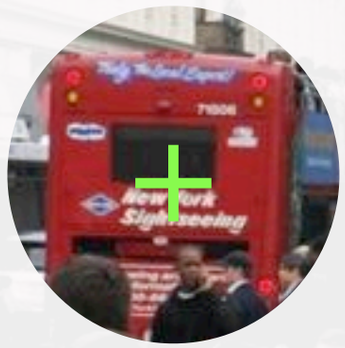
# Different mechanisms and pathways for perceiving objects, sets, and ensembles

Hee Yeon Im

A. A. Martinos Center for Biomedical Imaging
Department of Radiology
Massachusetts General Hospital
Harvard Medical School

# How do we see the world?

# We do not see the world like this

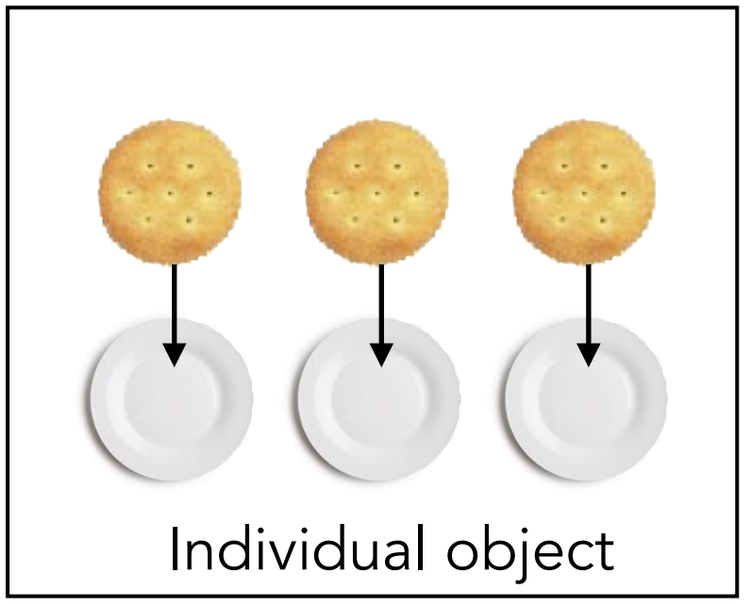




# Groups of objects

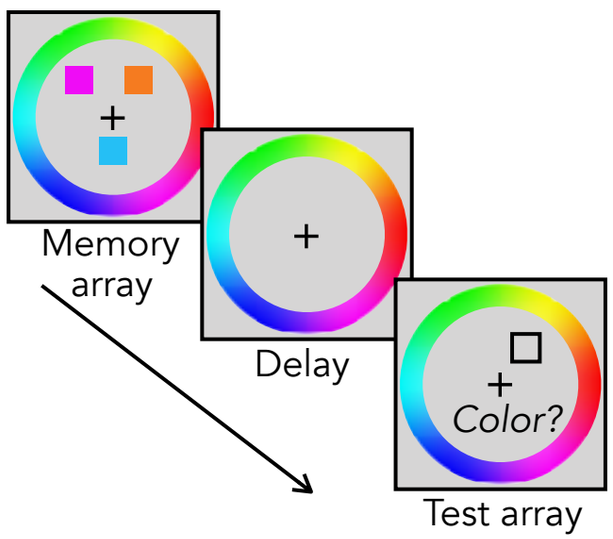
# Spatial layout of the scene

# Gist of the scene

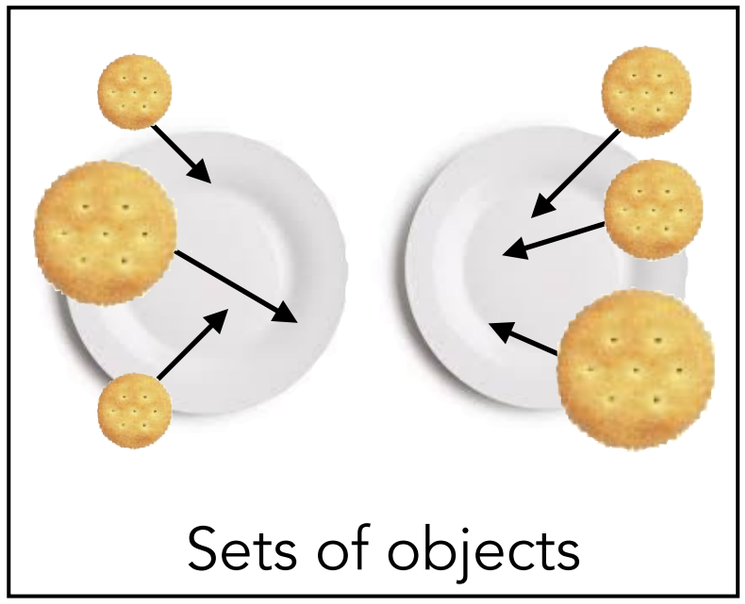
# Objects, Sets, and Ensembles




- One-to-one correspondence between objects
- Perceiving or remembering features of individual objects



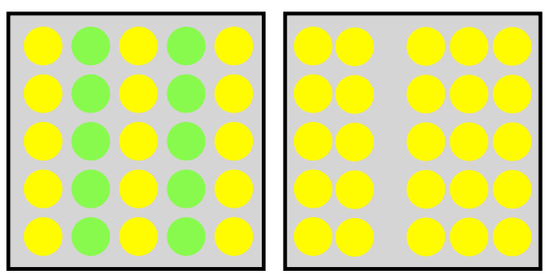

Luck & Vogel, 1997

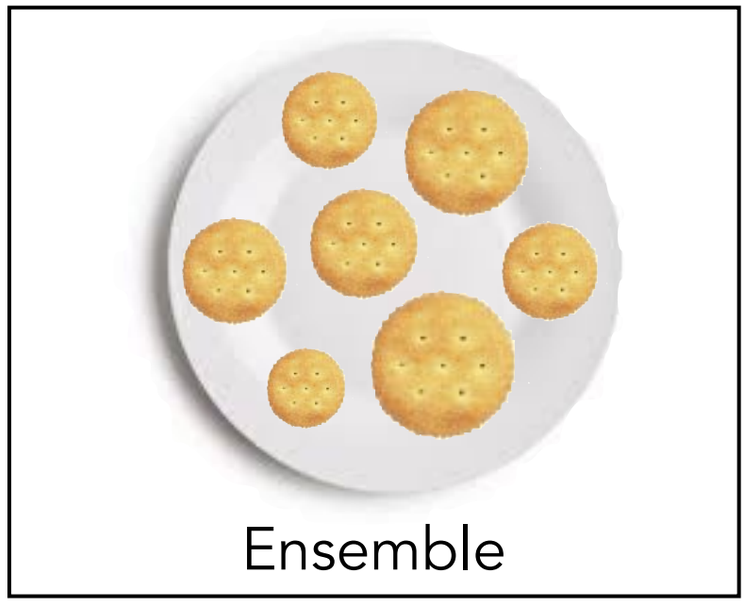



- One-to-one correspondence between objects or sets
- Chunking

  **F-B-I-C-I-A-N-S-A-C-A-T**

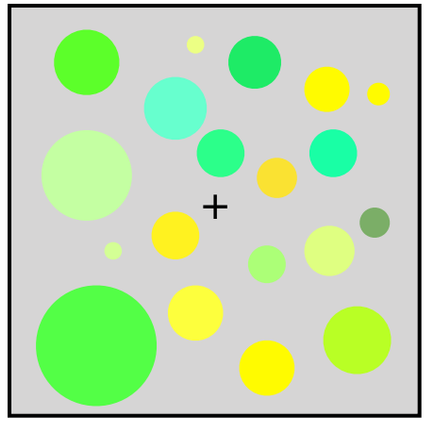
  **FBI-CIA-NSA-CAT**
- Grouping





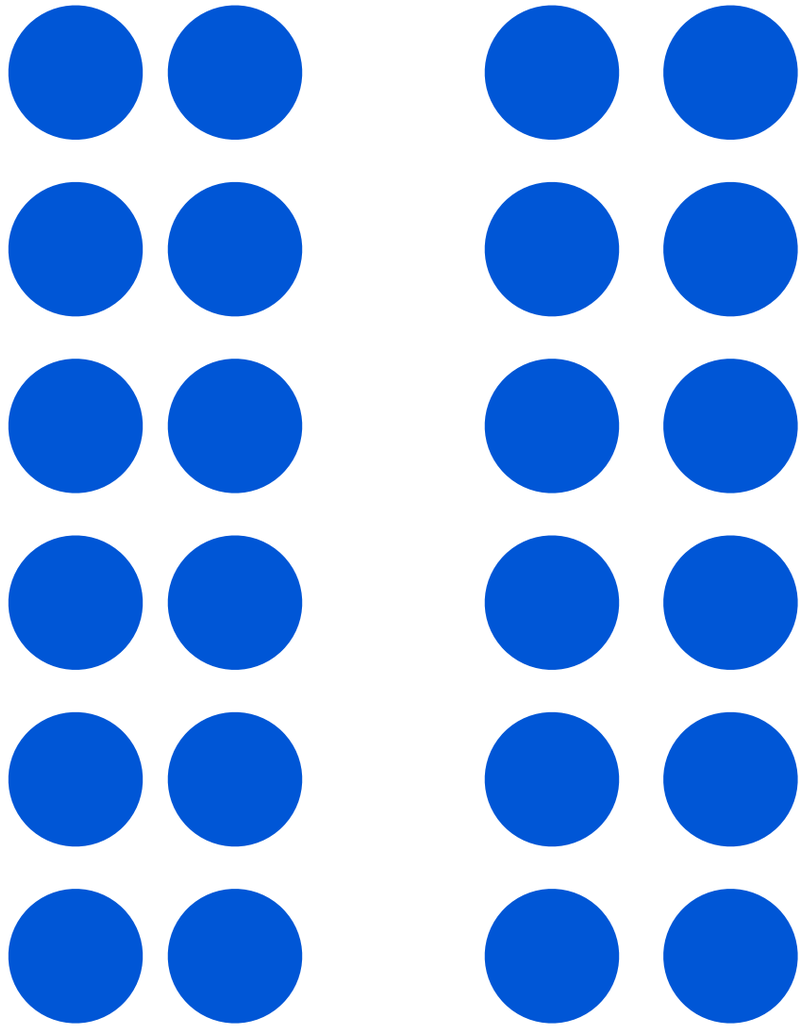
Ensemble

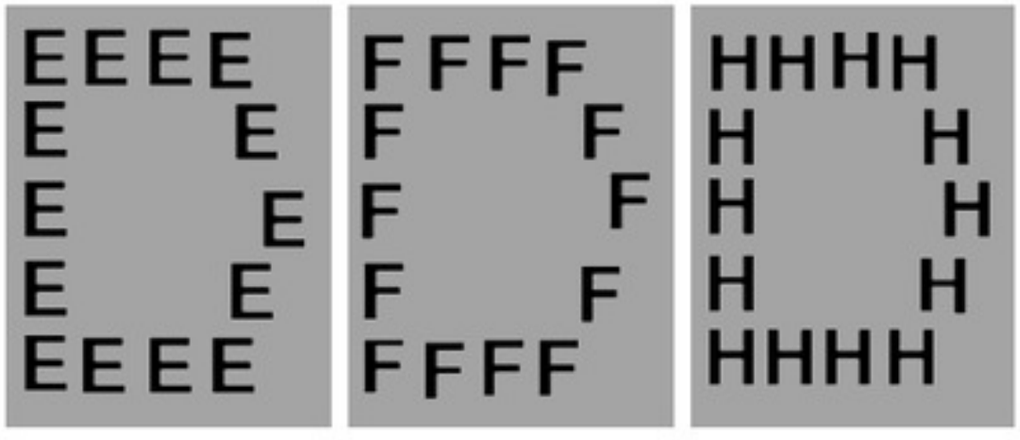
- Averaging



  - Average hue (Maule & Franklin, 2015)
  - Average size (Ariely, 2001)
- Numerosity estimation
  - Approximate number (Halberda et al., 2006)

# Grouping and visual impression of number





# How many dots do you see?

Trial 1



Answer: 14

Trial 2



Answer: 41

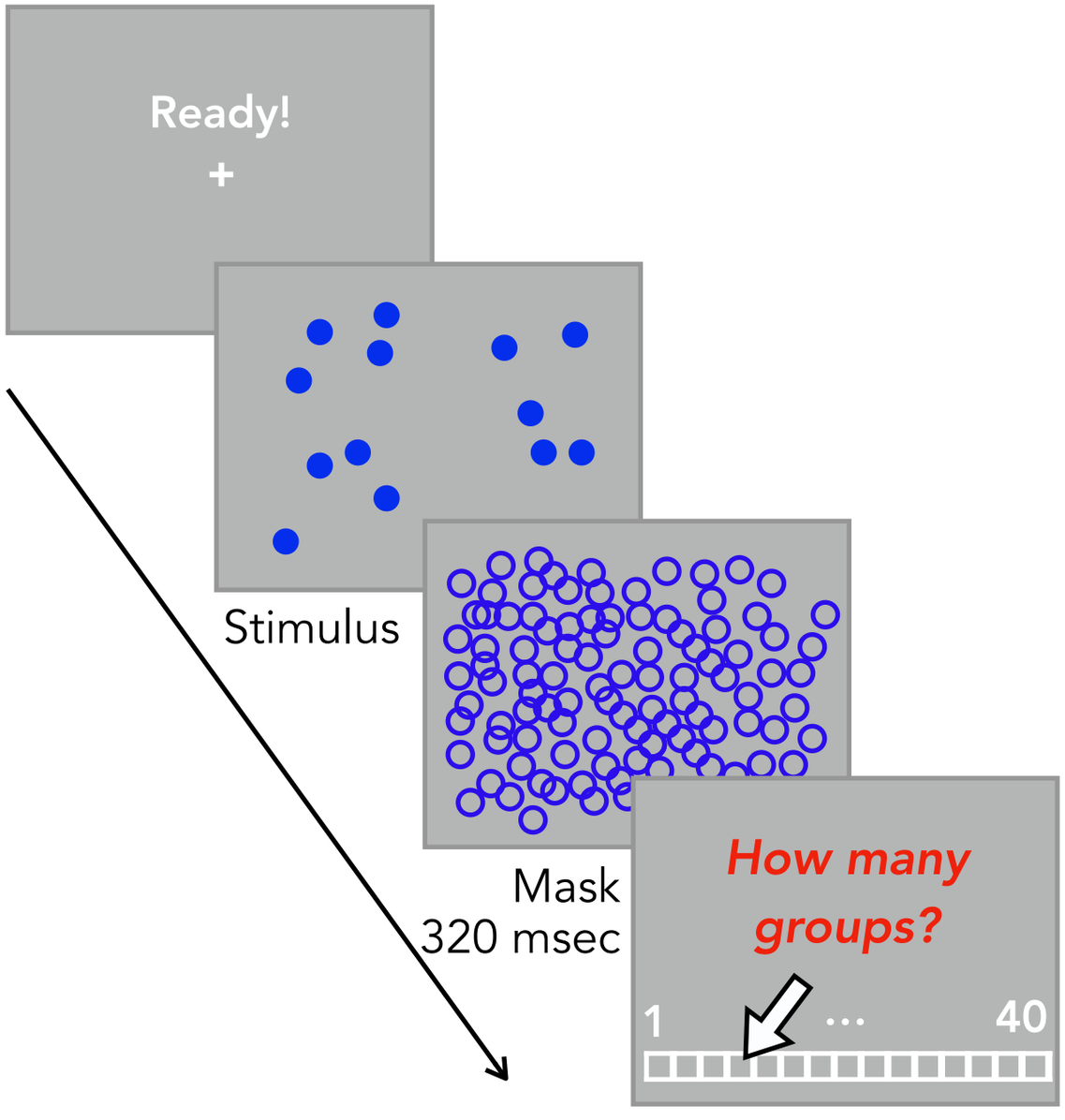
Trial 3



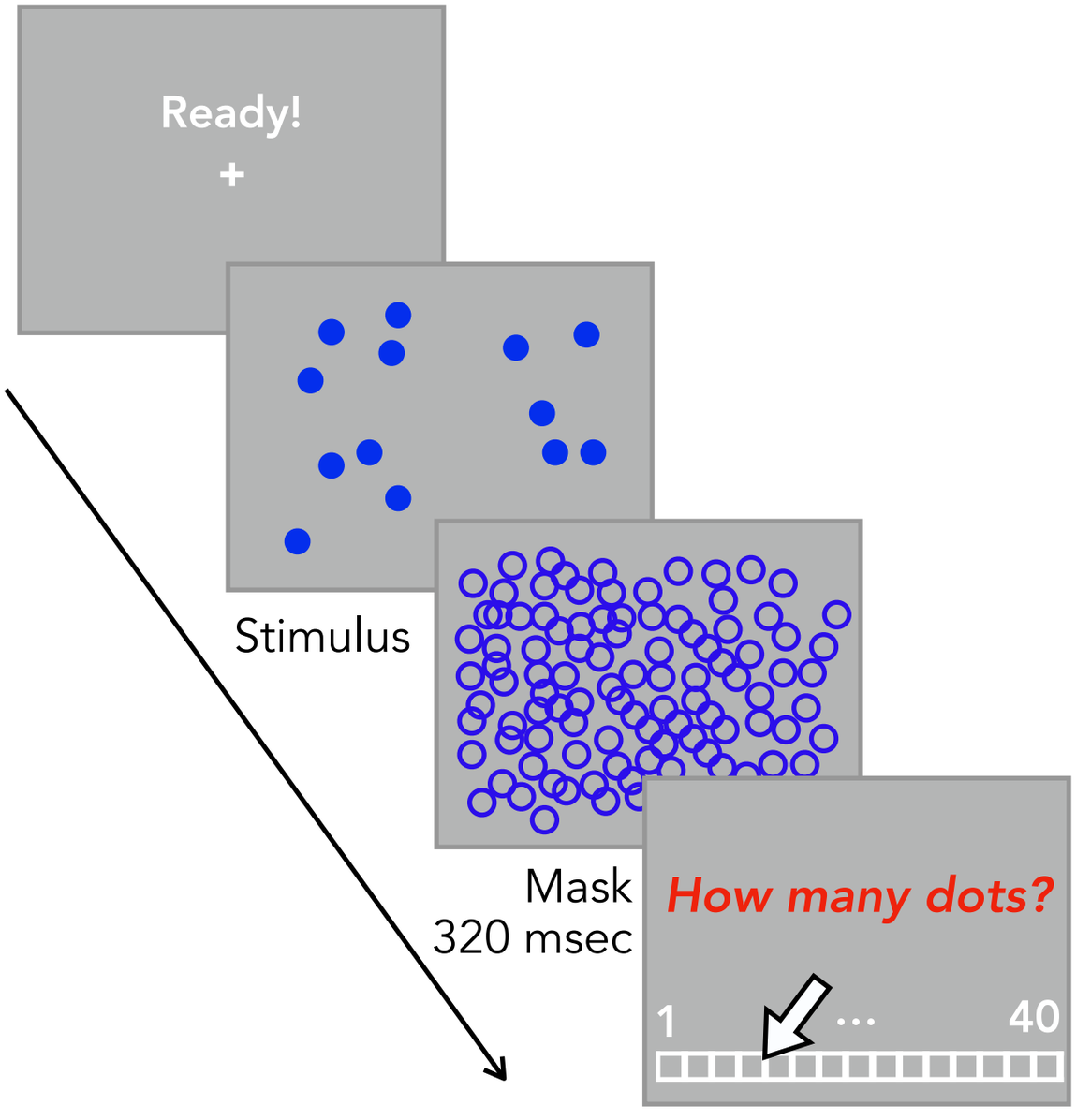
Answer: 41

# Number estimation of sets and objects

## Exp.1: How do we see sets?




## Exp.2: How do we see objects?



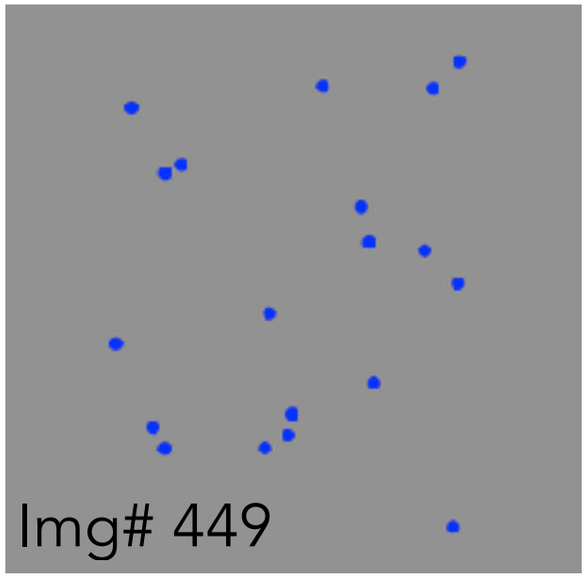

- Stimulus duration: 50, 99, 198, 330 msec
- 5-35 randomly located dots

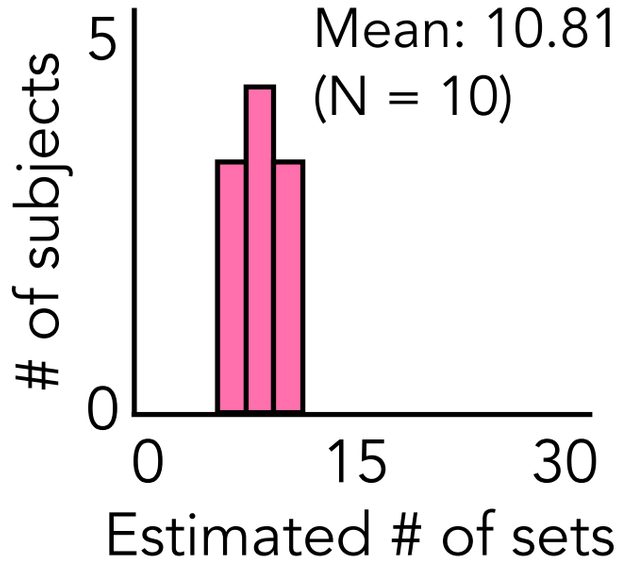
Im, Zhong, & Halberda, 2016

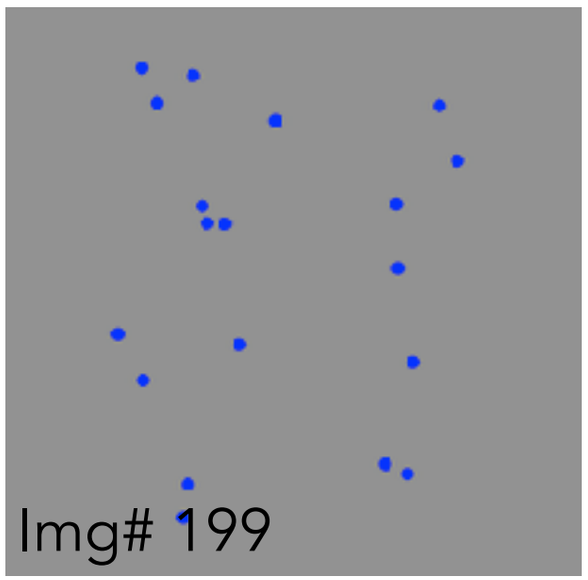
# Perceiving sets

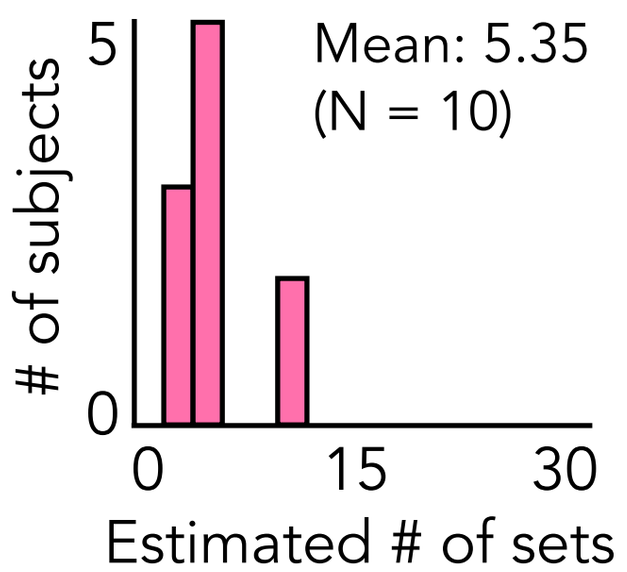
$R^2$ values  $p < 0.01$  $p < 0.05$

| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | | 0.37 | 0.48 | 0.18 | 0.45 | 0.40 | 0.36 | 0.50 | 0.45 | 0.22 |
| S2 | | | 0.69 | 0.26 | 0.53 | 0.39 | 0.37 | 0.22 | 0.42 | 0.33 |
| S3 | | | | 0.12 | 0.24 | 0.14 | 0.38 | 0.19 | 0.34 | 0.32 |
| S4 | | | | | 0.43 | 0.11 | 0.13 | 0.10 | 0.26 | 0.32 |
| S5 | | | | | | 0.38 | 0.31 | 0.45 | 0.33 | 0.36 |
| S6 | | | | | | | 0.15 | 0.23 | 0.28 | 0.21 |
| S7 | | | | | | | | 0.32 | 0.34 | 0.20 |
| S8 | | | | | | | | | 0.21 | 0.29 |
| S9 | | | | | | | | | | 0.42 |
| S10 | | | | | | | | | | |



