



NATIONAL RESEARCH  
UNIVERSITY

Vladislav Khvostov



**Part #1: Independent and parallel visual processing of ensemble statistics: Evidence from dual tasks**

**Part #2: Confidence intervals in within-subject designs**

Part #1



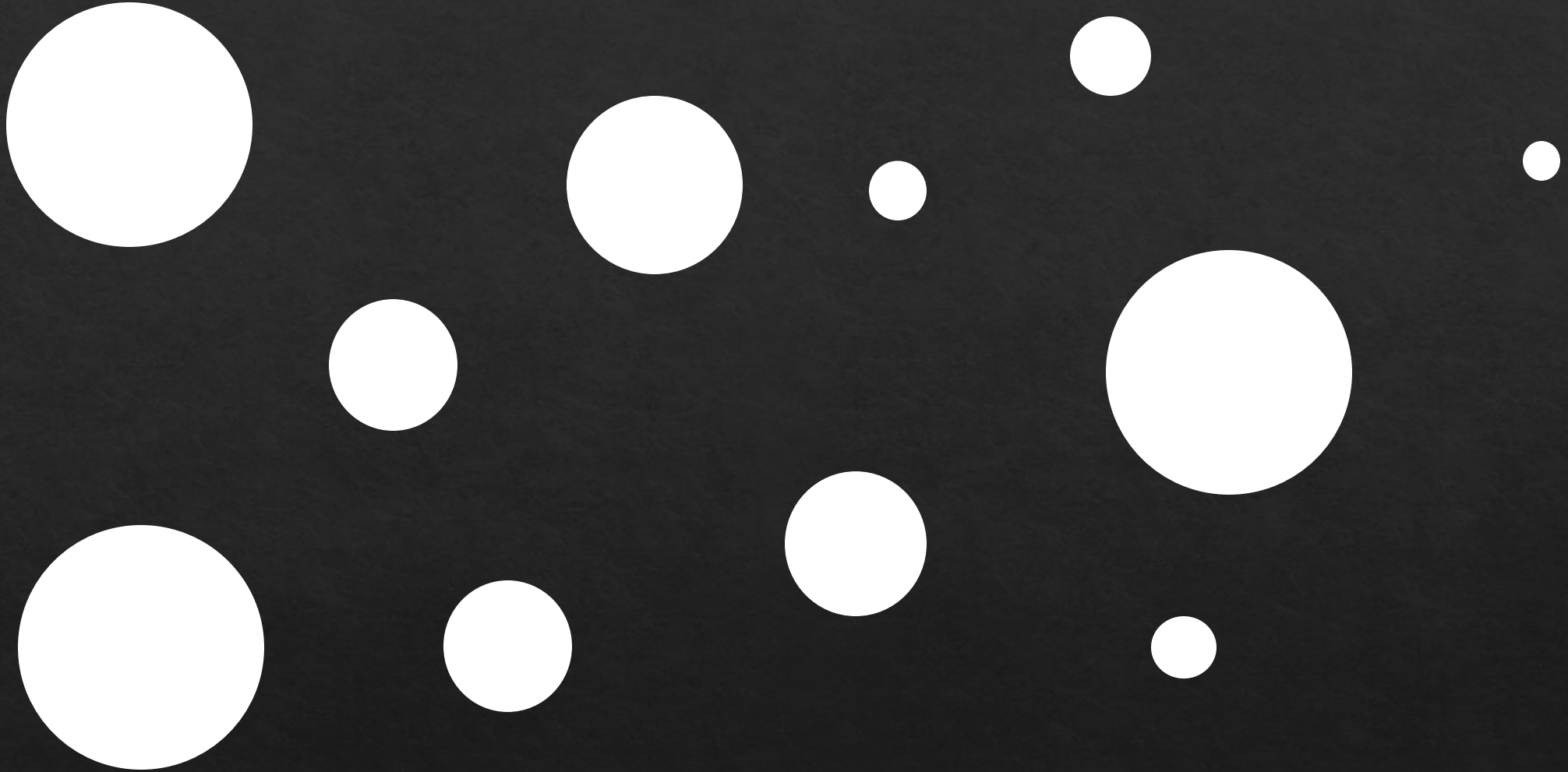
NATIONAL RESEARCH  
UNIVERSITY

# Independent and parallel visual processing of ensemble statistics: Evidence from dual tasks

spoiler

Vladislav Khvostov  
and Igor Utochkin

# An example



Greater or smaller than average?



# Ensemble summary statistics

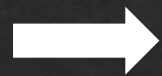
- ◇ The visual system can compute mean (Alvarez & Oliva, 2009), numerosity (Halberda, Sires, & Feigenson, 2006), variance/range (Dakin & Watt, 1997)
- ◇ Ensemble statistics can be calculated for low-level features:
  - color (Gardelle & Summerfield, 2011),
  - orientation (Parkes, Lund, Angelucci, Solomon, & Morgan, 2001),
  - size (Ariely, 2001),and for high-level features:
  - emotions, gender, etc. (Sweeny & Whitney, 2014, Haberman & Whitney, 2007, 2009).

# Independence

e

## Independent mechanisms

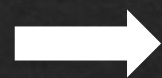
INPNH



MEAN



NUMEROSITY



RANGE

## One mechanism

INPNH



«GENERAL  
ENSEMBLE  
PROCESSOR»  
Mean, Numerosity,  
Range

# Correlational approach

## Independence

## Prediction

### Independent mechanisms



MEAN



NUMEROSITY



RANGE

Different sources of noise



**No correlation**  
between errors in reports of different statistics

### One mechanism



«GENERAL ENSEMBLE PROCESSOR»  
Mean, Numerosity, Range

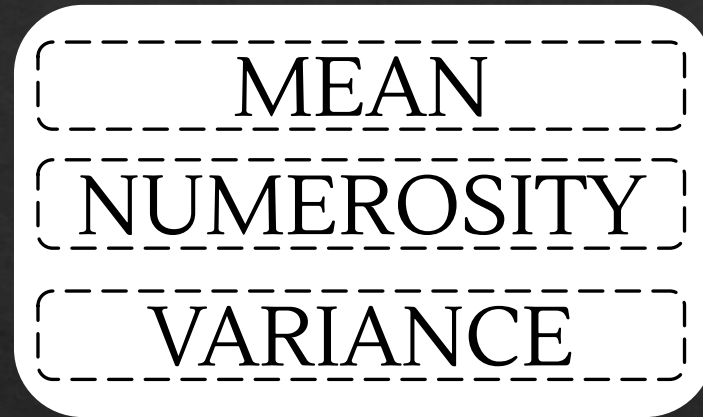
One source of noise



**Correlation**  
between errors in reports of different statistics

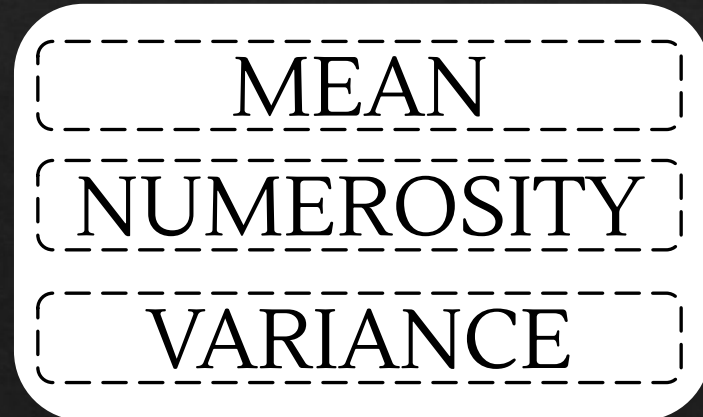
# Parallelism

Parallel  
access  
(no  
interference)



REPORT  
REPORT  
REPORT

**Non**-parallel  
access  
(interference)



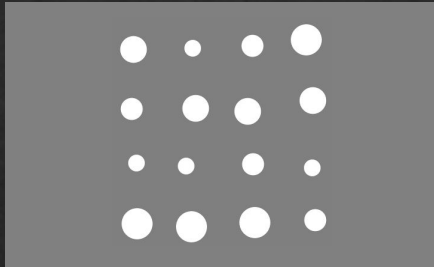
REPORT



# Parallelism test

## *Single task*

“Calculate MEAN”

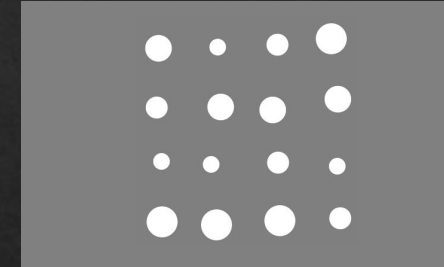


MEAN report

Observers should compute  
only one statistics

## *Dual task*

“Calculate MEAN and RANGE”



MEAN report



RANGE report

Observers should compute  
both statistics

# Parallelism test

Access

Prediction

Parallel access



No interference

**Error in single task = Error in dual task**

Non-parallel access



Interference

**Error in single task < Error in dual task**

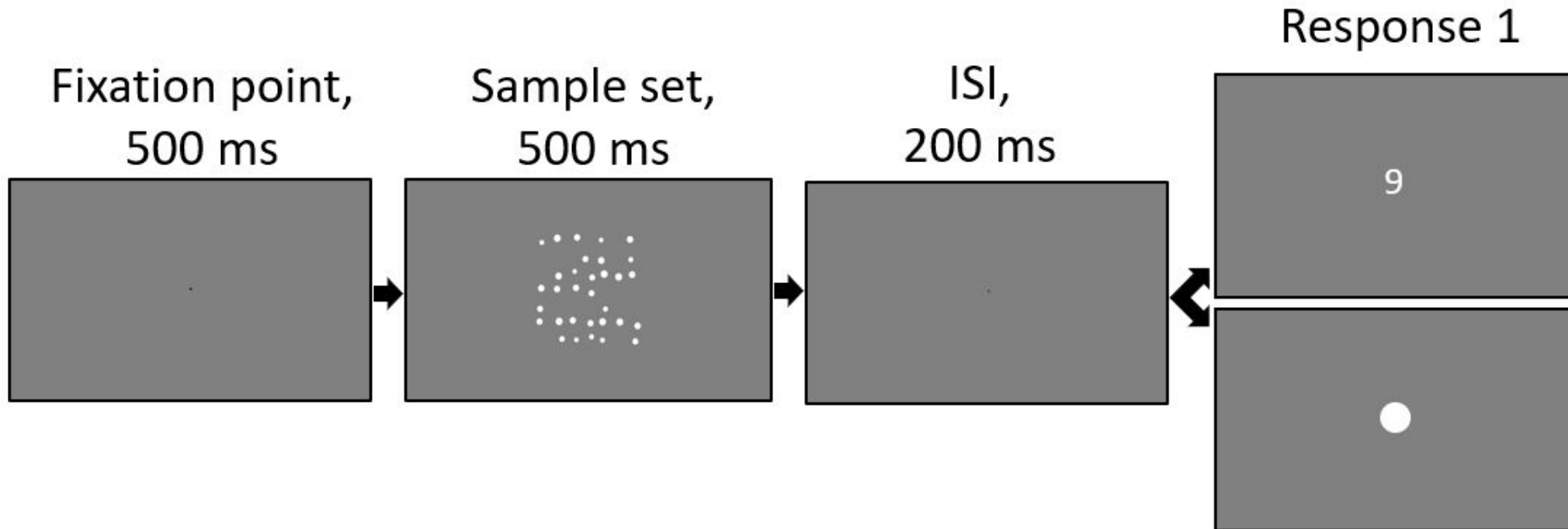
# Experiment 1

Whether mean and numerosity can be calculated independently and in parallel?

