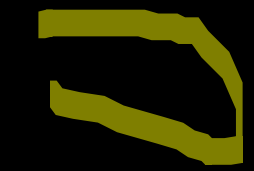
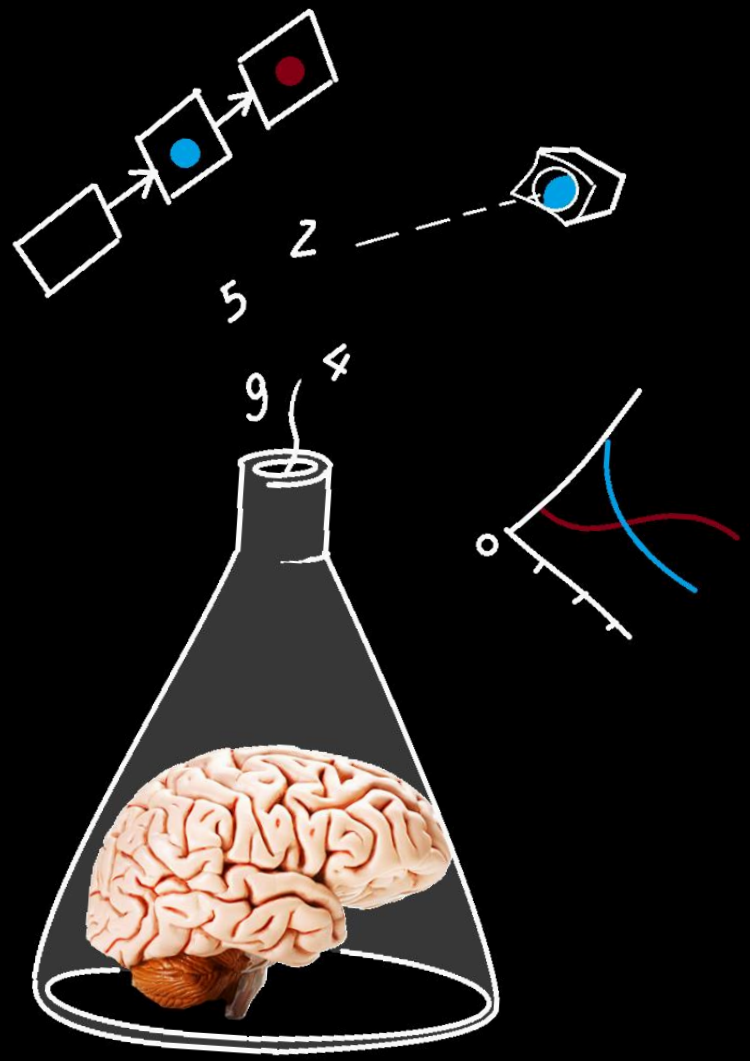
Multi-dimensional cognition: Reading





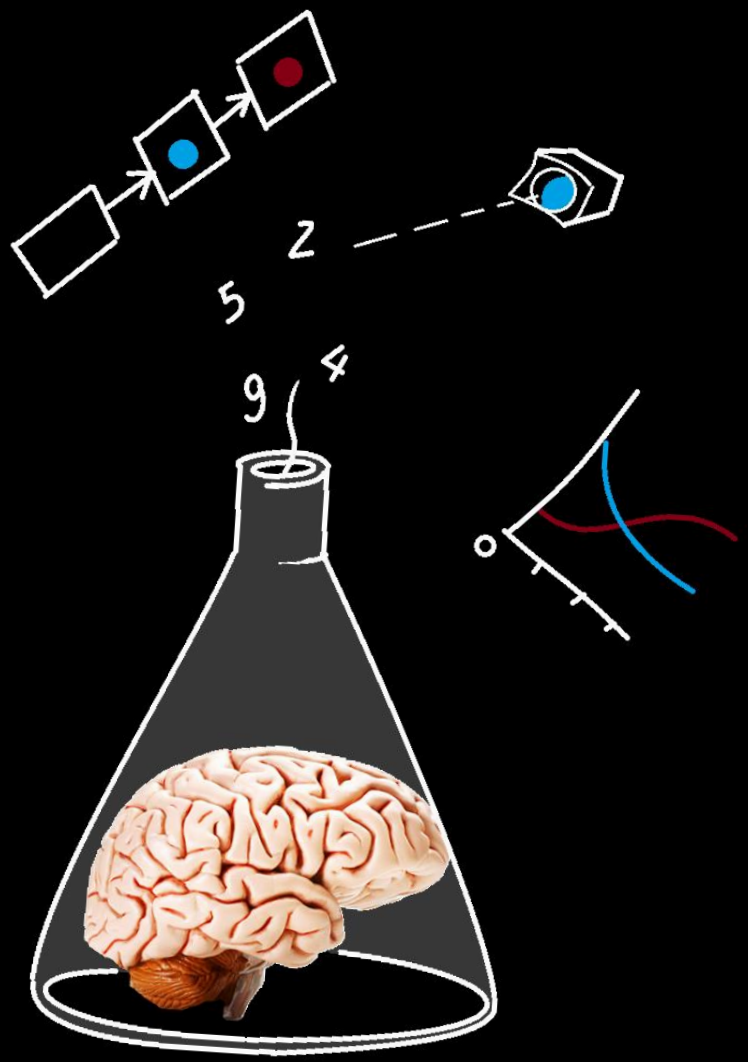
Practical points

Pupillometry assignment due Wednesday 23:59

LMM assignment on Canvas tomorrow, due Wednesday next week 23:59

This week: finish experiment and start data collection

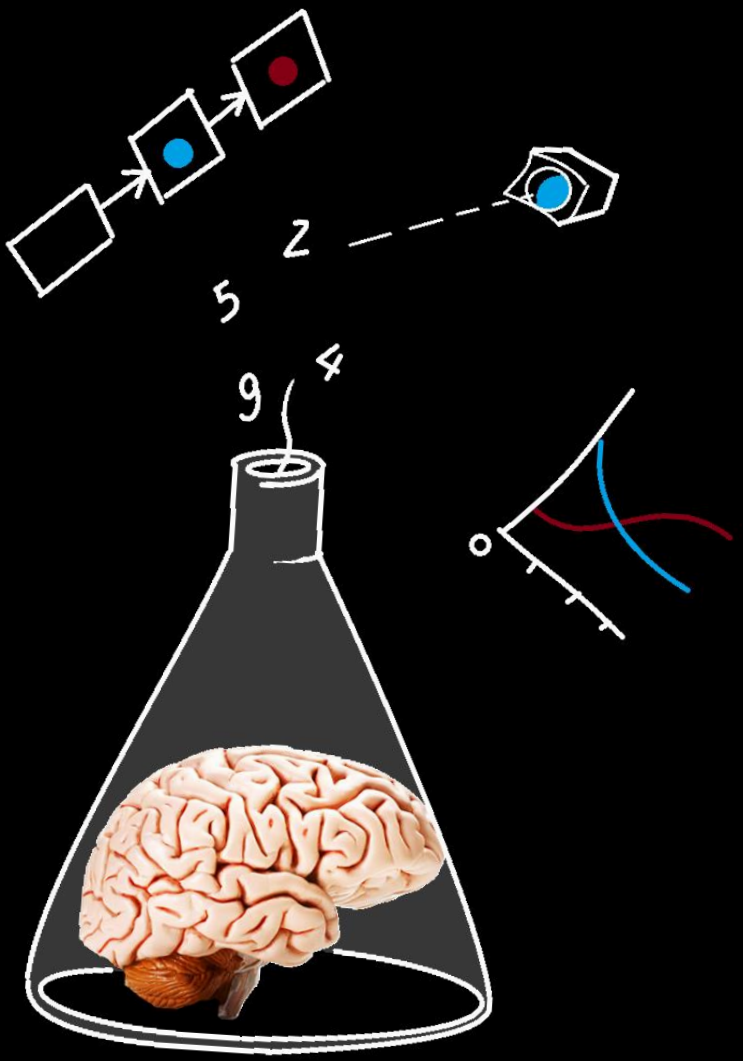
Next week: collect data and write paper

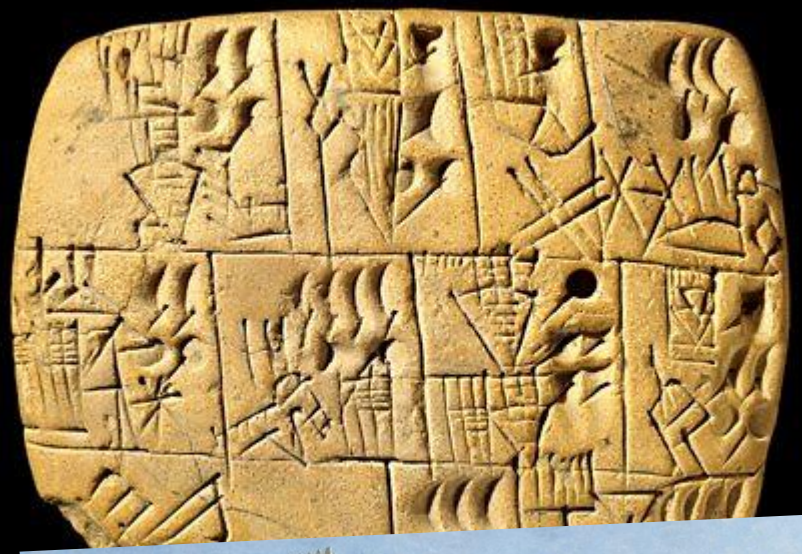


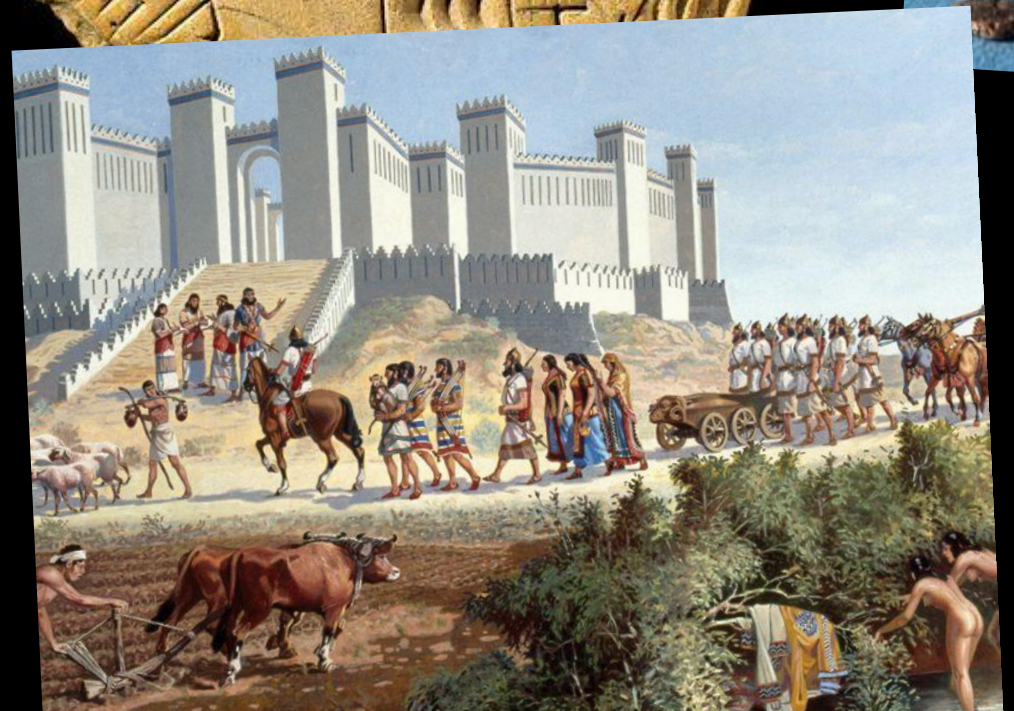
Today

- Orthographic processing
- Attention
- Sentence processing

- *Instructions for report*







~8000 BC: accountancy system
~3000 BC: logography &
alphabet

It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness...

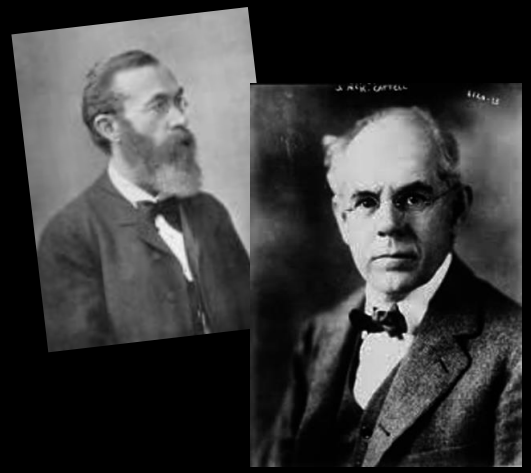
Why is reading interesting for the cognitive psychologist?

Reading relies on many realms of cognition

- Vision
- Attention
- Memory
- Language processing
- Oculomotor control

How do these functions come together?
How do these functions operate in applied contexts?

One of the earliest topics of cognitive psychology

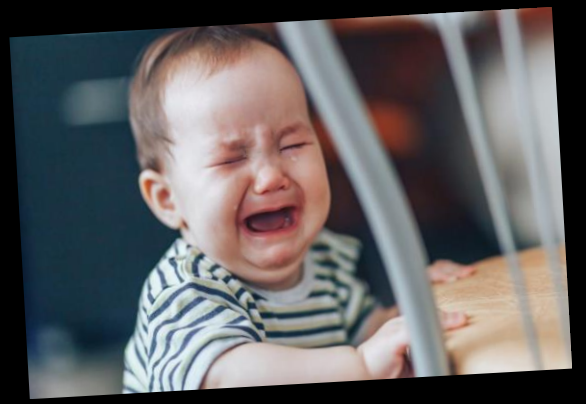


1886
Cattell

1908
Huey

"[…] to completely analyze what we do when we read would almost be the acme of a psychologist's achievements, for it would be to describe very many of the most intricate workings of the human mind."

