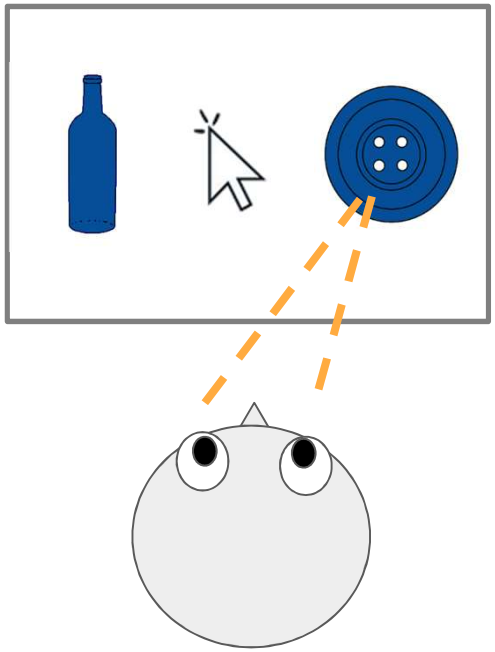


Martin and Sarah have to clean up the house before their parents get home

Critical window

“Klicke auf sein**en** blauen Knopf”

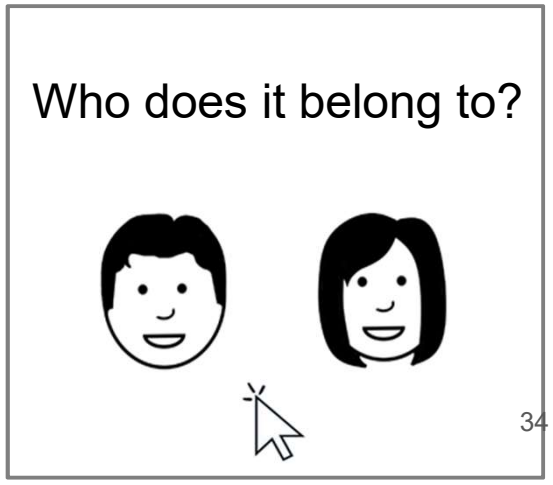
die Flasche.fem
COMPETITOR



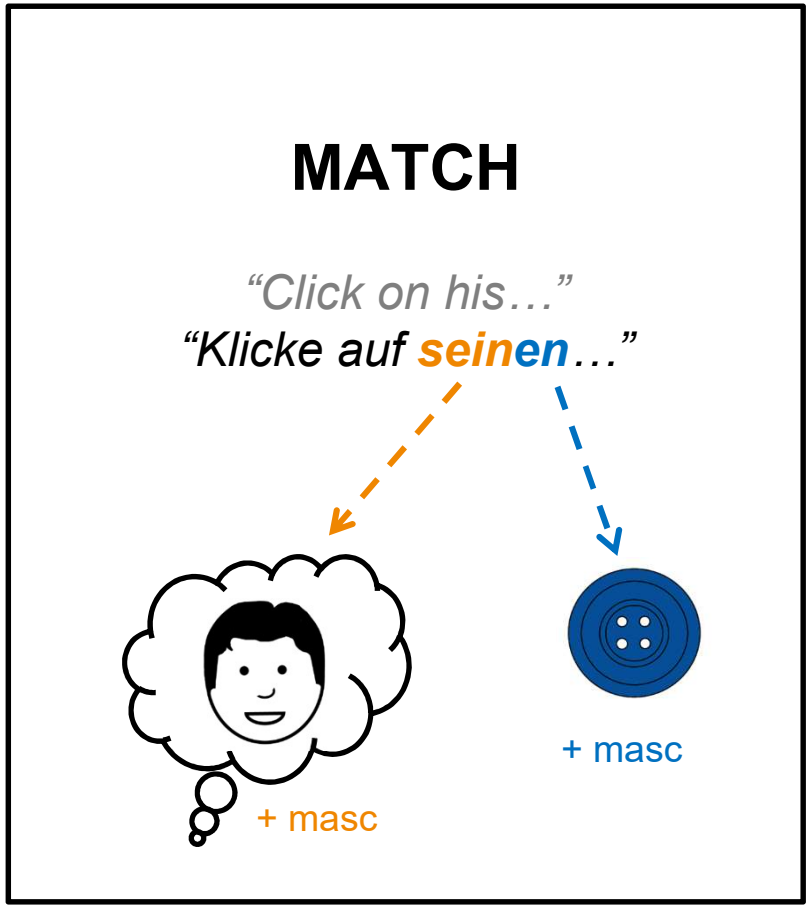
der Knopf.masc
TARGET

Martin and Sarah have to clean up the house before their parents get home

“Klicke auf sein**en** blauen Knopf”



Two conditions



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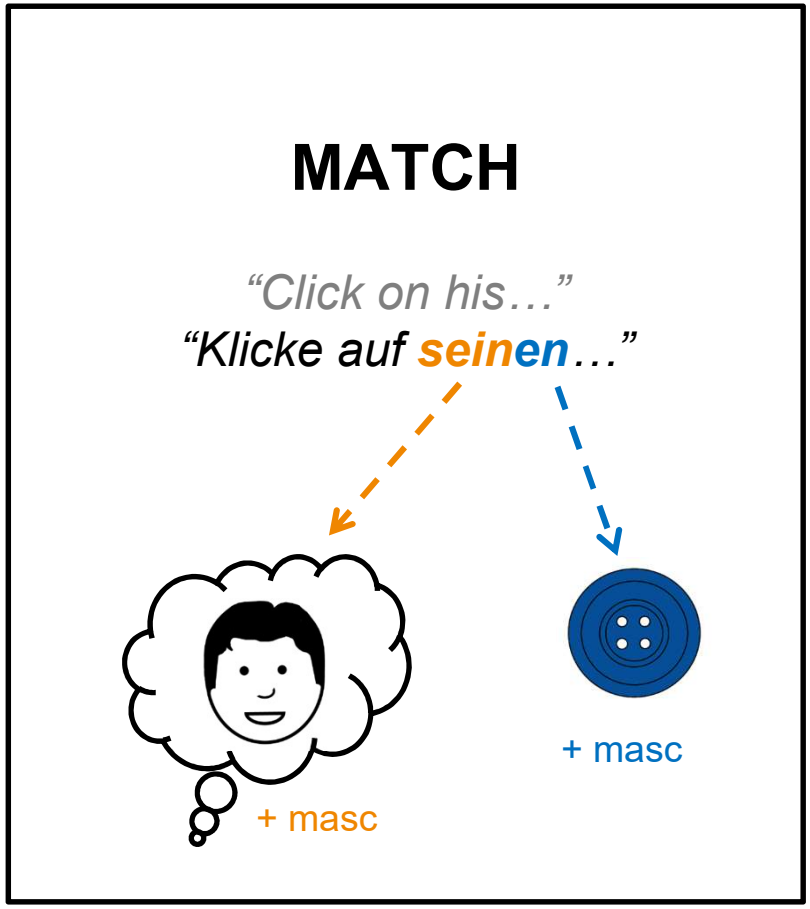

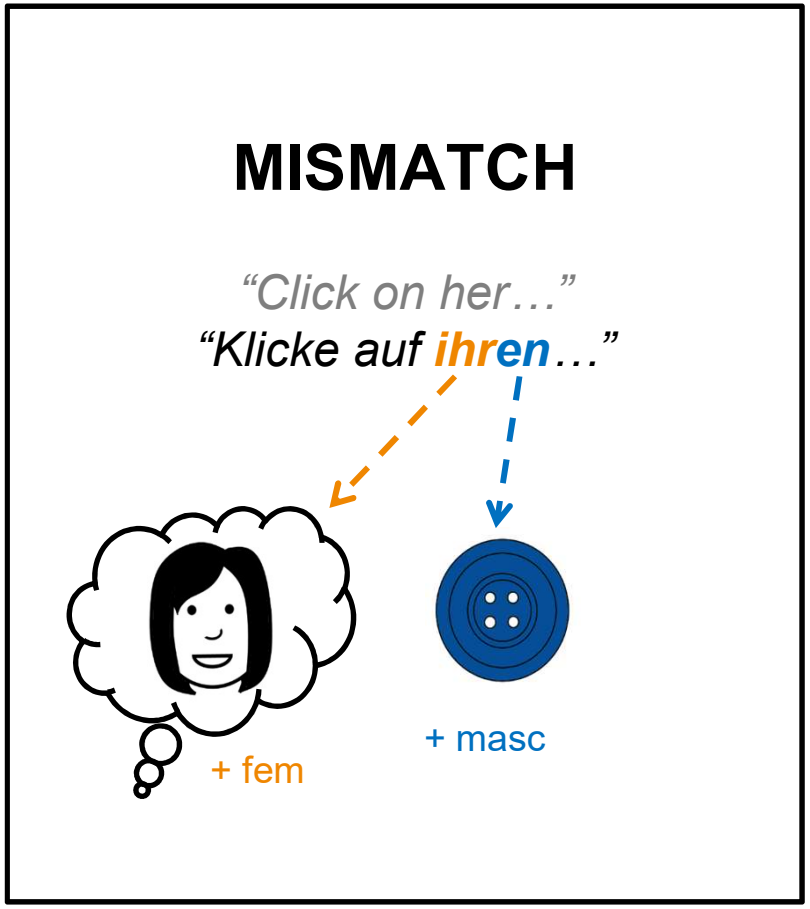

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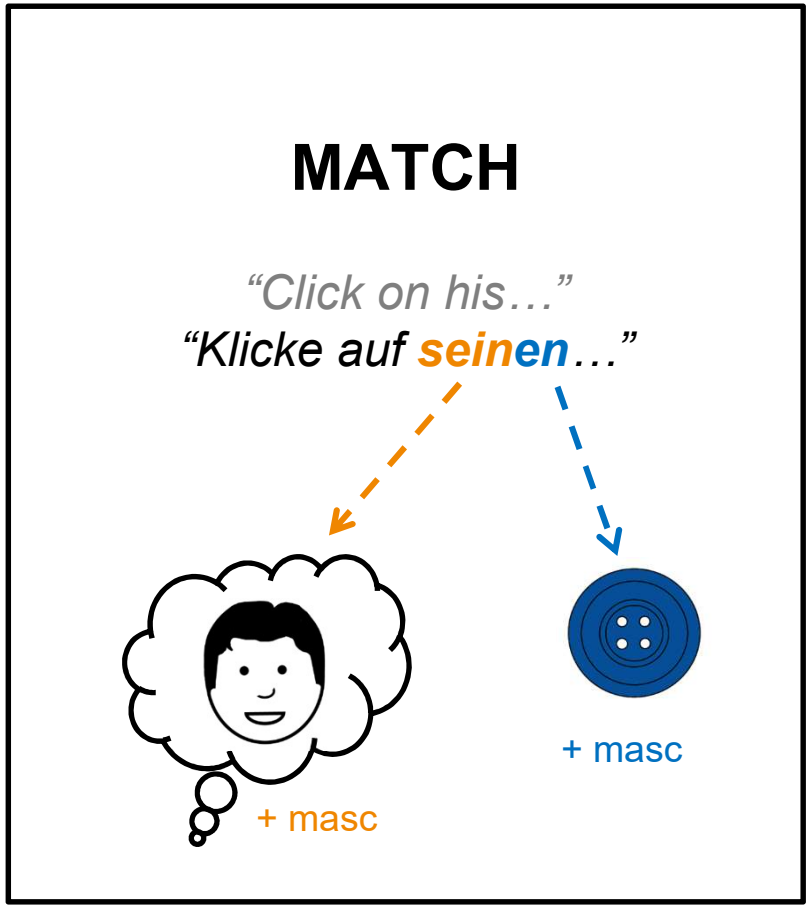

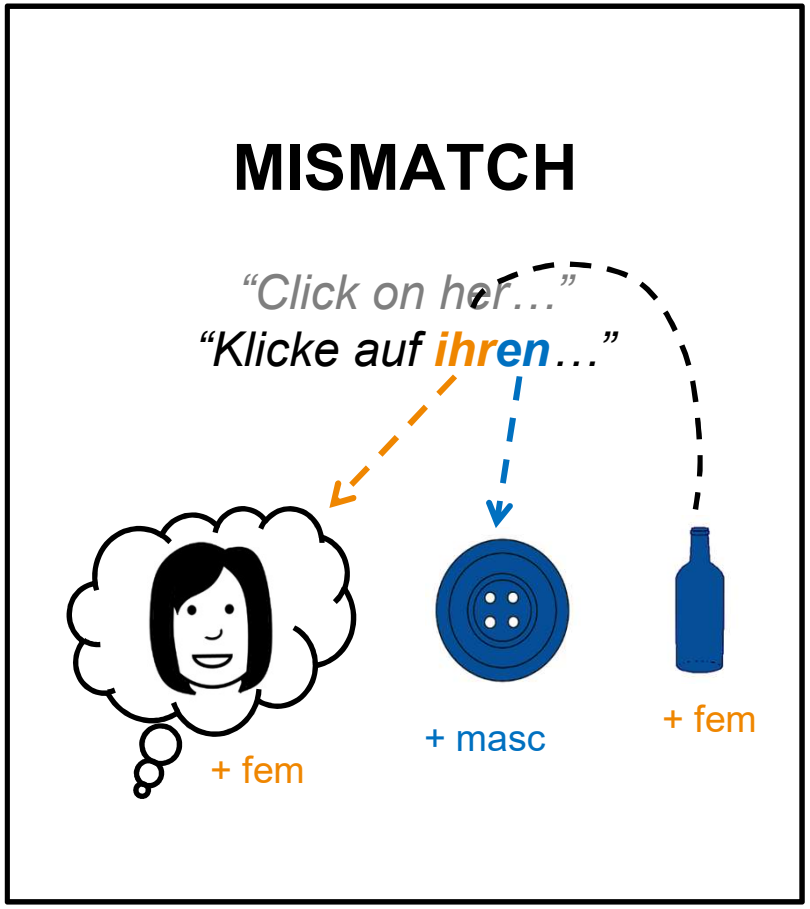

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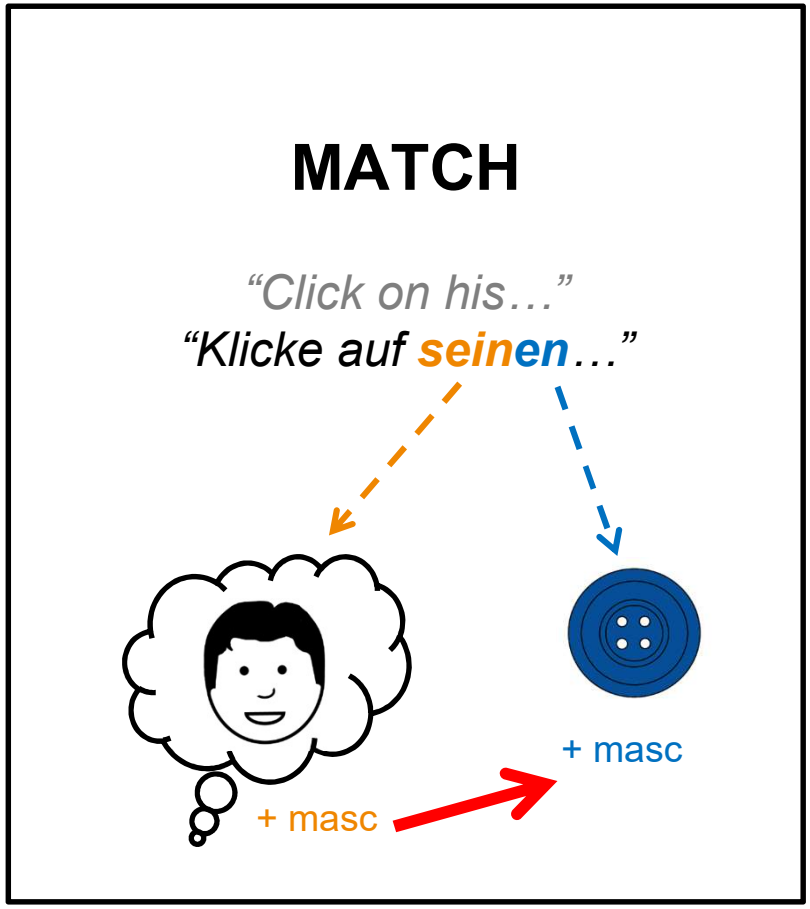

