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Inductive Biases for Compositionality-capable Deep Learning Models of Natural Language

January 2024

Evolution of Large Language Models (LLMs)

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- Outstanding successes on most NLP benchmarks have been substantially improved since 2018 and the birth of **transformers**

Position of the project

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Natural language is compositional

- The amount of training data and the amount of computing resources required by current models is unrealistic

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Topics in Cognitive Psychology, 2024, 124, Septembre 2024 / September 2024

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SPECIAL ISSUE/ NUMÉRO SPÉCIAL
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LLMs demonstrate that it is possible to produce grammatical sentences on the basis of statistical learning and without the slightest syntactic intervention

Are LLMs the end of the story?

Certainly not.

LLM training corpora are far too large compared to the amount of information a human is confronted with early in life to learn to produce language

Statement 1: We are exposed to less linguistic information to develop our language skills

Statement 2: Our memory capacity is actually quite large

=> Which suggests that we may not need a very large learning set

Statement 3: With the development of our production capacity, we can **self-generate** linguistic forms, sometimes in a totally hidden way, within our inner language.

=> we can't rely on a simple assessment of what children are confronted with

- do you remember what you had for **dinner last night**?

- do you remember **everything you've done** since you woke up this morning?

=> we are constantly memorizing a whole range of information **without** the slightest intention of memorizing it

=> all we have to do is **process** this information to create a transitory memory

⇒ most of these transitory memories disappear

⇒ However, if this information **repeats** itself (as is the case for regularities in our environment),

these transitory memories are **reinforced**, becomes more and more **stable**, and ultimately **structures** our subsequent mental states

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The self-organizing consciousness

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BEHAVIORAL AND BRAIN SCIENCES (2002) **25,** 297–388

- consciousness = attention = what we are **processing** at a given moment t

- we transiently memorize everything we **process**
(e.g., you remember almost everything you have processed/thought about in the last few minutes/hours)

- this memorization is based on **elementary associative mechanisms**
(that we don't yet fully understand)

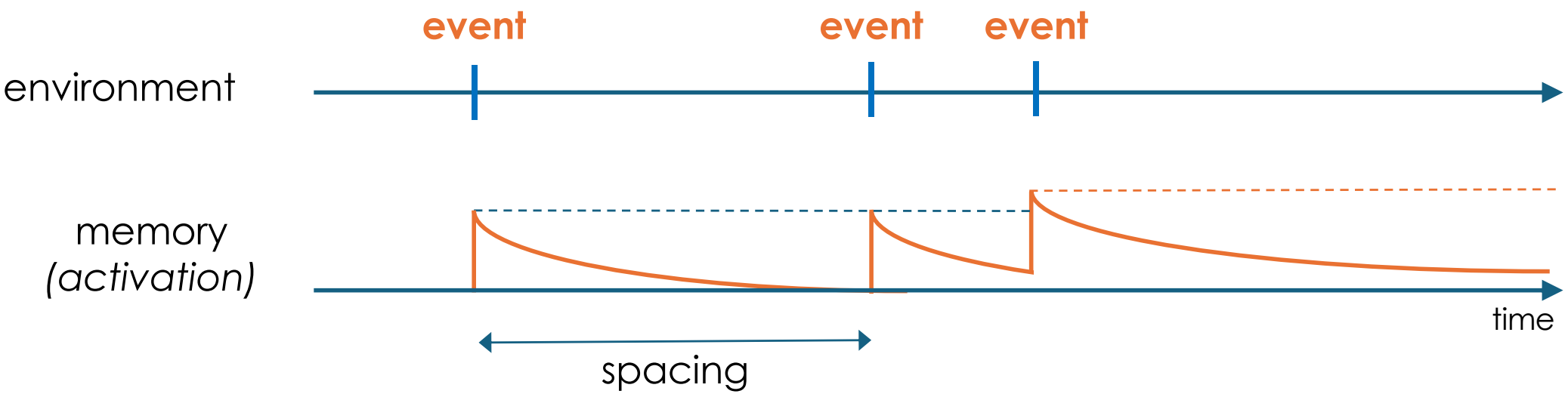
- these associative mechanisms enable us to **extract regularities** from the environment whose main property is to be **repeated** and thus be increasingly memorized

Question : Can we estimate the **time** during which transient memory traces **survive**?

=> for an environmental regularity to be **memorized**, it is necessary that:

1. the transient memory of its first occurrence must **survive** until its **first repetition**

2. the **interval between two repetitions** must not be too great,
   so that the memory trace benefits from the repetitions to consolidate.



