Intuitive averaging of perceptual properties and numerical values: behavioral data and **neural mechanism**

Marius Usher

Cognitive Psychology & Brain and Cognition Colloquium

Intuitive averages

Decisions are made based on values of alternatives

How do we evaluate values:

i) a crowd of faces (angry/friendly)

ii) the average height of the people in the crowd

iii) a sequence of numbers (stock returns, marks of competitors in contest, etc)

iv) attitude toward a person based on character descriptions (honest, selfish, ...)

No time to compute & take-notes. Need to select the best based on information available

Does intuitive averaging help to make good decisions?

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Participants presented with commercials videos and asked to pay attention to content for future test. As “distraction” asked to read aloud running numbers corresponding to returns of 4 stocks. After queries of commercials Ss asked to indicate how “attractive” each stock-option feels

- Good sensitivity to average and sum of the values

Betsch et al., 2001; PSPB

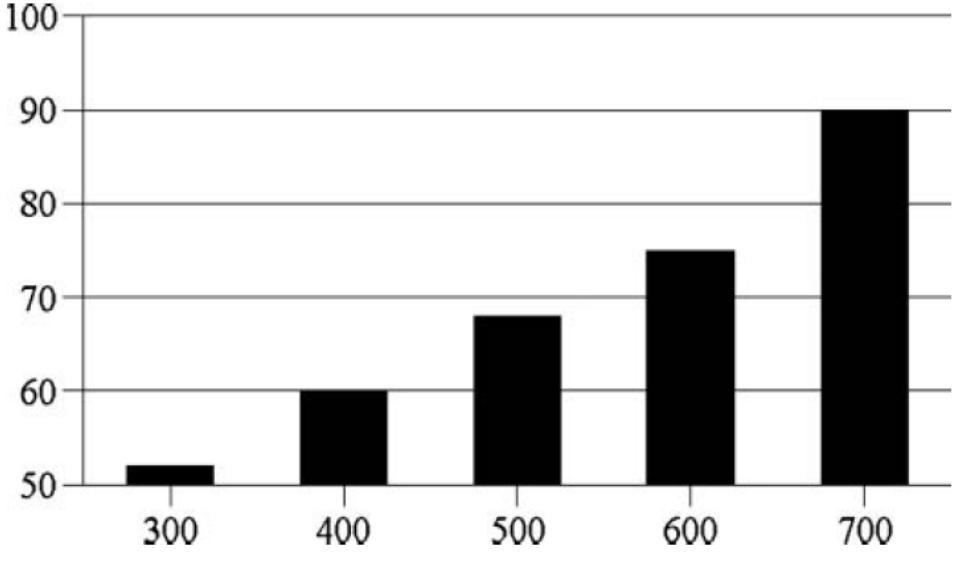


Figure 2. Results from Betsch, Plessner, Schwieren, and Gütig (2001, Exp.1). *Note.* Evaluative judgments of five target shares differing with regard to sum of return values. Higher values indicate a more intense liking.

The wisdom of the crowd

Francis Galton's ox-weighting (Nature, 1907)

- 787 people in Plymouth gave estimations for weight of a particular fat ox:
- The mean value was only 1 pound from actual weight (1,198 lb), closer to actual than prediction of each individual (see also, Surowiecky, 2004)

Later studies indicate that even individuals can make statistically accurate judgments:

*the **intuitive statistician***

Summary statistics of perceptual properties

Dan Arieli (2001)
Psyc. Sci.

Set-display is made of circles of 4 different sizes (easy to discriminate)

Is the test spot one that was presented in the first display? (which of the two was presented)

Is the test spot > than the average of the set display?

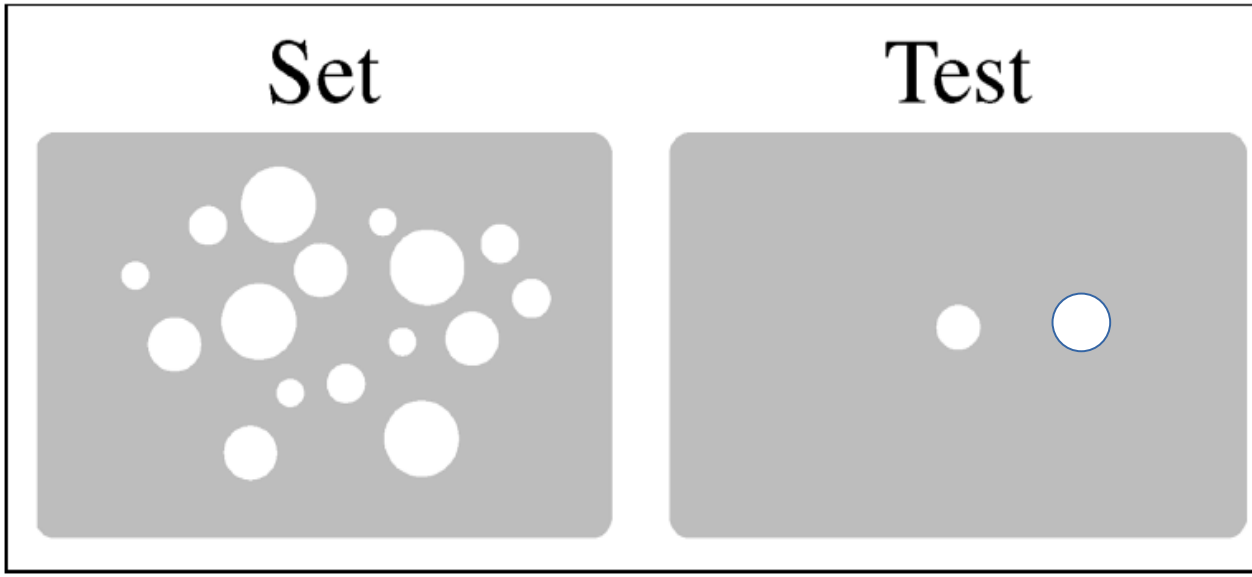


Fig. 1. Schematic representation of the two intervals used in eac
trial. Observers first saw a set of circles for 500 ms, and then a te
stimulus consisting of one or two test spots. This example shows a s
of 16 items with a similarity factor of 1.4,

Results

- Chance level in identifying if the particular spot was presented
- Good ability to discriminate the average
- Discriminability does not reduce with set-size

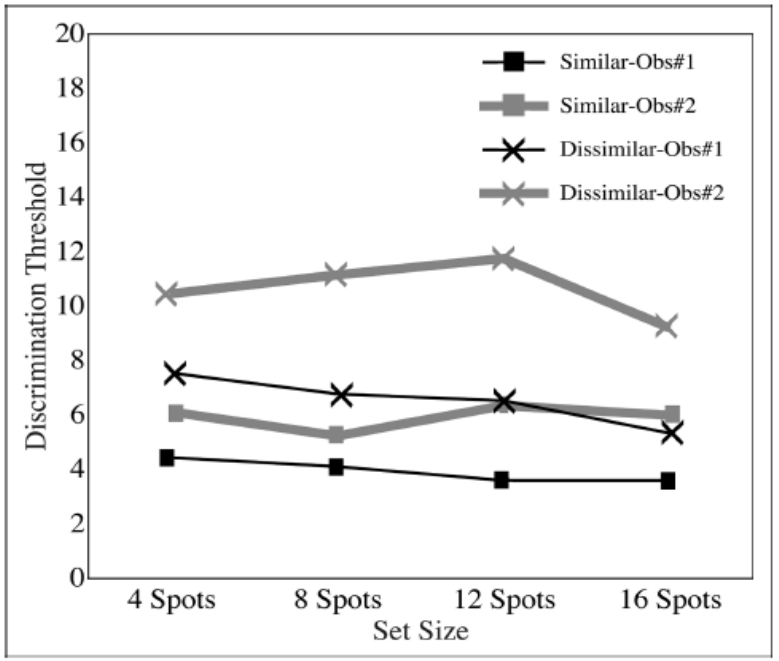
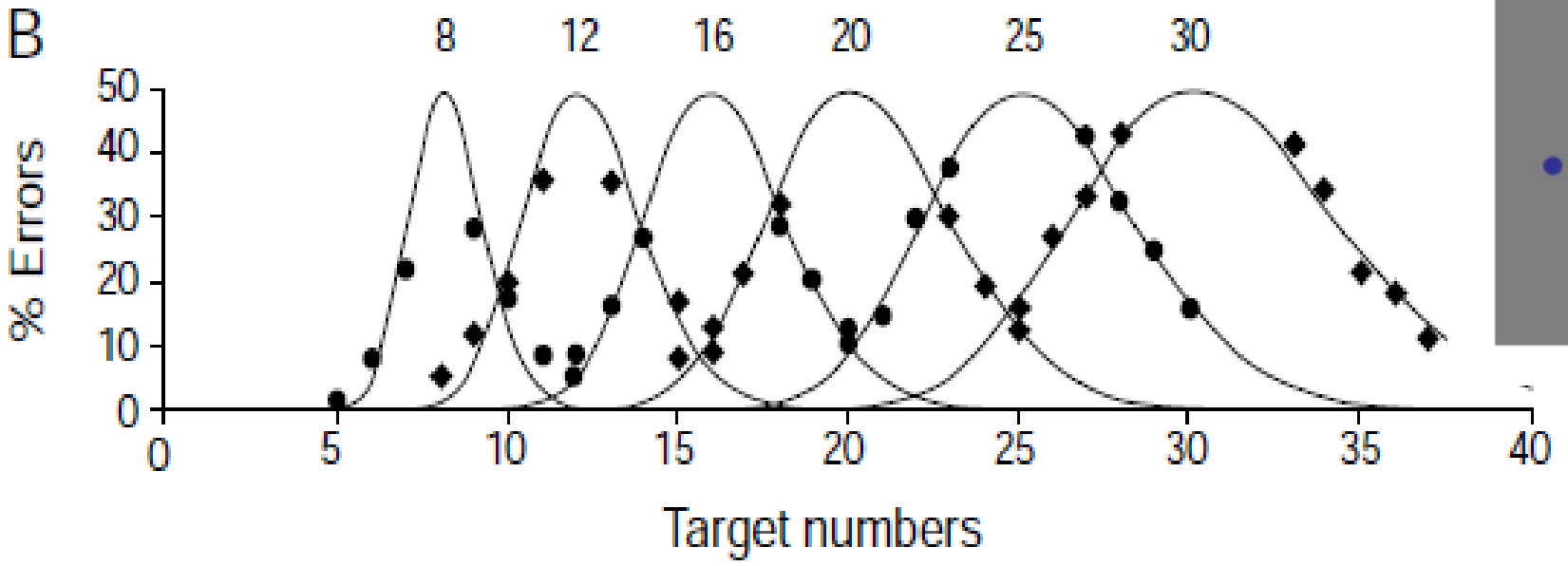
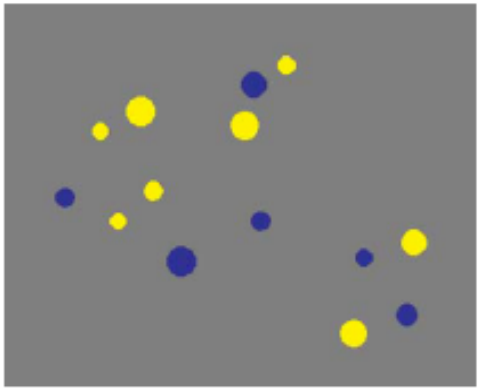


Fig. 4. Mean discrimination thresholds for the four set sizes. Data are shown separately for the 2 observers ("Obs") and the two set distributions (similar and dissimilar).