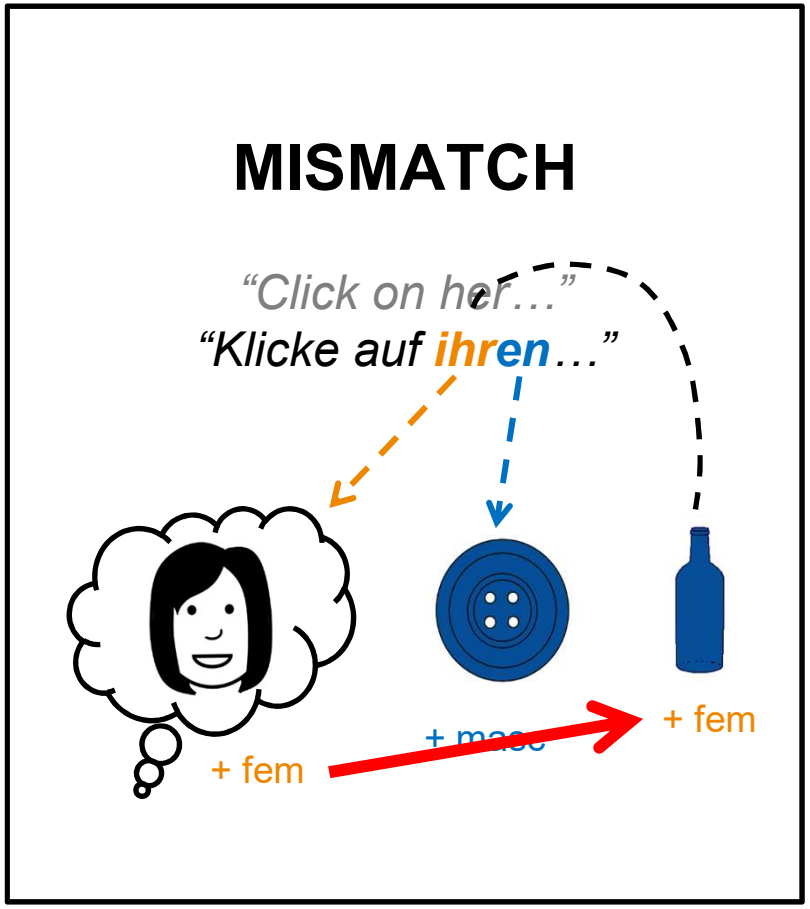

Results

N = 72 native
German speakers

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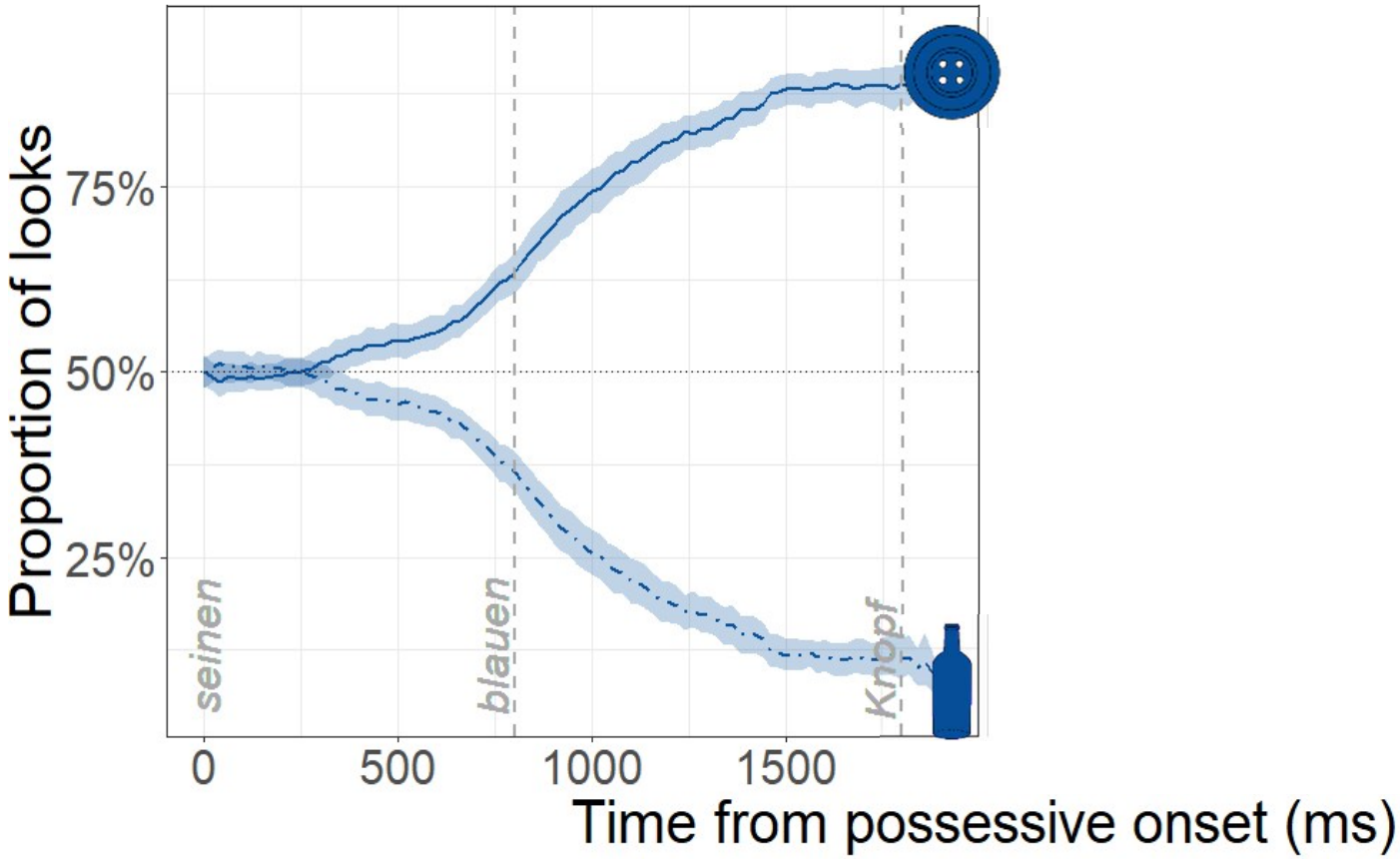

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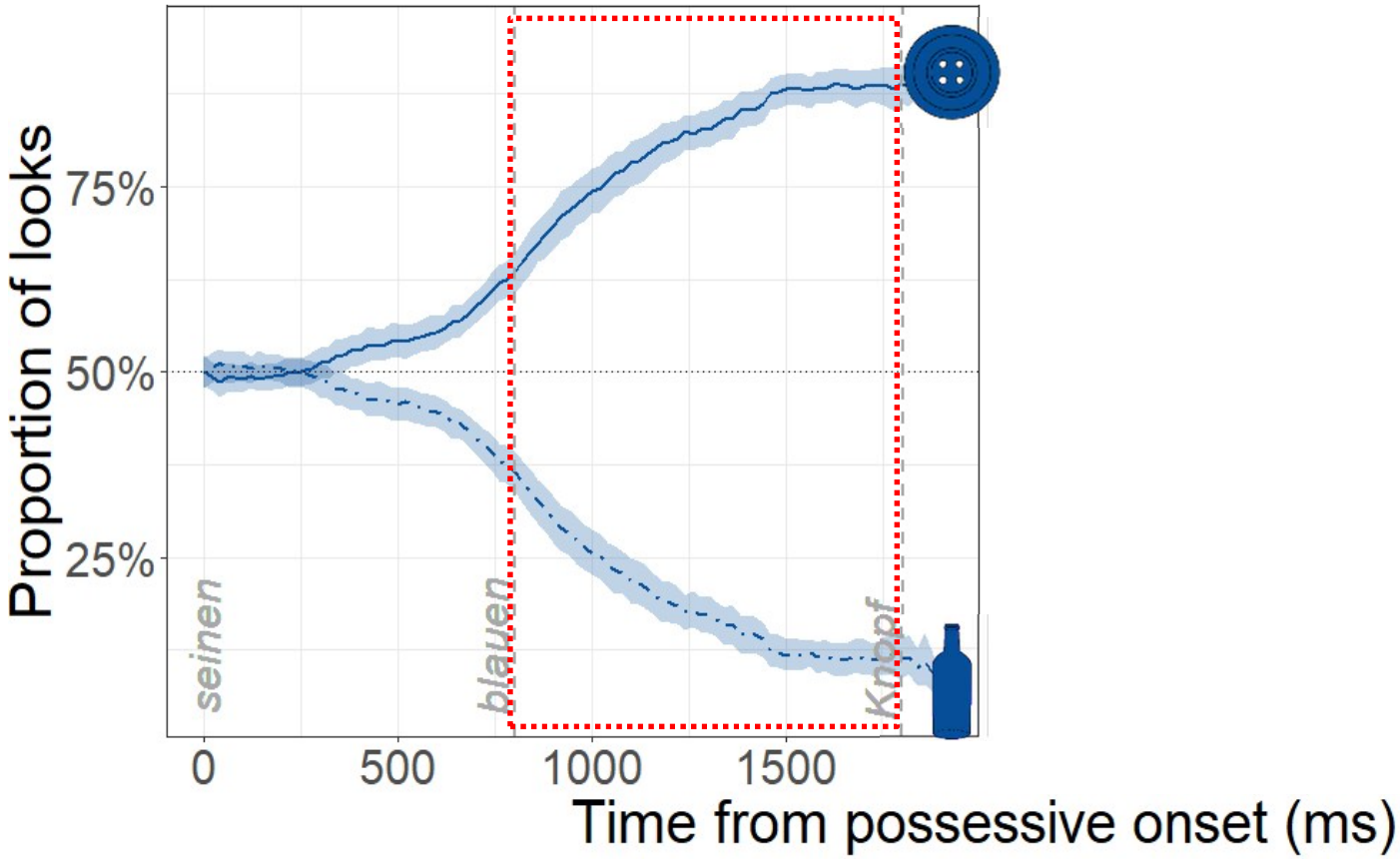

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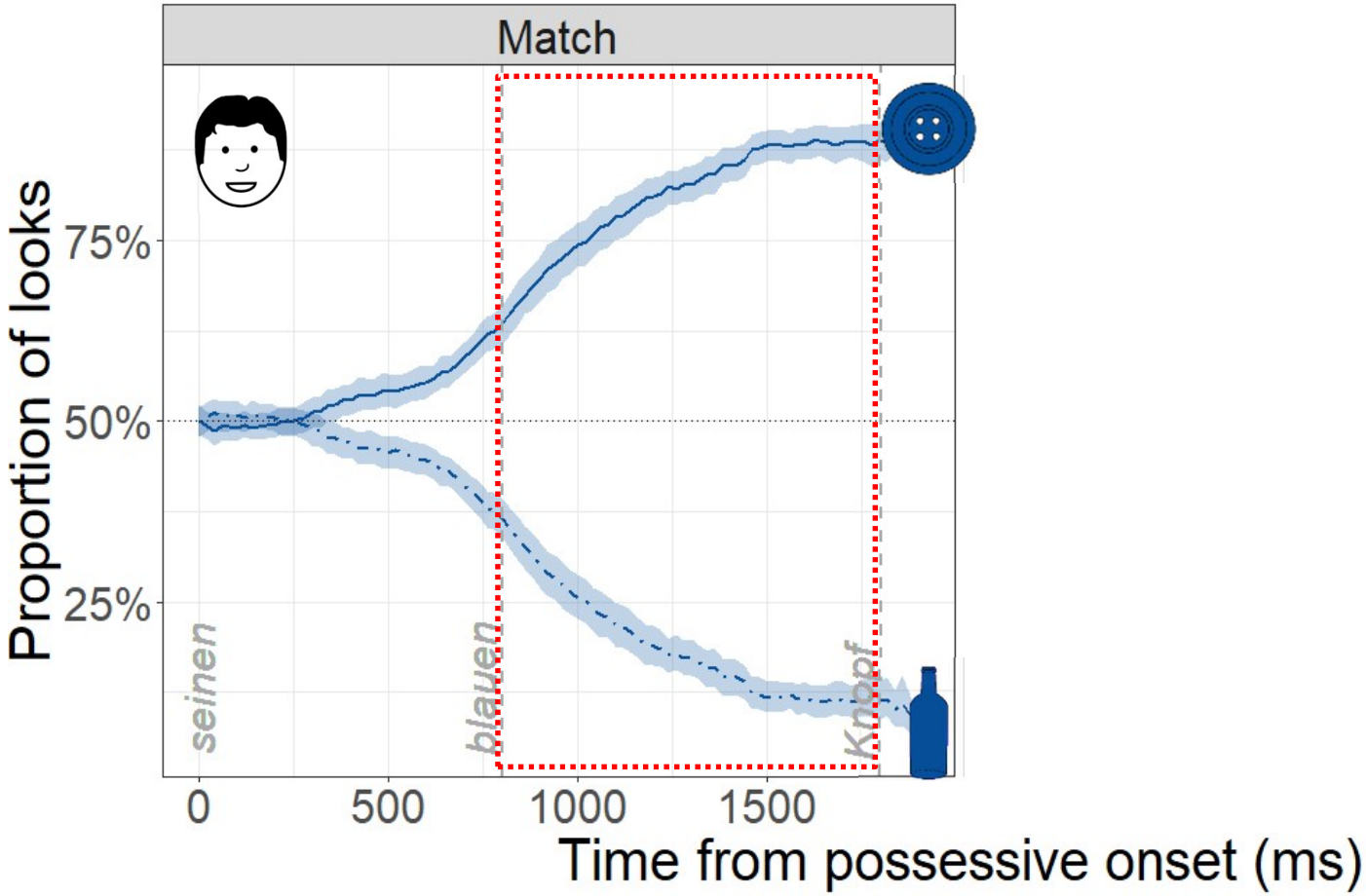

