

Order Processing is Characterised by a Familiarity Effect, Not a (Reverse) Distance Effect

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What is order processing?

2 1 3

Not in order 😞

Who cares?

Order task



Why?????



Arithmetic task

$$4 + 7 =$$

$$5 \times 7 =$$

$$16 - 8 =$$

$$9 \times 5 =$$



The reverse distance effect



Serial-scanning explanation

1 2 3



1 2 3 4 5 6 7 8 9

Serial-scanning explanation

1 3 5



1 2 3 4 5 6 7 8 9

Associative explanation



Associative explanation

Consecutive

1 2 3 4 5 6 5 6 7

2 3 4 3 4 5

6 7 8 7 8 9

Non-consecutive

1 3 5 4 6 8 3 6 9

2 4 6 5 7 9

3 5 7 2 5 8

Differentiating between these explanations



Vos et al. (2017)

Ascending

1 2 3

→
1 2 3 4 5 6 7 8 9

1 3 5

→
1 2 3 4 5 6 7 8 9

Descending

3 2 1

←
1 2 3 4 5 6 7 8 9

5 3 1

←
1 2 3 4 5 6 7 8 9

Vos et al. (2017)

Ascending

Consecutive	1 2 3	4 5 6	5 6 7
	2 3 4	3 4 5	
	6 7 8	7 8 9	

Non-consecutive	1 3 5	4 6 8	3 6 9
	2 4 6	5 7 9	
	3 5 7	2 5 8	

Descending

Consecutive	3 2 1	6 5 4	7 6 5
	4 3 2	5 4 3	
	8 7 6	9 8 7	

Non-consecutive	5 3 1	8 6 4	9 6 3
	6 4 2	9 7 5	
	7 5 3	8 5 2	

Vos et al. (2017)

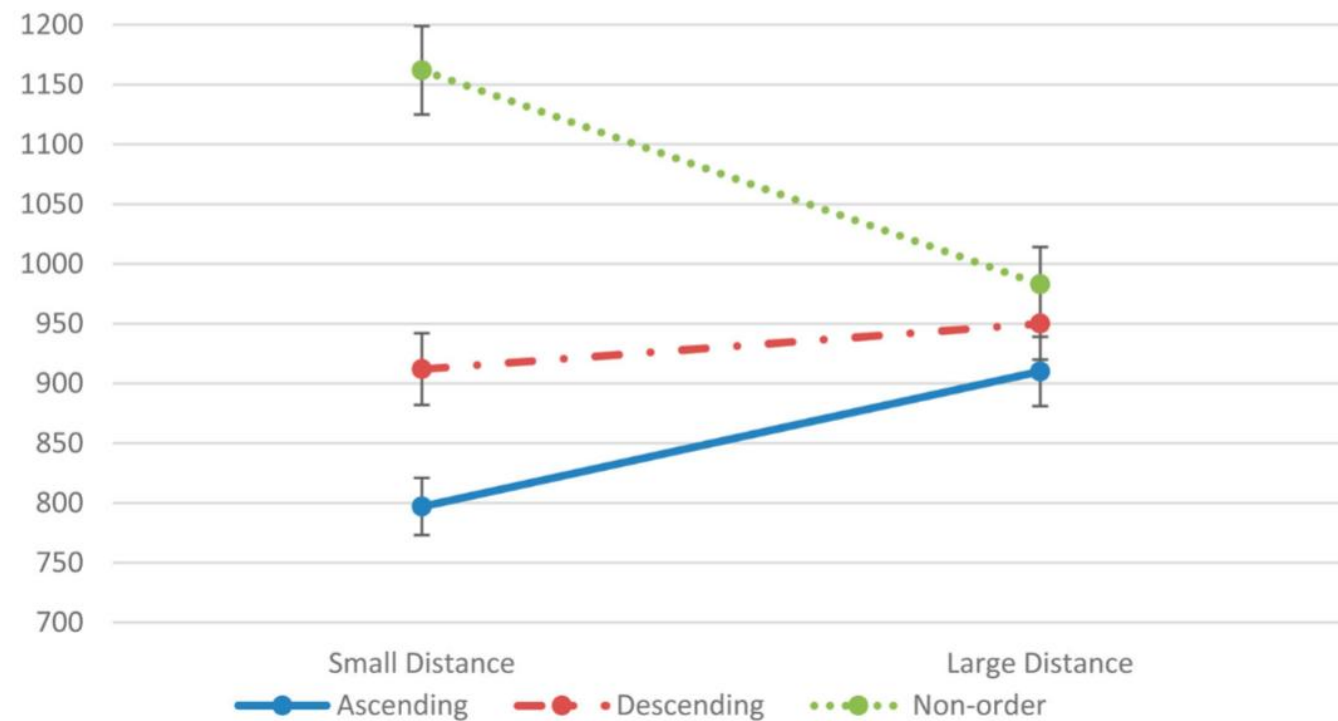


Figure 1. Median reaction times across the conditions of the order task with digits (Experiment 1). [To view this figure in color, please see the online version of this journal.]

(Vos et al., 2017)

Strategy use

Dubinkina et al. (2021)

Memory retrieval was the most commonly self-reported strategy, especially for familiar sequence types:

	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

(Dubinkina et al., 2021)

Association with arithmetic

Association with arithmetic



(e.g., [Sasanguie & Vos, 2018](#))

Association with arithmetic

- ❖ Memory-retrieval strategies also during arithmetic, in particular problems involving smaller numbers (e.g., [Ashcraft, 1992](#); [Grabner et al., 2009](#); [LeFevre et al., 1996](#)).
- ❖ Performance on smaller arithmetic problems showed a stronger association w/ order processing in participants who showed a RDE ([Vogel et al., 2021](#)).
- ❖ In fact, [Dubinkina et al. \(2021\)](#) found the association b/w order processing and arithmetic only remained significant for the specific order trials for which memory-retrieval strategies were reported.

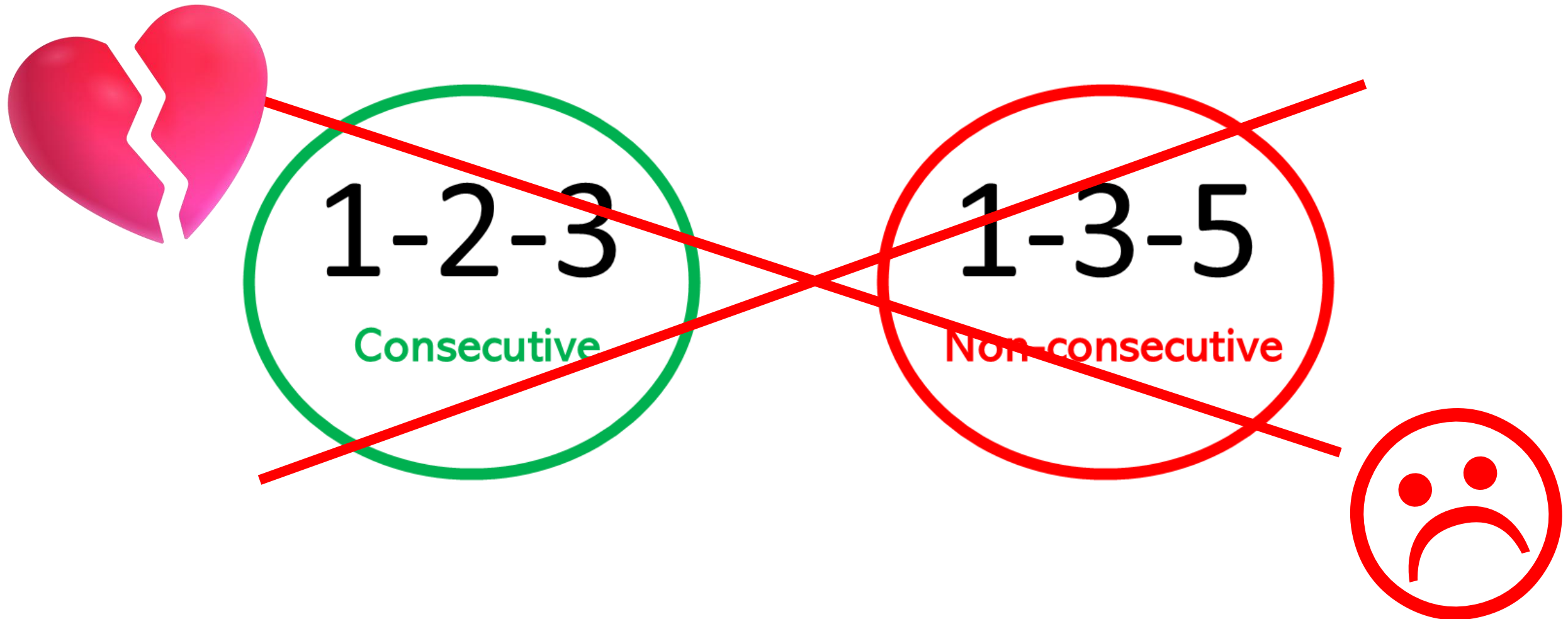
Association with arithmetic



These findings suggest both that i) memory-retrieval mechanisms underlie order processing, but also that ii) this memory-retrieval aspect of order processing likely drives its association with arithmetic.

