Anything special about visual word identification?

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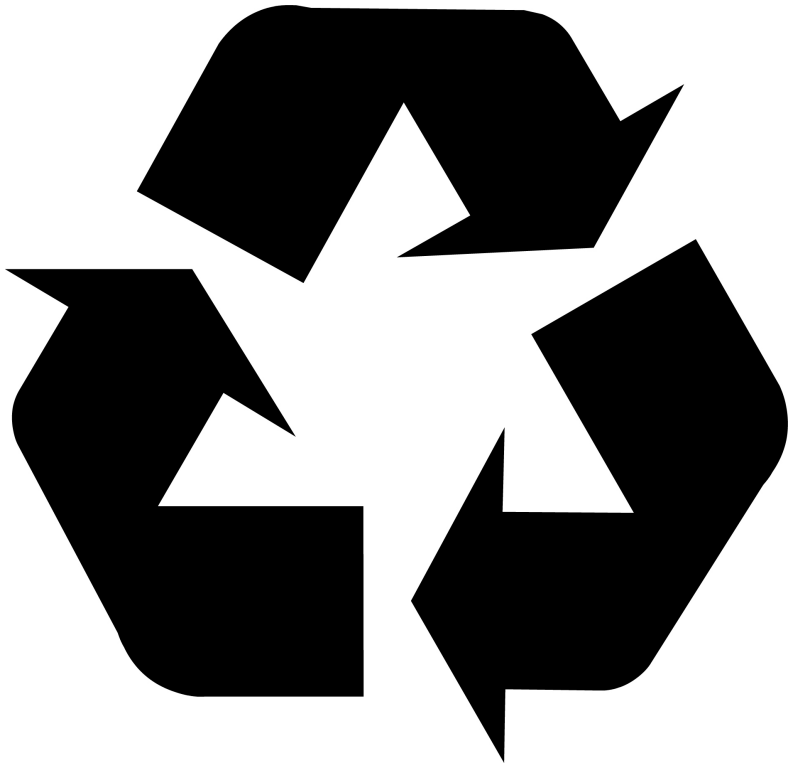
Reading is a human wonder

- We can read 8–letter words in ~35ms (e.g., Forster and Davis, 1984)
- We gather information about ~20 letters every ~200ms (e.g., Rayner, 1998)
- We read ~250 words per minute (e.g., Brysbaert, 2019)

No genetic endowment

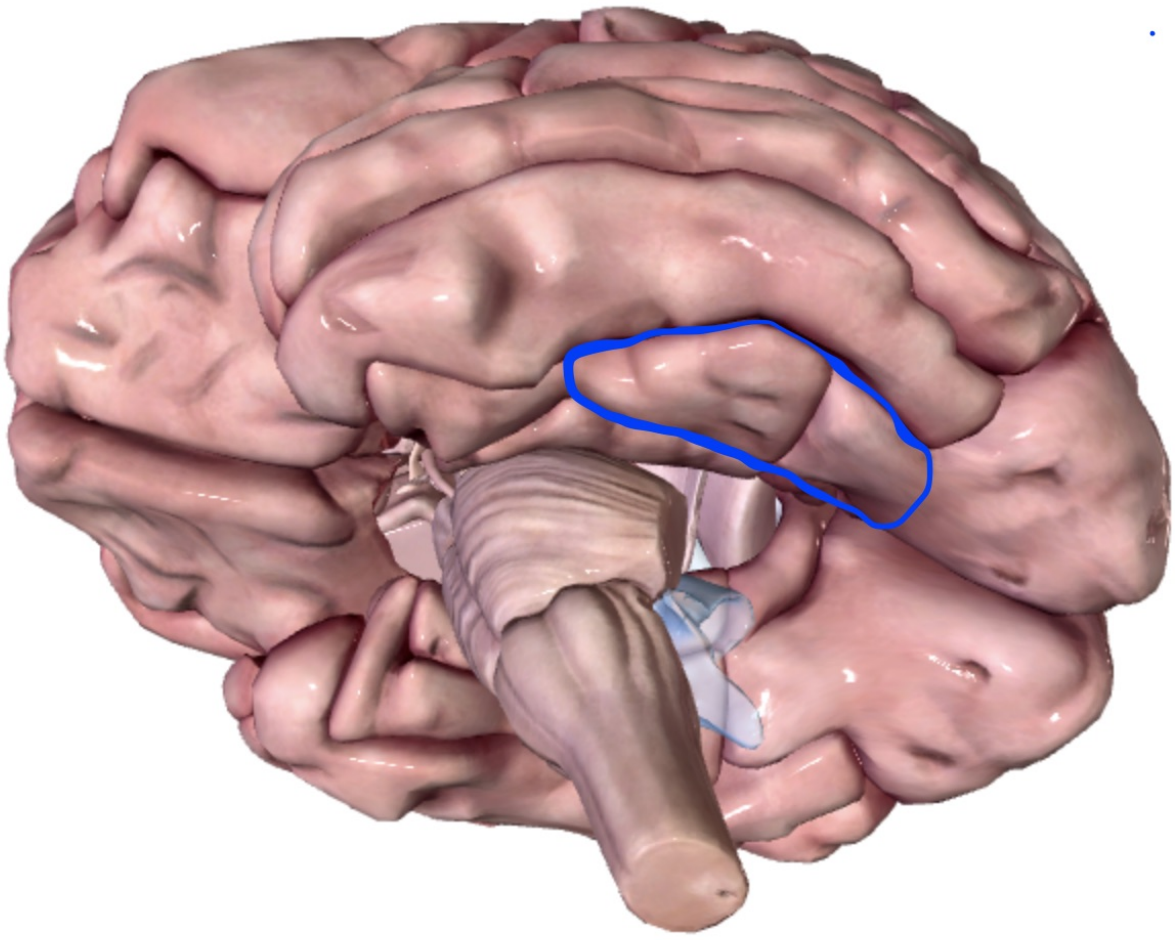
- Written language isn't observed universally
- Literacy isn't acquired spontaneously
- Writing appeared ~5.5K years ago (e.g., Woods, 2010)

Neural Recycling



(e.g., Dehaene et al., 2005; Dehaene and Cohen, 2007)

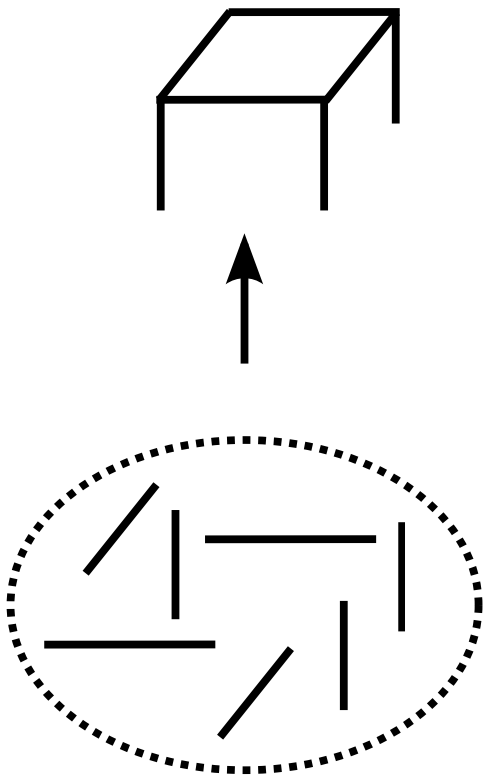
The ventral occipito–temporal cortex (VOTC)



(e.g., Cohen et al., 2000; Hasson et al., 2003; Gaillard et al., 2006)

The Statistical Learning hypothesis

- Progressively compact the input taking advantage of its regularities (redundancy)



The Statistical Learning hypothesis

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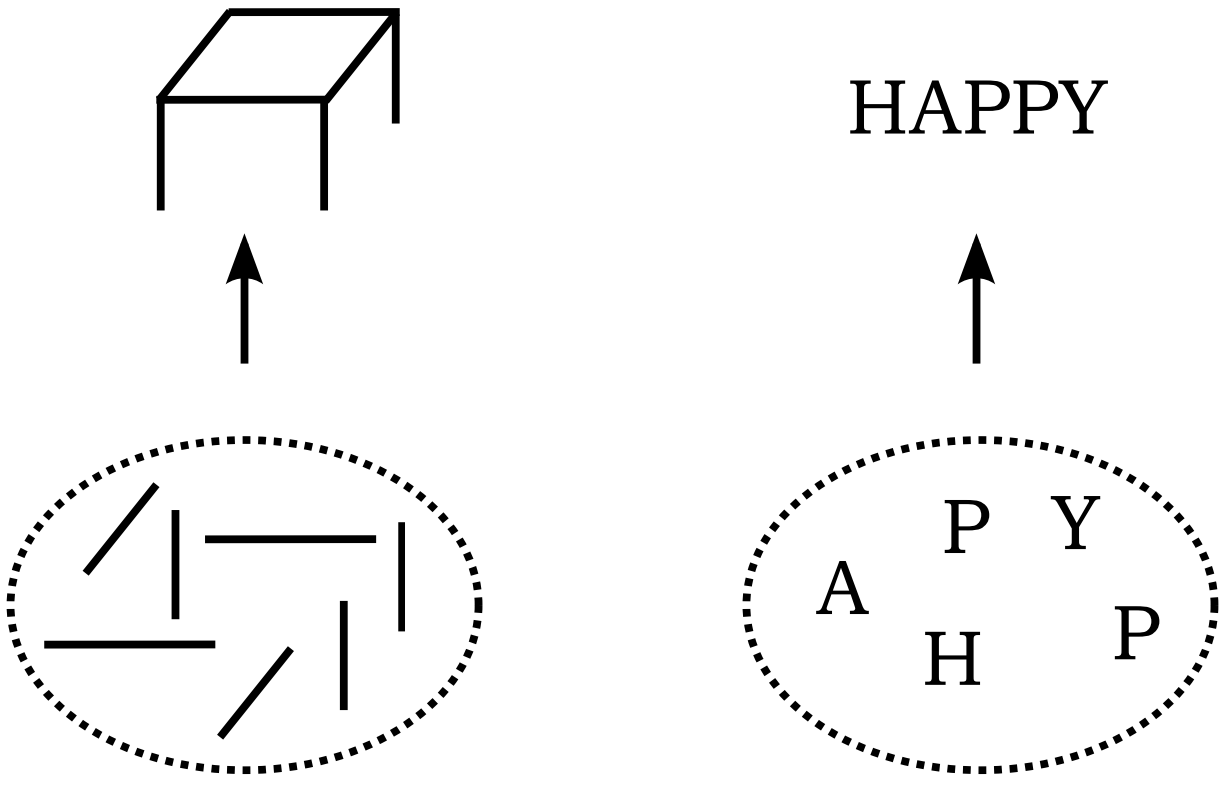


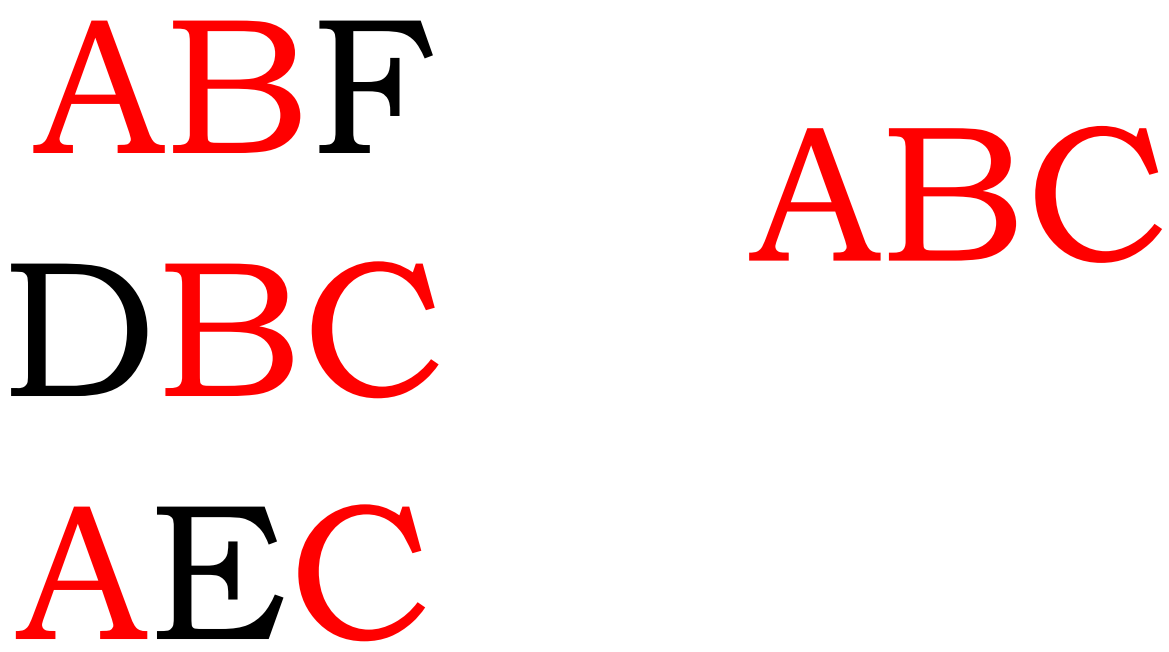
Phantom words paradigm (Endress and Mehler, 2009)

