

What do order verification tasks actually measure?

A multi-strategy perspective

Declan Devlin

MCLS 2026

What is order processing?

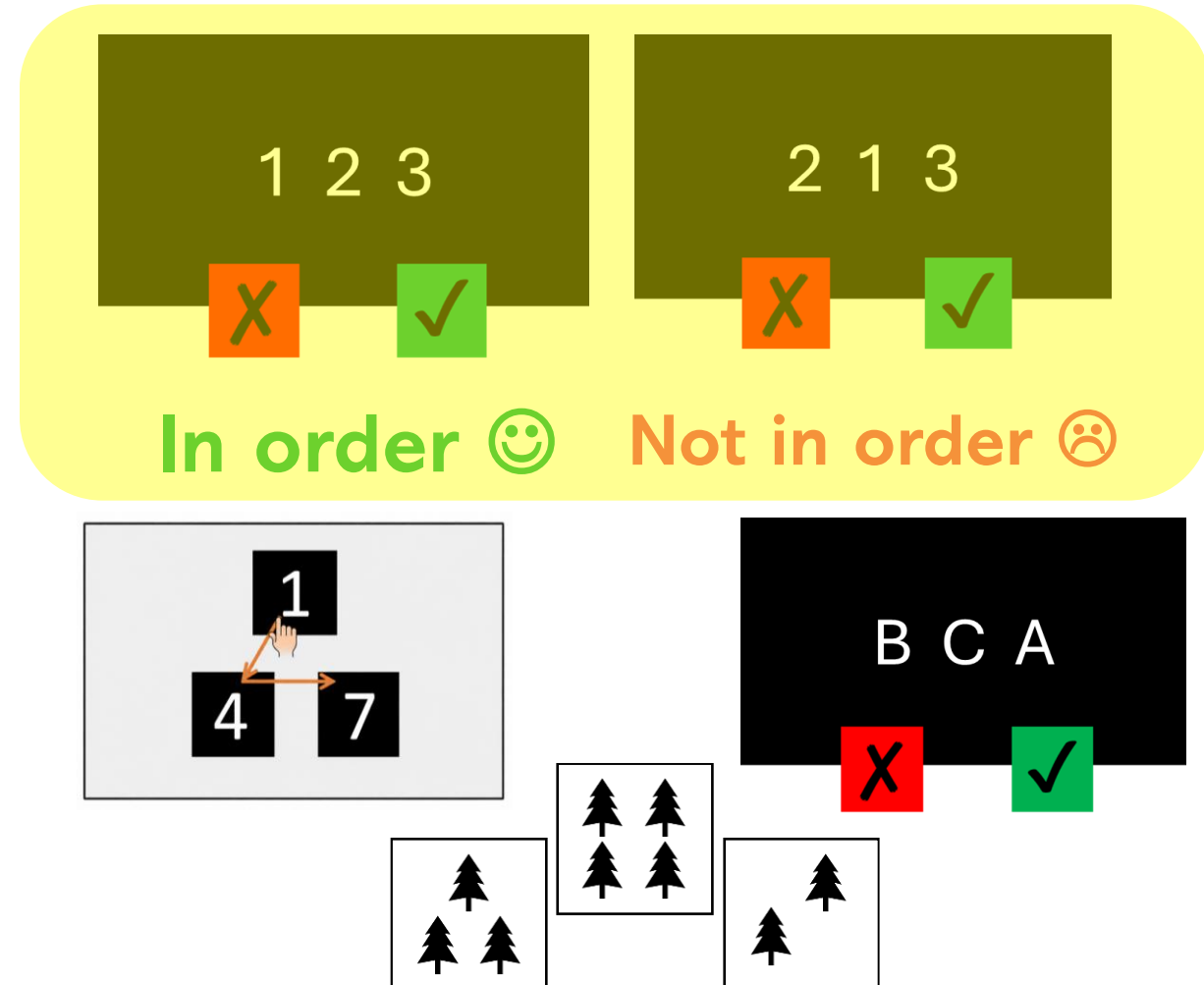
Order processing can be defined and measured in many ways

Harju & Van Hoof (2025)

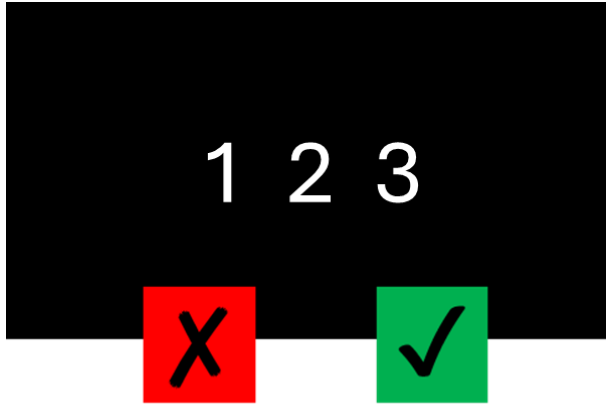
638 unique terms referring to ordinality

151 distinct descriptions of ordinality,
clustered into ten categories.

18 different types of measures were
used to assess ordinality



How do we identify underlying mechanisms?



Instead of explaining how people perform a skill, we try to explain how they do so in a specific way so as to produce a set of behavioural phenomena

Which phenomena we focus on explaining may influence our proposed explanations

Preprint

Non-symbolic quantity estimation may be characterised by many signatures, yet we typically focus on only a few

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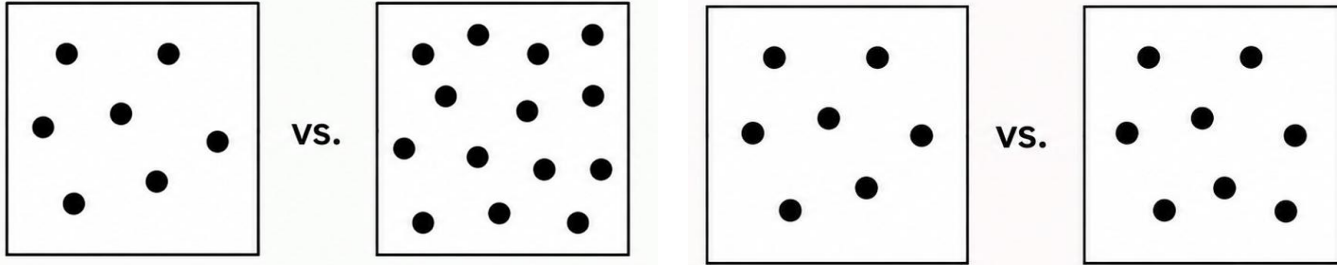
ABSTRACT

When a person estimates non-symbolic quantities, they typically do so in a way that produces a characteristic set of behavioural patterns. For example, small quantities may be estimated with near-perfect accuracy, whereas estimates of larger quantities become increasingly variable. Consequently, attempts to identify the mechanisms underlying quantity estimation involve explaining not only how people are able to estimate quantities, but also how they do so in a way that gives rise to these recurring behavioural phenomena. Over the past several decades, an increasing number of candidate “signatures” of quantity estimation have been identified, including effects relating to visual cues, previous estimates, and individual differences. Despite this, theoretical accounts often differ both in which phenomena they attempt to explain and in how they prioritise even shared behavioural signatures. In this sense, competing perspectives may disagree not only on what mechanisms underlie quantity estimation, but also on what aspects of estimation behaviour we should even be trying to explain. In this review, we examine how different theoretical approaches select and prioritise behavioural signatures, discuss conceptual questions concerning what should count as a “signature” of quantity estimation, and consider the implications of these issues for how competing models are developed and evaluated. In particular, we propose treating candidate signatures as a provisional “dataset to be explained” against which competing models may be compared within a shared explanatory framework. Although we do not claim to resolve these issues definitively, we hope that articulating them explicitly will encourage greater transparency regarding explanatory assumptions and contribute towards a clearer and more cumulative understanding of non-symbolic quantity estimation and its underlying mechanisms.

Keywords: quantity estimation, numerosity, behavioural signatures, numerical cognition

Example from numerosity

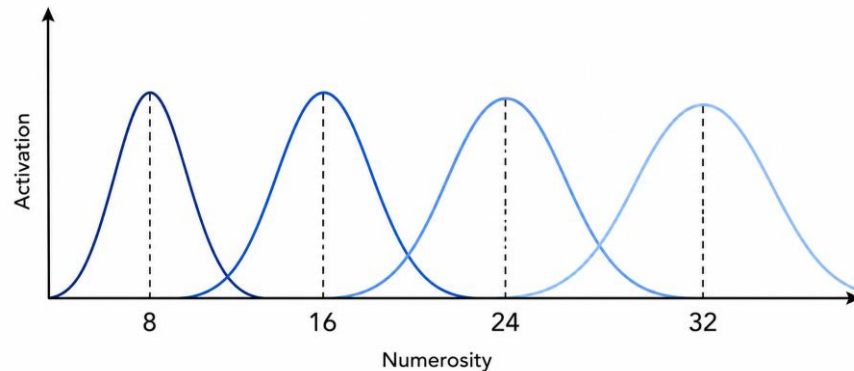
The ratio effect



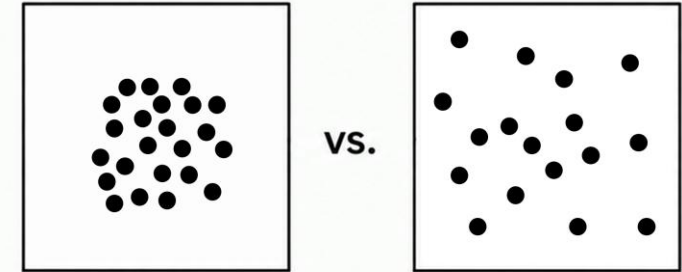
Large ratio = easier

small ratio = harder

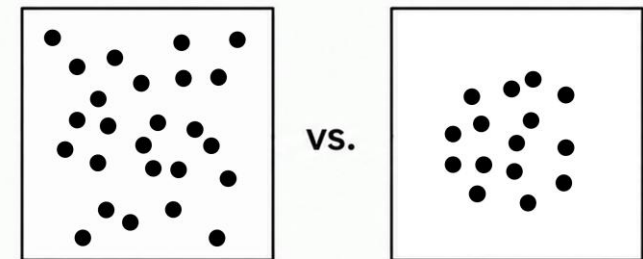
Naturally leads to ANS-type explanations



Visual cue effects



Congruent = easier



Incongruent = harder

Implies a sensory-integration account

Which effects we focus on influences our explanations

Preprint

Non-symbolic quantity estimation may be characterised by many signatures, yet we typically focus on only a few

Please read this!