N=23

# Procedure

~~Baseline condition~~  
**2 blocks (MEAN-NUMBERSSY)**



# Design

3  
blocks

6 “variables”

MEAN

MEAN baseline

NIMEROSITY

NIMEROSITY baseline

BOTH

MEAN  
reported first  
NIMEROSITY  
reported first

MEAN reported  
second  
NIMEROSITY  
reported  
1

# Data analysis

$$\mathbf{Error} = \left| \frac{\text{observer's response} - \text{correct response}}{\text{correct response}} \right|$$

(1) Correlation between mean errors of 6 variables (across observers)

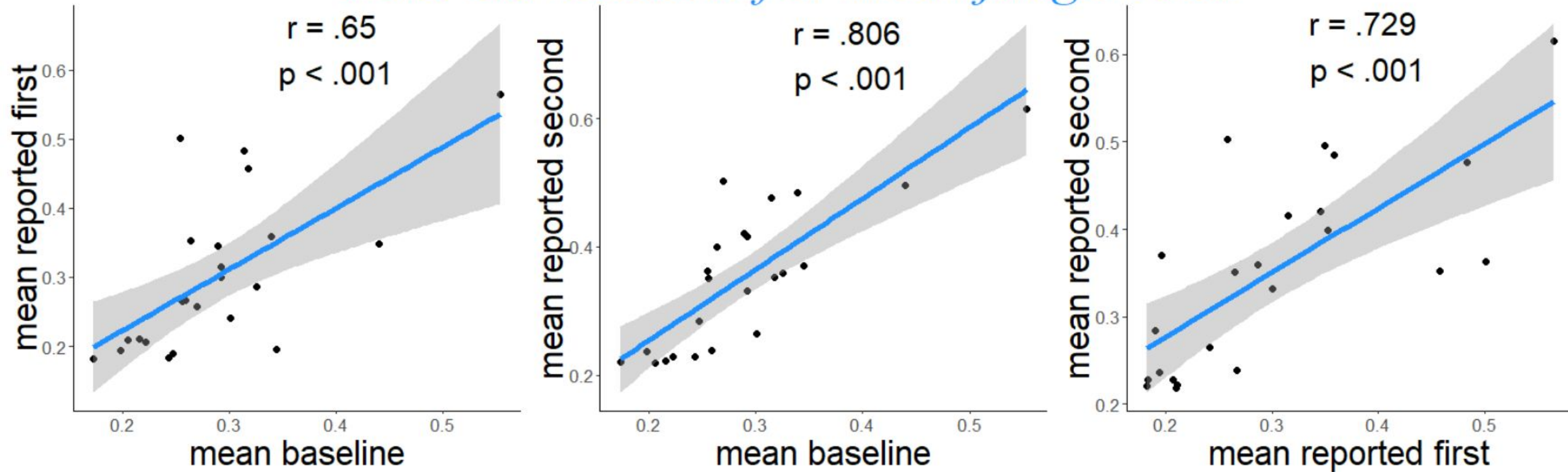
(2) Trial-by-trial correlation between an error in the mean judgment and an error in the numerosity judgment (separately for each participant)

(3) Comparison of mean errors in baseline and both conditions

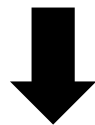
Independence

Parallelism

## *Auto-correlations for Mean judgements*

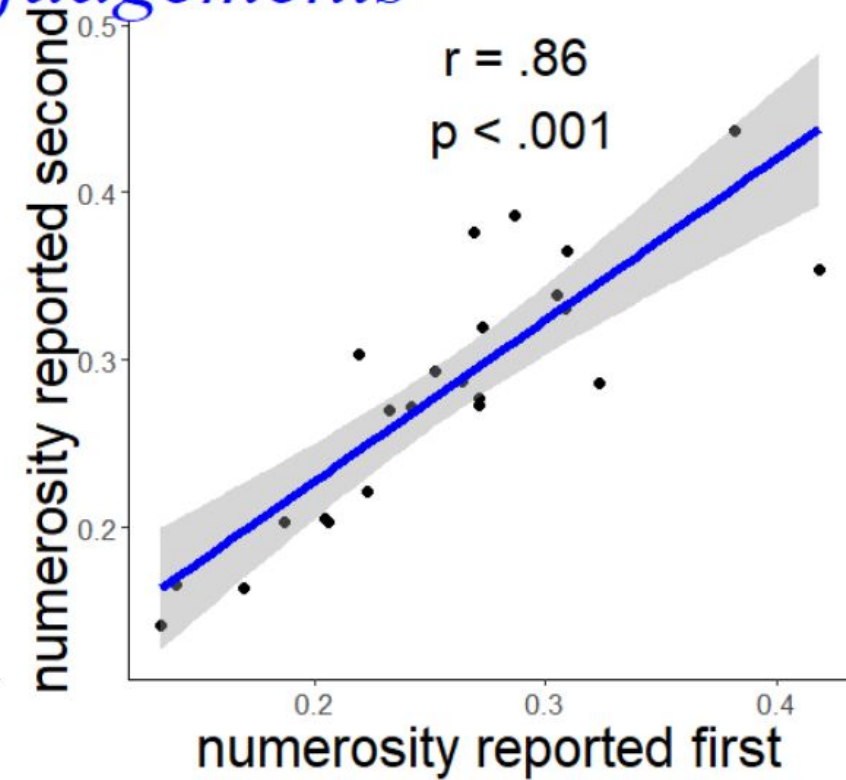
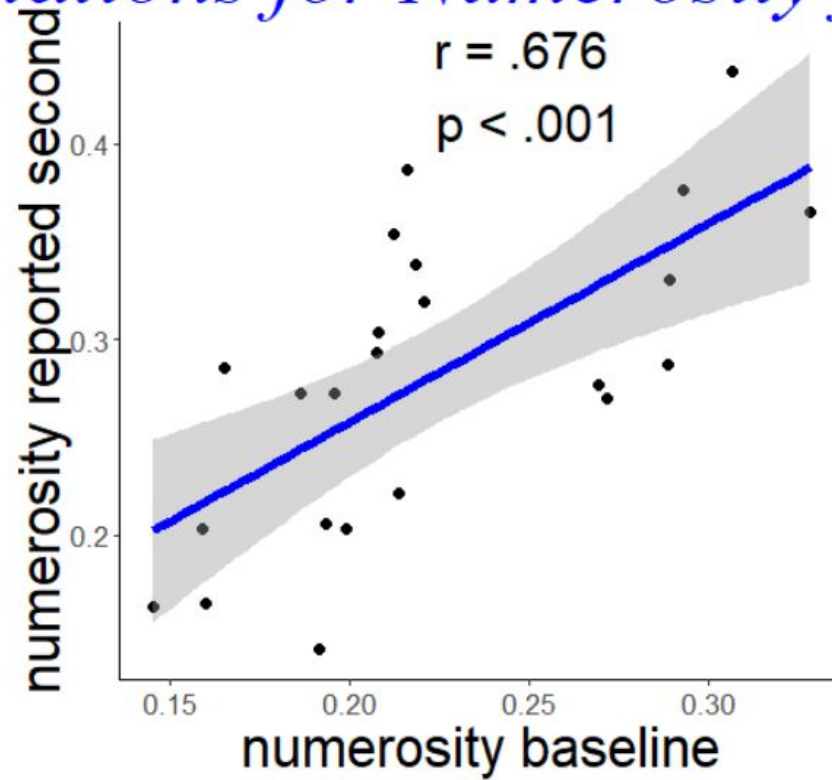
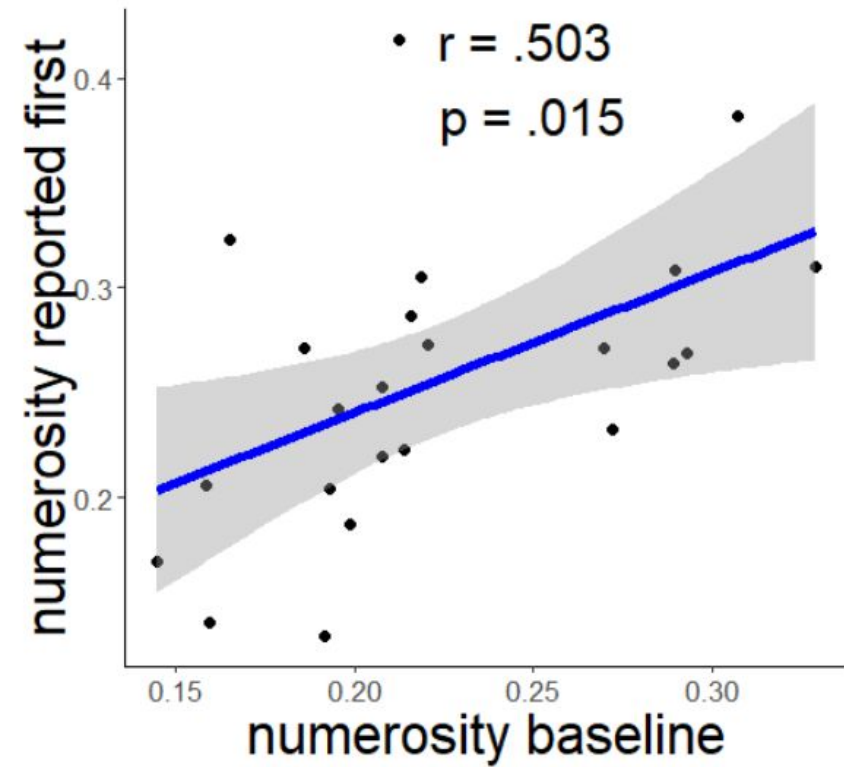