ABF

DBC

AEC

Phantom words paradigm (Endress and Mehler, 2009)



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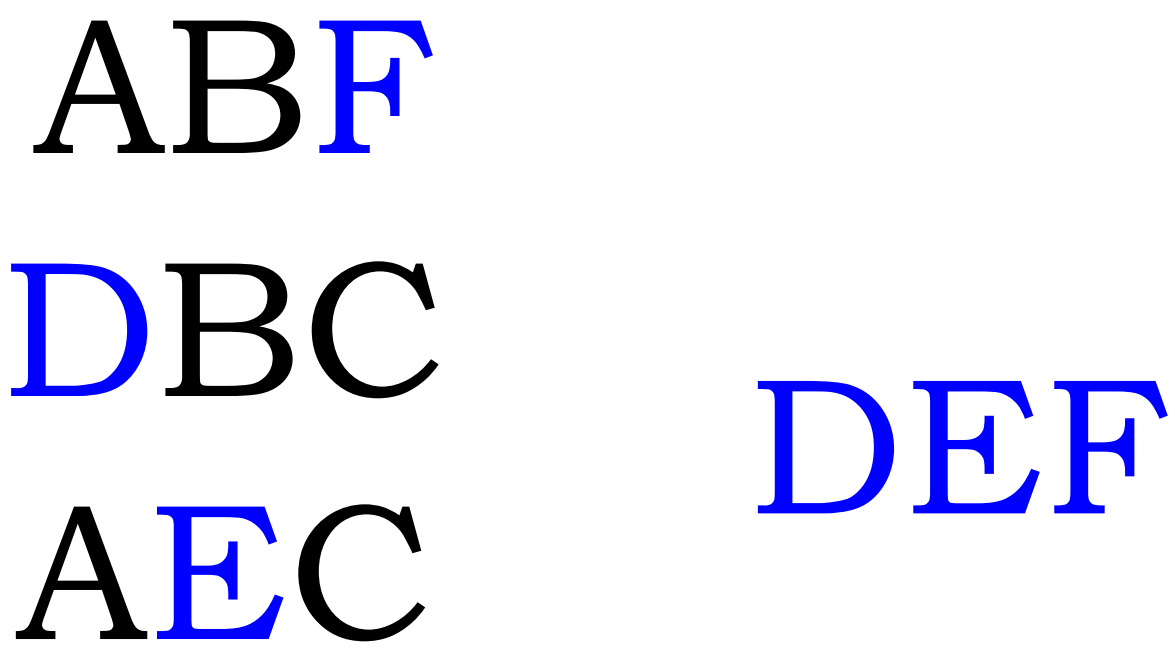

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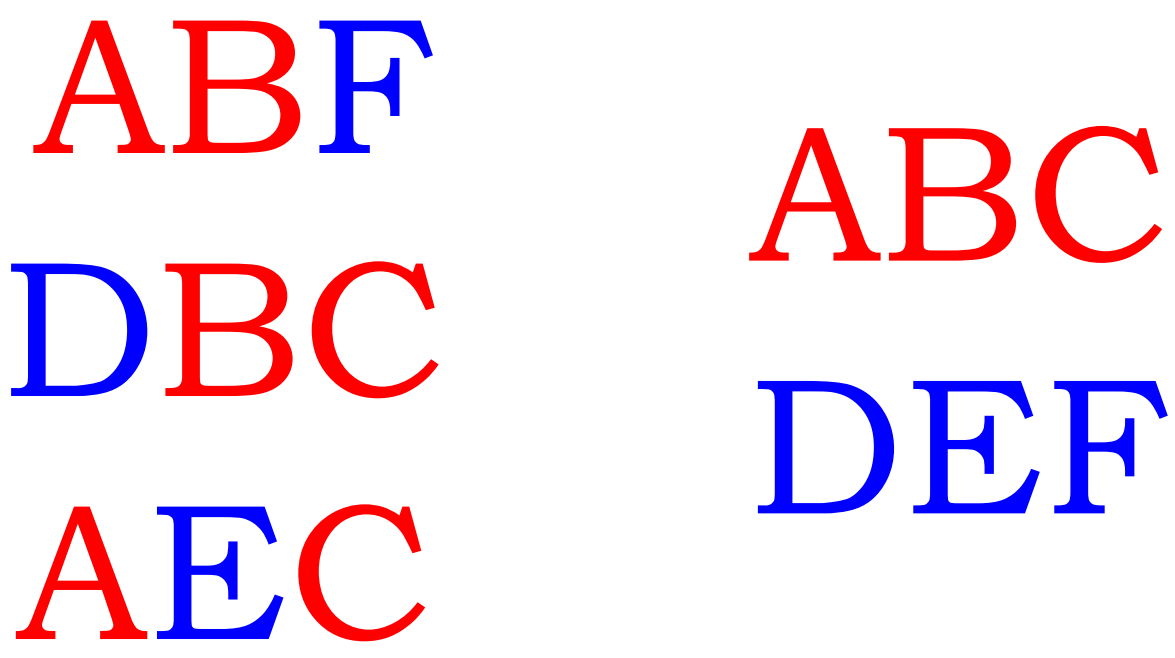
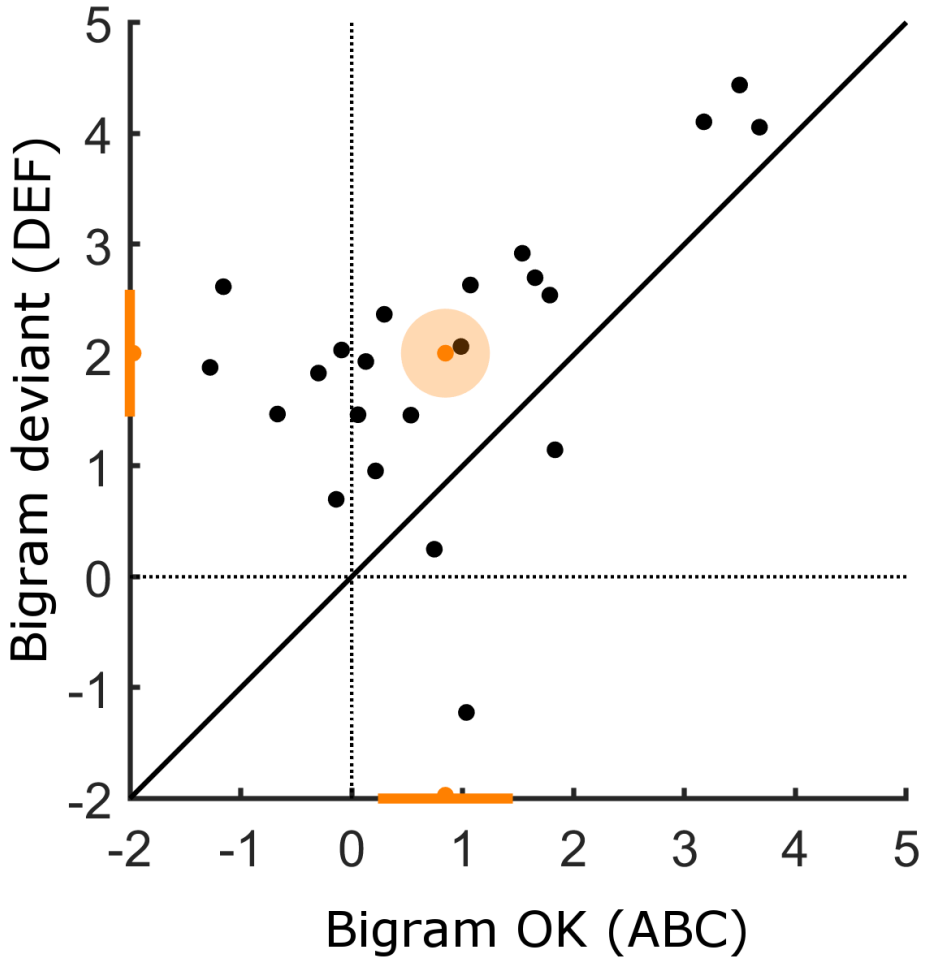


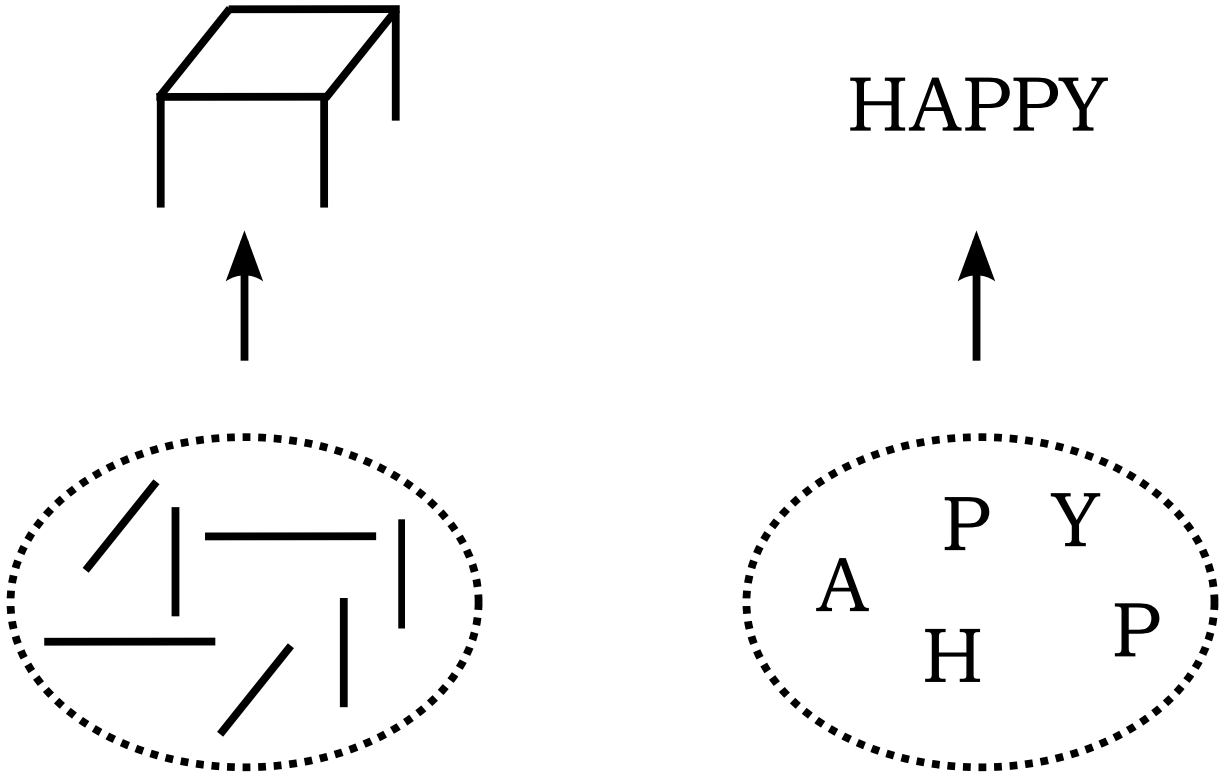
Pseudo–letters (Vidal et al., 2017)