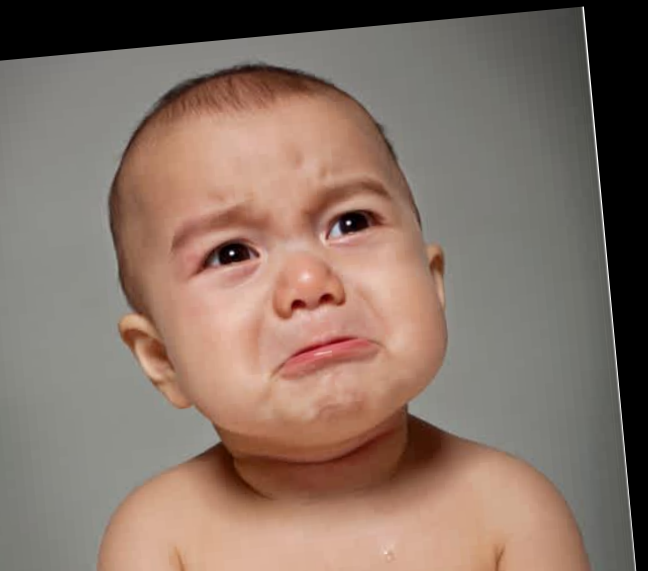
What is language?

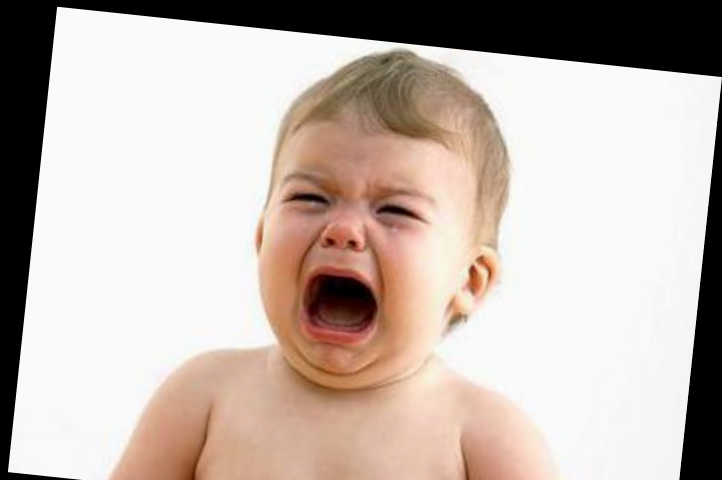


Language vs. communication

Communication: *any* transmittance of any signal
in any perceptual modality

Communication is the overarching thing;
language is but a means to communicate





What is language?

Language is a *hierarchical system*

Comprises *building blocks* that can be combined into building blocks that can be combined into building blocks…

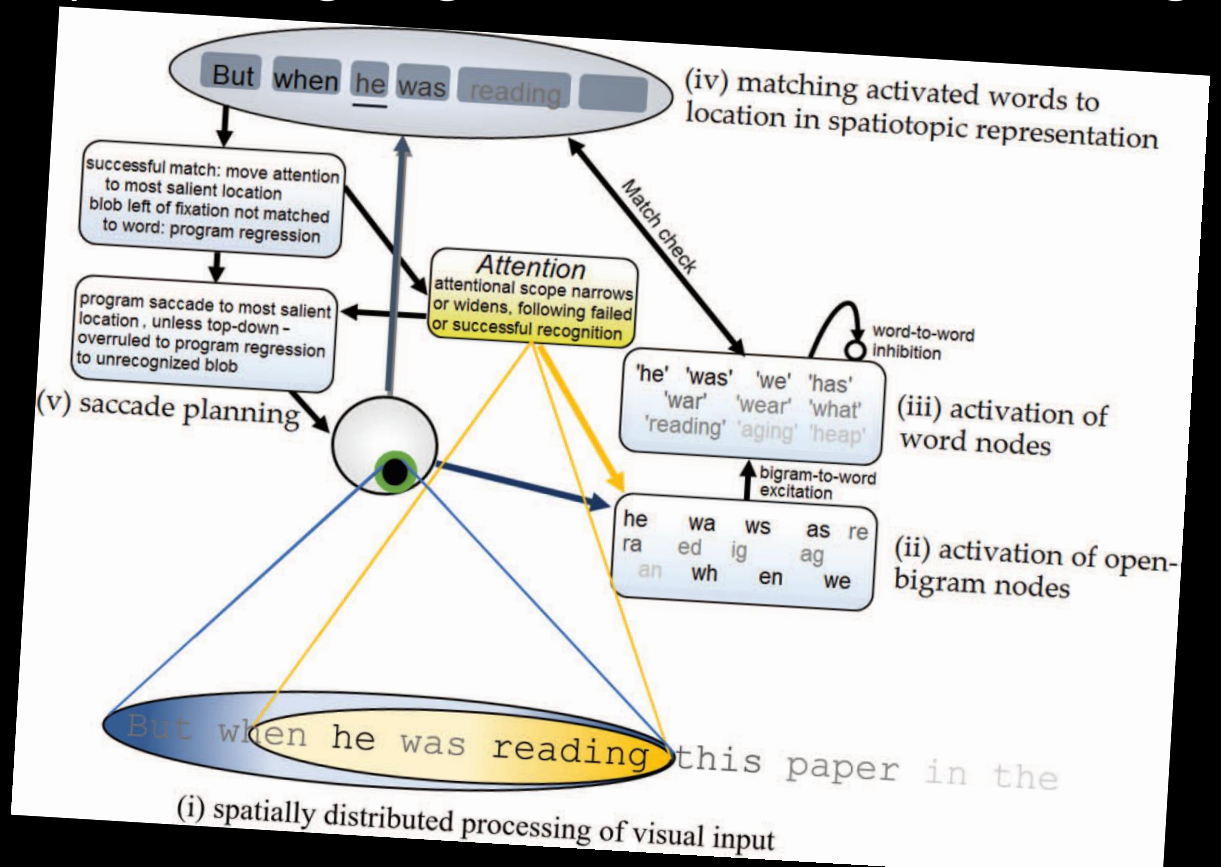
Comprises *rules* about *how to combine* building blocks at each level of the hierarchy…

The set of structures that can be built following the rules is *infinite*

Building blocks

visual features > letters > words > sentences > context

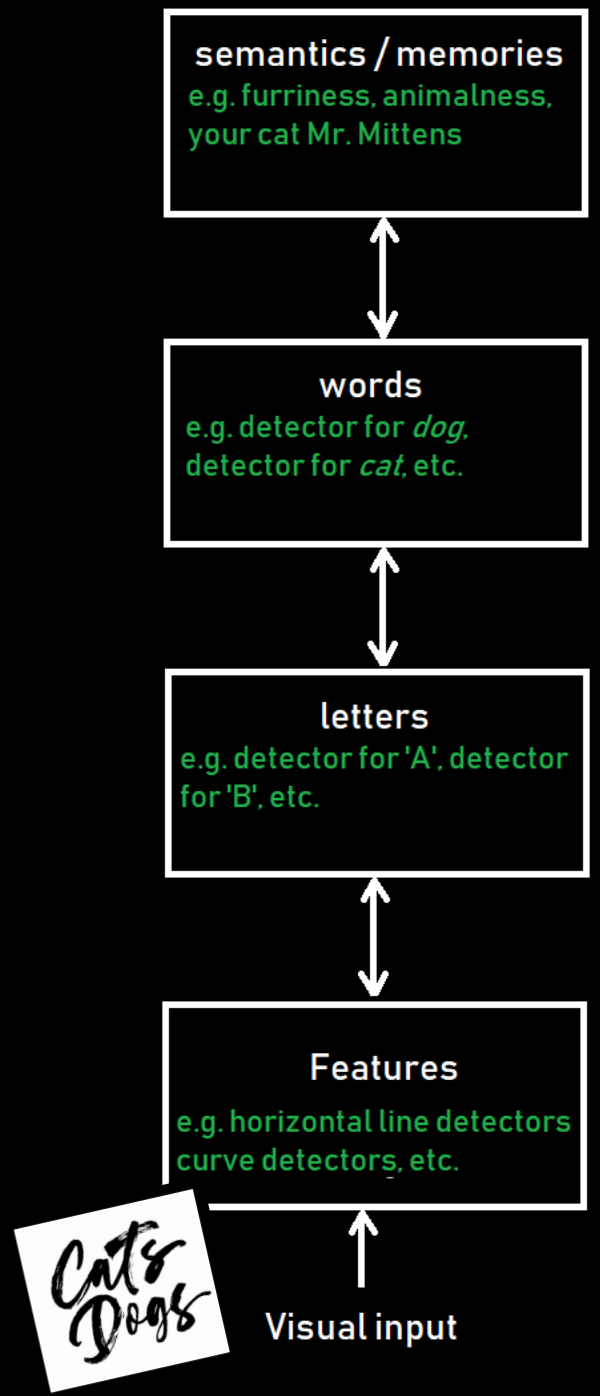
Does the brain have distinct processing stages for these various building blocks? Cognitive models: *yes*.



Perception lecture:

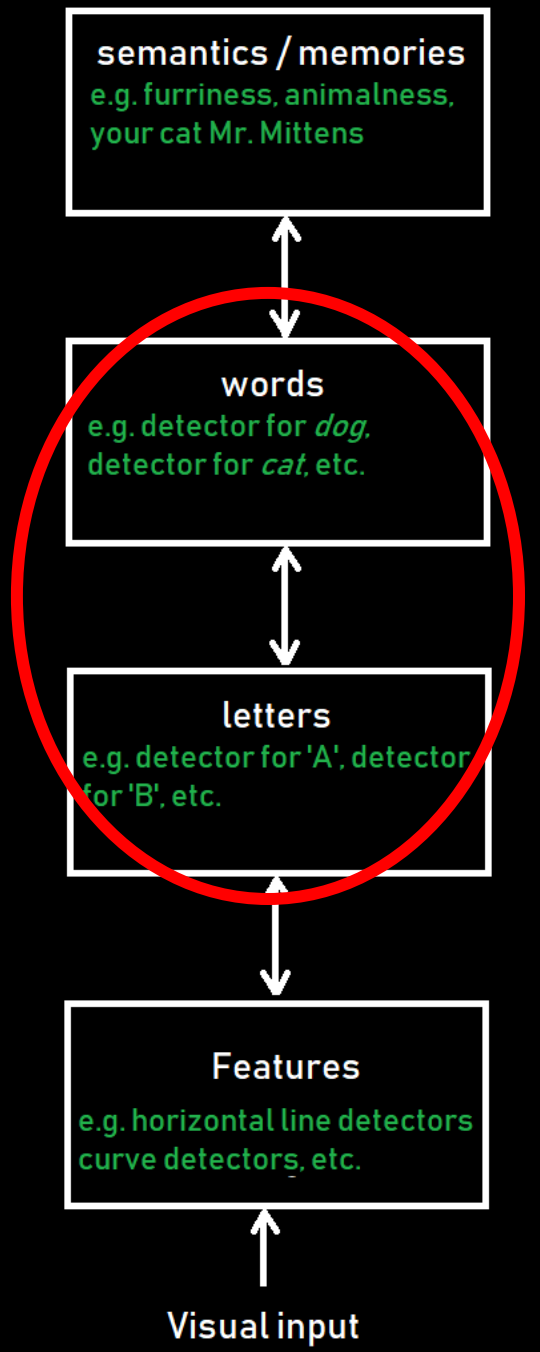
- various levels of processing
- interactions among levels