However...

Instability of the RDE



Instability of the RDE

Individual level

- ❖ No RDEs in majority of first graders and approximately half of second graders (Sasanguie & Vos, 2018).
- ❖ RDEs observed in less than half of adults (Vogel et al., 2021).

Group level

- ❖ Vos and colleagues (2021) repeatedly failed to observe RDEs when using an order

**Any mechanism proposed to explain the presence of the reverse distance effect
should also be able to explain its absences!**

Familiarity explanation

Familiarity explanation

~~“Consecutive sequences should be processed faster than
non consecutive sequences”~~

“Familiar sequences should be processed faster than
unfamiliar sequences”

Familiarity explanation

Consecutive

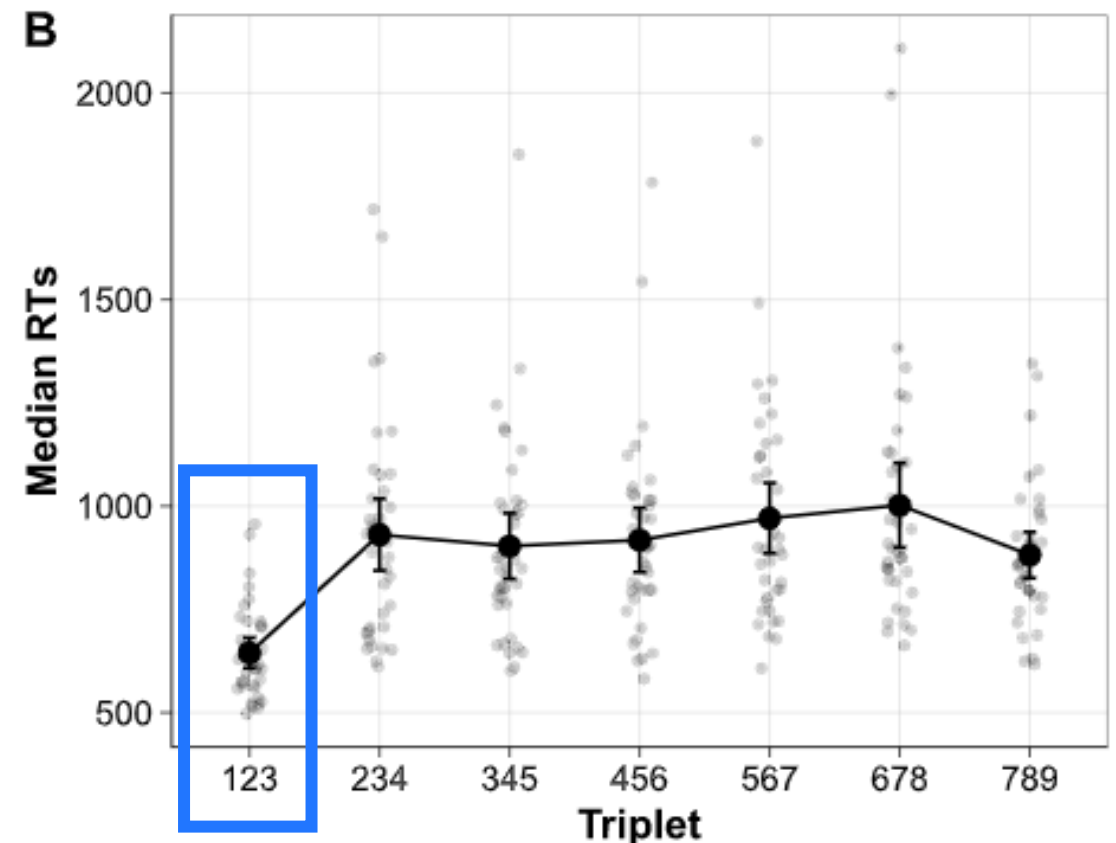
1 2 3 4 5 6 5 6 7
2 3 4 3 4 5
6 7 8 7 8 9

Non-consecutive

1 3 5 4 6 8 3 6 9
2 4 6 5 7 9
3 5 7 2 5 8

Sella et al. (2020)

Familiarity may vary within ascending-consecutive sequences, as some are processed faster than others (i.e., 1-2-3).



(Sella et al., 2020)

Dubinkina et al. (2021)

	MEMORY (%)	DECOMPOSITION (%)	ARITHMETIC (%)	OTHER (%)
AC	70.68	18.55	8.77	2.01
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DnC	44.09	38.22	14.70	2.89

(Dubinkina et al., 2021)

Group-level absences of the RDE: Vos et al. (2021)

Consecutive

~~1 2 3~~ 4 5 6 5 6 7

Reverse distance effects were present when 1-2-3 and 2-3-4 were included, but not when 1-2-3 and 2-3-4 were excluded (Vellán & LeFevre, MCLS 2023).

0 7 8 7 8 9

One should only expect to observe a reverse distance effect when the included consecutive sequences are more familiar than the included non-consecutive sequences

(Devlin et al., 2022; Vos et al., 2021).

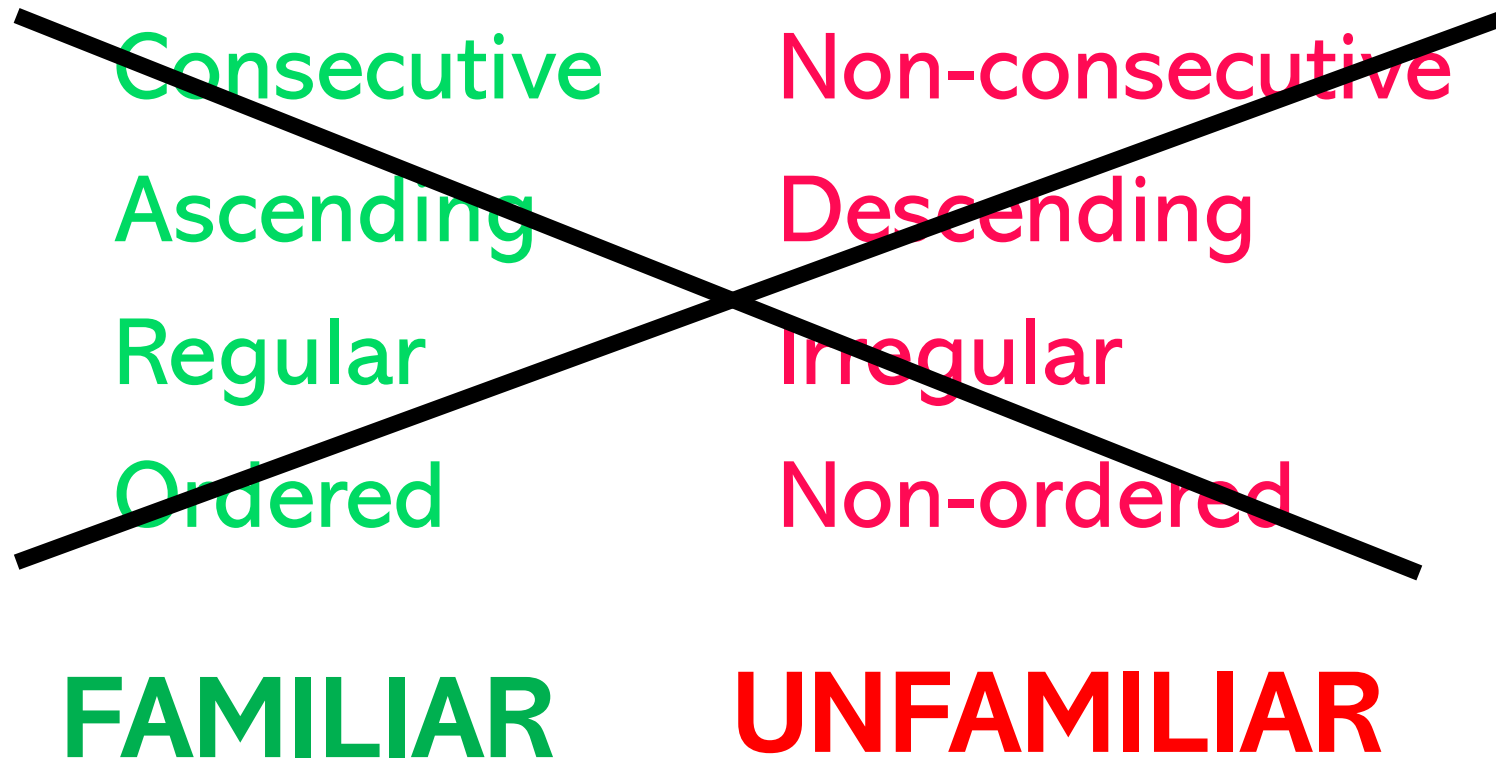
3 5 7 2 5 8

Individual absences of the RDE

~~“Consecutive sequences should be processed faster than
non consecutive sequences”~~