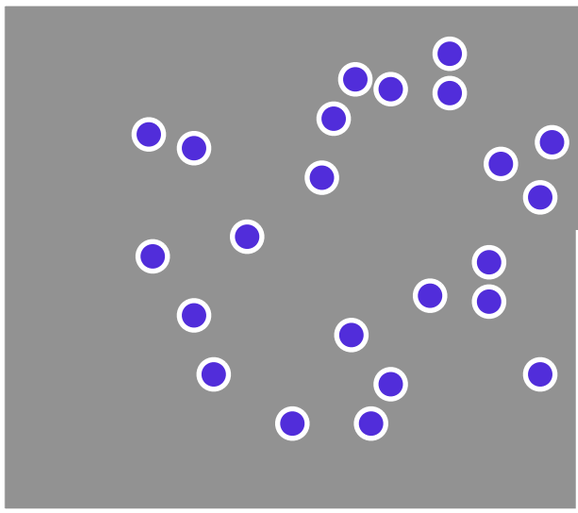



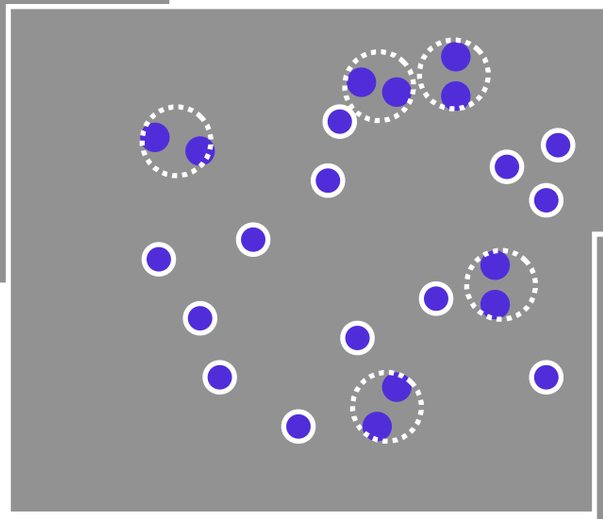




Im, Zhong, & Halberda, 2016

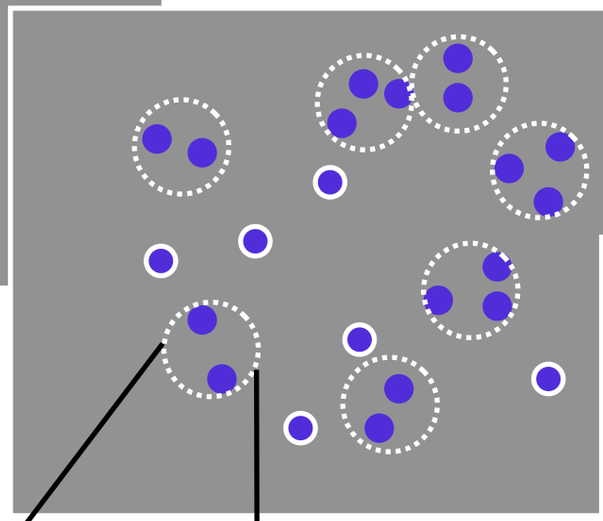
# Hierarchical grouping algorithm



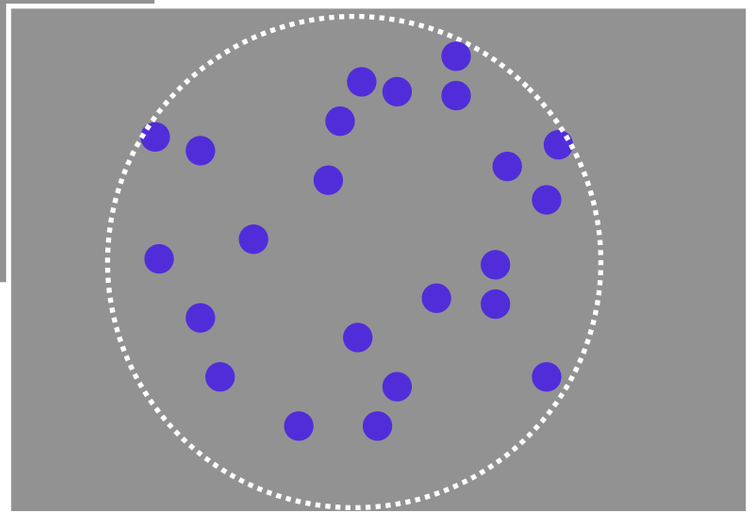
Iteration 1
# of groups: 23



Iteration 2
# of groups: 18

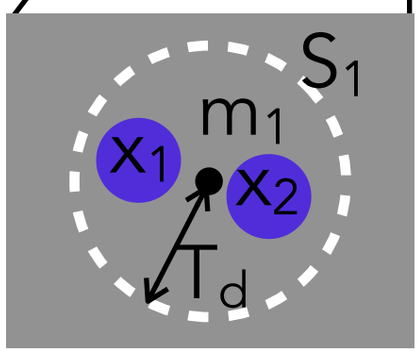


Iteration 3
# of groups: 13



Iteration N
# of groups: 1

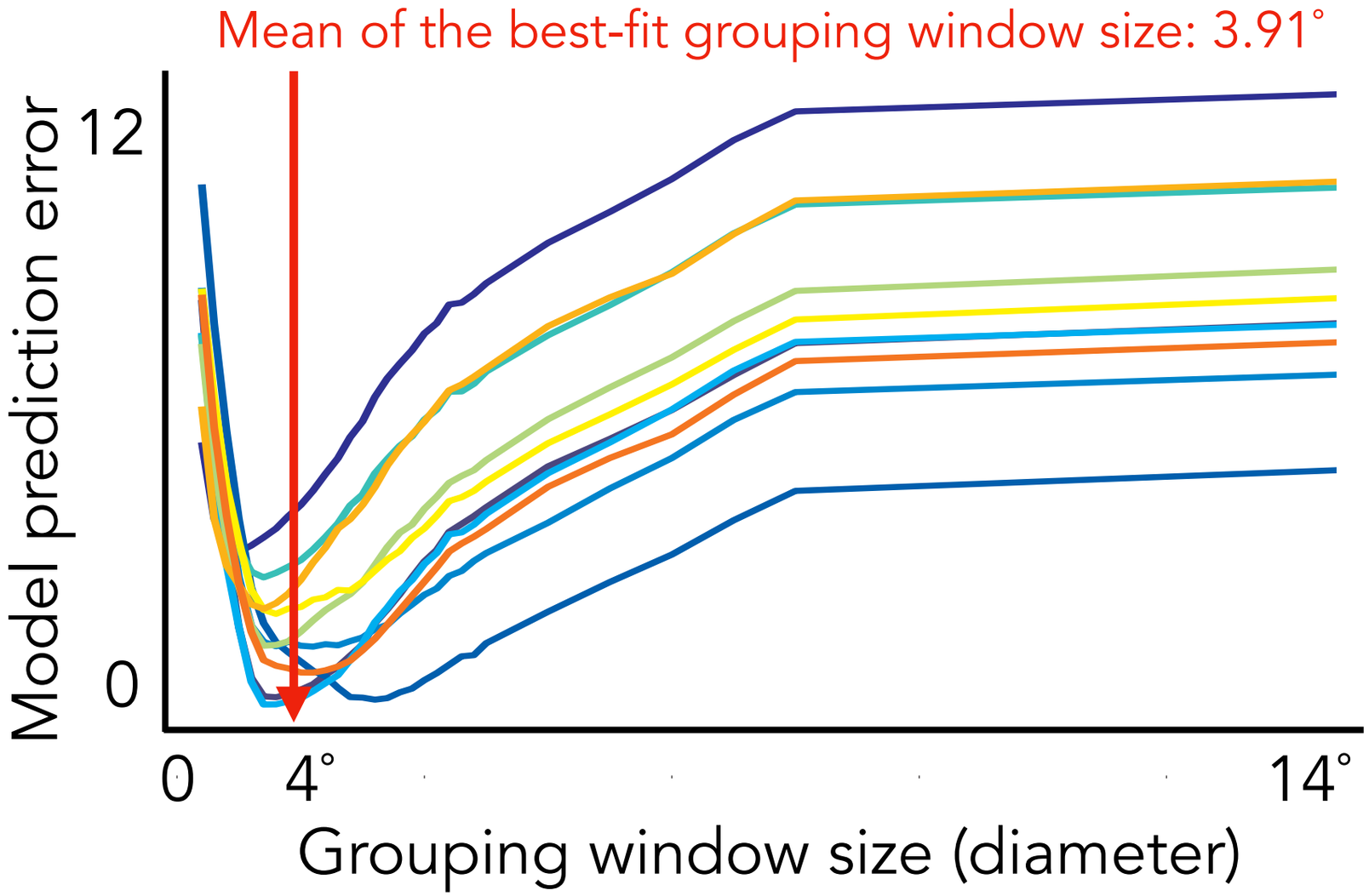
$$\left\| x_p - m_i \right\| \leq T_d, \forall x_p \in S_i$$

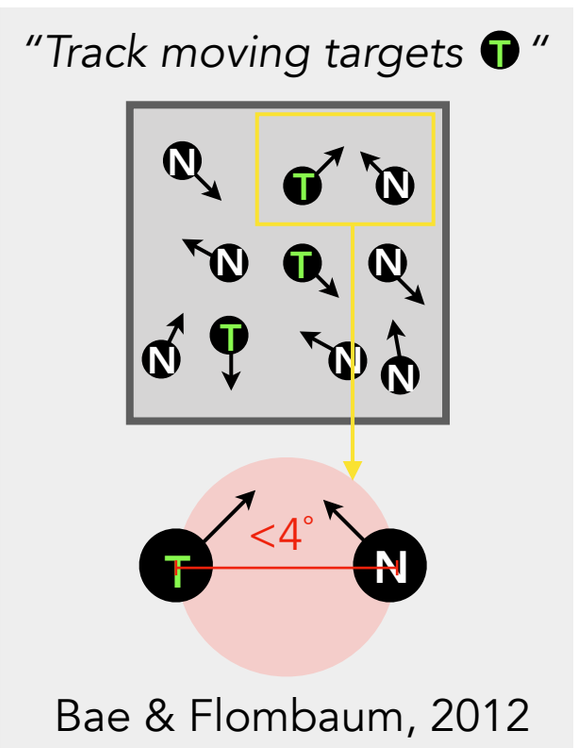



Im, Zhong, & Halberda, 2016

# Model-predicted grouping window size

Model prediction error = Model-predicted number of sets - human response

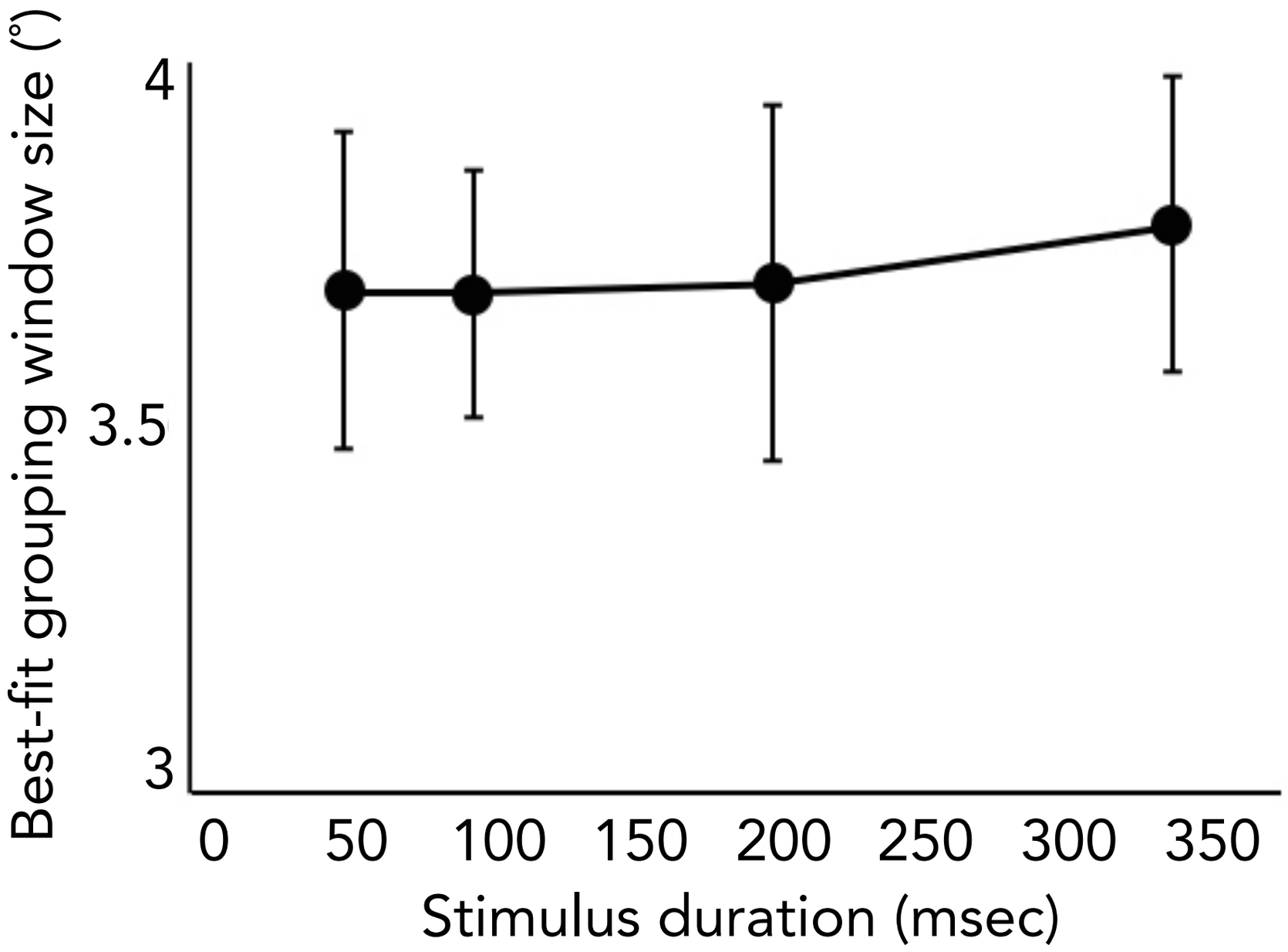



Bae & Flombaum, 2012

Im, Zhong, & Halberda, 2016

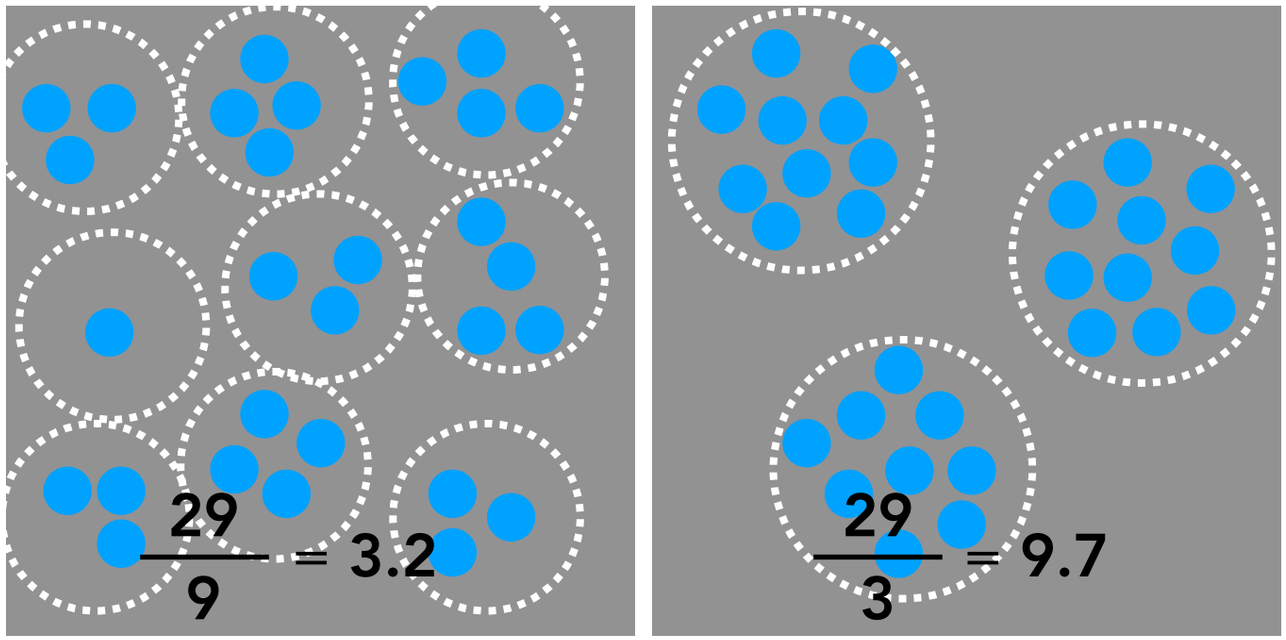
# Grouping can happen very quickly

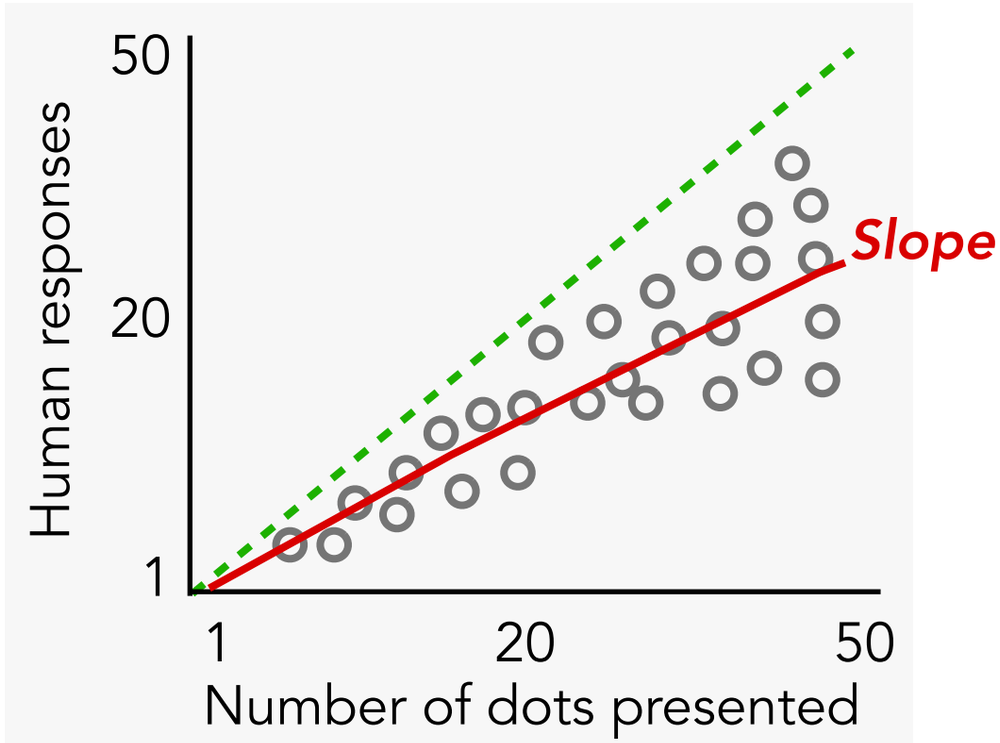


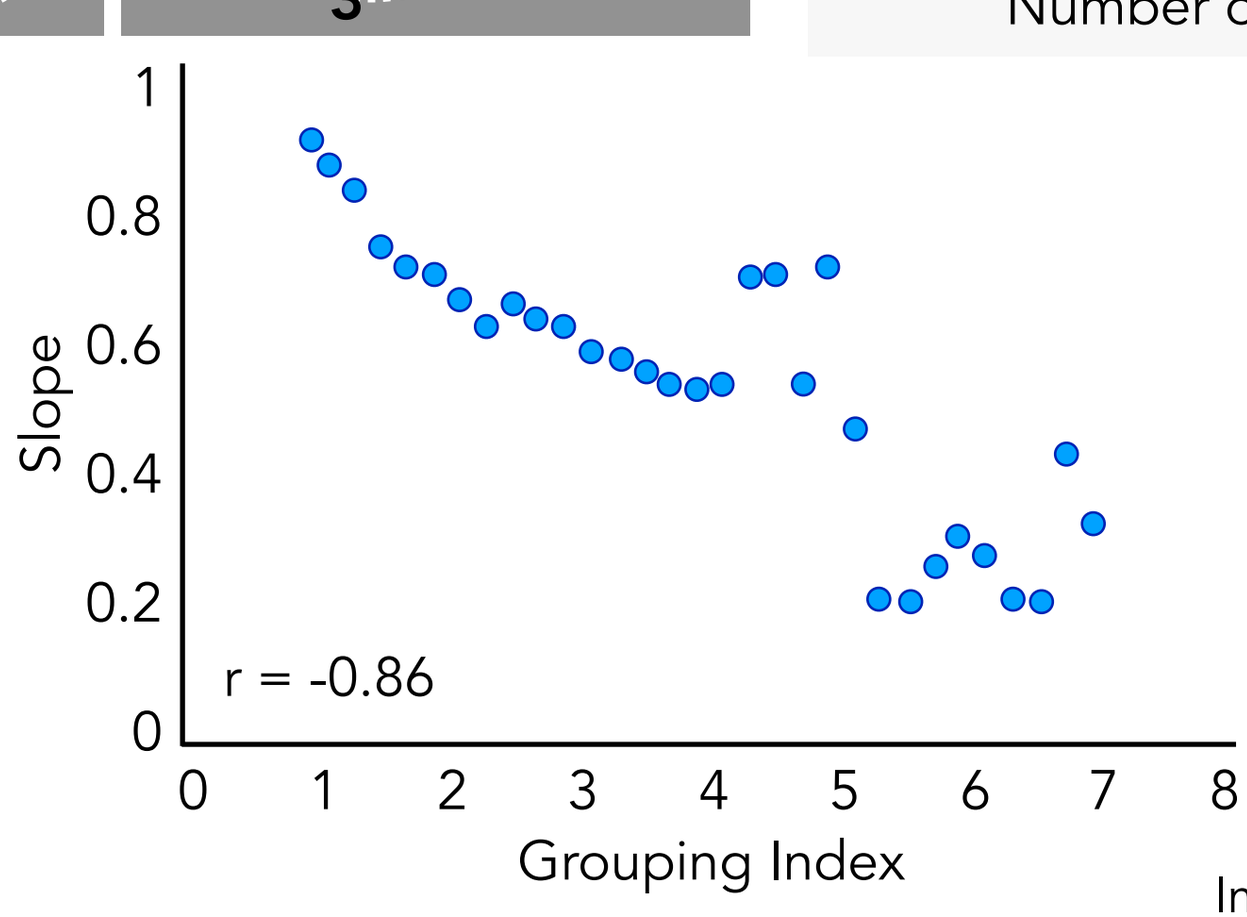

Im, Zhong, & Halberda, 2016

# More grouping leads to more underestimation

$$\textbf{Grouping Index} = \frac{\text{Number of dots}}{\text{Number of sets}}$$