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- starting point: **Hebb's repetition task** (1961)

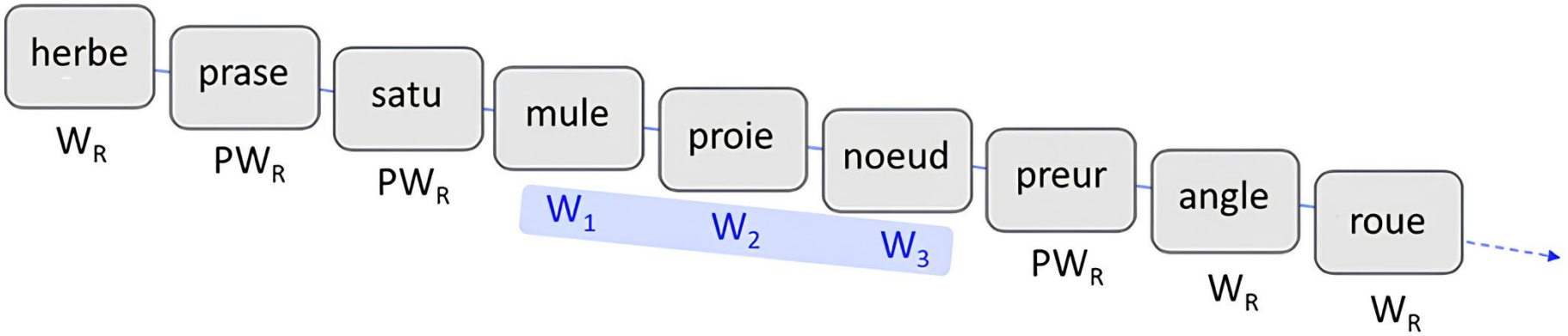
  => serial recall of sequences of digits
  => a sequence is repeated every 3 sequences

- Hebb **naming** task (Rey et al., 2020 - QJEP)

  => read aloud isolated letters
  => a triplet of **letters** is repeated regularly
  => measures RT evolution over repetitions

- Hebb **lexical decision** task (Pinto Arata, ..., Rey, 2024 - QJEP)

  => lexical decision task on items presented one by one
  => a triplet of three items is repeated
  => repetition **spacing**: between 3 and 5 item fillers



…– PW_R – W_1 – W_2 – W_3 – W_R – PW_R – PW_R – W_1 – W_2 – W_3 – PW_R – W_R – W_R – PW_R – W_1 –…

spacing 3-5 spacing 3-5

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Present study (currently submitted):

- Hebb lexical decision task (Pinto Arata, ..., Rey, 2024 - QJEP)

- 5 spacing conditions :

=> 3-5	= F4
=> 6-8	= F7
=> 9-11	= F10
=> 19-21	= F20
=> 29-31	= F30
=> 59-61	= F60

- 420 participants, 84 per condition

- online experience: www.prolific.co

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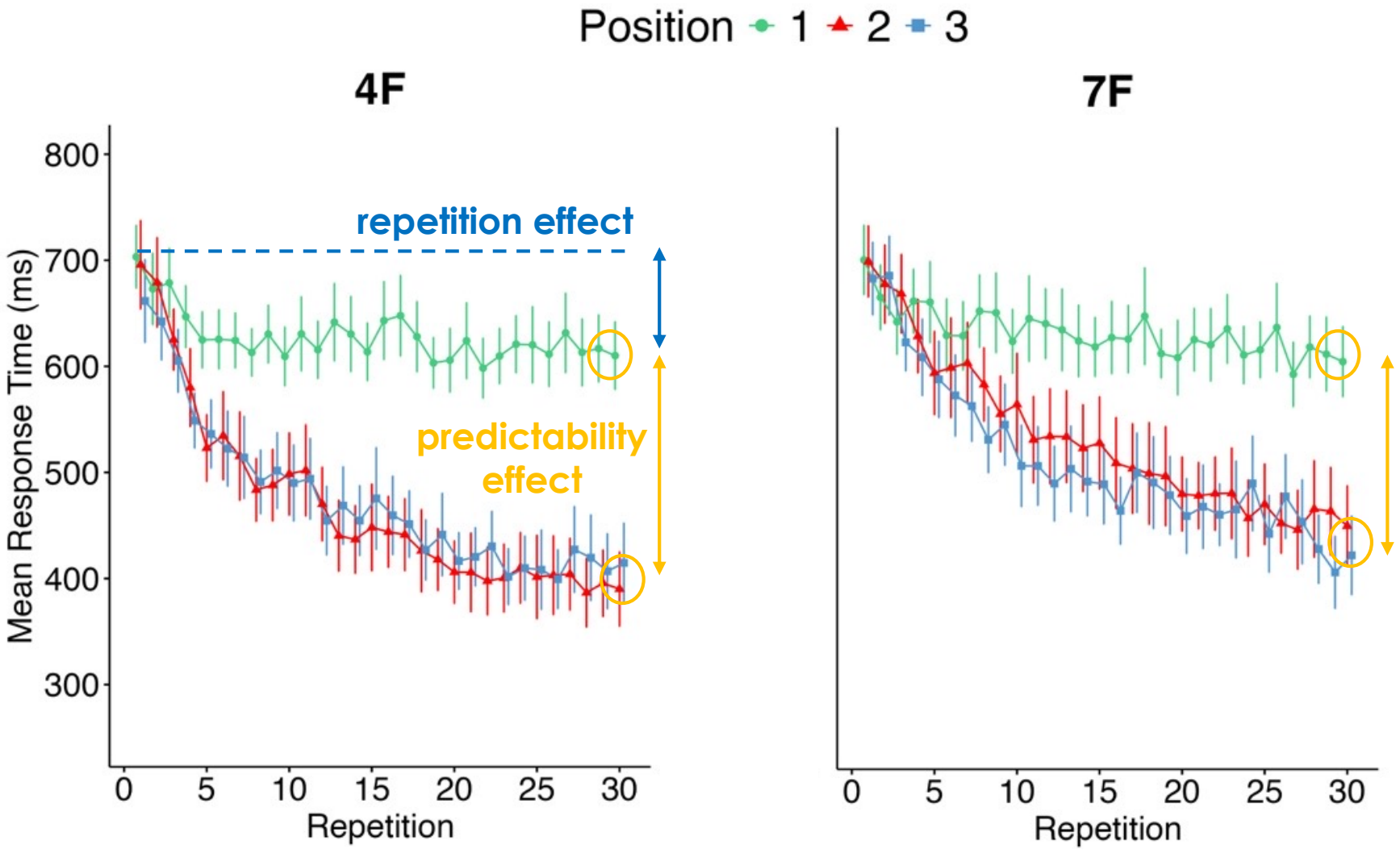