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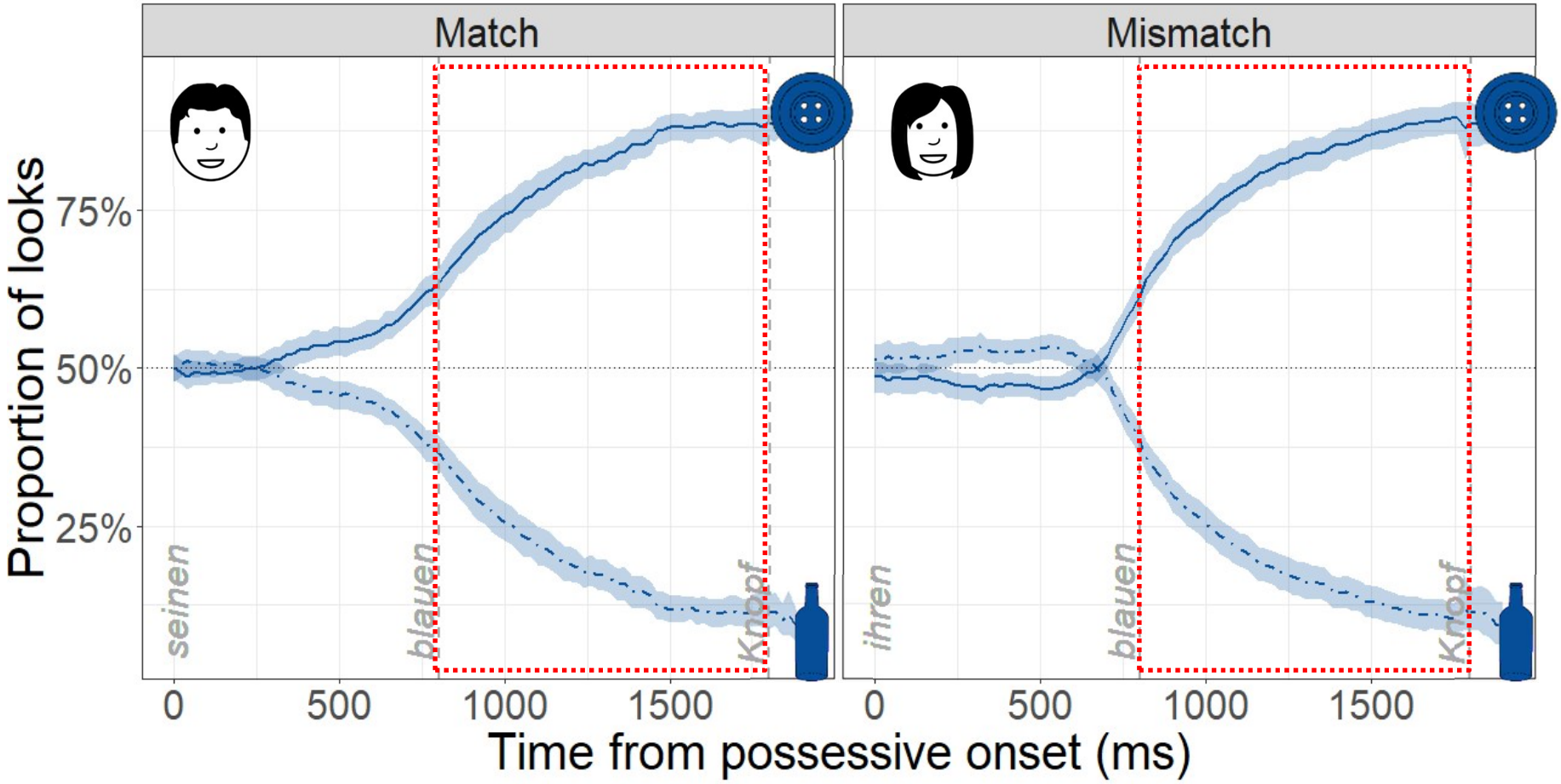

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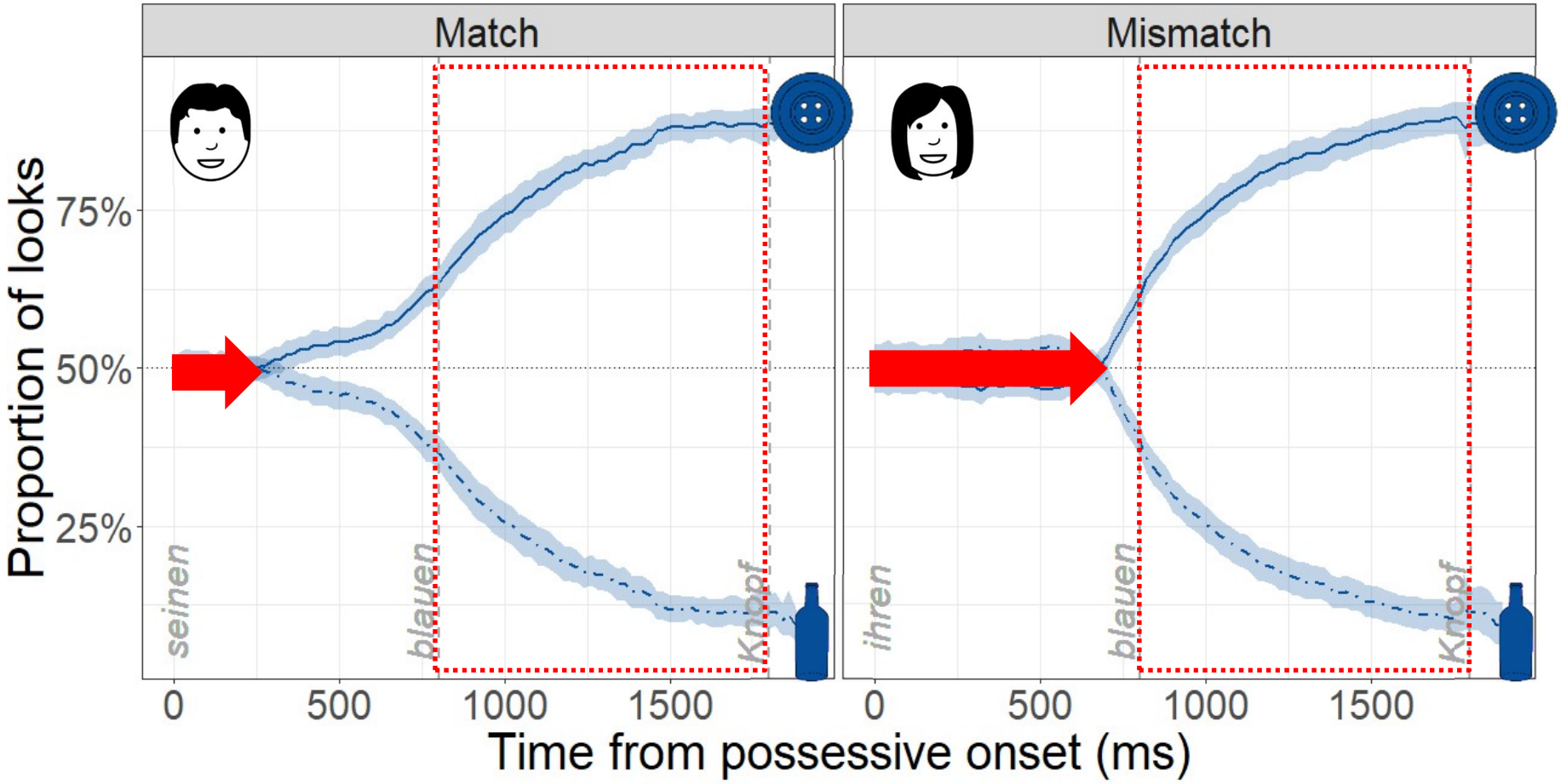
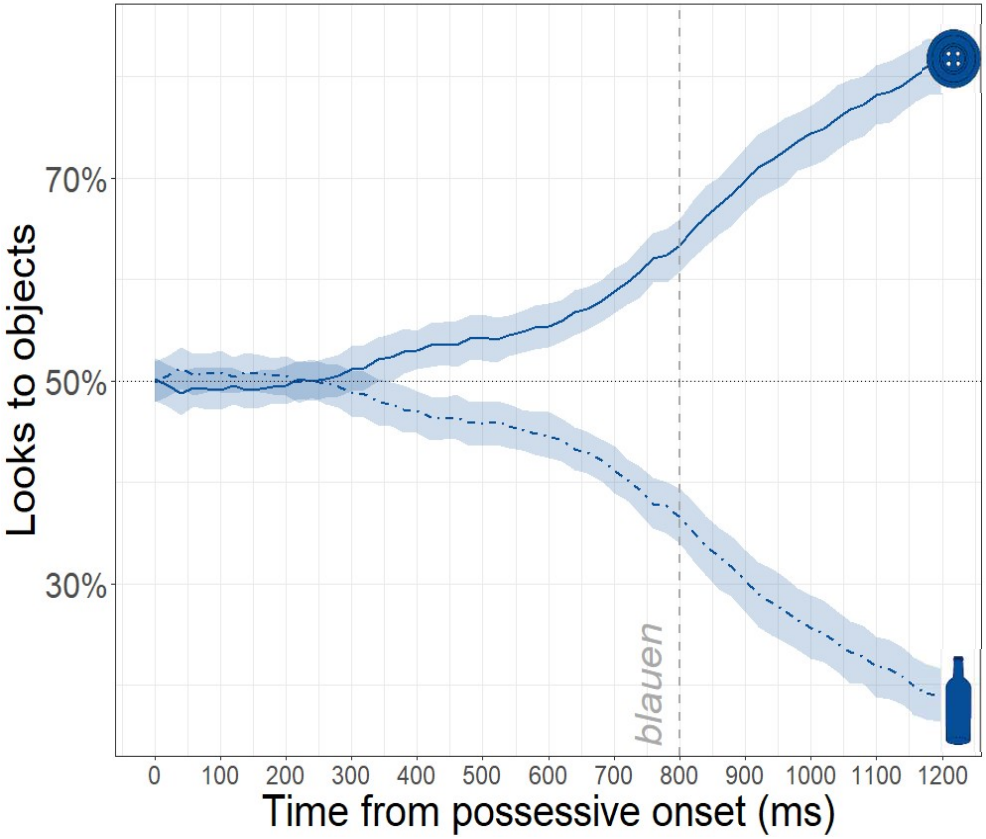


A bootstrapping approach

Adapted from Sheridan & Reingold 2012; Reingold & Sheridan, 2014



Steps:

Stone, Lago & Schad (under review)

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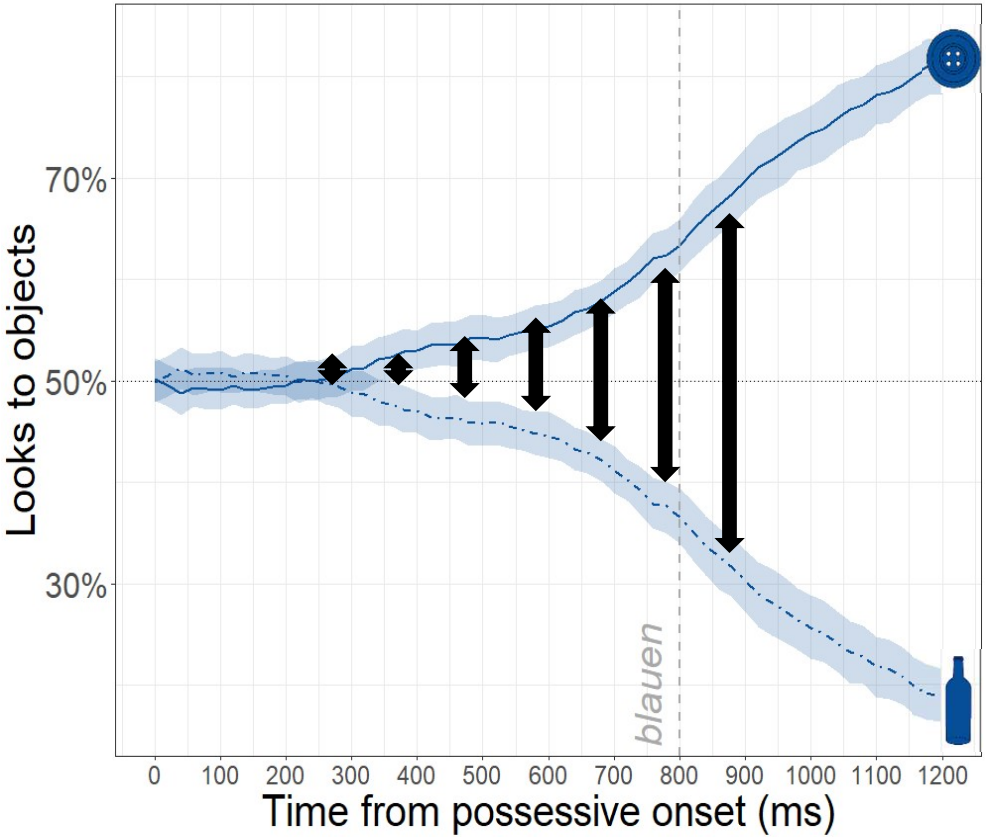

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Stone, Lago & Schad (under review)