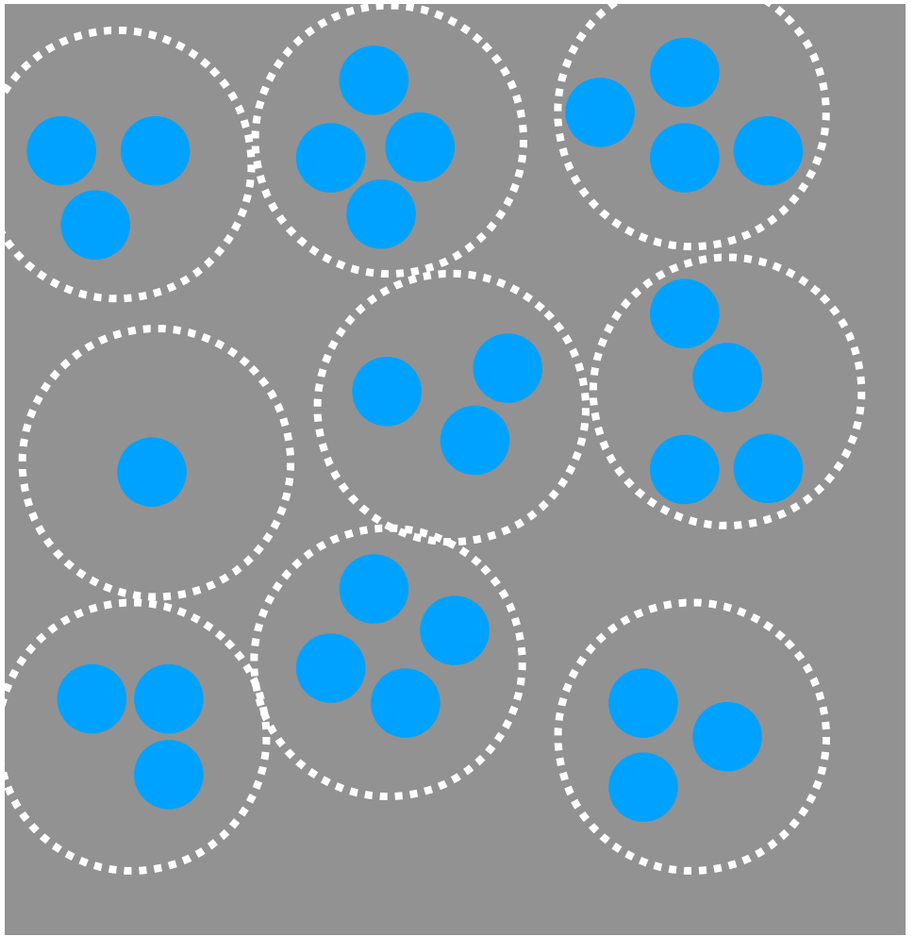


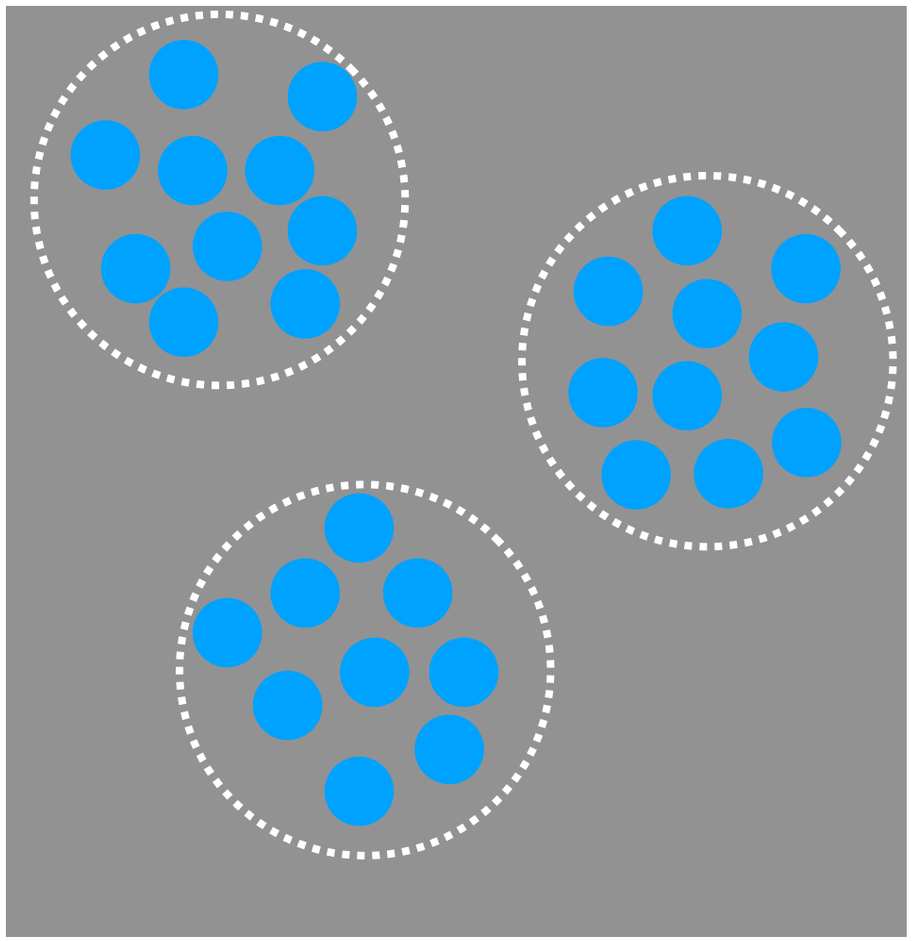




Im, Zhong, & Halberda, 2016

# Hierarchical coding of “set” and “object”



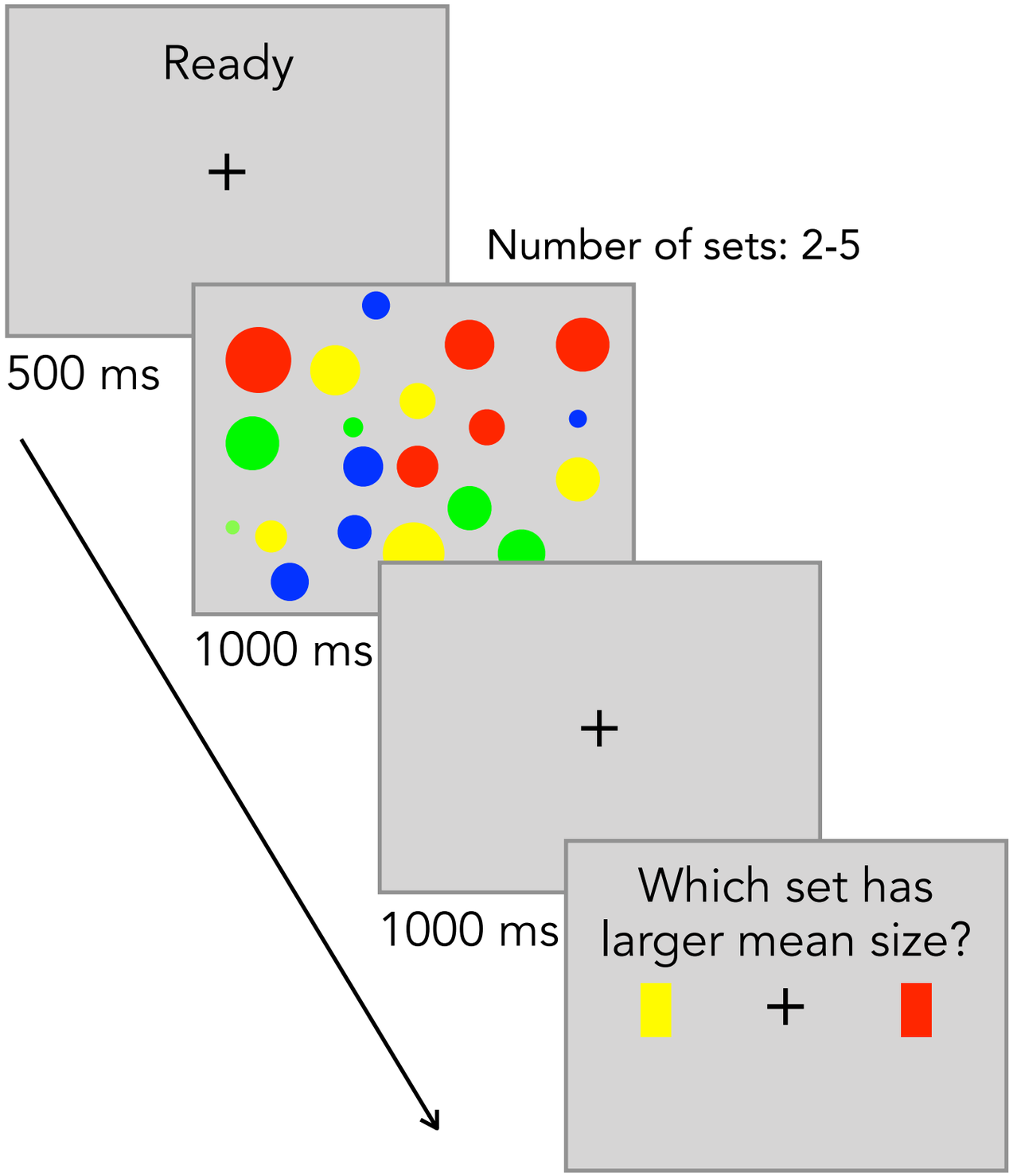
*Less underestimation of dots*



*More underestimation of dots*

Grouping modulates visual impression of number.

# How many ensembles can we remember?

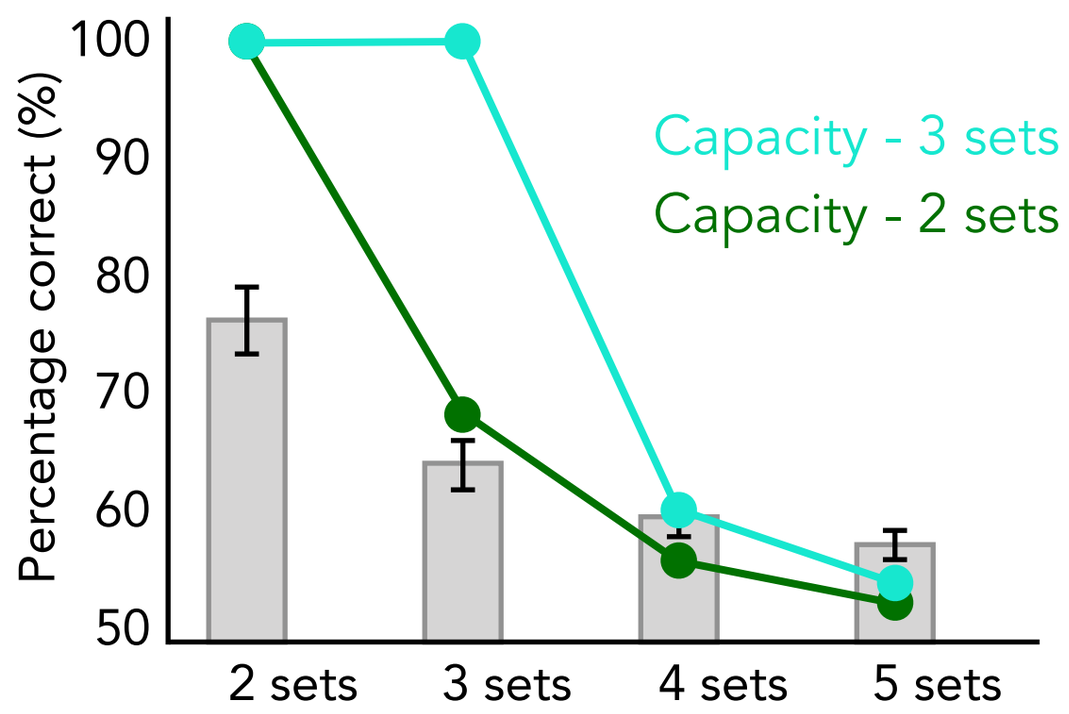



Predicted accuracy for an ideal observer

$$\text{Accuracy} = \underbrace{100*p}_{\text{Two sets are in memory}} + \underbrace{50*(1-p)}_{\text{Lucky guess}}$$

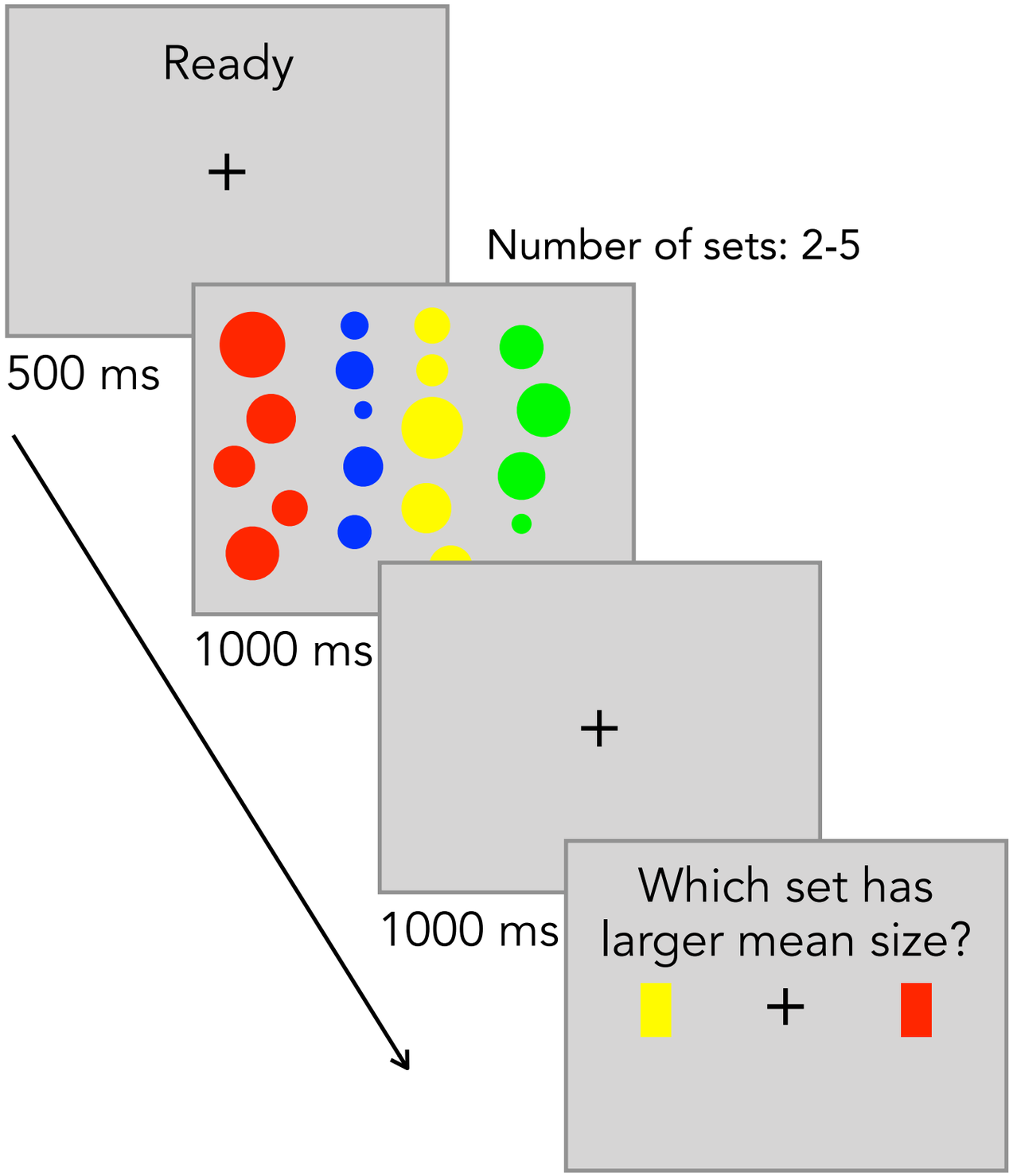
p = probability that the two remembered sets are tested from N sets displayed; 1/(N choose 2)

*Capacity: 2.5 sets (on average)*




Im & Chong, 2014

# Grouping increased capacity limit of ensembles




Predicted accuracy for an ideal observer

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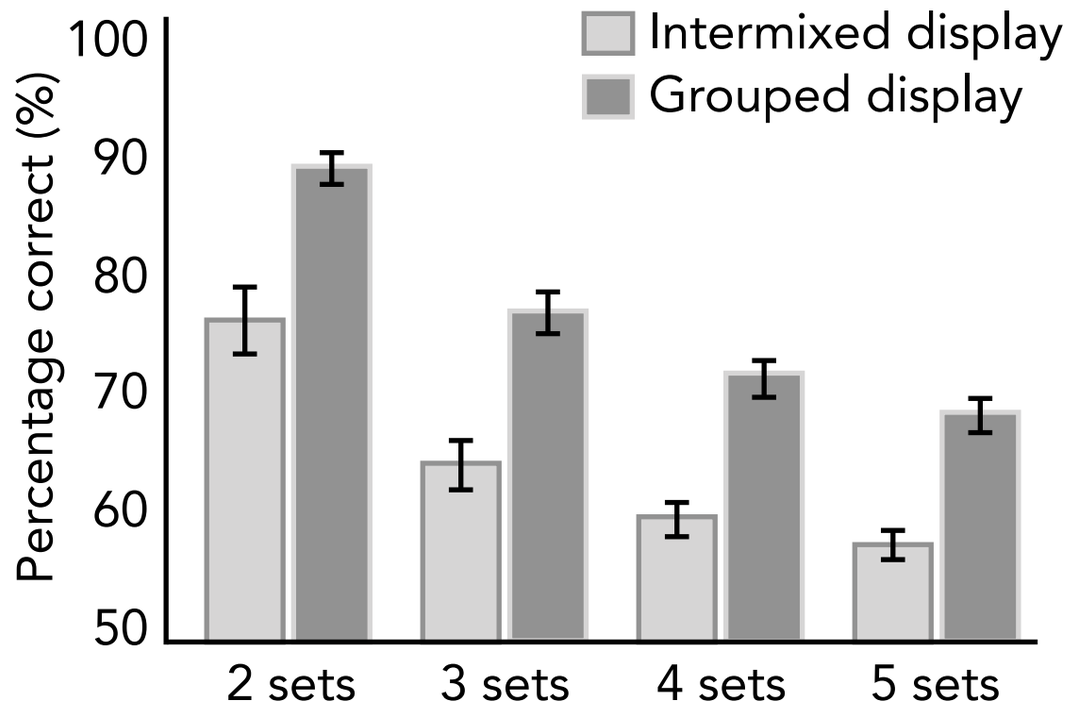
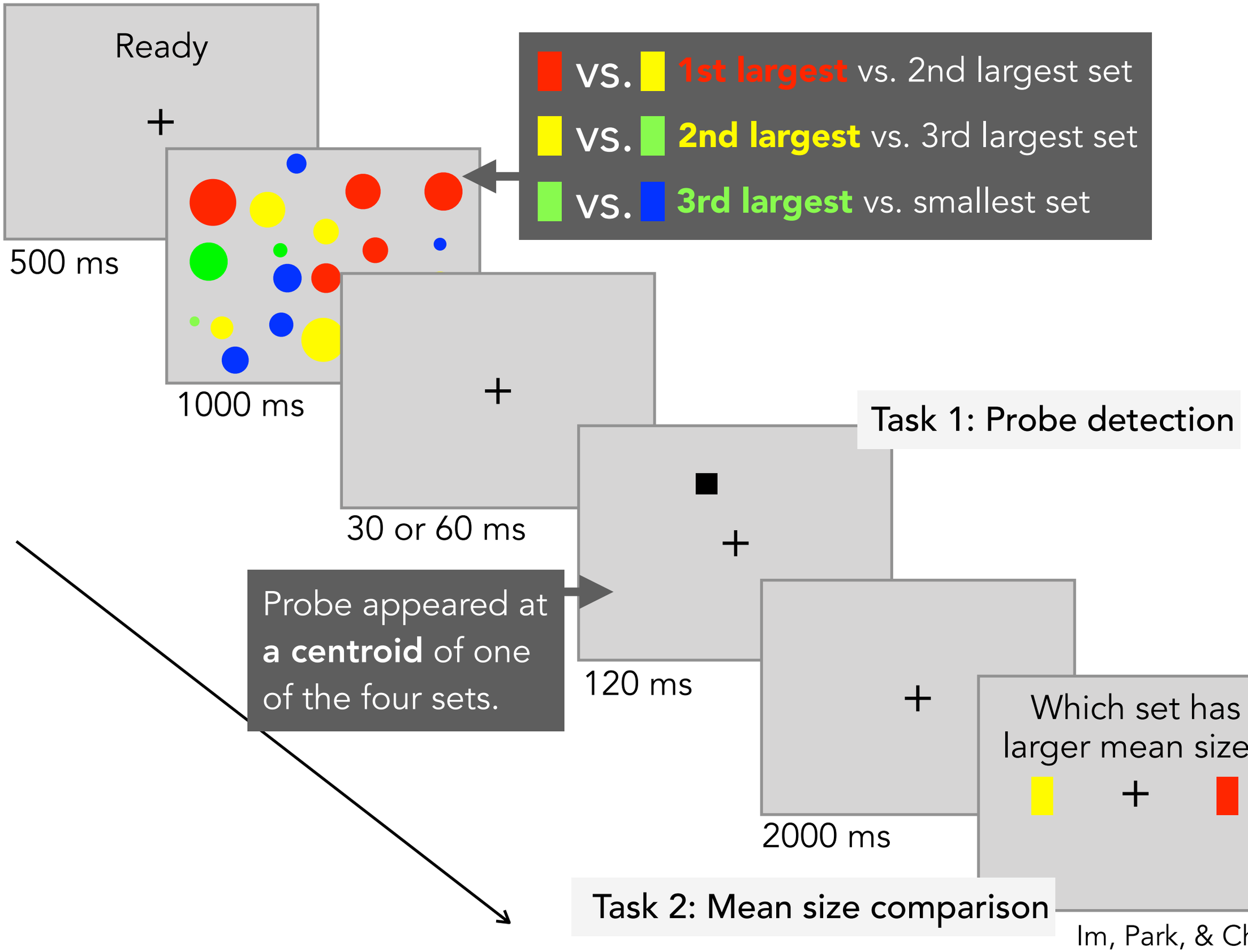
p = probability that the two remembered sets are tested from N sets displayed; 1/(N choose 2)