**Positive correlation** between errors in reporting  
MEAN in different conditions



Reliable measure of MEAN calculation across

# *Auto-correlations for Numerosity judgements*



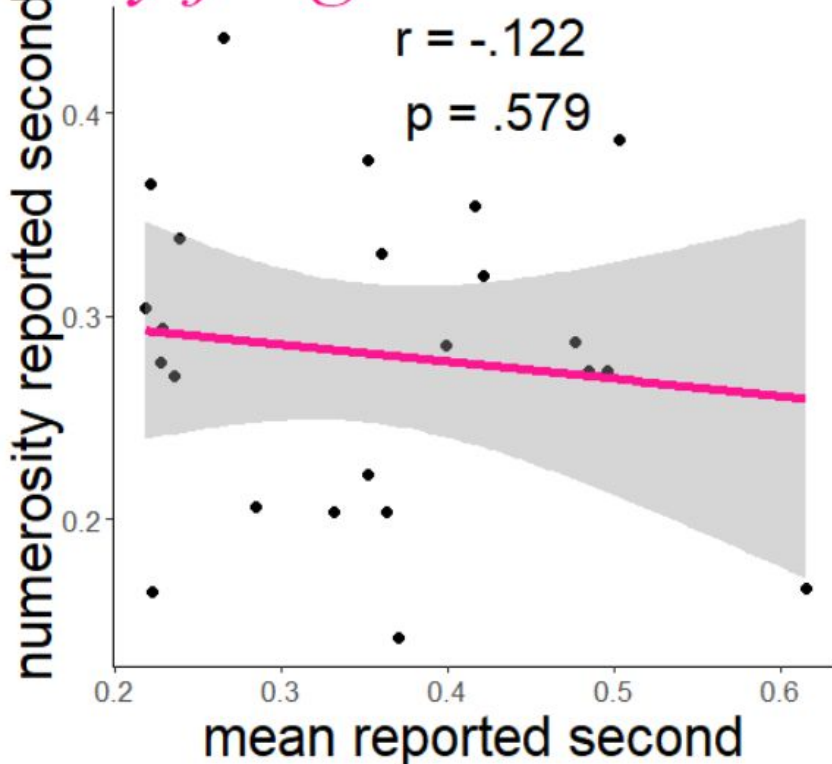
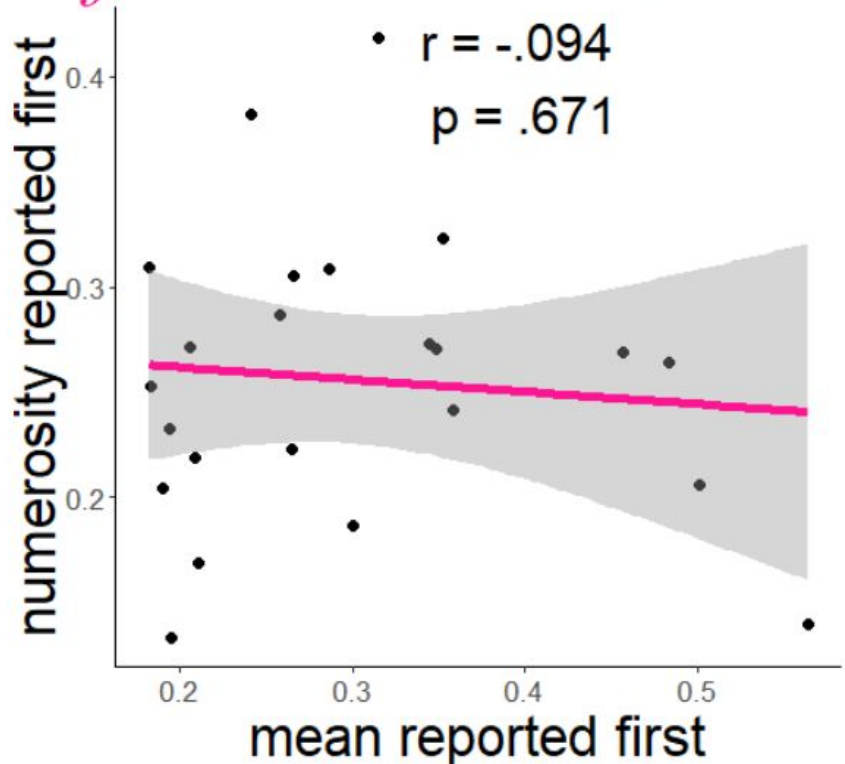
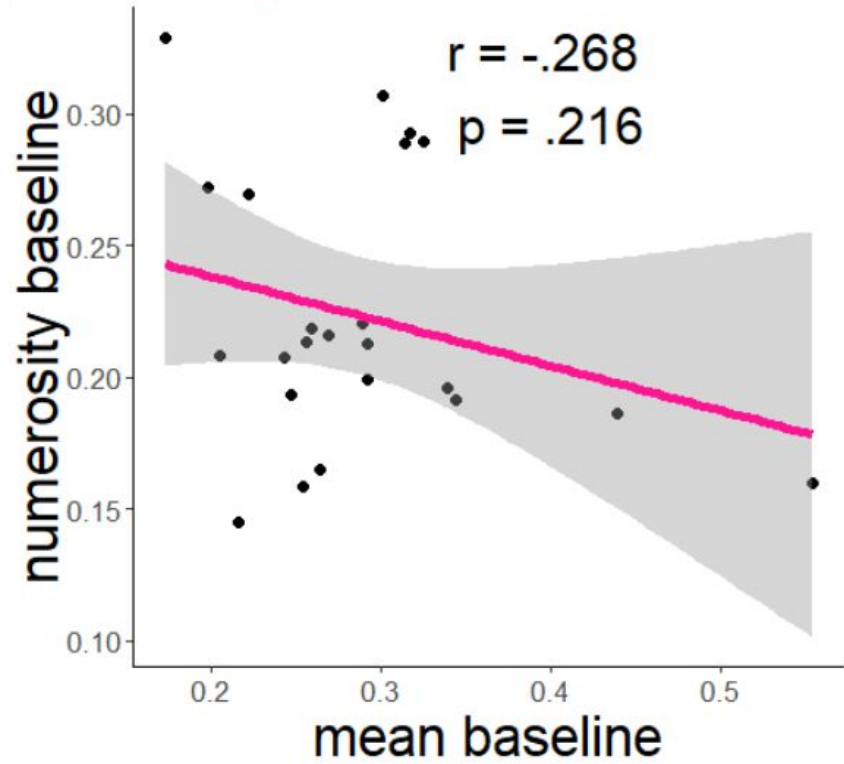
**Positive correlation** between errors in reporting  
NUMEROSITY in different conditions



Reliable measure of NUMEROSITY calculation across



# *Cross-correlations for Mean and Numerosity judgements*

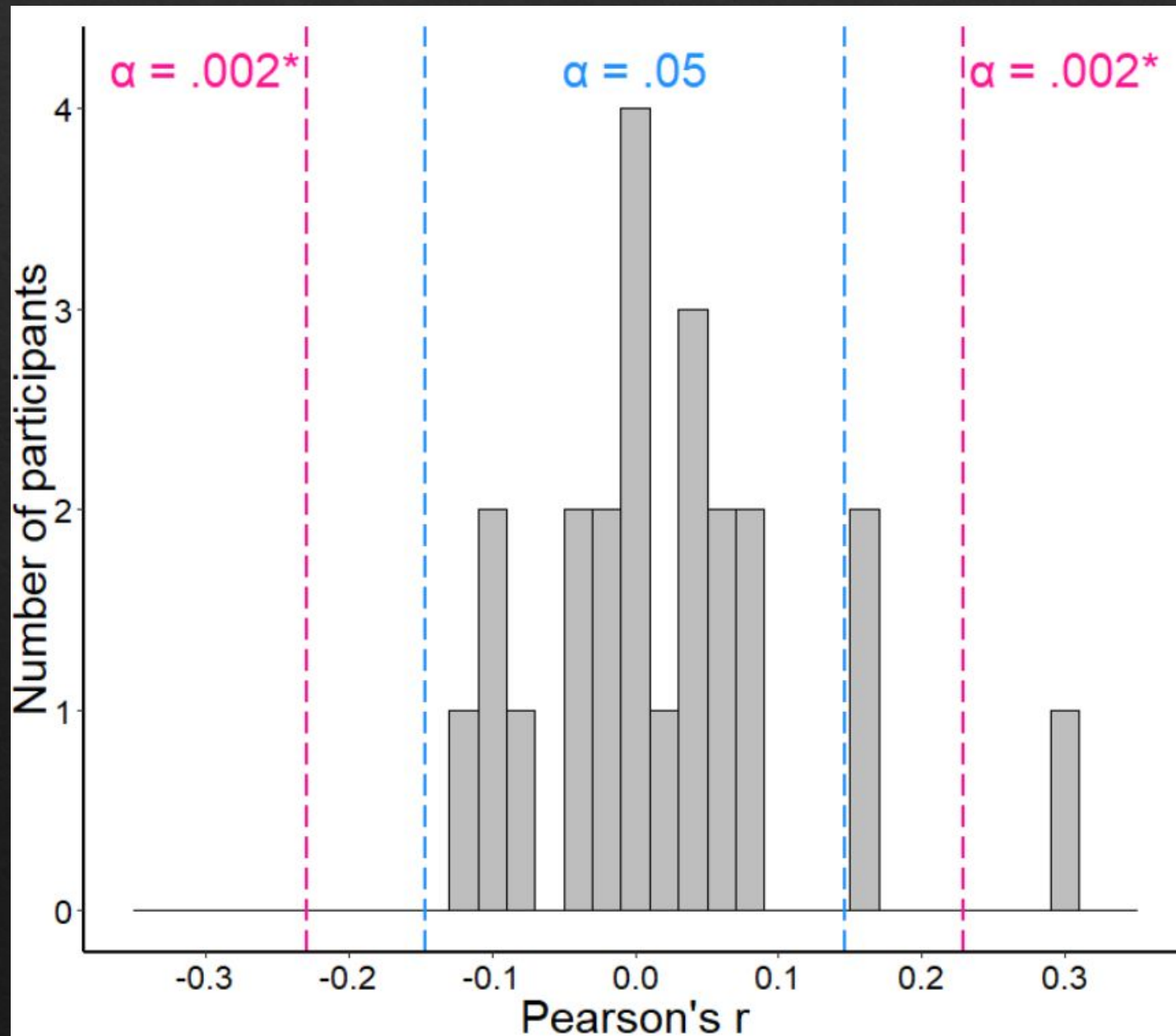


**No correlation** between errors in reporting different statistics



**Independence between MEAN and NUMEROSITY calculations**

# Individual correlations

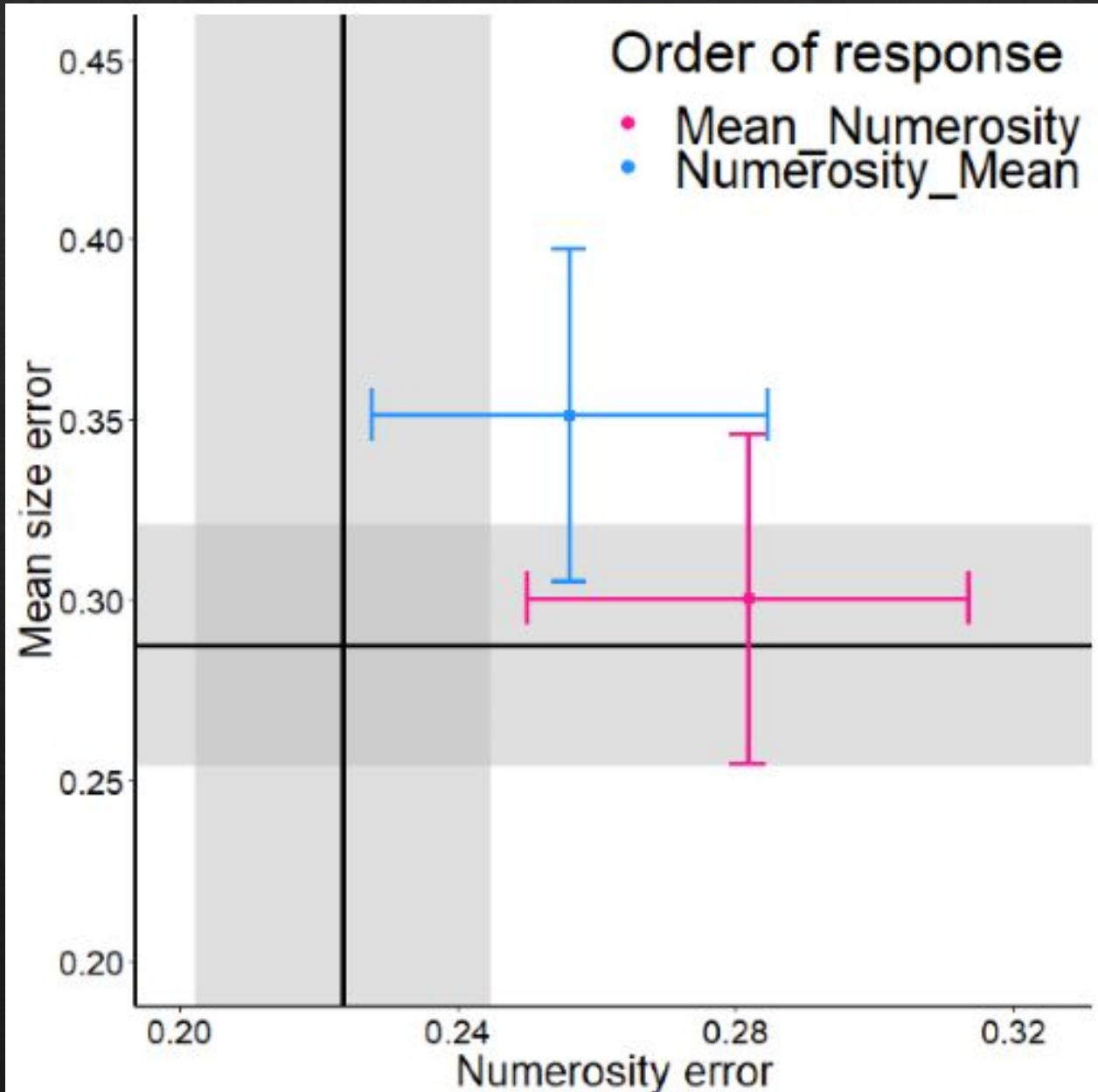


Only one participant showed significant correlation between raw errors in *both* condition



Independence between MEAN and NUMEROSITY calculations

# Average errors



**No difference** between mean errors in *baseline condition* and the first response in *both condition* (both for NIMEROSITY and MEAN).

# Conclusion

Mean and numerosity are calculated  
**independently and in parallel**

# Experiment 2

Whether mean and range can be calculated independently and in parallel?