Intuitive numerical cognition (Dehanae)

- Two systems for numerical computation:
- Symbolic (relies on memory and use of rules)
- **Analog representations (PPC; noisy computation of numerosity)**: subject to Weber-law



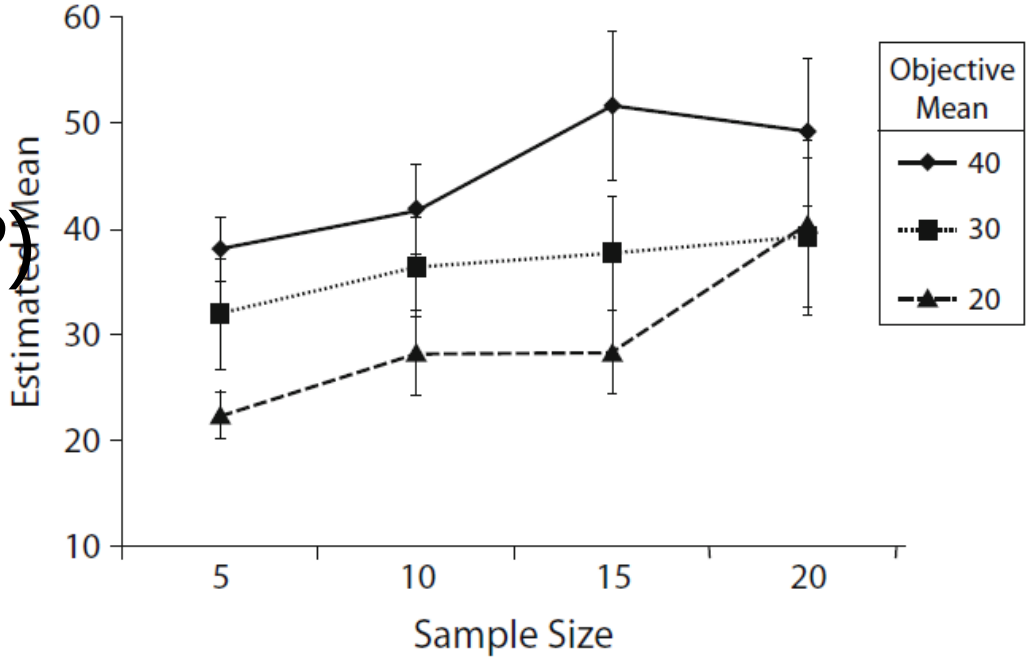


- Humans compare numerosity of dot pattern to a fixed standard of 8, 12, 16, 20, 25, 30

Summary

- Observers can summarize perceptual information in a holistic way (spread mode of attention), even when they do not have access to properties of individual elements
- Can also estimate numerical averages quite well with fast sequences (intuitive mode); but set-size bias effects

(Smith & Price, 2010; *PBR*)



Questions

- How well do people average numbers in an intuitive way?
- Intuitive vs analytical and set size effects
- A neural mechanism (population code)
- How does this affect decisions (intuitive/analytic)
- Higher summary statistics (beyond averaging): sensitivity to variance

Mind set manipulation on numerical averaging

(Rusou, Usher & Zakay, *under review*)

Estimate the average of a sequence:

(1) 54,47,50,45,35,39,31,42,26,35,40,36,54,49,53,55,60,59 = 45.

(2) 69,64,68,70,75,74,46,57,41,50,55,51,69,62,65,60,50,54 = 60.

Two manipulations (factorial):

Mind set (between-groups):

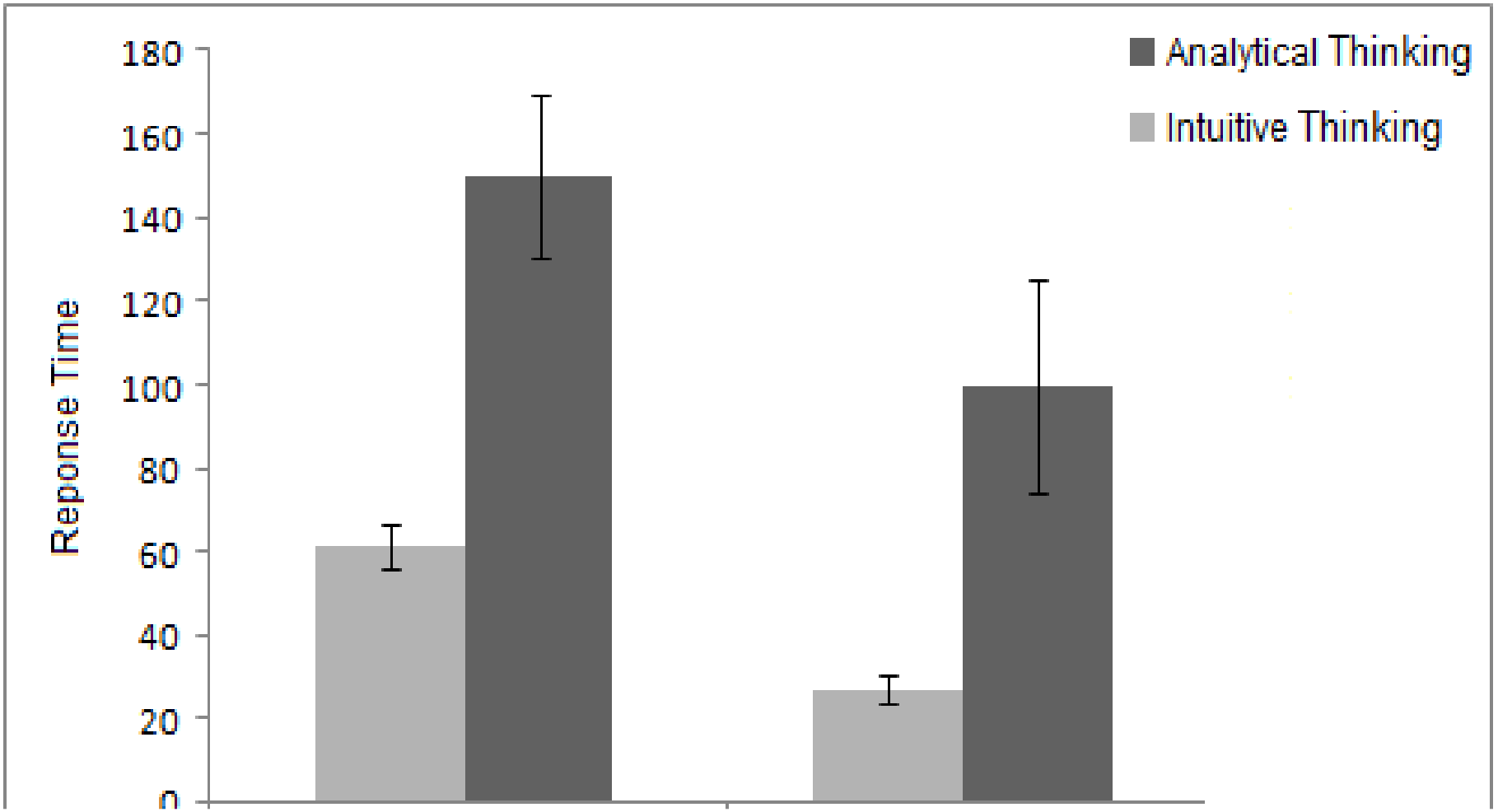
i) analytic (use arithmetic rules): N=14

ii) intuitive (general impression of magnitudes): N=14

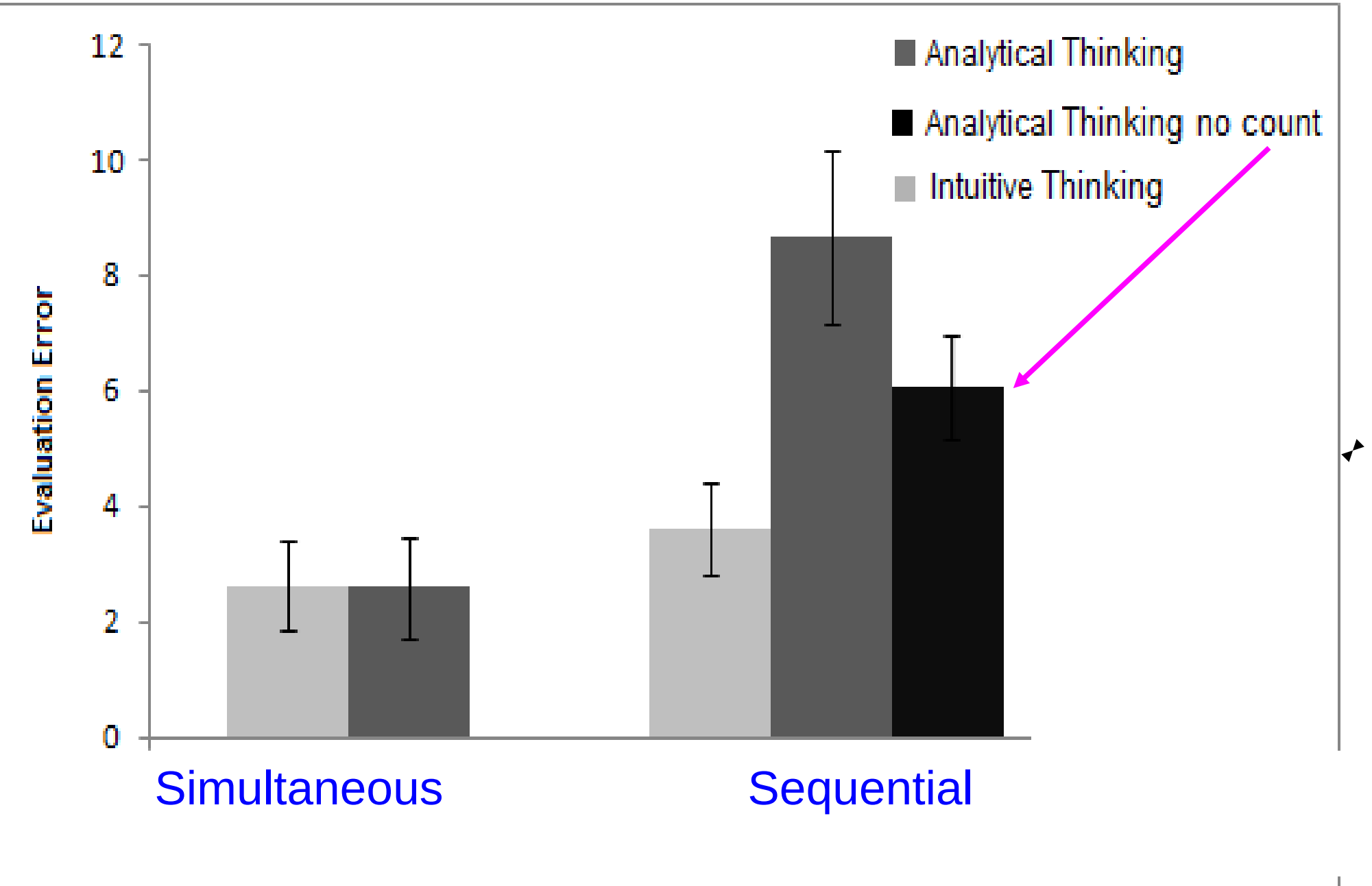
Presentation format (within Subjects):

- Sequential (self paced)
- Simultaneous (3 rows of 6)

Results: RT


Analytical Thinking
Intuitive Thinking
Reponse Time
180
160
140
120
100
80
60
40
20
0
Simultaneous
Sequential

Results: accuracy (abs-deviation)