*Capacity: 2.5 sets → 3.5 sets*




Im & Chong, 2014

# Attentional selection of ensembles

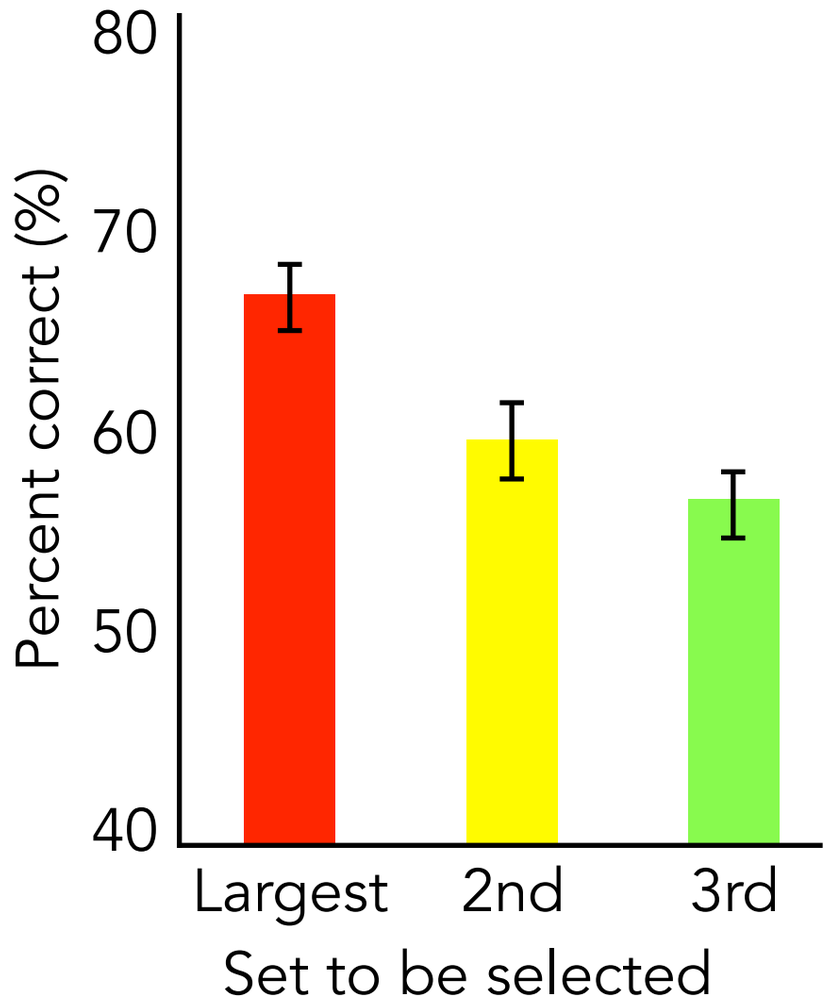



Im, Park, & Chong, 2015

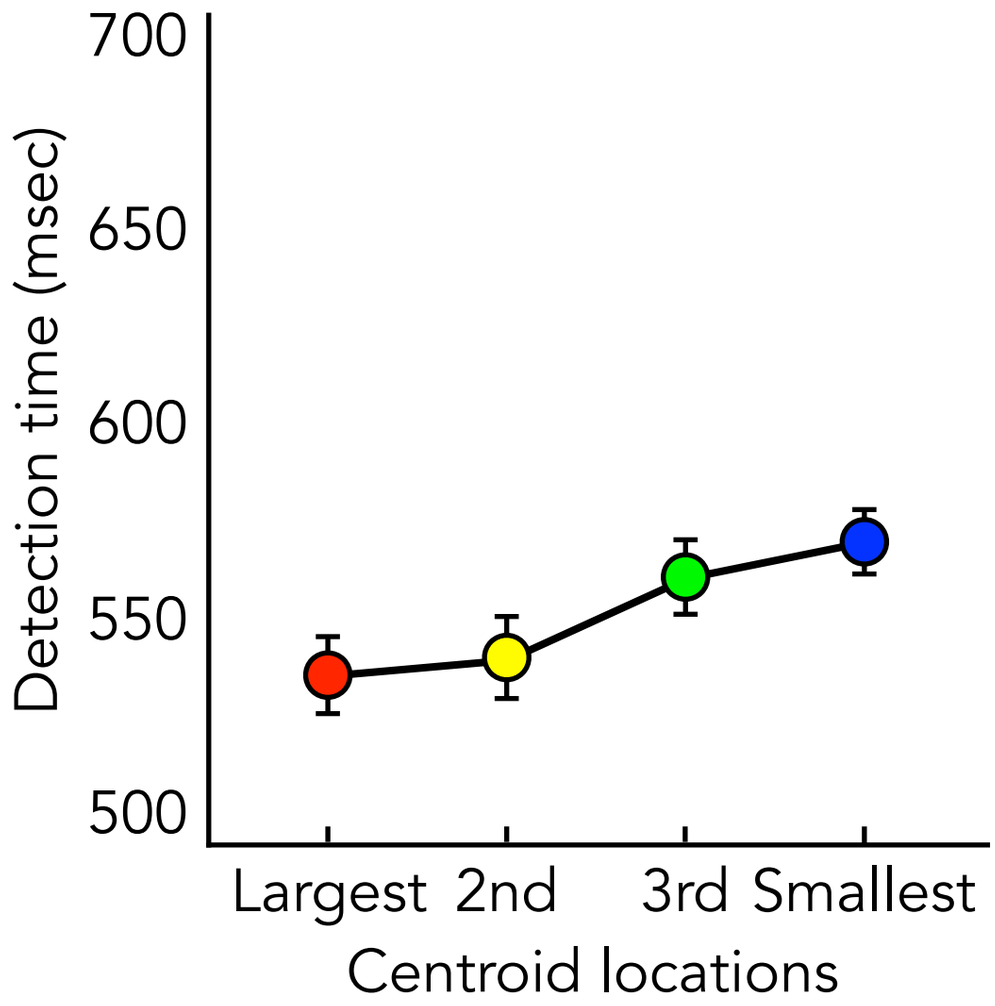
# Largest set attracted attention

Which set has ***larger*** mean size?


Mean size comparison




Probe detection




Im, Park, & Chong, 2015

# Can smallest set attract attention?

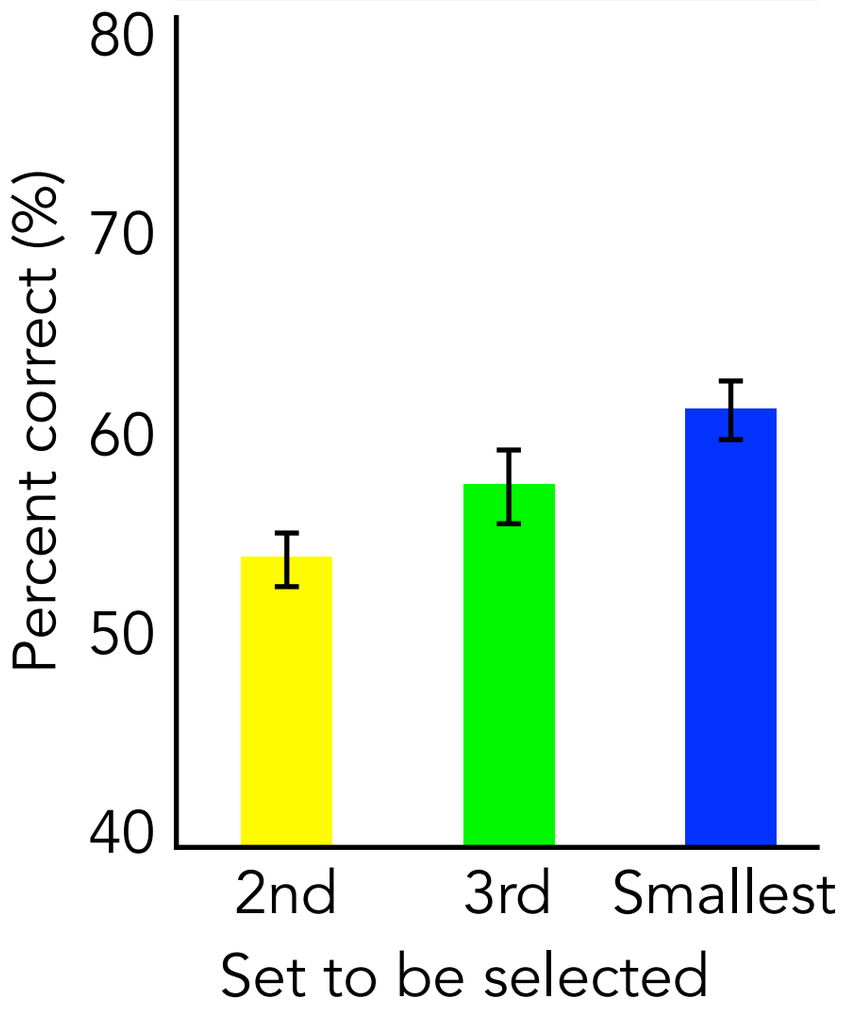
Which set has ***smaller*** mean size?