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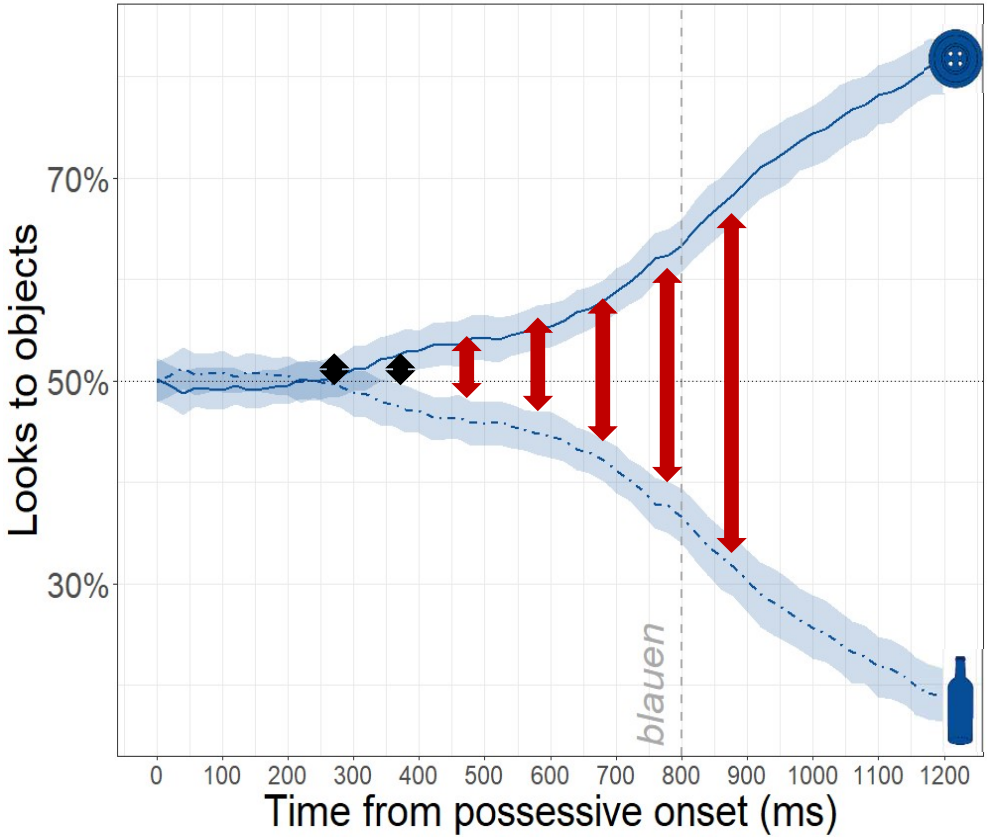

Steps:

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2. Find the **first** significant test statistic in a run of five

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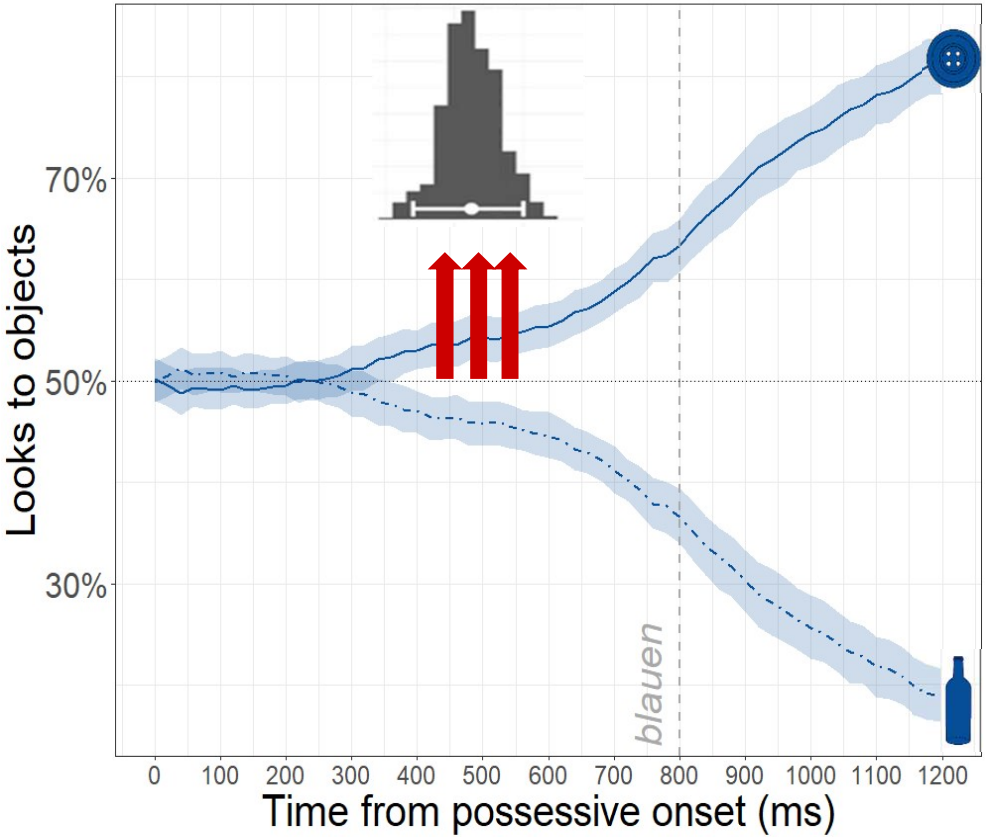
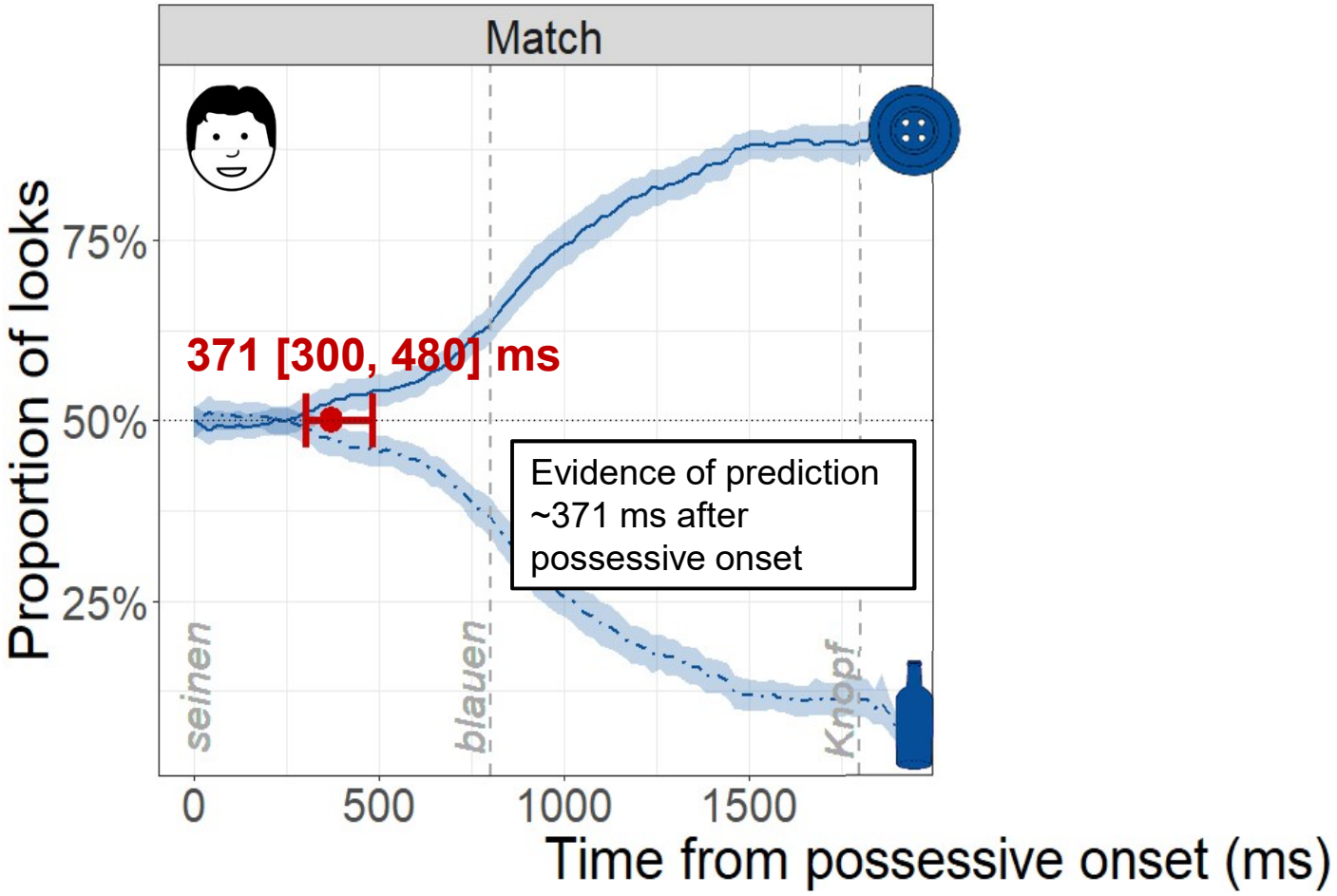


Steps:

1. Test between curves at each timepoint
2. Find the **first** significant test statistic in a run of five
3. Resample the data, repeat 2000 times

Stone, Lago & Schad (under review)

Bootstrap results



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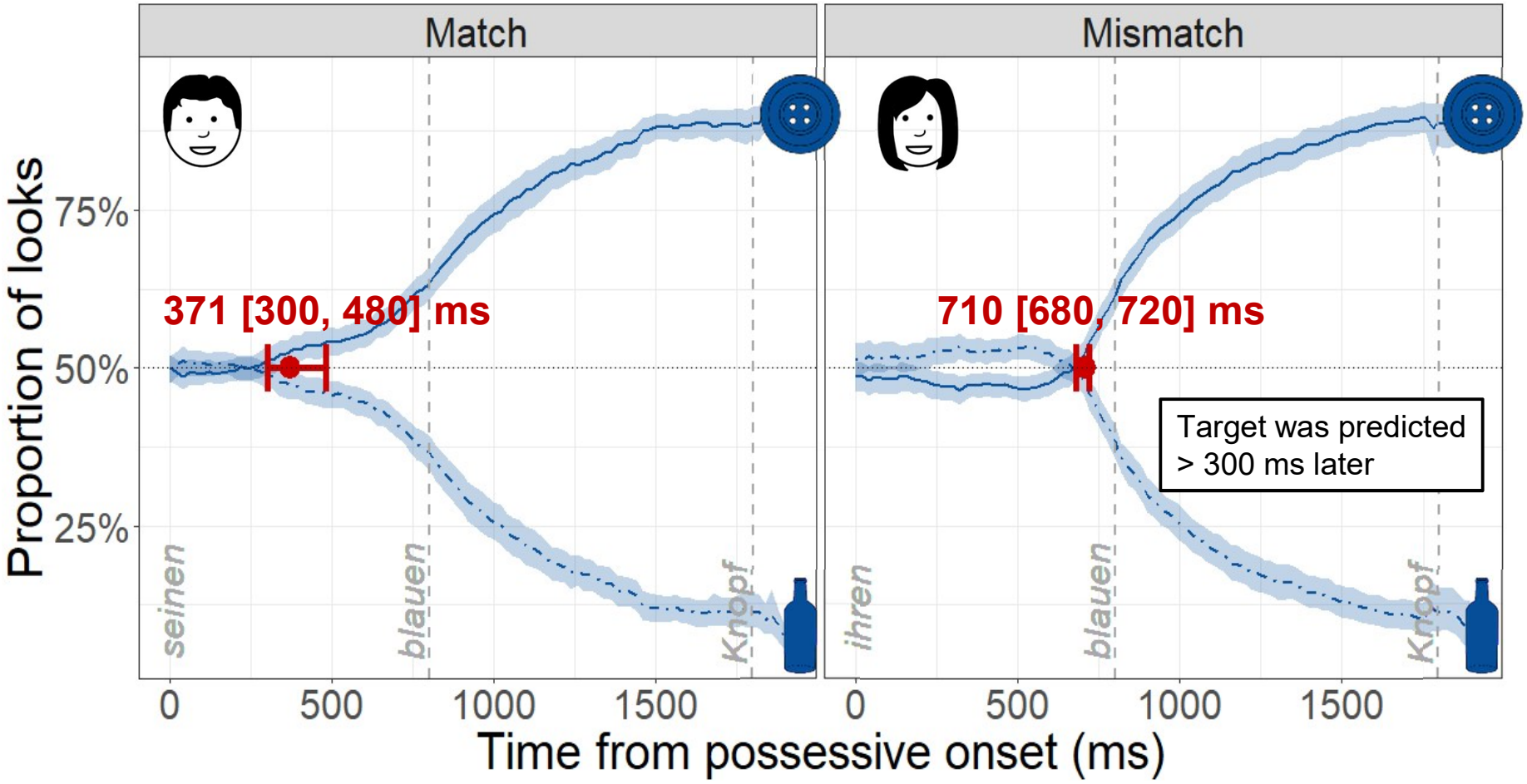

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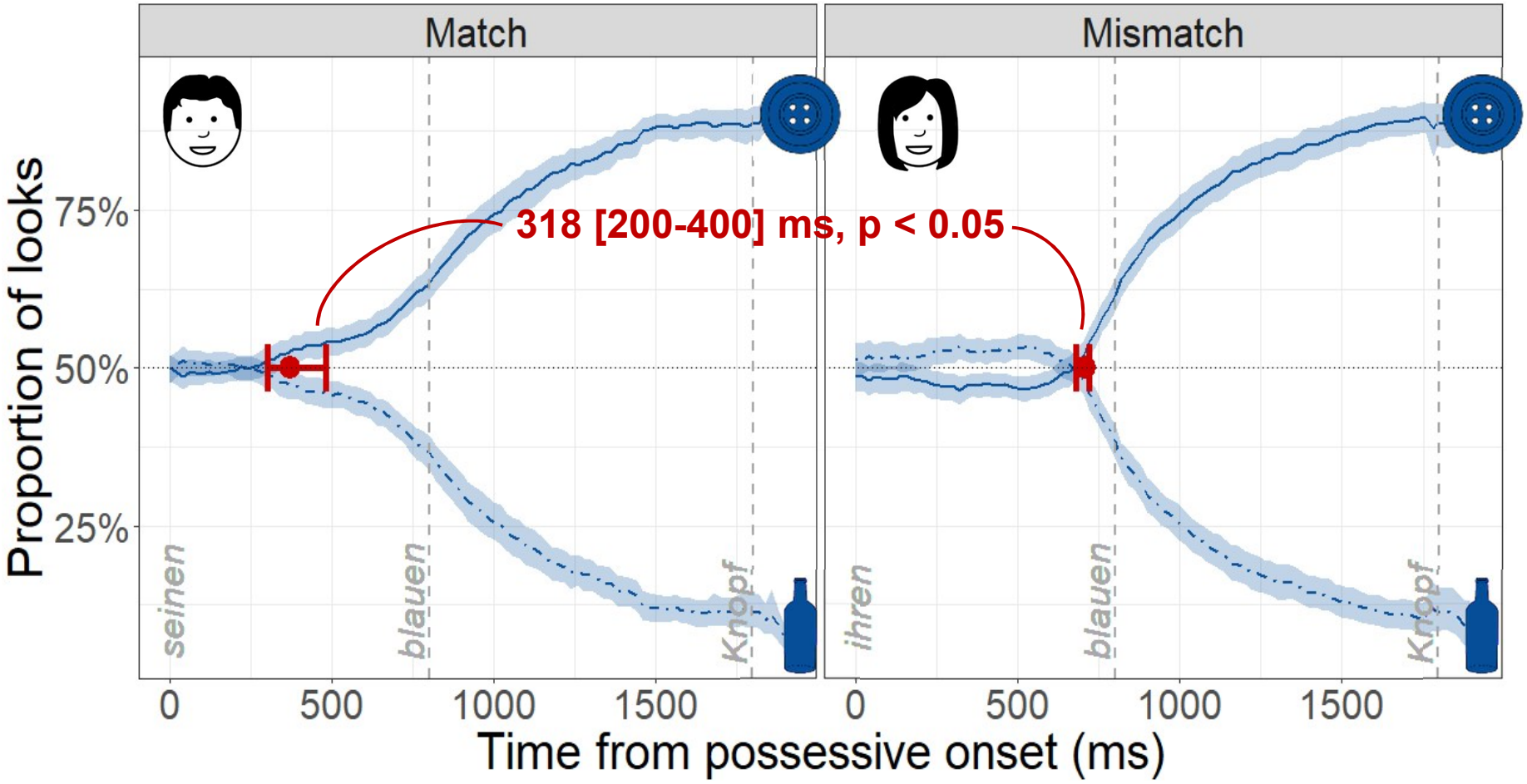