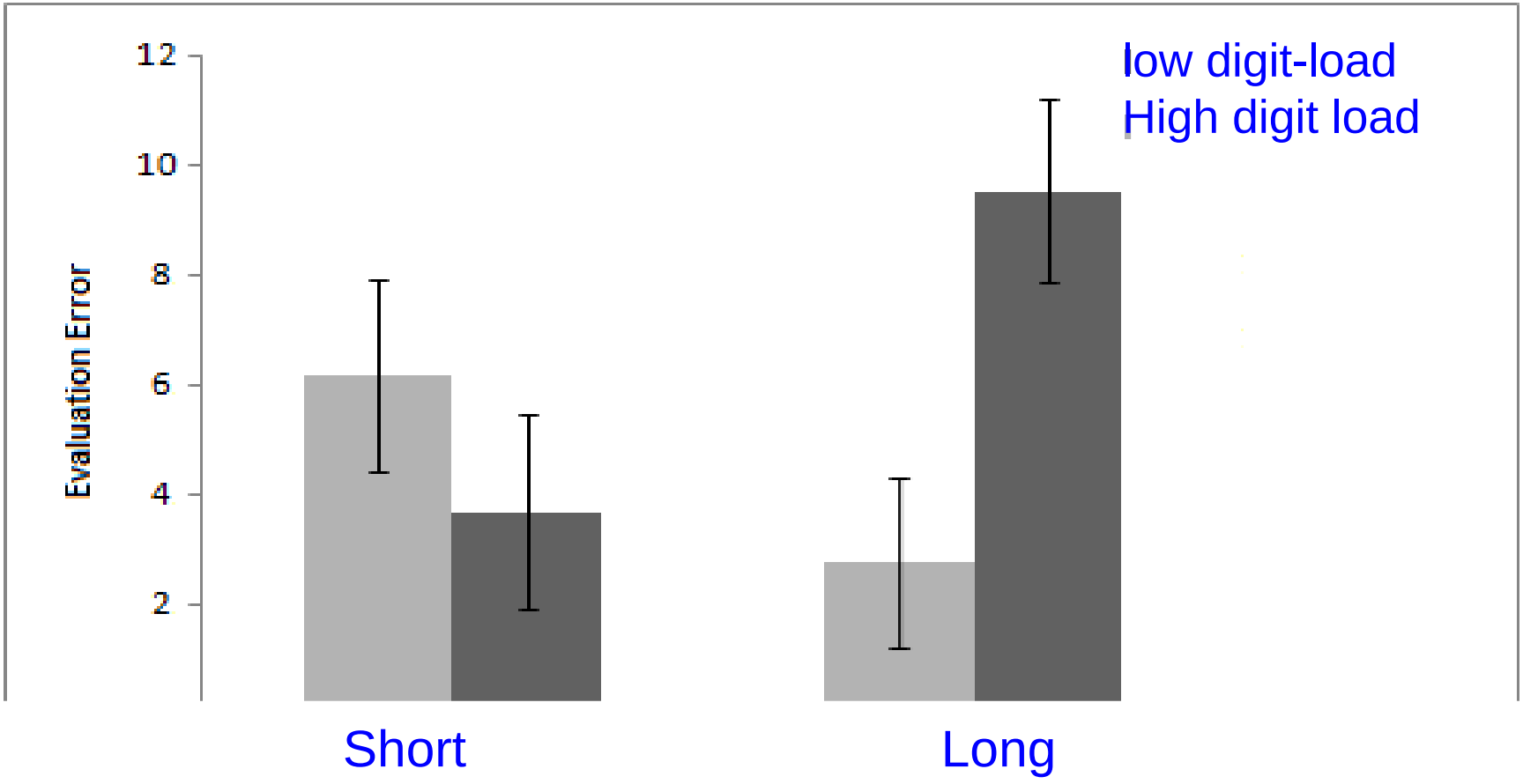


Indirect mind-set manipulation: WM-load

N=42 randomly allocated to high/low concurrent digit-load

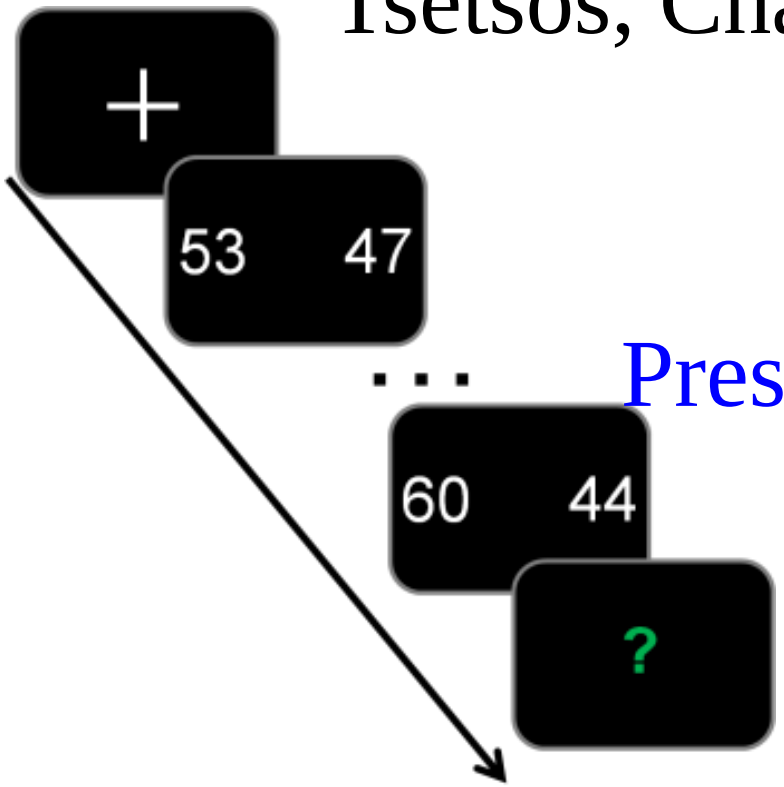
intuition/rule-based-computation

Numbers are presented sequentially every 5sec and Ss required to estimate average: I)short sequence, n=3 ii)long sequence, n=15



Value-psychophysycs: rapid value integration task

Tsetsos, Chater & Usher, *PNAS, 2012*



Presentation rate: 250-500 ms/frame

Which stock has largest overall return?

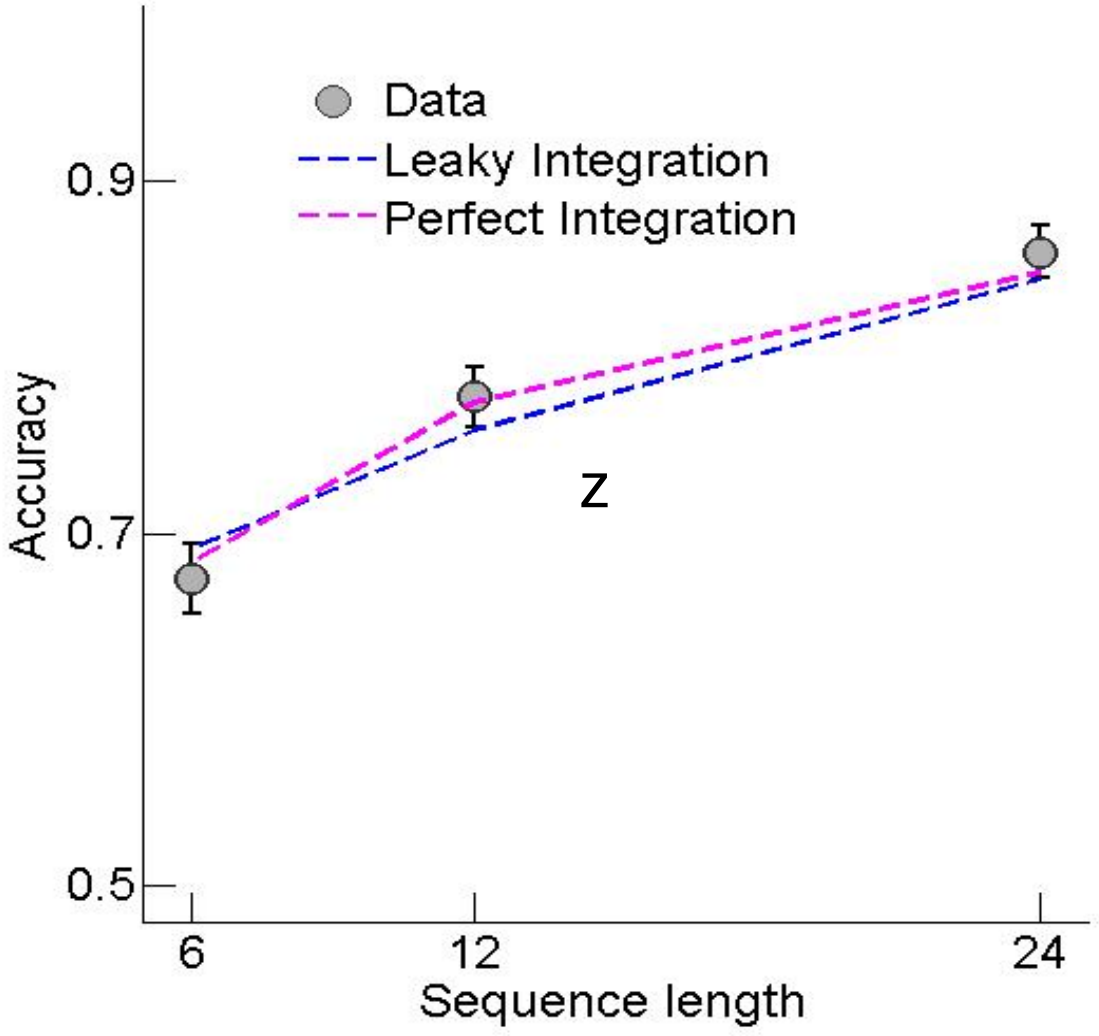
Which sequence you would like to draw an extra sample from ?

Sequence length and order

1. Can observers do ***fast*** (250 vs. 450 ms) numerical integration?
   Improvement with sequence-length (6/12/24)?

- No effect of rate
- **Accuracy increases with length**

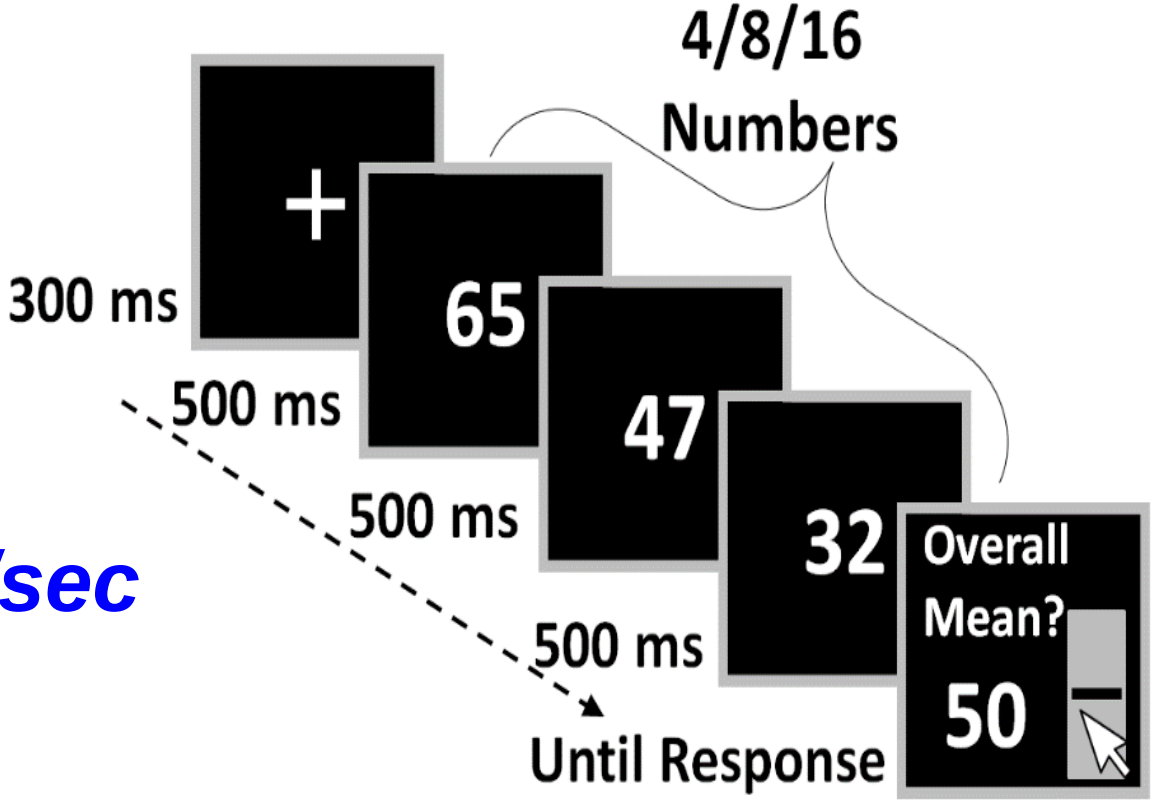
Noise averaged out



Probing the intuitive averaging: give average estimate (DV=abs-deviation)