vs. 1st largest vs. **2nd largest set**

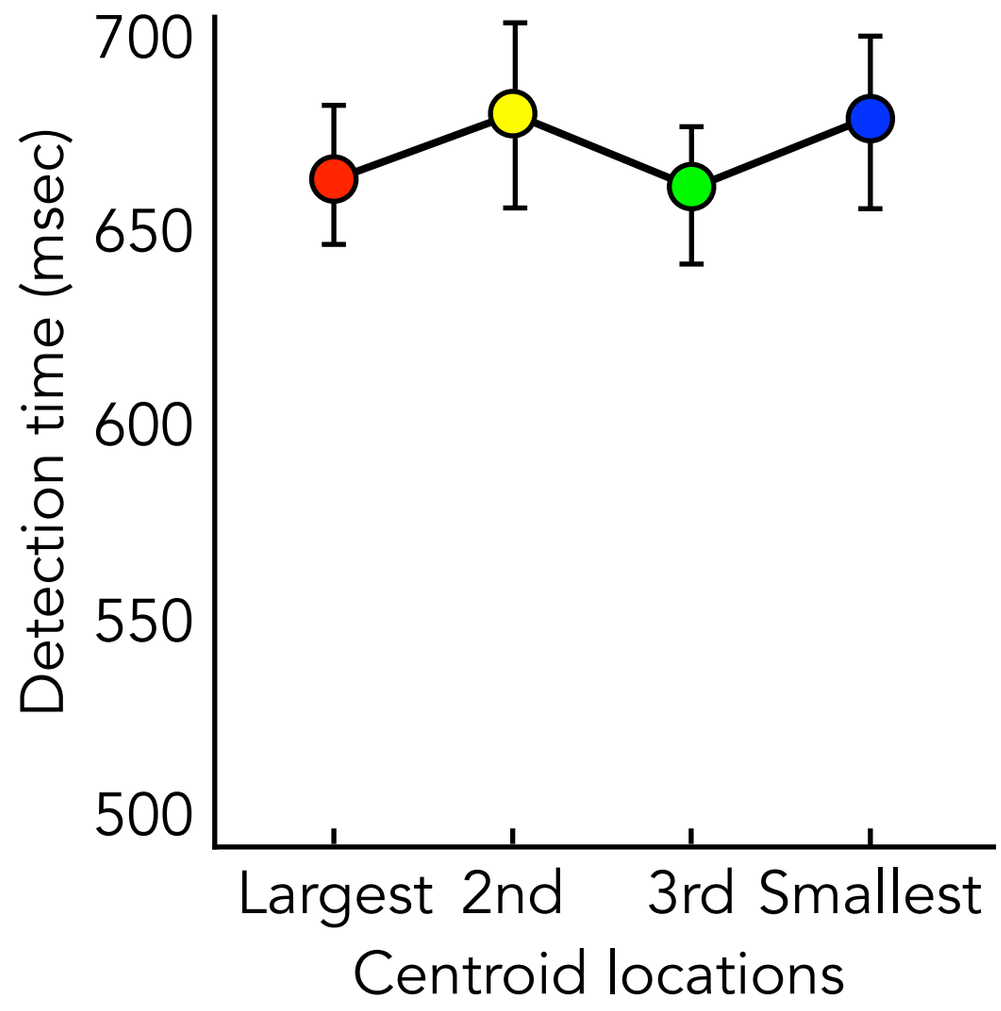
vs. 2nd largest vs. **3rd largest set**

vs. 3rd largest vs. **Smallest set**

Mean size comparison

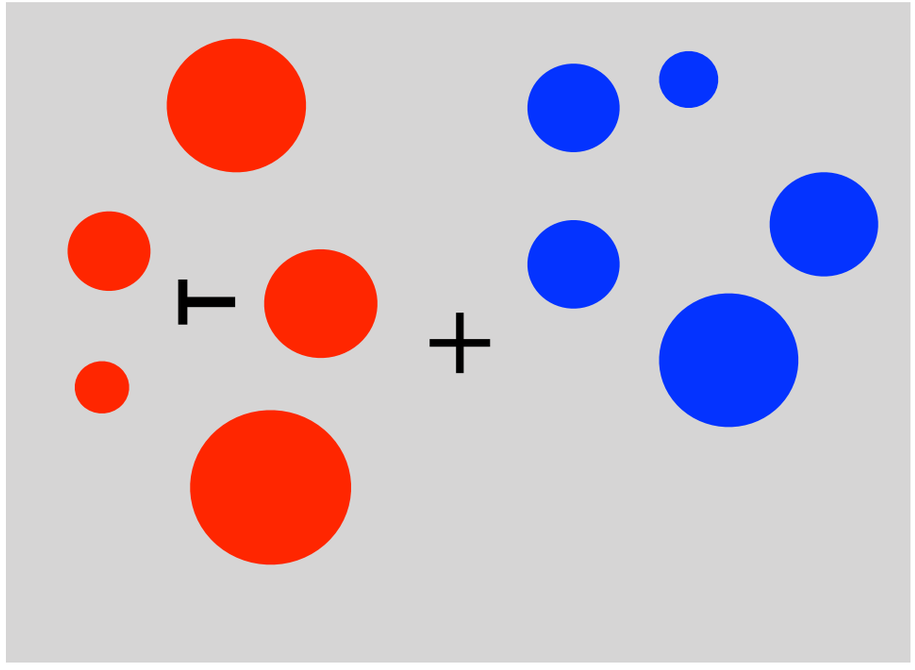


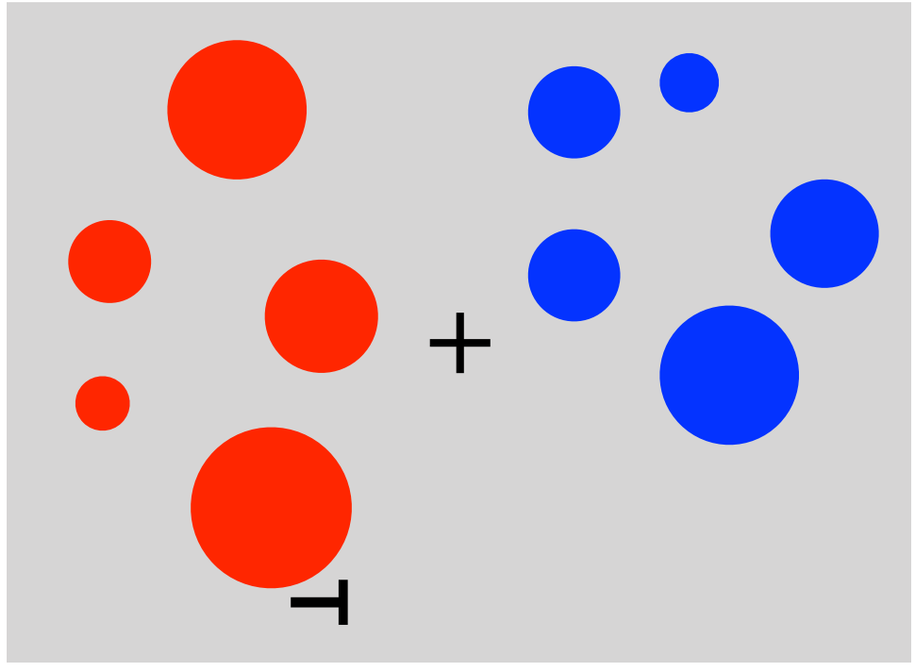

Probe detection



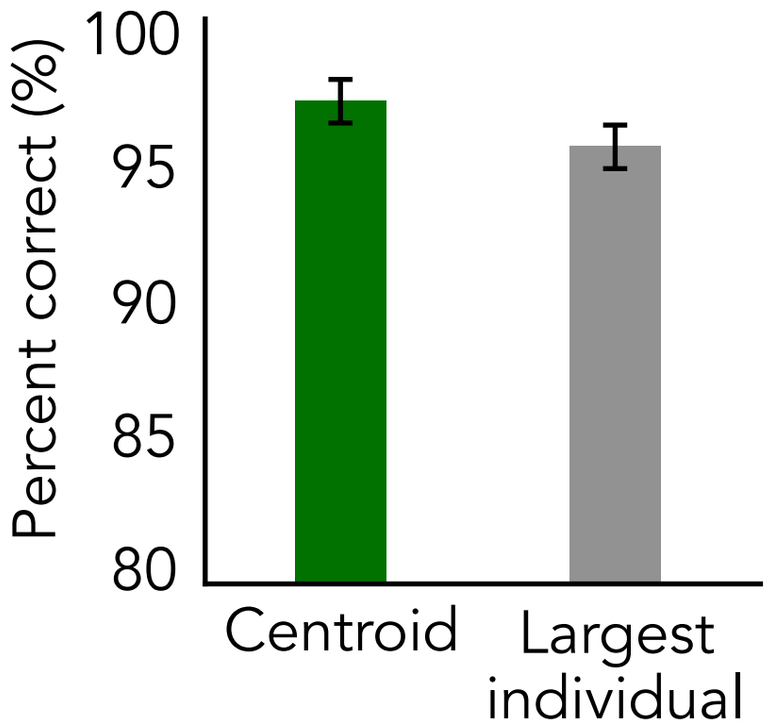

Im, Park, & Chong, 2015

# Attention toward an ensemble, not an object

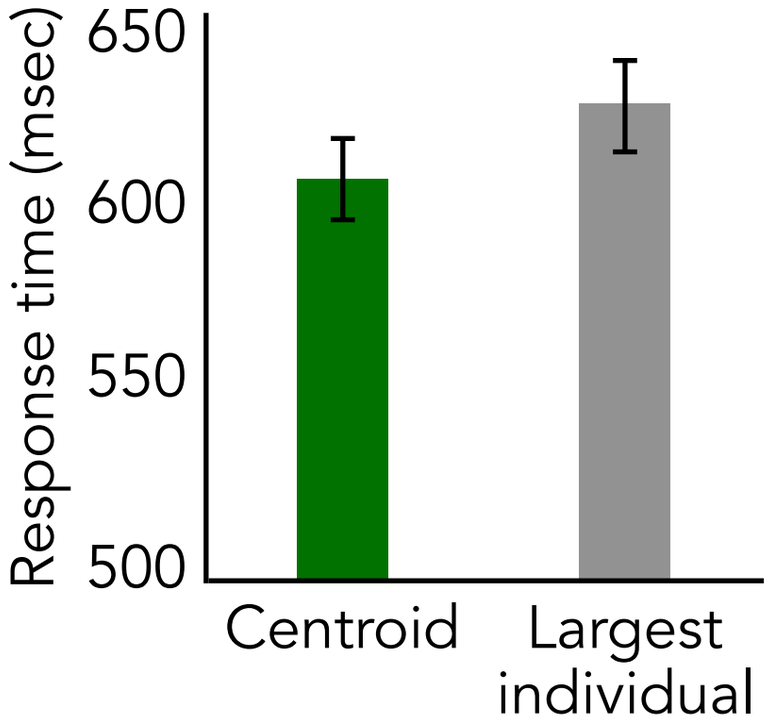




Probe at the centroid of larger set

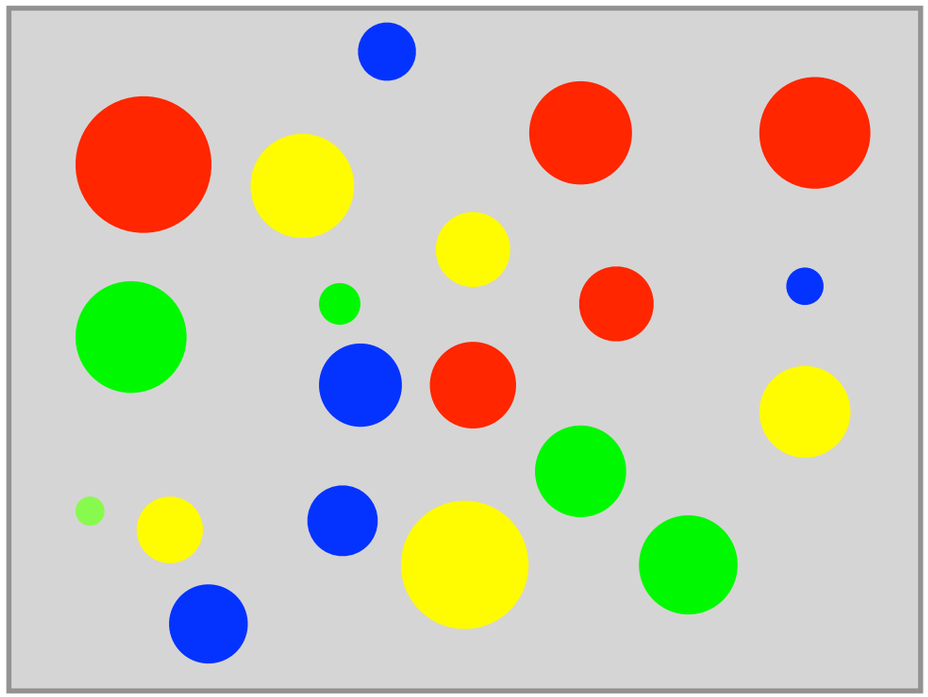



Probe next to the largest individual



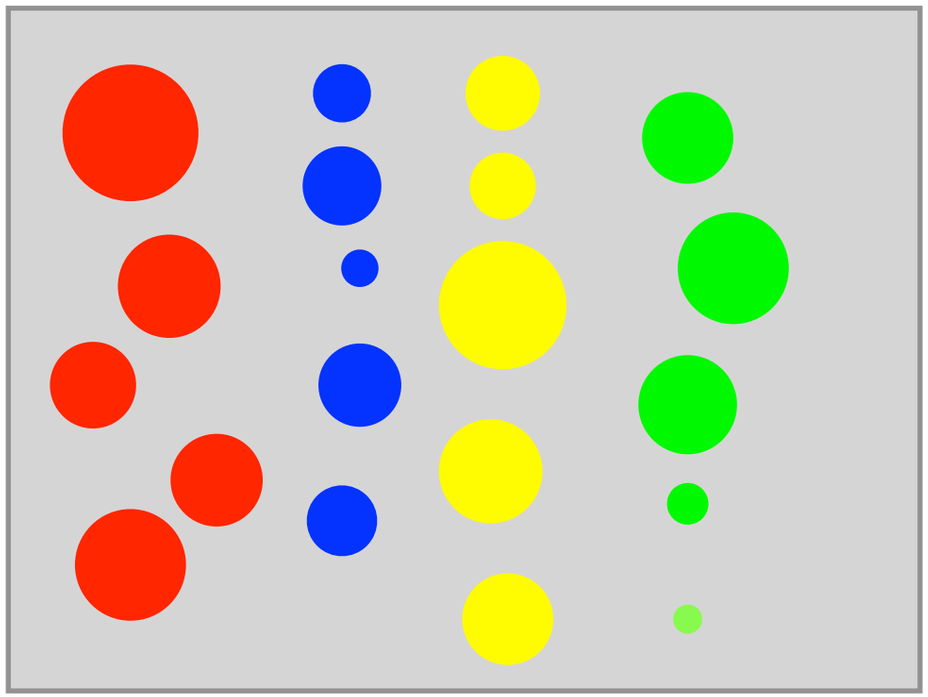

Im, Park, & Chong, 2015

# Ensembles as units of selection and storage



*Poorer segmentation of sets*

~2.5 sets in memory

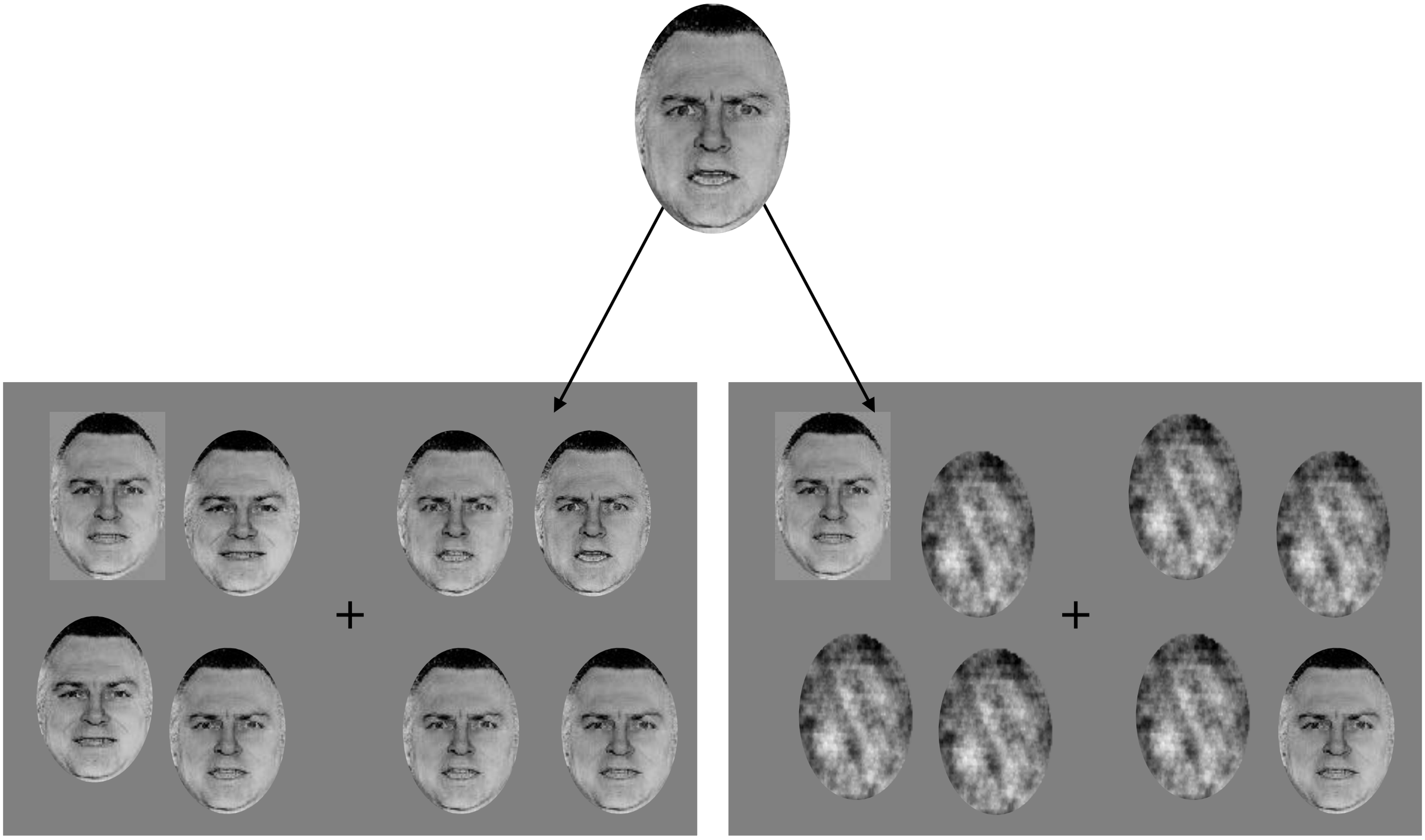


*Better segmentation of sets*

~3.5 sets in memory

- Grouping increased memory capacity for ensembles.
- Centroid of the largest set attracted attention.

# How can ensembles be extracted so quickly?



Comparing ensembles

Comparing individuals

# Making emotional crowds

Angry 100% | Angry 68% Happy 32% | Angry 60% Happy 40% | Angry 50% Happy 50% | Angry 40% Happy 60% | Angry 32% Happy 68% | Happy 100%

-25 … -9 … -5 … 0 … +5 … +9 … +25

51 morphed emotional faces

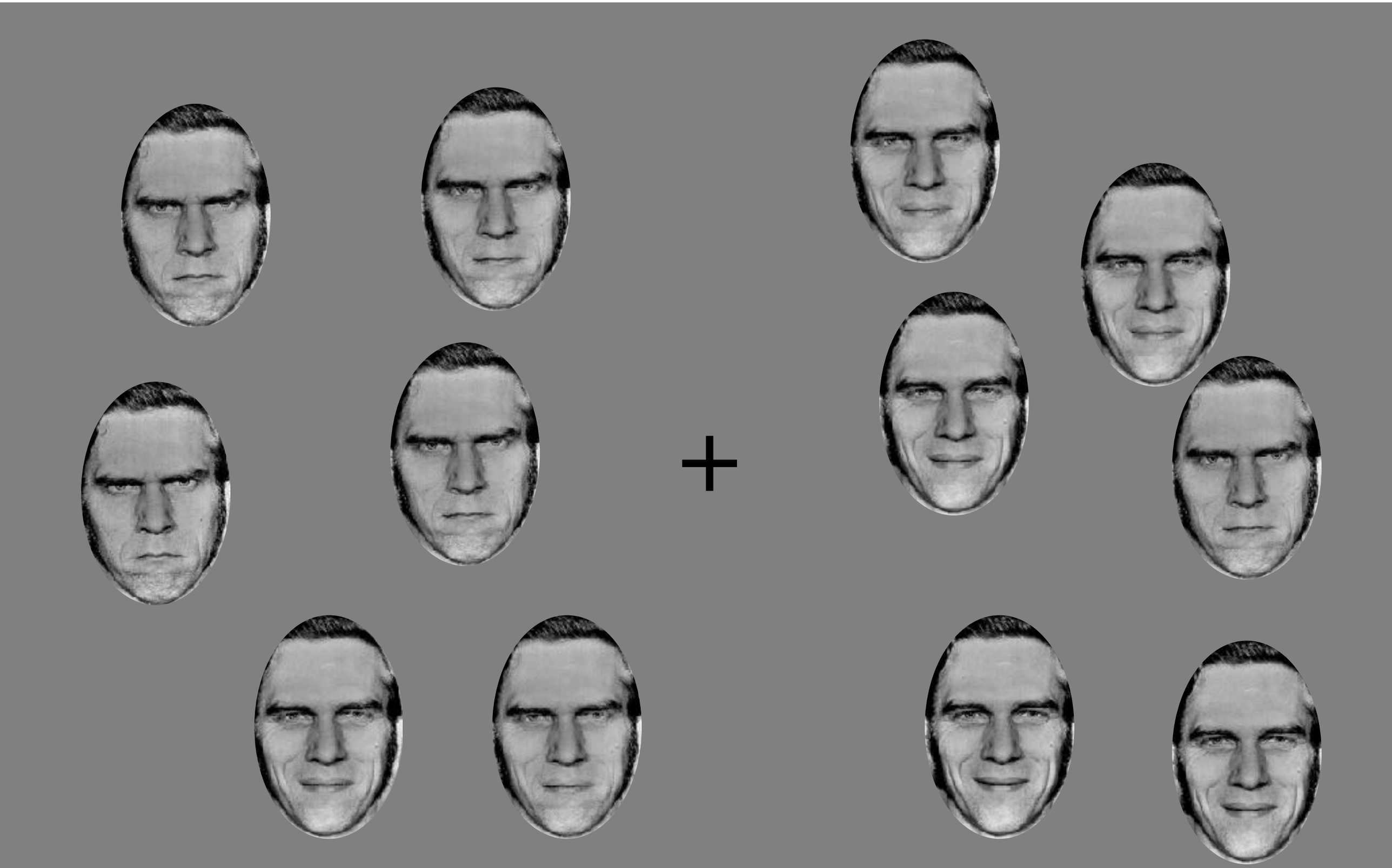
- Six identities (3 females, 3 males)
- Number of faces in a crowd: 4 or 6 (8 or 12 total)

Im et al., 2017

Which crowd would you rather avoid?

Ready

# Which crowd would you rather avoid?

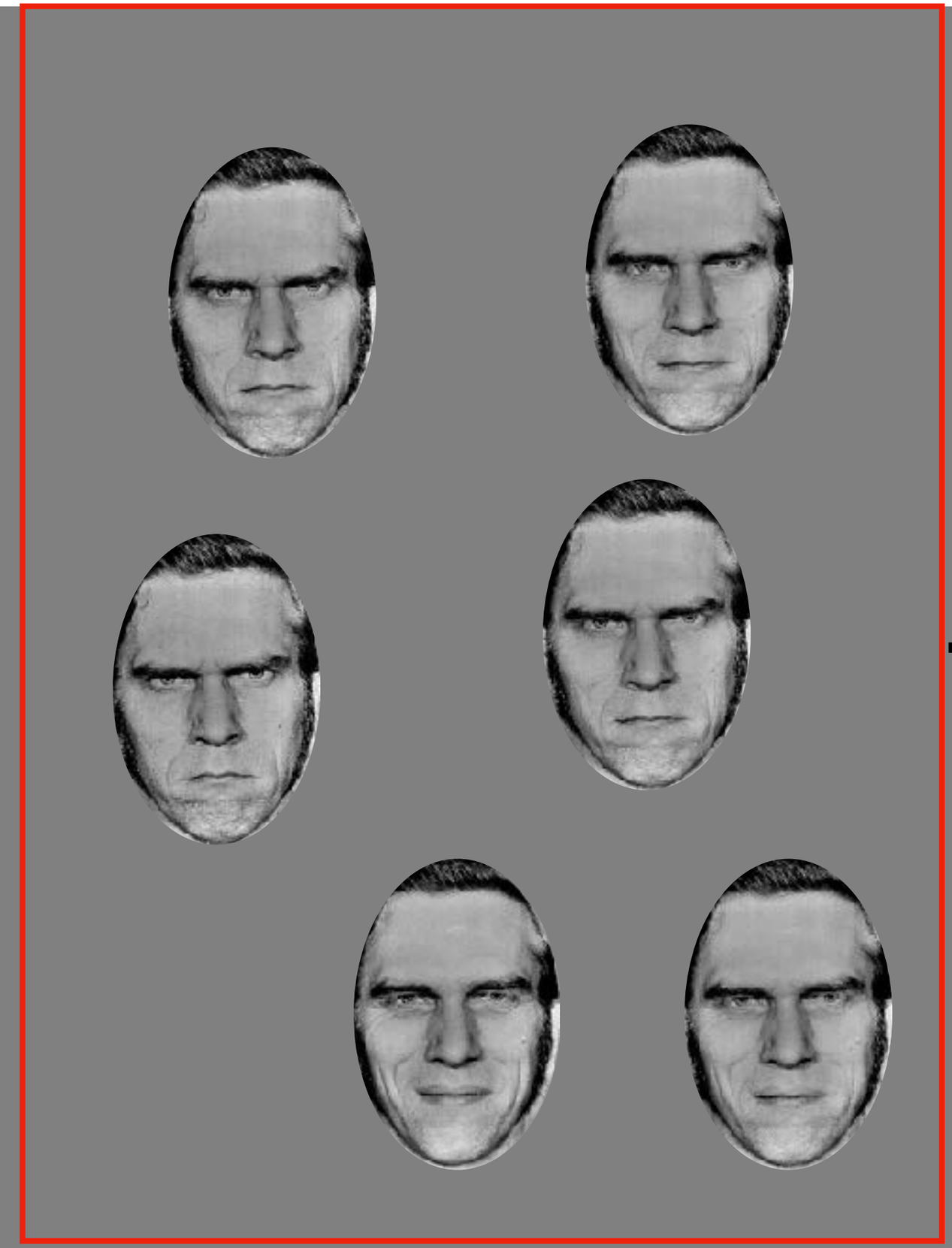


Which crowd would you rather avoid?

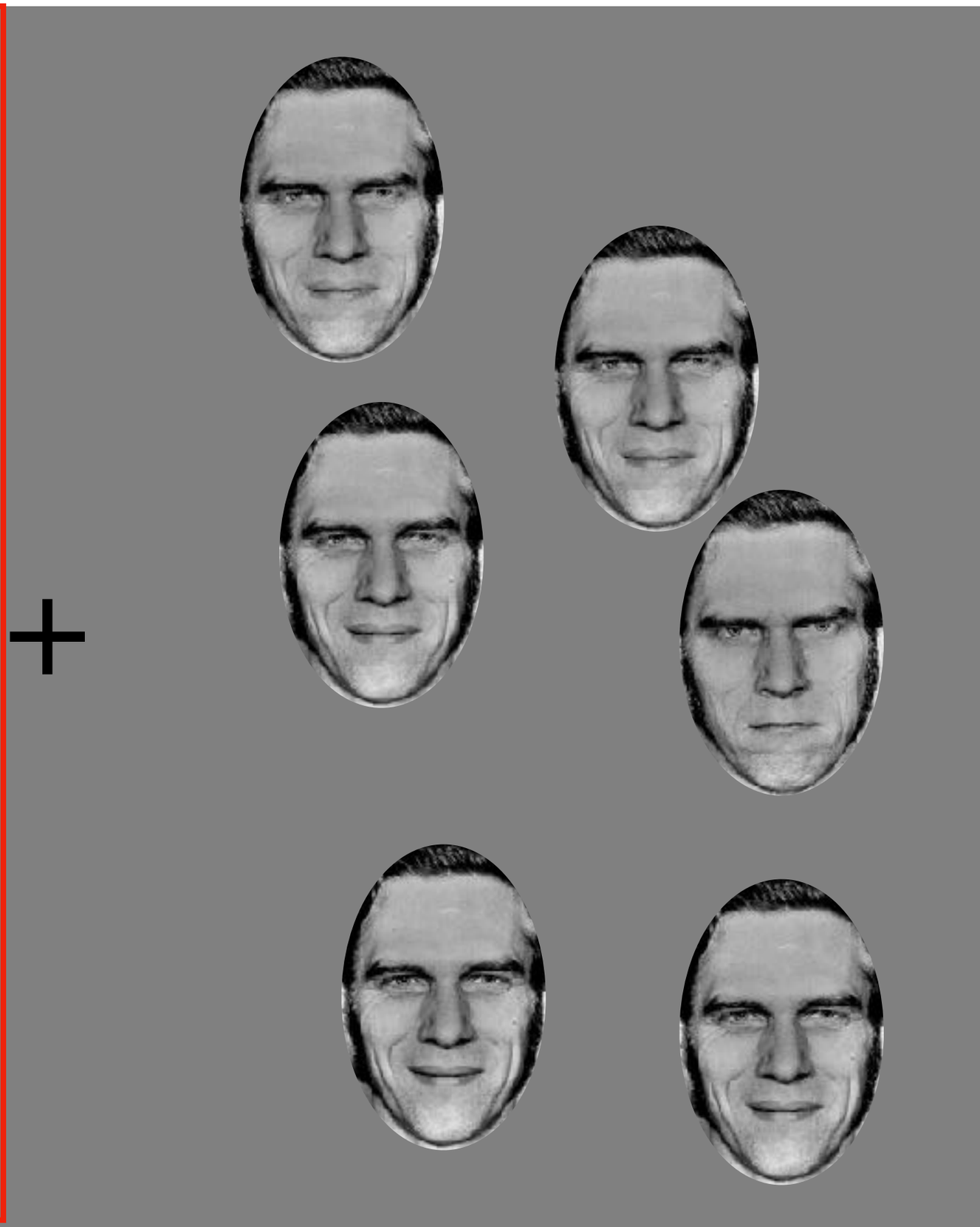
Which crowd would you rather avoid?

Left or Right?

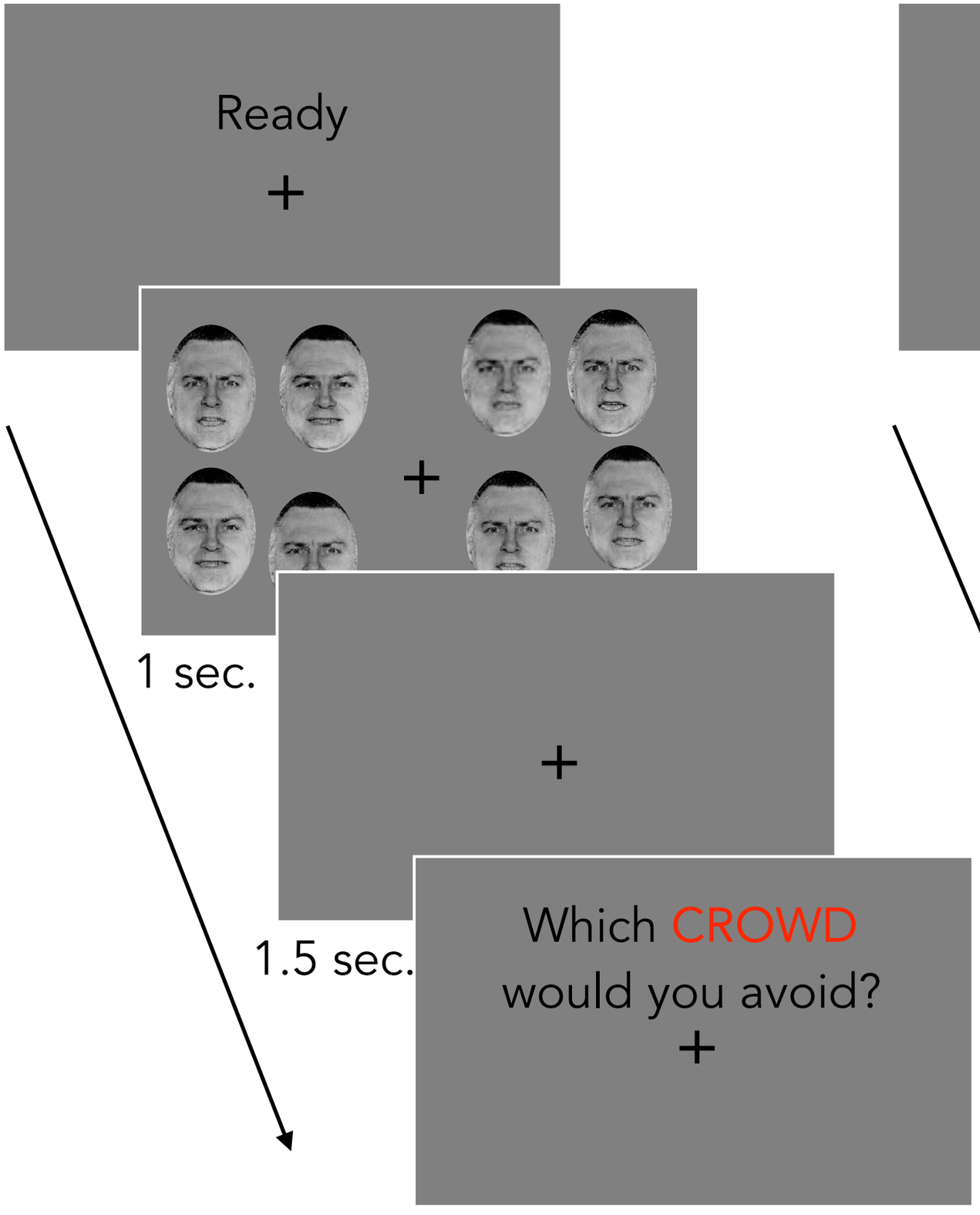
# Which crowd would you rather avoid?