Top-down vs. bottom-up

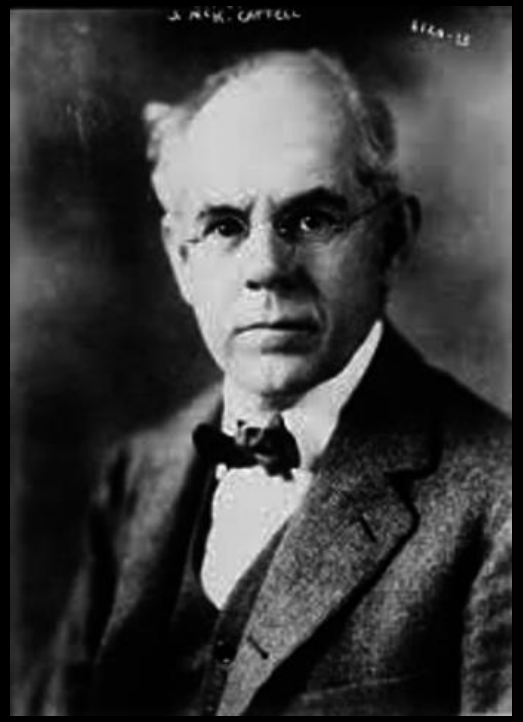


Orthographic processing

The interface between letters and words



Let’s go back to 1886…

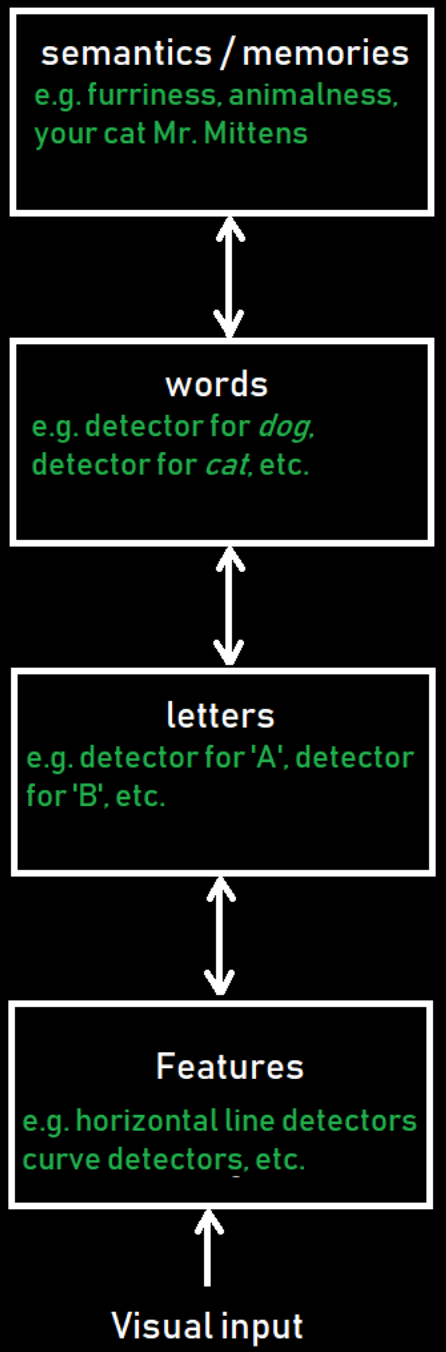


James McKeen Cattell

Letters in words are recognized faster than letters in nonwords

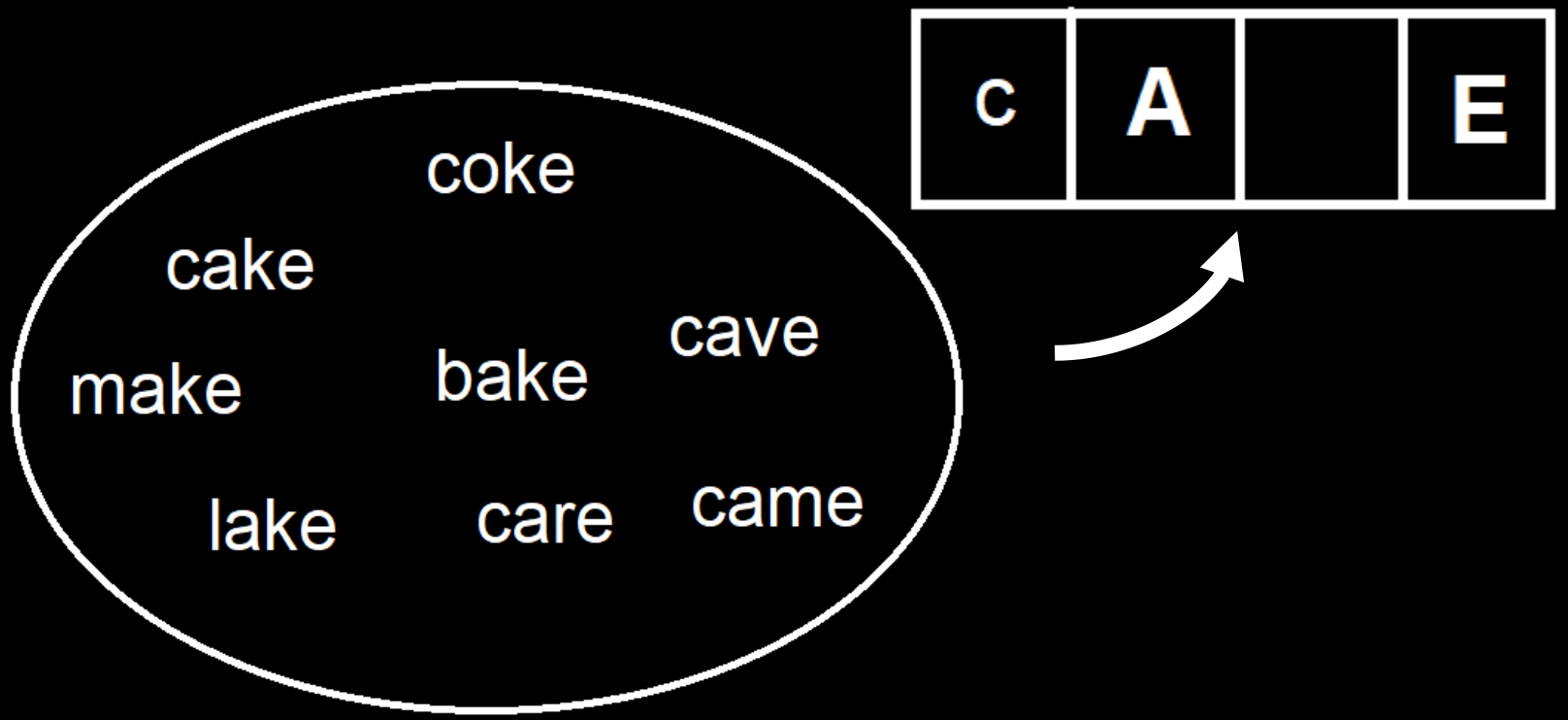
PLUMP PMULP

(word superiority effect)



And then a century forward…

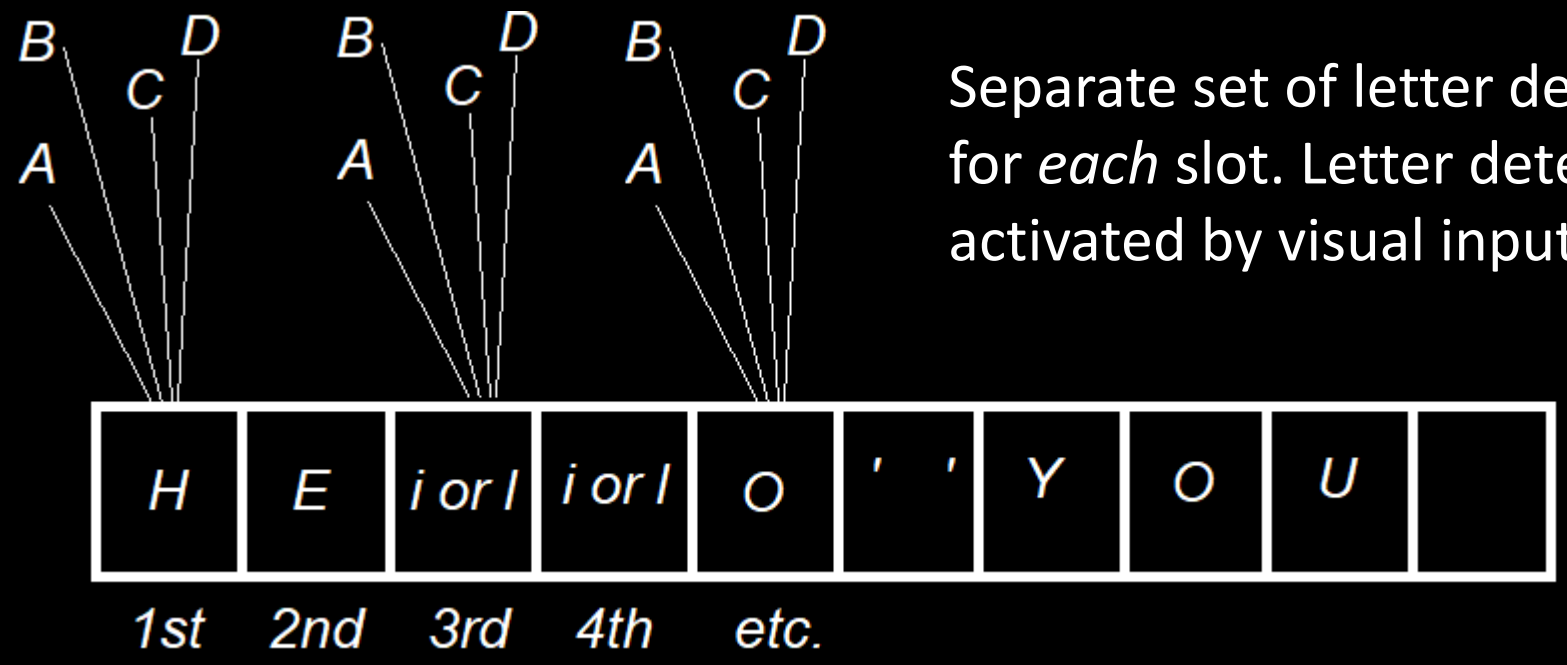
Words with large ‘orthographic neighborhoods’ are recognized faster



How do we start processing a word?

Orthographic processing — *Recognizing letters and their positions*

1970's: somewhere in the brain, we have an array of 'slots'



Separate set of letter detectors for *each* slot. Letter detectors are activated by visual input

How do we start processing a word?

Orthographic processing — *Recognizing letters and their positions*

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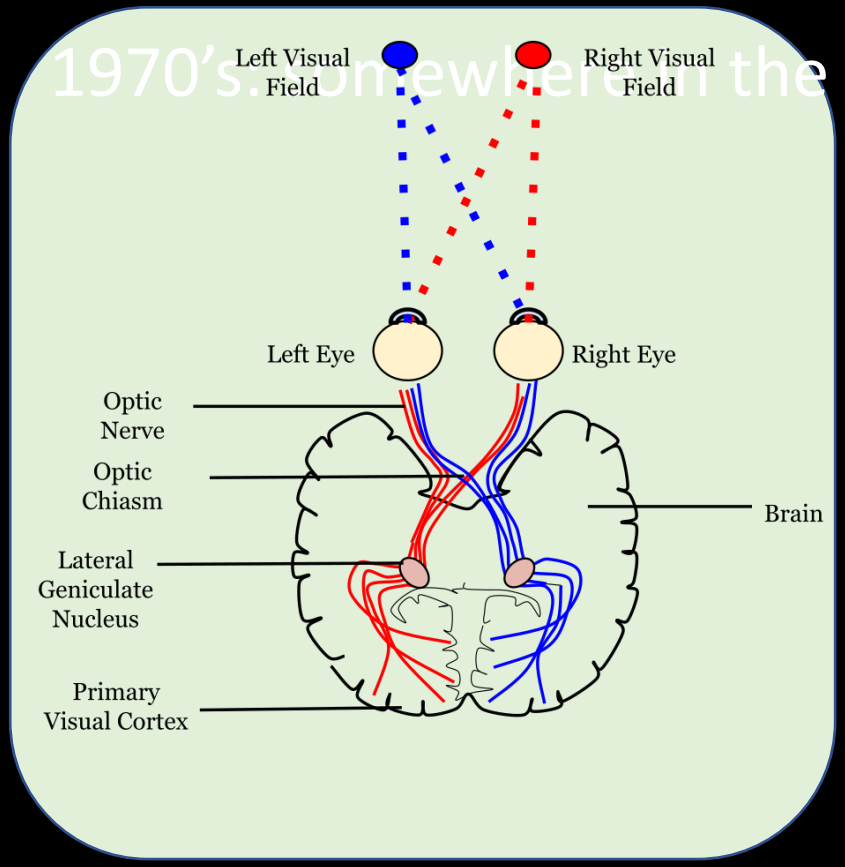
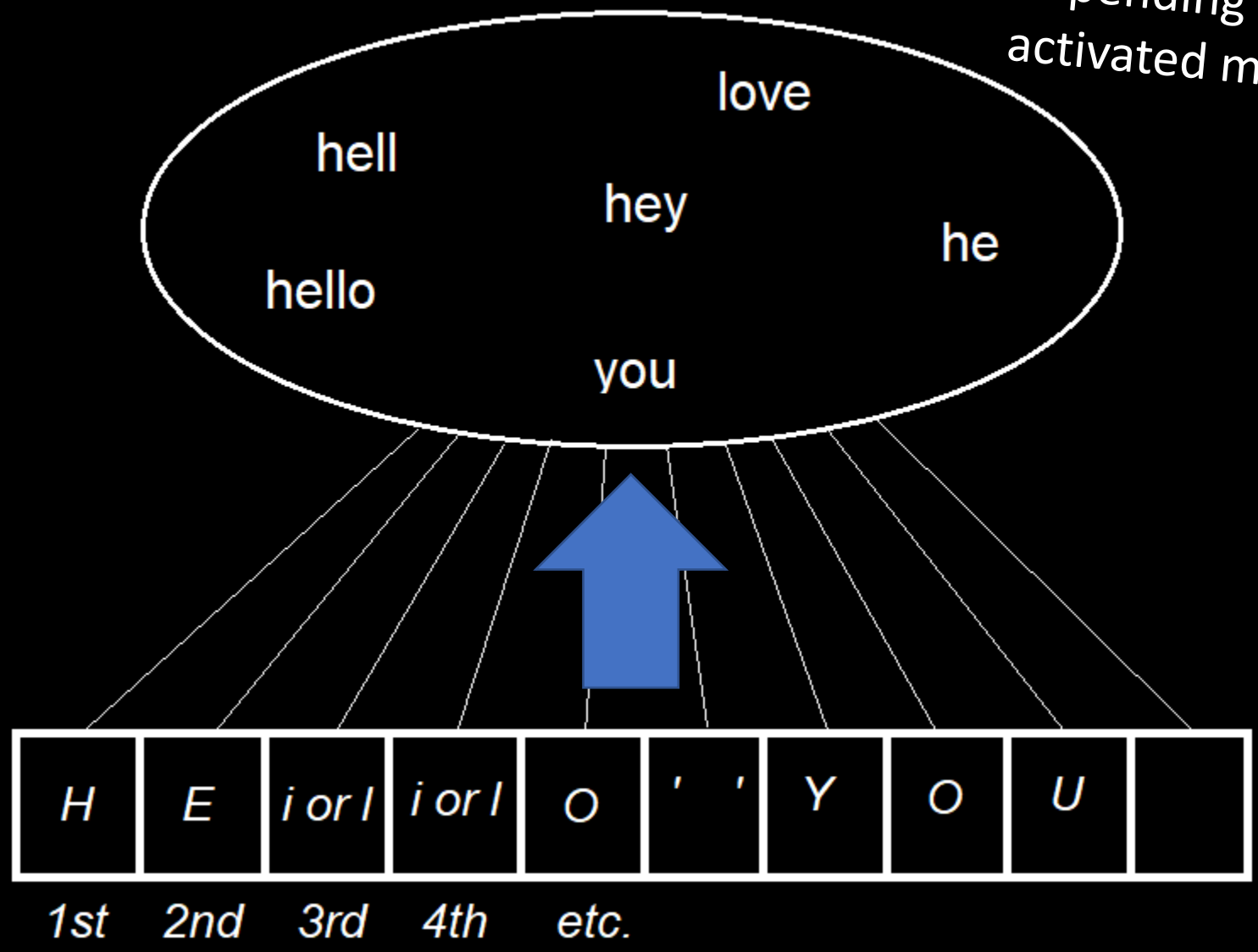