“Familiar sequences should be processed faster than
unfamiliar sequences”

Measuring familiarity



One more problem...

Familiarity vs. count-list explanations

Familiarity explanation



Count-list explanation



The count-list explanation of the RDE

We may have an intuition that “in order” refers only to sequences that directly match the count-list:

1-2-3
In order!

1-3-5
?????

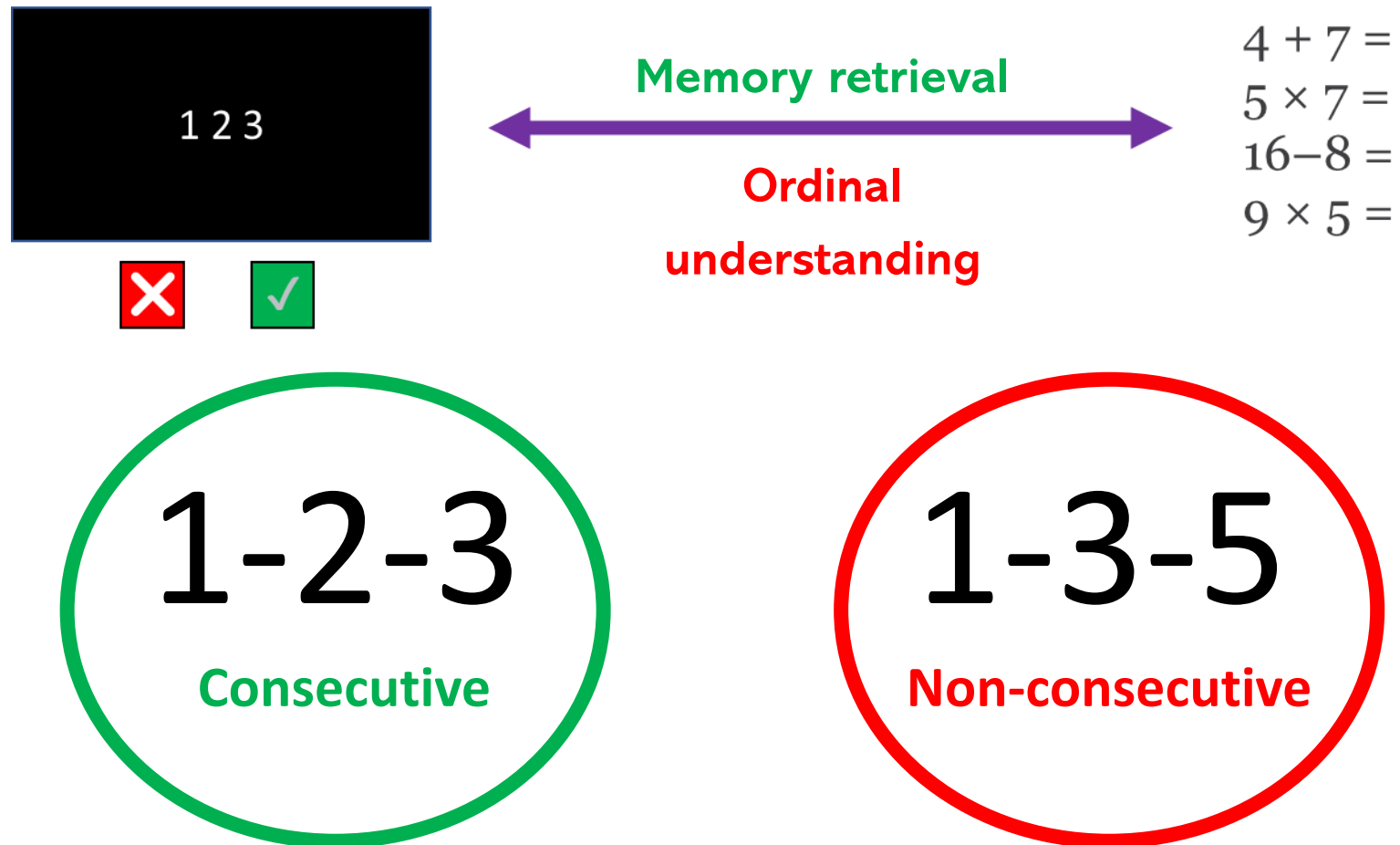
Perhaps analogous to the natural number bias:

$\frac{1}{3}$

$\frac{1}{2}$

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

Why is this important?



Familiarity vs. count-list explanations

Consecutive
(Count-list)

Consecutive	1 2 3 4 5 6 5 6 7
	2 3 4 3 4 5
	6 7 8 7 8 9

Non-consecutive	1 3 5 4 6 8 3 6 9
	2 4 6 5 7 9
	3 5 7 2 5 8

Non-consecutive
(Non-count-list)

2 4 6
3 6 9

The present study

Aims/RQs (1/2)

#1 Develop a reliable/valid measure of individual sequence familiarity

- Are more familiar sequences processed faster than less familiar sequences?
- Does familiarity explain unique variance in RTs beyond the effects of distance and direction?

#2 Test the familiarity explanation for the instability of the RDE

- Do people who do not show a RDE still process familiar sequences faster than unfamiliar sequences?

Aims/RQs (2/2)

#3 Differentiating between count-list and familiarity explanations of the RDE

- Are familiar non-consecutive sequences (e.g., 2-4-6) facilitated due to being familiar or inhibited due to not matching the count-list?

#4 Does memory-retrieval drive the association b/w order processing and arithmetic?

- Do RTs for familiar sequences show a stronger association with arithmetic fluency than RTs for unfamiliar sequences?

Method

Tasks

Comparative judgement

Left Which is more familiar? Right

1 2 3 1 3 5

Order verification

1 2 3

Arithmetic (TTR)



$4 + 7 =$
 $5 \times 7 =$
 $16 - 8 =$
 $9 \times 5 =$

N = 56

Mage = 22.30 years

Comparative judgement task

Left

1 2 3

Which is more familiar?

Right

1 3 5

N = 56

30 unique sequences

1 2 3

2 3 4

1 3 5

2 4 6

4 6 8

5 6 7

6 7 8

5 7 9

Most familiar



Least familiar

435 comparisons per participant

Total comparisons = 24,360

Order verification task

Order verification



Sixty unique sequences:

- 30 ordered, 30 non-ordered.
- Half ascending, half descending
- Distances 1, 2, and 3.