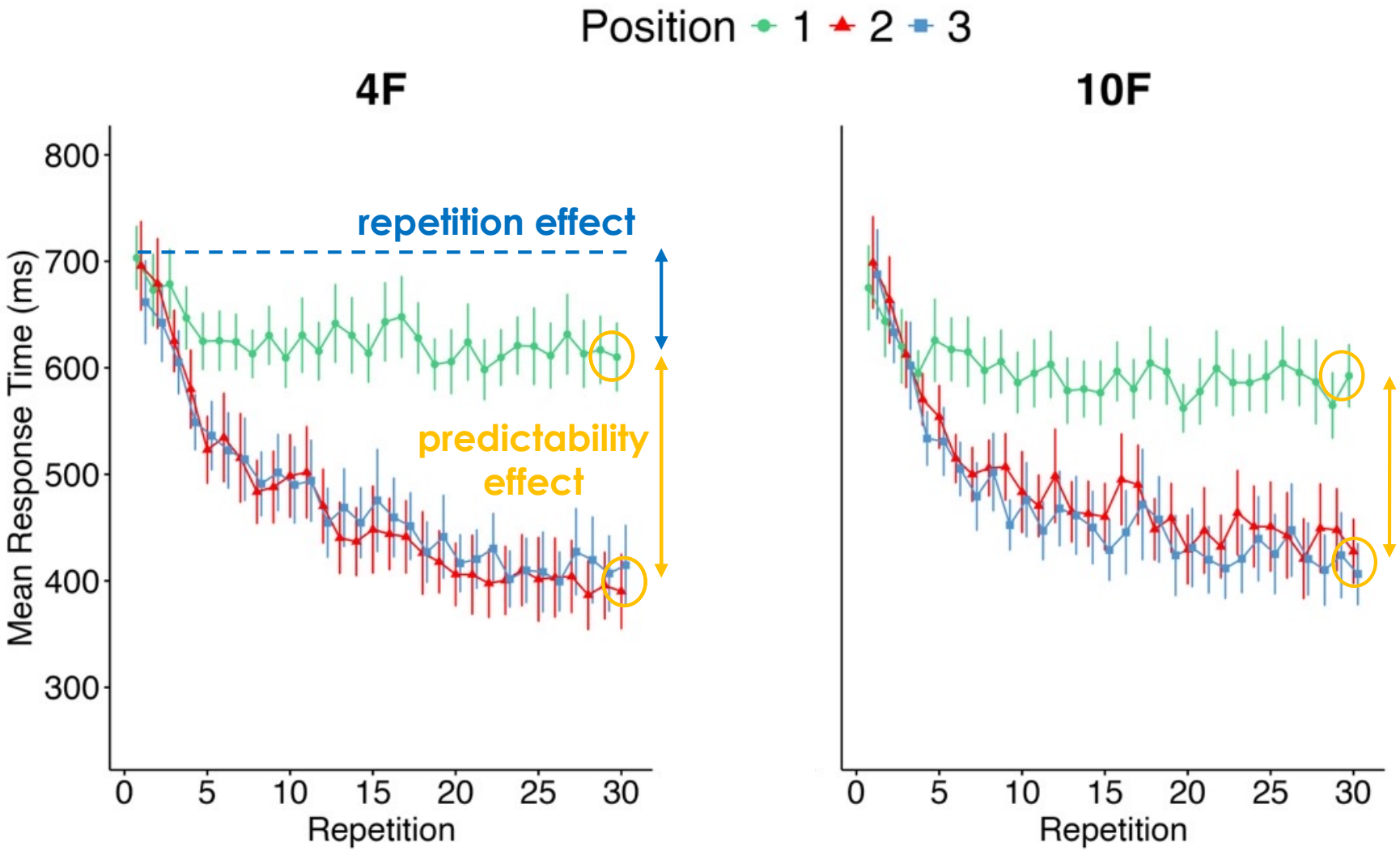
Position 1 2 3
4F
10F
repetition effect
predictability effect
Mean Response Time (ms)
800
700
600
500
400
300
0
5
10
15
20
25
30
Repetition