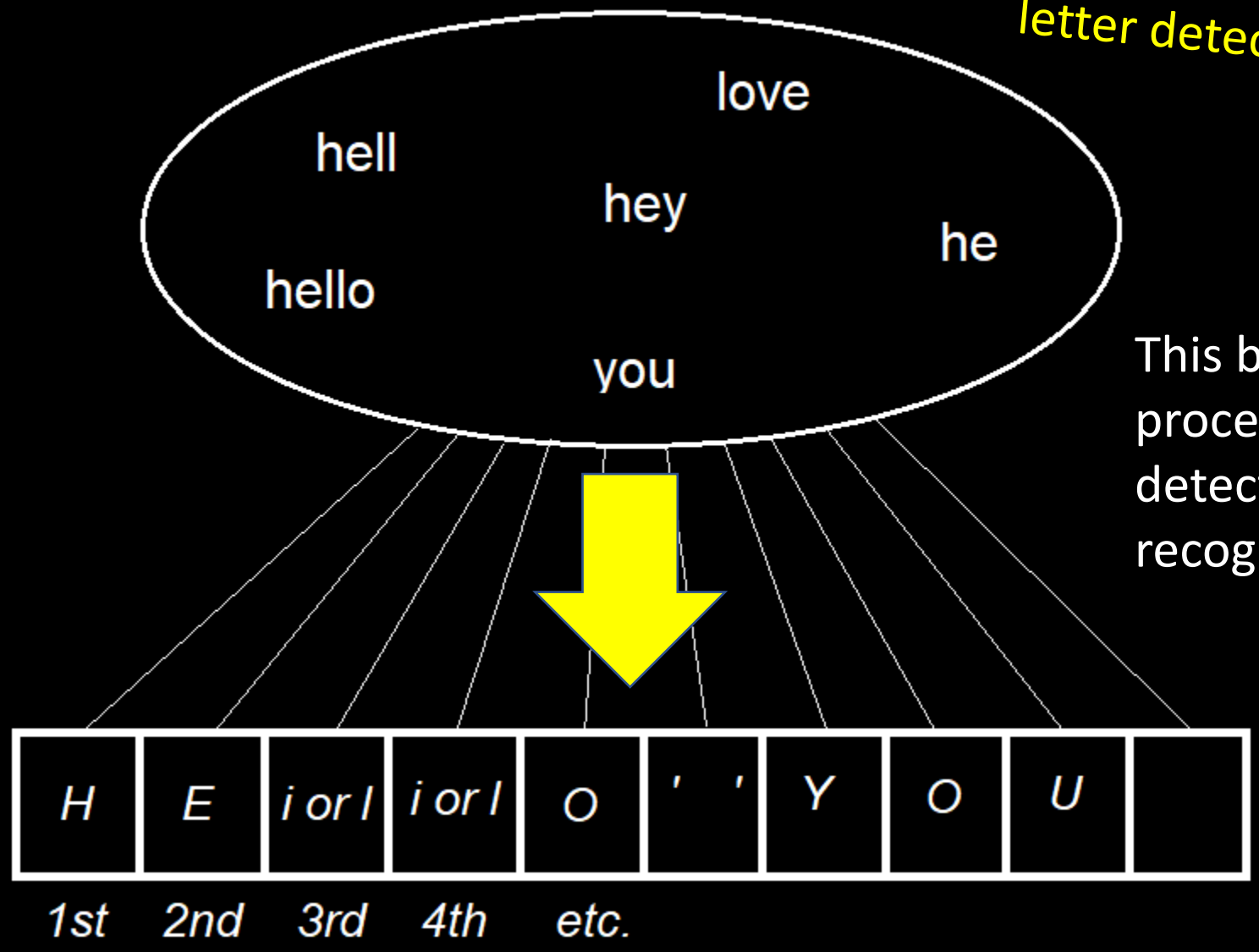
Separate set of letter detectors for *each* slot. Letter detectors are activated by visual input

Population receptive fields

Word detectors are activated depending on which letter is activated most at each position



Activated word nodes constrain letter detectors



This back-and-forth process repeats until word detector reaches a recognition threshold

But hold on a sec…

Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

Letters are *flexibly* encoded for their positions

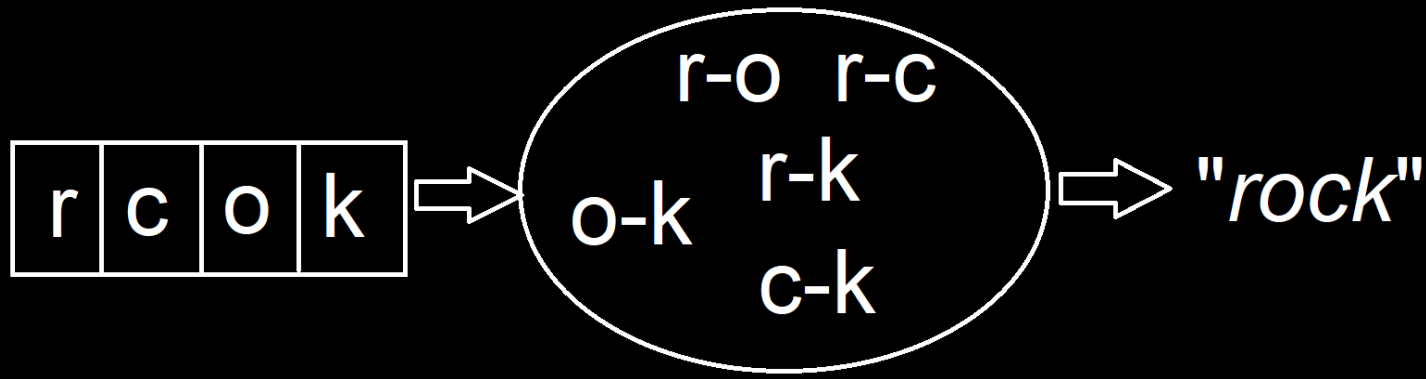
But hold on a sec…

Letters are *flexibly* encoded for their positions!

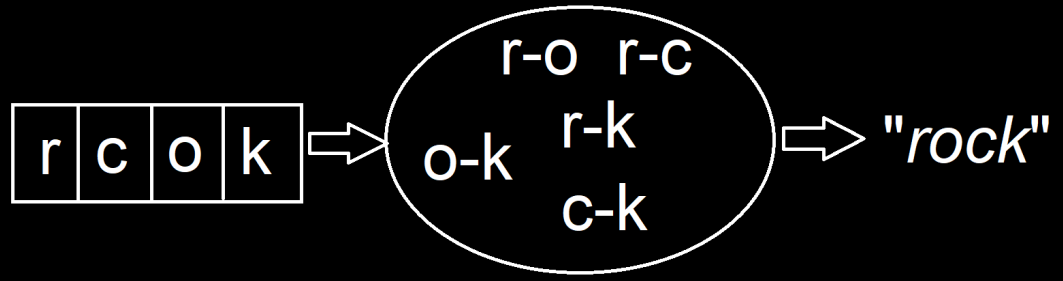
Potential solutions:

- Positional noise: letters activate not only their slot but also surrounding slots

- Bigram representations: an intermediate layer between letters and words, where (location-invariant) letter combinations are activated



Positional noise versus bigrams



Some recent research...

How does the distance between two letters affect recognition of the bigram?

abcdefgh → C-D

abcdefgh → C-F

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https://doi.org/10.3758/s13423-021-02039-z

BRIEF REPORT

Relative letter-position coding revisited

Joshua Snell[1] · Jonathan Grainger[2] · Martijn Meeter[3]

Accepted: 9 November 2021 / Published online: 19 January 2022

Abstract
The notion that the brain achieves visual word recognition by encoding the relative positions of letters with open-bigram representations (e.g., '*h-e*', '*h-r*' and '*e-r*' driving recognition of '*her*') has been successful in accounting for many behaviors and phenomena. However, one characteristic of open-bigrams has remained unexplored: How is the activation of a bigram modulated by the distance between its constituents in the visual field? On the one hand, contiguous letters (e.g., '*at*' in '*father*') may allow for a clearer percept of the bigram. On the other hand, an increasing distance between letters (e.g., '*ae*' in '*father*') should create more certainty about their relative positions, which is precisely what the bigram is meant to convey. This matter was investigated with two experiments in which participants indicated whether target pairs of letters occurred in random letter strings. They were instructed that letter order mattered (i.e., '*a-b*' does not occur in '*kbac*'), while letter contiguity did not (i.e., '*a-b*' occurs in '*akcb*'). Controlling for crowding and eccentricity, bigrams were recognized faster upon decreasing the letter distance. However, when switching the target letter order (meaning the string should be met by a 'no' response), shorter letter distances yielded slower responses and more false positives. Neither relative position-coding models nor absolute position-coding models accommodate both these patterns at once. We discuss how a complete account of our effects may instead combine elements from both model types.

Keywords Orthographic processing · Reading · Letter position coding

Introduction

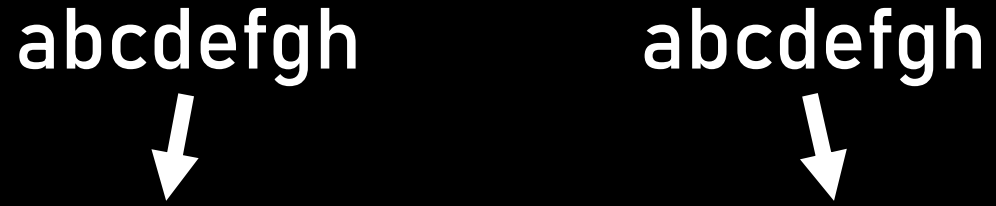
A longstanding debate in word recognition research concerns the question of whether the brain encodes the absolute or relative positions of letters (Davis, 2010a, 2010b; Gomez et al., 2008; Grainger & van Heuven, 2004; Kinoshita & Norris, 2013; McClelland & Rumelhart, 1981; Norris & Kinoshita, 2012; Snell, Bertrand, & Grainger, 2018a; Whitney, 2001, 2008). According to absolute position coding, individual letters would be associated with spatial locations (*"I see an 'h' at the first position and an 'e' at the second position; hence I see 'he'"*). Relative position coding, on the other hand, states that the position of a letter is solely determined in relation to other letters (*"I see an 'h' on the left of an 'e' and an 'e' on the right of an 'h'; hence I see 'he'"*). Although these two classes of theory paint decidedly different pictures with respect to the cognitive architecture underlying reading, they have more or less provided equally good fits to the data. Consequently, neither hypothesis has been effectively falsified. The present study is to arbitrate between absolute and relative letter-position coding with a novel paradigm that sparks novel predictions.

Bigrams and noise channels

Relative letter-position coding was conceived as a means to account for various behaviors that could not be explained if readers were to straightforwardly perceive letters in their canonical order. The lion's share of these behaviors was observed in the masked priming lexical decision task (Forster et al., 1987; Forster & Davis, 1984). Broadly speaking, the extent to which a given string of letters primes a target word follows a graded function, based both on the number of shared letters between the prime and target, and on how many of those letters are correctly positioned in the prime (e.g., '*reak*' primes '*rock*' to a greater extent t

Some recent research...

How does the distance between two letters affect recognition of the bigram?

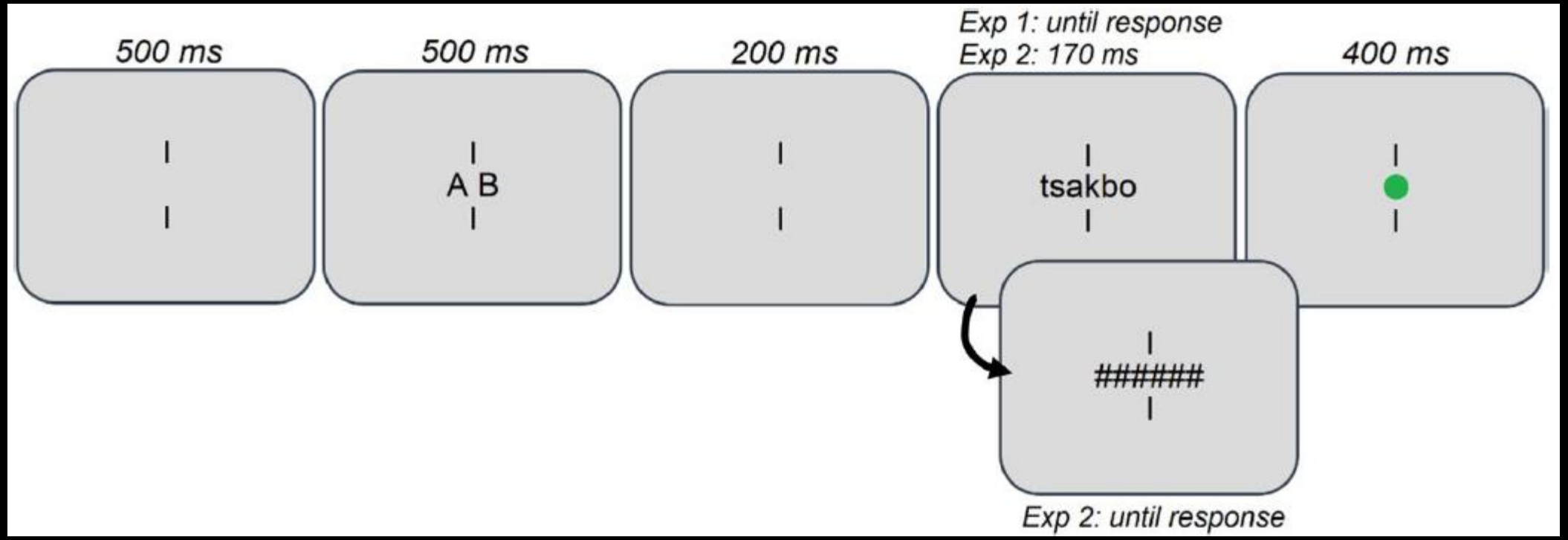


“ Do you see the bigram CD ? ”

“ Do you see the bigram CF ? ”

Some recent research…

How does the distance between two letters affect recognition of the bigram?



Some recent research...

How does the distance between two letters affect recognition of the bigram?

abcdefgh → C-D

abcdefgh → C-F

“ Do you see the bigram CD ? ”

“ Do you see the bigram CF ? ”

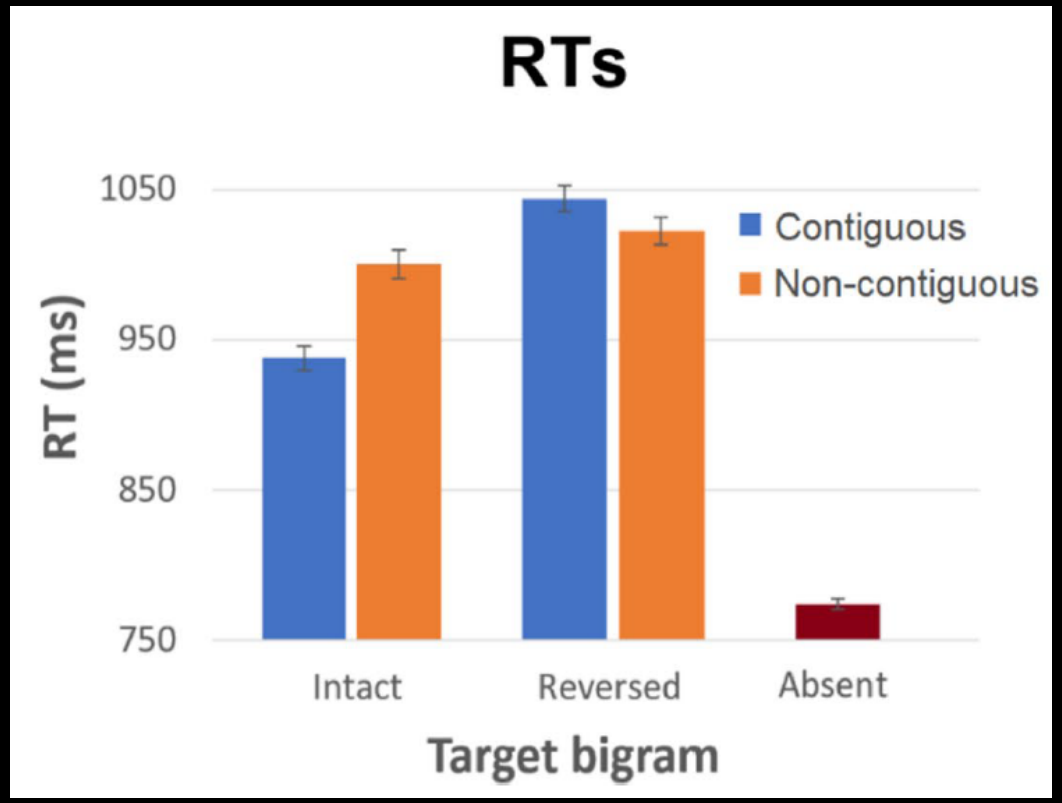
“ Do you see the bigram DC ? ”

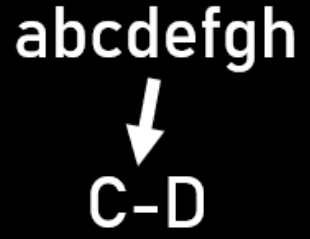
“ Do you see the bigram FC ? ”

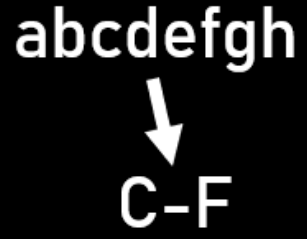
: *erroneous recognition of DC*

Some recent research...