Results



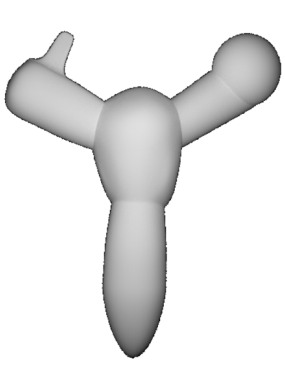
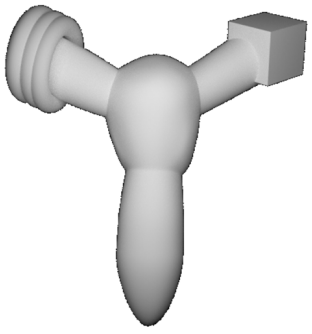
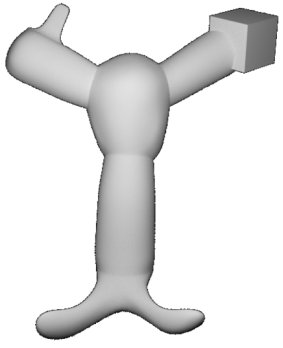
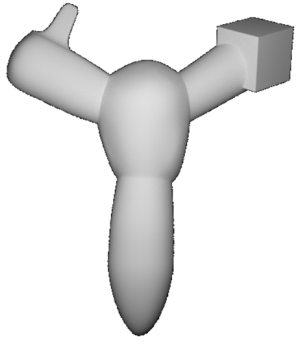
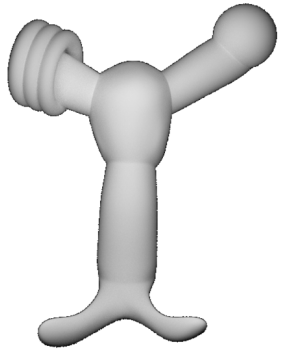
(Vidal et al., 2021)

The Statistical Learning hypothesis

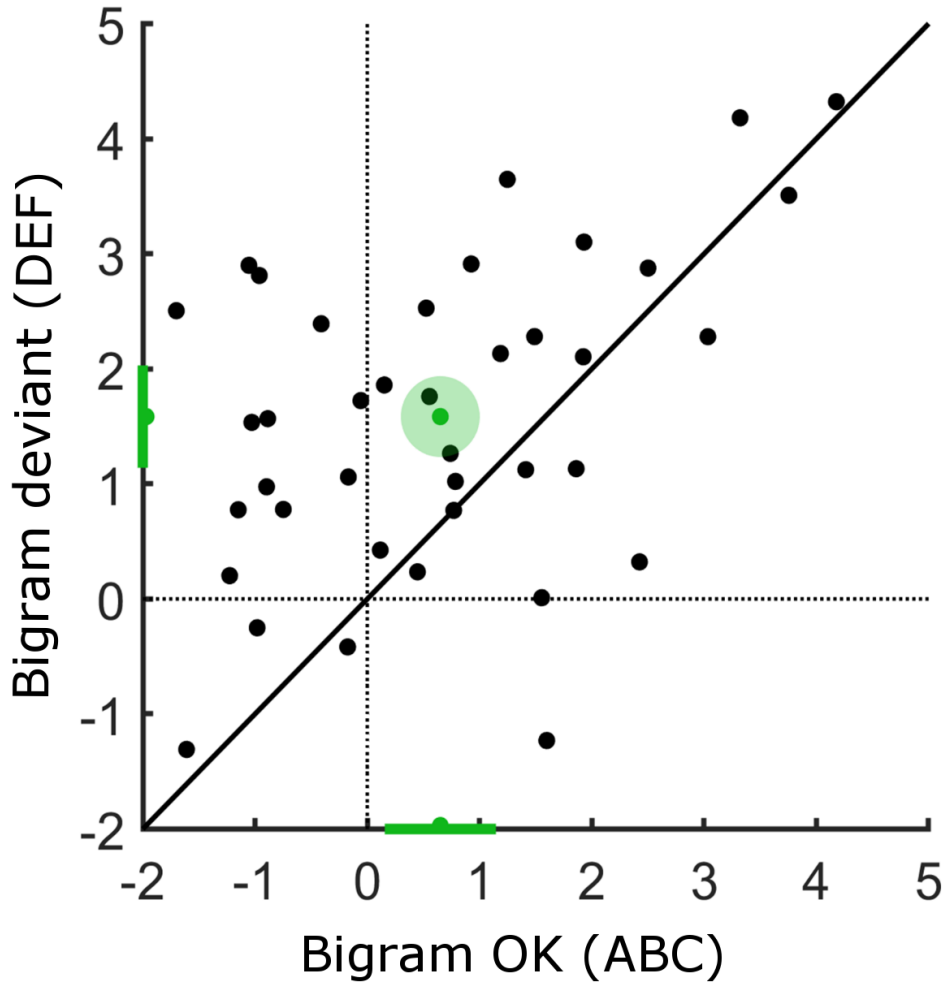


Vision, not language

Phantom tripods

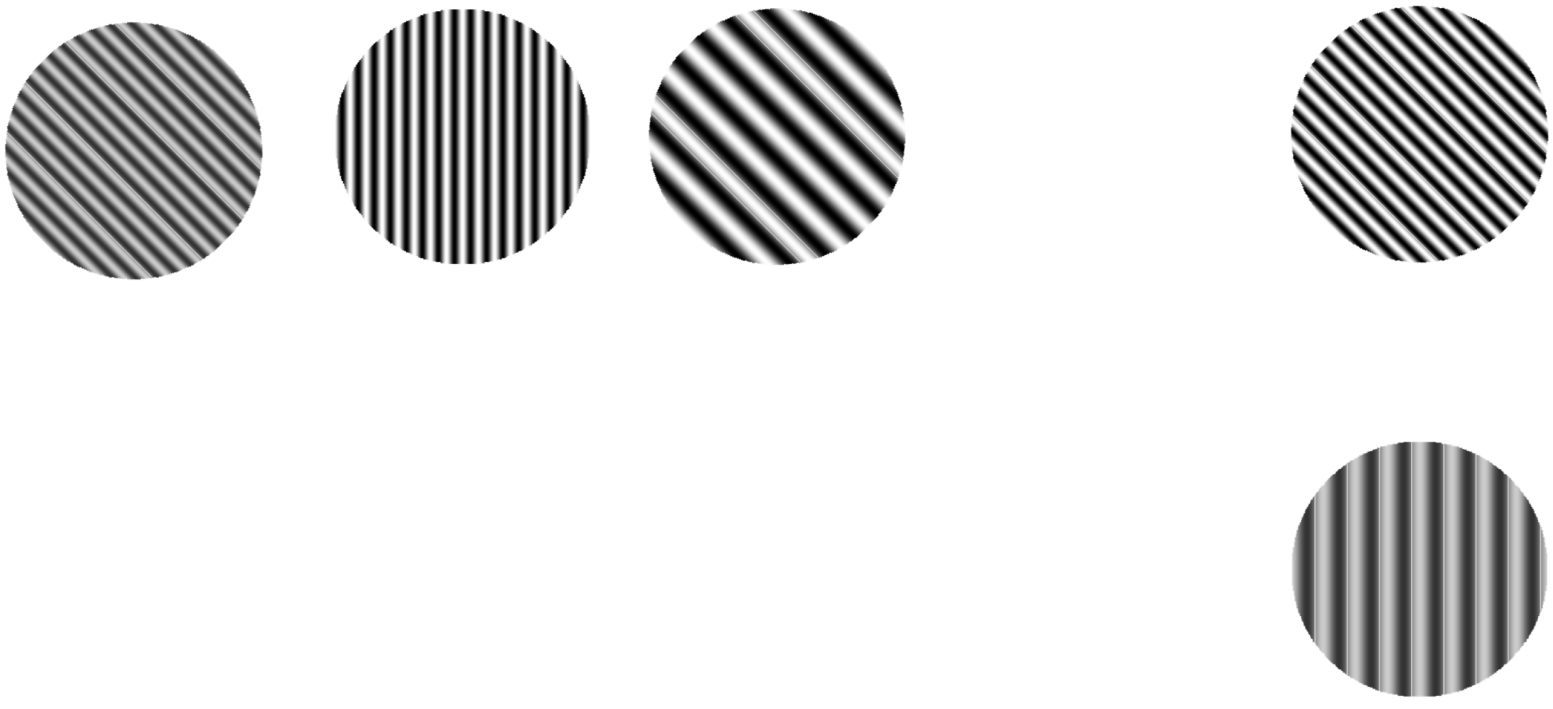






Phantom tripods

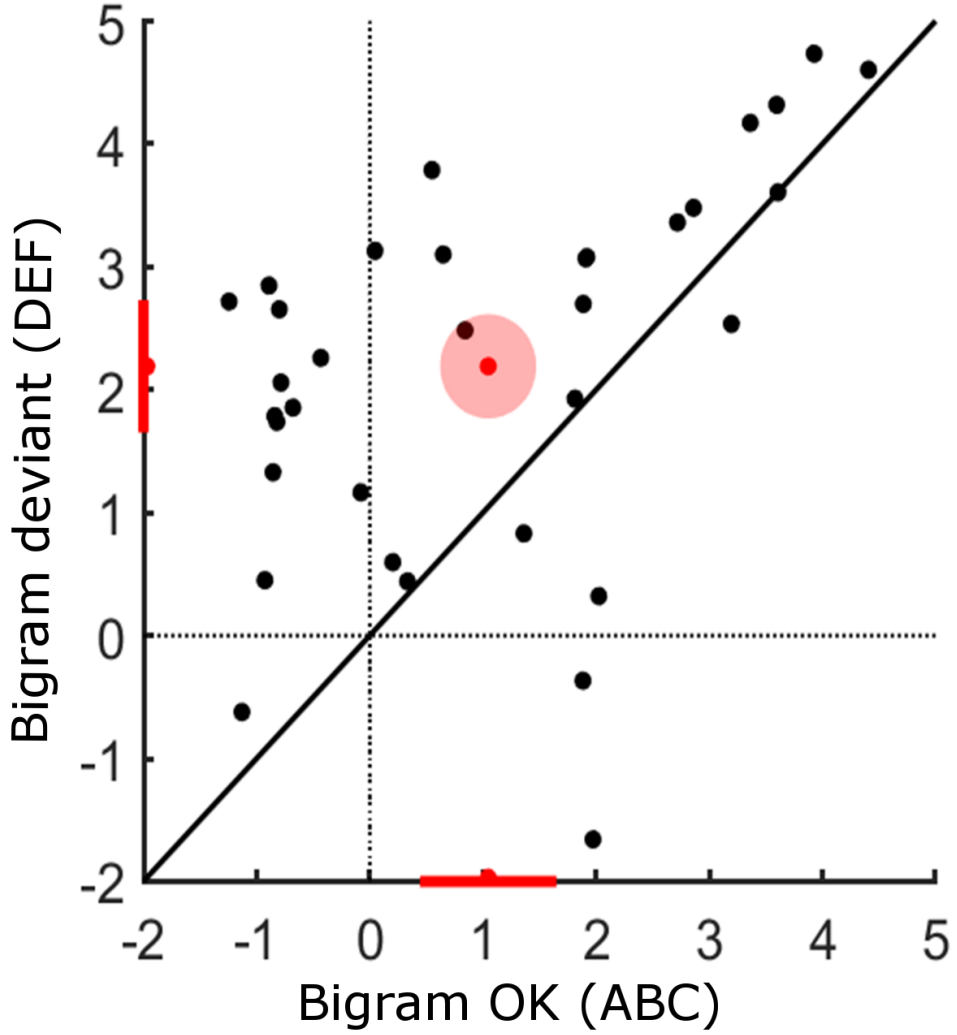


(Vidal et al., 2021)

Phantom Gabors



Phantom Gabors



(Vidal et al., 2021)

Take–home message

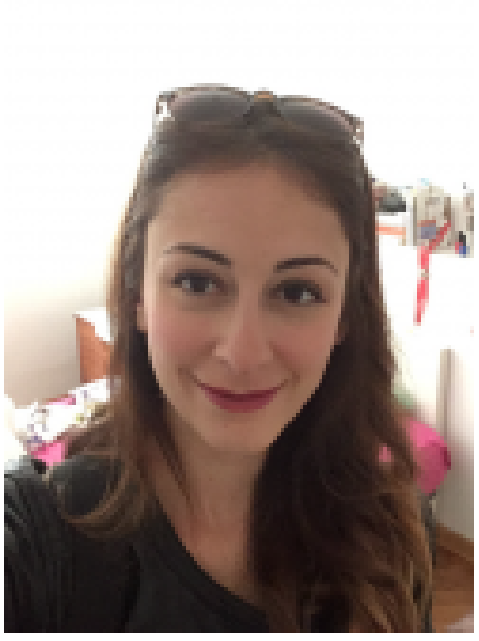
- We code for nGrams/letter transition stats while learning novel words
- We use the same mechanism while learning novel objects, where the lower–level units are:
  - not arranged horizontally, and very different visually from letters
  - not even spatially segregated