$N=20$

# Procedure

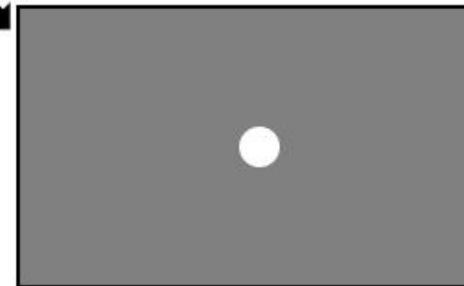
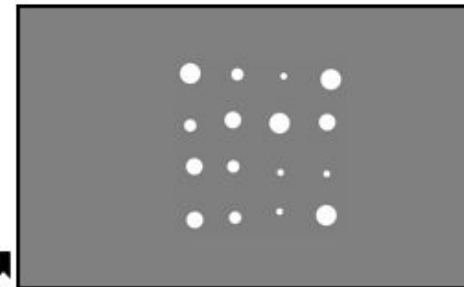
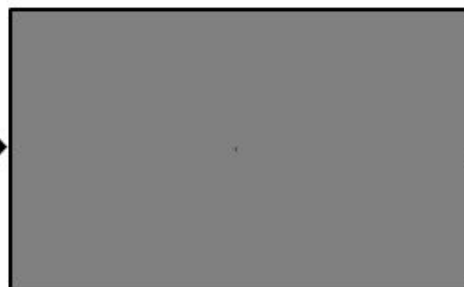
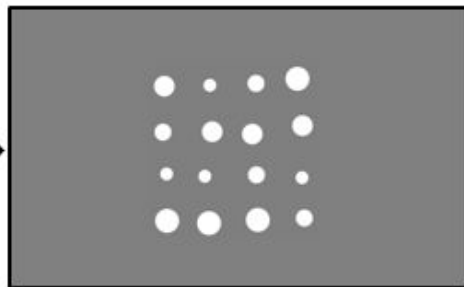
*Baseline condition*  
2 blocks (MEAN-RANGE)

Fixation point,  
500 ms

Sample set,  
500 ms

ISI,  
200 ms

Response 1



# Design

3  
blocks

6 “variables”

MEAN

MEAN baseline

RANGE

RANGE baseline

BOTH

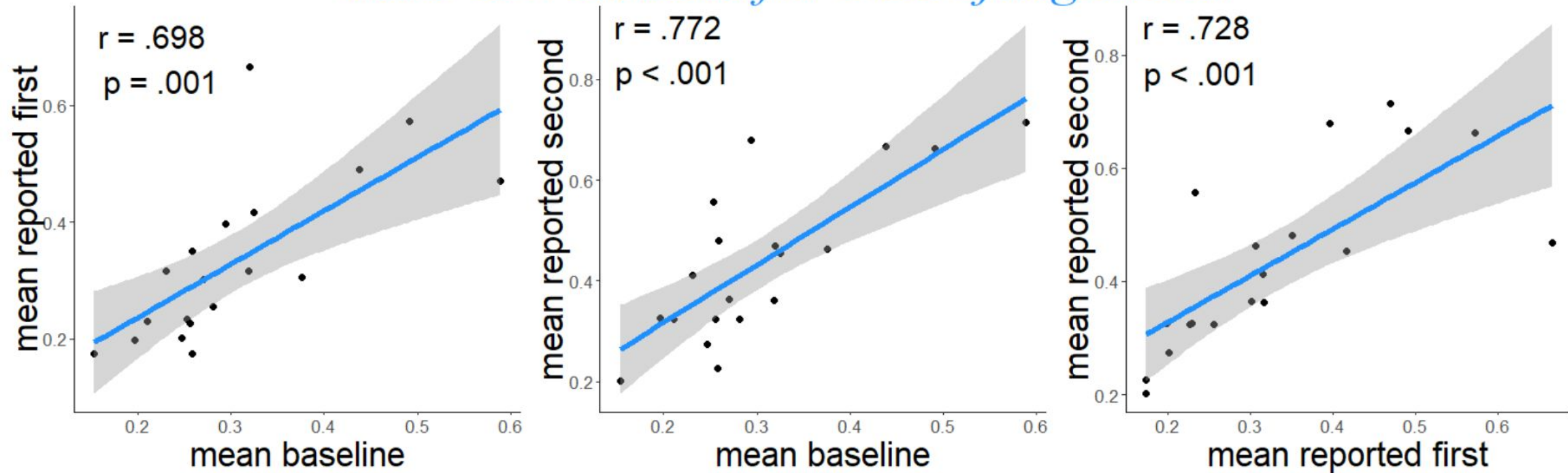
MEAN  
reported first

MEAN reported  
second

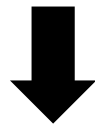
RANGE  
reported first

RANGE  
reported

## *Auto-correlations for Mean judgements*



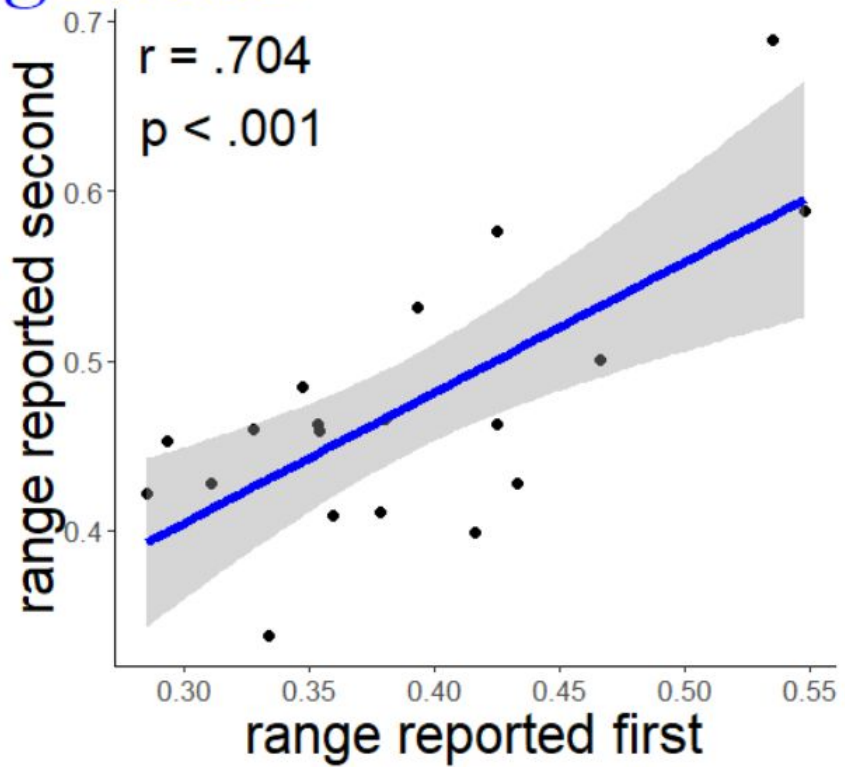
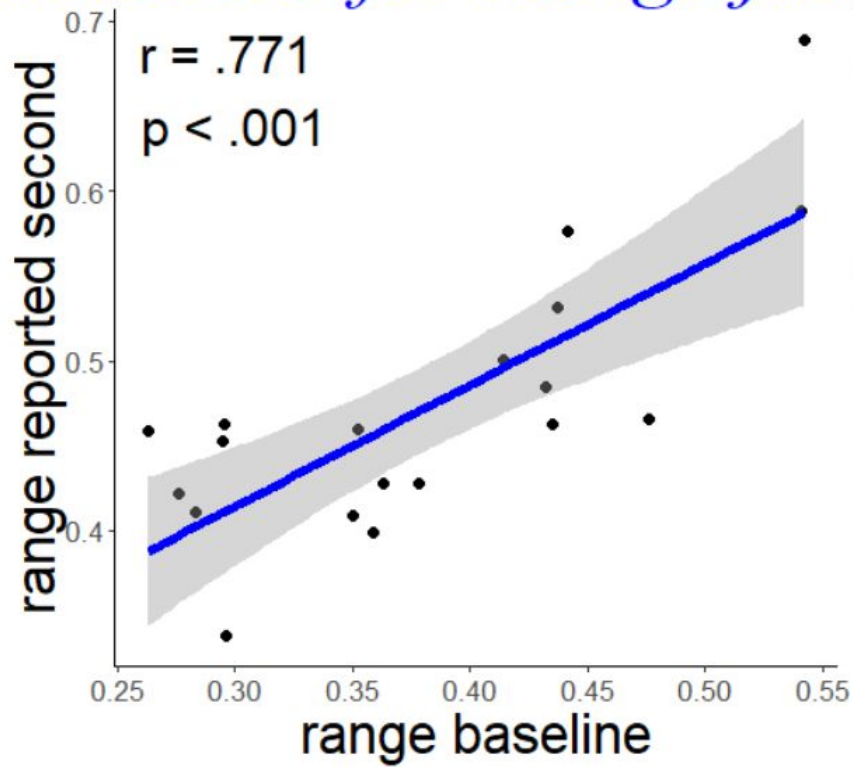
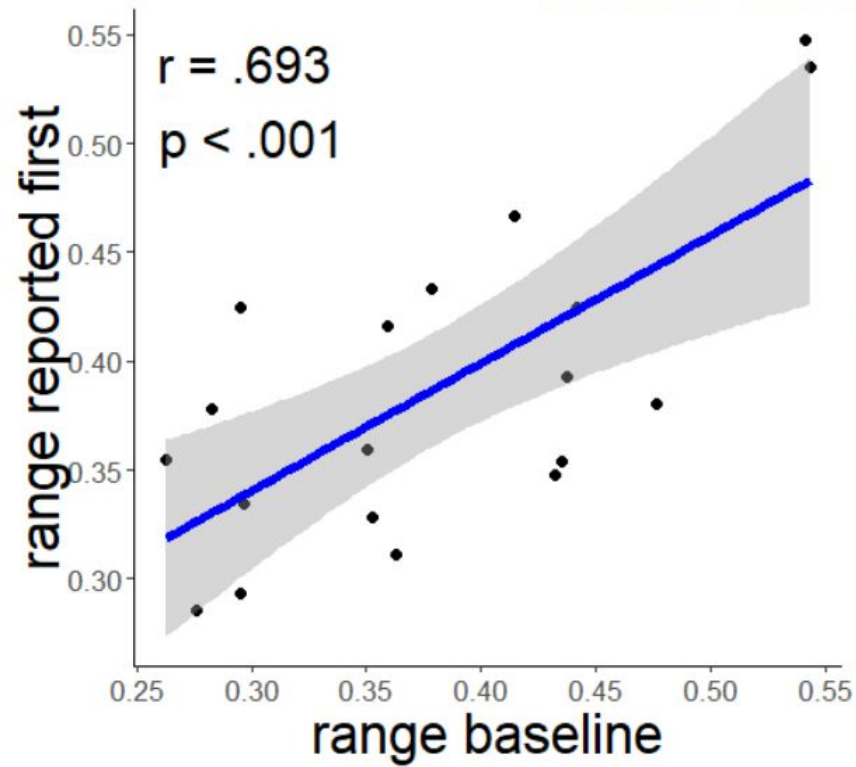
**Positive correlation** between errors in reporting  
MEAN in different conditions



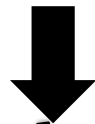
Reliable measure of MEAN calculation across