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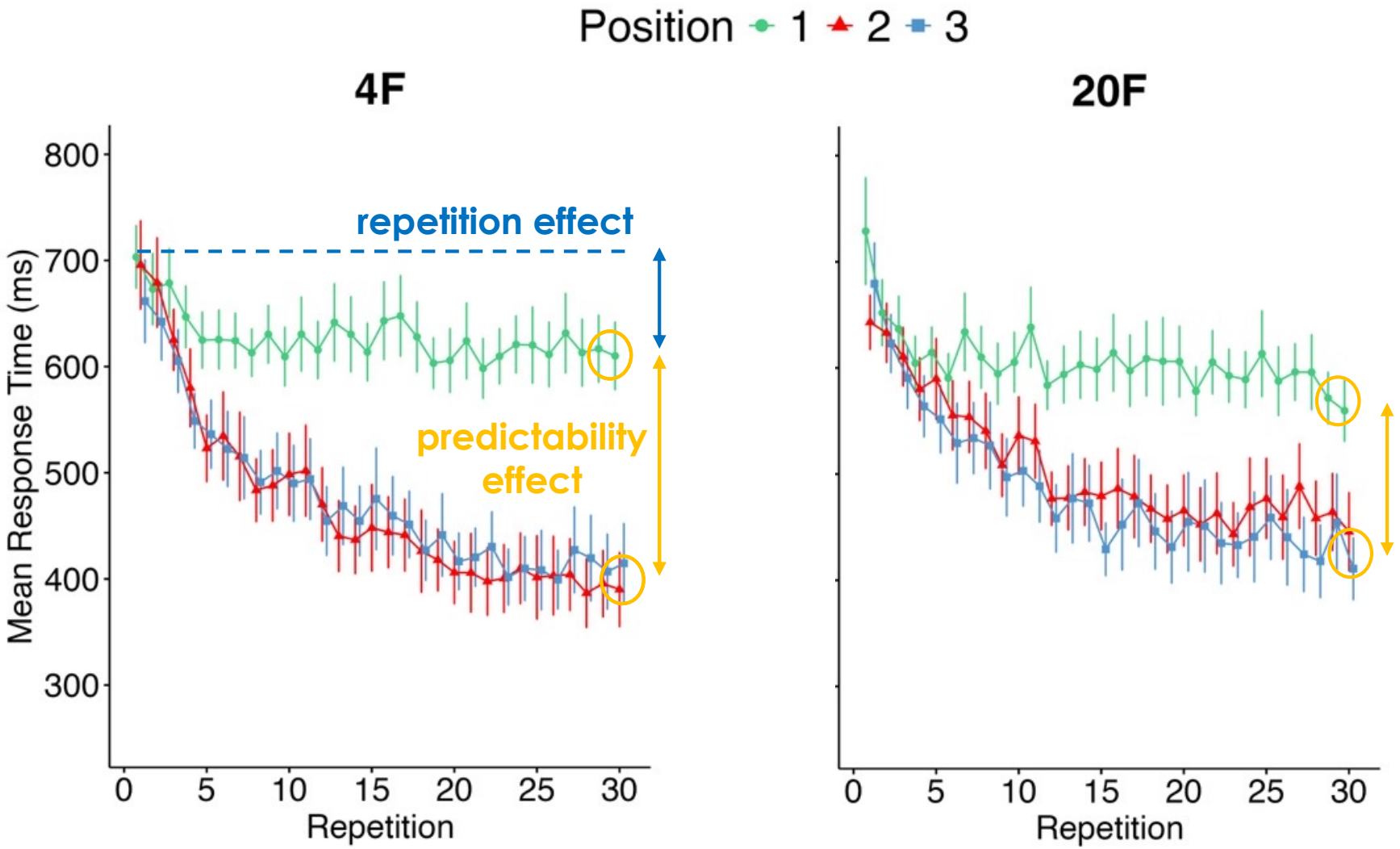