- More generally, reading shares (part of) its computational core with vision
- This computational core is captured by the statistical learning hypothesis

The team

Yamil Vidal

Eva Viviani



Davide Zoccolan

Linguistic morphology

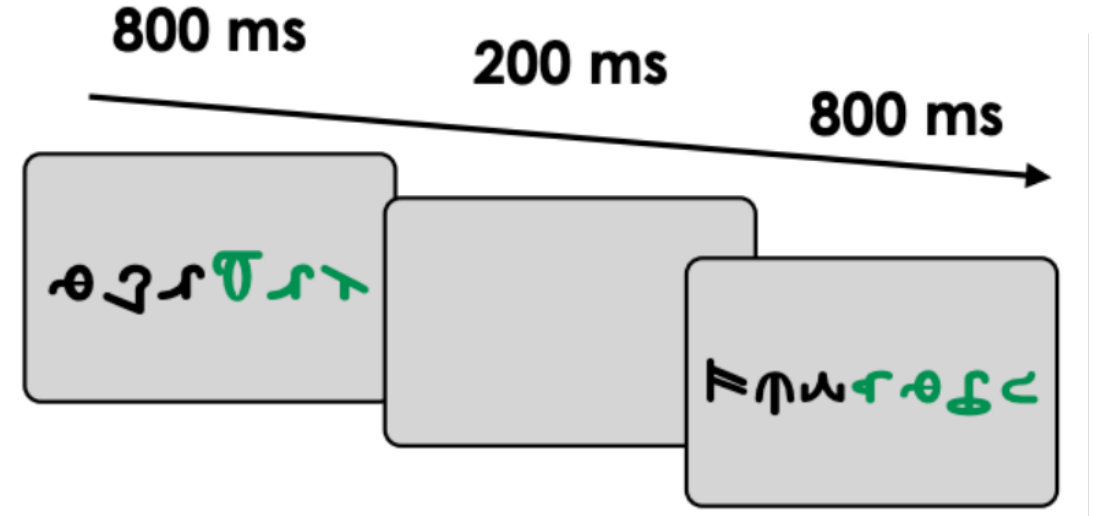
fall-s, deal-er, basket-ball, *corner*, *carpet*

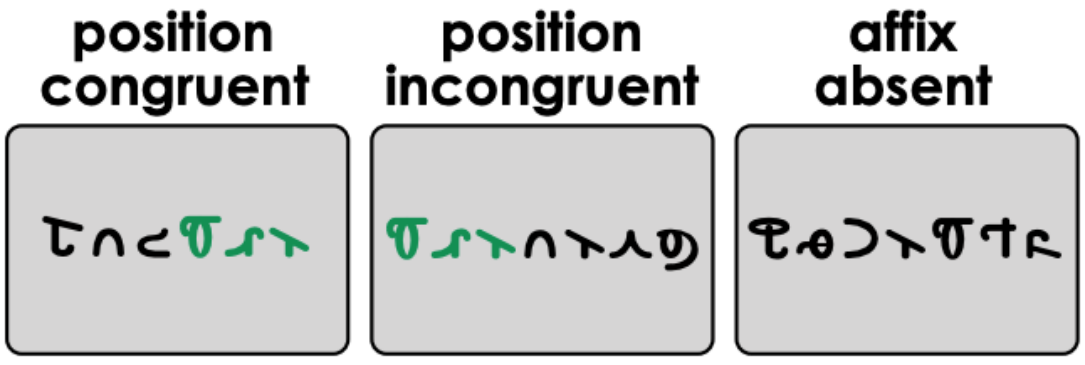
- *Corner* primes *corn* similarly to how *dealer* primes *deal* (e.g., Longtin et al., 2003; Rastle et al., 2004)

Morphemes as visual objects, clusters of recurring letter chunks

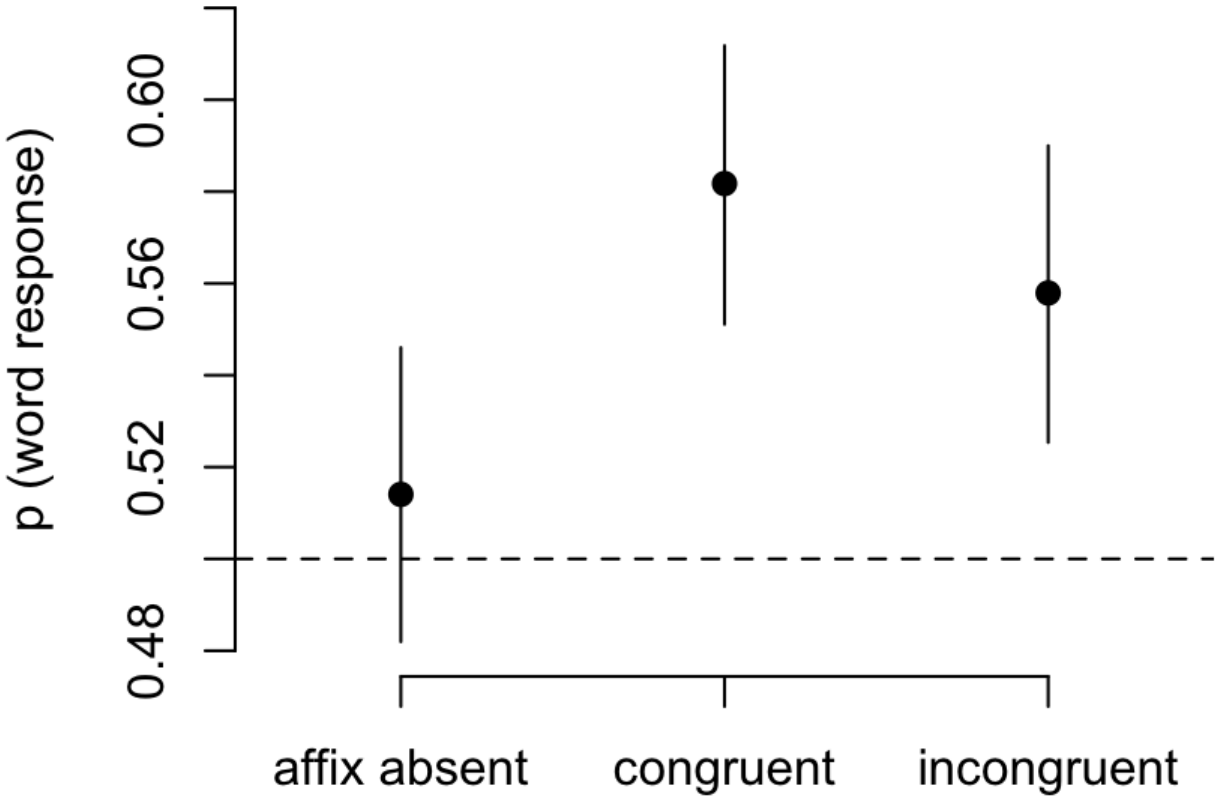
Morphemes as visual objects

- Pseudocharacters, so no previous knowledge, no meaning, no phonology
- 10 different "affixes" appear in 20 different "words"



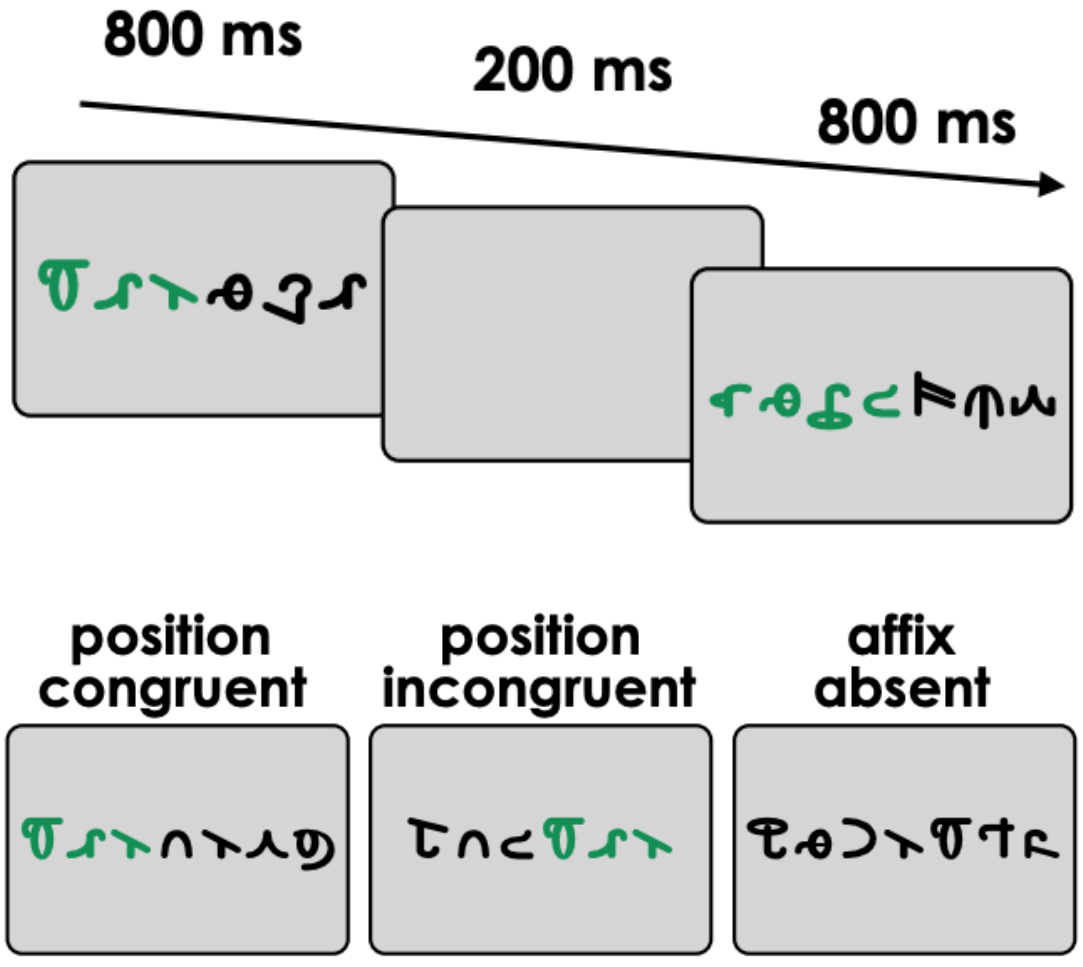


Sensitivity to affixes (and their position)