## *Auto-correlations for Range judgements*

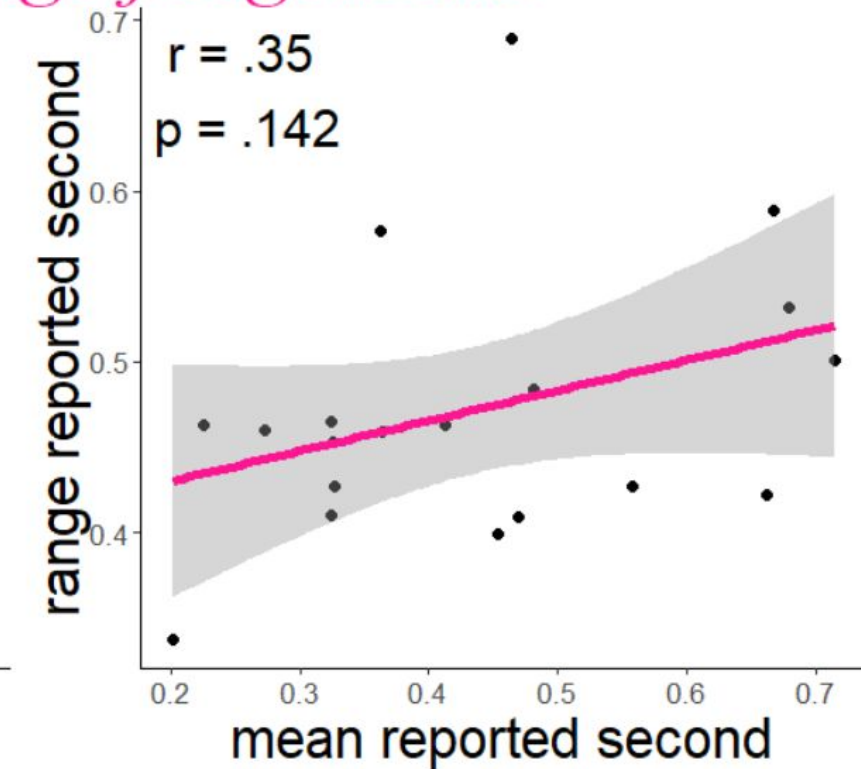
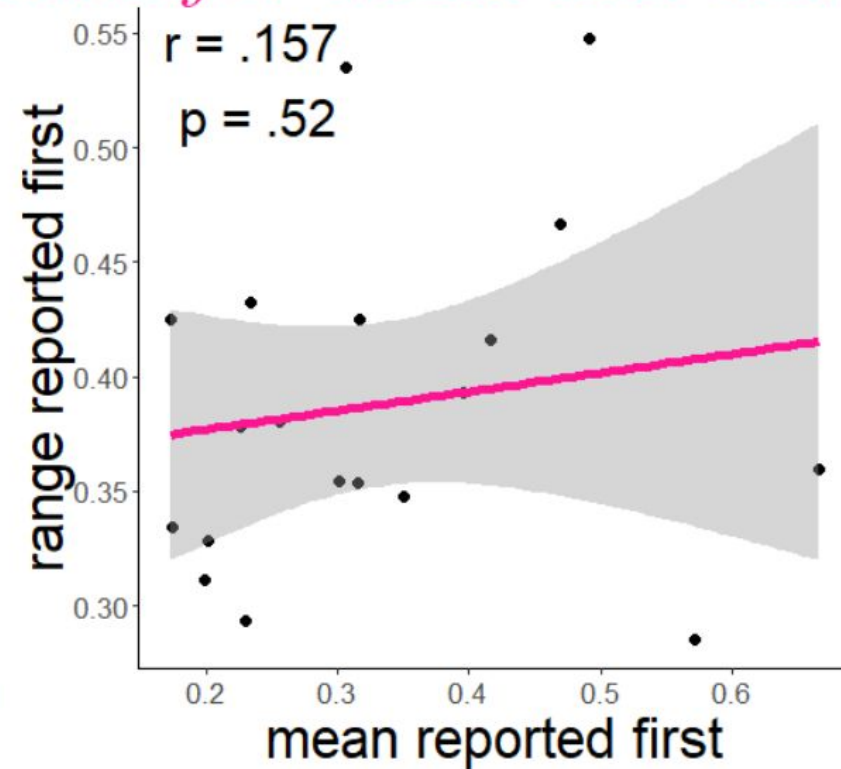
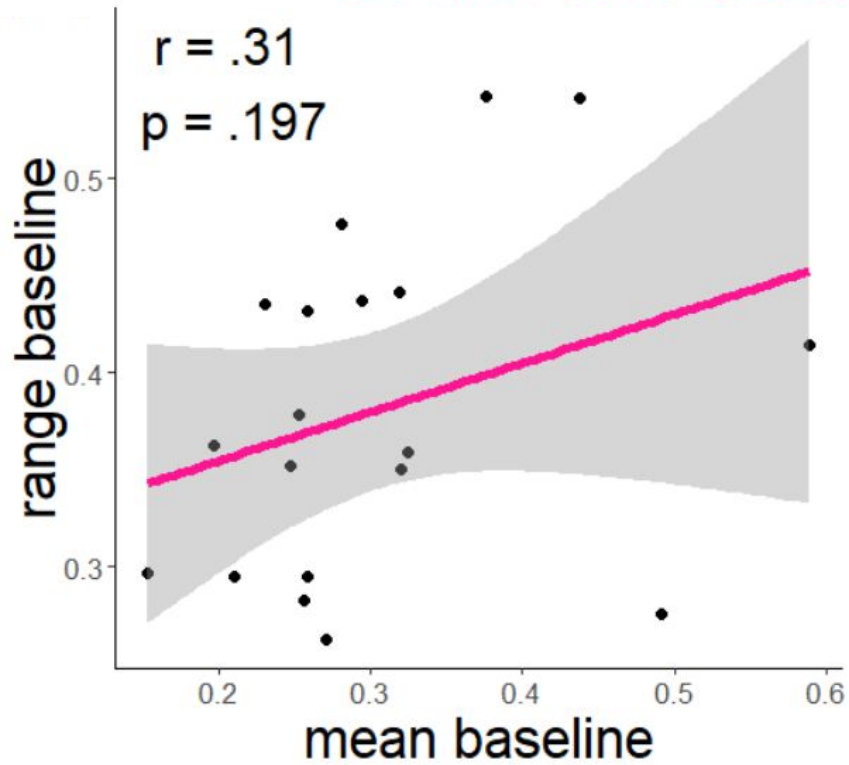


**Positive correlation** between errors in reporting RANGE  
in different conditions



Reliable measure of RANGE calculation across conditions

# Cross-correlations for Mean and Range judgements

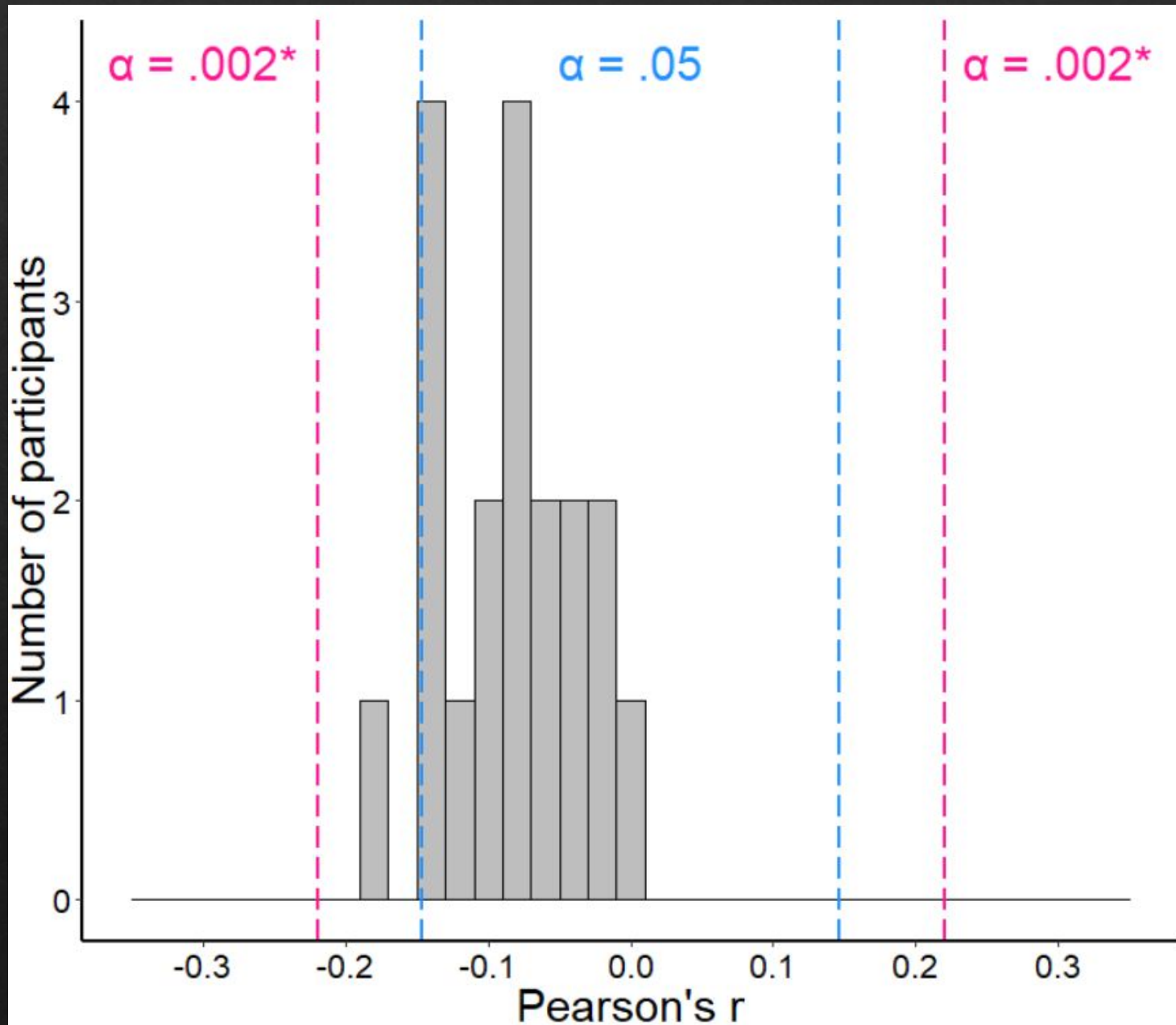


**No correlation** between errors in reporting different statistics



**Independence between MEAN and RANGE calculations**

# Individual correlations

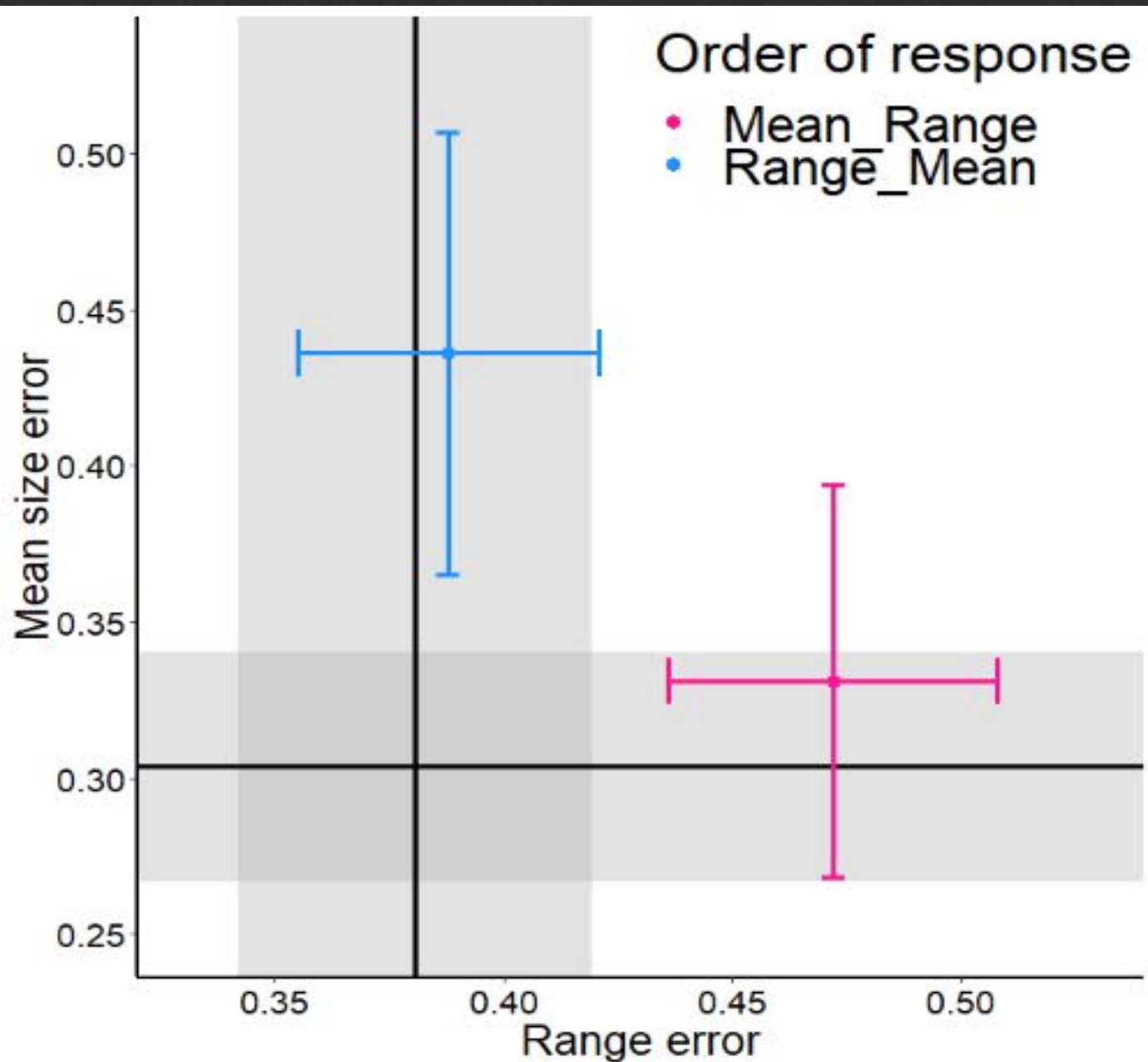


No one showed significant correlation between raw errors in *both* condition



**Independence** between MEAN and RANGE calculations

# Average errors



**No difference** between mean errors in *baseline condition* and the first response in *both condition* (both for RANGE and MEAN).