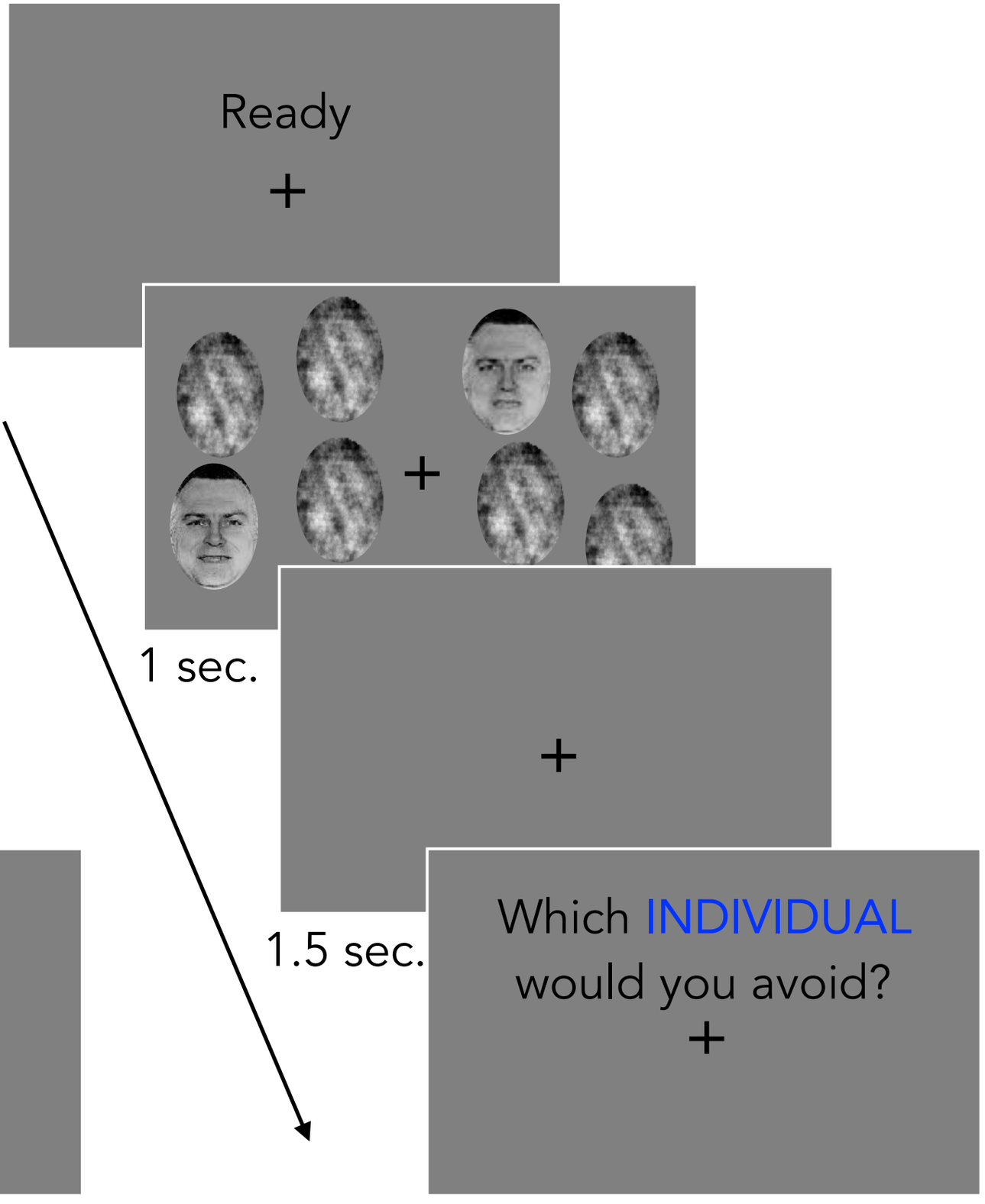


+



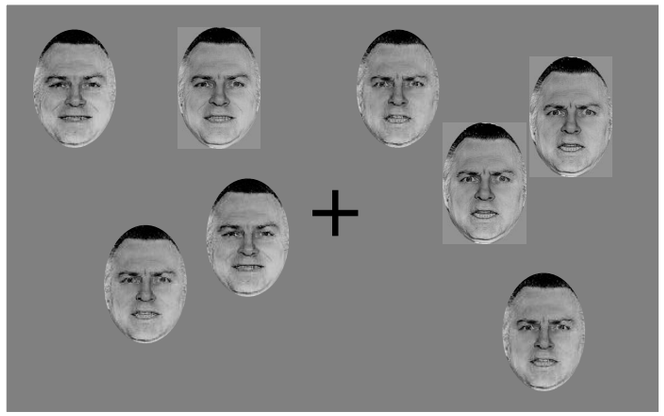
# Crowd emotion vs. Individual emotion



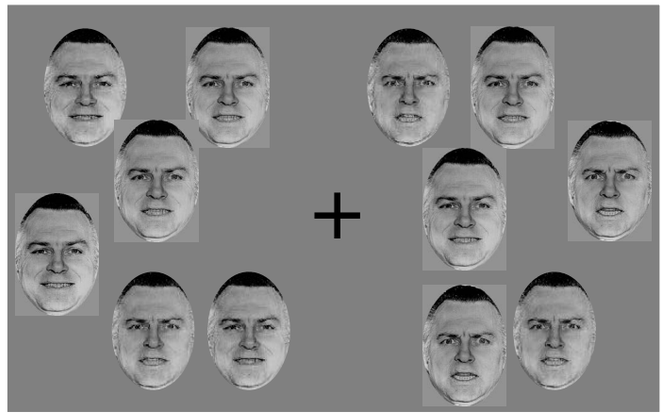




Im et al., 2017

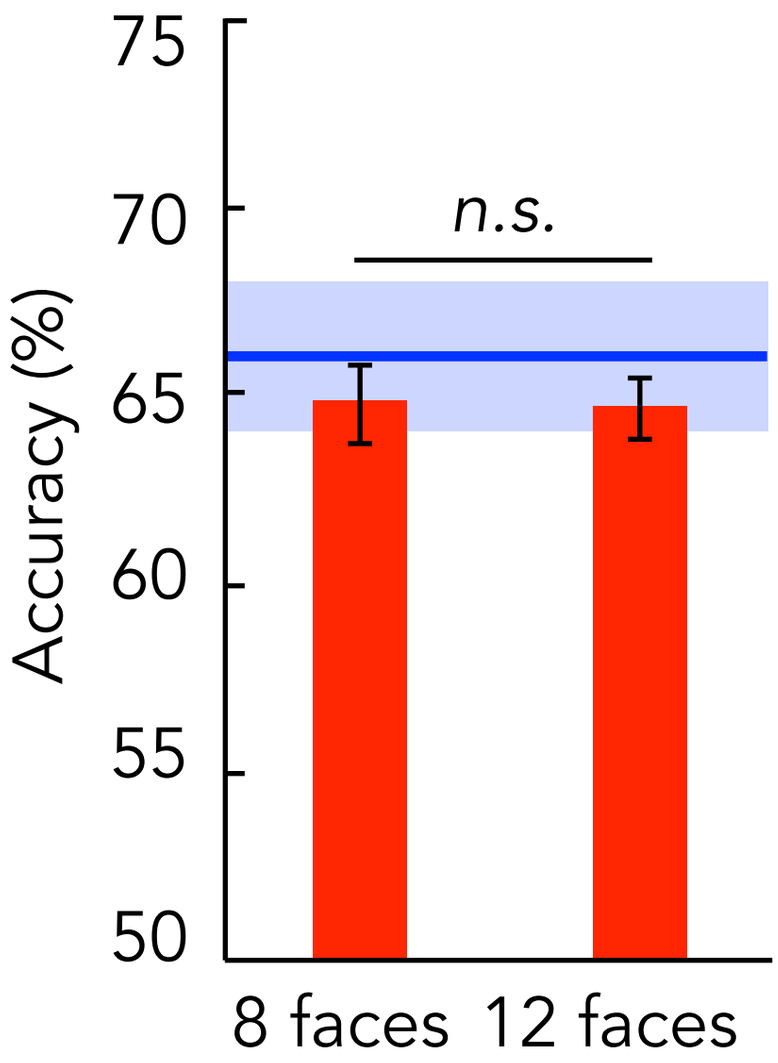
# Parallel processing of crowd emotion

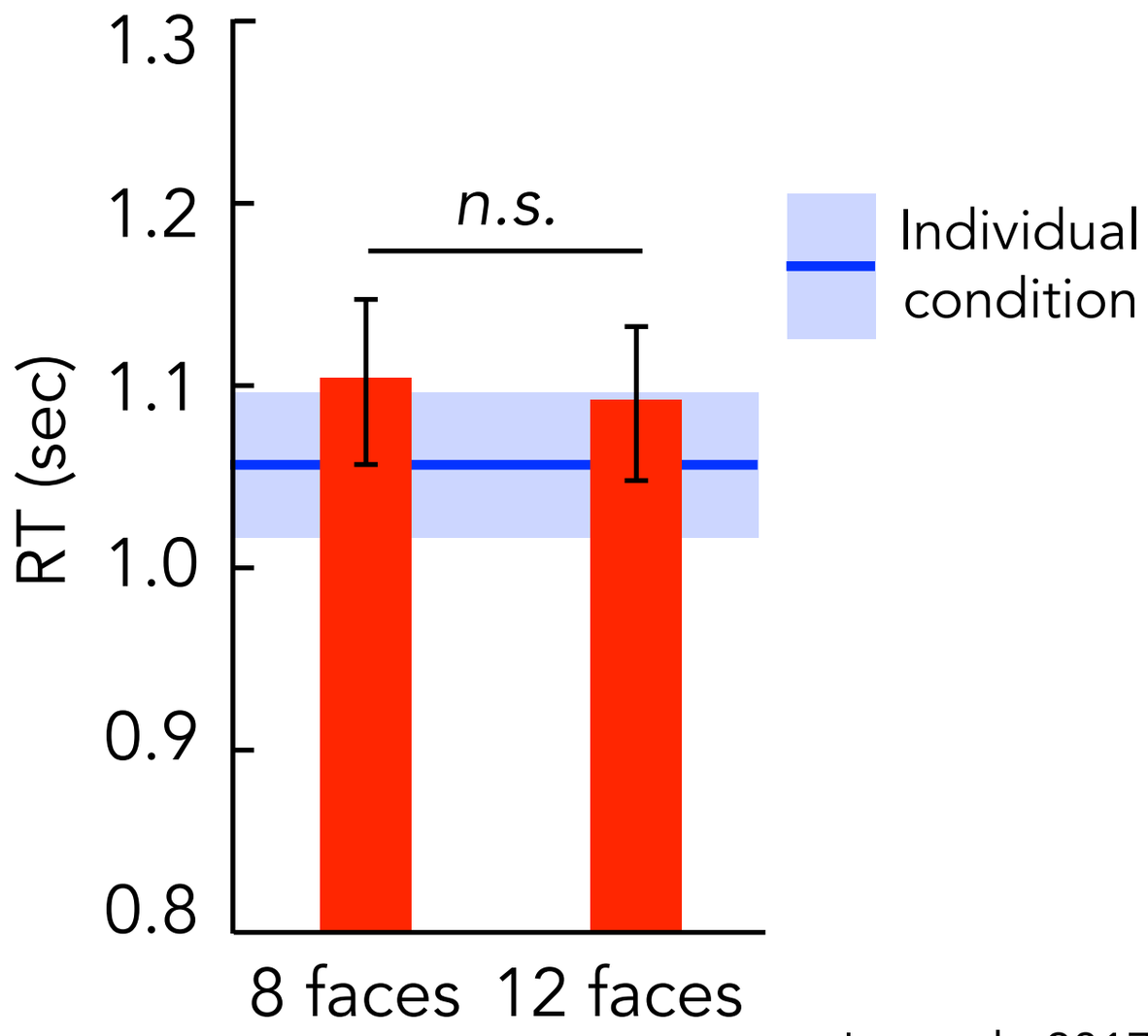


8 faces



12 faces

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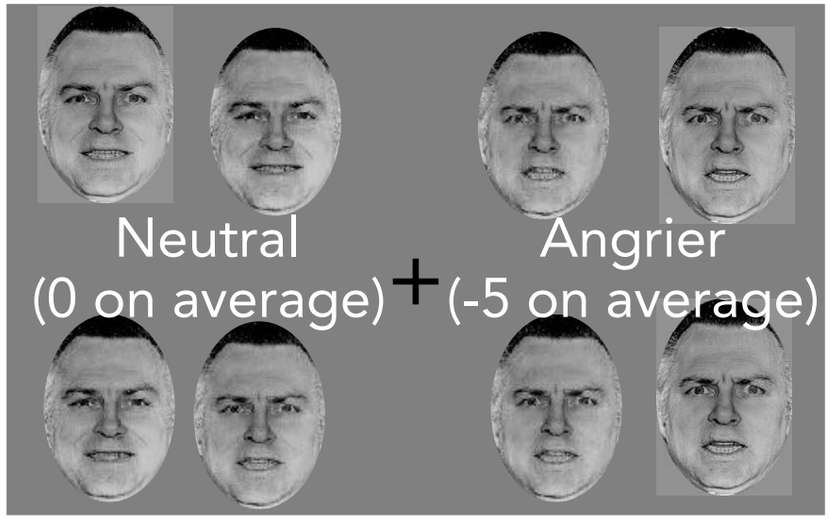
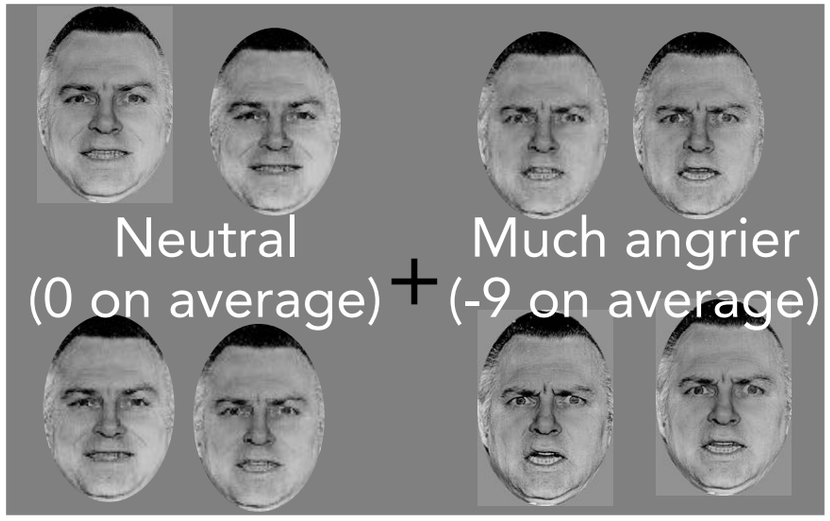
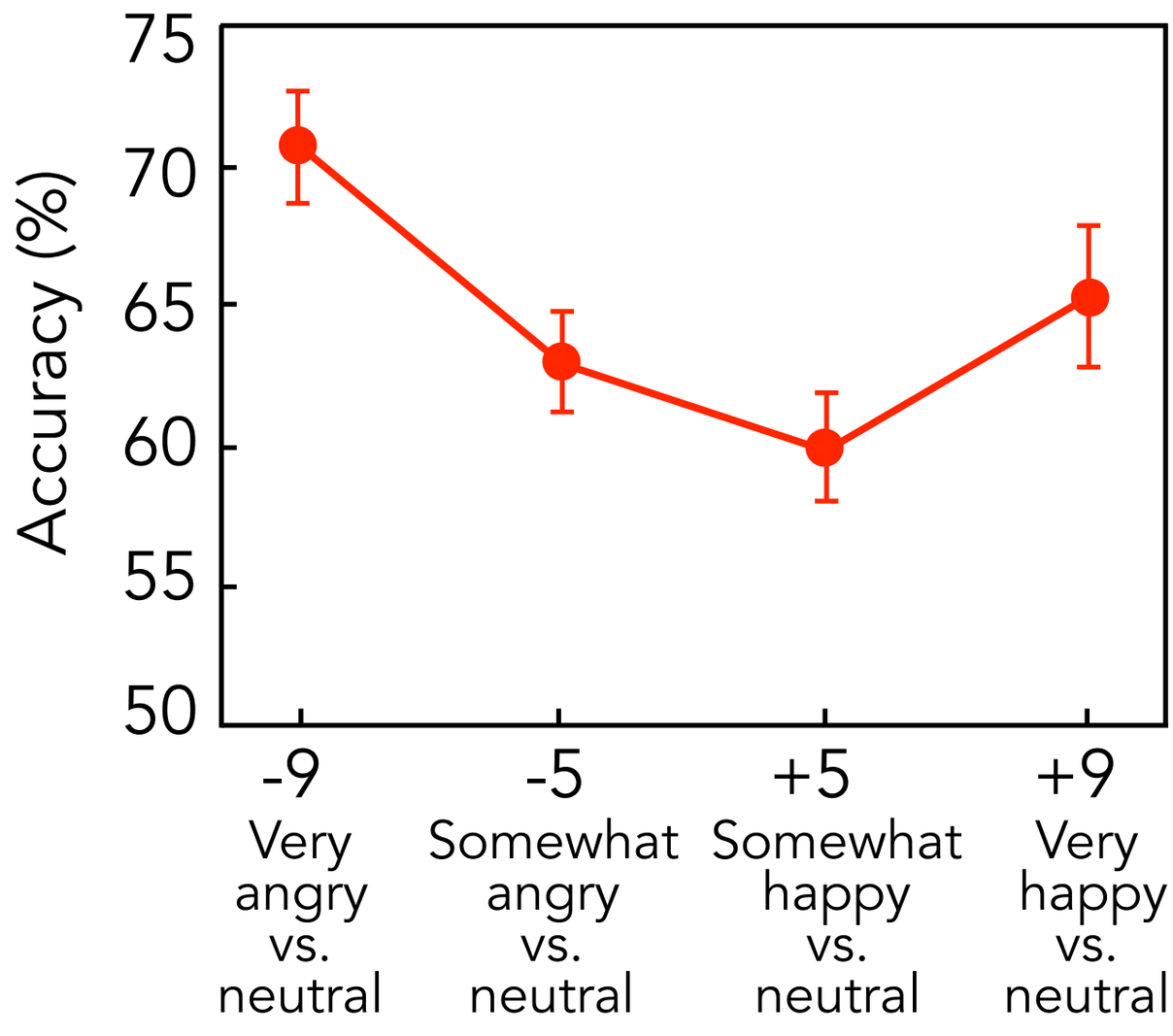
# Emotional distance between crowds

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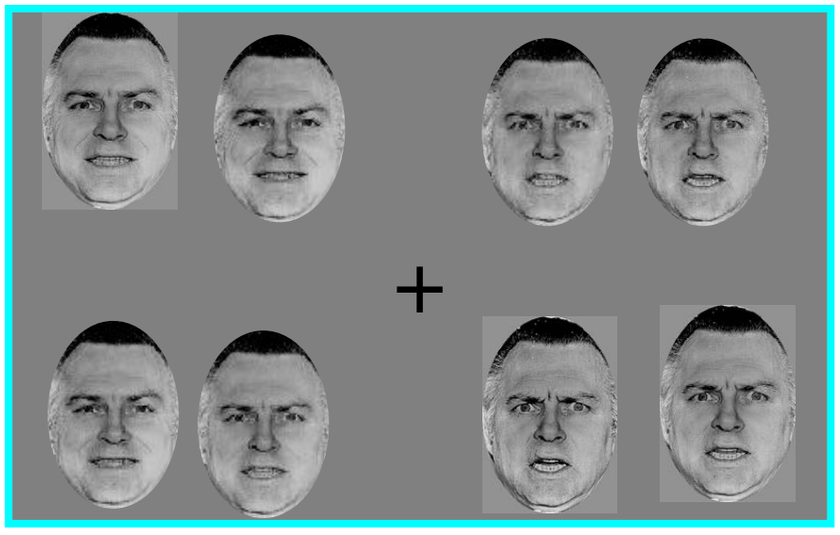
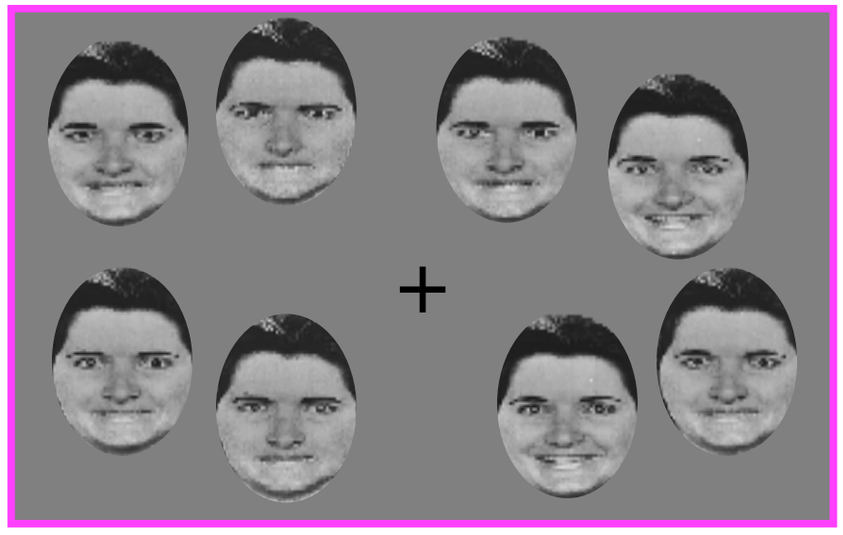
# Gender of facial crowds



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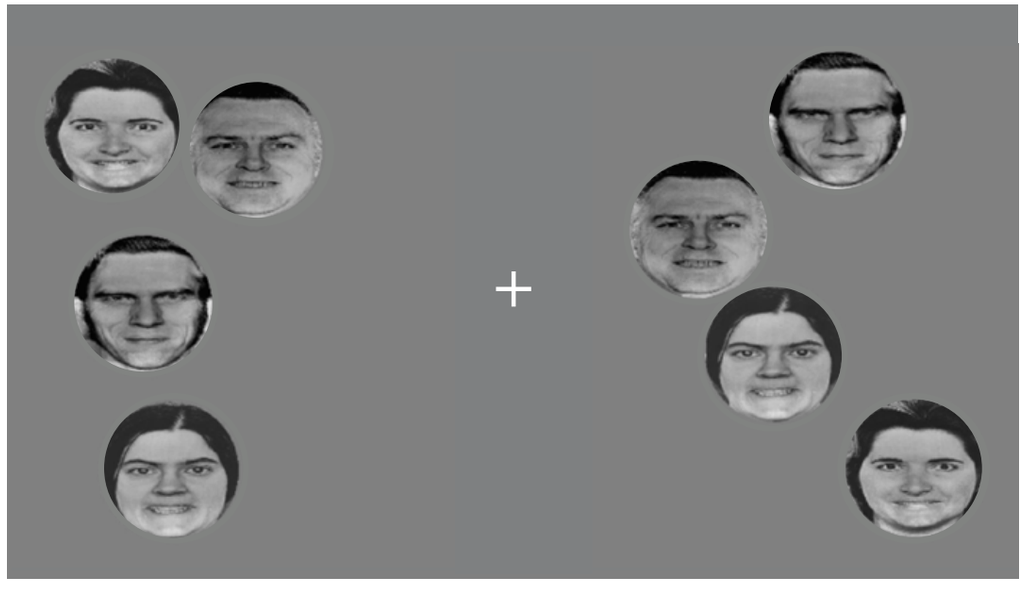
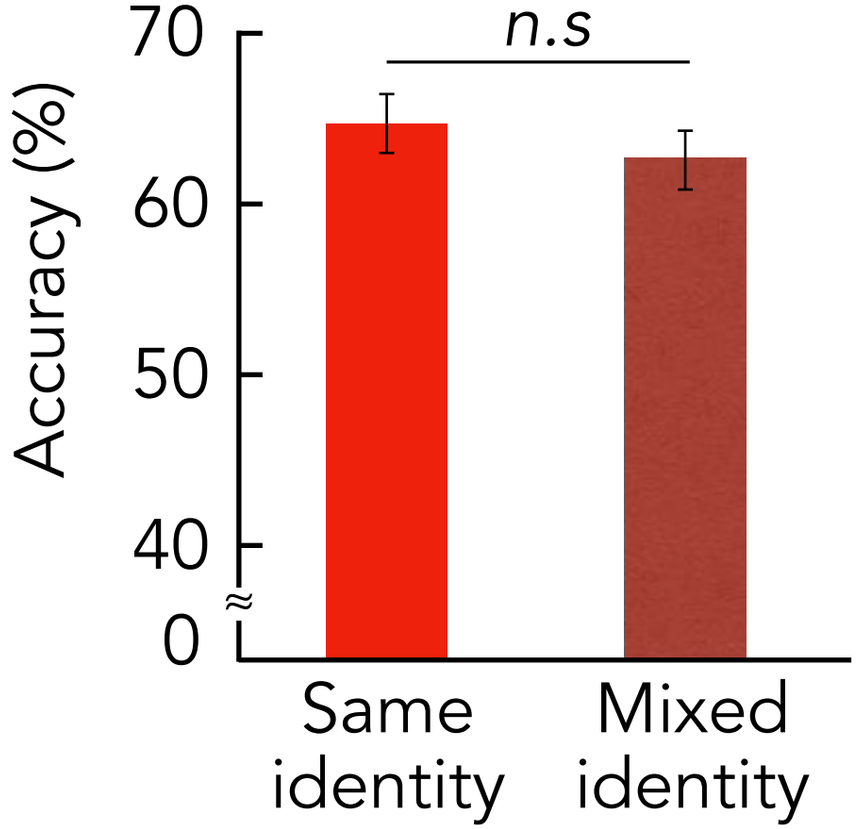
# Intermixed identities