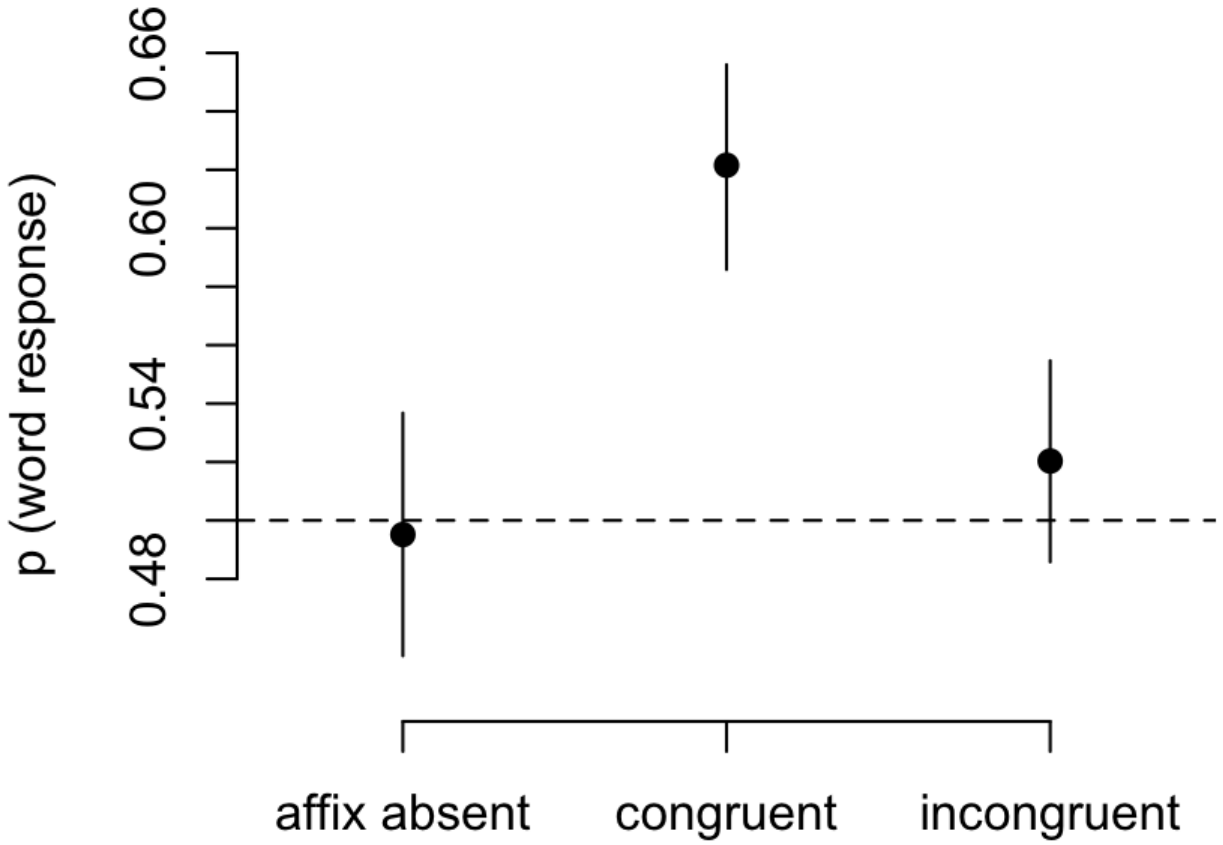


(Lelonkiewicz et al., 2020)

“Prefixes”


800 ms
200 ms
800 ms
position congruent
position incongruent
affix absent

Sensitivity to affixes (and their position)



(Lelonkiewicz et al., 2020)

Mimicking morphology

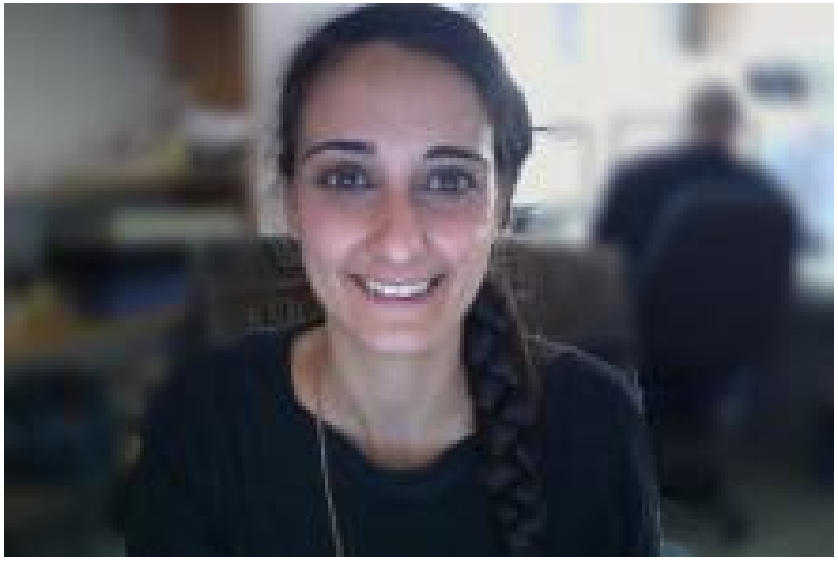
- *Gasful* more difficult to reject than *gasfil*; the effect shrinks with *fulgas* vs. *filgas* (e.g., Crepaldi et al., 2010)

- We obtain morphology without familiar letters, without meaning and without phonology
- Learning to read