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When we try to explain a cognitive skill, we typically try to explain its effects

Because there are lots of effects, we have to exhibit some degree of choice in what we explain

What effects we choose to explain may influence our proposed explanations

Candidate signatures

Exact estimation range

Influence of non-numerical visual cues

Overestimation of medium numerosities

Numerosity-specific error reductions

Estimation bias

Feedback-dependent estimation bias

Underestimation of large numerosities

Scalar variability

Serial dependence

Stimulus-duration effects

Sigmoidal response time functions

The many effects of order verification

Order effect

234 vs 243

Reverse distance effect

123 vs 135

Direction effect

234 vs 432

Regularity effect

135 vs 136

Single-digit effect

7-8-9 vs 17-18-19

The many effects of order verification

We only really care about this one!

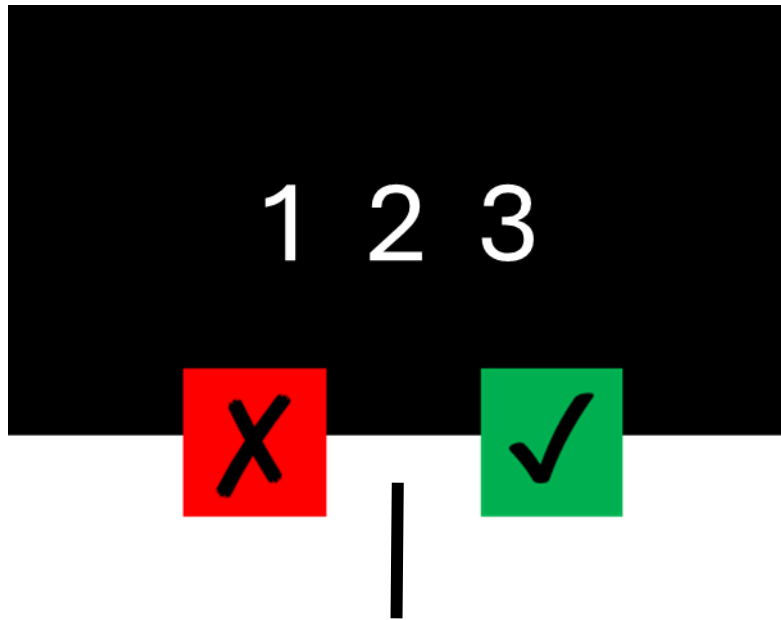
Reverse distance effect

123 vs 135

*The **RDE** has often been described as a “hallmark” or order processing (e.g., Lyons & Ansari, 2015)*

*...and some going as far as to suggest that if no **RDE** is observed, then “order processing” is not really occurring (i.e., Wong et al., 2021)*

Implications of explaining the RDE



Latent construct of “ordinality” or
“order processing”

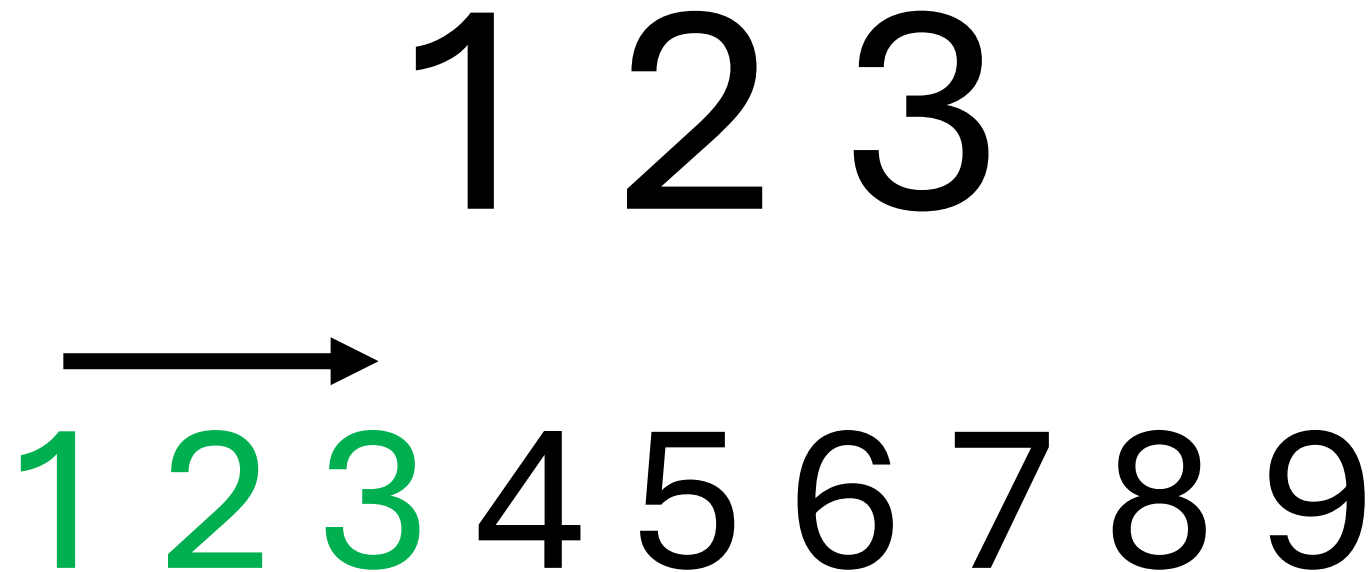
Reverse distance effect

123 vs 135

*Explaining the RDE will tell us something
about this latent construct of ordinality*

Serial-scanning mechanisms

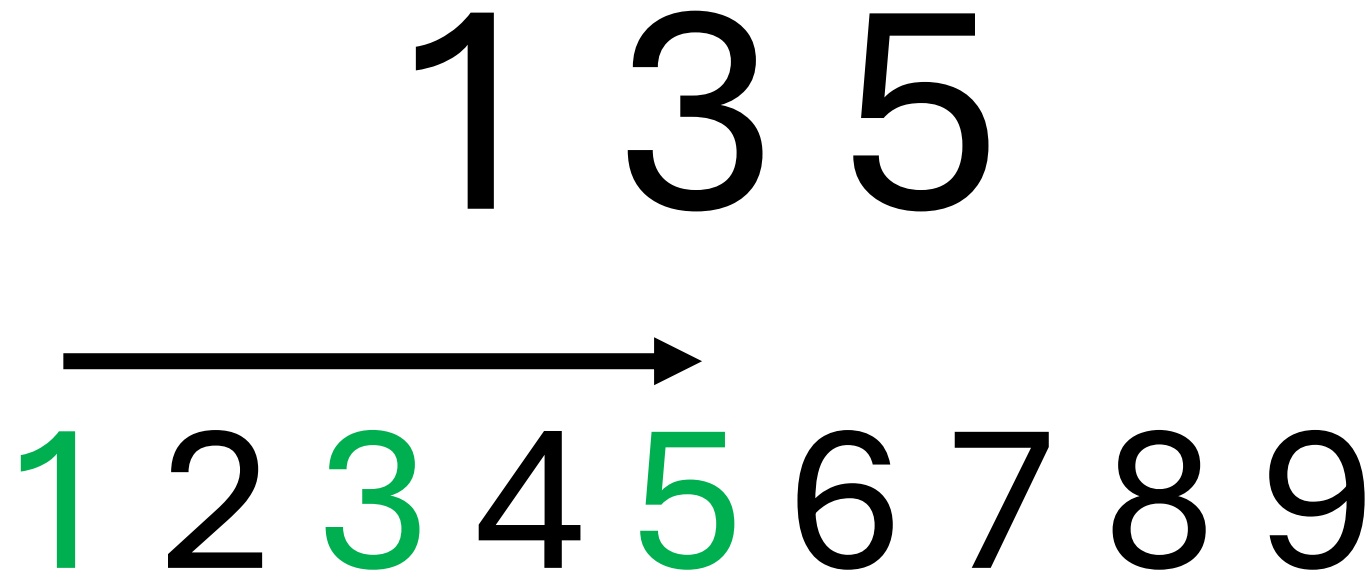
Prioritising the RDE naturally encourages distance-based accounts of order processing, such as a proposed **serial-scanning mechanism**:



(e.g., Franklin et al., 2009; Turconi et al., 2004, 2006)

Implications of explaining the RDE

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OK, but...