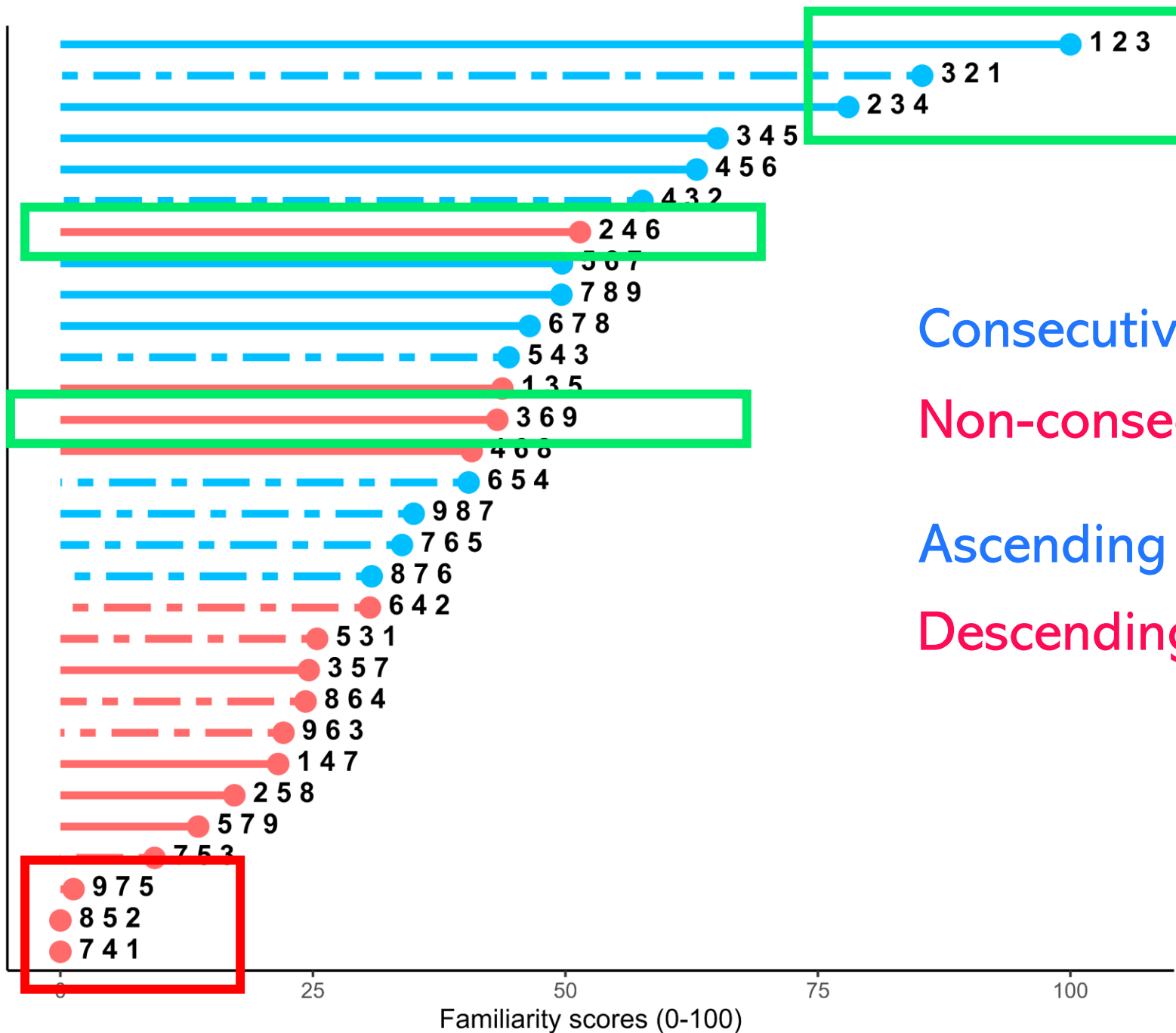
600 total trials:

- Each sequence presented 10 times
- Five blocks of 120 trials

Arithmetic (TTR-adapted)

	1		2		3		4		5	
	1+1=	_____	2-1=	_____	1x4=	_____	4:2=	_____	2+1=	_____
	2+1=	_____	3-2=	_____	2x2=	_____	5:1=	_____	2-1=	_____
	3+0=	_____	4-2=	_____	1x7=	_____	12:2=	_____	2x5=	_____
	4+1=	_____	3-0=	_____	0x5=	_____	15:3=	_____	4:2=	_____
	5	2+3=	_____	5-2=	_____	8x1=	_____	10:5=	_____	3+2=
	7+2=	_____	8-3=	_____	3x10=	_____	6:3=	_____	8-4=	_____
	3+5=	_____	6-0=	_____	2x9=	_____	20:2=	_____	9:3=	_____
	0+7=	_____	9-2=	_____	4x4=	_____	24:3=	_____	4x5=	_____
	2+5=	_____	7-5=	_____	5x8=	_____	36:6=	_____	7+2=	_____
	10	4+6=	_____	8-6=	_____	6x0=	_____	9:3=	_____	9-5=
	6+3=	_____	7-4=	_____	10x4=	_____	24:6=	_____	15:5=	_____
	4+3=	_____	8-7=	_____	3x3=	_____	18:2=	_____	3x9=	_____
	8+2=	_____	7-5=	_____	6x3=	_____	35:5=	_____	10-3=	_____
	3+6=	_____	8-3=	_____	7x3=	_____	27:9=	_____	5+4=	_____
	15	5+2=	_____	6-5=	_____	2x8=	_____	16:4=	_____	5x5=
	3+8=	_____	15-3=	_____	6x6=	_____	49:7=	_____	8+5=	_____

Results



N = 56
SSR = .997
IRR = .98

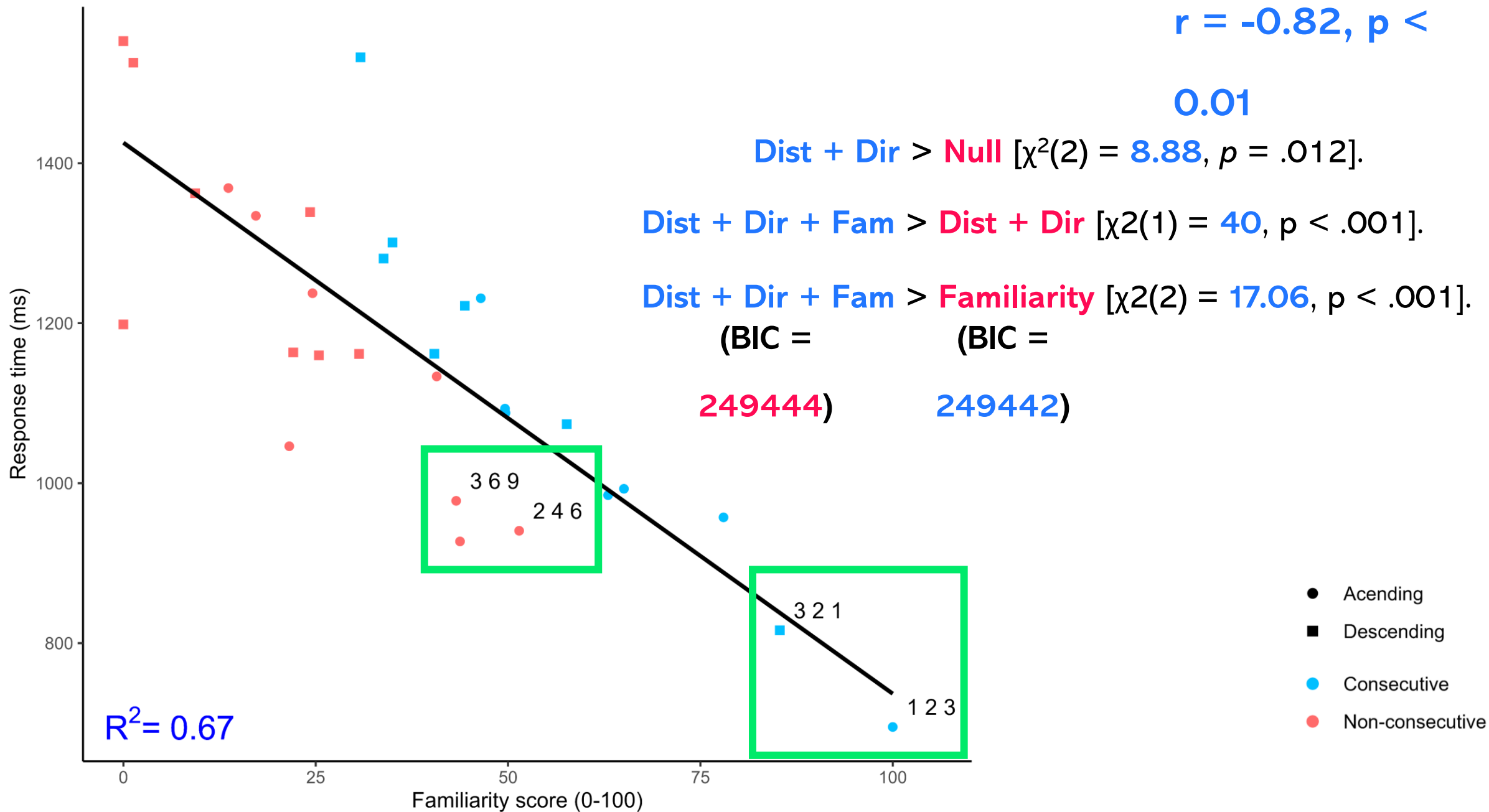
Consecutive = 55.65

Non-consecutive = 23.08

Ascending = 47.20

Descending = 29.36

Consecutive
Non-consecutive
Ascending
Descending



At the group level...