The team

Jarosław Lelonkiewicz

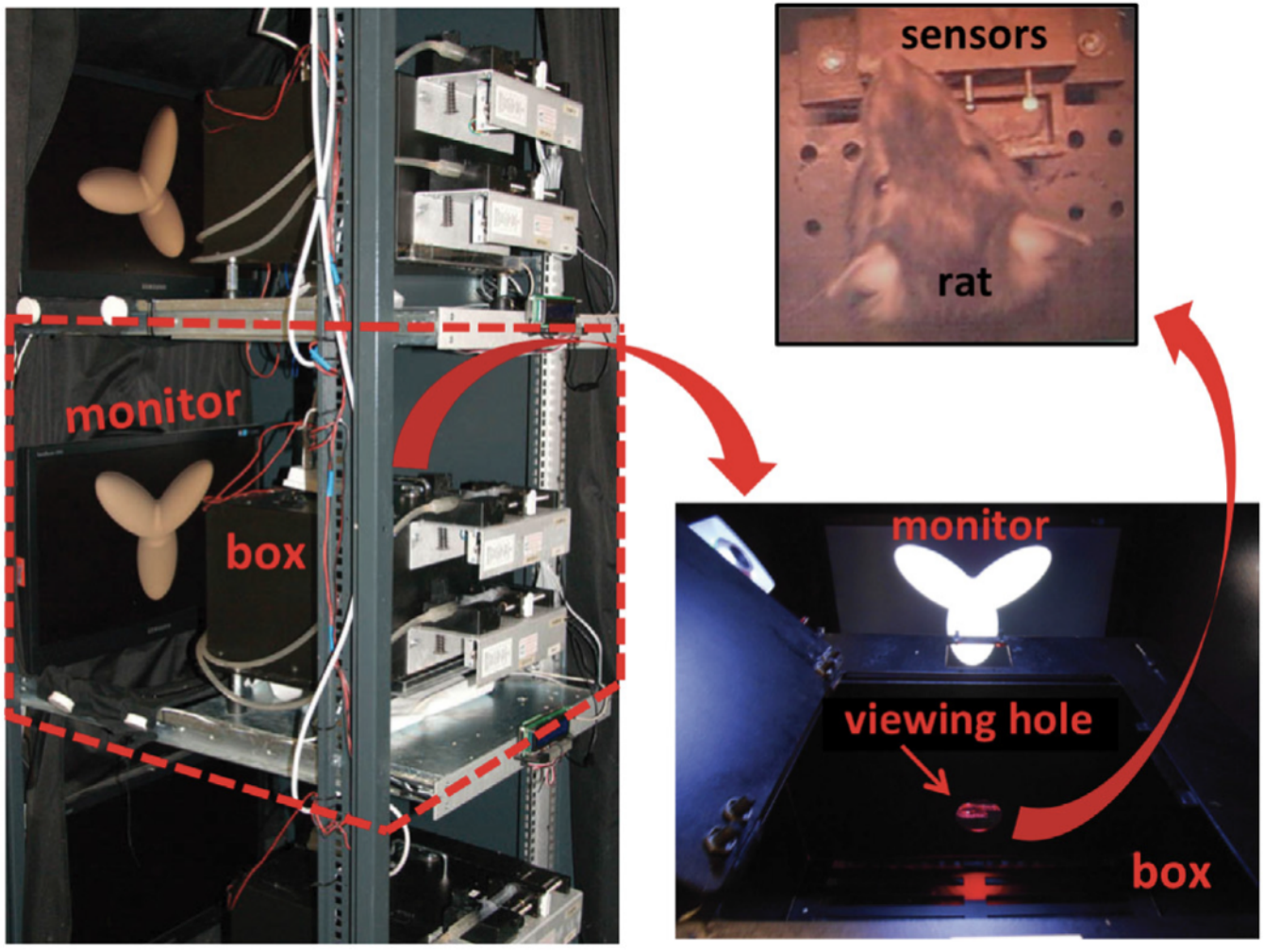
Maria Ktori



Unlikely readers

Long-Evans rats

The setup

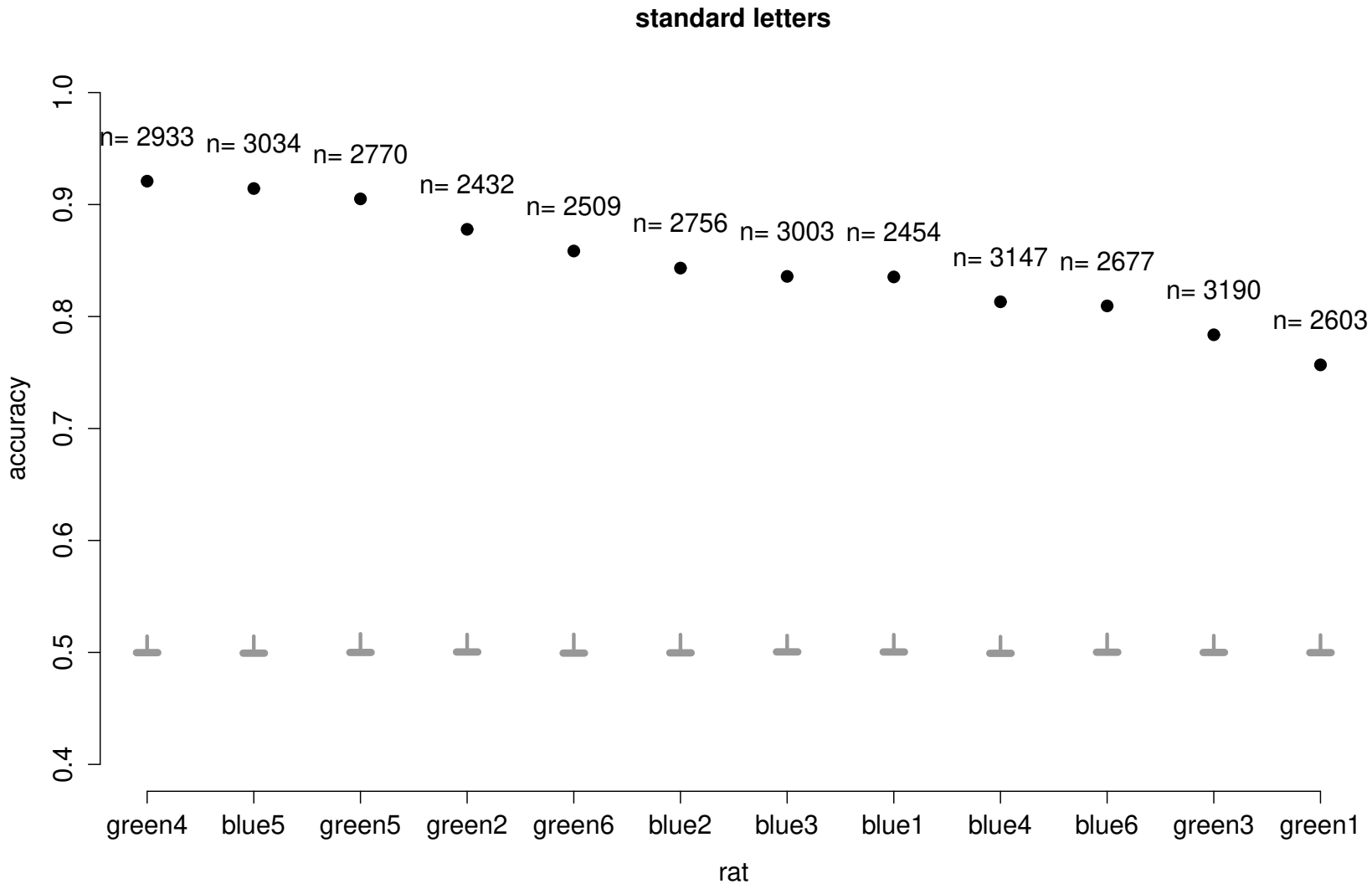


Letter identification

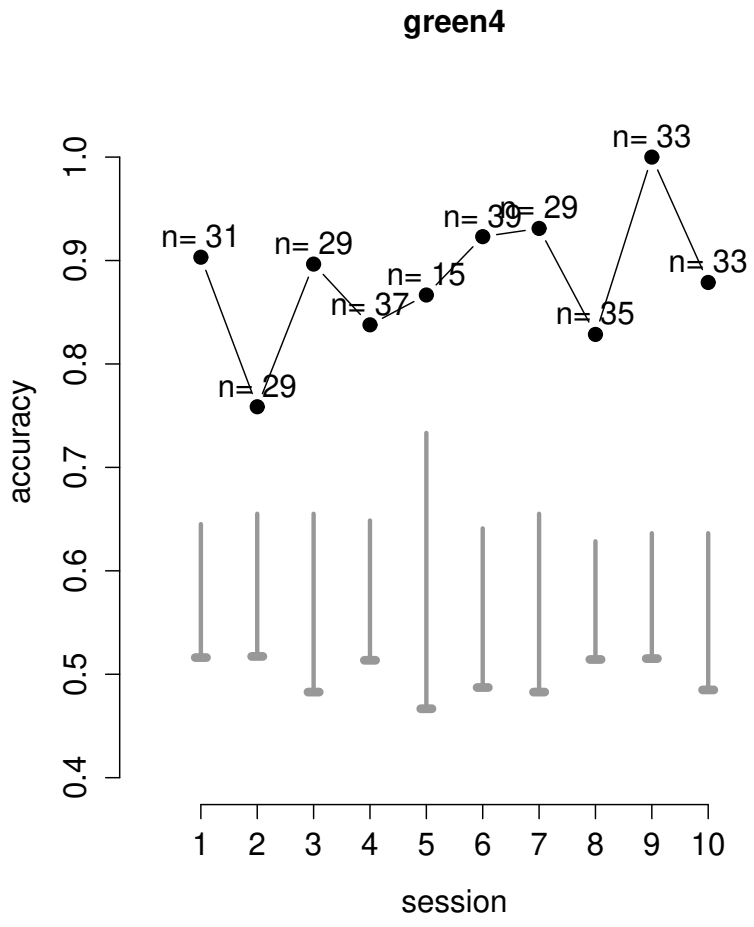
Go-left letters

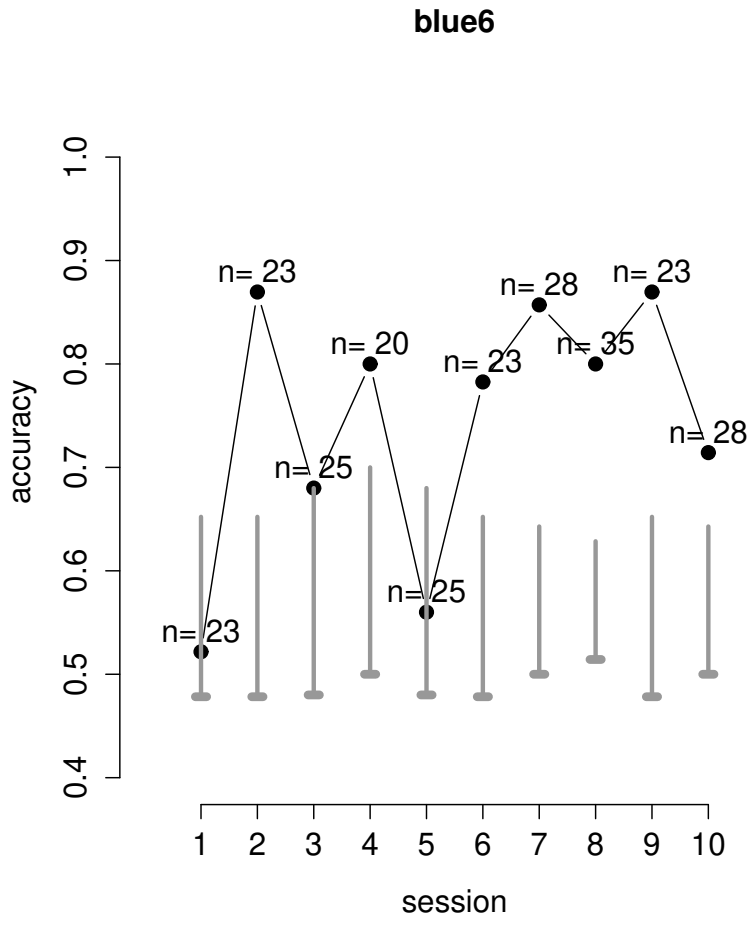
Go-right letters

Letter identification



Letter identification





Letters as abstract objects

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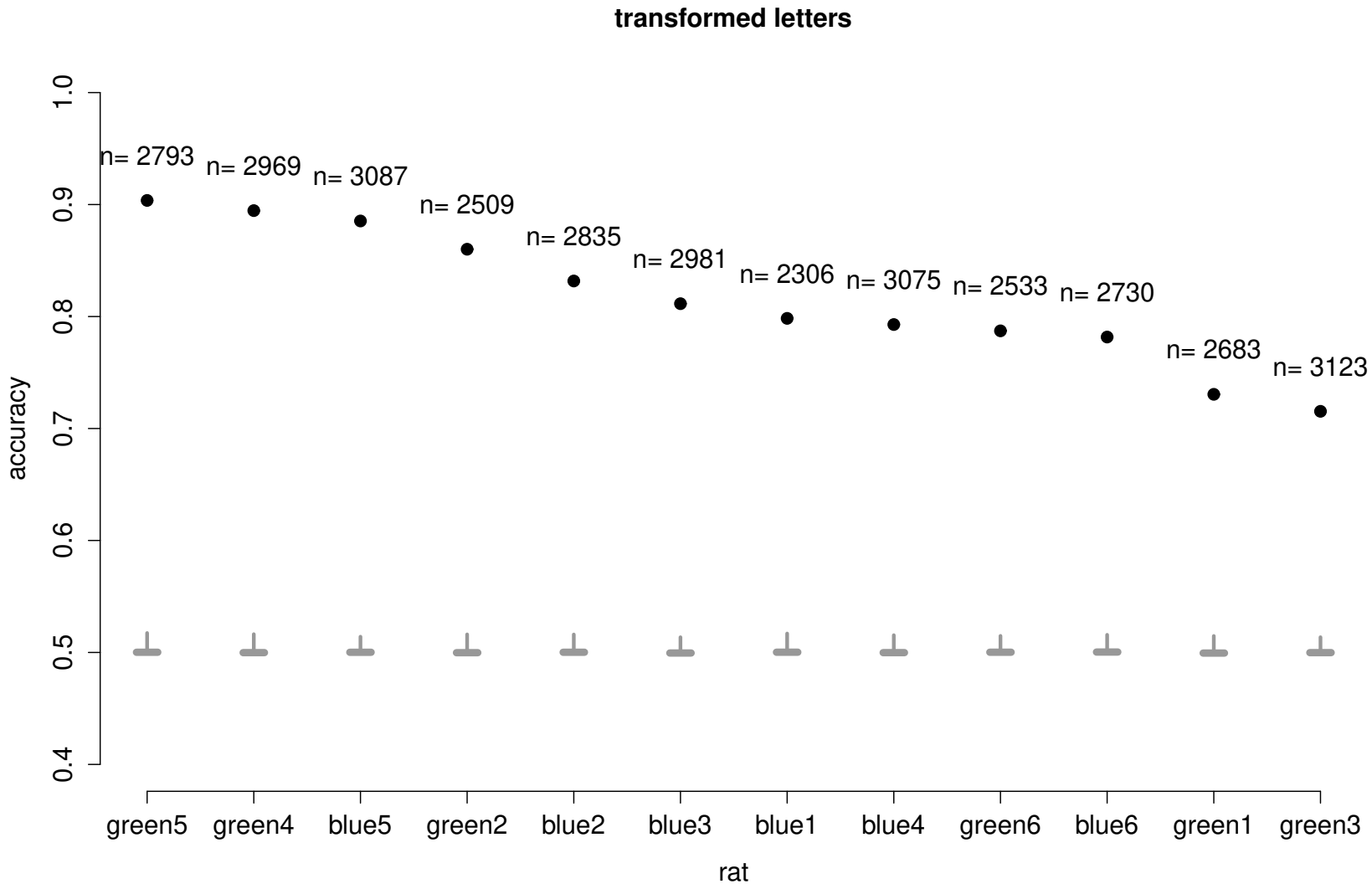
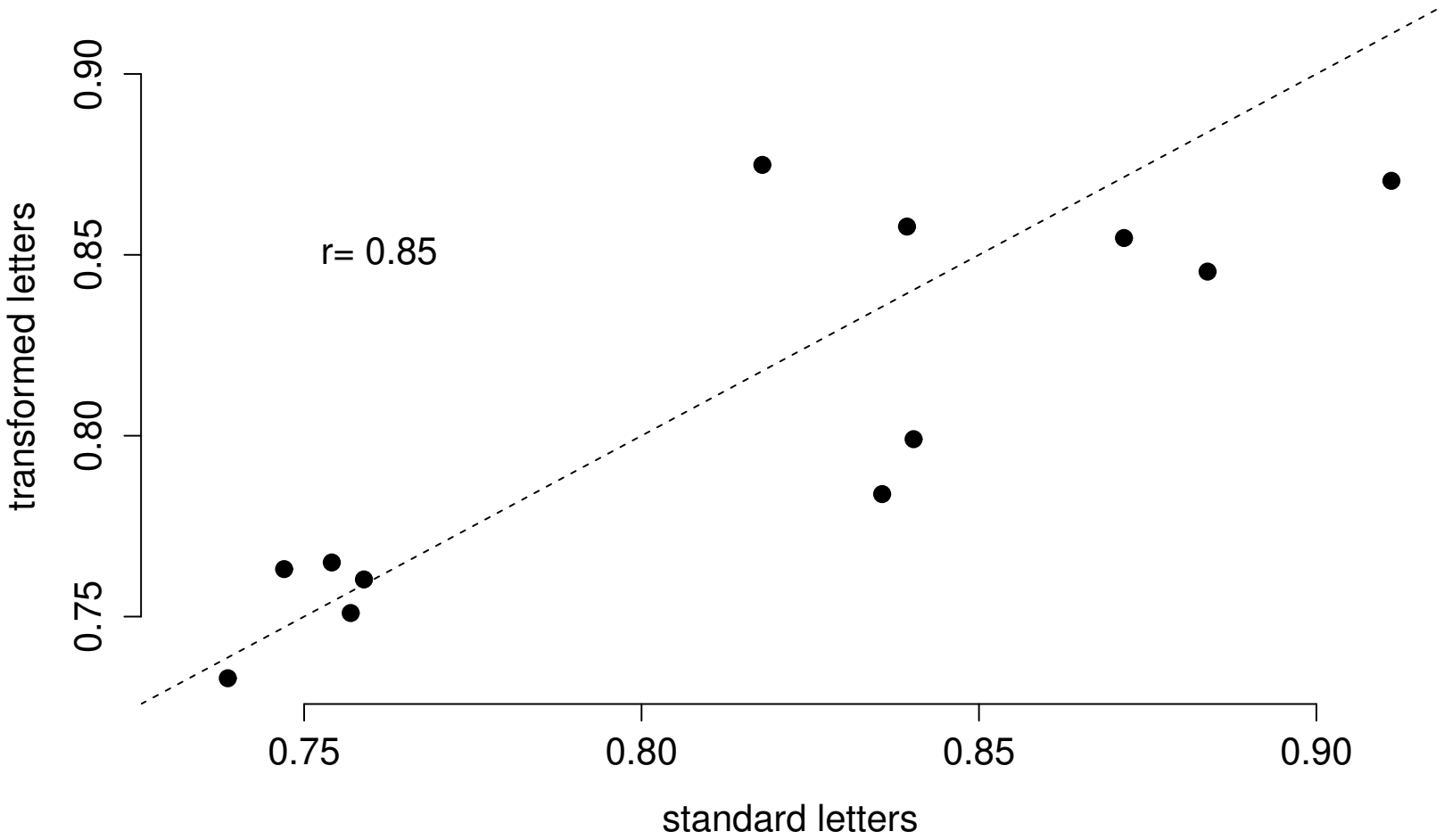