How does this explain all those other effects?



Order effect

234 vs 243

Reverse distance effect

123 vs 135

Direction effect

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Regularity effect

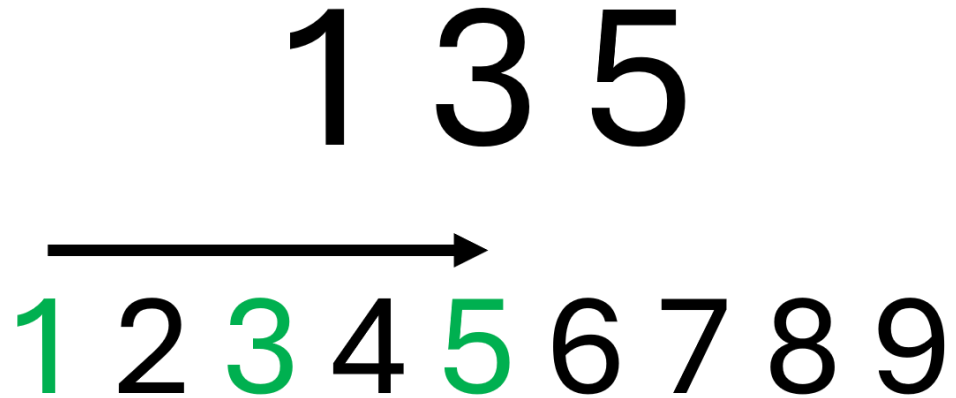
135 vs 136

Single-digit effect

7-8-9 vs 17-18-19

Is the RDE really a RDE?

The term “**reverse distance effect**” implies a **linear relationship** whereby RTs increase as distance between digits increases



*Serial scanning mechanism can
account for linear increases in RTs*

Reframing as a consecutiveness effect

The “**reverse distance effect**” may be better thought of as a “**consecutiveness effect**”

1 2 3

Distance 1

1 3 5

Distance 2

1 4 7

Distance 3

Faster processing appears **specific to distances of 1**, as greater distances produce either no distance effect or even standard distance effects (e.g., Turconi et al., 2006; Vogel et al., 2017).

~~Reverse distance effect~~



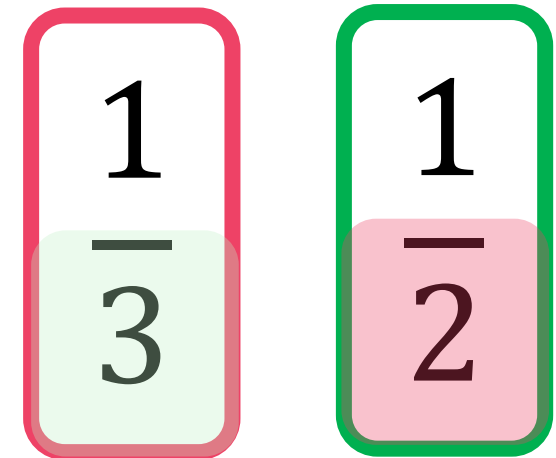
Consecutiveness effect

Implications of the consecutiveness effect

Most studies now operationalise the RDE as a consecutiveness effect, which has recently led to count-list-based theories:

Early experiences with order come from learning the verbal count-list
“one, two, three, four, five...”

Leading to an intuition that “in order” == “matches the count-list”



(e.g., Gattas et al., 2021; Hutchison et al., 2022)

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...But is the RDE really a consecutiveness effect?

~~“Small distance sequences are processed faster than large distance sequences”~~

~~“Consecutive sequences are processed faster than non consecutive sequences”~~

“Familiar sequences are processed faster than unfamiliar sequences”

The familiarity effect

Consecutive

1 2 3 4 5 6 5 6 7

2 3 4 3 4 5

6 7 8 7 8 9

2 4 6

Non-consecutive

1 3 5 4 6 8 3 6 9

2 4 6 5 7 9

3 5 7 2 5 8

3 6 9

Devlin et al. (2024)

Used a comparative judgement approach to create a measure of sequence familiarity

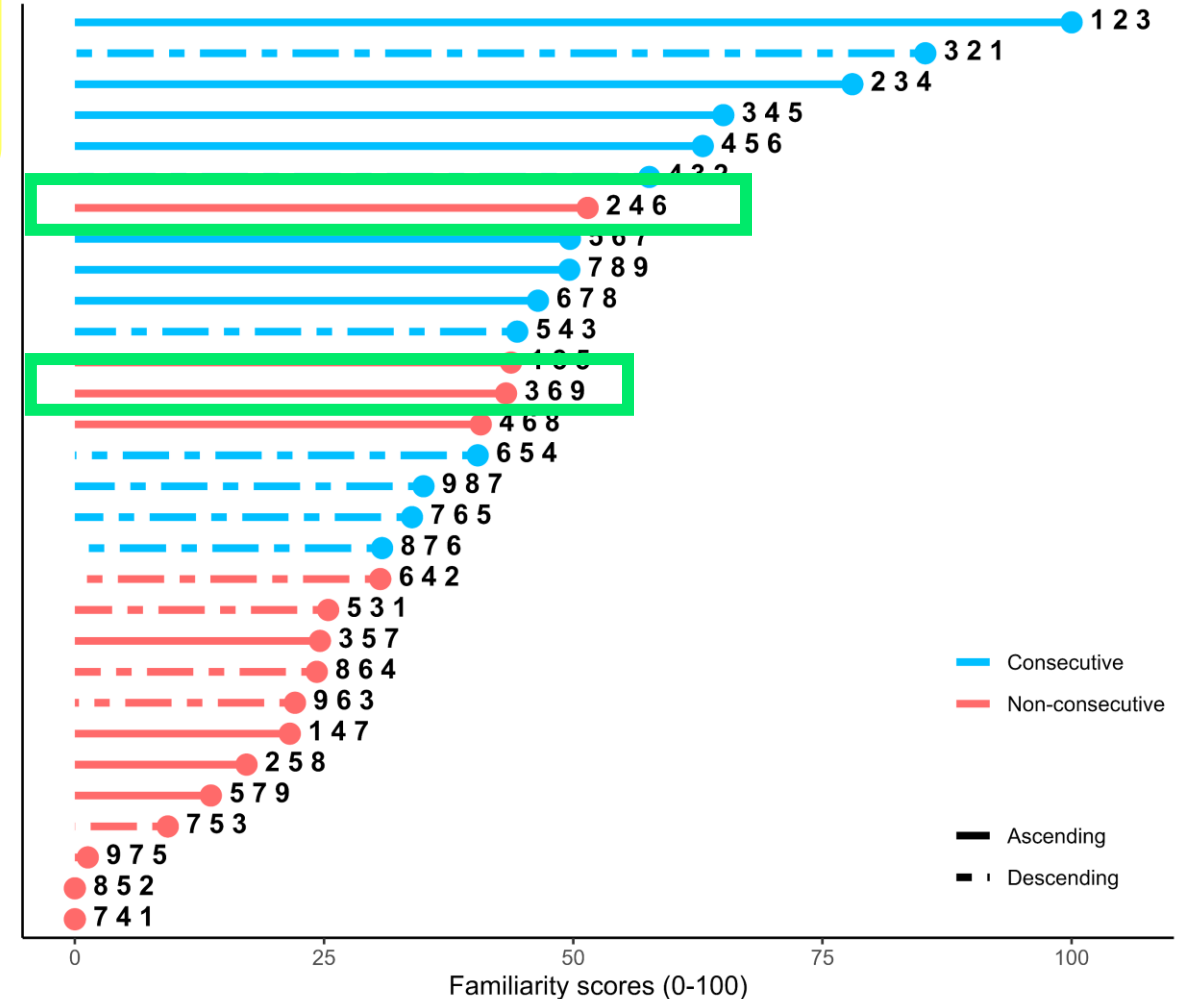
Left

Which is more familiar?