Data can only be explained by a combination of absolute position coding and bigrams!







" Do you see the bigram CD ? "

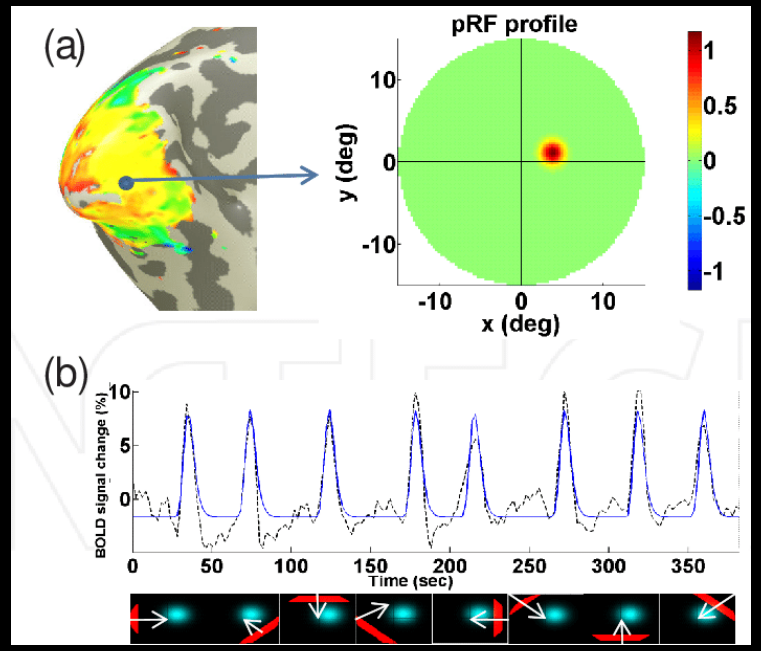
" Do you see the bigram CF ? "

" Do you see the bigram DC ? "

" Do you see the bigram FC ? "

Some recent research…

Population receptive fields aren't small enough to know single letter locations



NeuroImage
Volume 139, 1 October 2016, Pages 427-438

ELSEVIER

Systematic variation of population receptive field properties across cortical depth in human visual cortex

Alessio Fracasso [a b c], Natalia Petridou [b 1], Serge O. Dumoulin [a c 1]

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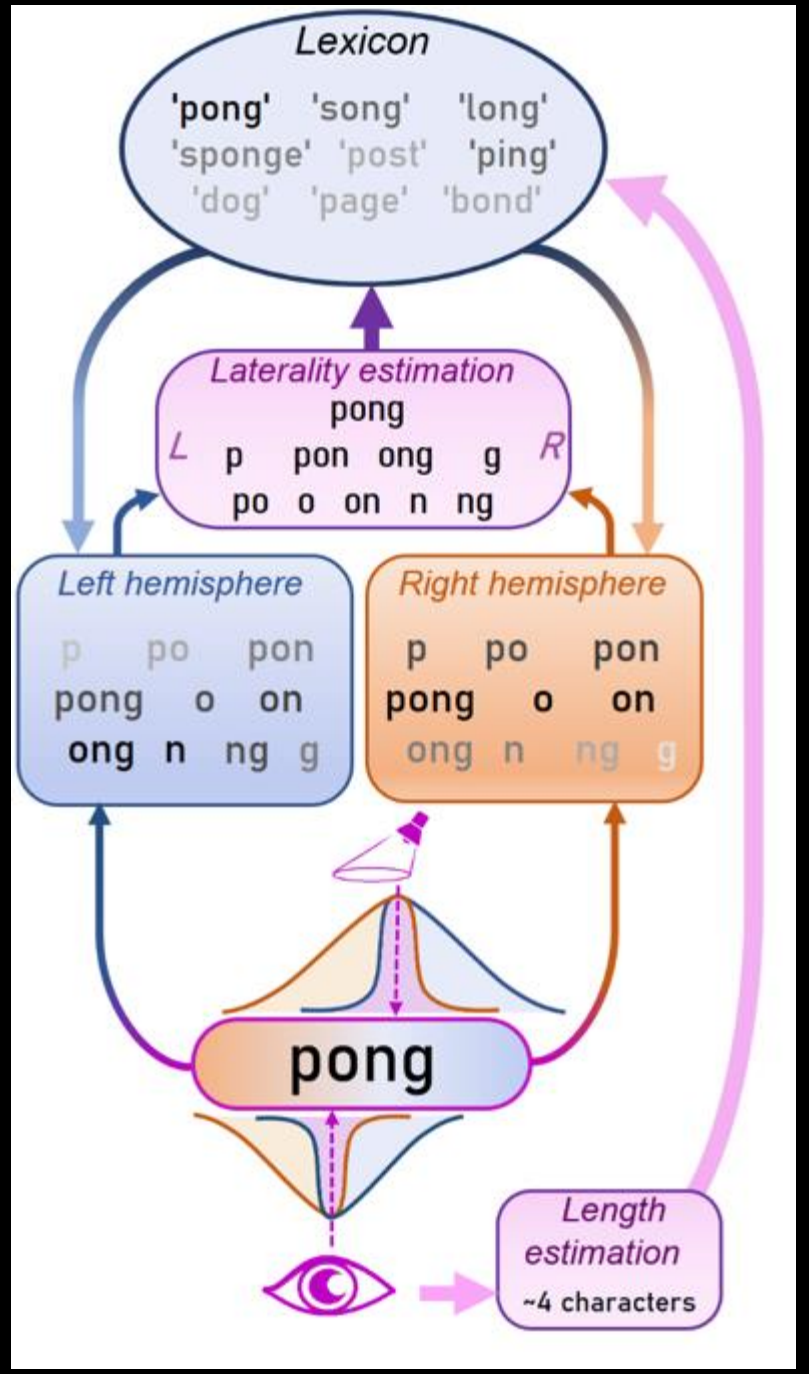
A new theory of orthographic processing…

PONG (the *Positional Ordering of N-Grams*)

- The brain is a sequence learner
  t, th, the, ther, there, here, ere, re, e

- The brain estimates the laterality of N-grams through bi-hemispheric activation differences



INTERMEZZO

Report instructions

Four sections: Introduction, Methods, Results, Discussion
Separately: Abstract (brief ~200 word summary) that conveys the entire story

Introduction: Question, background literature, hypotheses
Methods: Participants, Expt. design, Apparatus, Procedure
Results: Description of data cleaning procedures, analyses
Discussion: Recap, Answer to question, critical evaluation

INTERMEZZO

Presentations in 2 weeks

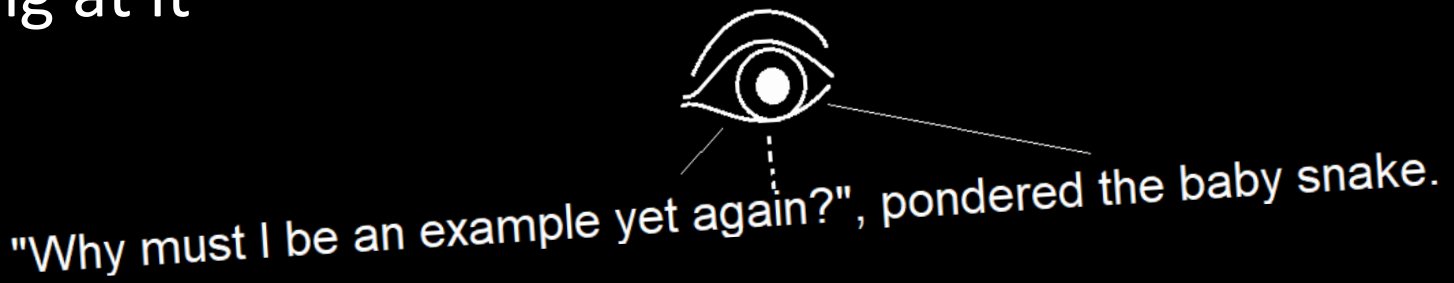
5 mins per group – *blitz talks*

Attention in reading

Attention in reading

When do we start processing a word?

The key to a smooth read is to start processing a word already before looking at it



Limits imposed by visual acuity: you'll get some letters
and visual cues such as word length (Rayner: *preview benefit*)

Visuo-spatial attention
(and acuity)

Chfon du phin septonder a vory bock sphenctle woth polery send. Evel yoi e plofenint eetri snacks un prenk sciontofoc at efrtoi songle a you can read this quite well but hfon du phin septonder you cannot tell whether the text beyond evel yoi e plofenint entho is really meaningful at all bechefrtoi songle hfon du phin septonder a vory bock sphenctle woth polery send evel yoi e plofenint extri snacks un prenk a sivintisivin squer mitors.

When do we start processing a word?

Our visuo-spatial attention is not confined to the word at which we look directly.
Covert attention moves ahead of the eyes to the next word.

…*or* maybe attention was directed at multiple words from the get-go.

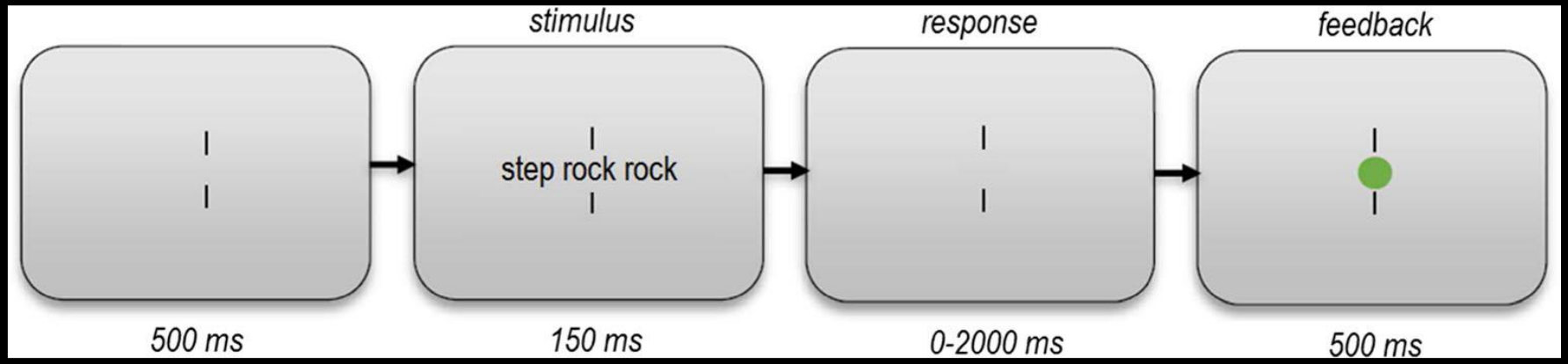
A longstanding debate about attention in reading

Rayner & co.: “Only one word is attended at a time”

Joshua & others: “Maybe not”

Serial processing of words?

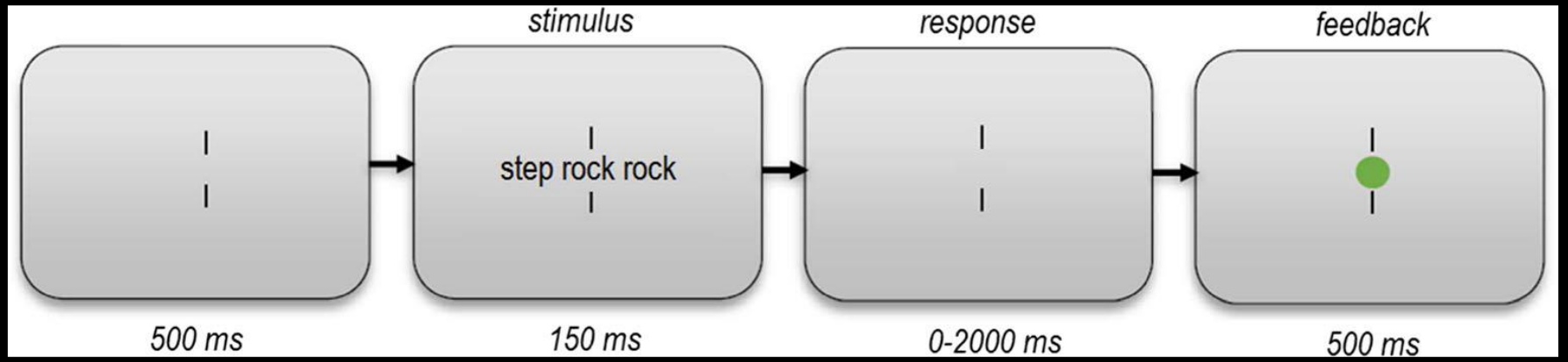
Flankers lexical decision task:

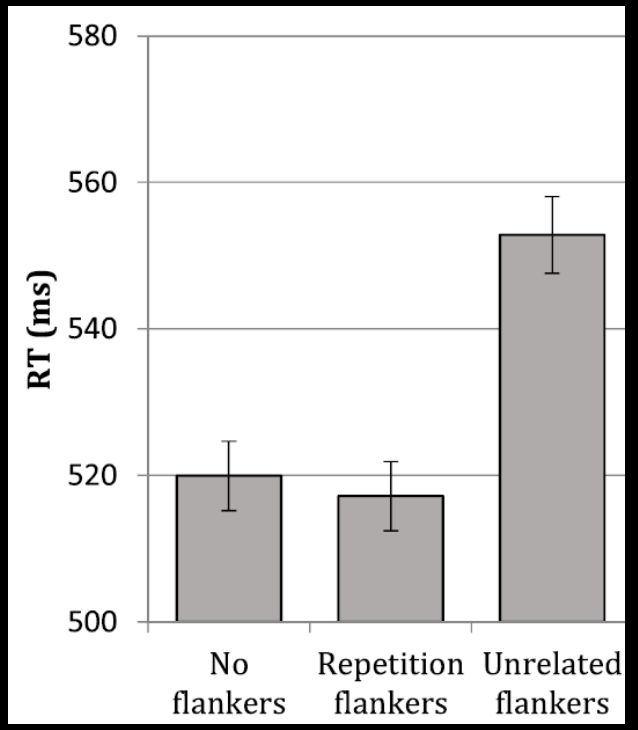


Rayner: word recognition takes +-200 ms.