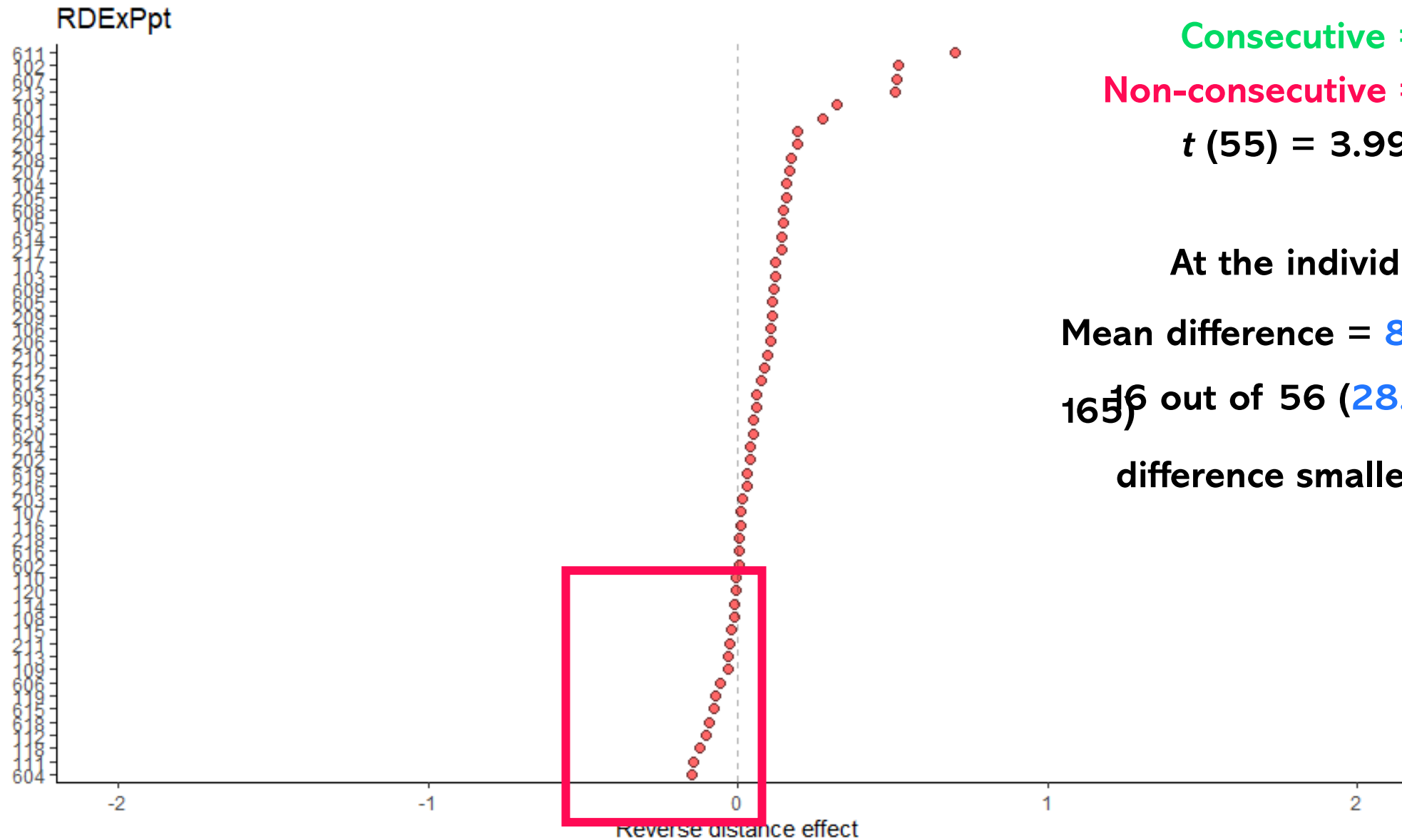
Consecutive = 1,056 ms

Non-consecutive = 1,144 ms

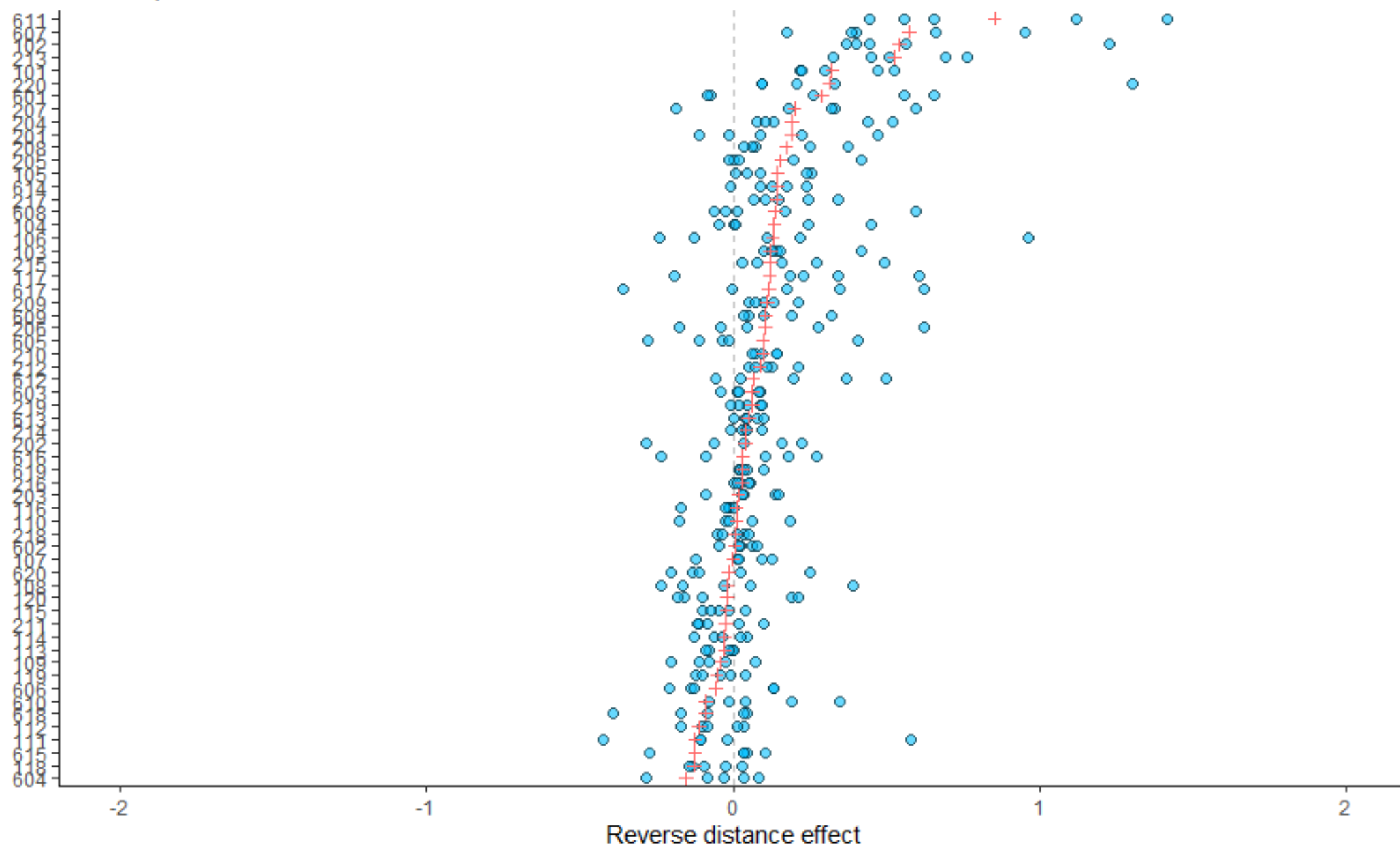
$t(55) = 3.99, p < .001$

At the individual level...