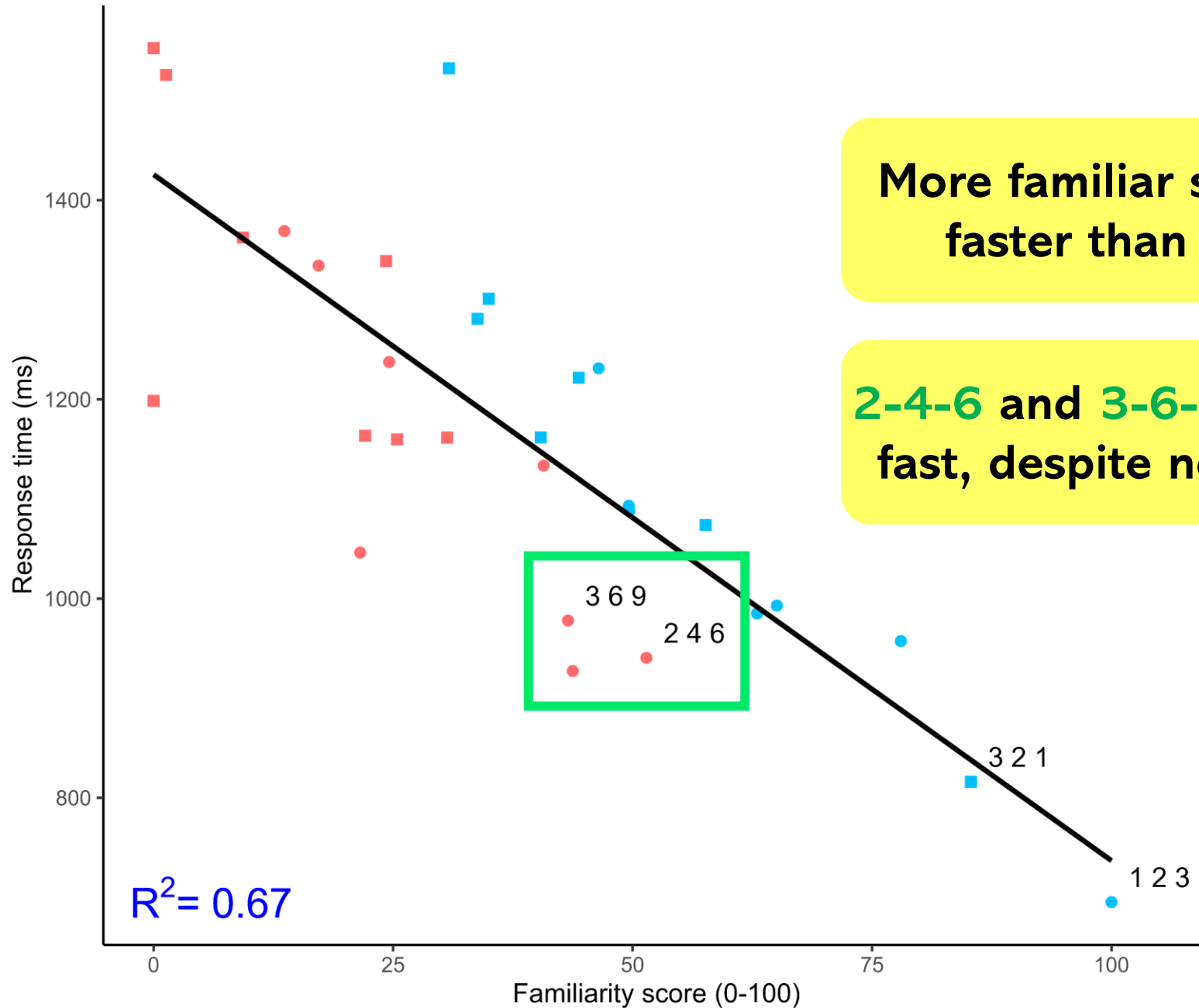
Right

1 2 3

1 3 5



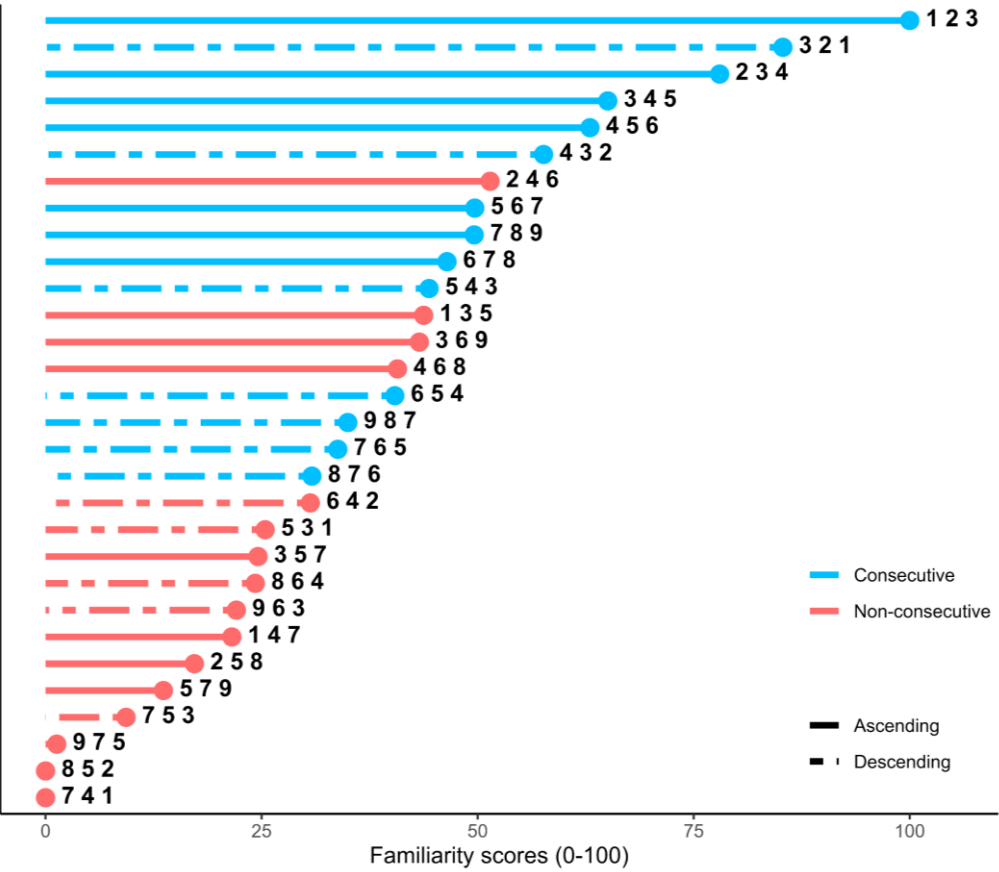
$$r = -0.82, p < 0.01$$



More familiar sequences were processed faster than less familiar sequences

2-4-6 and 3-6-9 were processed relatively fast, despite not matching the **count-list!**

Devlin et al. (2025)



Enhanced familiarity condition

Table 8.1. All ordered sequences in enhanced familiarity condition

Left	Centre	Right	Distance	Familiarity
1	2	3	Consecutive	100
2	3	4	Consecutive	78
3	4	5	Consecutive	65.06
1	4	7	Non-consecutive	21.56
2	5	8	Non-consecutive	17.22
5	7	9	Non-consecutive	13.64