…meaning there should be no time to process flankers

Serial processing of words?





We cannot prevent ourselves from processing the flankers!

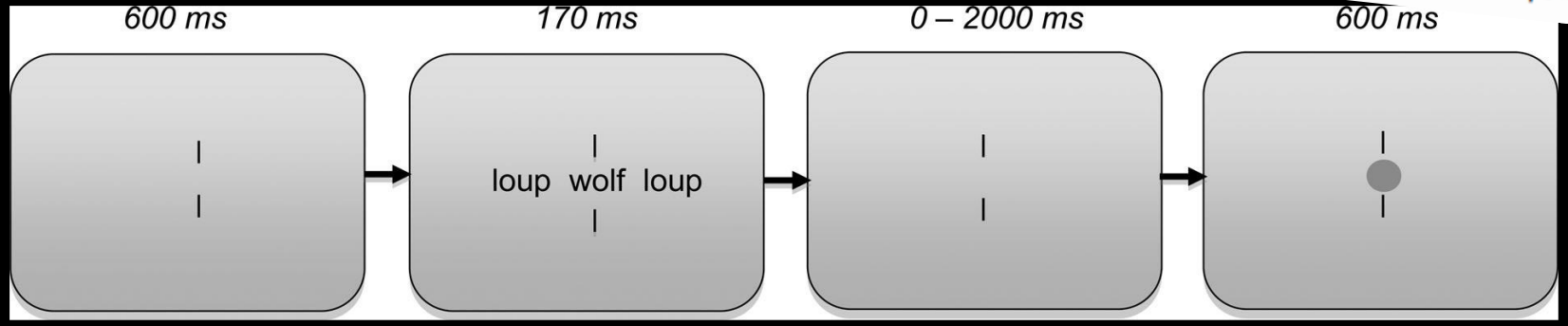
Only (sub-lexical) orthographic processing?

Serial processing of words?

Table 5. Mean RT's and error rates for the no-flanker, translation and control condition of Experiment 3.

	RT	Error
No-flanker	608.44 (219.50)	.178 (.081)
Translation	638.95 (224.08)	.168 (.073)
Control	672.47 (232.76)	.179 (.092)

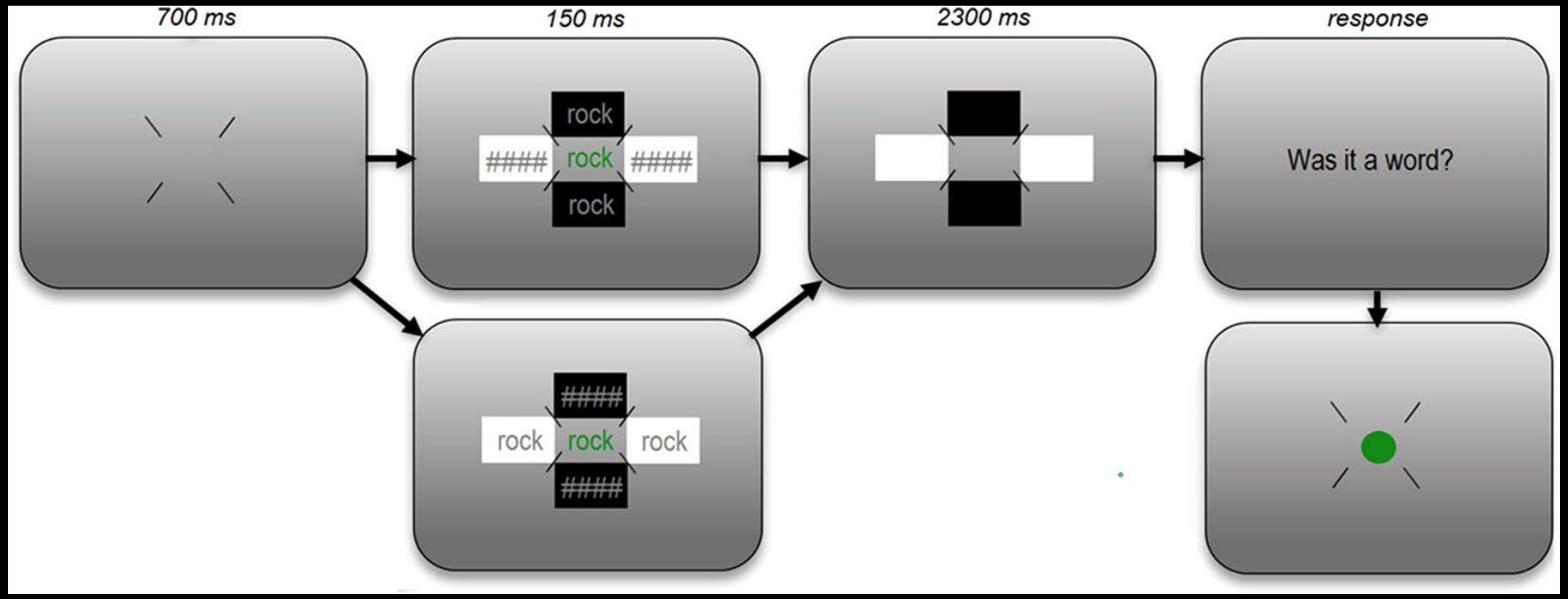
Note: values in between parentheses indicate standard deviations.

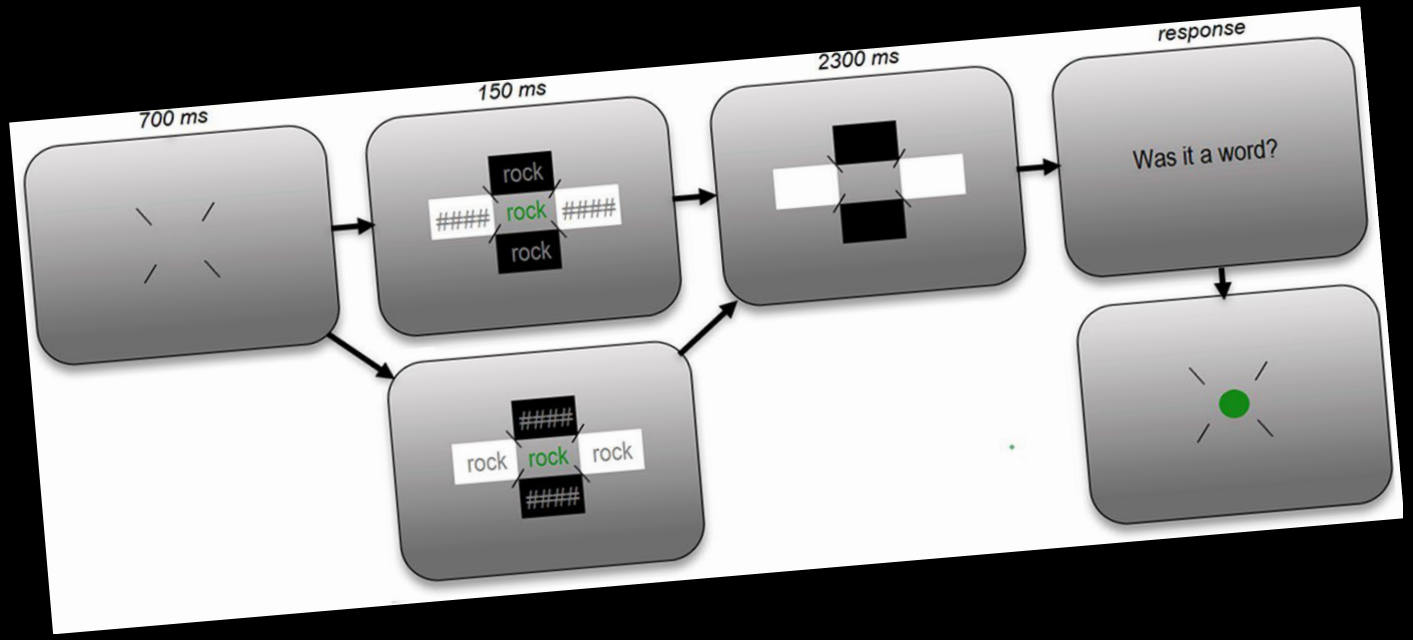


Similar effects with semantically related flankers

How to track covert attention (during reading)?

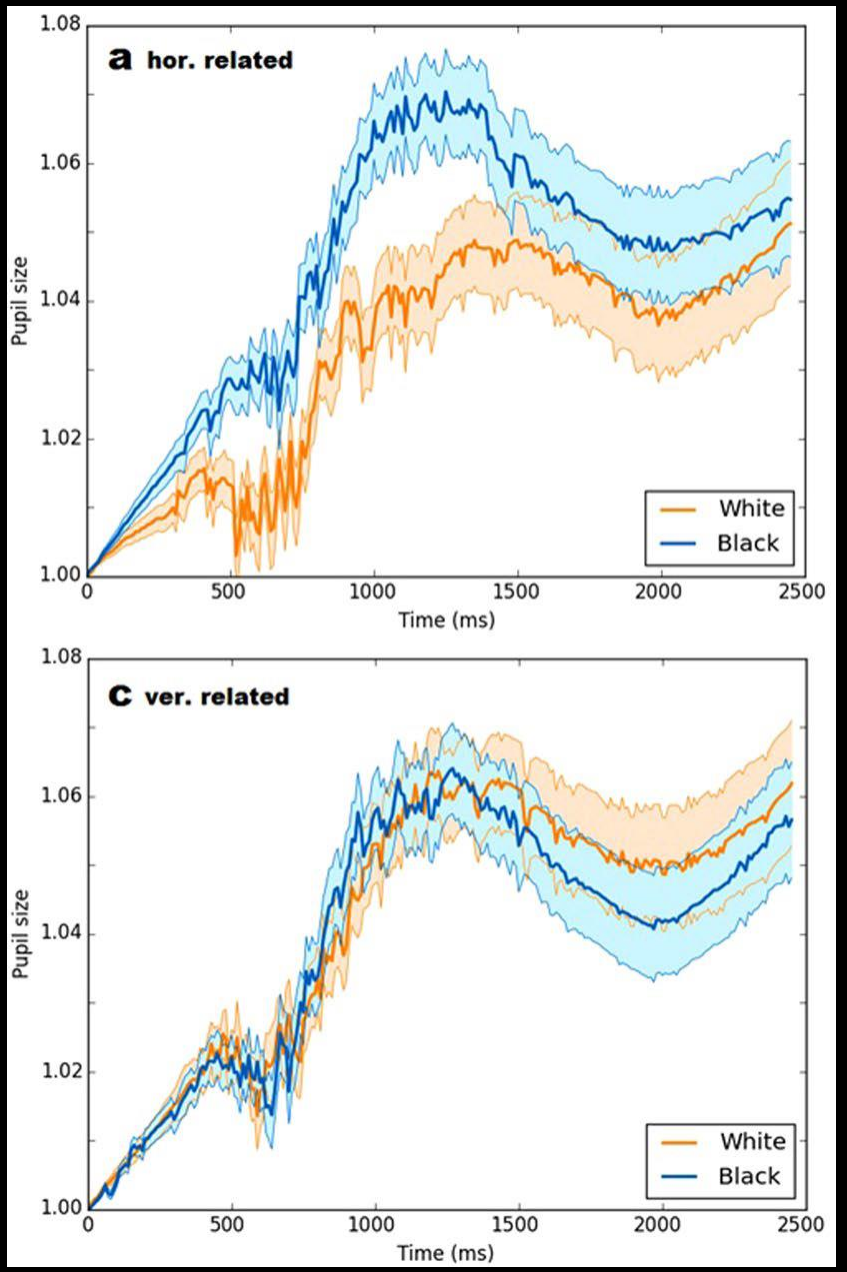
Vary the brightness of flanker locations:





Target recognition speed influenced by words on the left and right but not above and below…

And pupil responds to brightness of words left & right, but not above & below the target!



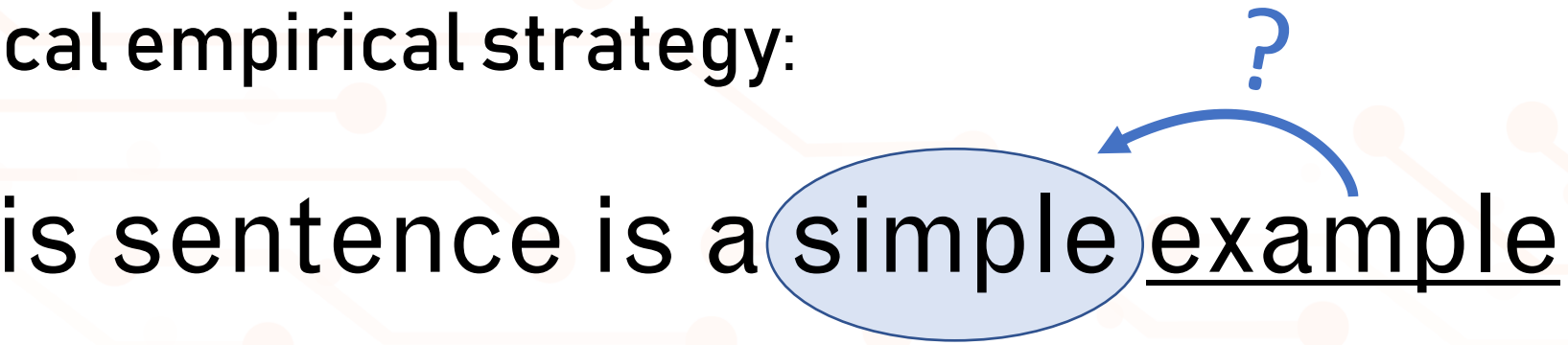
But the flanker paradigm is an artificial task.