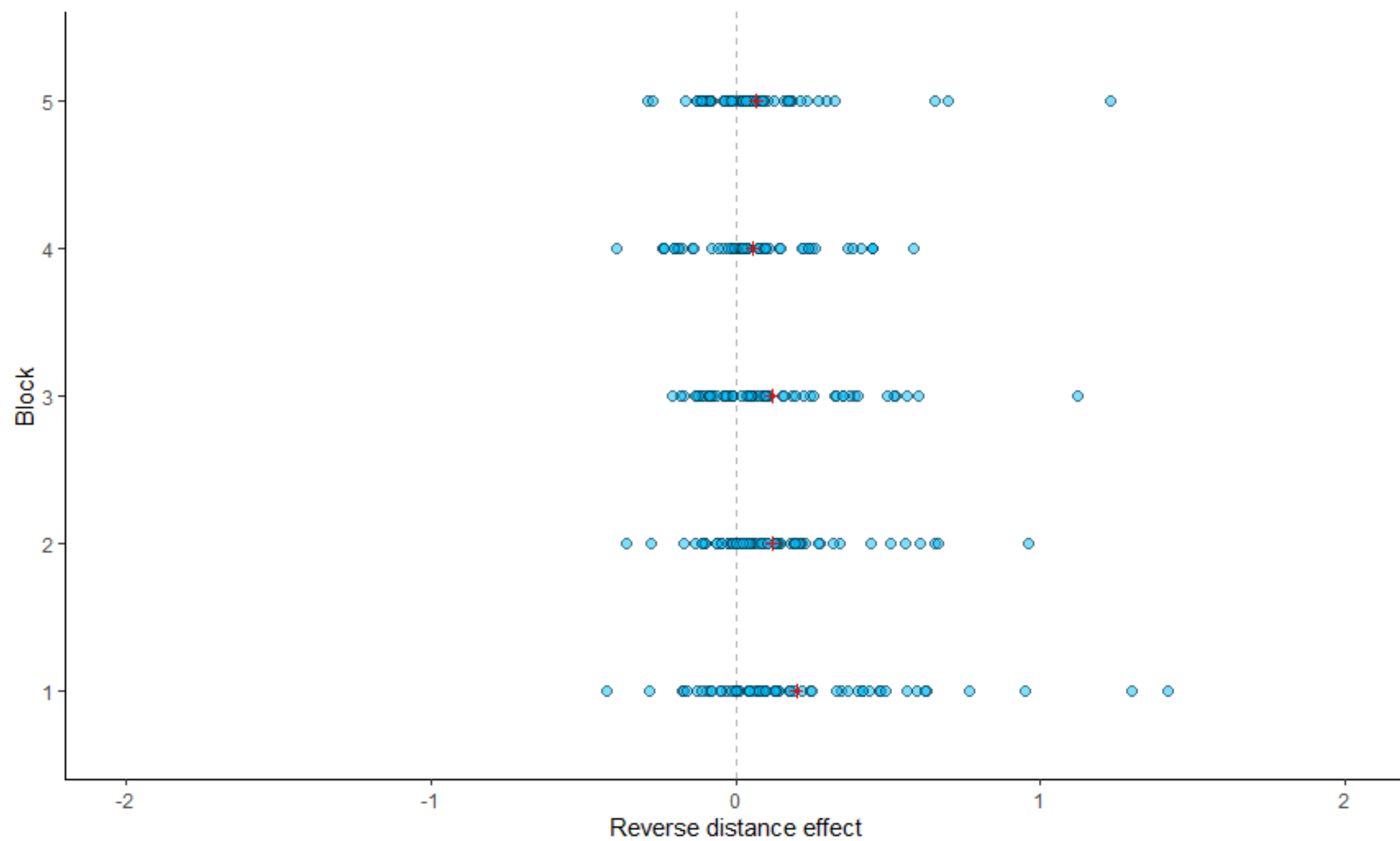
Mean difference = 88 ms ($SD = 165$)
16 out of 56 (28.57%) had a
difference smaller than 0 ms