# Conclusions

**Ensemble summary statistics** (mean and numerosity, mean and range) are calculated

**independently** and **in parallel**

## Independent mechanisms



MEAN

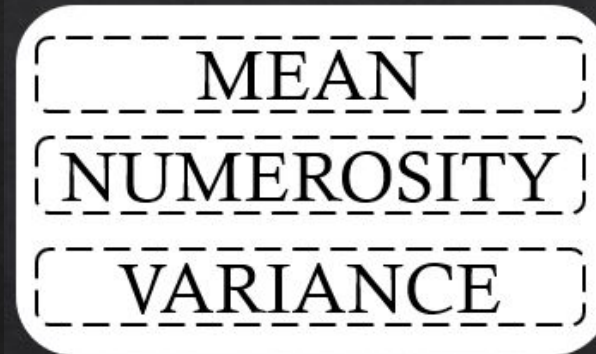


NUMEROSITY



RANGE

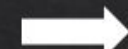
## Parallel access



REPORT



REPORT

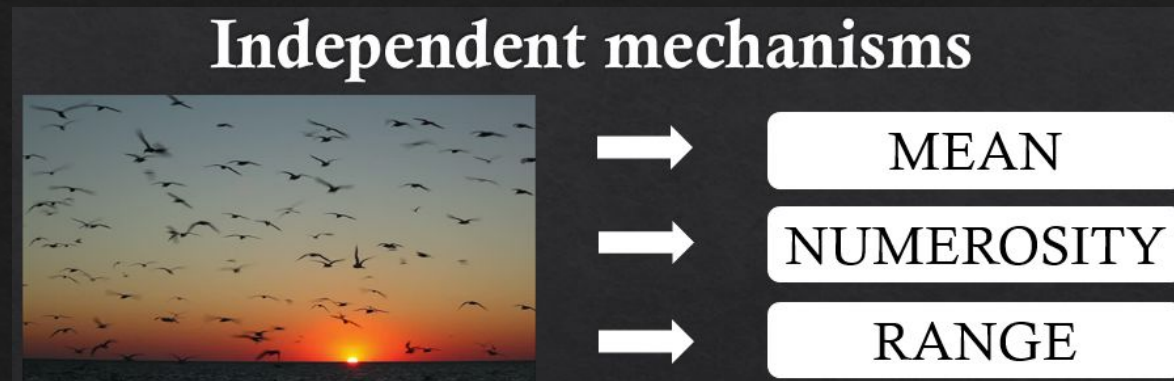


REPORT

# Conclusions (2)

**Independent calculation** of ensemble summary statistics means:

- (1) Different summaries are calculated by different (partly non-overlapping) brain regions.
- (2) The result of one calculation does not influence the result of the other calculation (unlike in mathematical statistics)



For d  
please  
Khvost  
process  
Journal



August 2019  
Volume 19, Issue 9

< ISSUE >

Jump To...

- [Introduction](#)
- [Experiment 1](#)
- [Experiment 2A](#)
- [Experiment 2B](#)
- [General discussion](#)
- [Acknowledgments](#)
- [References](#)

OPEN ACCESS

Article | August 2019

# Independent and parallel visual processing of ensemble statistics: Evidence from dual tasks

Vladislav A. Khvostov; Igor S. Utochkin

+ Author Affiliations

Journal of Vision August 2019, Vol.19, 3. doi:10.1167/19.9.3

VIEWES

PDF

SHARE

TOOLS

## Abstract

The visual system can represent multiple objects in a compressed form of ensemble summary statistics (such as object numerosity, mean, and feature variance/range). Yet the relationships between the different types of visual statistics remain relatively unclear. Here, we tested whether two summaries (mean and numerosity, or mean and range) are calculated independently from each other and in parallel. Our participants performed dual tasks requiring a report about two summaries in each trial, and single tasks requiring a report about one of the summaries. We estimated trial-by-trial correlations between

t  
visual  
tasks //  
19.9.3

Thank you for being with me  
till the end of the first part



Part #2



NATIONAL RESEARCH  
UNIVERSITY



# Confidence intervals in within-subject designs

\*Based on Cousineau,  
2005

# It is all from this 4-pages paper

*Tutorials in Quantitative Methods for Psychology*  
2005, Vol. 1(1), p. 42-45.

DOI: 10.20982/tqmp.01.1.p042

## **Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method**

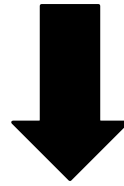
**Denis Cousineau**

*Université de Montréal*

Within-subject ANOVAs are a powerful tool to analyze data because the variance associated to differences between the participants is removed from the analysis. Hence, small differences, when present for most of the participants, can be significant even when the participants are very different from one another. Yet, graphs showing standard error or confidence interval bars are misleading since these bars include the between-subject variability. Loftus and Masson (1994) noticed this fact and proposed an alternate method to compute the error bars. However, i) their

# The problem

Different subjects can perform very differently which increases a size of error bars



Inconsistency between the results of ANOVA and the graph:  
ANOVA shows the effect, but the graph do not

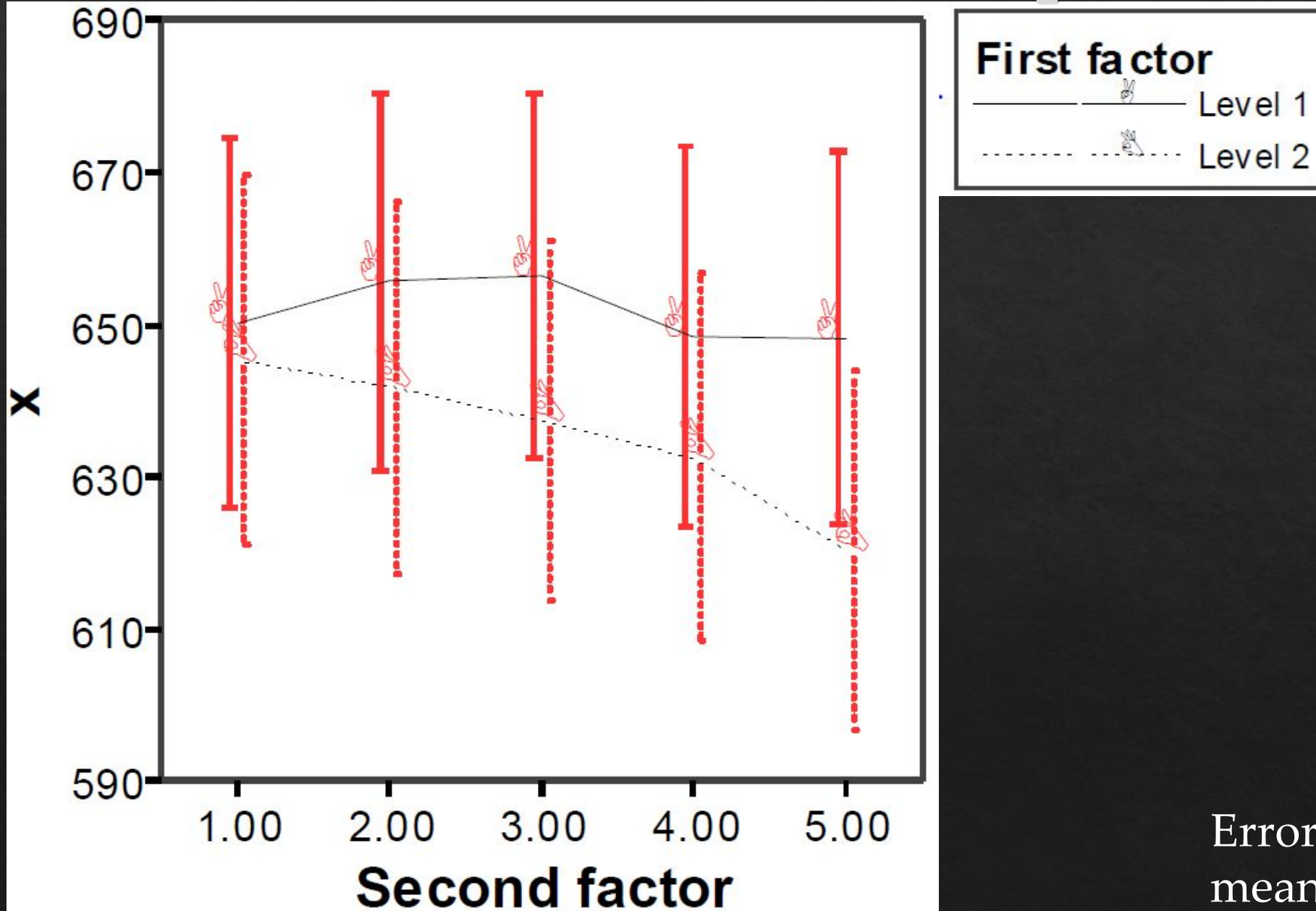
# ANOVA results

an experiment with two factors, the first with two levels and the second with 5 levels

Effect name	SS	df	MS	F	
Factor 1	10621	1	10621	76.8	***
Error	2073	15	135		
Factor 2	11784	4	8196	16.4	***
Error	4378	60	72.9		
Interaction	2250	4	562	6.52	***
Error	5171	60	86.2		

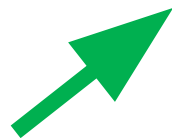
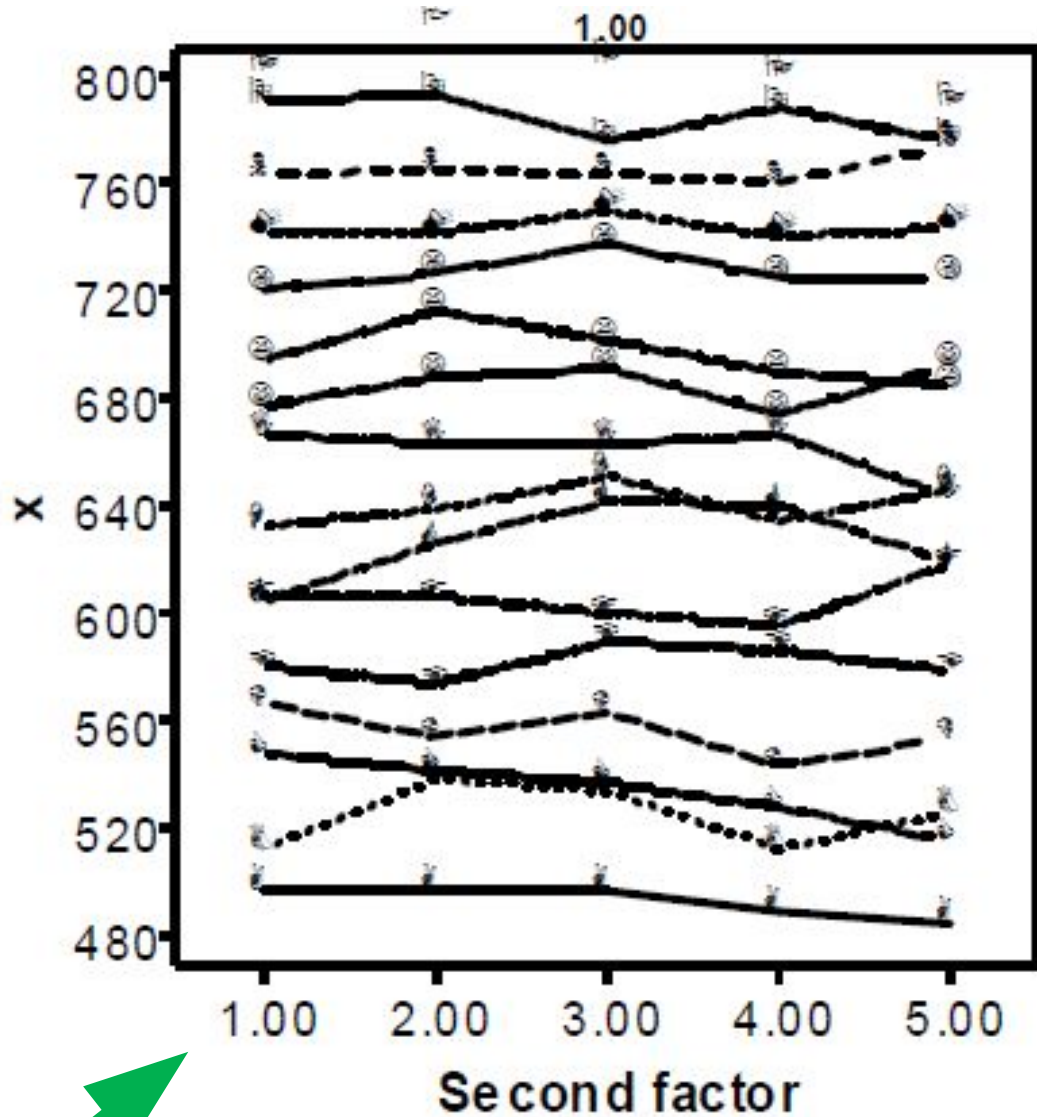
\*\*\*:  $p < .001$