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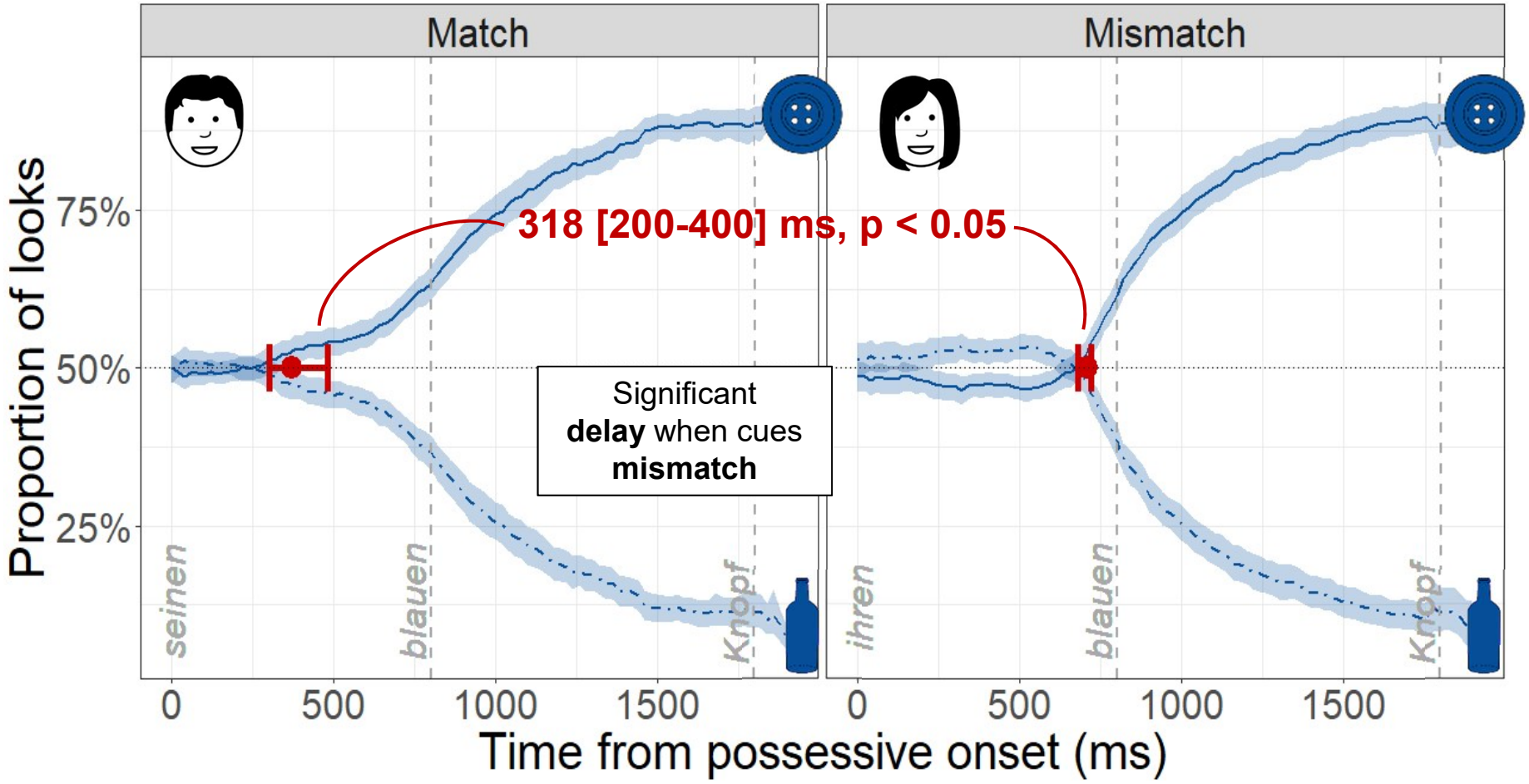
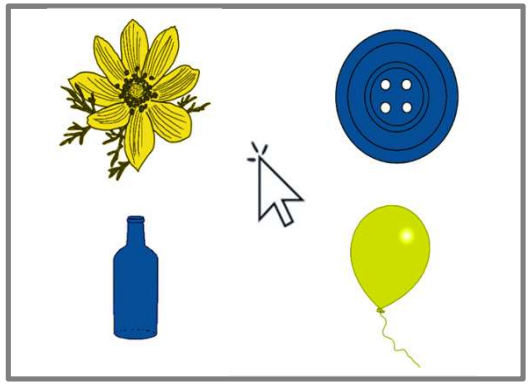
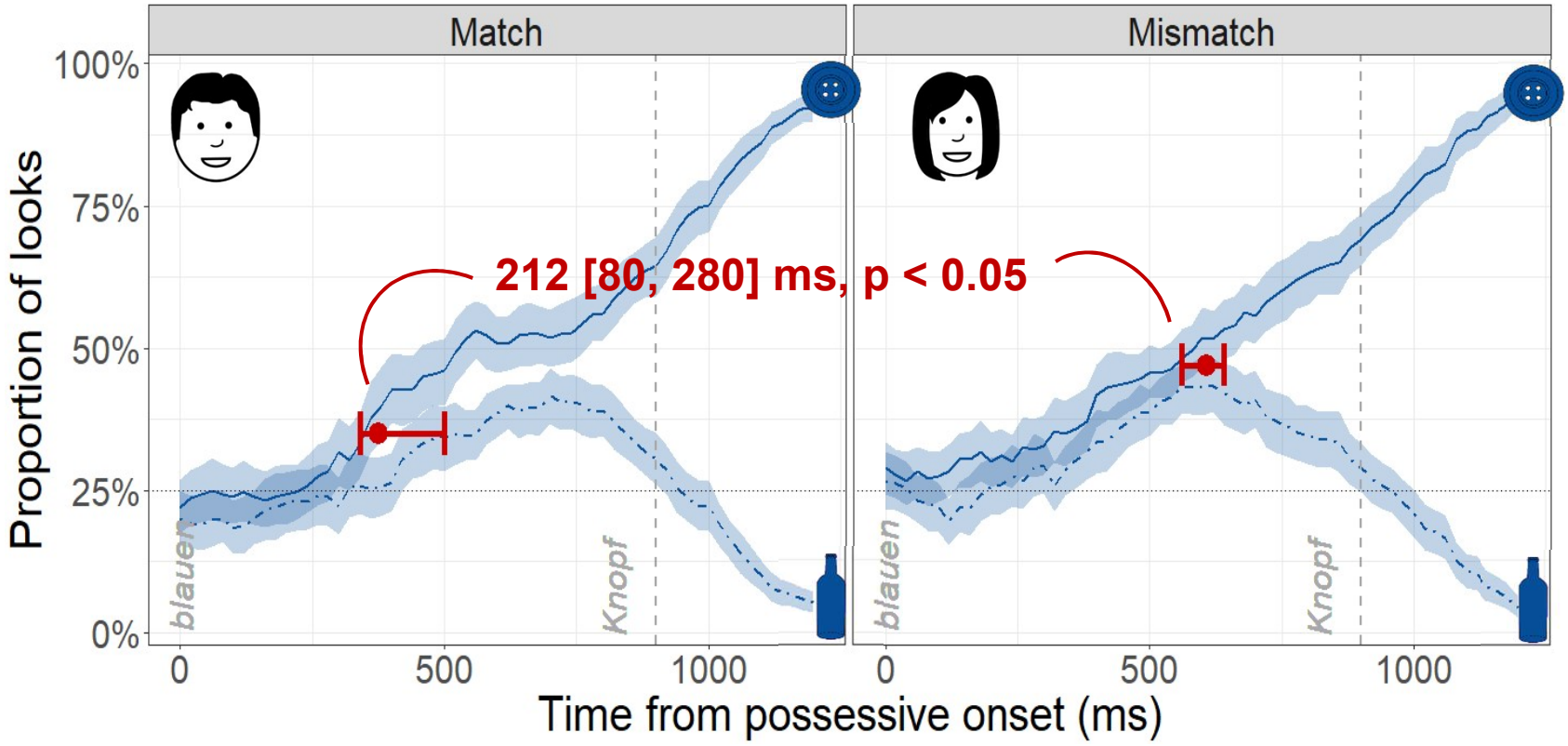


Previous experiment: 4 objects

N = 74 native
German speakers





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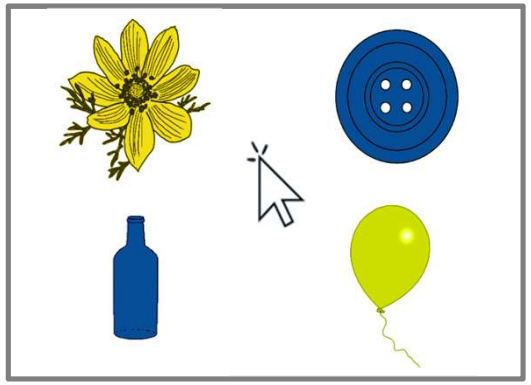
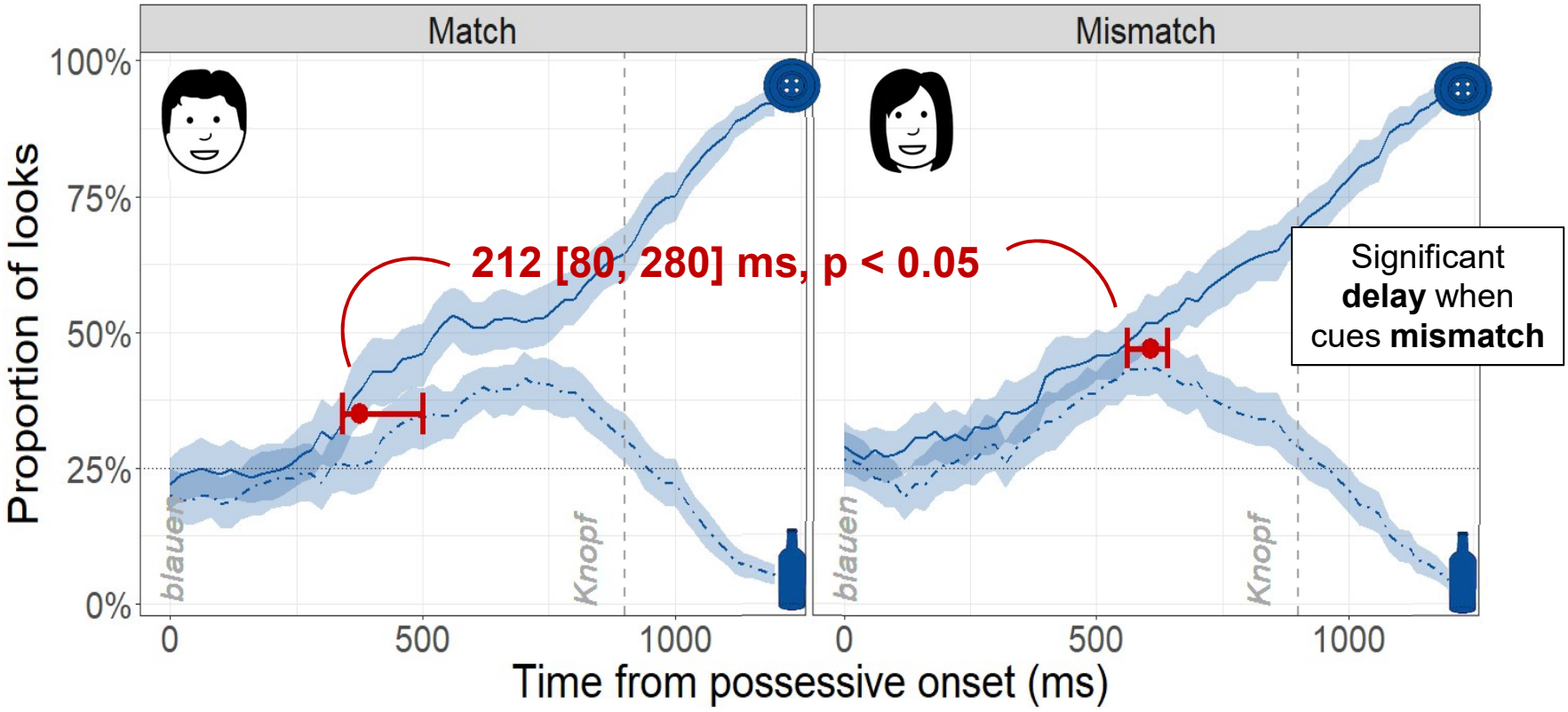
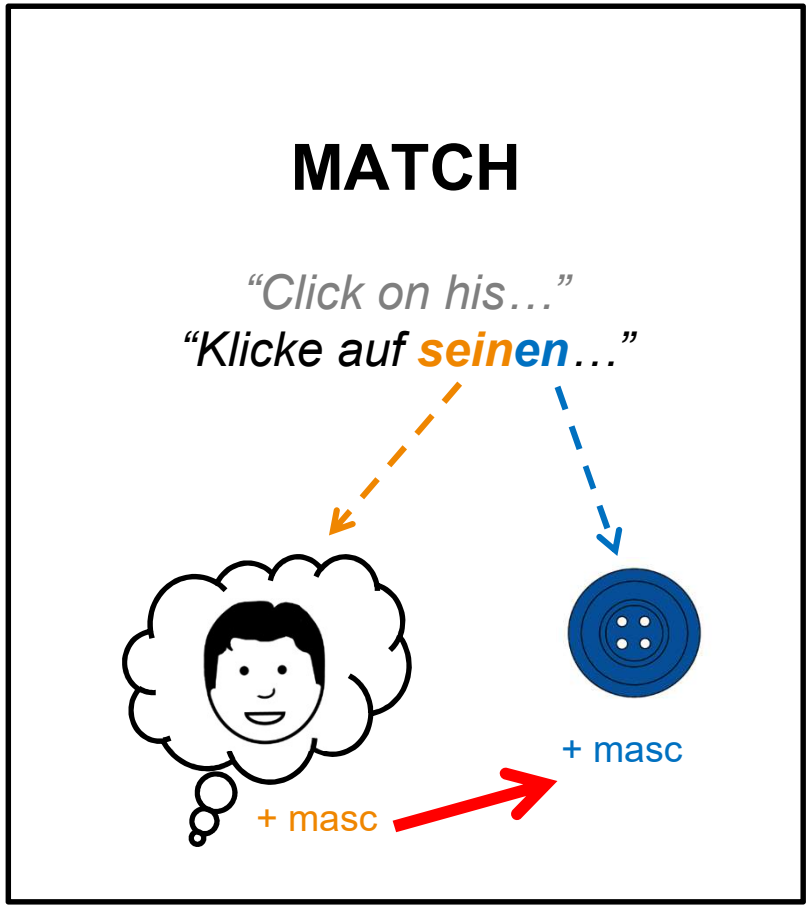
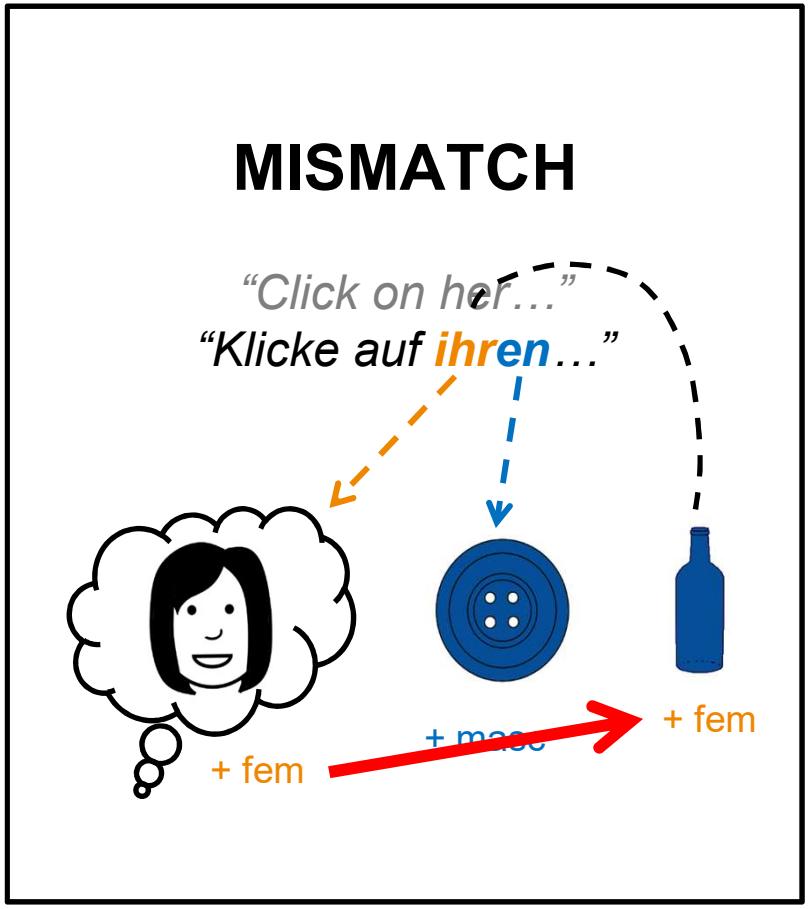