Strong RDE

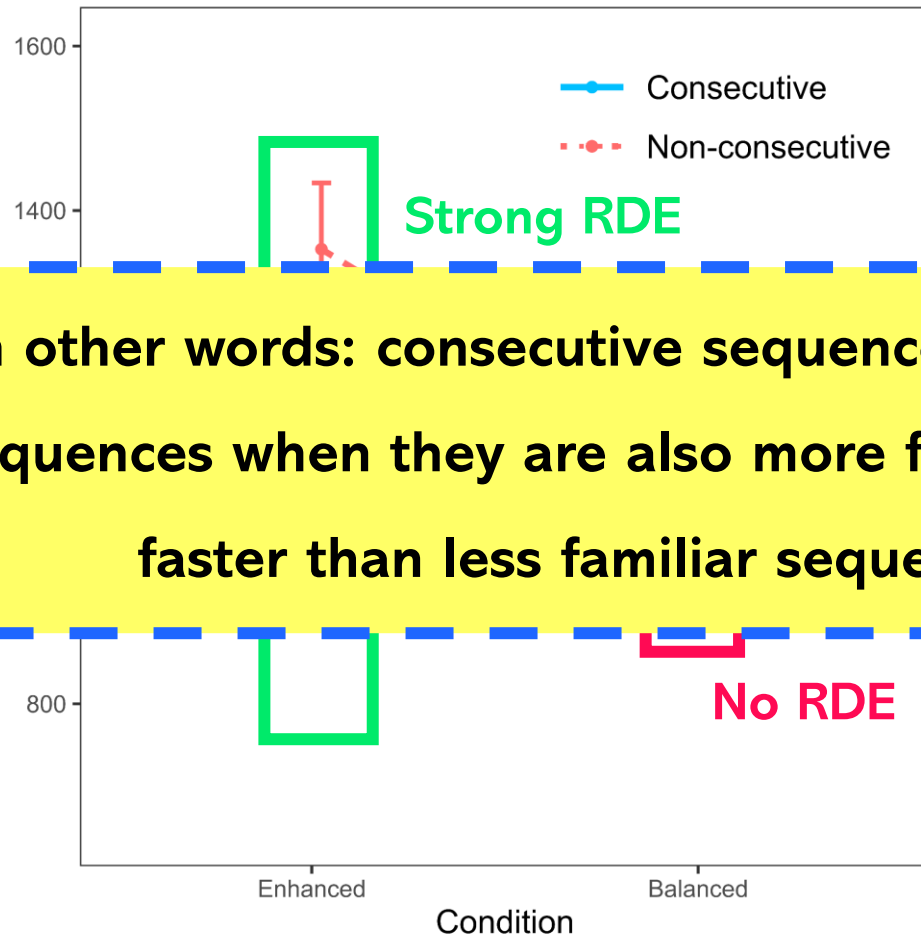
Balanced familiarity condition

Table 8.2. All ordered sequences in inversed familiarity condition

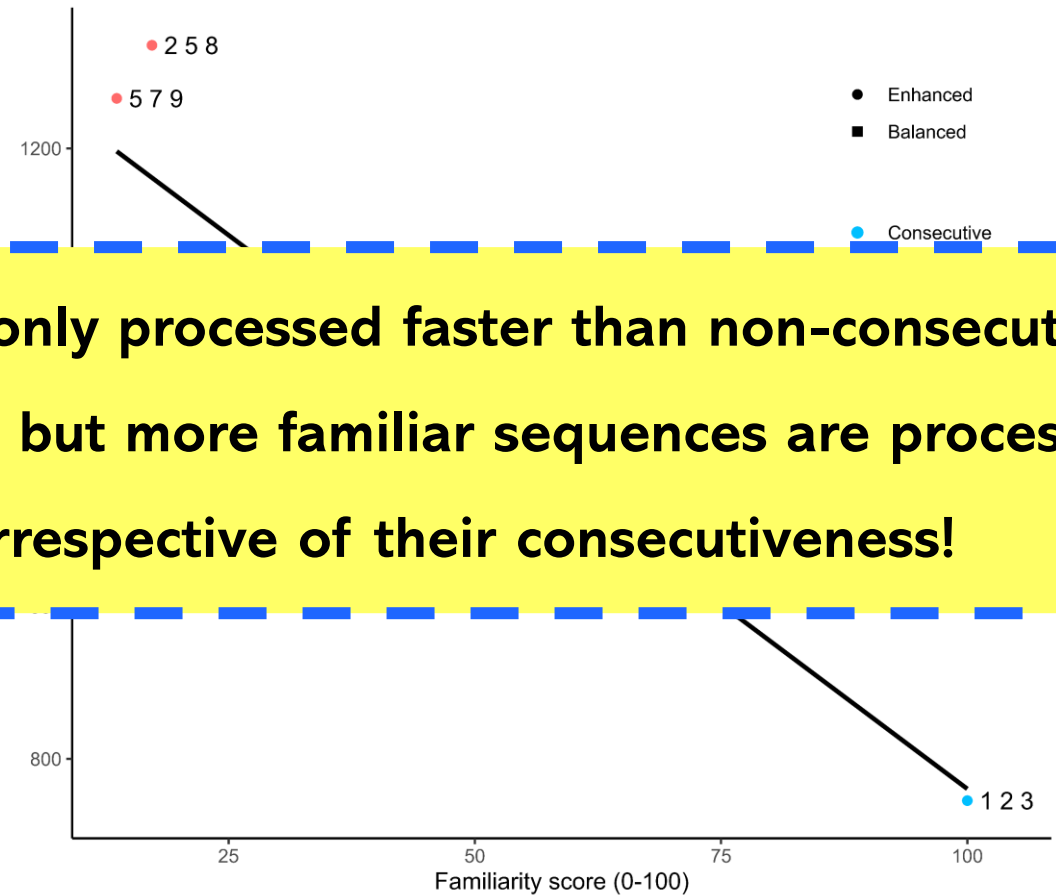
Left	Centre	Right	Type	Familiarity
5	6	7	Consecutive	49.67
7	8	9	Consecutive	49.60
6	7	8	Consecutive	46.46
2	4	6	Non-consecutive	51.44
1	3	5	Non-consecutive	43.75
3	6	9	Non-consecutive	43.25

No RDE

Devlin et al. (2025)

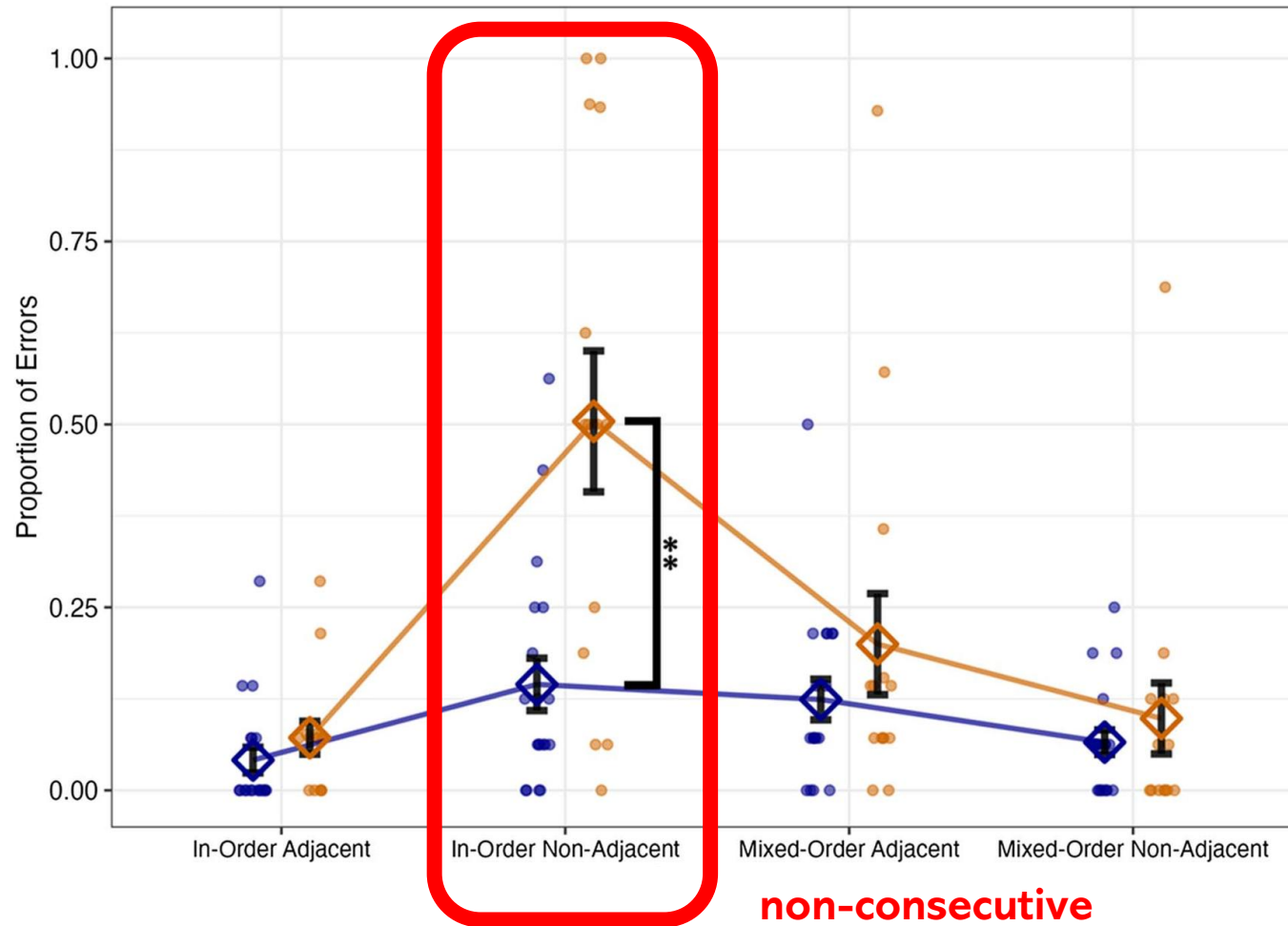


In other words: consecutive sequences are only processed faster than non-consecutive sequences when they are also more familiar, but more familiar sequences are processed faster than less familiar sequences, irrespective of their consecutiveness!



$$r = -0.88$$

Order processing deficits in dyscalculia



Deficits are not general but specific to **non-count-list** sequences

control
dyscalculia

Slipenkyj et al. (2025)

Devlin et al. (2026)

We tested whether the deficits on **non-count-list sequences** were driven by sequence familiarity:

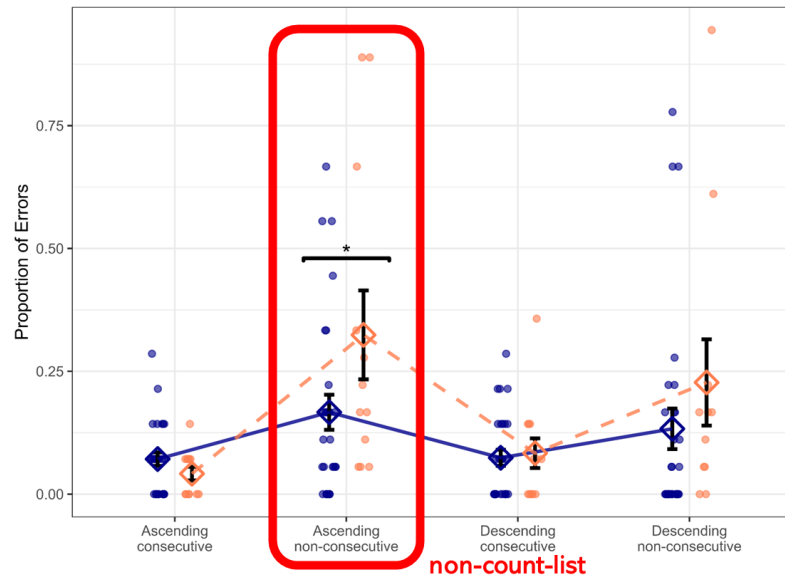
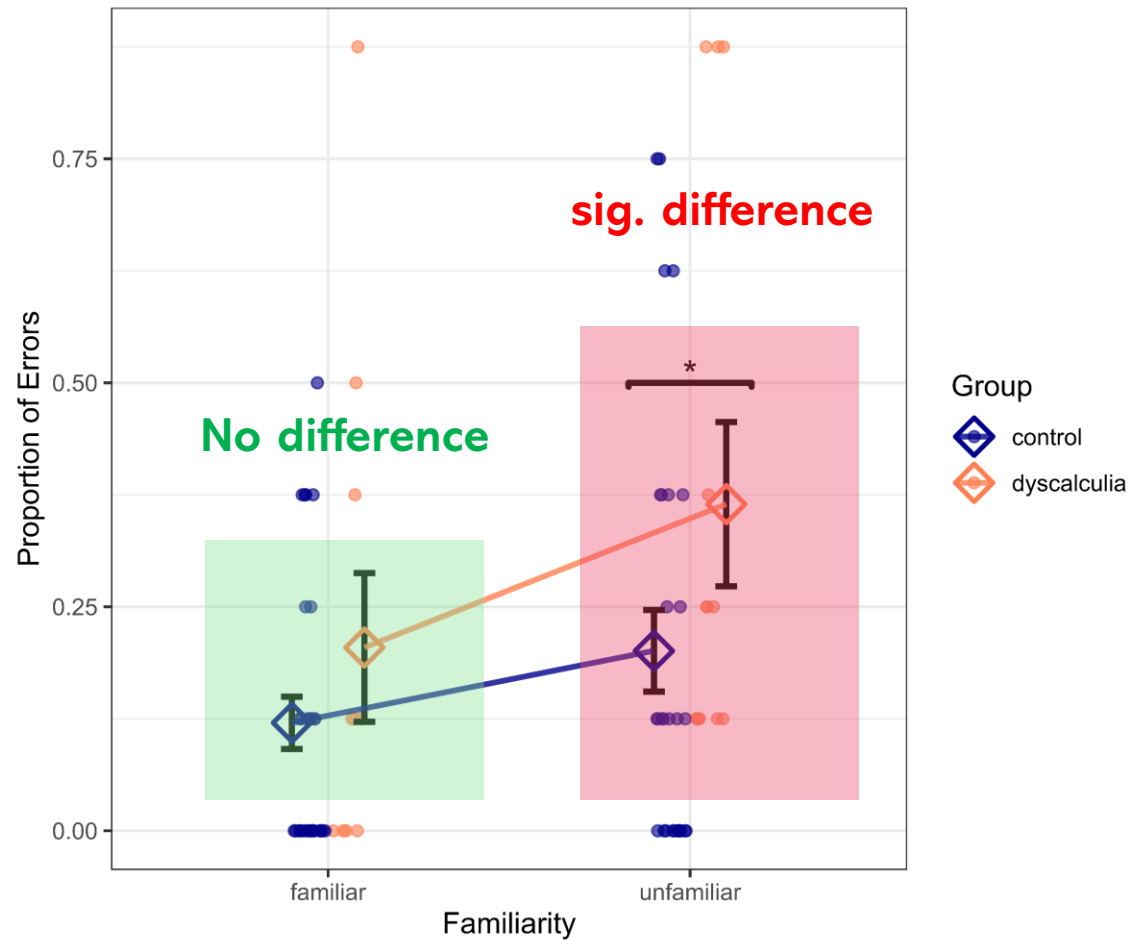


Table 1. Most familiar and least familiar ascending non-consecutive sequences

Sequence			Type	Familiarity score
2	4	6	Familiar	51.44
1	3	5	Familiar	43.75
3	6	9	Familiar	43.25
4	6	8	Familiar	40.72
3	5	7	Unfamiliar	24.59
1	4	7	Unfamiliar	21.56
2	5	8	Unfamiliar	17.22
5	7	9	Unfamiliar	13.64

We separated the **non-count-list** sequences into “**familiar**” and “**unfamiliar**”

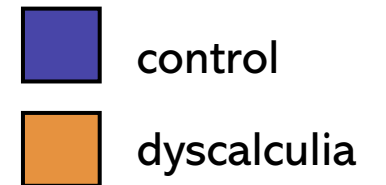
Devlin et al. (2026)



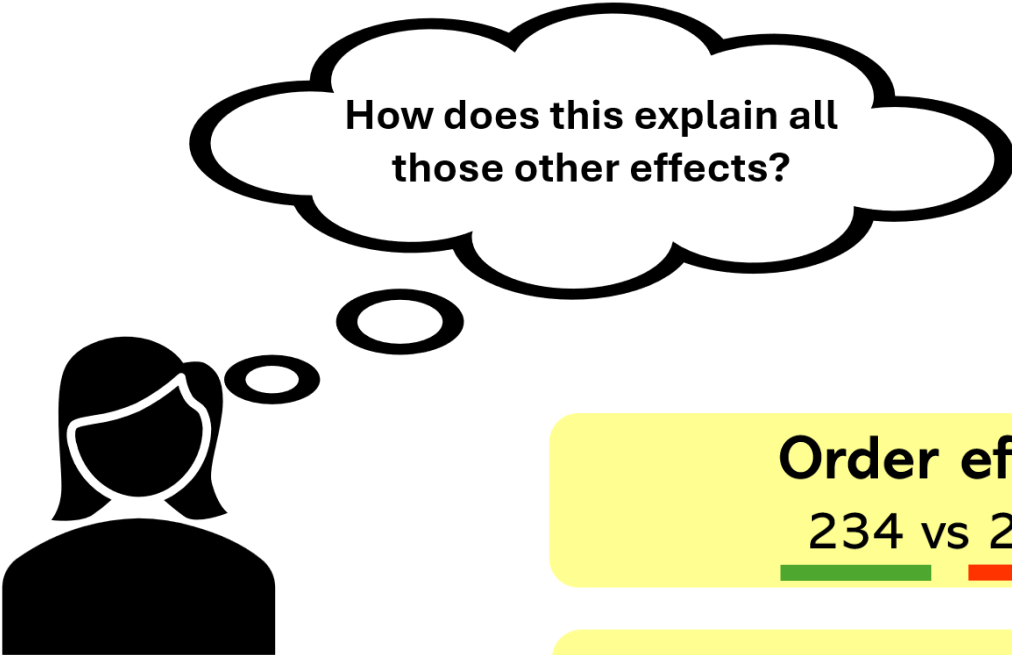
Dyscalculic children displayed:

Comparable performance on
familiar non-count-list sequences

Impaired performance on
unfamiliar non-count-list
sequences



OK, but...



How does this explain all those other effects?

These effects may be viewed as **specific instances** of a **general familiarity effect**

Order effect

234 vs 243



Reverse distance effect

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Direction effect

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Regularity effect

135 vs 136



Single-digit effect

7-8-9 vs 17-18-19



Descriptive vs causal argument

~~“Small distance sequences are processed faster than large distance sequences”~~

~~“Consecutive sequences are processed faster than non consecutive sequences”~~

“Familiar sequences are processed faster than unfamiliar sequences”