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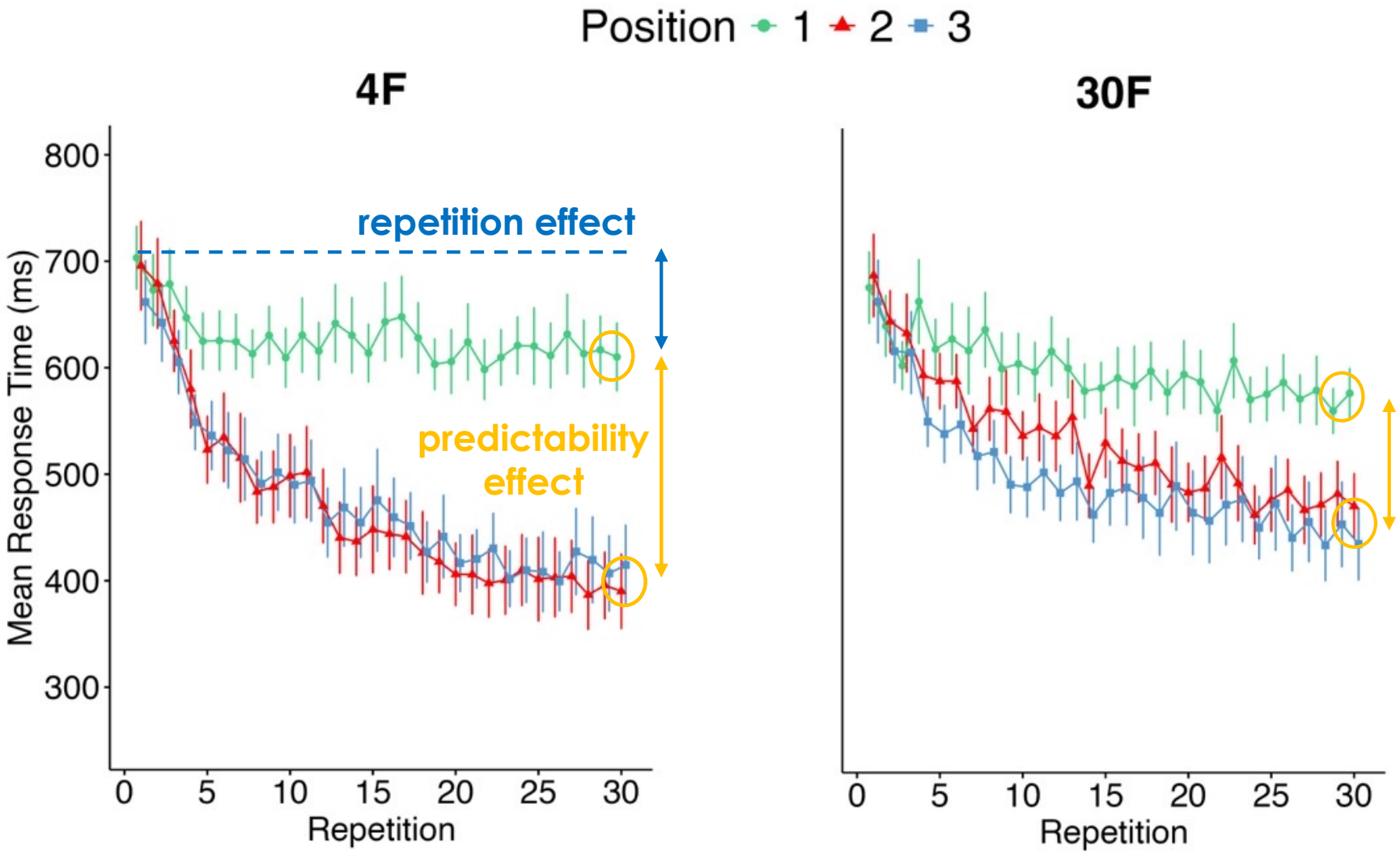