Maybe attention is distributed differently during normal text reading?

Various papers: eye movements are unaffected by higher-order properties of upcoming words… so let’s look at brain activity

Do readers process multiple words at once?

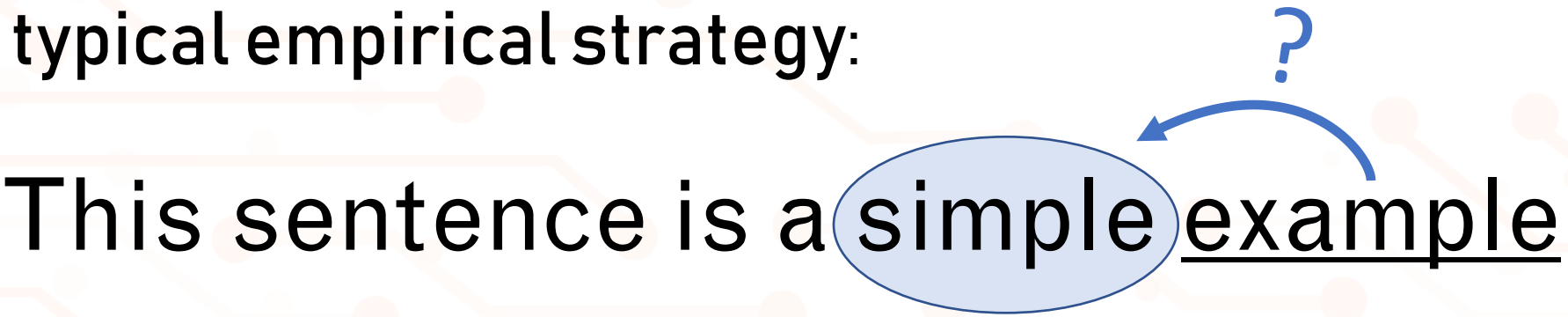
The typical empirical strategy:



VU VRIJE UNIVERS AMSTER

Do readers process multiple words at once?

The typical empirical strategy:



Typical outcomes:

- Word 1 influenced by letter overlap with Word 2
- Word 1 ***not*** influenced by frequency or semantics of Word 2

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EEG: Fixation-related potentials

Time-lock the electrophysiological window of interest to the start of a fixation on a target word

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EEG: Fixation-related potentials

Time-lock the electrophysiological window of interest to the start of a fixation on a target word

Prediction:

Syntactic processing of the target word should be hampered by a syntactically incompatible adjacent word

THE DOG JUMPED AWAY

THE DOG YELLOW AWAY

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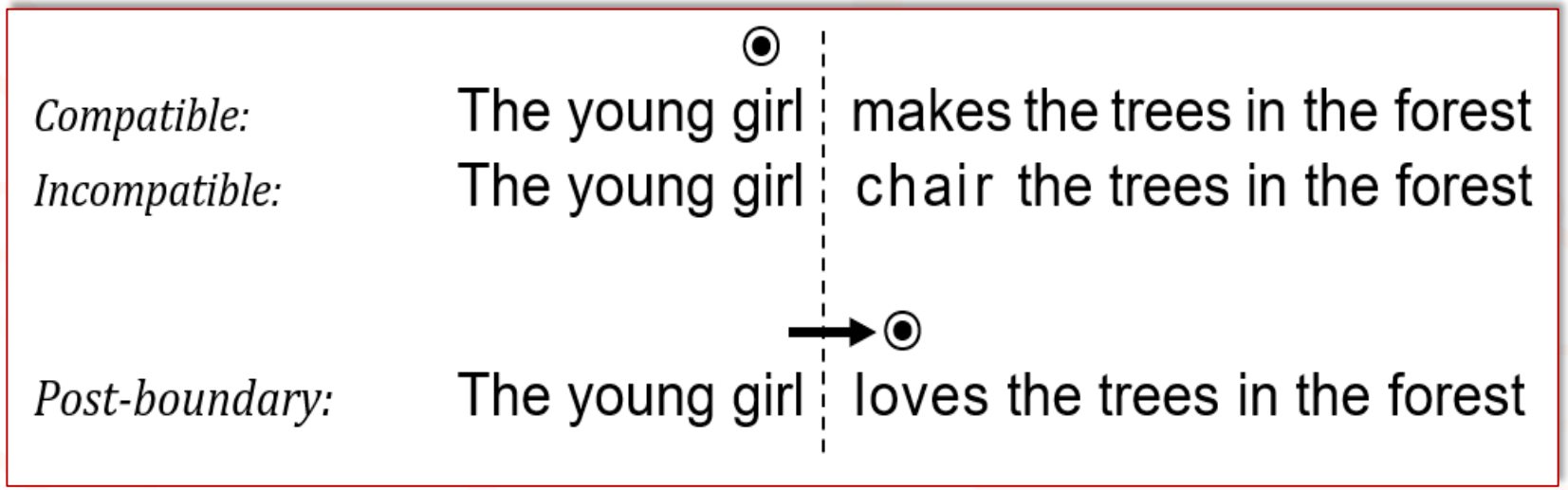
Methods



→ Any effect of the syntactic manipulation of word *n+1* must have been triggered during the fixation on word *n*.

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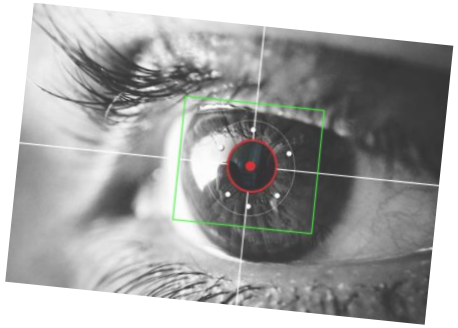
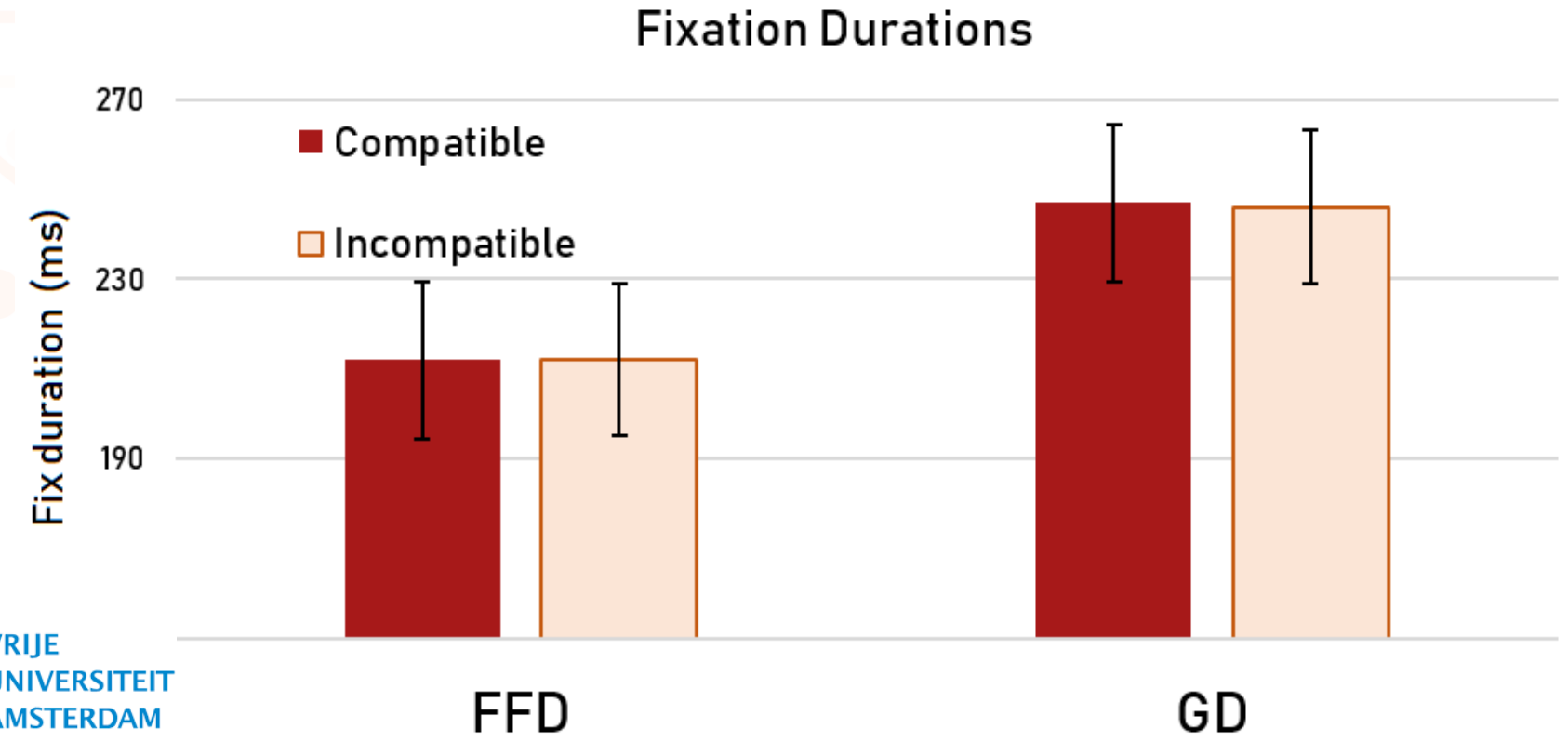
Results: oculomotor data



No effects in oculomotor data



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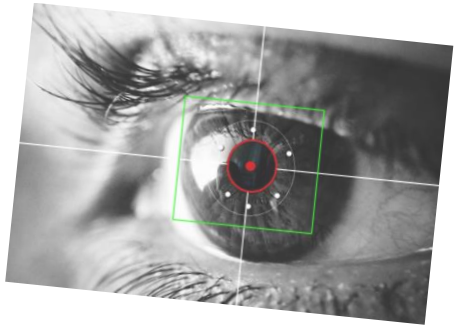
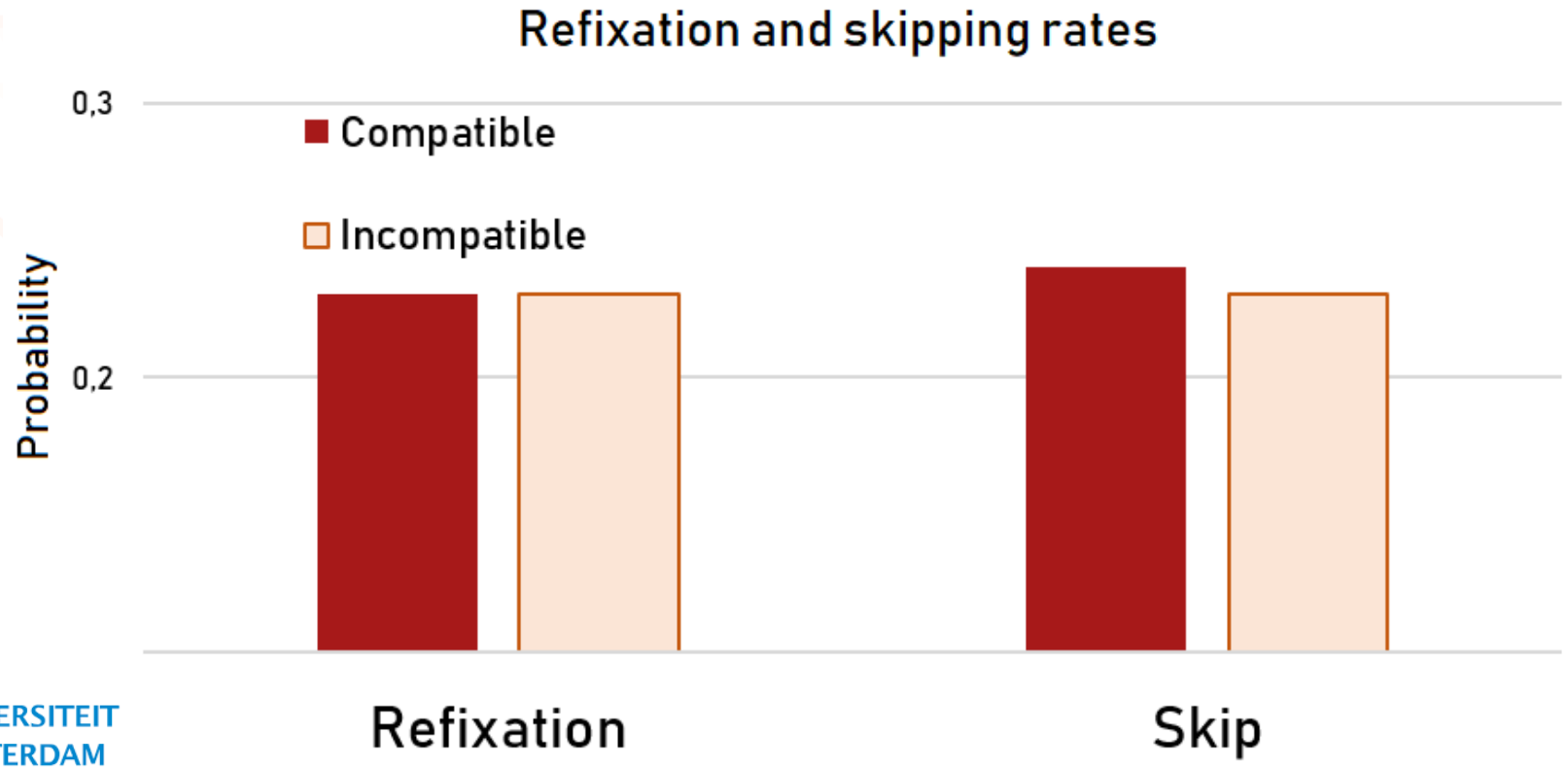
Results: oculomotor data