# Results of the experiment

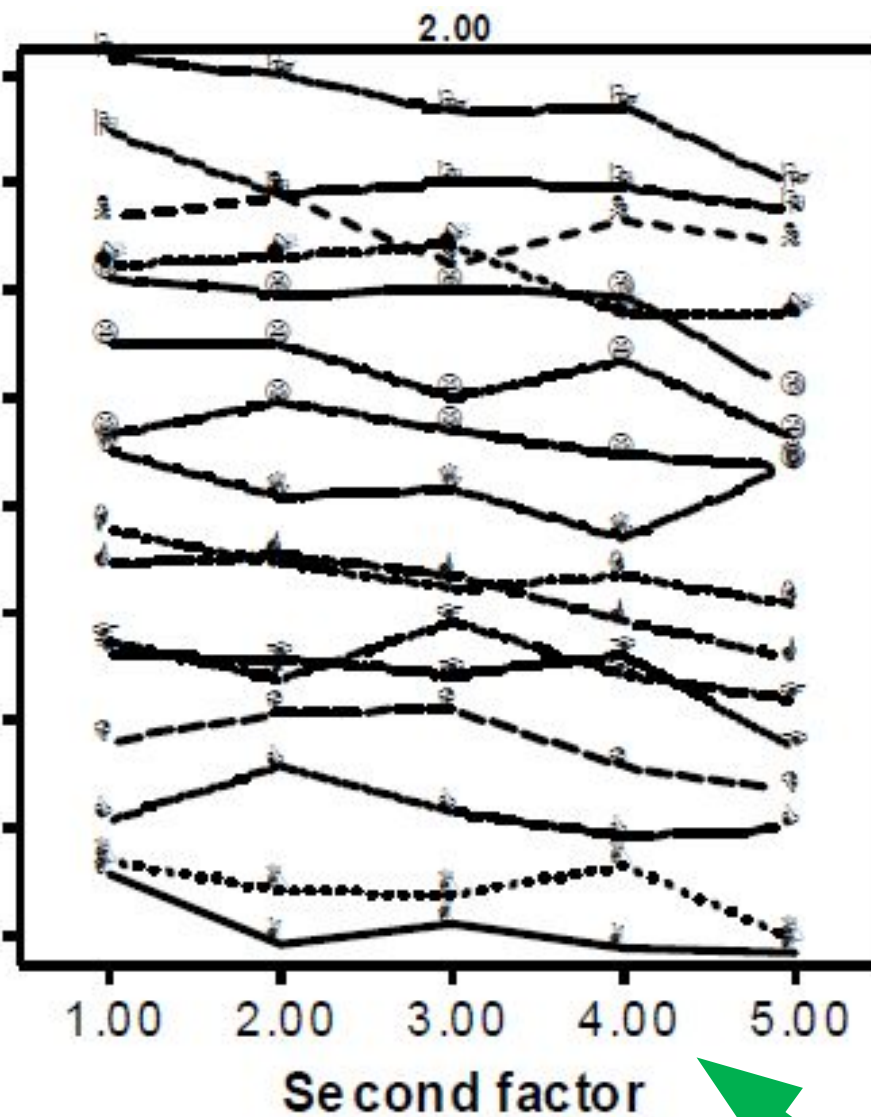


Error bars show the mean  $\pm 1$  standard error.

# The individual results of the 16 participants



The first level of the first factor.



The second level of the first

# The solution of the problem

$$Y = X_{ij} - \bar{X}_1 + \bar{X}$$

$Y =$  results of the participant in a particular condition  $-$  the participant mean  $+$  the group mean

# Example of calculations

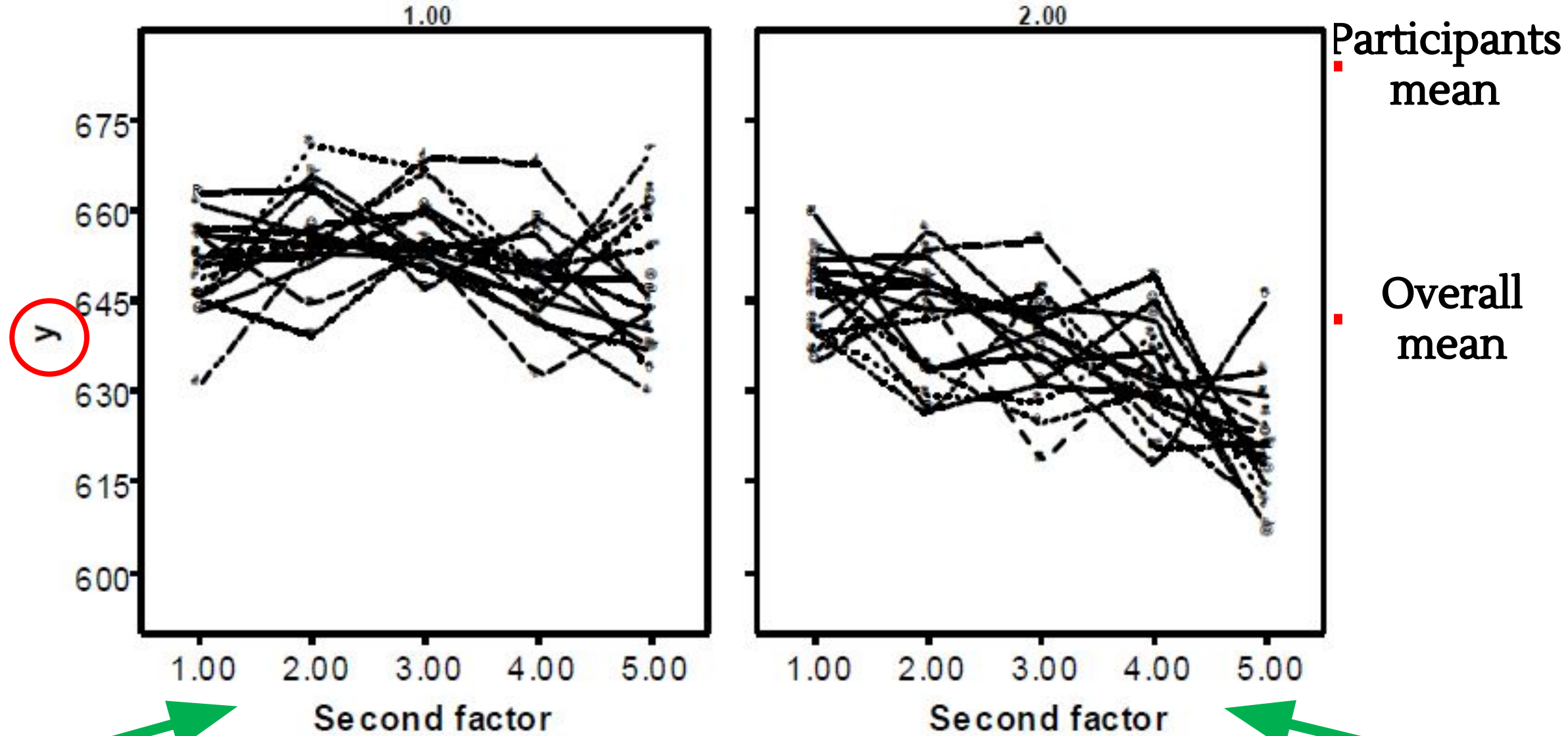
Participant	Condition			Mean
	1	2	3	
1	550	580	610	580
2	605	635	655	635
3	660	690	710	690
<i>Mean</i>	605	635	655	635



Participant	Condition			Mean
	1	2	3	
1	$550 - 580 + 635 = 60$	$580 - 580 + 635 = 63$	$610 - 580 + 635 = 66$	580
2	$605 \overset{5}{=} 635$	$635 - 635 + 635$	$655 - 635 + 635$	635
3	$660 \overset{+635}{=} 690$	$690 - 690$	$710 - 690$	690
<i>Mean</i>	605	635	655	635



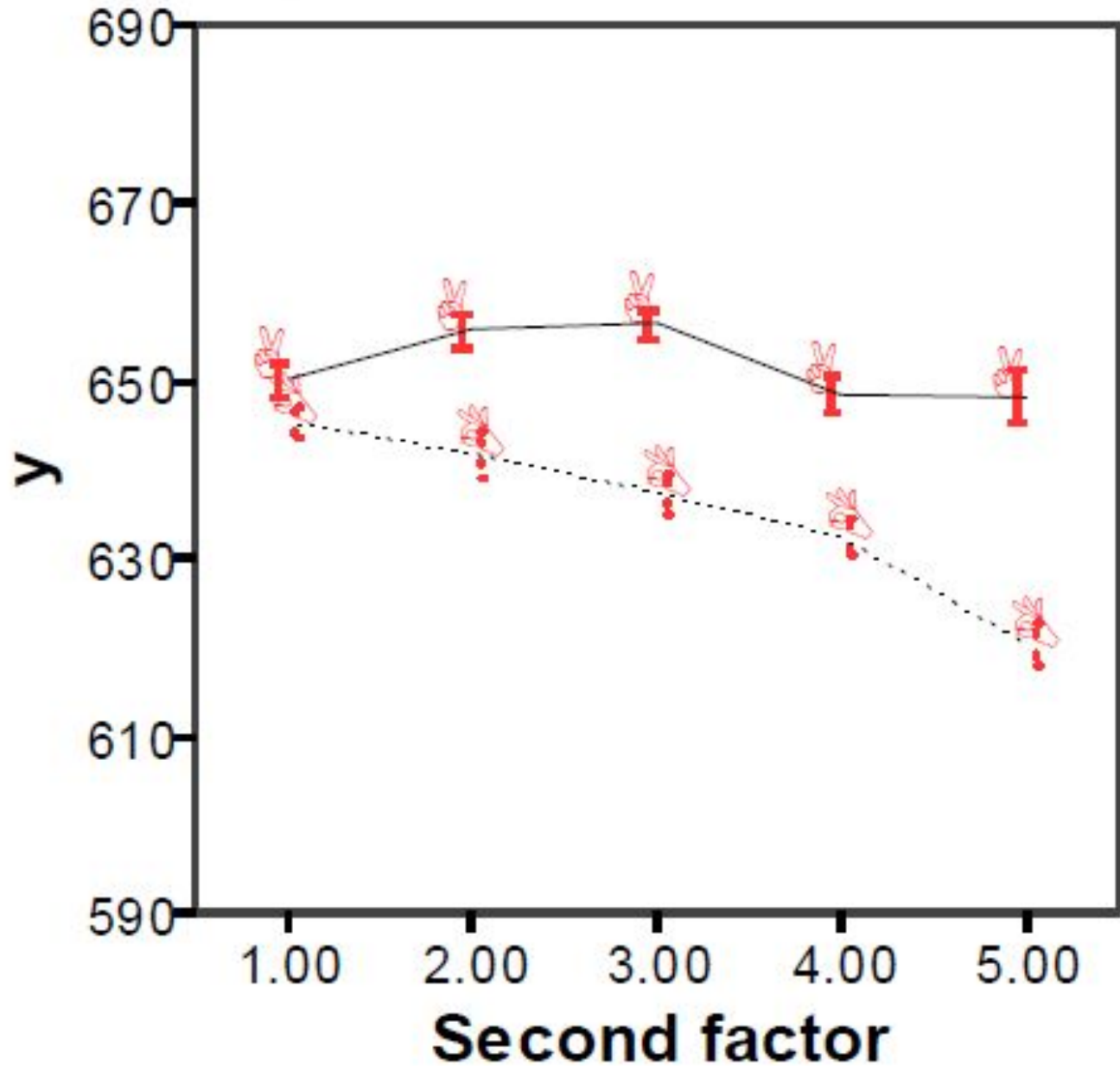
# The individual results of the 16 participants after the individual differences were removed



The first level of the first factor.

