Parallel extraction of summary information across multi-element arrays

Jan Balaguer[1], Andrei Gorea[2], Elizabeth Michael[1], Christopher Summerfield[1]

[1] Department of Experimental Psychology, University of Oxford, Oxford OX1 3UD, UK
[2] CNRS UMR 8158, Laboratoire Psychologie de la Perception, 75006 Paris, France

Introduction

Observers are capable of making rapid and accurate judgments of the average information in an array of multiple elements.

To which extend this is achieved through serial or parallel mechanisms is still a matter of discussion.

Purpose

Summary statistics propose an efficient way of extracting information from perception.

This experimental and computational study brings evidence towards a parallel extraction of average information in human visual perception.

Task

Items are colored shapes between squares and circles ('squircles').

Participants need to report the category (square / circle) or the estimation of the average.
Relevant dimension was shape, or the interaction between shape and color.

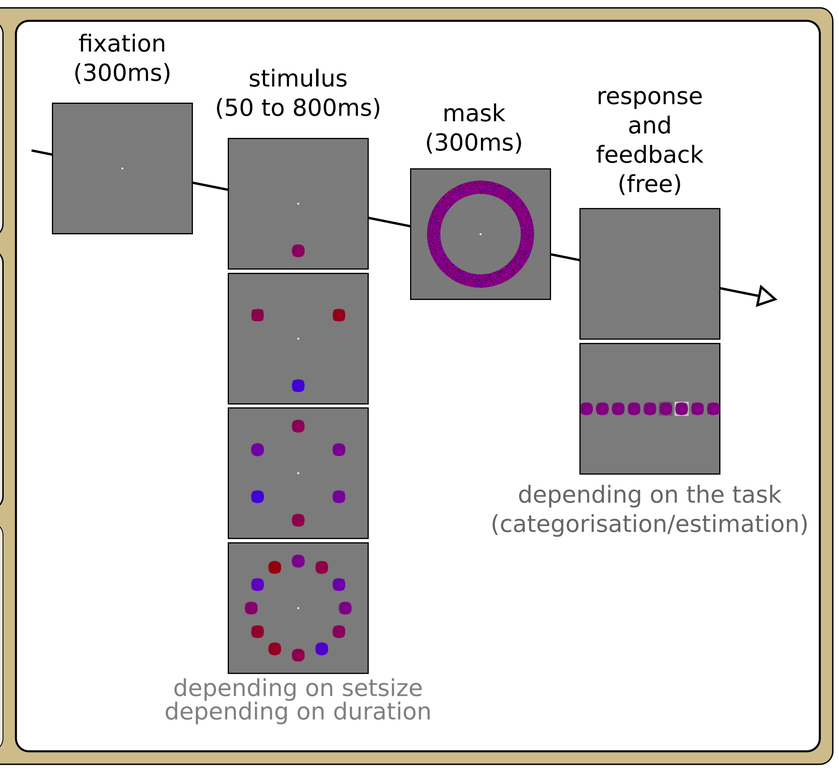
Methods

We used a blocked-design for all conditions. Positions of items given a setsize were fixed.

Sampling from underlying distributions was constrained (both mean and variance of the array were representative of the underlying distribution).
Thus, there was no theoretical advantage of bigger setsizes.

List of experiments

Experiment 1: categorization on shape	(mean + setsize + variance)
Experiment 2: categorization on shape	(mean + setsize + duration)
Experiment 3: estimation on shape	(mean + setsize + duration)
Experiment 4: categorization color x shape	(mean + setsize + variance)



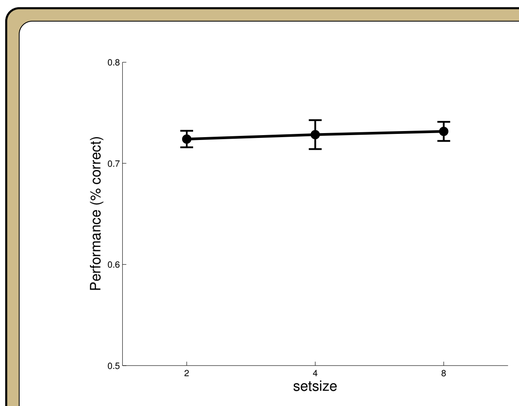


Figure 1 Human behavior (exp 1)

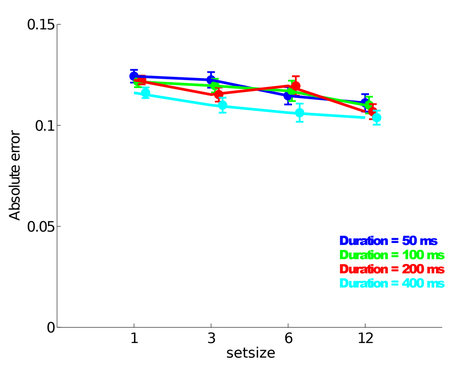


Figure 2 Human behavior (exp 3)