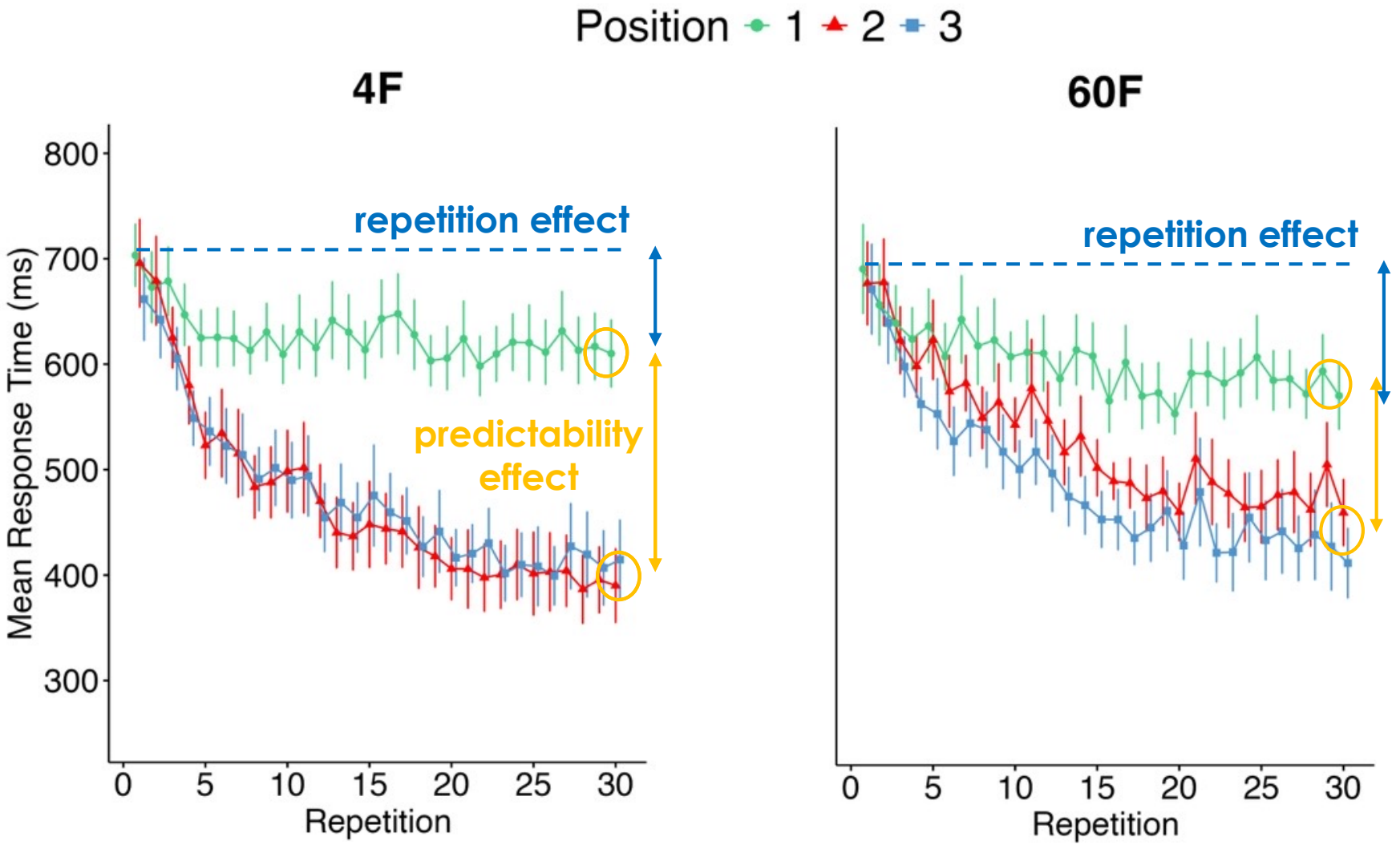
Position 1 2 3
4F
60F
repetition effect
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Repetition
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Repetition