The second level of the first

# The graph after the individual differences were removed



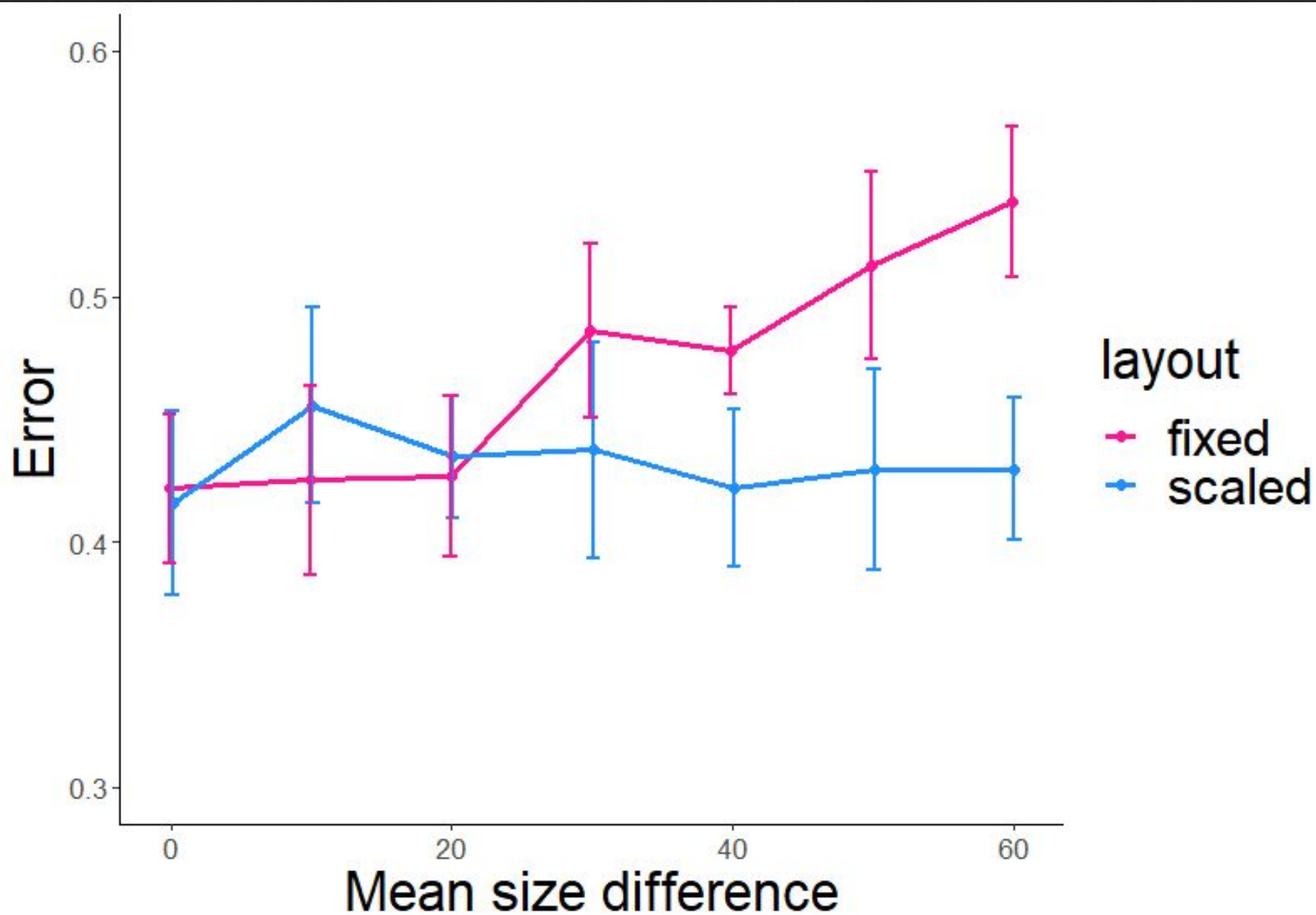
Error bars show the mean  $\pm$  1 standard error.

$$Y = X_{ij} - \bar{X}_1 + \bar{X}$$

$Y =$  results of the participant in particular condition  $-$  the participant mean  $+$  the group mean

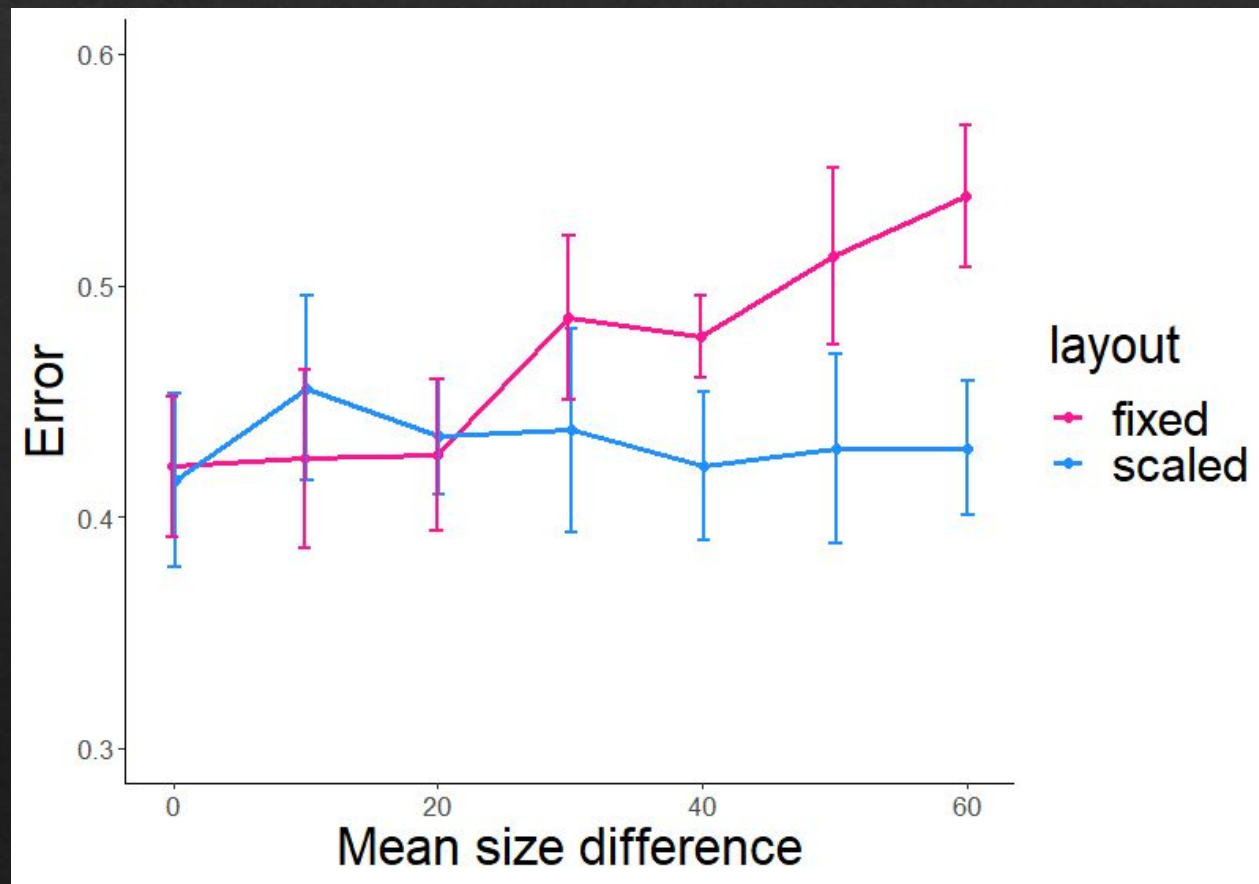
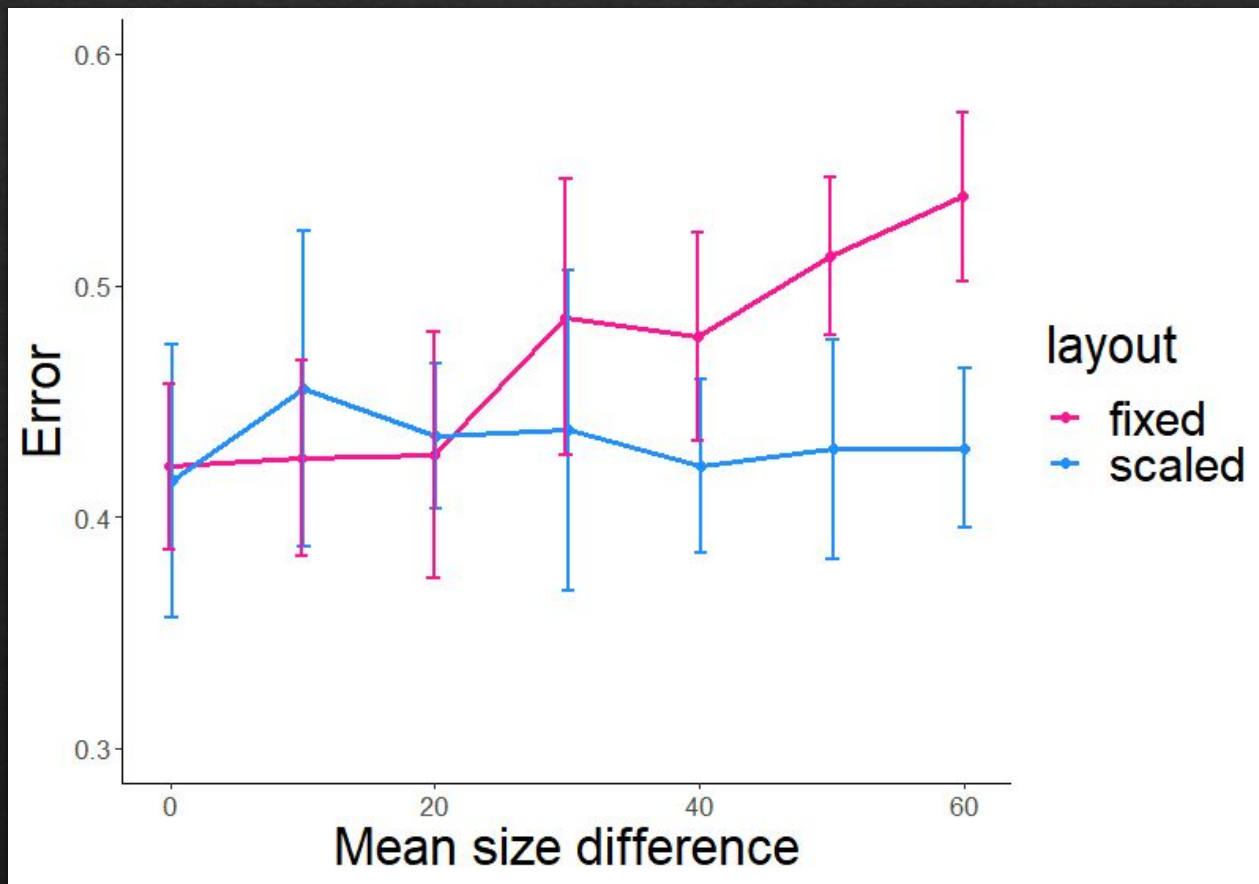
*NOTE: Y is only useful for graphing purposes; for the analyses, continue to use the original data.*

# Example from real life



Error bars show SEM.

# Example from real life



Error bars show SEM.

Hope you will use it

Thank you  
For your attention