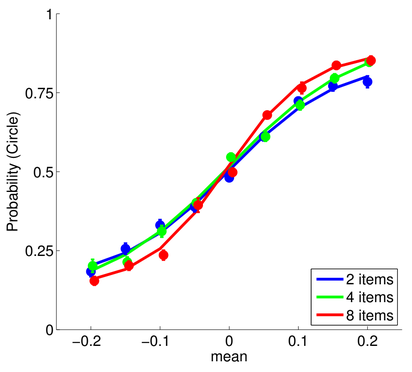
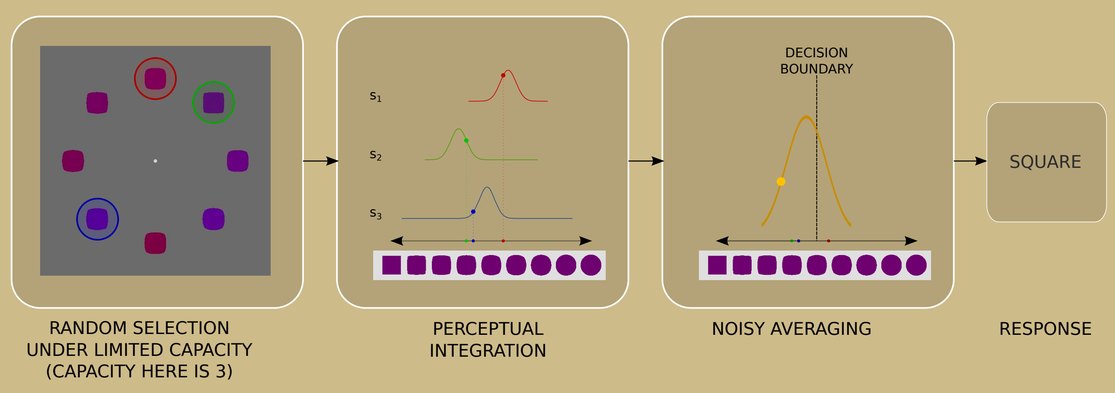


Figure 3 Human behavior (exp 4)

Results

1) No main effect of setsize on performance for experiments 1,2,3. (Figs 1, 2 and 4)
Performance increases with set-size for experiment 4 (Fig 3).
2) Duration matters but not much (Figs 2 and 4)

3) No interactions between setsize and duration for performance in exp 2 and 3 (Fig 2)



Model

Select a subset of the array limited by the capacity of the model.

The perception of each item is limited by some gaussian zero-mean perceptual noise.

Computes the average value with a given zero-mean decision noise.

Simulation (Figure 3)

Performance increases with setsize only if perceptual noise is relevant.

Performance increases with setsize when setsize > capacity.

Performance decreases setsize when setsize > capacity.

Model predicts inverted U-shaped performance as a function of setsize.

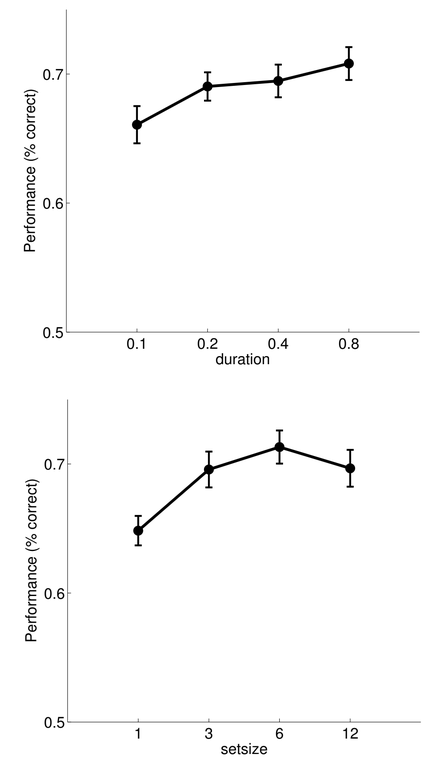


Figure 4 Human behavior (exp 2)

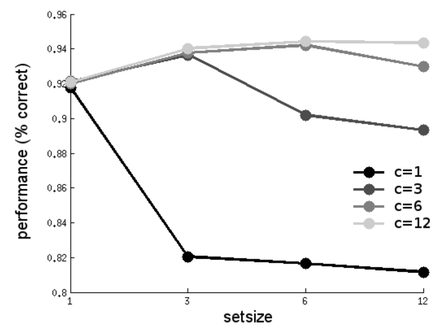


Figure 5 Simulations of the model

Discussion

1) Performance does not decrease with setsize, meaning that the whole array, or the same proportion of it, is processed at all times.

2) Serial sampling of the whole array can be discarded (see Result 3) if sampling requires 50 ms or more.

3) Higher (positive) correlation between performance and setsize only occurs in experiment 4 (see Fig 2) as predicted by the model.

4) Fittings of the model on behavior point towards a human capacity of at least six to twelve items processed in parallel.

Conclusion

Humans seem to be able to extract the average by processing the whole array in a parallel way rather than resampling.

This study brings evidence that can't be explained by random subsampling or resampling strategies.

References

[1] Ariely, D. (2001). Seeing sets: Representation by statistical properties. Psychological Science, 12, 157–162

[2] Myczek, K., & Simons, D. (2008). Better than average: Alternatives to statistical summary representations for rapid judgments of average size. Perception & Psychophysics, 70, 772–788.