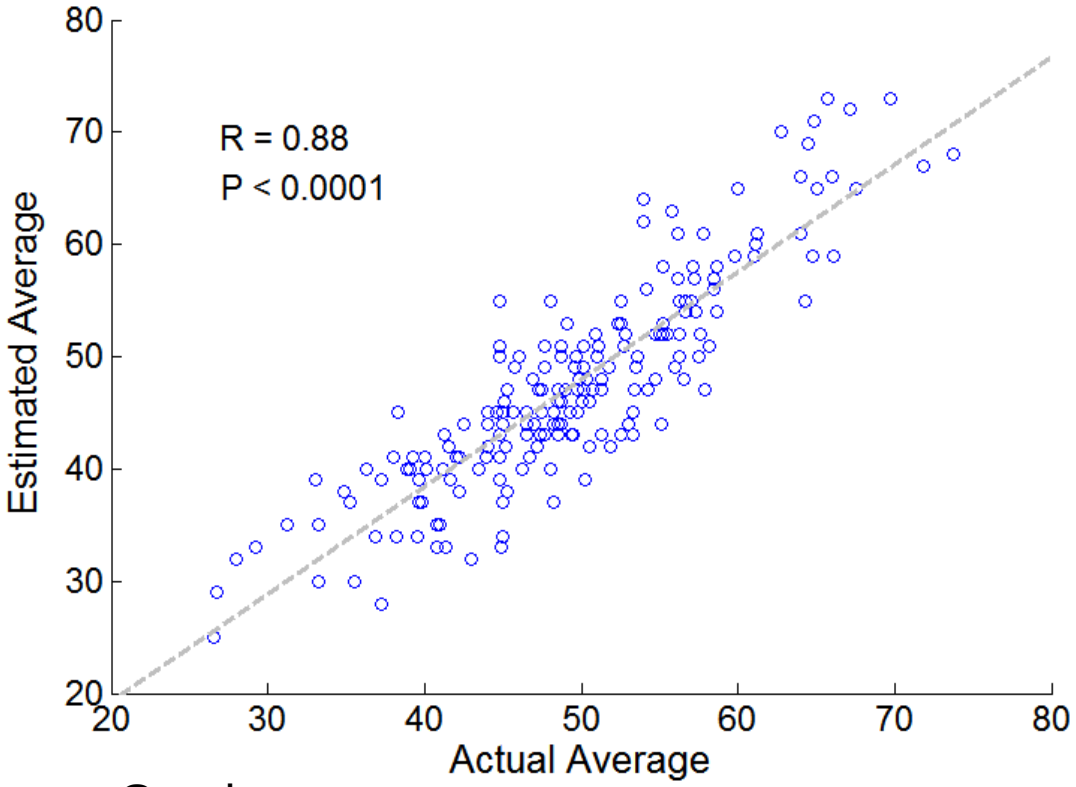
How fast and dependency on set-size

Brezis, Bronfman & Usher (under review)

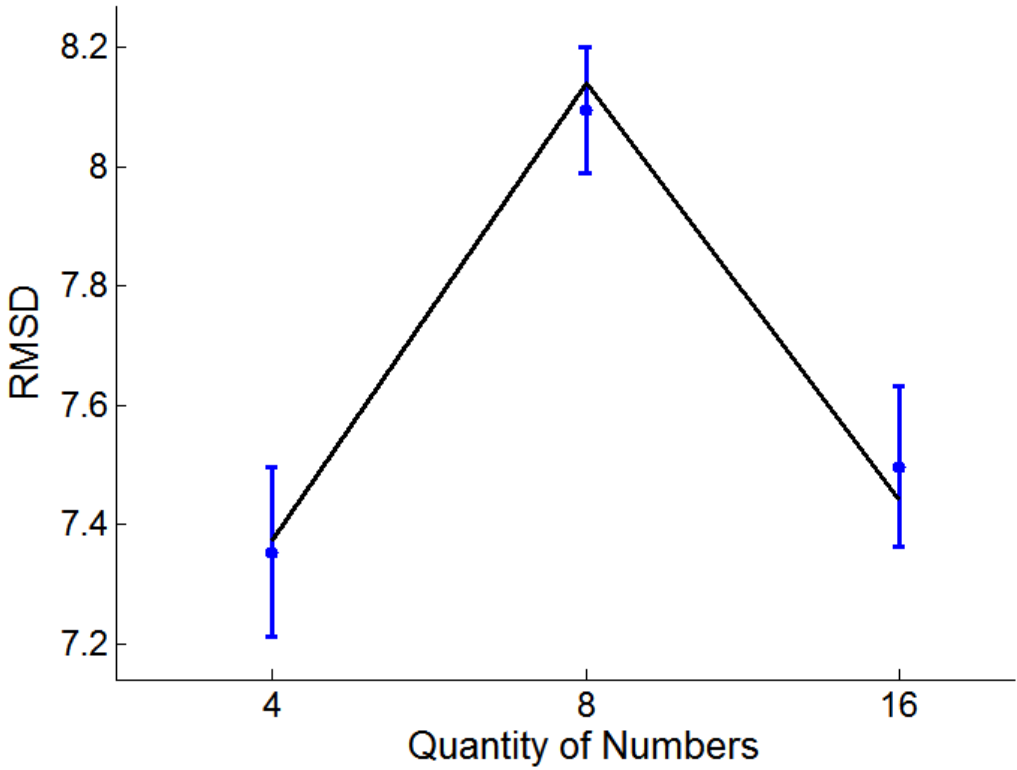


Rate: 2/sec

Results: Accuracy measure



Good

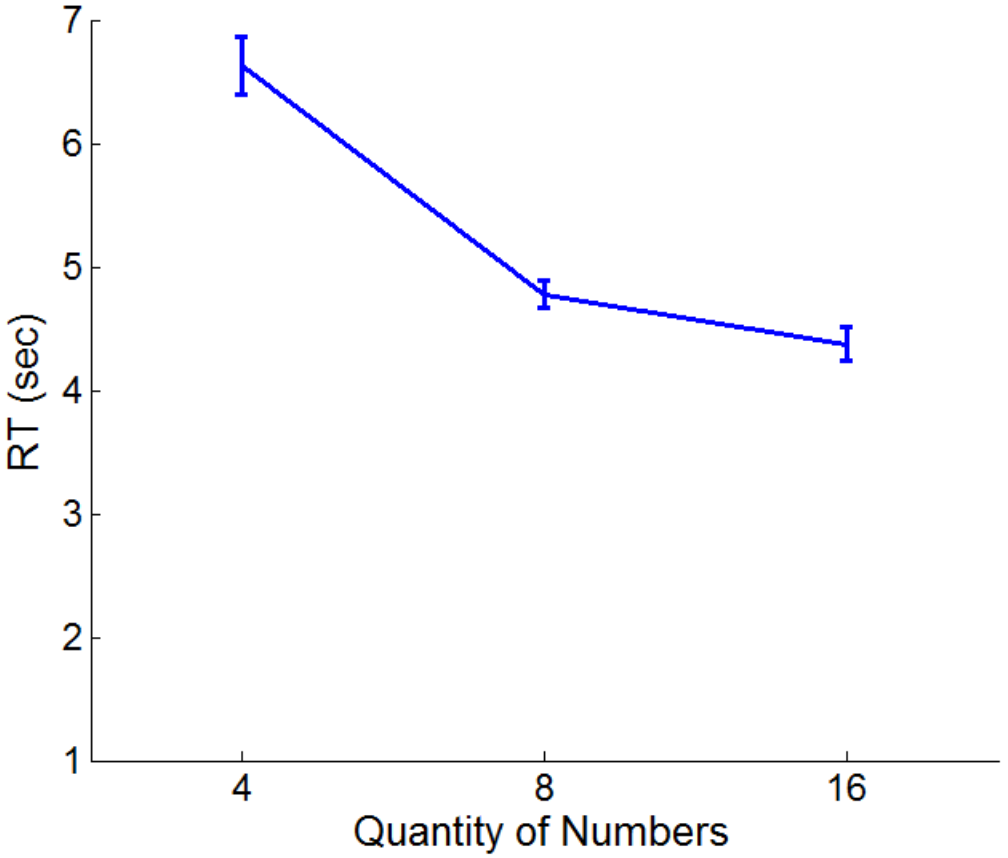


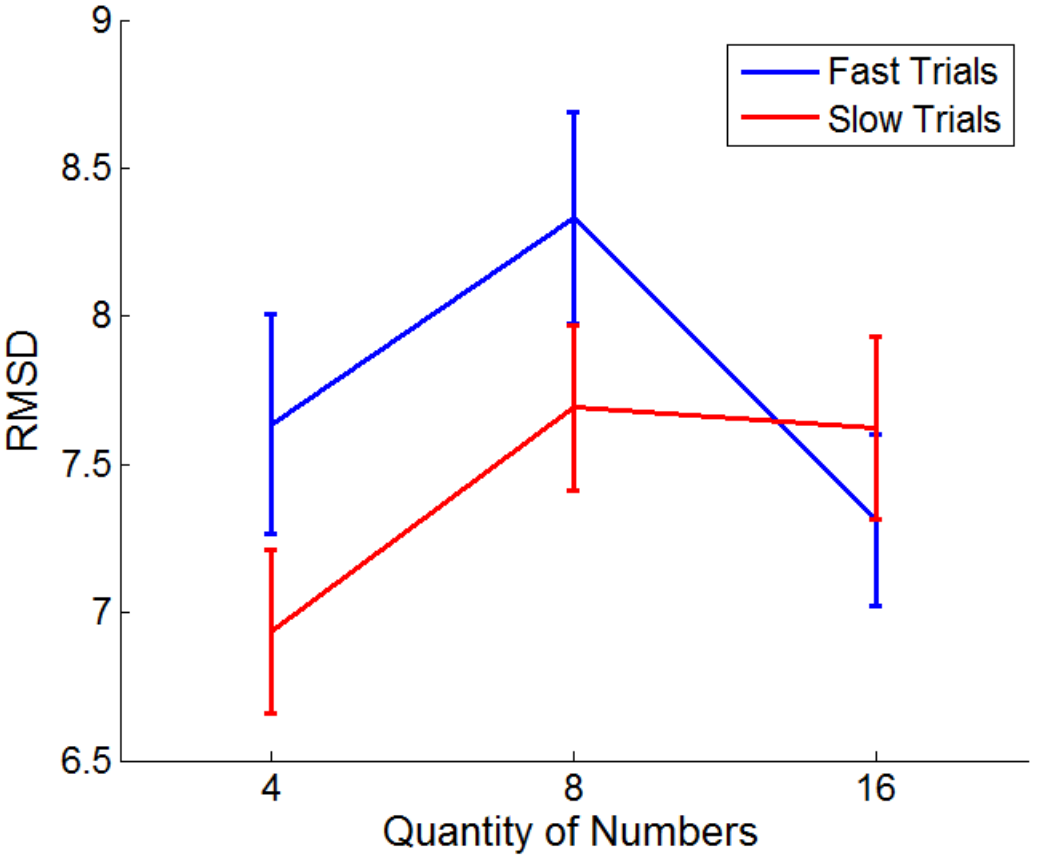
i) Good estimation performance

ii)Set size effects (4 and 16 better than 8)