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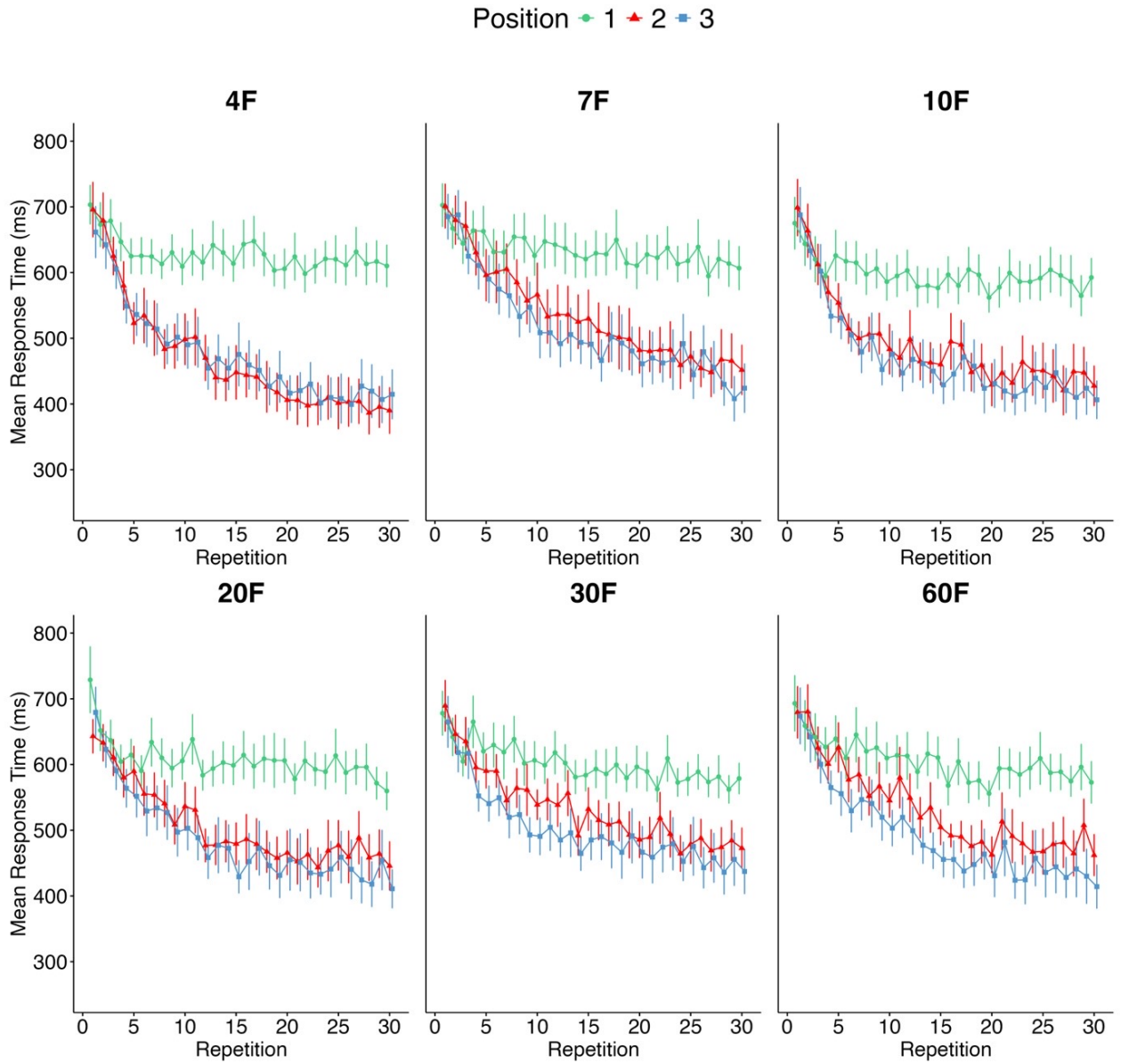
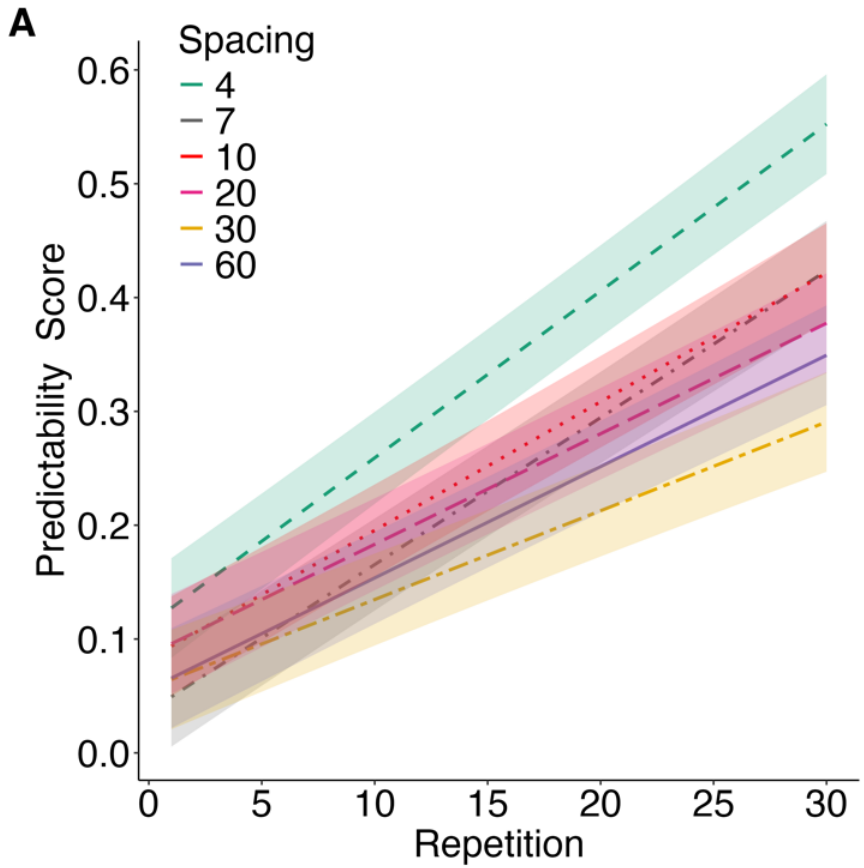


Predictability score : $logRT_{2/3} - logRT_1$



=> **power law**

Statement 2: Our memory capacity is actually quite large

=> Which suggests that we may not need a very large learning set

Statement 3: With the development of our production capacity, we can **self-generate** linguistic forms, sometimes in a totally hidden way, within our inner language.