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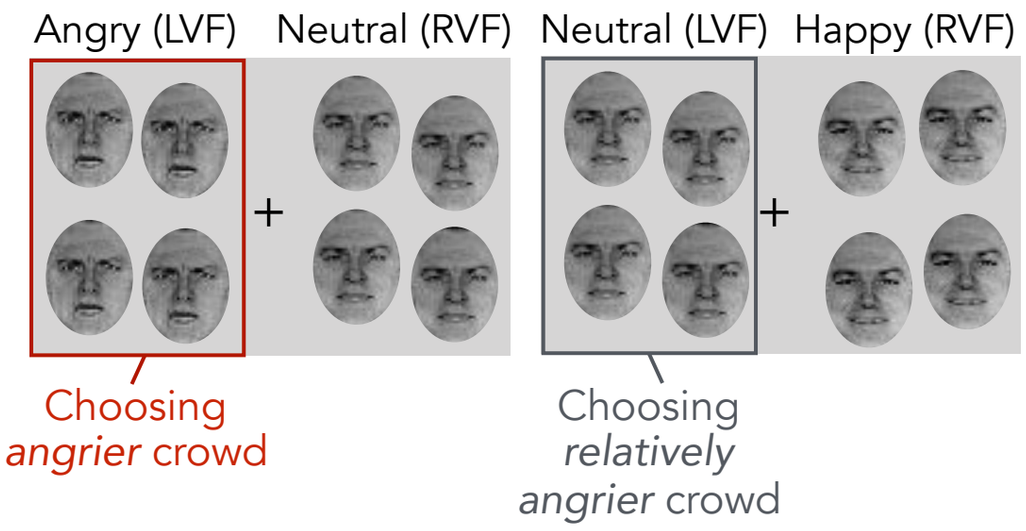
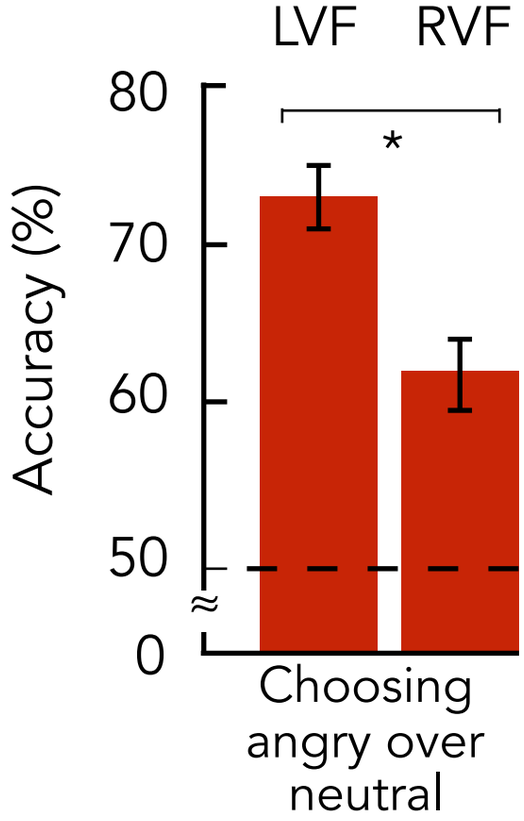
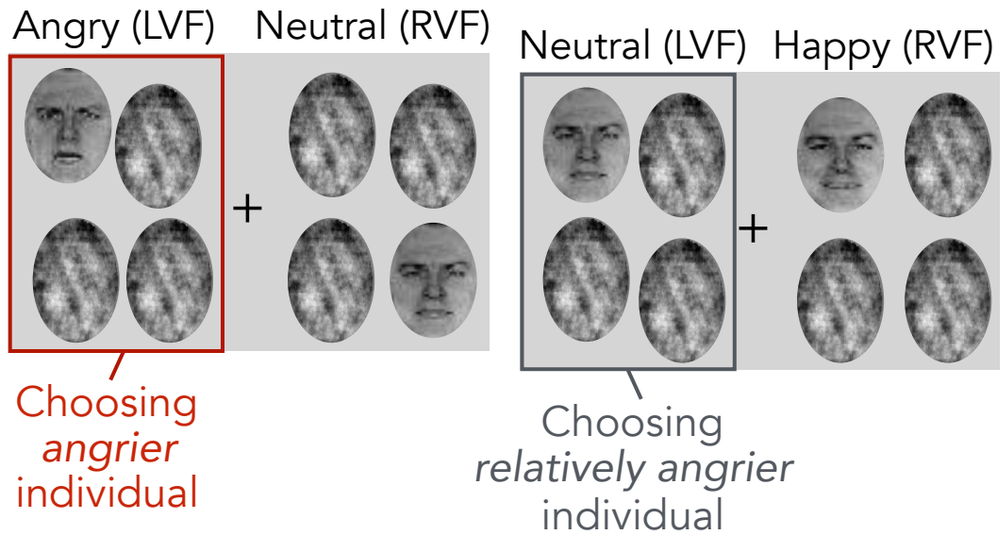
# Laterality effects: Crowd vs. Individual

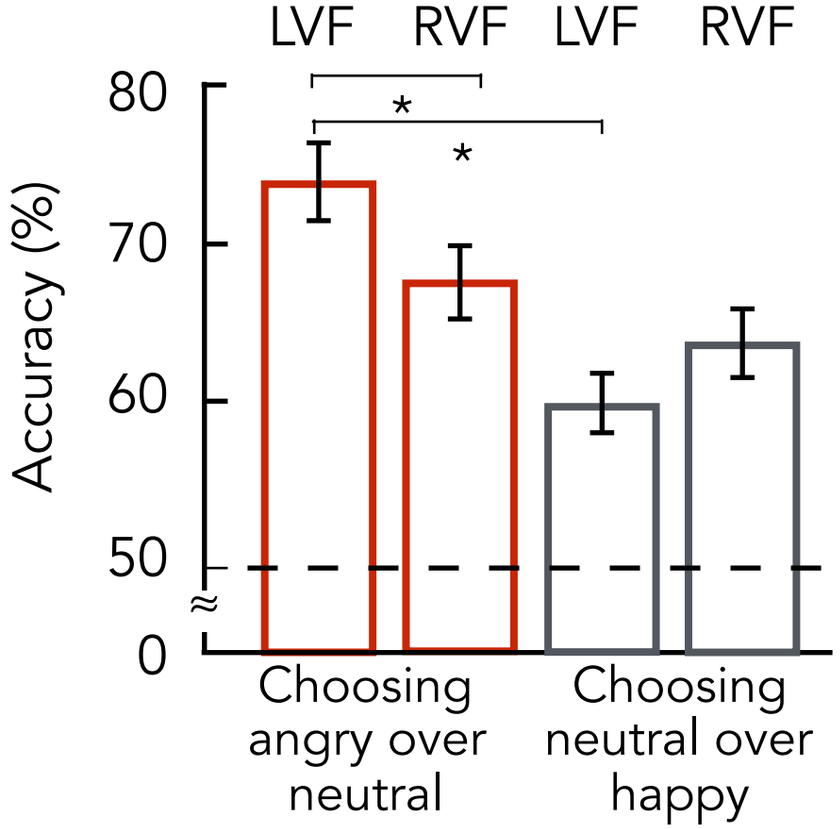
## Crowd emotion




## Individual emotion

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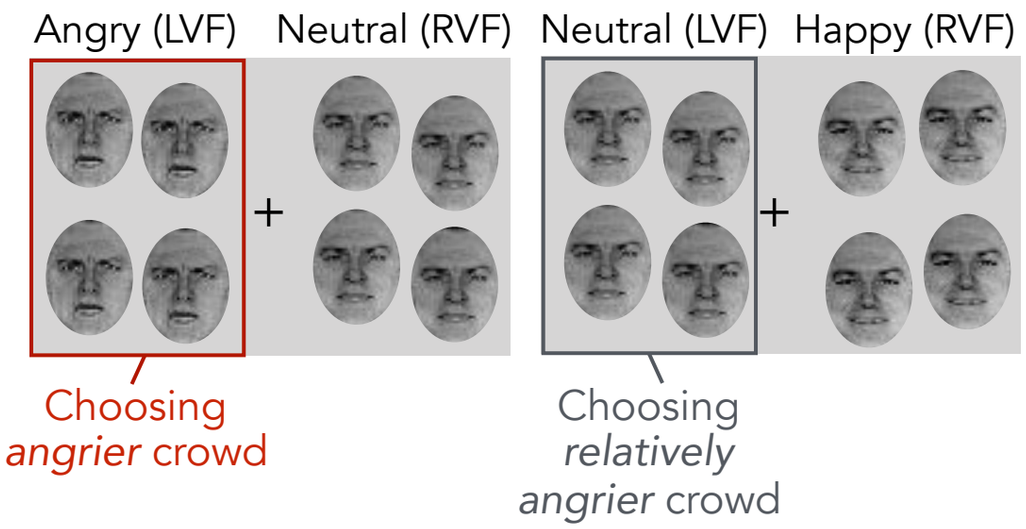
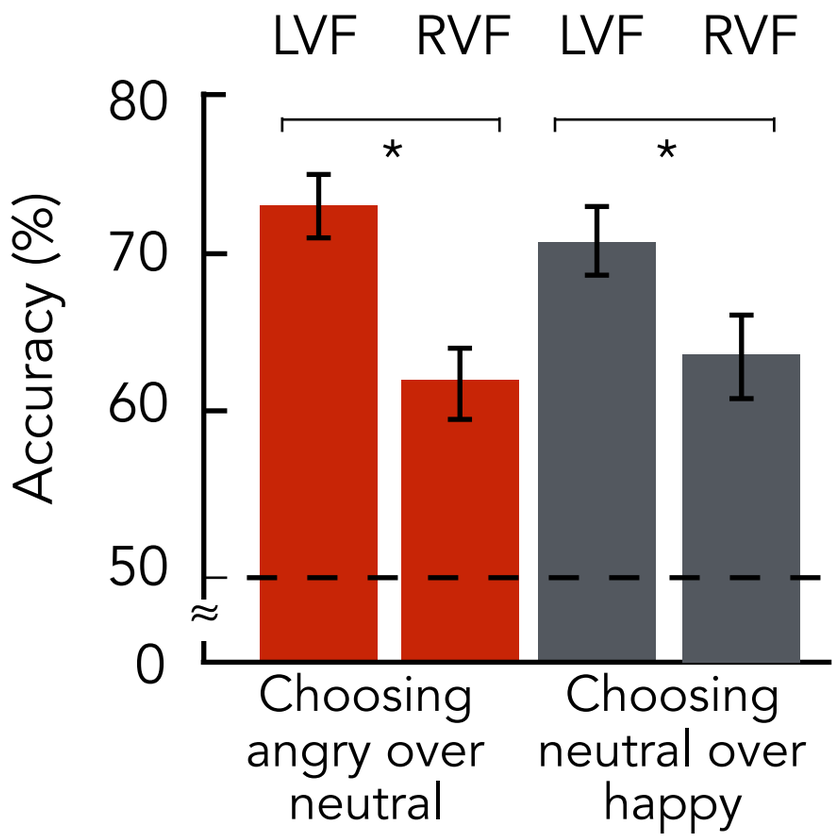
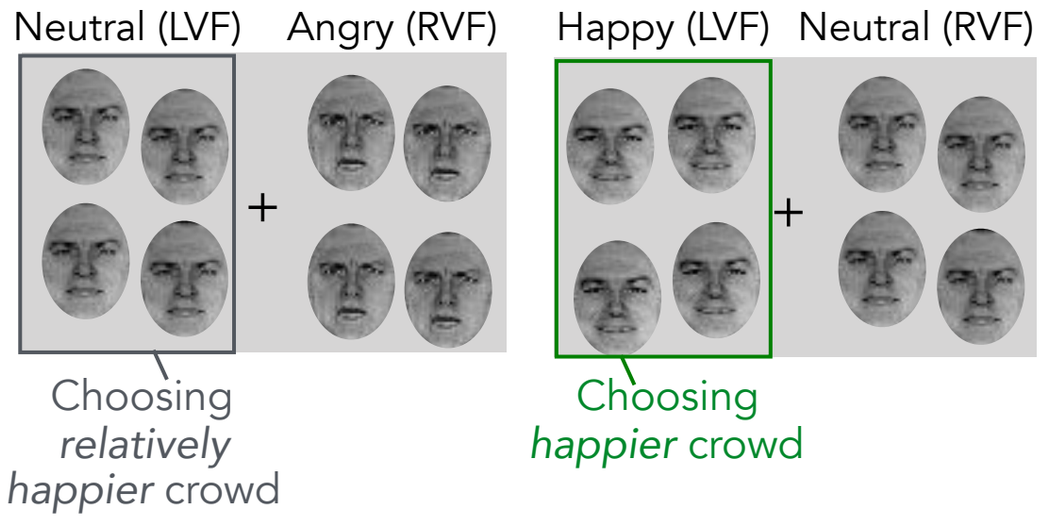
# Task-dependent laterality effects for crowds

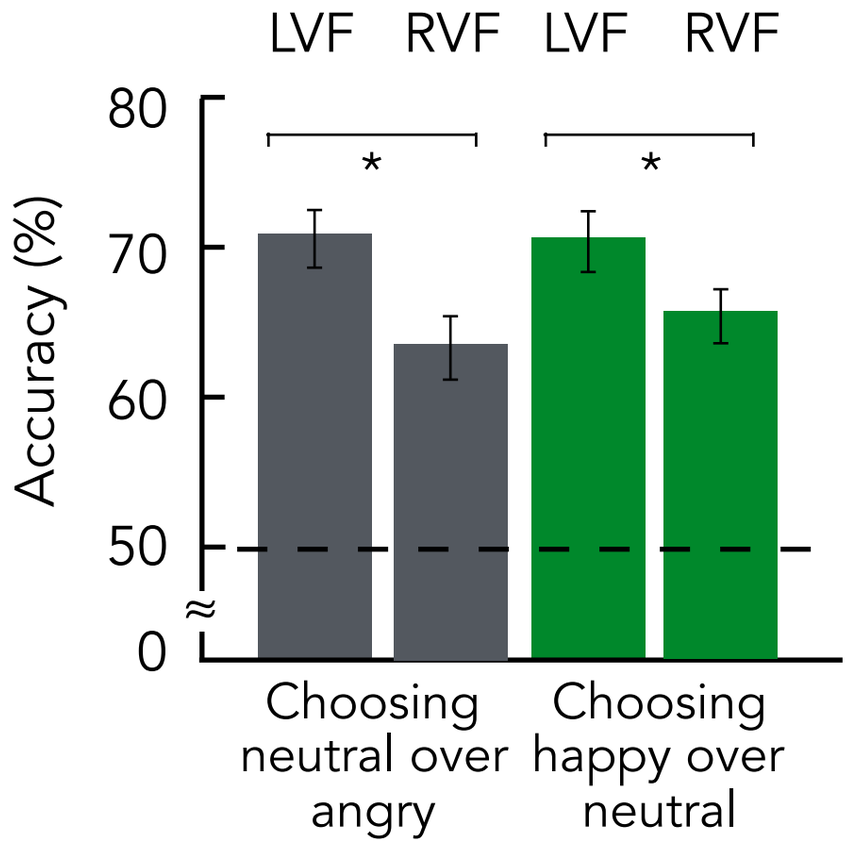
## Crowd emotion: Avoidance task



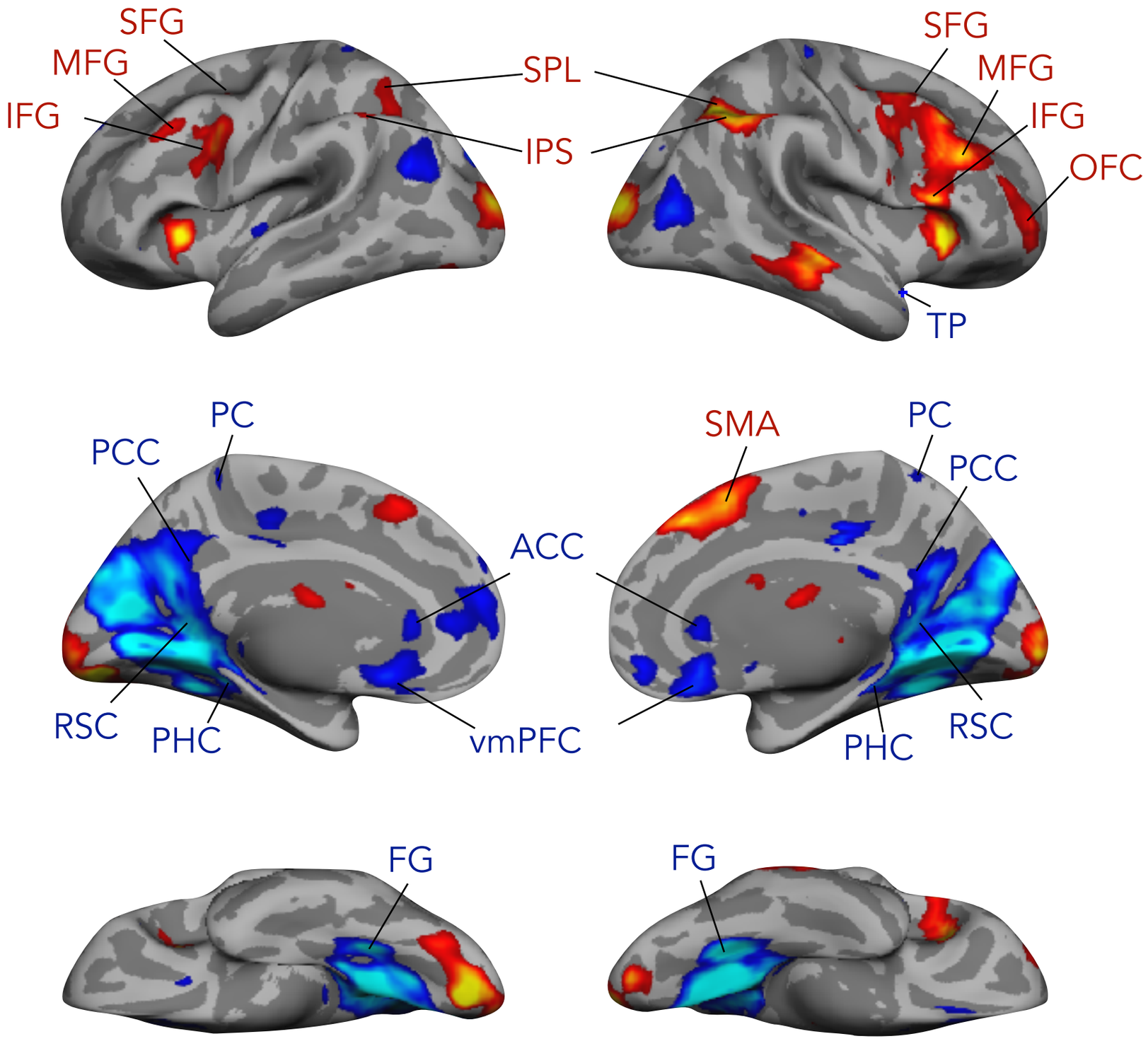

## Control: Approach task



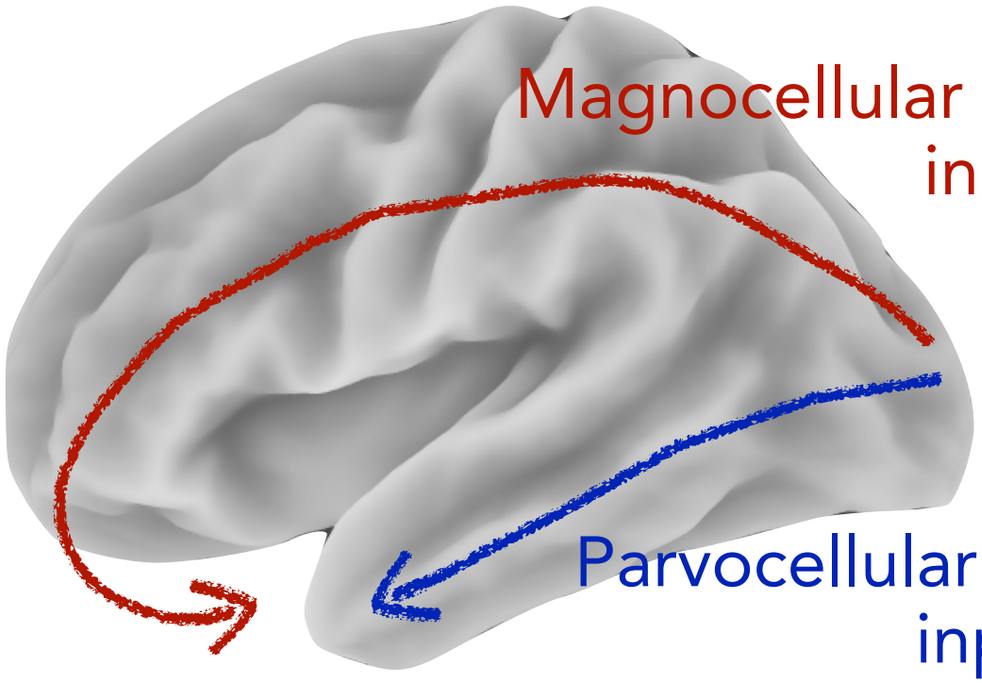

Im et al., 2017

# fMRI results: Crowd vs. Individual

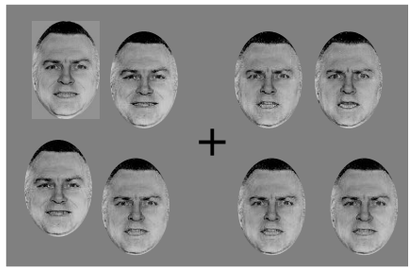



Im et al., 2017

# Dorsal and ventral pathways

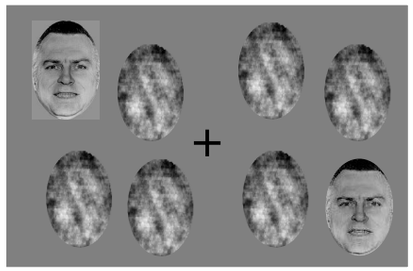


Magnocellular (M) input

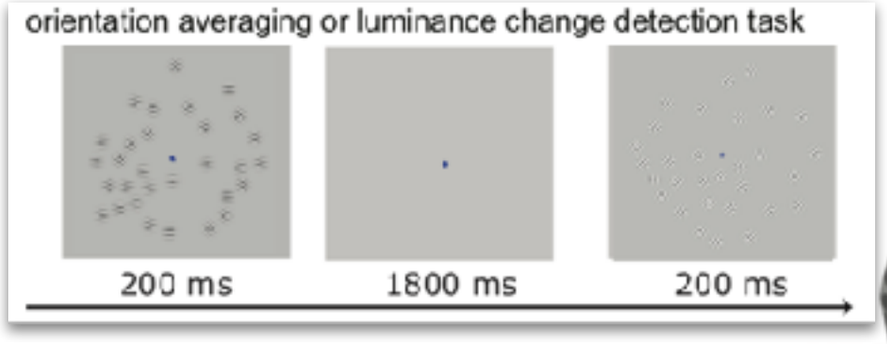


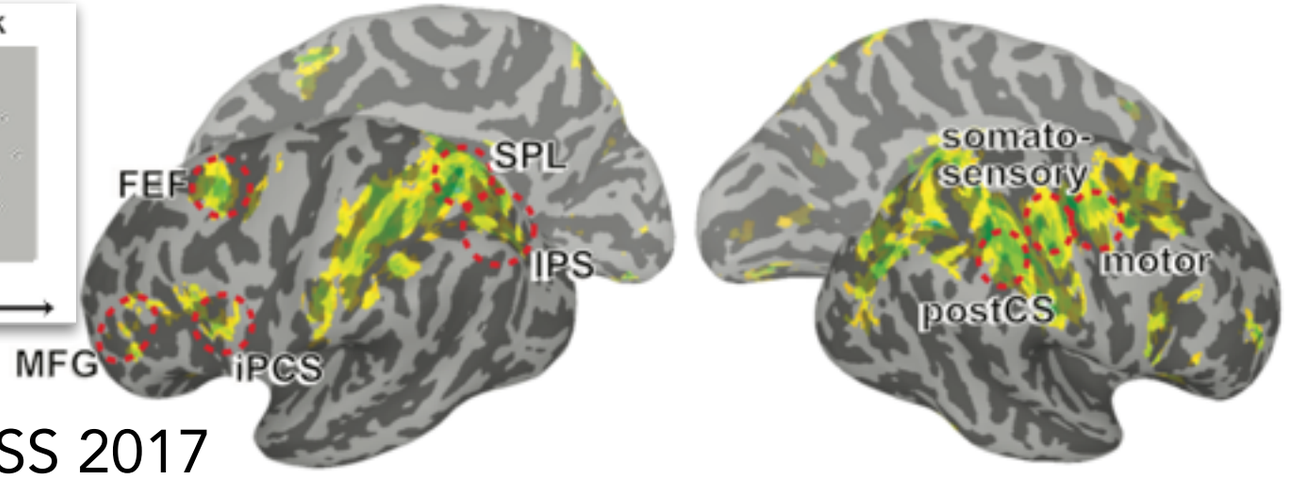
- Quick and dirty processing of global, low-spatial frequency
- Goal-dependent, rapid action execution