Implications of explaining a familiarity effect

Reverse distance effect

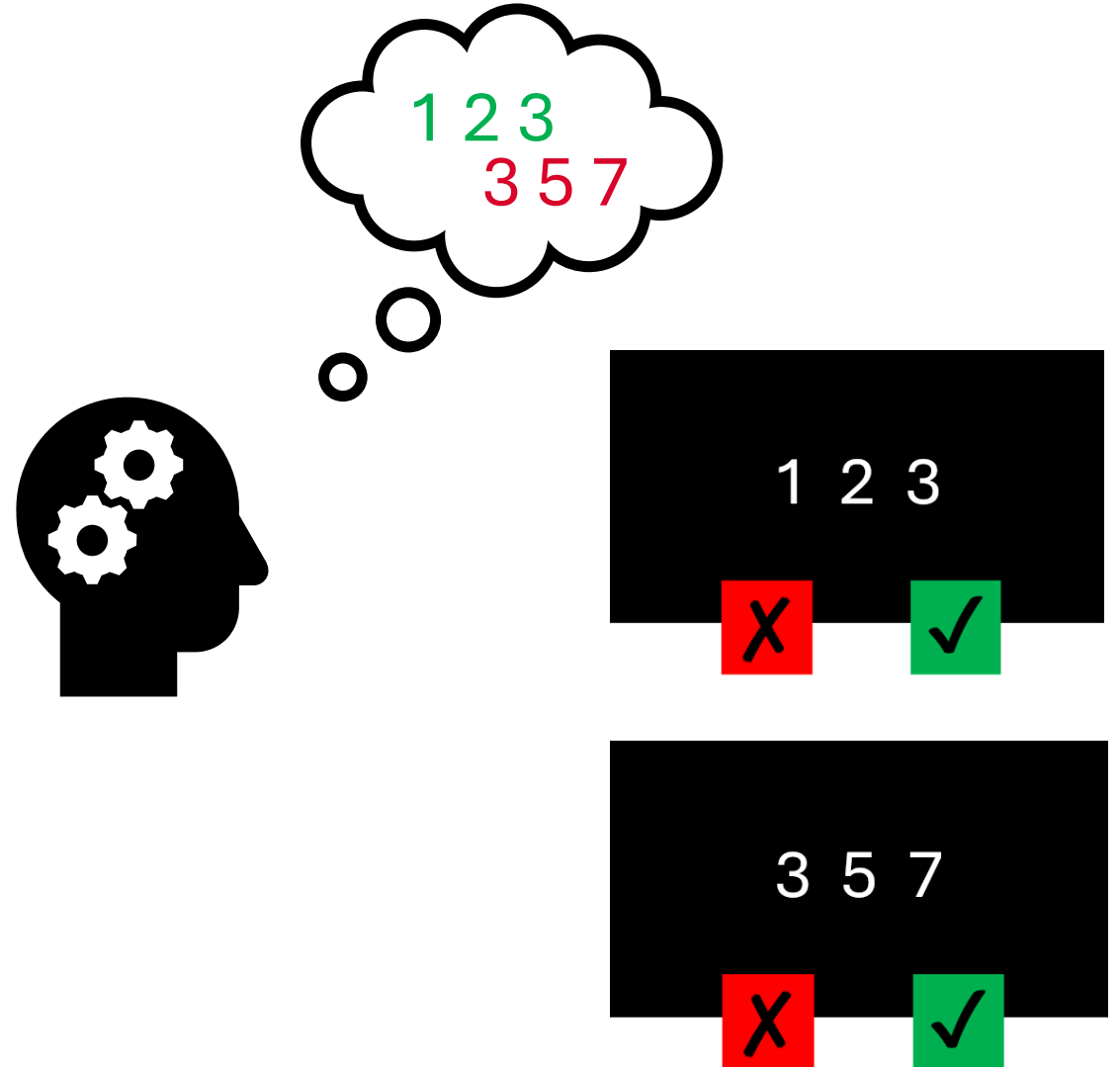
Order effect

Direction effect

Regularity effect

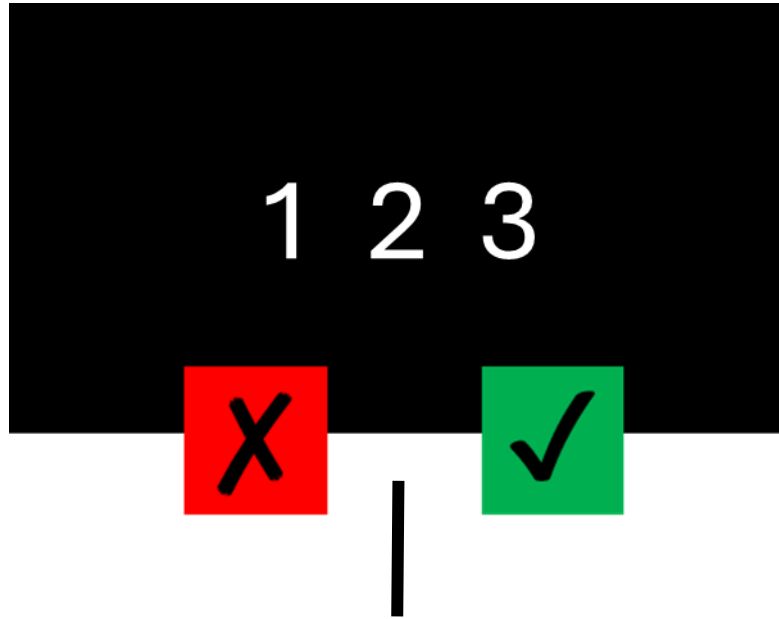
Single-digit effect

General familiarity effect



(Vos et al., 2017, 2021)

Ordinality vs. multi-strategy



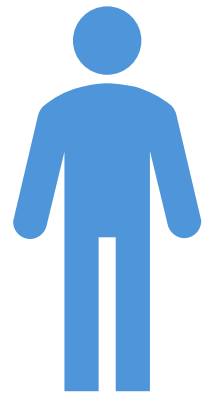
~~Latent construct of "ordinality" or
"order processing"~~

Memory retrieval
Sequential comparison
Other???

**General
familiarity effect**

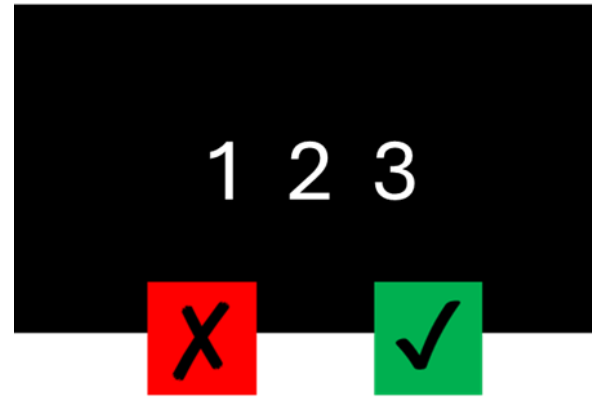
	MEMORY (%)	DECOMPOSITION (%)	ARITHMETIC (%)	OTHER (%)
AC	70.68	18.55	8.77	2.01
AnC	49.74	29.64	15.98	4.64
DC	63.73	42.35	9.59	2.38
DnC	44.09	38.22	14.70	2.89

Implications of the multi-strategy perspective (1)

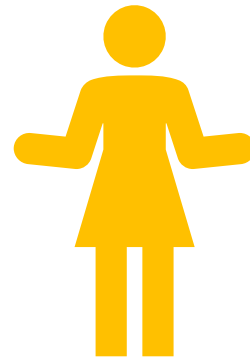


800 ms
99% accuracy

Order verification

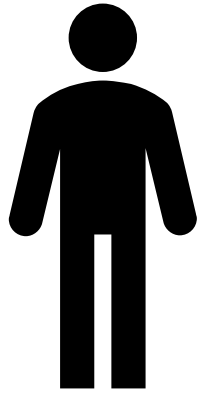


1,500 ms
86% accuracy



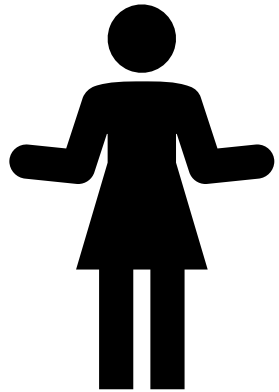
1,100 ms
95% accuracy

Implications of the multi-strategy perspective (1)



1,100 ms
96% accuracy

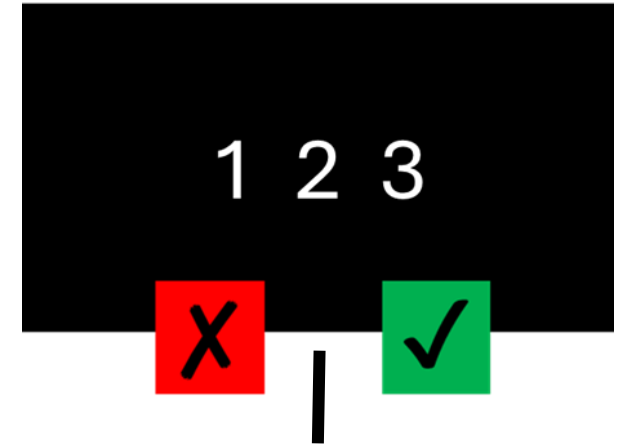
Memory retrieval
Sequential comparison



1,100 ms
96% accuracy

Memory retrieval
Sequential comparison

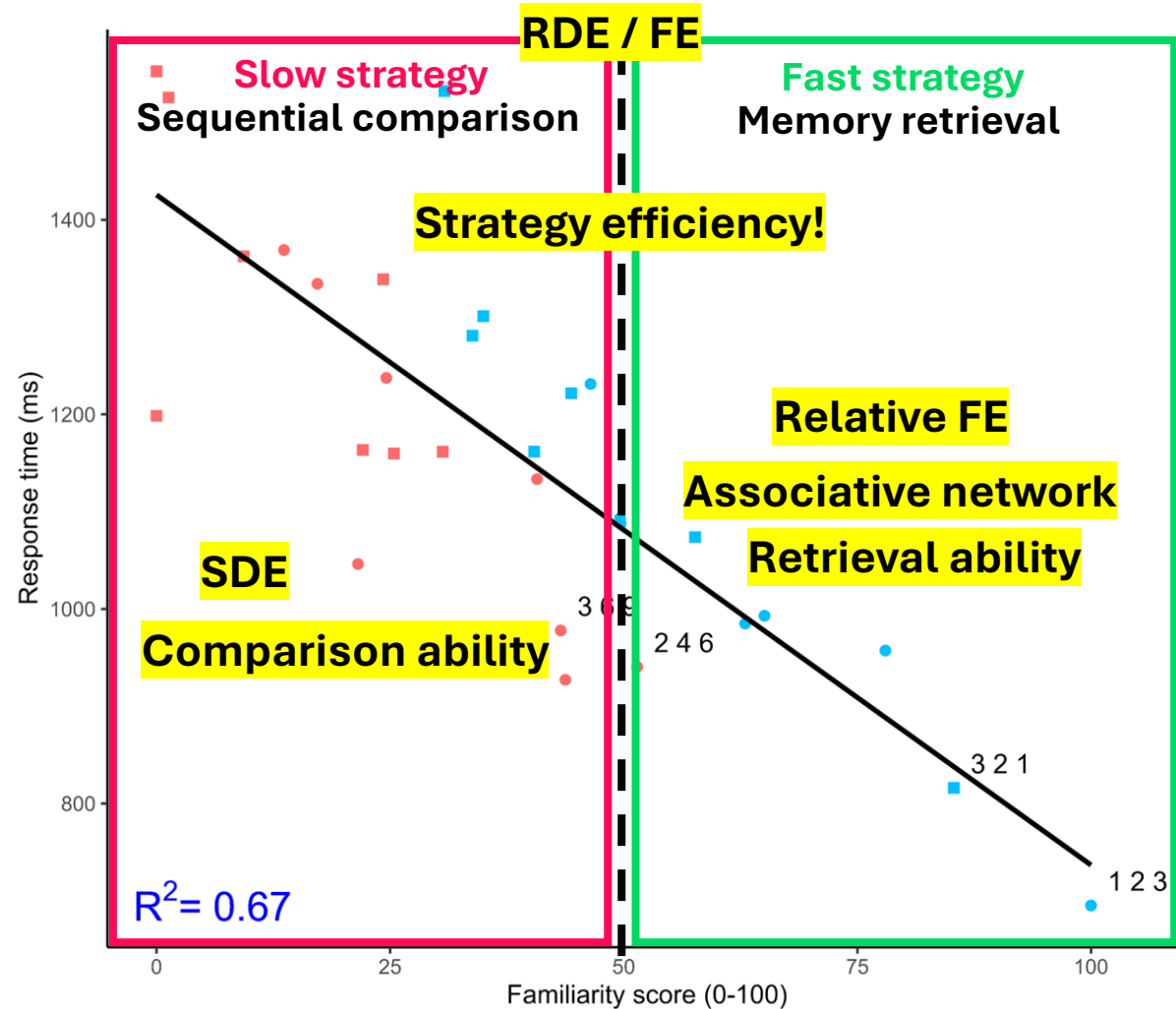
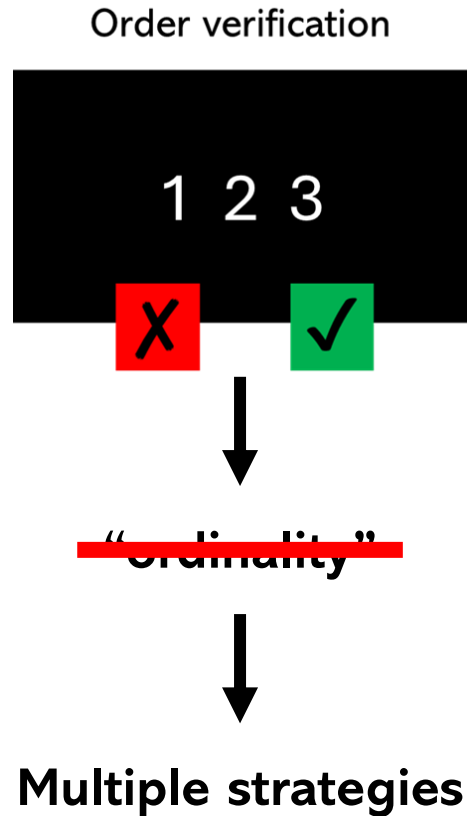
Order verification