=> self-generation produces repetitions = reinforced memory traces

=> the poverty of the stimulus is compensated by the richness of self-productions

Statement 4: This is not the end of the story.
We need to develop the fourth stage of connectionist modeling

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Topics in Cognitive Psychology, 2024, 124, Juin 2024 / June 2024

Associations are all we need

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ABSTRACT

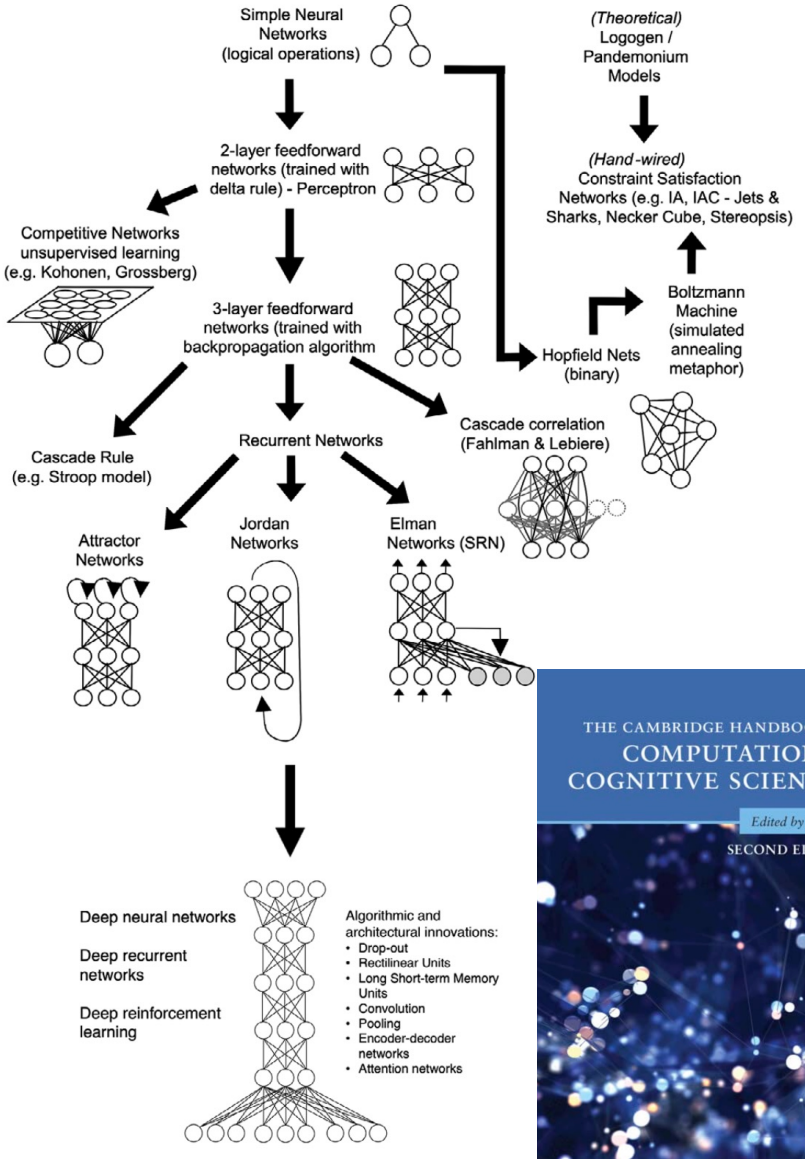
In this opinion article, I argue that the time has come for a unified radical associationism that is built around the assumption that associations are all we have and probably all we need to account for mental activities. This radical associationism should be able to *merge* the fields of associative, statistical and Hebbian learning and unify these theoretical and empirical approaches. A direct consequence of adopting such a theoretical stance is a revision of several key psychological concepts (e.g., the notion of attention) based on neurobiological ones, leading to a unified neuropsychological theorization of mental activities.

Keywords: Associationism, statistical learning, Hebbian learning

First age

Second age

Third age



2 Connectionist Models of Cognition

MICHAEL S. C. THOMAS AND JAMES L. MCCLELLAND