4 → analytical estimations
16 →intuitive estimations
8 →mixed strategy

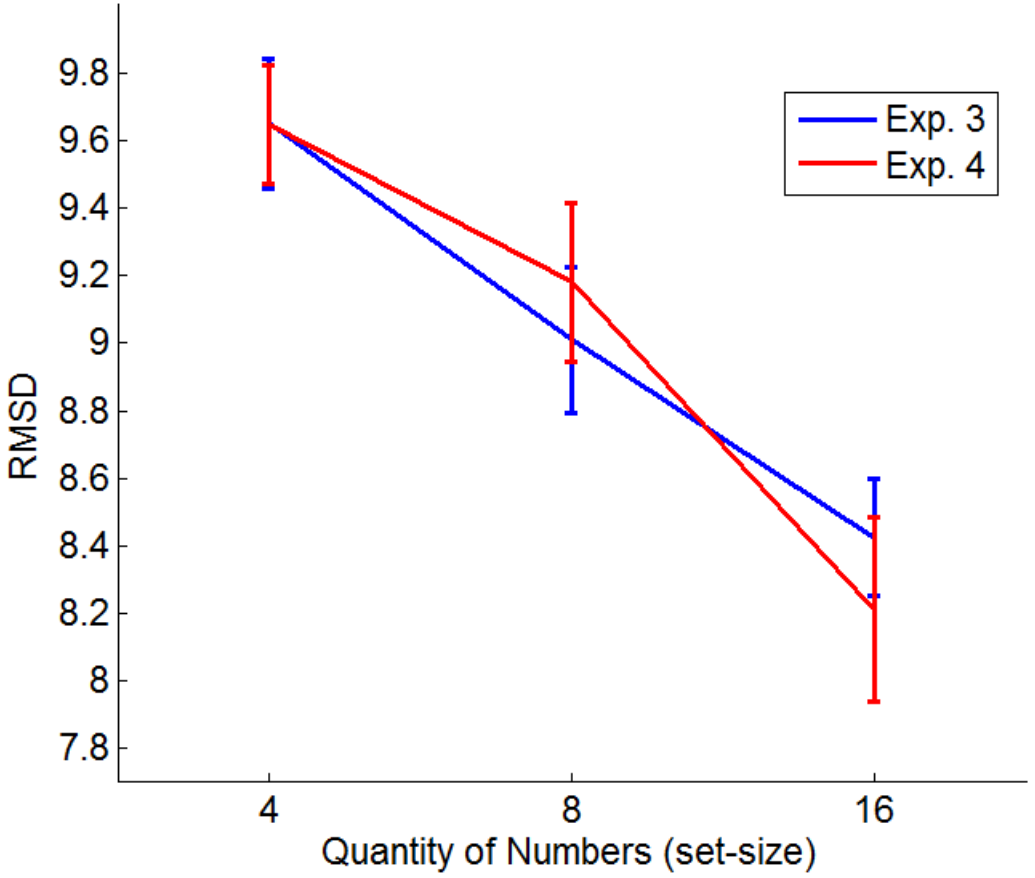
Results: RTs


RT (sec)
7
6
5
4
3
2
1
4
8
16
Quantity of Numbers

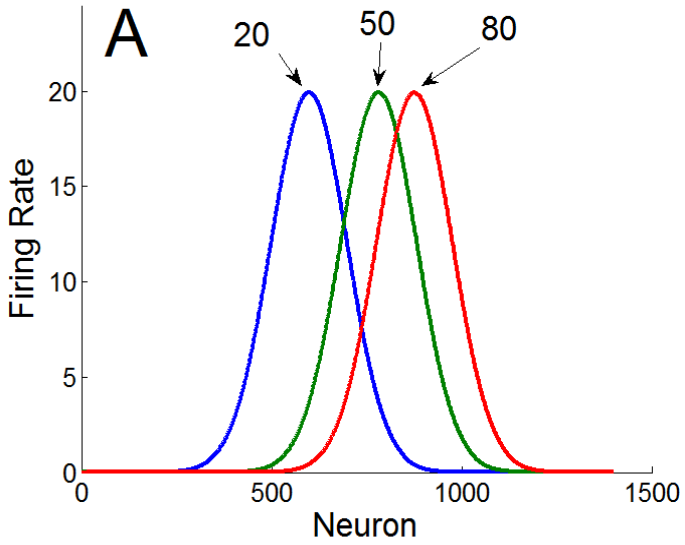

RMSD
9
8.5
8
7.5
7
6.5
4
8
16
Quantity of Numbers
Fast Trials
Slow Trials

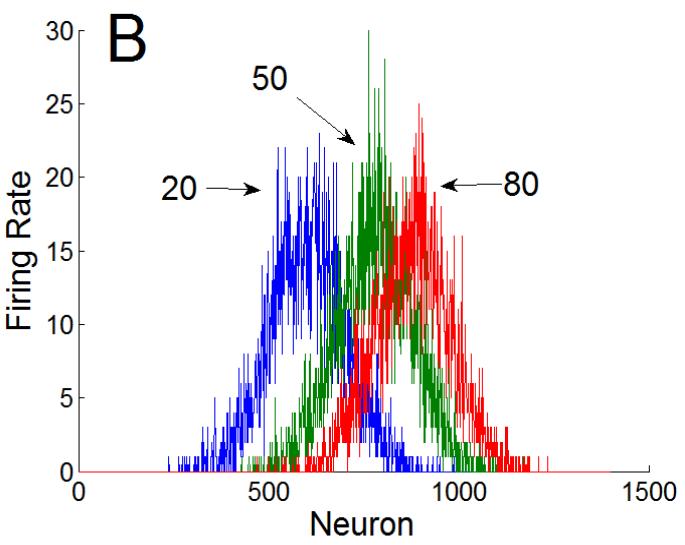
Speeding up the task

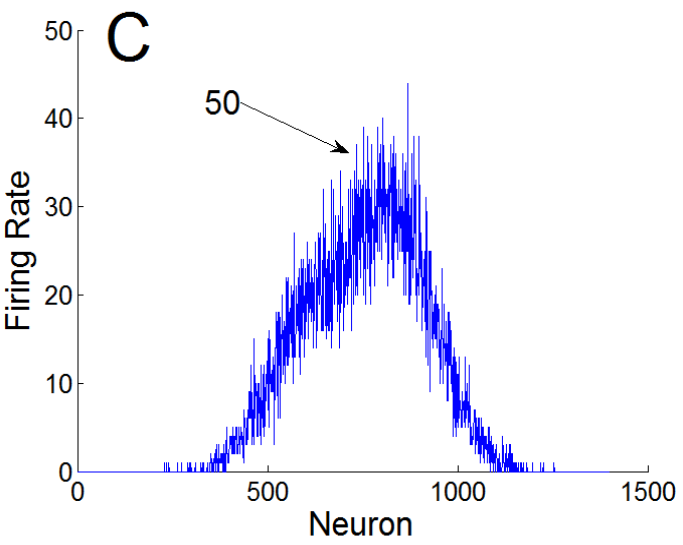
10/sec or fast deadline → accuracy improves with set-size