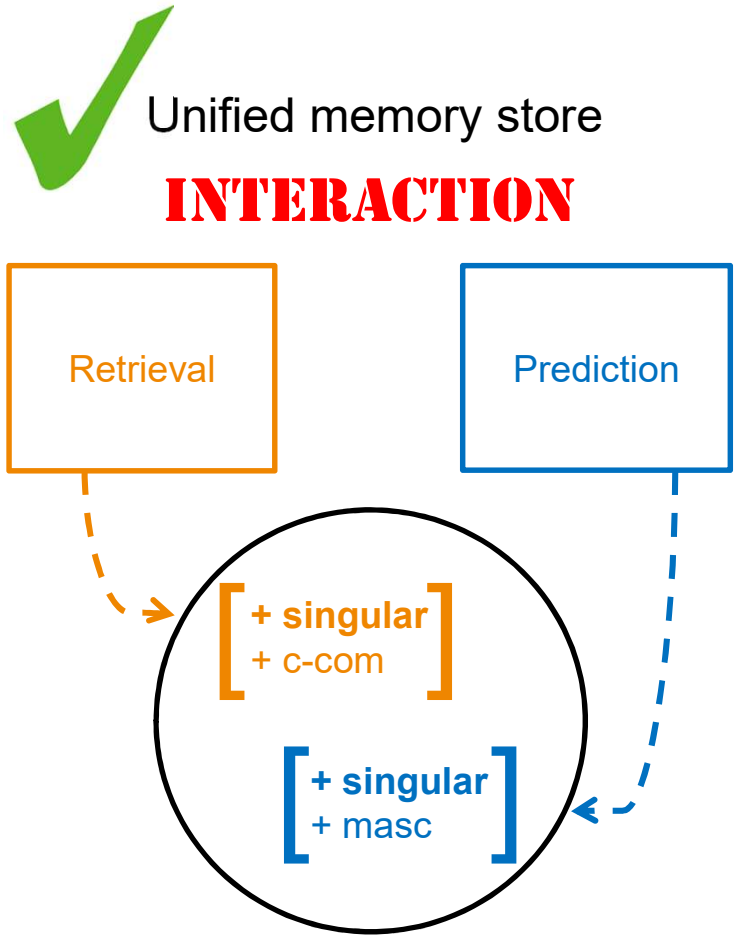


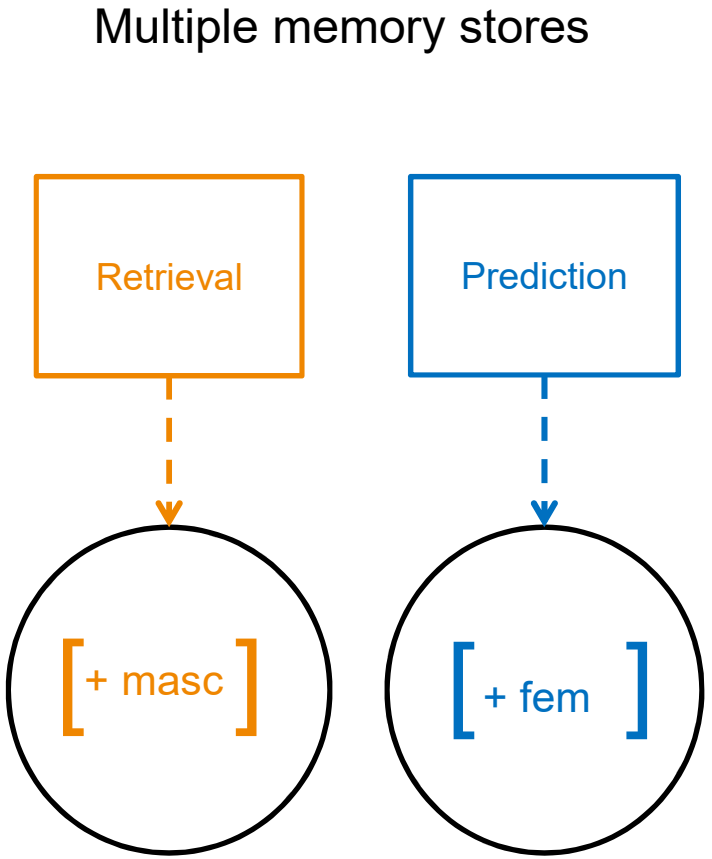
Discussion


MATCH
“Click on his…”
“Klicke auf seinen…”
+ masc
+ masc


MISMATCH
“Click on her…”
“Klicke auf ihren…”
+ fem
+ fem

Discussion

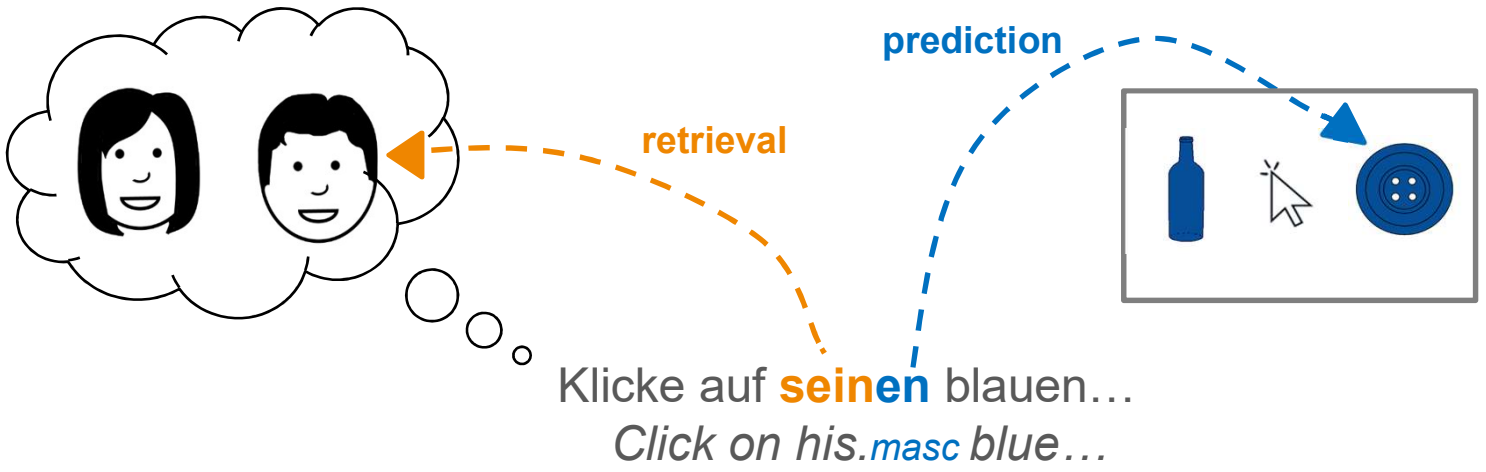

Unified memory store
INTERACTION
Retrieval
Prediction
+ singular
+ c-com
+ singular
+ masc


Multiple memory stores
Retrieval
Prediction
+ masc
+ fem

How do the gender cues “interact”: A (mis)retrieval account

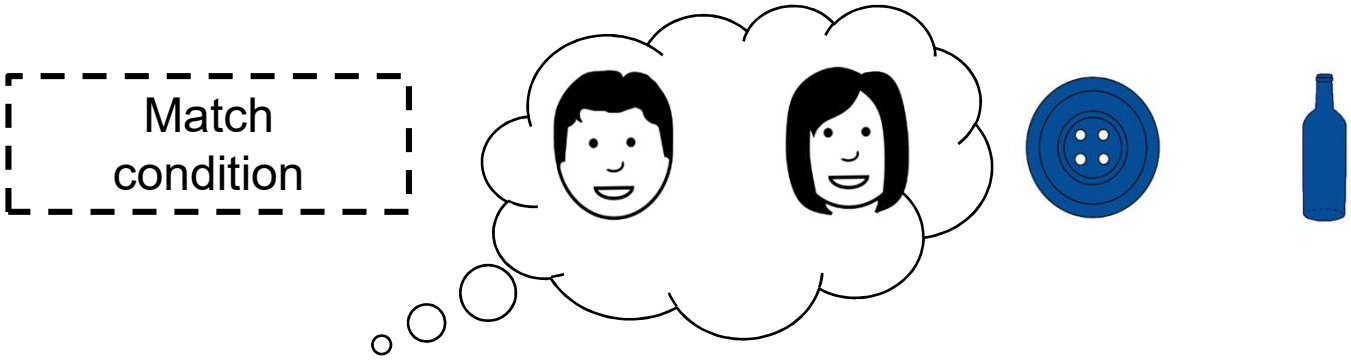
Anderson et al., 2004; Lewis & Vasishth, 2005

How do the gender cues “interact”: A (mis)retrieval account

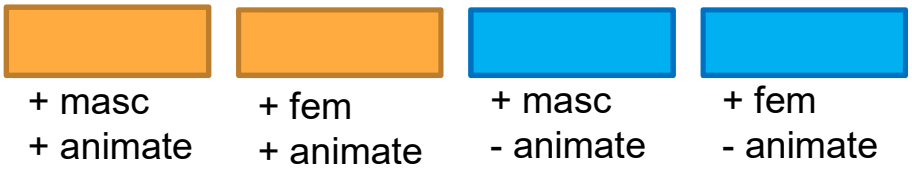


Anderson et al., 2004; Lewis & Vasishth, 2005

How do the gender cues “interact”: A (mis)retrieval account



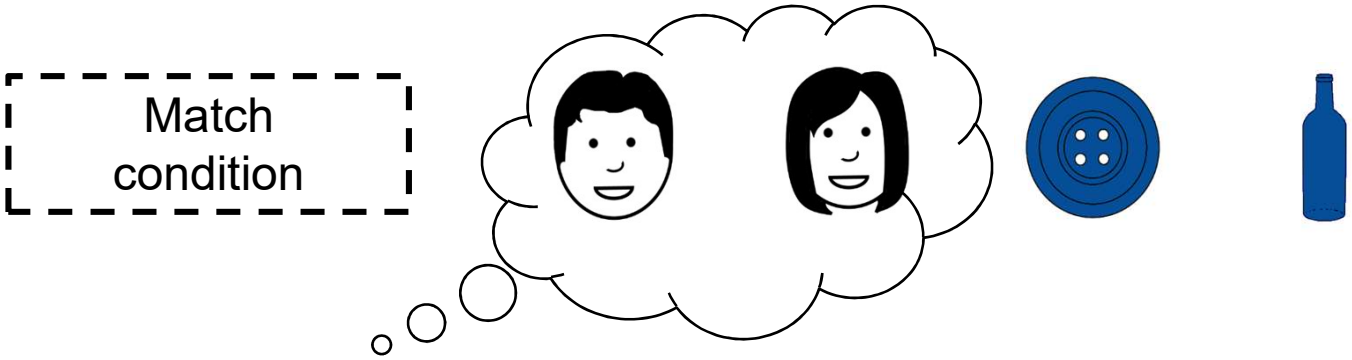
Activation level:

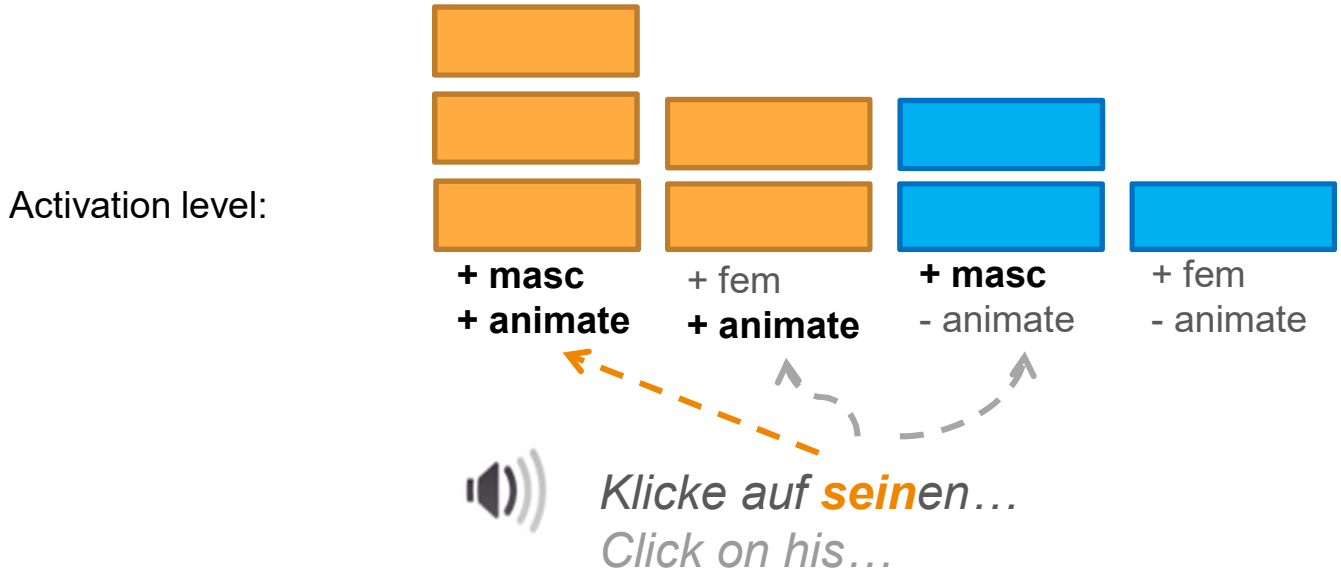


Klicke auf
Click on

Anderson et al., 2004; Lewis & Vasishth, 2005

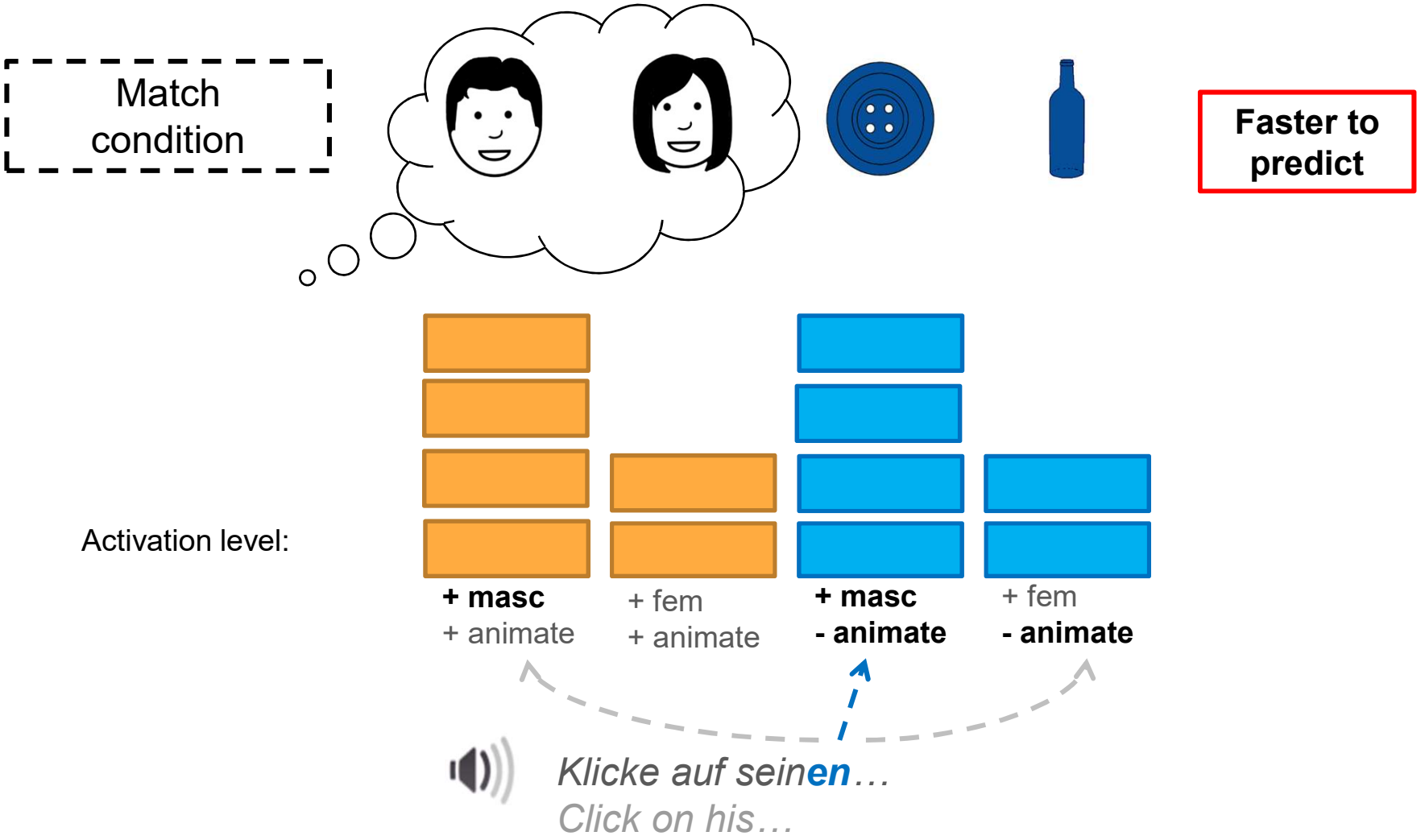
How do the gender cues “interact”: A (mis)retrieval account





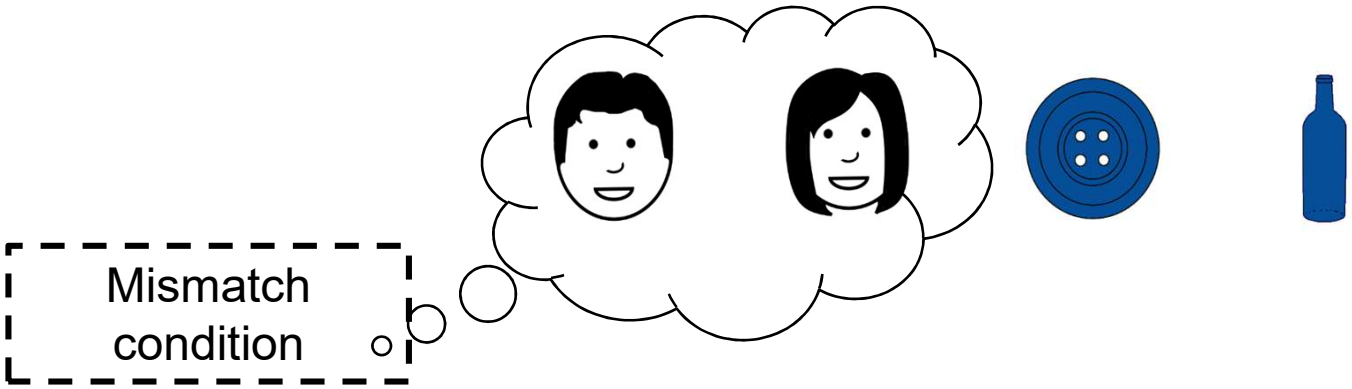
Anderson et al., 2004; Lewis & Vasishth, 2005

How do the gender cues “interact”: A (mis)retrieval account

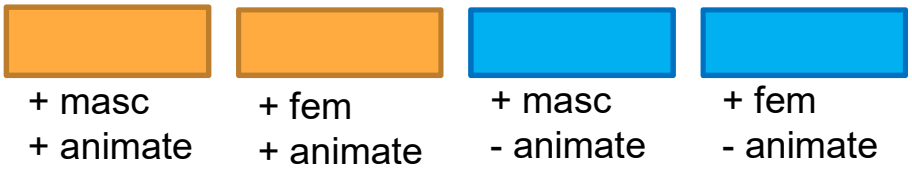


Anderson et al., 2004; Lewis & Vasishth, 2005

How do the gender cues “interact”: A (mis)retrieval account



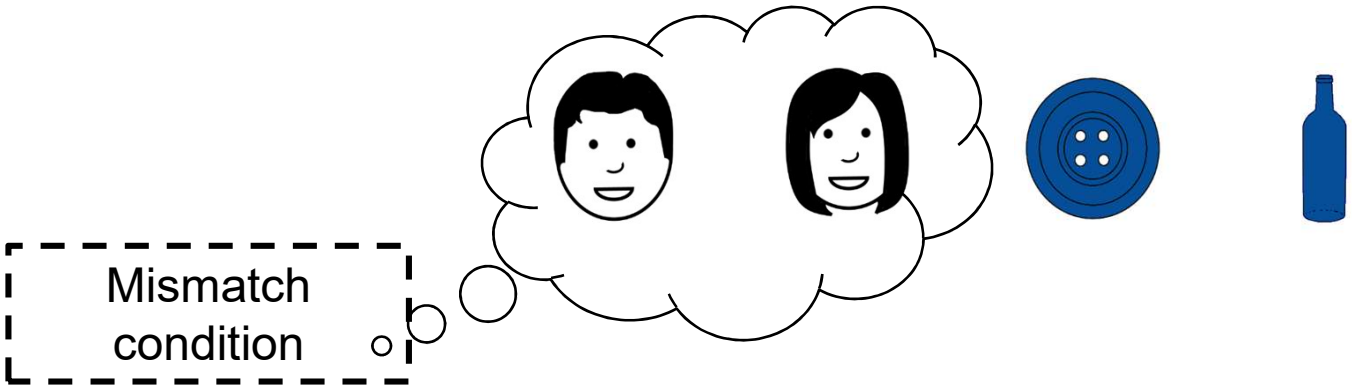
Activation level:

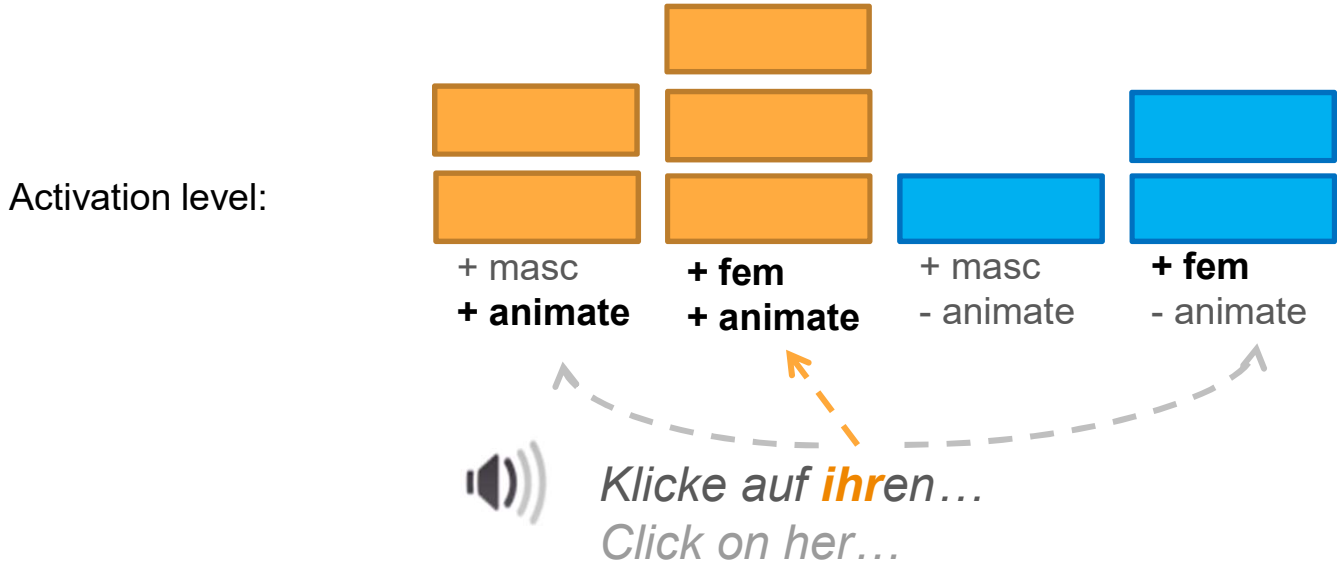


Klicke auf
Click on

Anderson et al., 2004; Lewis & Vasishth, 2005

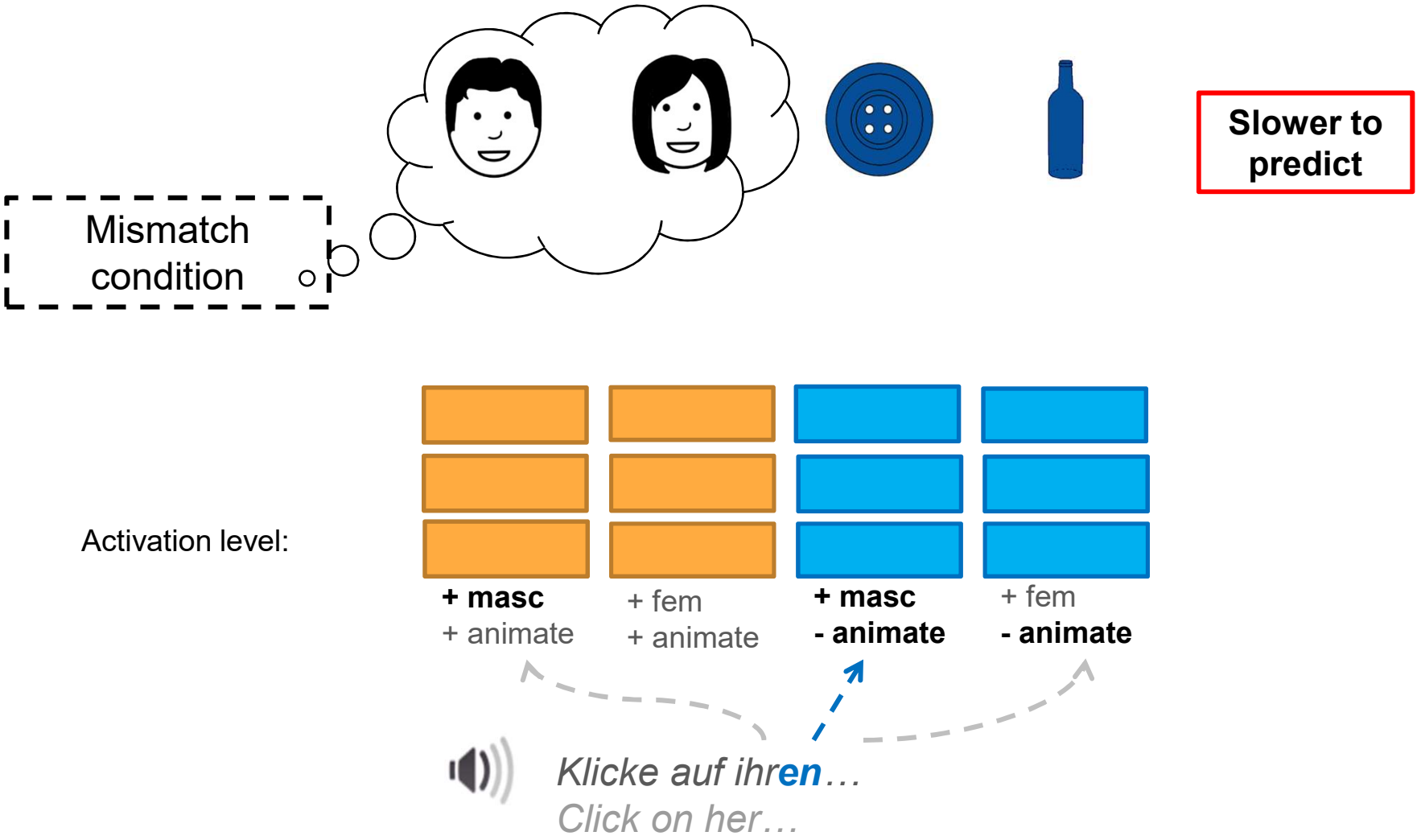
How do the gender cues “interact”: A (mis)retrieval account



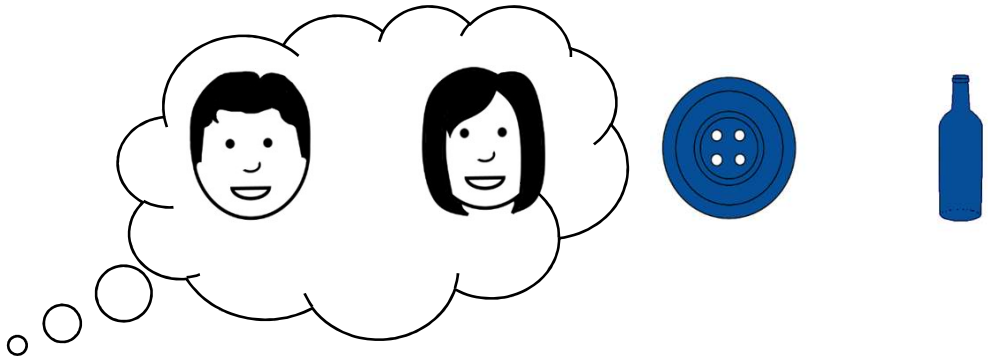


Anderson et al., 2004; Lewis & Vasishth, 2005

How do the gender cues “interact”: A (mis)retrieval account



Anderson et al., 2004; Lewis & Vasishth, 2005



Match condition

Mismatch condition

Faster to predict

Slower to predict

	+ masc + animate	+ fem + animate	**+ masc - animate**	+ fem **- animate**
Match condition				
Mismatch condition				

Next steps

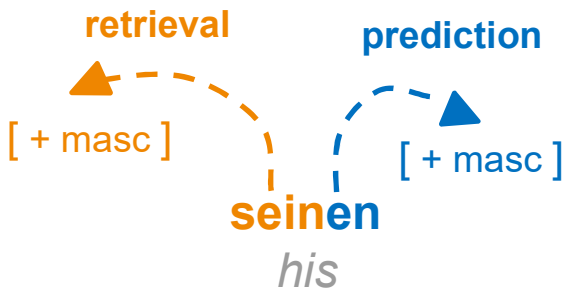
- Computational modelling
    - Can an existing model of retrieval explain the interaction with prediction? *(ACT-R; Anderson et al., 2004; Lewis & Vasishth, 2005)*

Next steps

- Computational modelling
    - Can an existing model of retrieval explain the interaction with prediction? *(ACT-R; Anderson et al., 2004; Lewis & Vasishth, 2005)*
- Is it really the (mis)retrieval that's influencing the prediction?

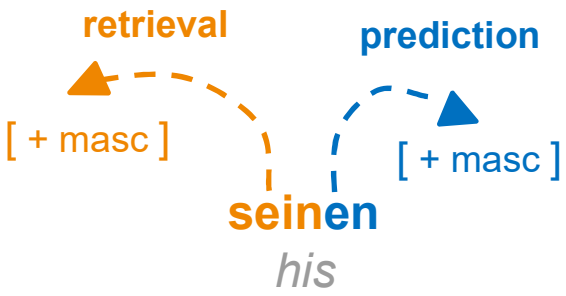
Next steps

(Mis)retrieval?



Next steps

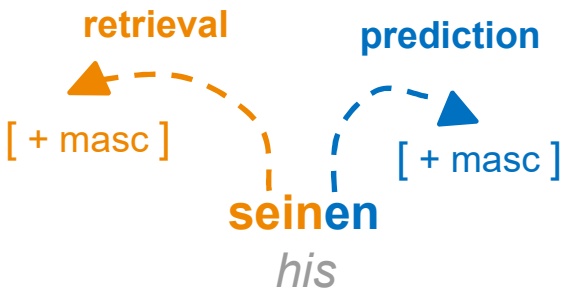
(Mis)retrieval?



Priming?

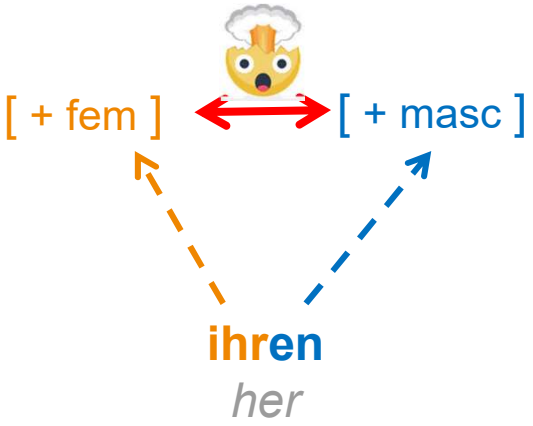
Next steps

(Mis)retrieval?

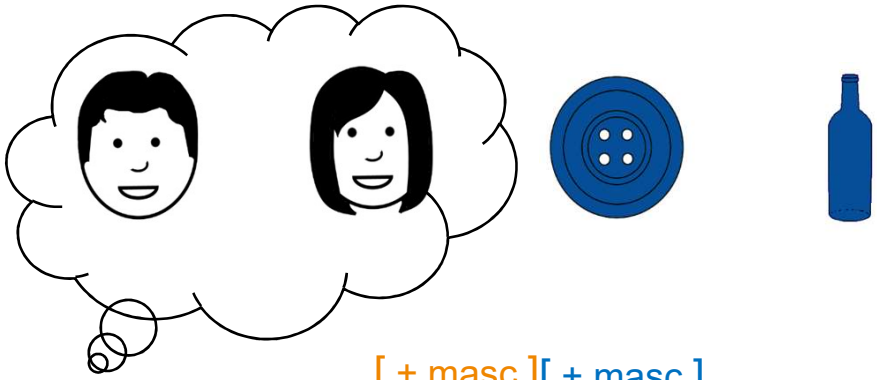


Priming?

A Stroop-like effect?



Next steps



[+ masc][+ masc]

Match condition

Gib Martin den…

Give Martin the.masc…

[+ fem] [+ masc]

Mismatch condition

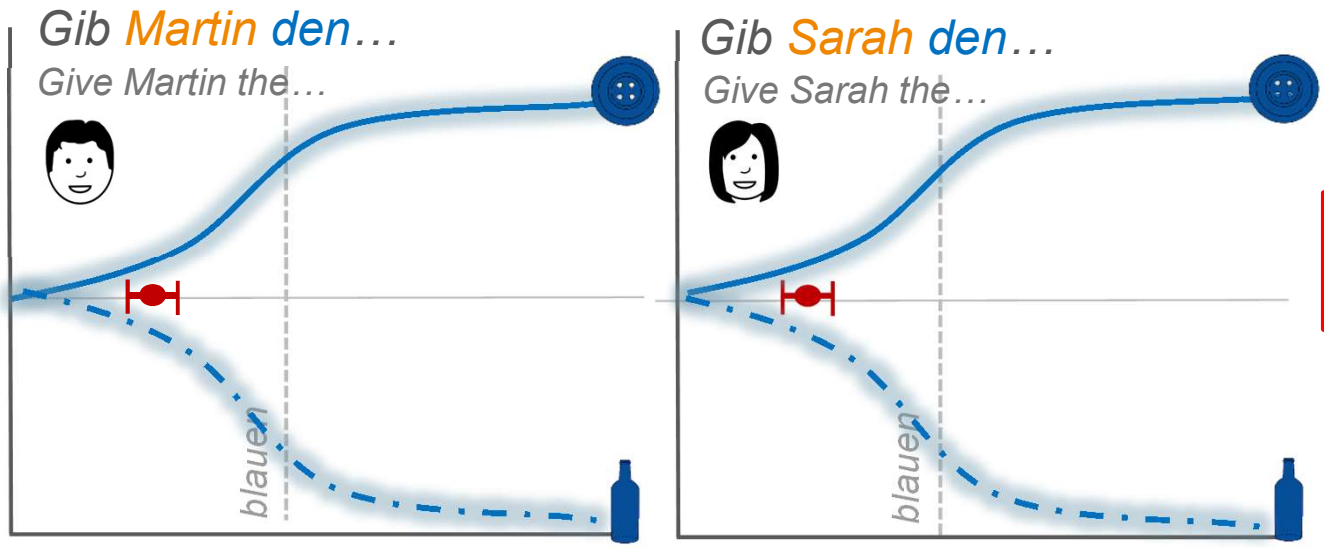
Gib Sarah den…

Give Sarah the.masc…

Next steps

Match condition [+ masc] [+ masc]

Mismatch condition [+ fem] [+ masc]



No retrieval =
No mismatch delay

Next steps

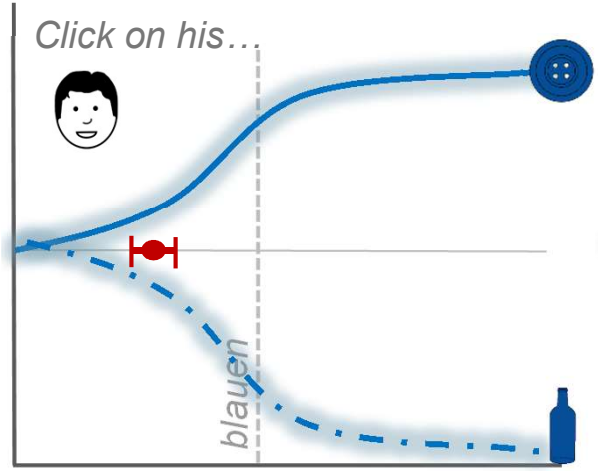
Match condition [+ masc] [+ masc]

Mismatch condition [+ fem] [+ masc]

Determiner condition [+ masc]

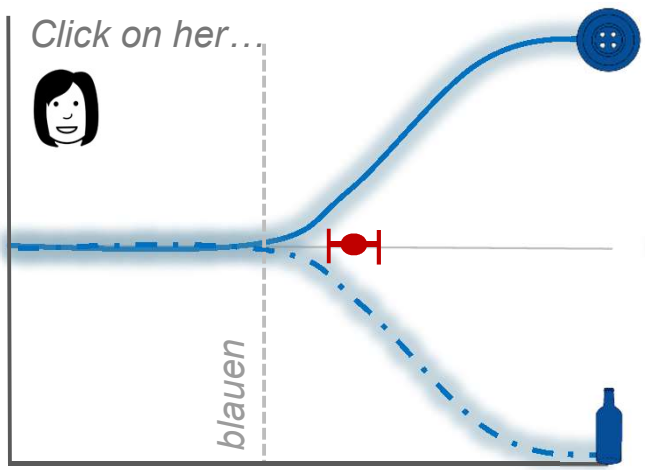
Klicke auf seinen…

Click on his…



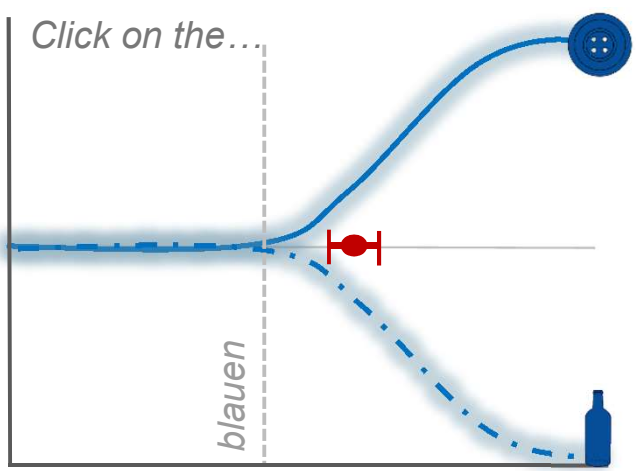
Klicke auf ihren…

Click on her…



Klicke auf den…

Click on the…



Determiner patterns with mismatch = Mismatch is the “default”

Thank you!

Sol Lago

Elise Oltrogge

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Universität Potsdam

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Shravan Vasishth