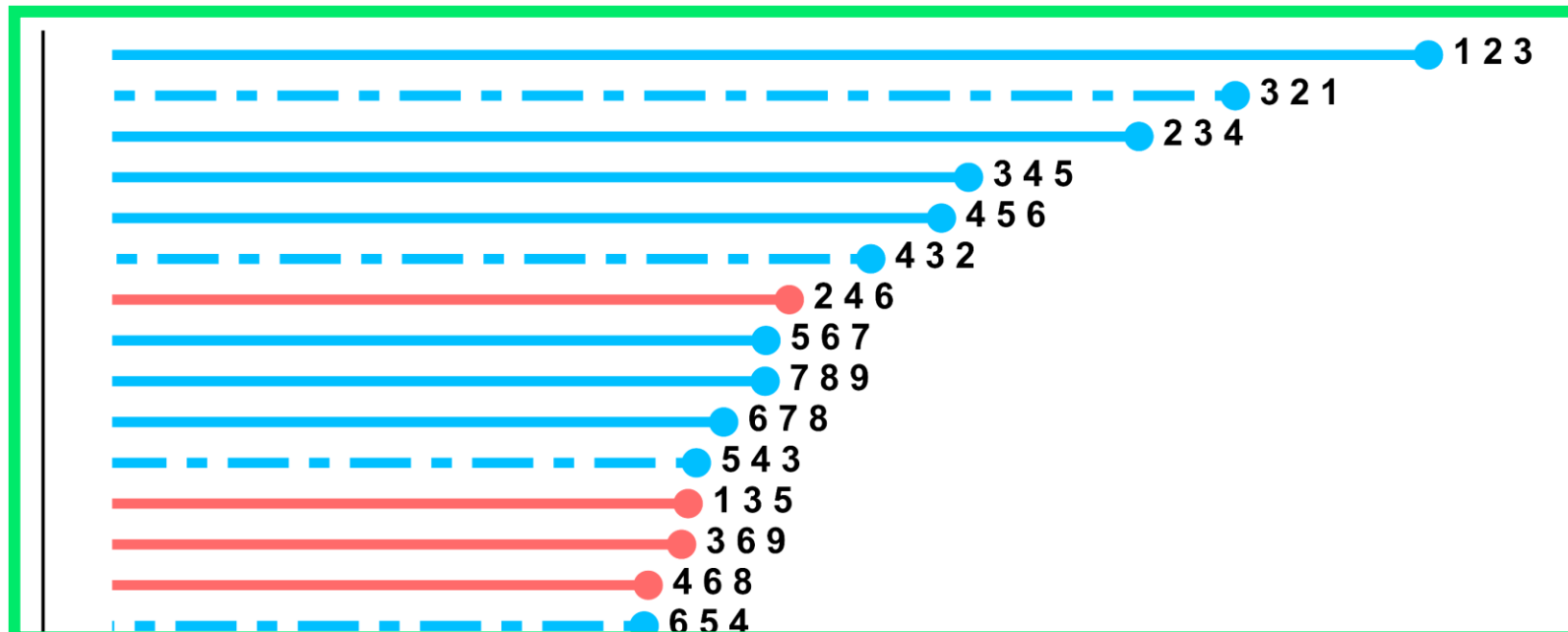


RDExPpt

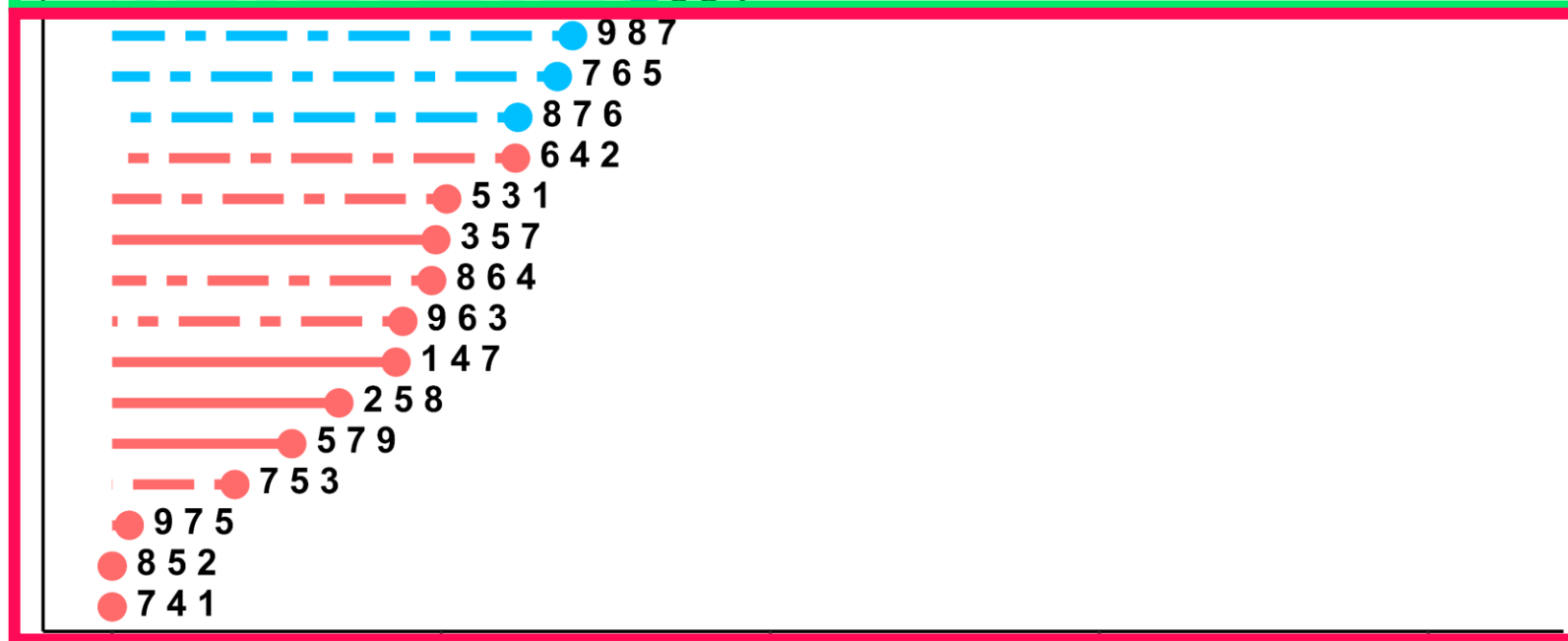


RDExBlock





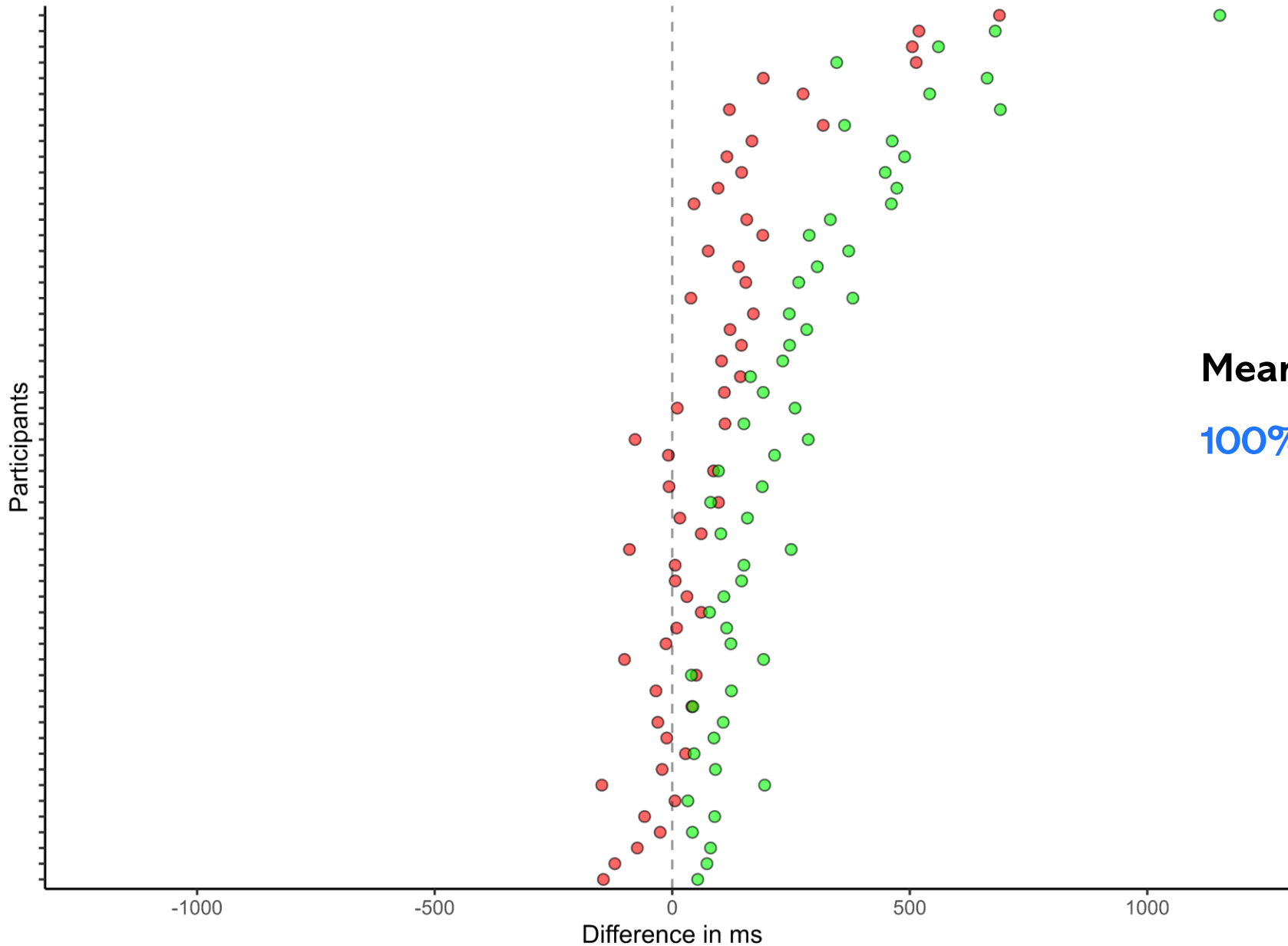
Familiar



Unfamiliar

0 25 50 75 100

Familiarity scores (0-100)



At the group level...

Familiar = 985 ms

Unfamiliar = 1,243 ms

$t(55) = 9.07, p < .001$

At the individual level...

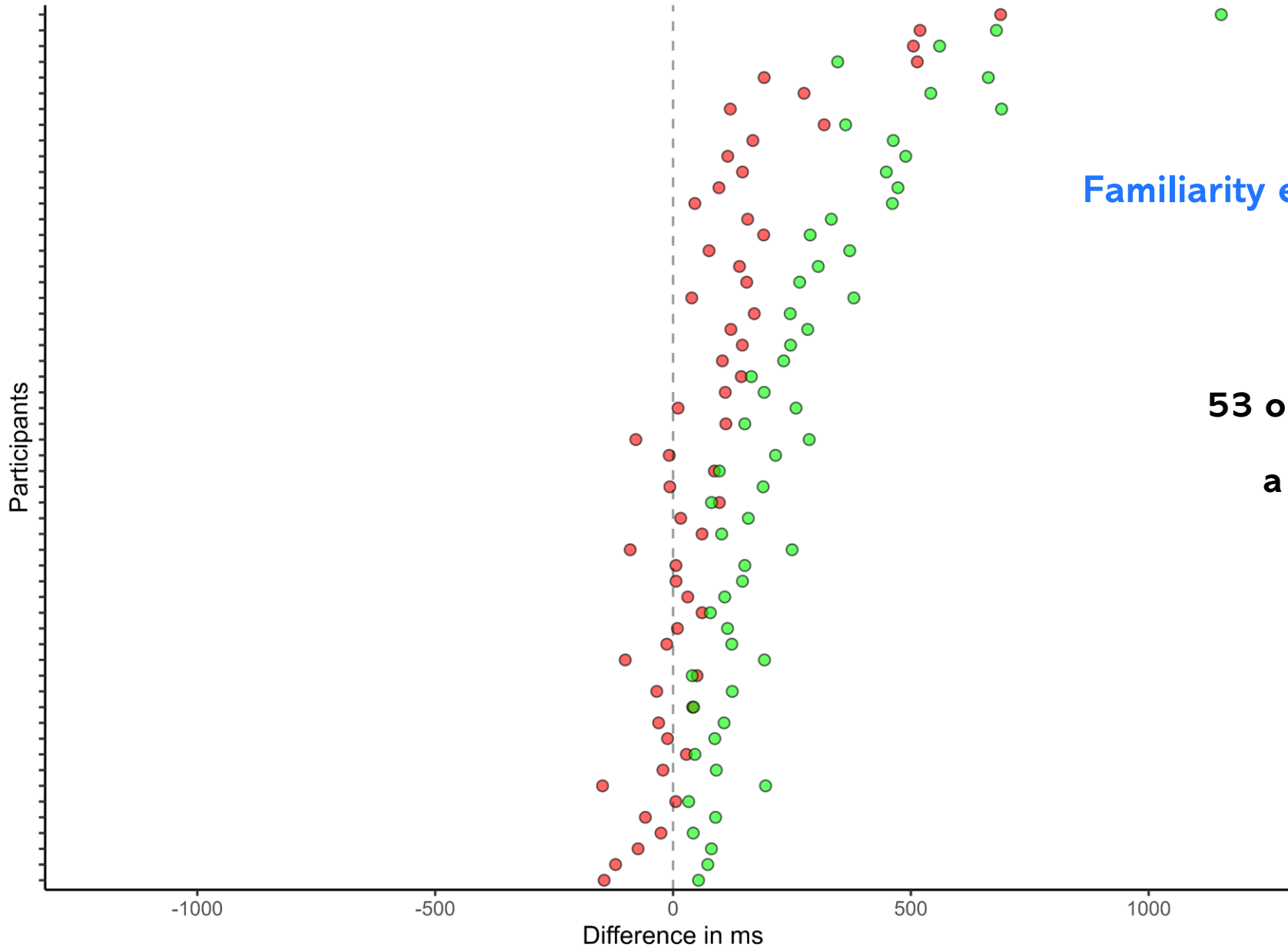
Mean difference = 258 ms ($SD = 213$)