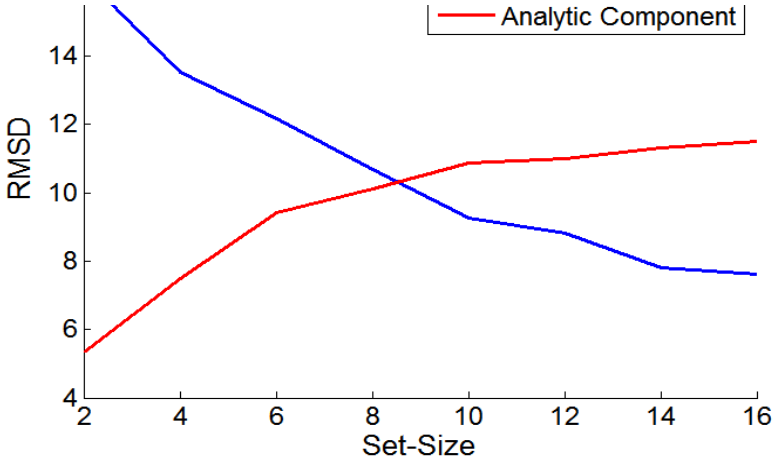
Neural population code model





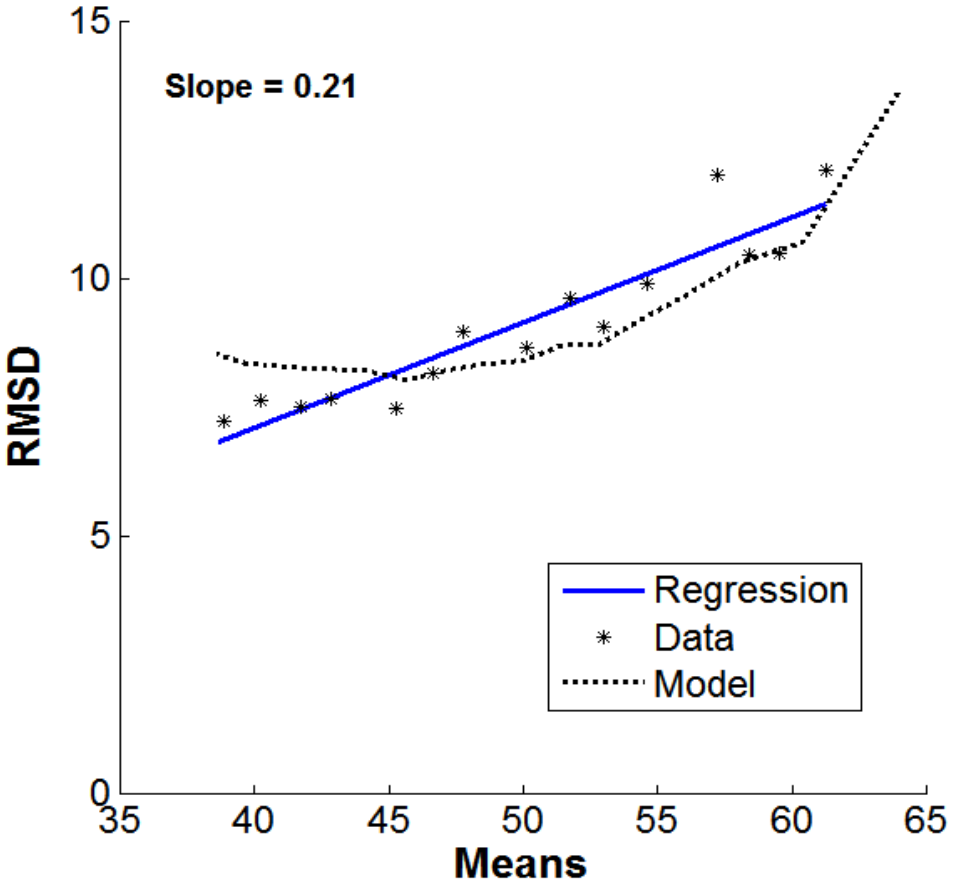


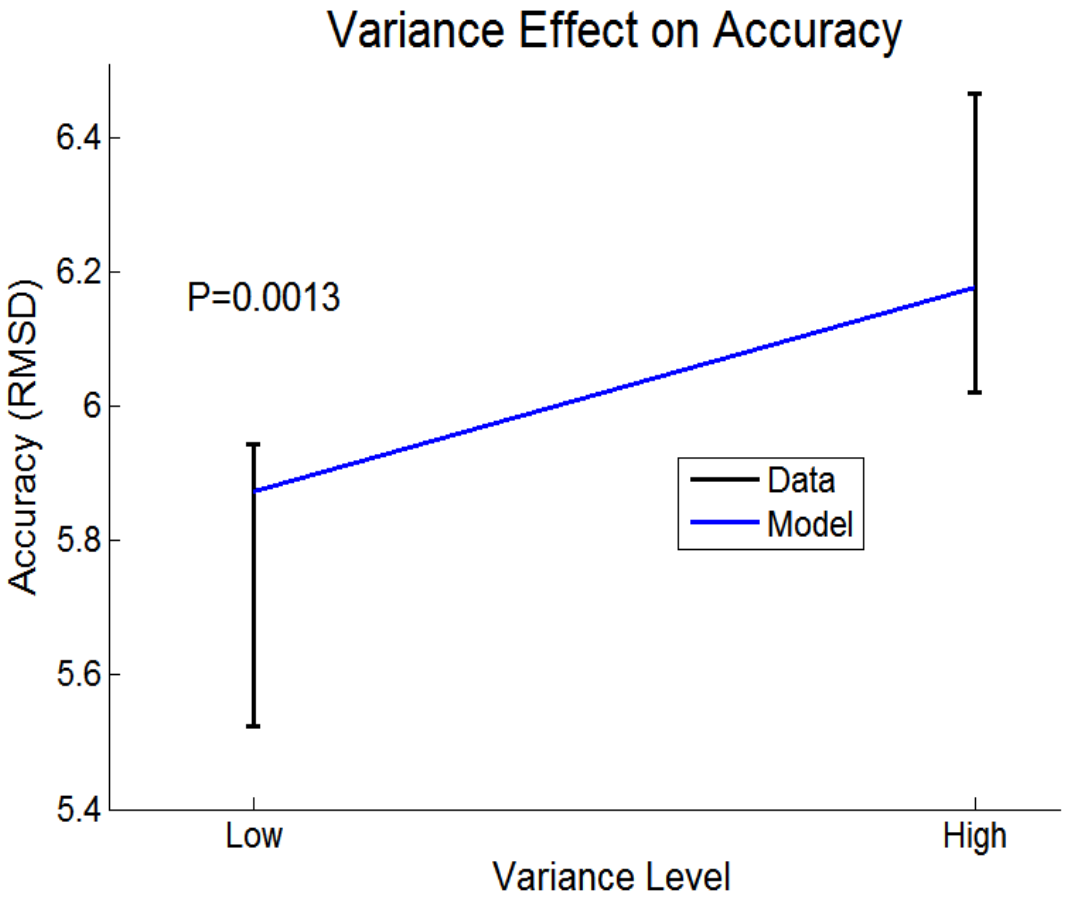
Estimation error decreases with number of items (noise averaging)



Weber law and variance effects

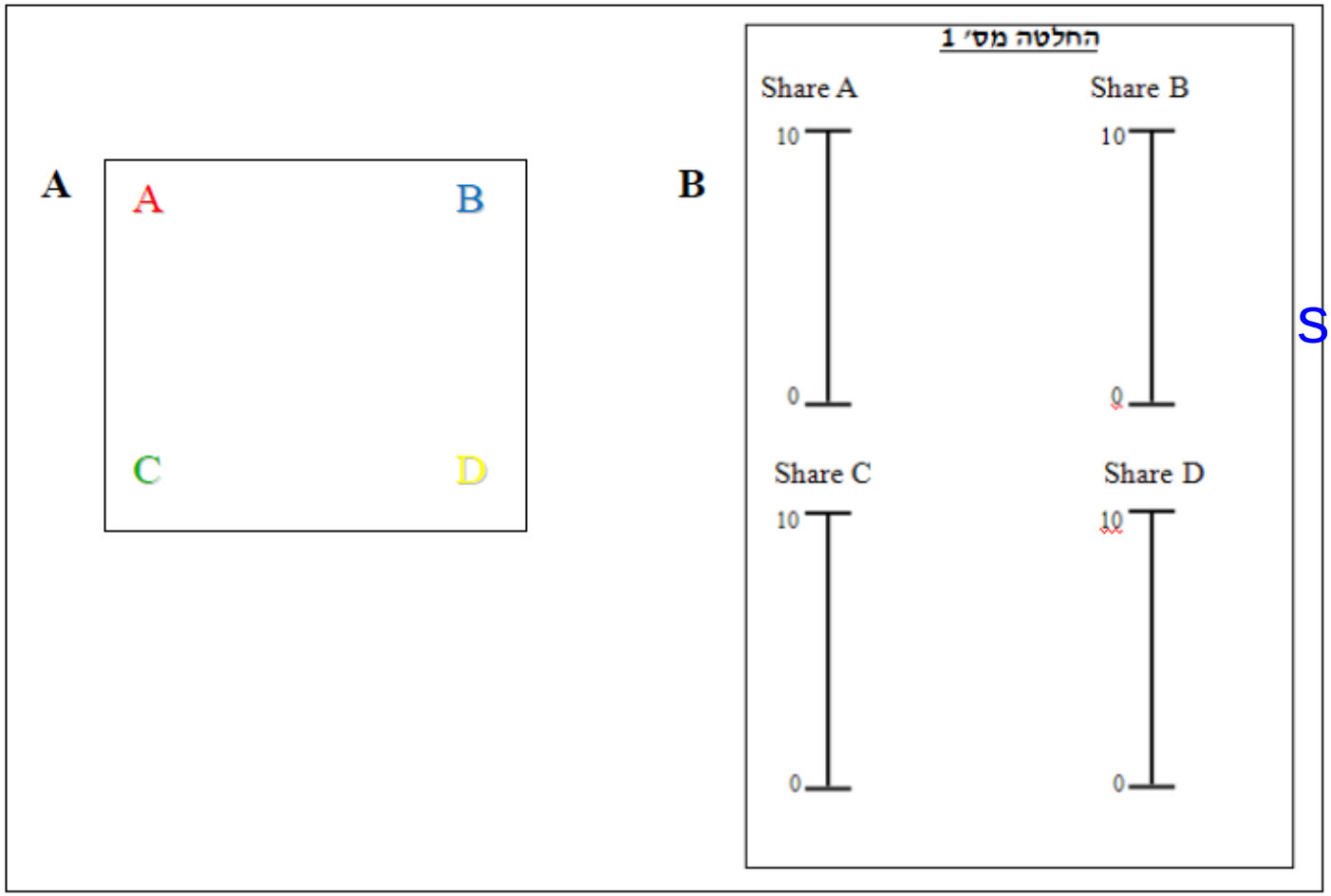
Error increases with value and with variance of the sequence





Probing implicit-intuitive averaging in ecological decisions (Brusovansky & Usher)

- Evaluating 4 stocks (presented at 4 corners, sequentially in random order), each stock composed of 12-6 numbers: 2 with high-average (~50), 2 with low average (~35) X 2 with 6 entries and 2 with 12.
- Is the intuitive system sensitive to averages or to sums?



Response on analog scale (attractiveness)

gure 1: (A) The spatial layout of the four shares in each decision. (B) An

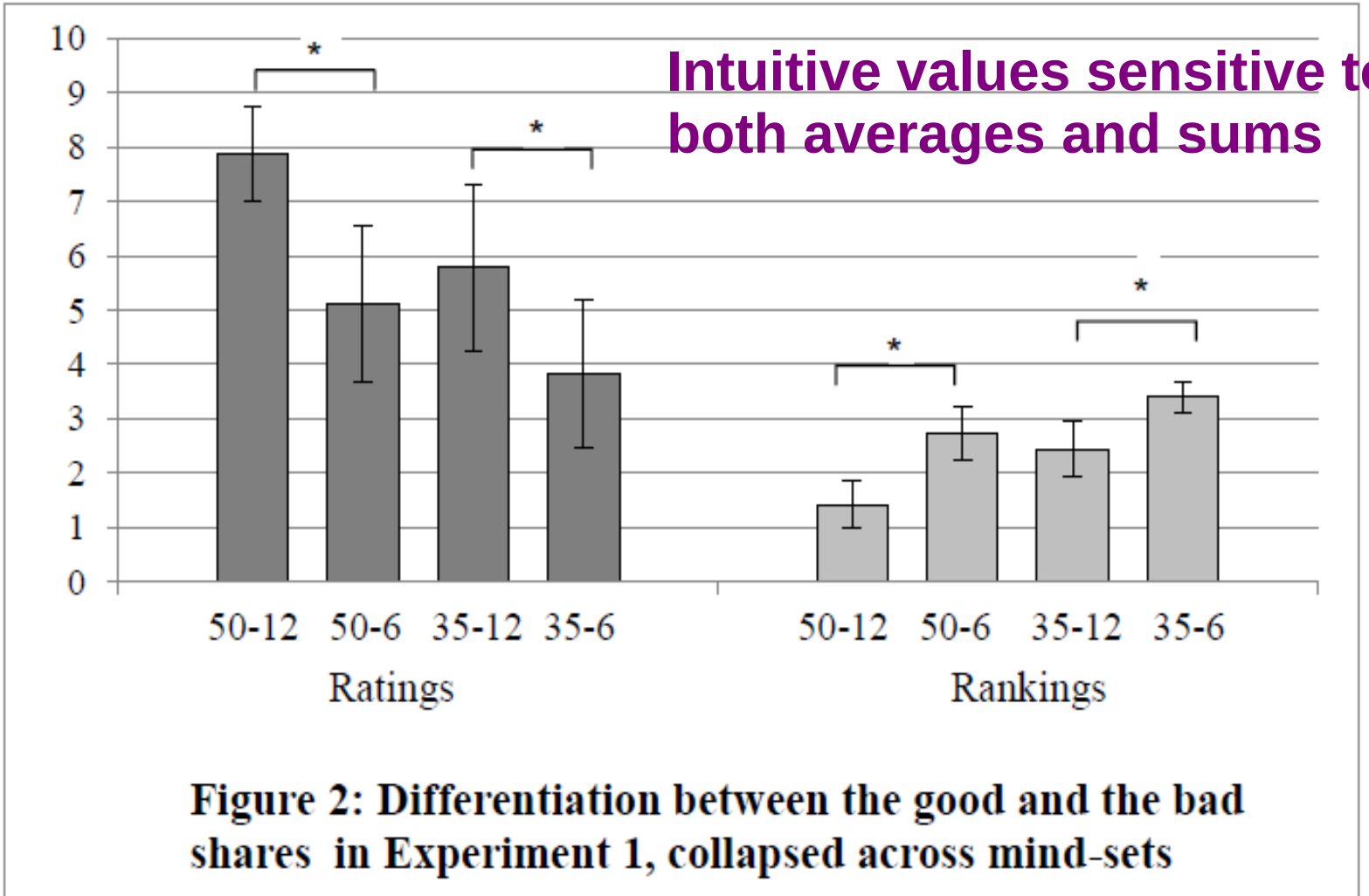
Mind-set manipulation within-S:

Intuitive: fast presentation 1sec/num + "use of intuition/impression"

•Analytic: slow presentation 3 sec/num + "remember and compute"

N=16, each did 10 estimations in each condition (blocked)

Results: observers can do the task



Intuitive values sensitive to both averages and sums

Figure 2: Differentiation between the good and the bad shares in Experiment 1, collapsed across mind-sets