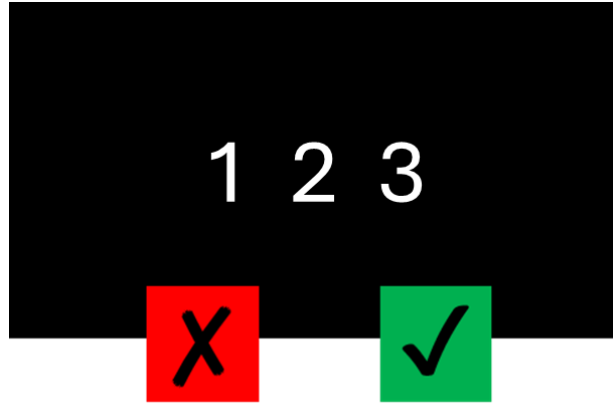
Arithmetic / numerical skills



Isolating the mechanisms



Summary & Conclusion (1)

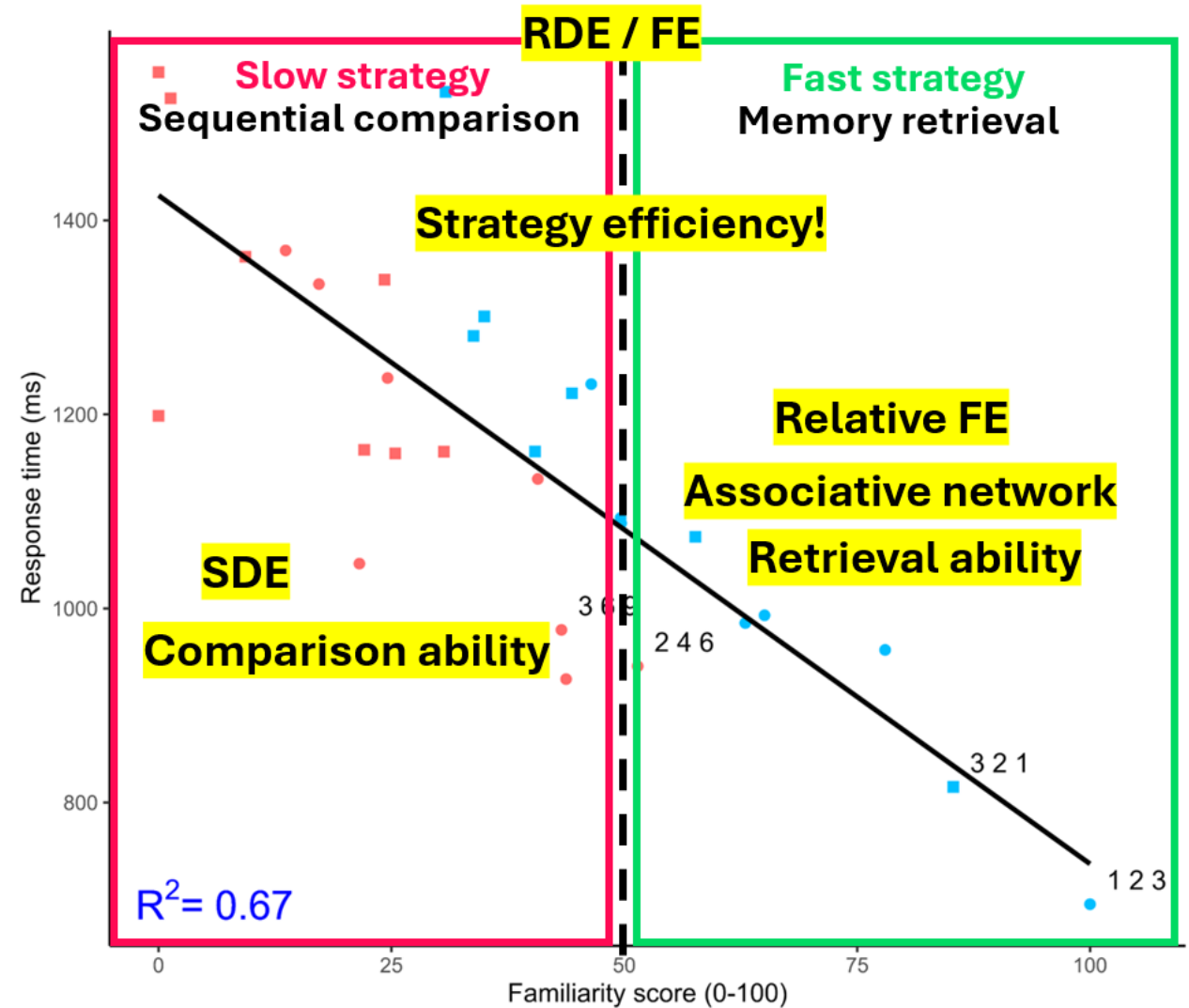


Order effect

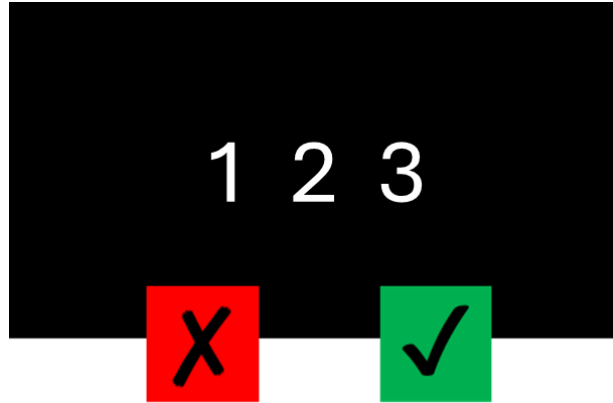
Direction effect

Regularity effect

Single-digit effect



Summary & Conclusion (2)

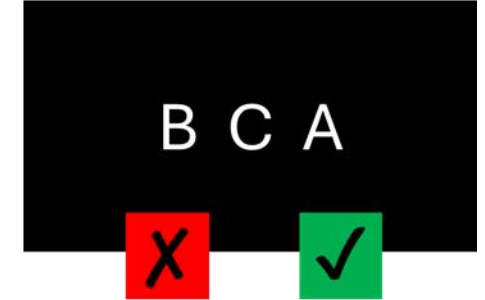
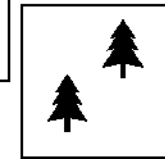
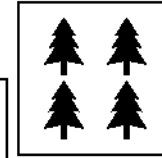
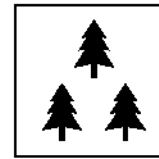
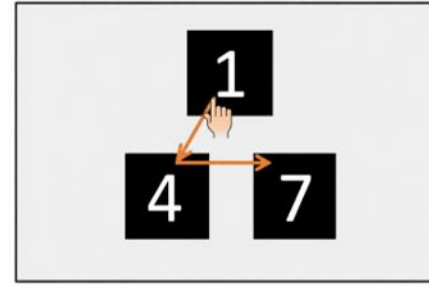


~~Latent construct of “ordinality”~~

~~or “order processing”~~



Multiple strategies (memory & comparison)



*for real this time, we
promise*

Latent construct of “ordinality” or “order
processing”



???



Grazie per l'attenzione!



I miei splendidi coautori:



Natalia Dubinkina



Francesco Sella



Iro Xenidou-Dervou



Bert Reynvoet