Letters as abstract objects

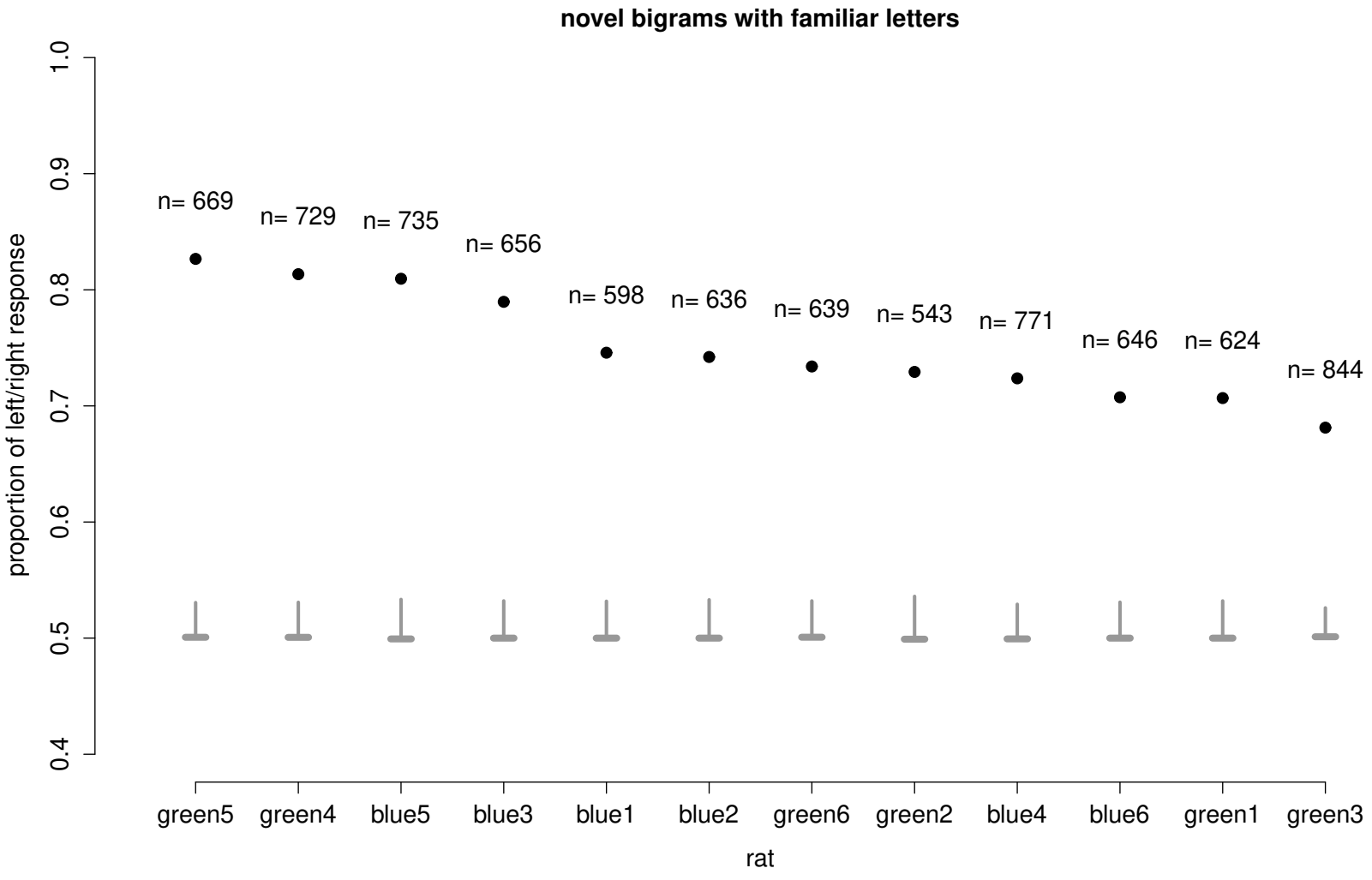


Reading rats, fact 1

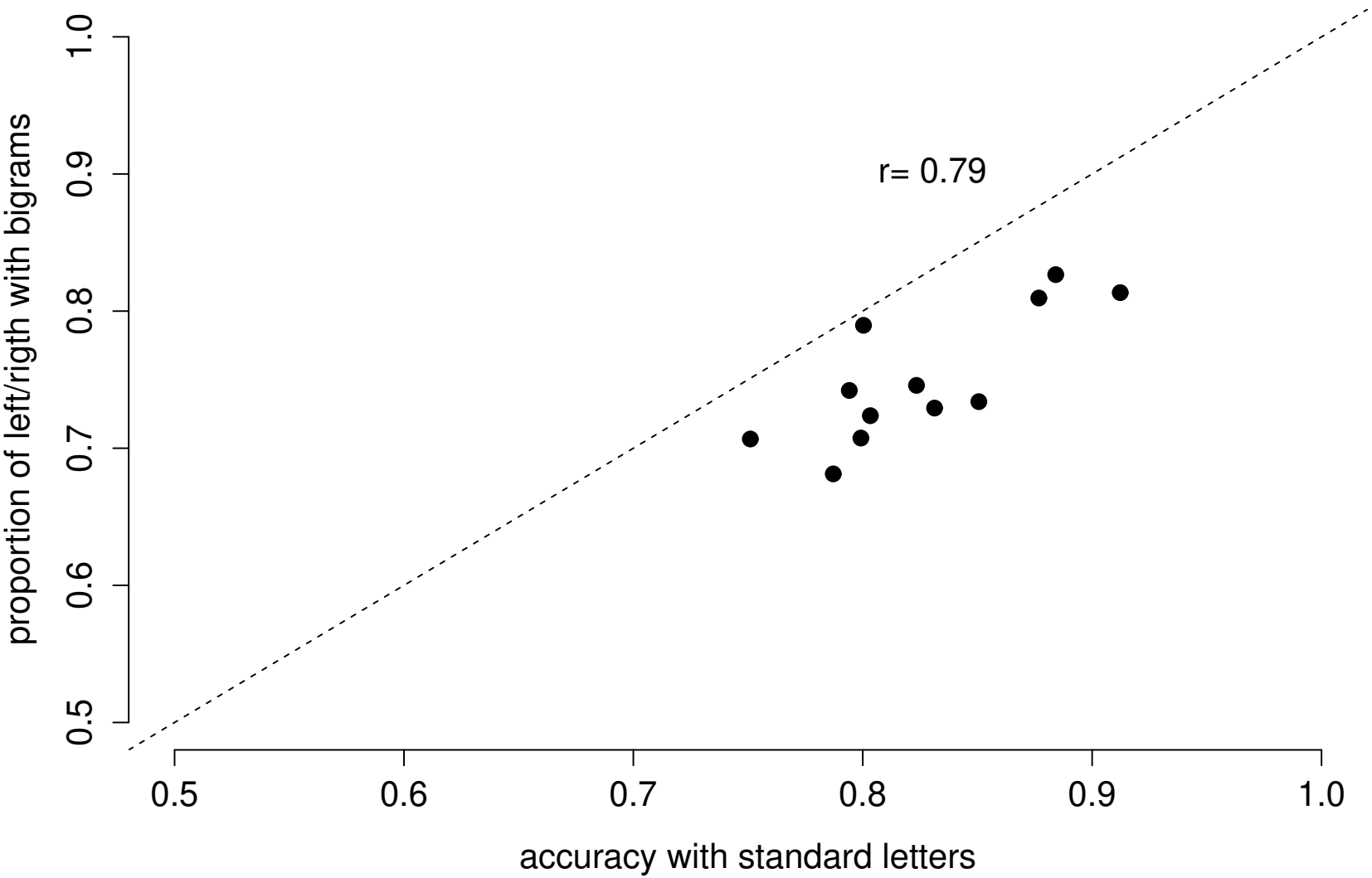
- Rats can be trained to identify letters as abstract objects
- Object invariance