Sensitivity to averages: *DV = V50-V35*

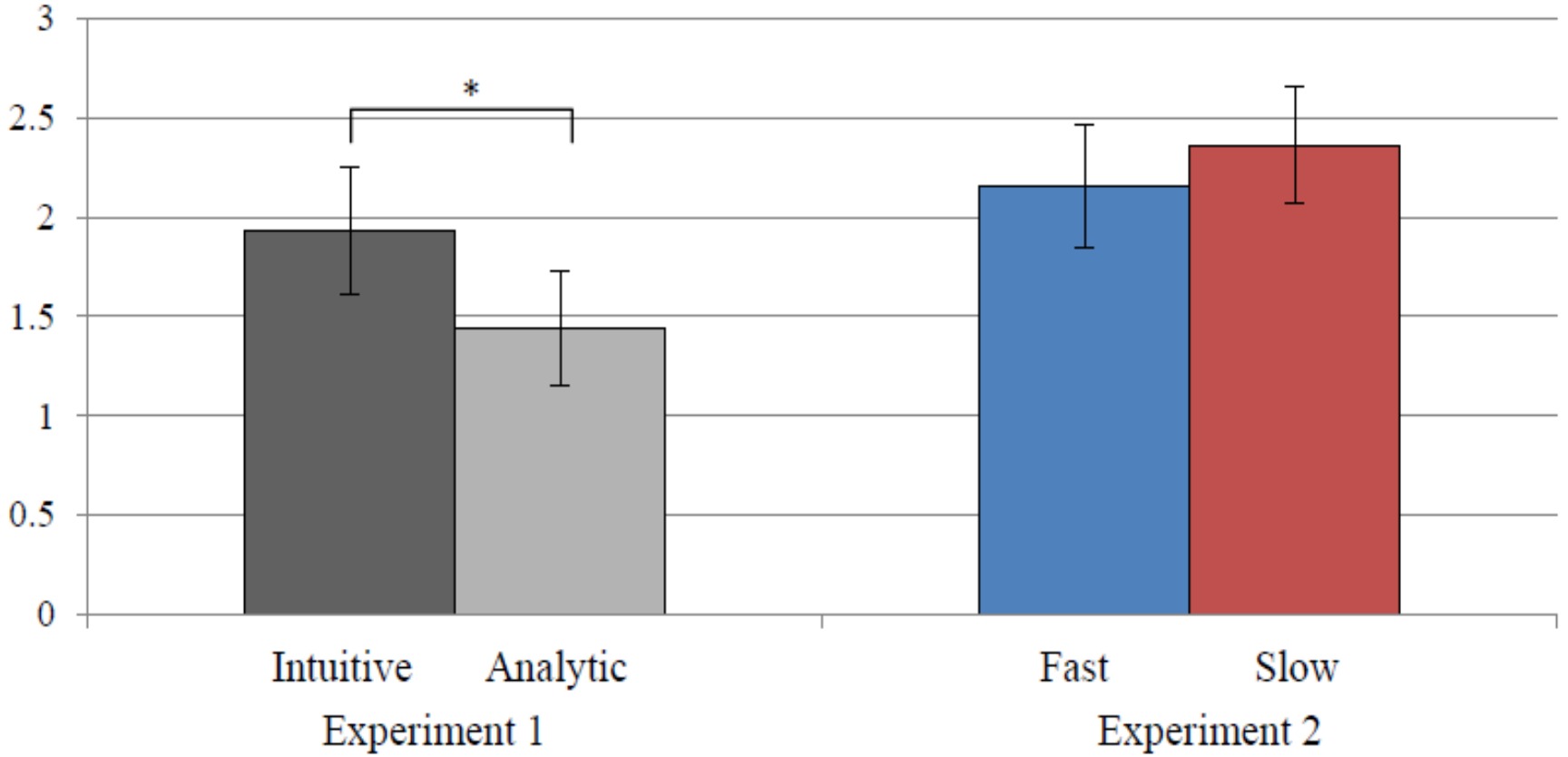


Figure 3: Sensitivity to averages in Experiments 1 & 2. Left Panel: under the intuitive and analytic mind-sets (Experiment 1). Right Panel: under fast and slow presentation rates (Experiment 2)

*p<.05

Setting sums vs averages in opposition: the Michael Jordan effect

Setting sums vs averages in opposition: the Michael Jordan effect

Select basketball candidates for the "Hall of Fame"

High-A low-S: 35, 30, 28, 33, 44, 22, 27, 30, 32

Low-A high-S: 35, 30, 28, 33, 44, 22, 27, 30, 32, **17, 21, 19**

Filler trials (10, 25, 40)

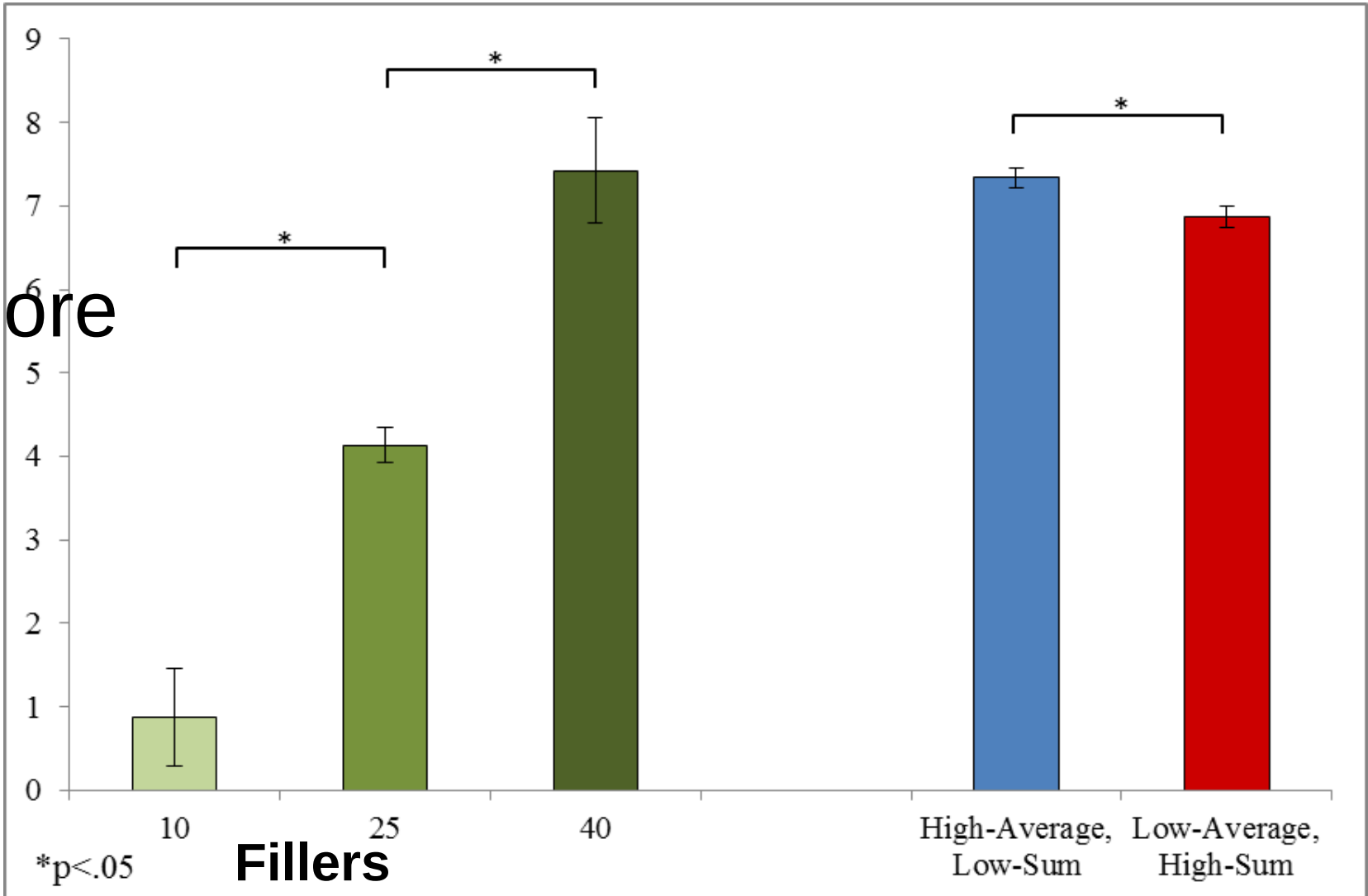
Setting sums vs averages in opposition: the Michael Jordan effect

Select basketball candidates for the "Hall of Fame"

High-A low-S: 35, 30, 28, 33, 44, 22, 27, 30, 32

Low-A high-S: 35, 30, 28, 33, 44, 22, 27, 30, 32, **17, 21, 19**

Average matters more than sum



Higher order summary statistics: variance

The Sperling paradigm

- Limited report-access (attention/WM) to multi-letter visual arrays – (3-4) items
- Temporary-access is much higher (iconic memory) but decays within about ½ sec.
- Observers report having seen more items but "loosing them" before the report.

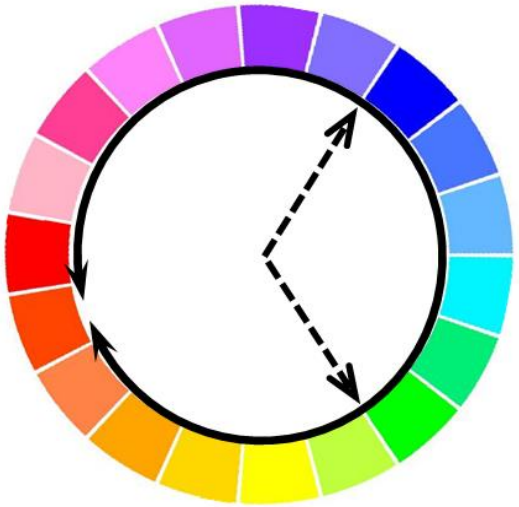
Rich vs. impoverished consciousness controversy

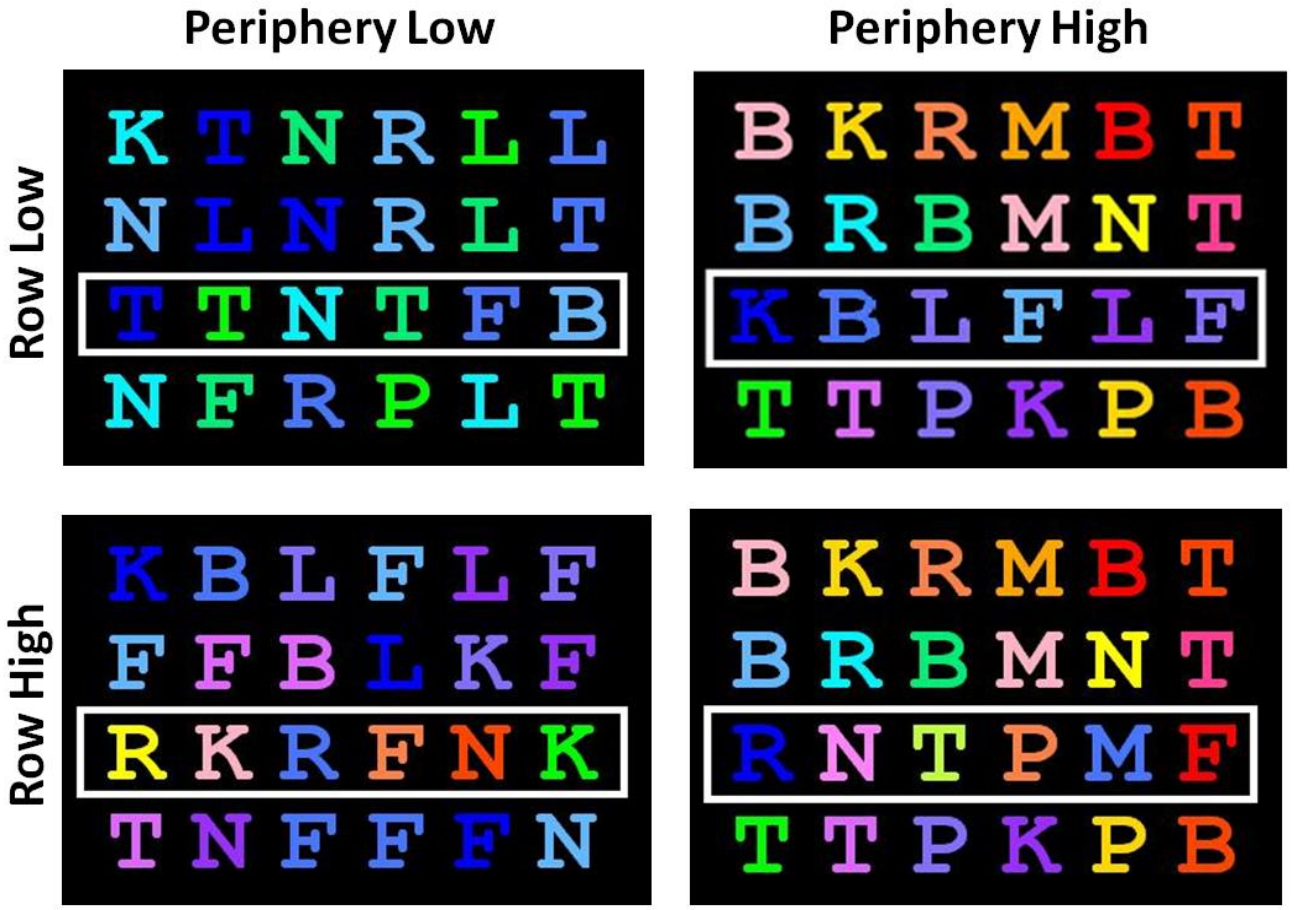
1. Rich phenomenal awareness of display properties (shapes & colors) *outside focal attention*, which is transient (not transferred to VWM) and lost
2. Impoverished awareness *outside focal attention* (fragments or generic representations)