100% had a difference larger than 0
ms

Effect

- Familiarity effect
- Reverse distance effect

Comparison between RDE and FE



At the group level...

Familiarity effect > RDE [$t(55) = 8.83$, $p < .001$]

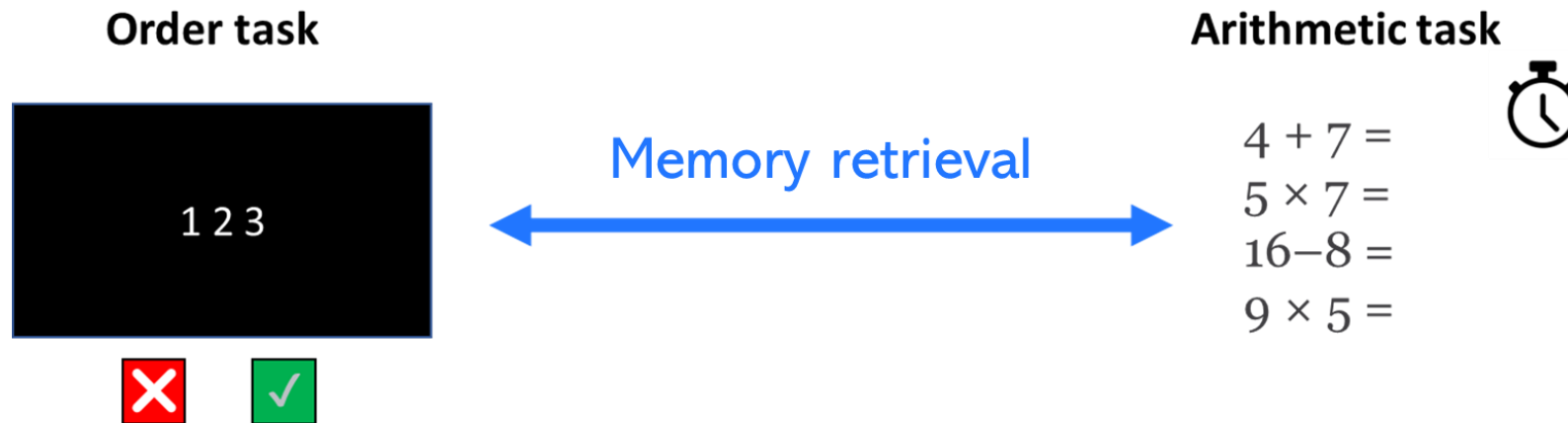
At the individual

level...
53 out of 56 (94.64%) displayed
a FE larger than their RDE.

Effect

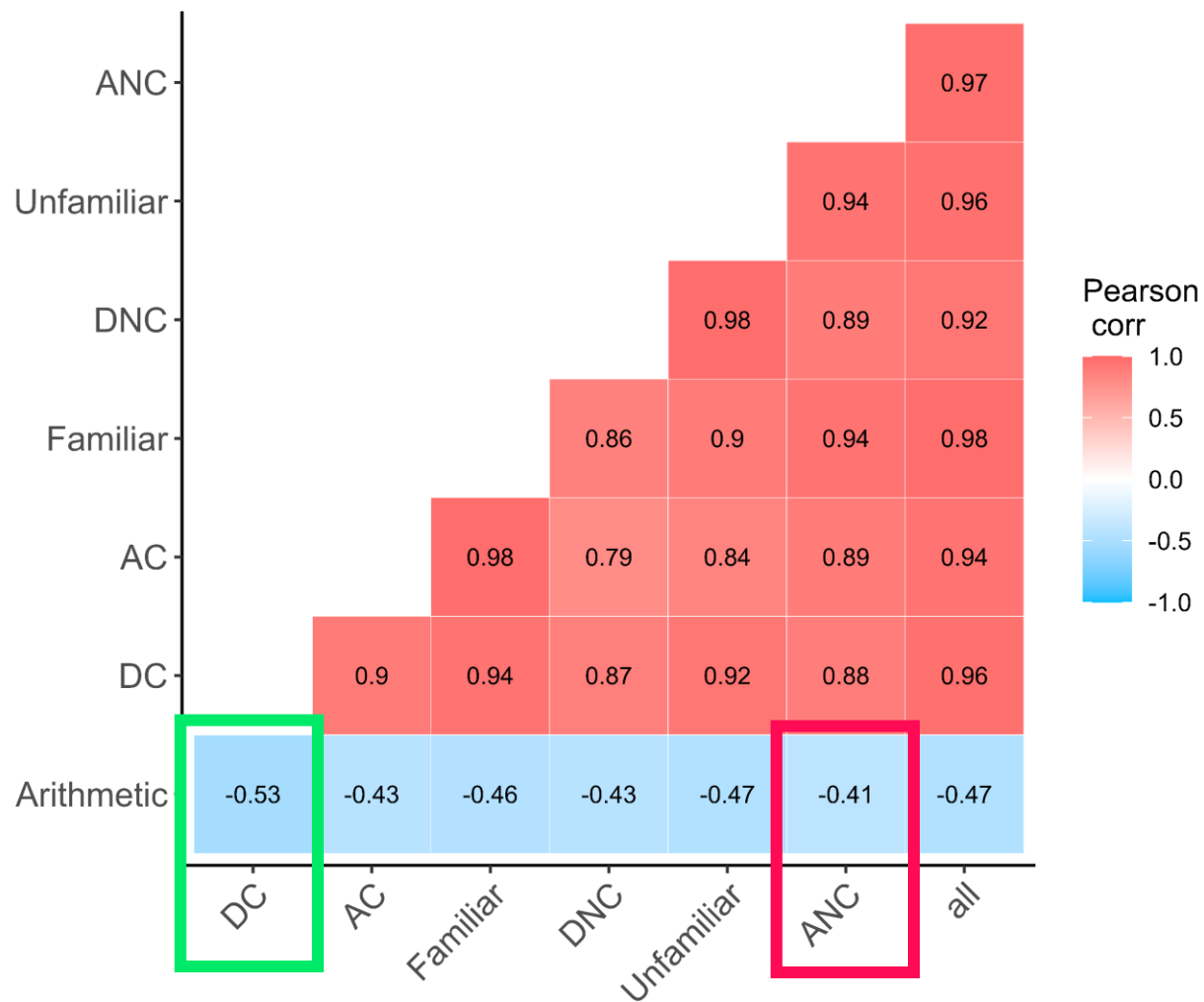
- Familiarity effect
- Reverse distance effect

RTs and Arithmetic scores



Familiar

Unfamiliar



*All displayed correlations are statistically significant ($p < .05$)

All sequences = -0.47

Familiar = -0.46

Unfamiliar = -0.47



Summary/conclusion

Aims/RQs (1/2)

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Effects in order processing

Reverse distance effect

Direction effect

Regularity effect

Ordered effect

**Familiarity
effect**

1 2 3 Count-list

2 4 6 Non-
consecutive

3 2 1 Descending

Order processing is characterised by a familiarity effect, not a (reverse) distance

effect! 😊

Thanks for your attention 😊