Letters in strings

Letters in strings



Letters in strings

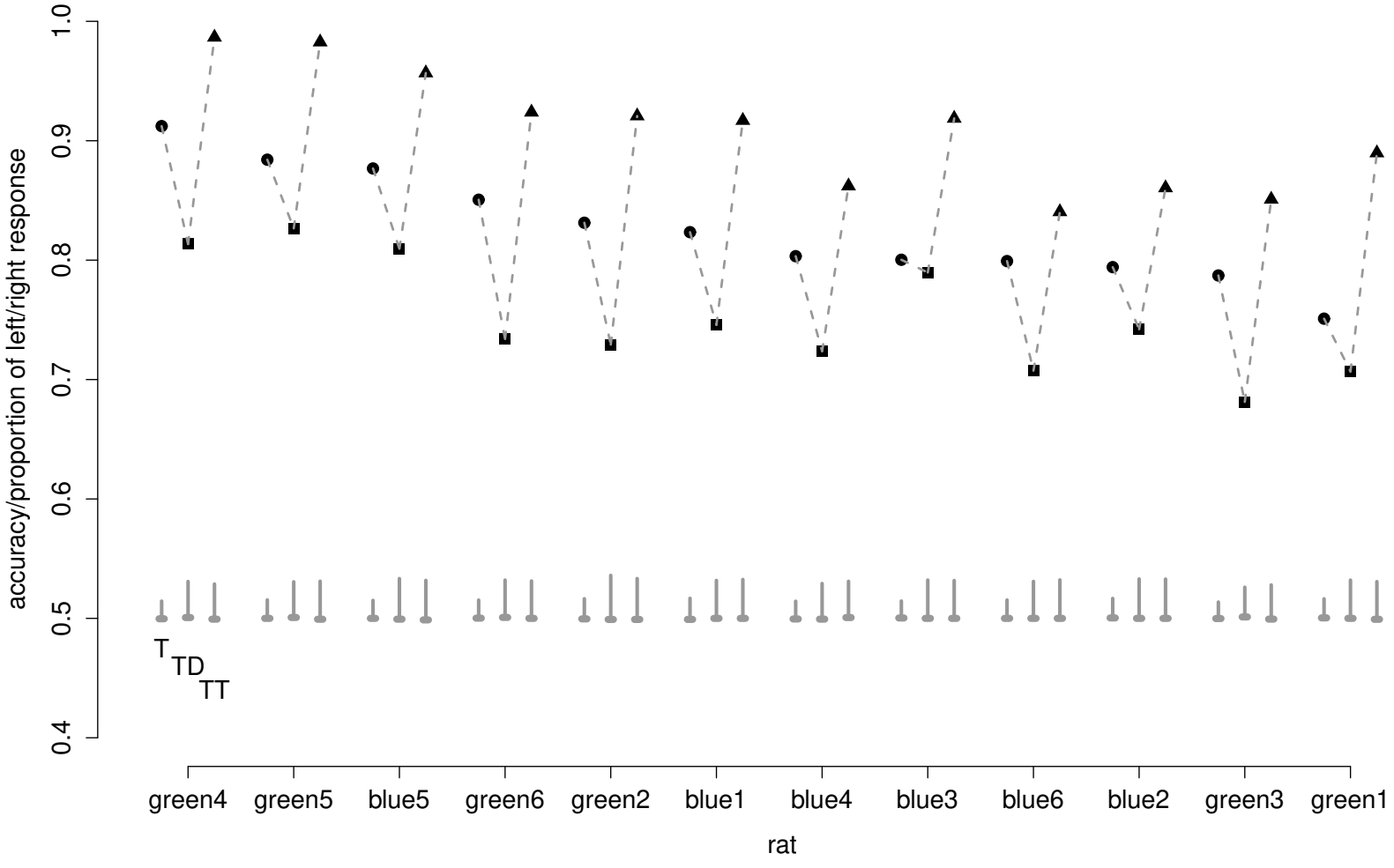


Reading rats, fact 2

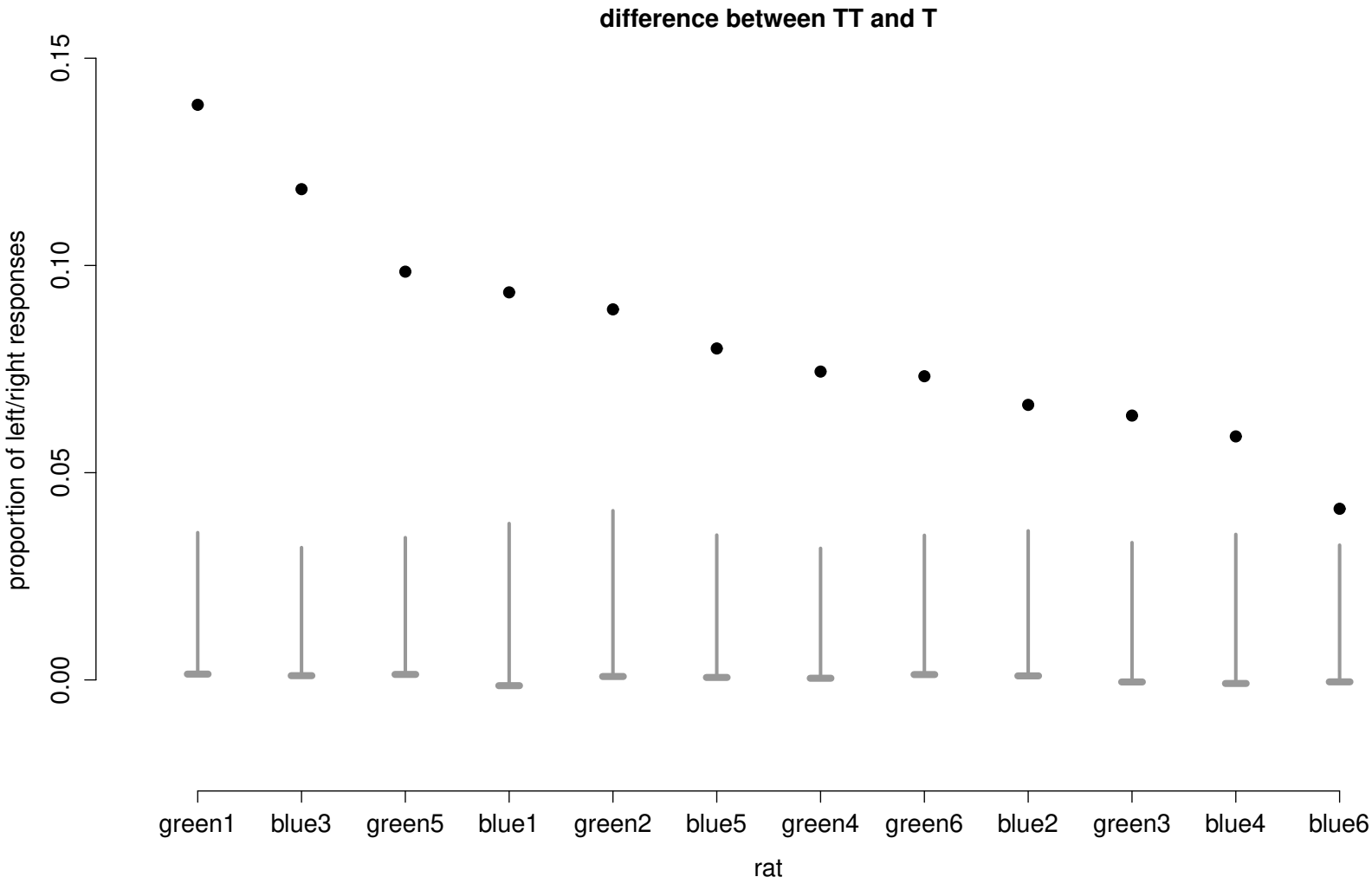
- Rats naturally identify letters withing strings
- Clutter tolerance

Two familiar letters

Performance on bigrams



Two letters is better than one



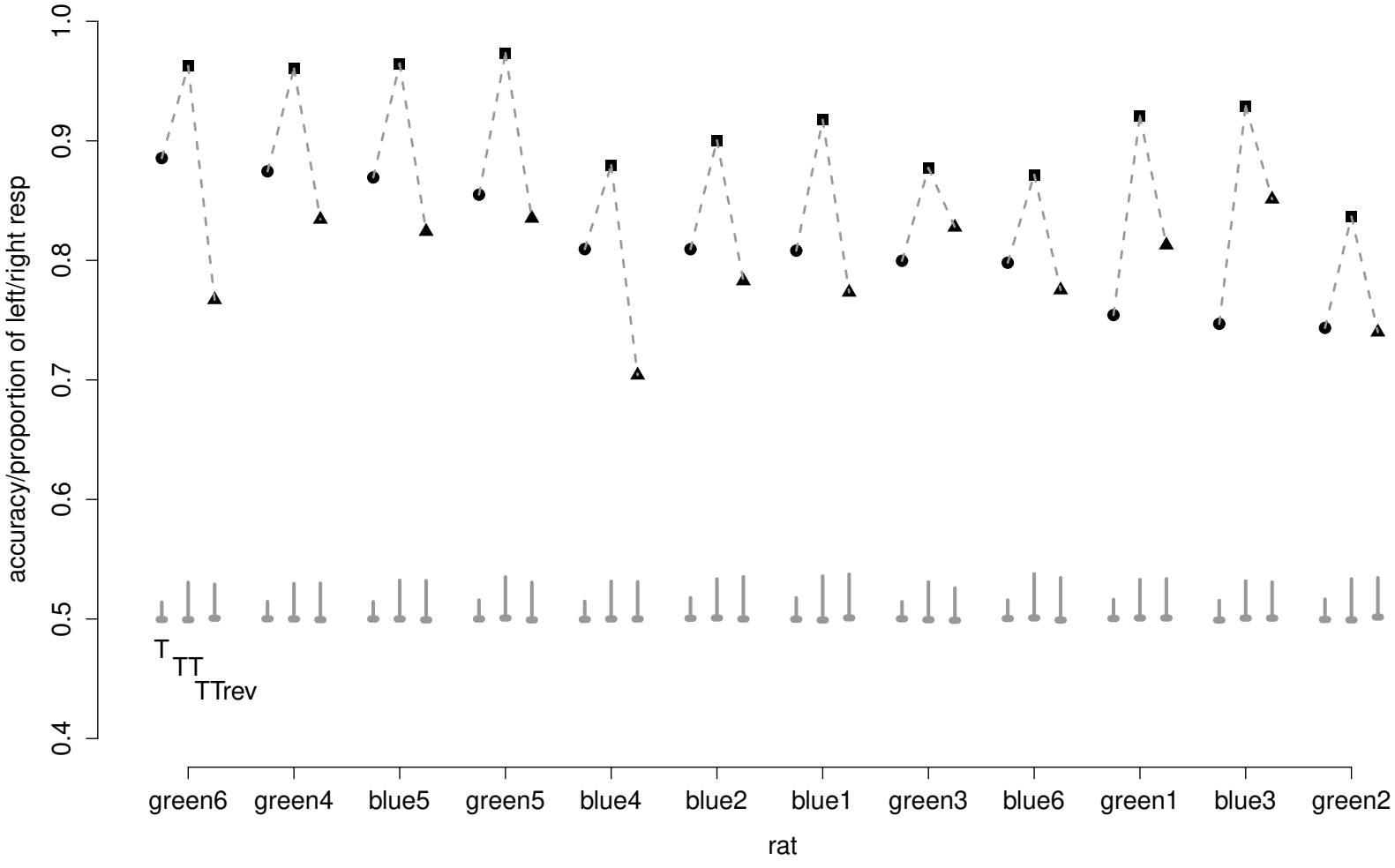
Reading rats, fact 3

- Rats spontaneously use information from multiple letters
- Cue integration

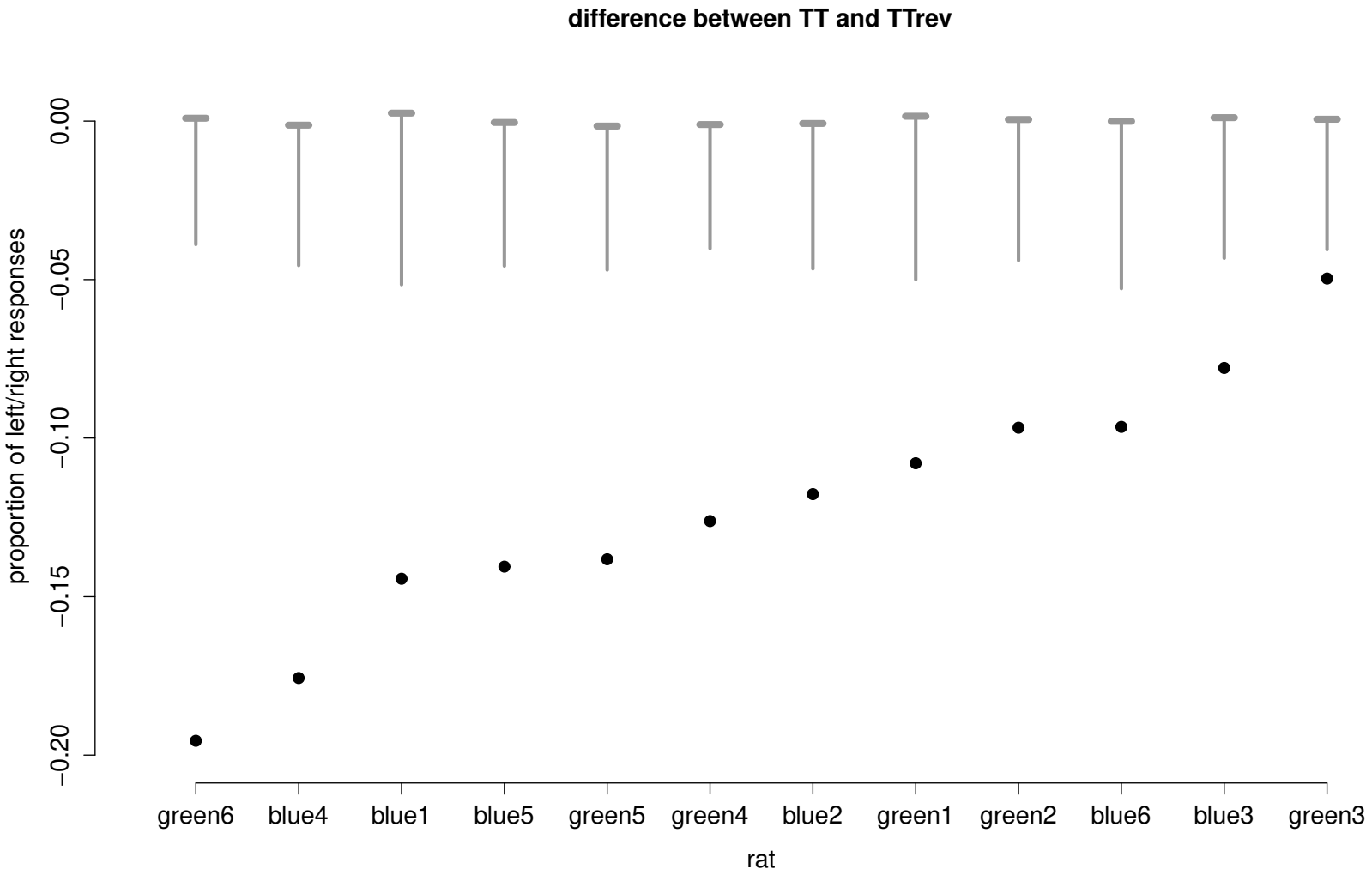
- Integration or summation?

Transposed-letter effects

Transposed-letter effects



Position coding



Reading rats, fact 4

- Rats identify letters in a position-invariant way
- Rats code for position within strings

> *"I will assume that most of the information used by skilled readers to silently read words for meaning concerns information about abstract (i.e., case and font independent) letter identities, plus information about letter positions – in other words, orthographic information."*

(Grainger, 2018)

Letters and words

- Natural processing of strings, given familiarity with letters
- But we human readers hold representations for both letters and words at the same time

- Training on bigrams and letters

Sum up

- Rats can be trained to identify letters as abstract objects
- After they're familiar with letters, they spontaneously:
  - identify letters within strings
  - use information from multiple letters
  - combine position-invariance with position coding (hallmark of orthographic coding)

The team

Jarosław Lelonkiewicz

Davide Zoccolan

A "visual" look into language

- Written language is too recent to have biologically-selected brain machinery; evolutionary older mechanisms must be recycled (Dehaene and Cohen, 2007)
- We showed that:
  - a general-purpose learning mechanism emerges across different types of visual stimuli, if one looks into the early stages of familiarization (Vidal et al., 2021)
  - this mechanism builds on the statistics of lower-level, fundamental units (perhaps to generate higher-level representations?)
  - these phenomena can explain linguistic effects (e.g., early morphology; Lelonkiewicz et al., 2020)
  - they're not dependent on language, to the point that they can be modeled in rodents

A "visual" look into language

- More broadly (and in the longer run):
  - the computational content of the Neuronal Recycling Hypothesis
  - a theory of learning to read that builds on these insights
  - a computational model of visual (word) identification

Anything special about visual word identification?

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9 February 2021

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