We see more than we can report

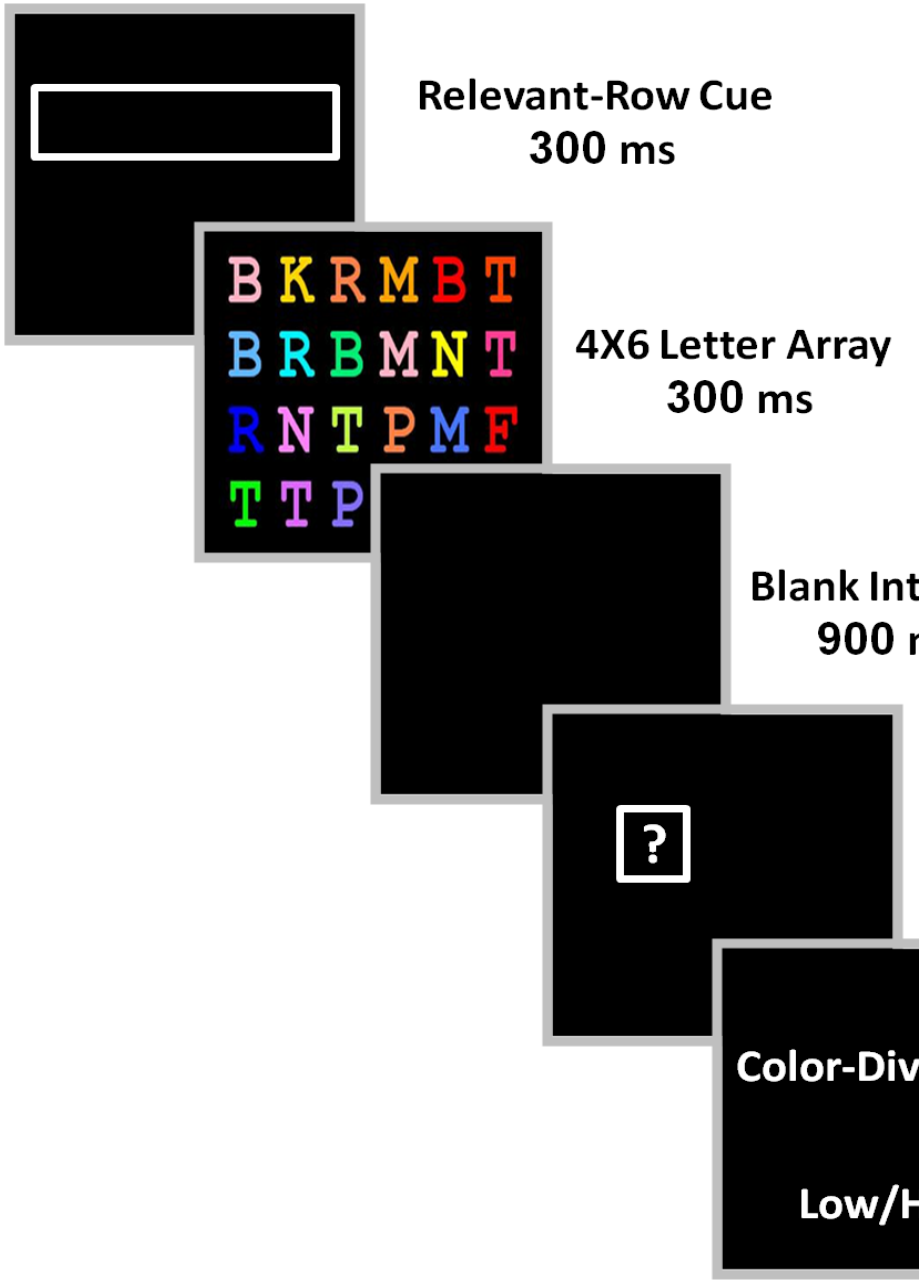
(Bronfman et al., *Psych Sci.*, 2014)

Color diversity manipulation





Procedure (Exp. 1 and 2)

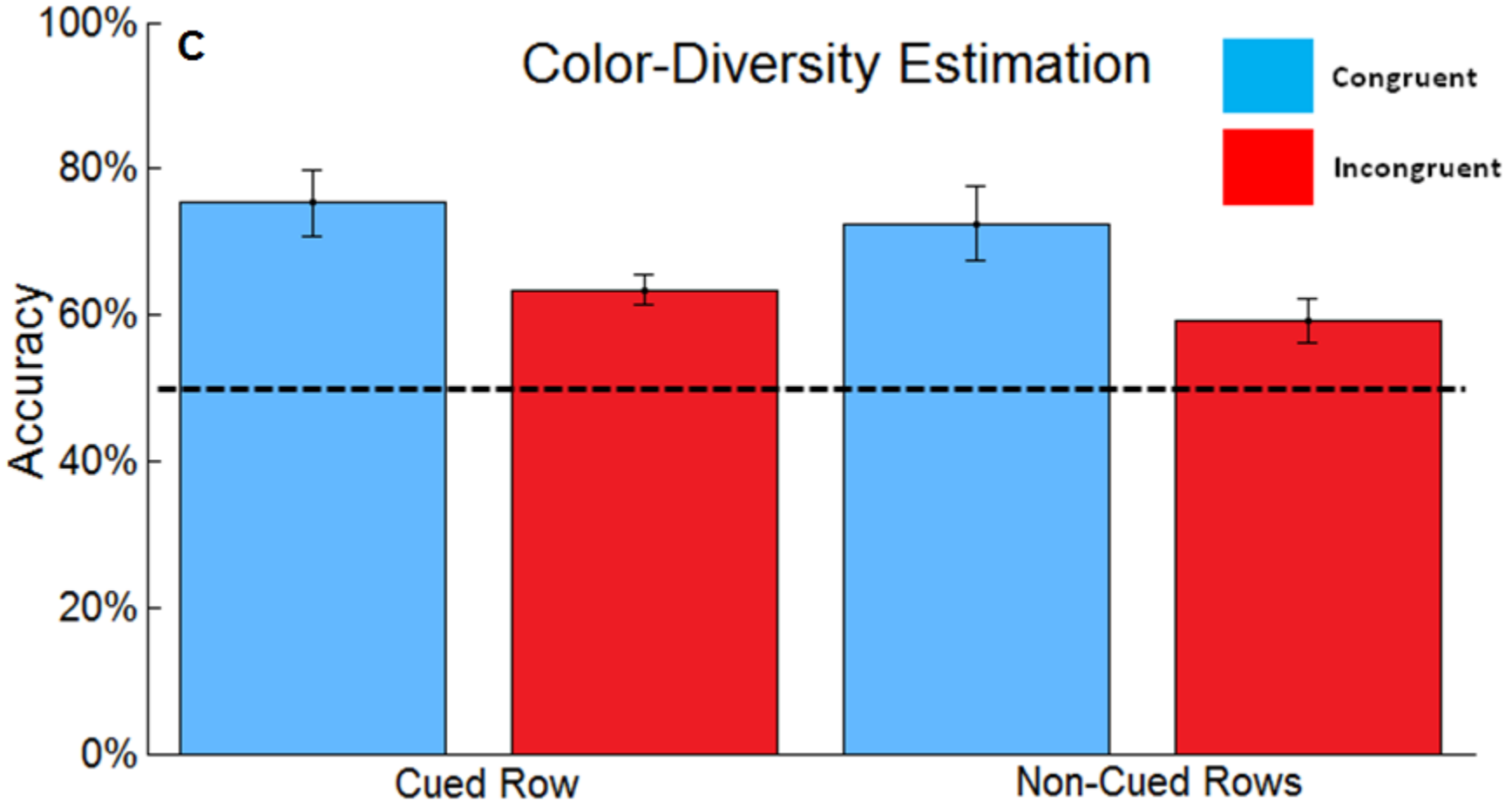


Capacity ~ 3 items
Does not depend on CD task

Color diversity judgments (N=12)

CD for cued row contaminated by CD of surround

CD for non-cued >chance



Interpretations

- While observers attend to cued-row to encode letters into VWM, they automatically (cost free) experience CD of the whole display (variance a high order stat).

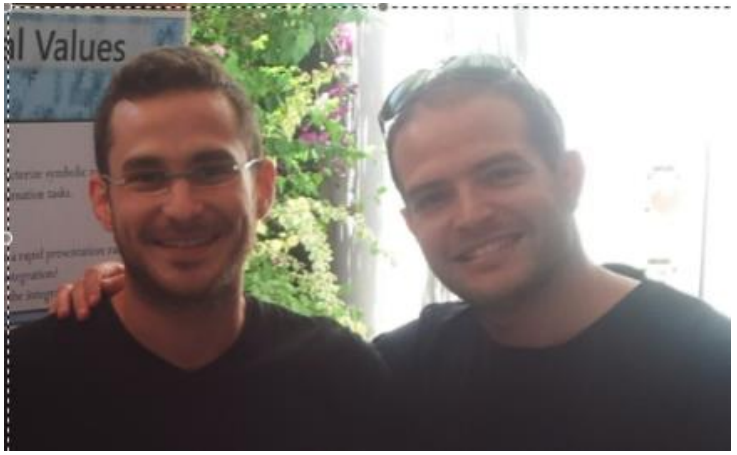
Argument: to estimate CD one needs differentiated representations of the colors outside attentional focus

Conclusions

- Rapid integration of numerical values is possible (improves with n)
- Population code model
- Intuitive averaging is better than analytical averaging at high complexity (fast presentation and large-n)
- Intuitive system sensitive to both averages and sums in difficult decisions, but more to average: the Michael Jordan effect
- Observers can estimate in parallel and without focal attention more complex perceptual statistics (variance)

Collaborators

Noam Brezis
Zohar Bronfman



Michael Brusovansky;

Zohar Rusou;

Dan Zakay; Konstantinos Tsestos, Nick Chater

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