No effects in oculomotor data



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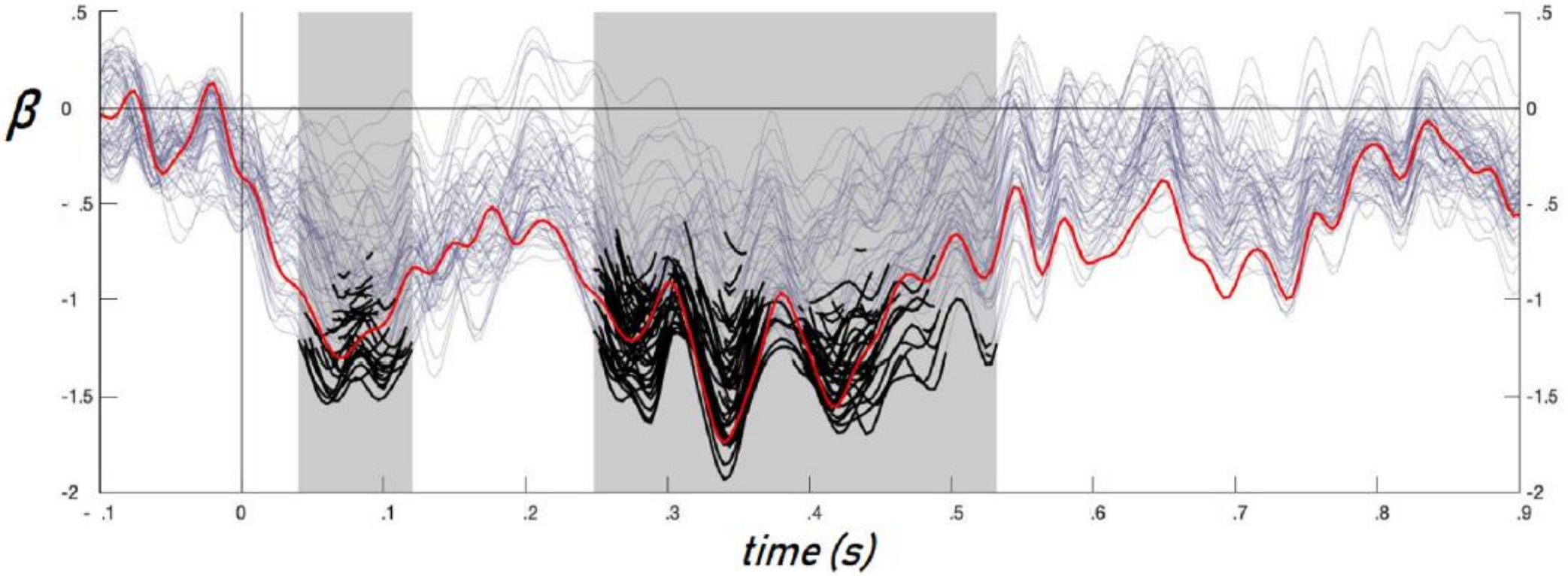
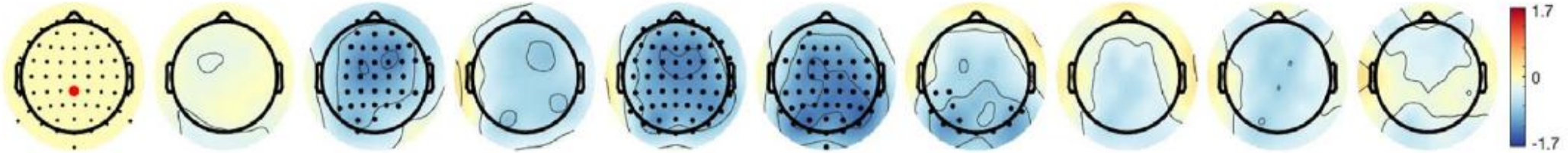
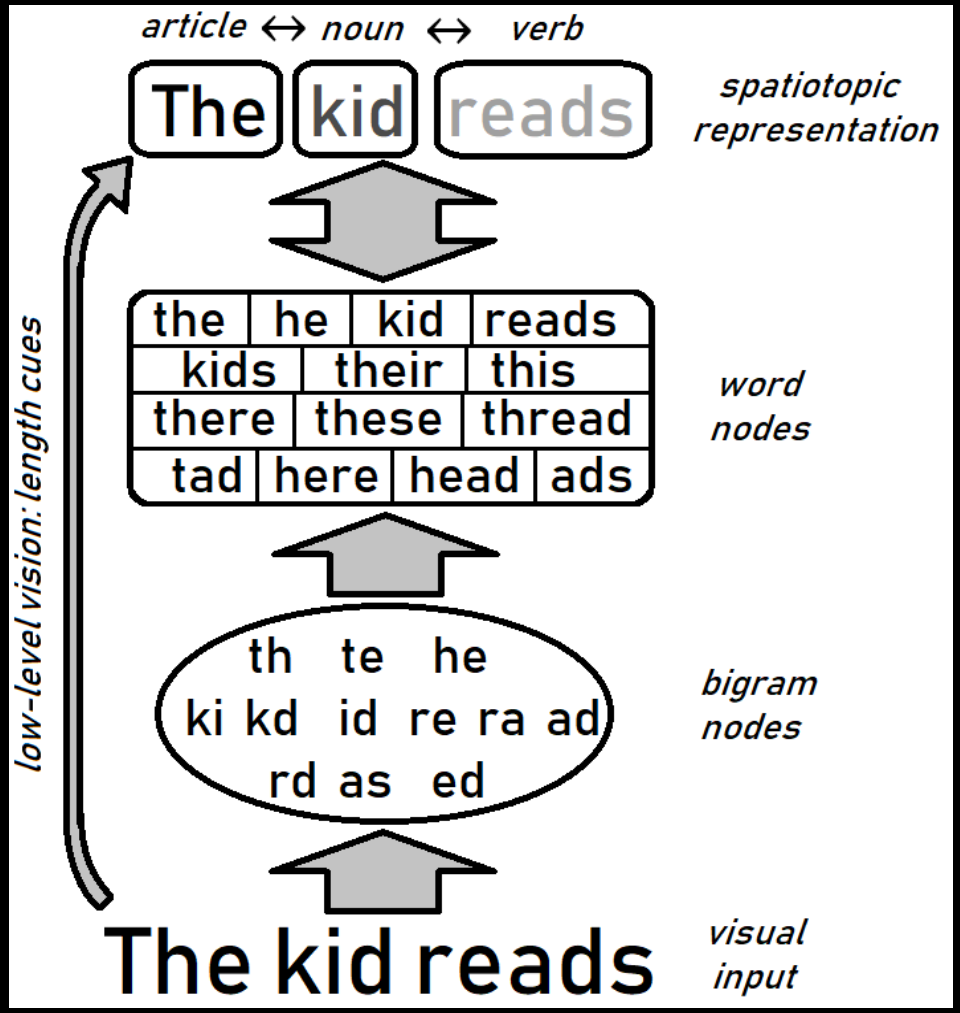
Results: EEG data





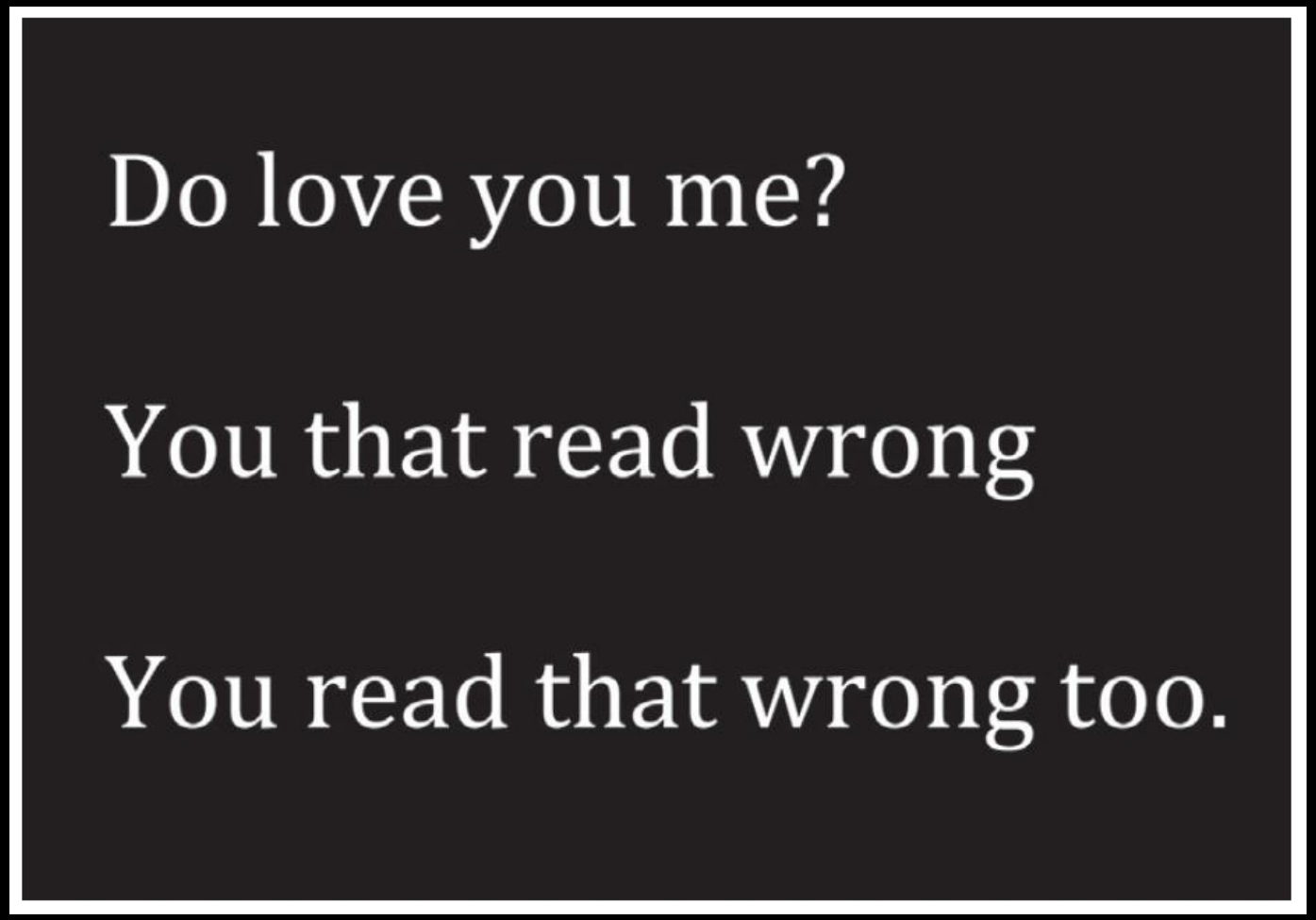
Readers process multiple words in parallel

OB1-reader



Sentence processing

Syntax



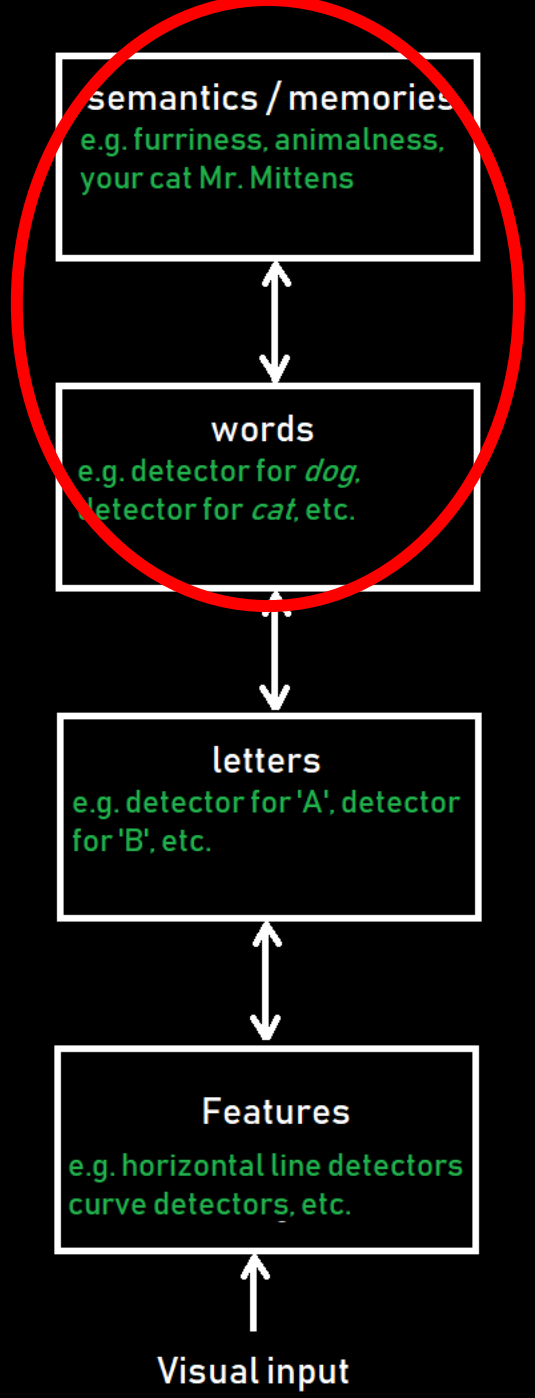
Additional evidence that we're multiple words in parallel

Syntax →

Do love you me?

You that read wrong

You read that wrong too.



Word superiority, and *sentence superiority*

‘man’ is recognized faster in
the man can run

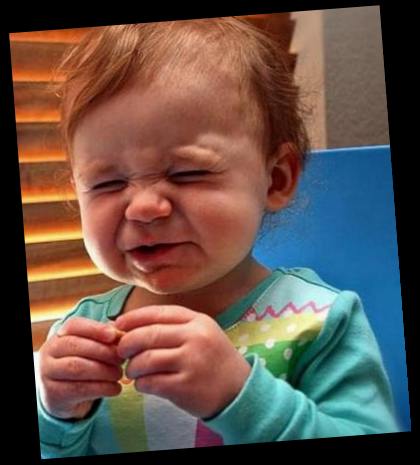
than in
run man the can

We (tentatively) recognize sentence structures, and these constrain the ongoing recognition of words

But are we completely flexible?

baby dog eats meat

baby eats dog meat



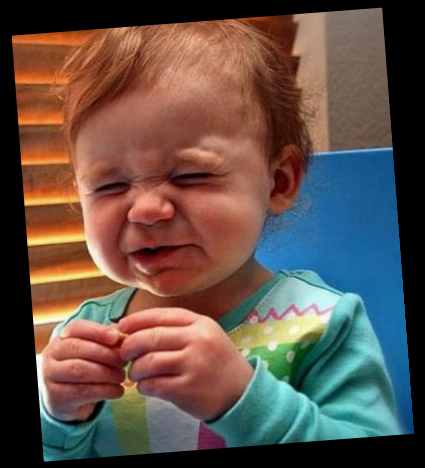
Our expectations constrain the mapping of words onto locations

Unsolved questions...

How does word position coding work?
When does it happen?
What factors influence it?

baby dog eats meat

baby eats dog meat



Recap

Our attention is directed to multiple words; not just to the word that we look at

Letters *and* words are flexibly associated with locations

Letters, words and sentences are separate things in the brain

There is cross-talk between regions coding for letters, words *and* sentence structures