Parvocellular (P) input



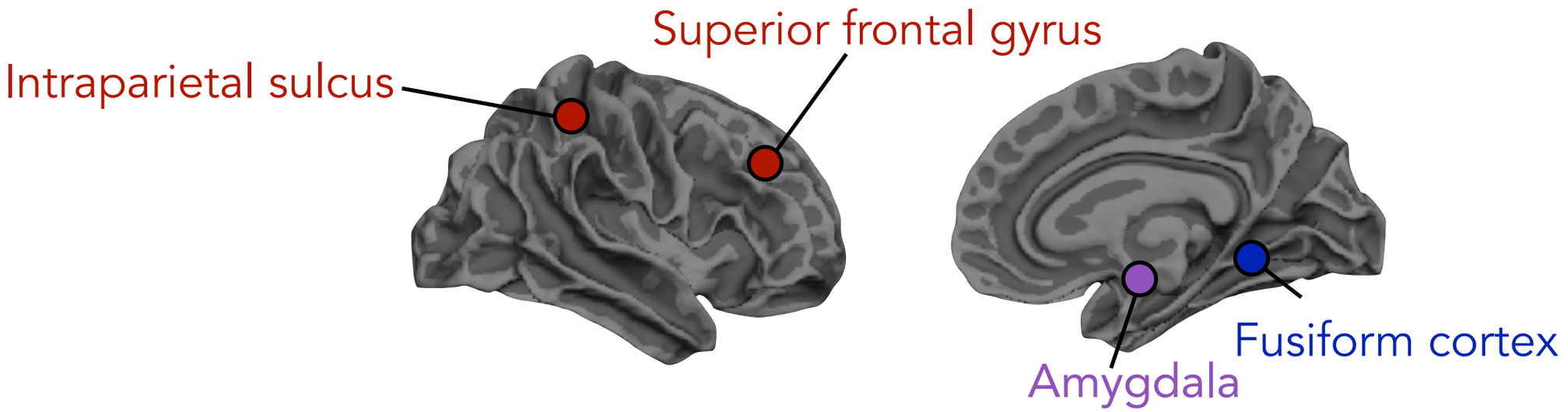
- Detailed visual processing of high-spatial frequency information

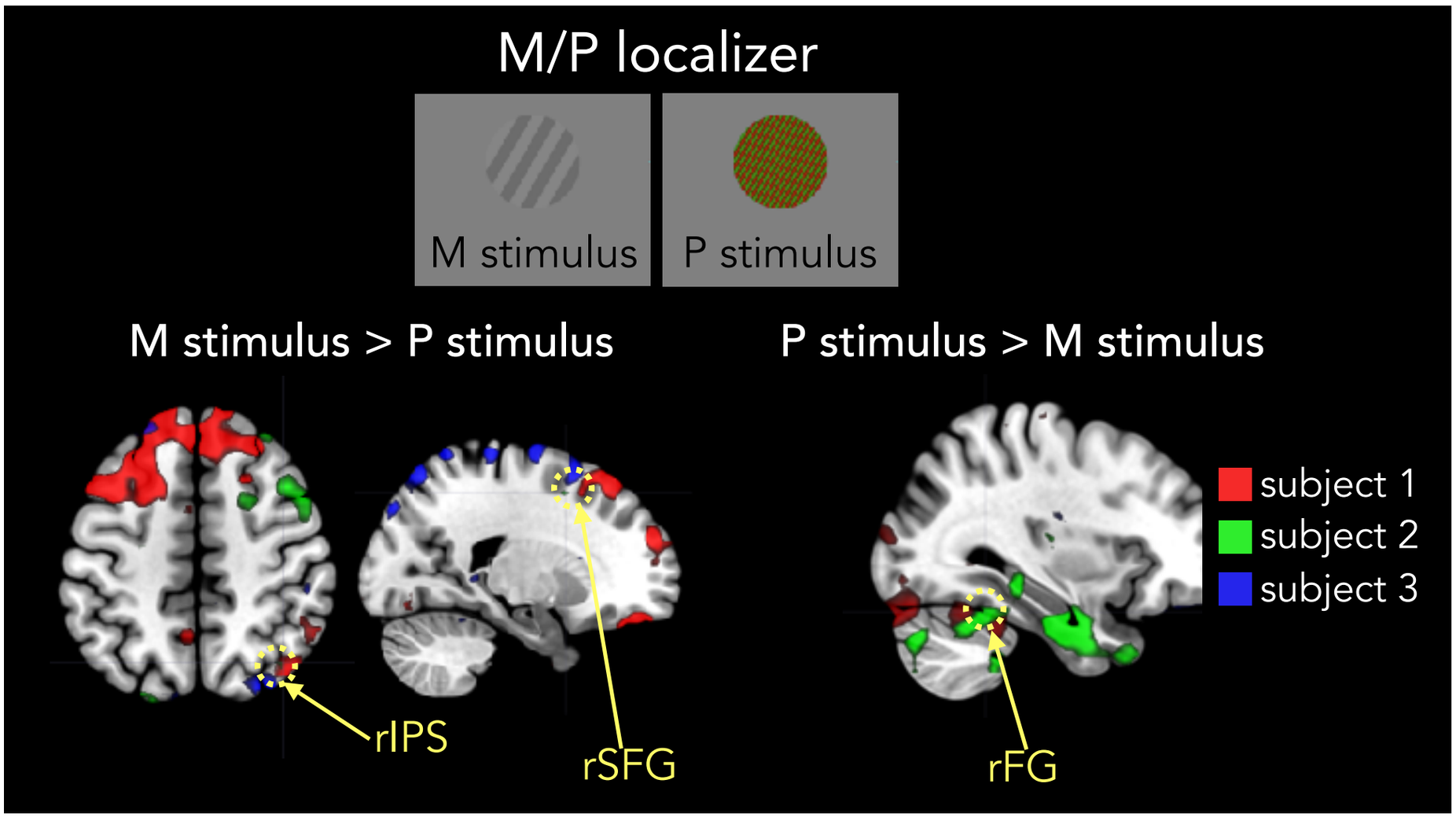



Tark et al., poster at VSS 2017

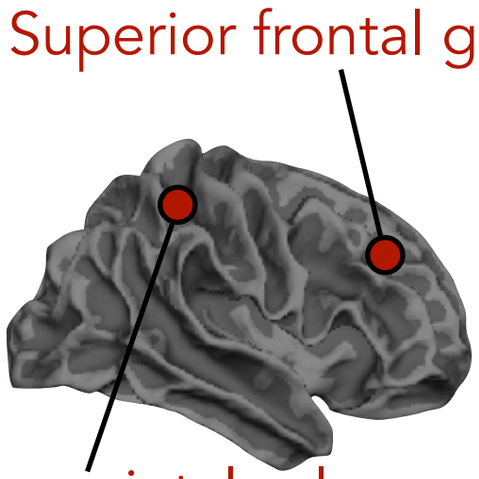
# Region-of-Interest analysis

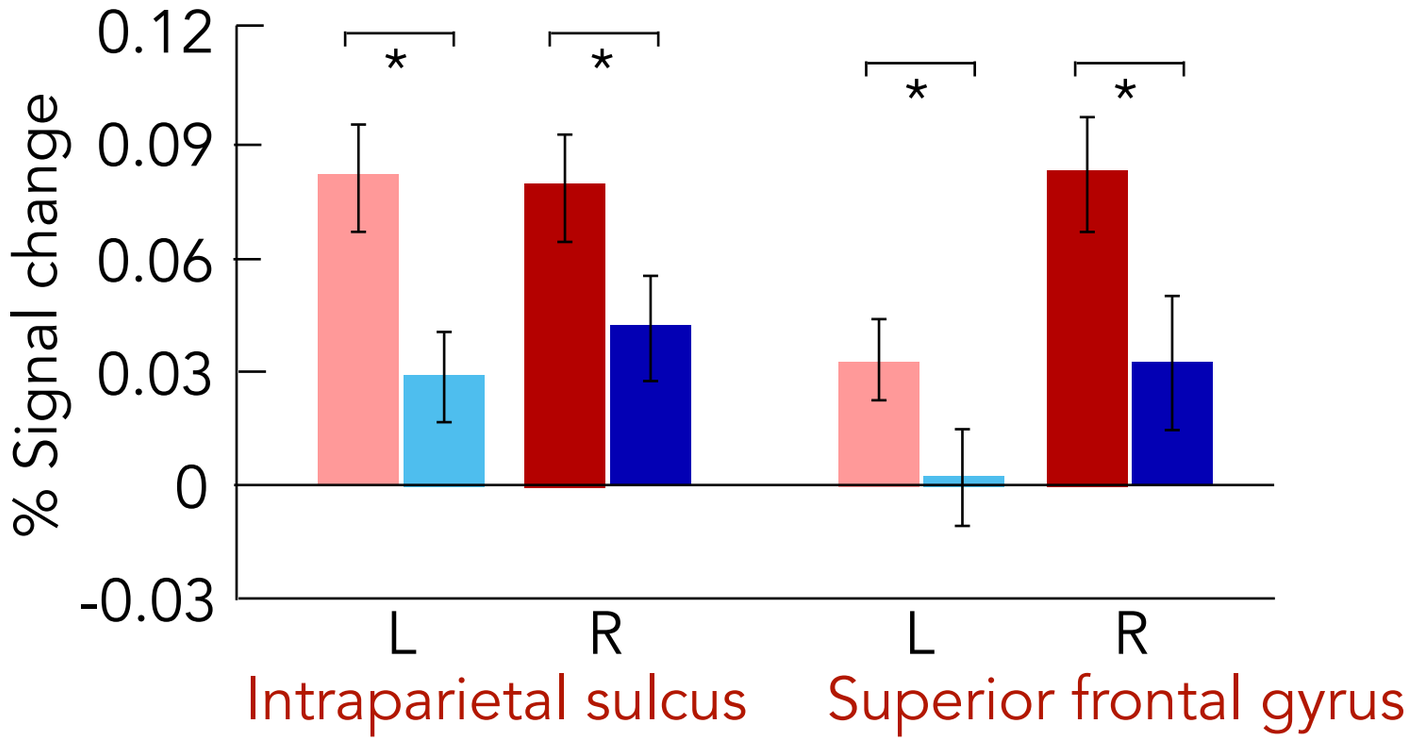


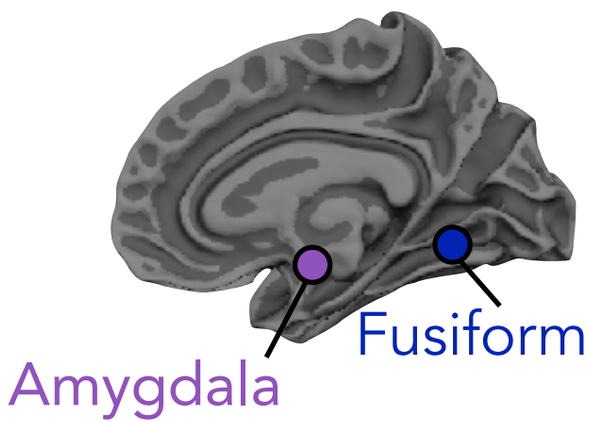



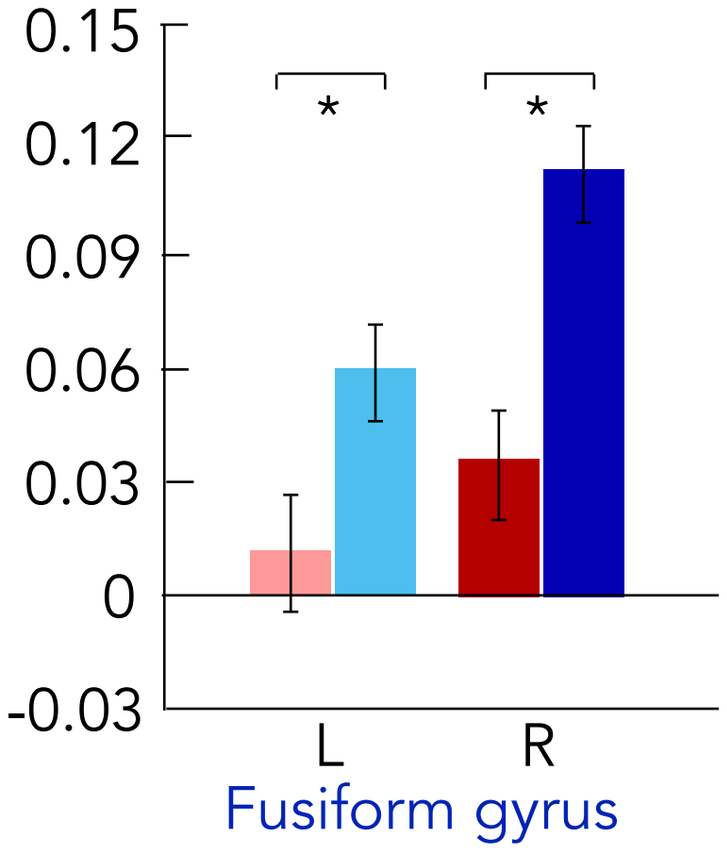

Im et al., 2017

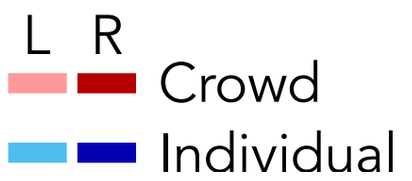
# M- and P-pathways for crowd and individual emotion



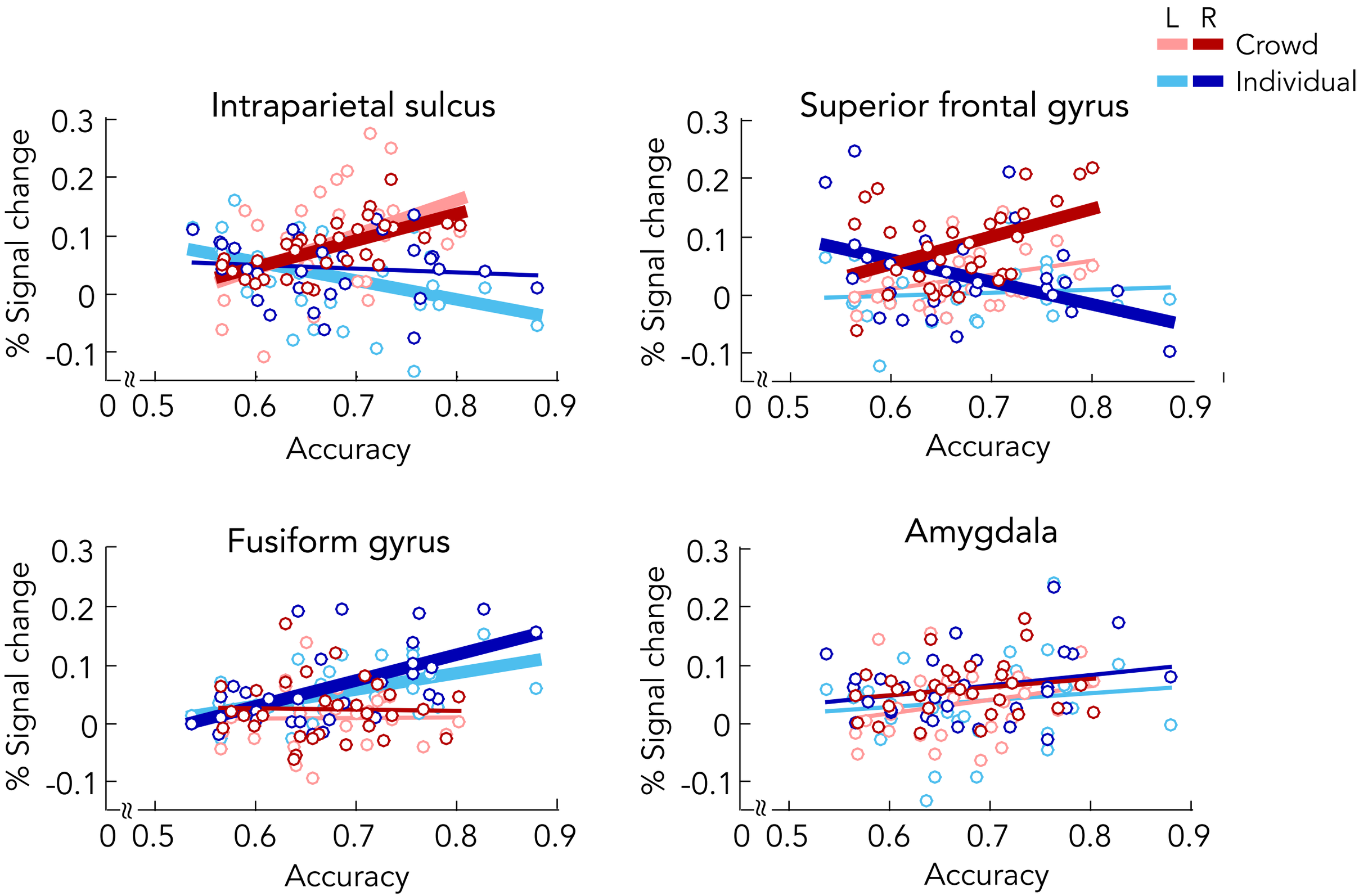



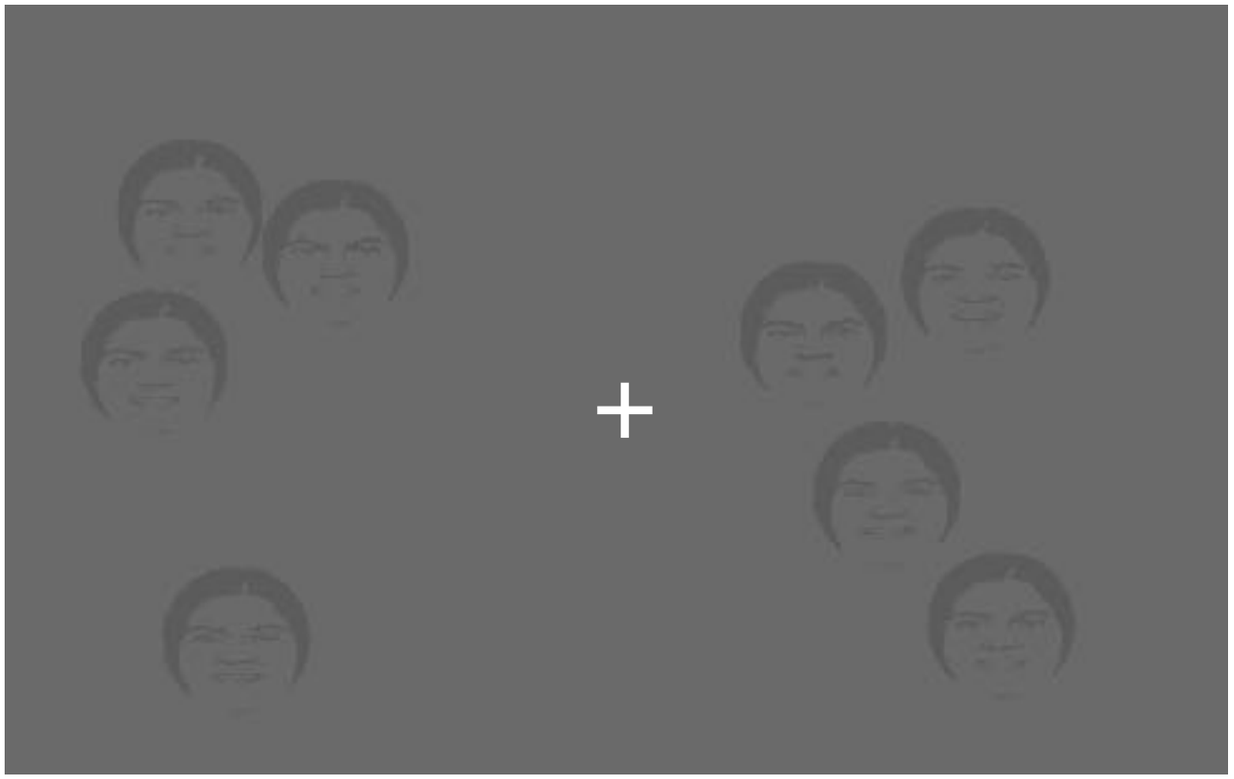

Im et al., 2017

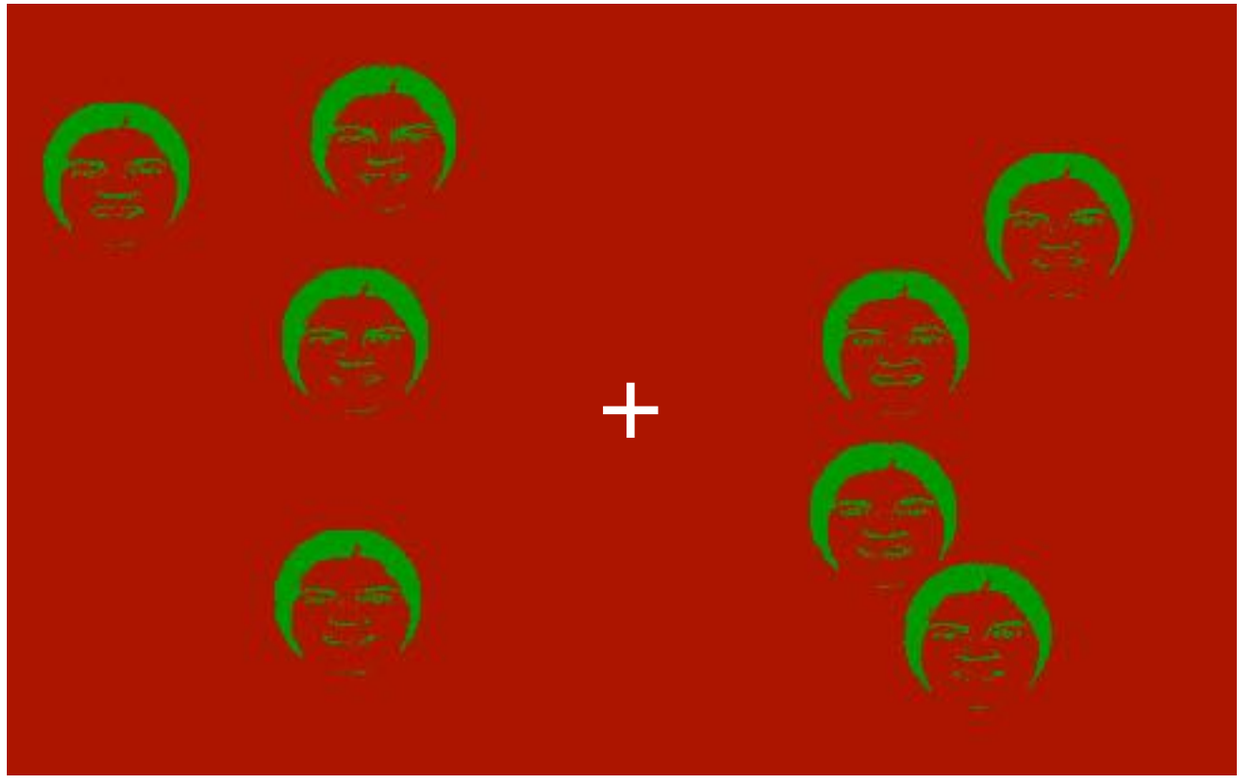
# Brain areas predicting accuracy for crowds and individuals




Im et al., 2017

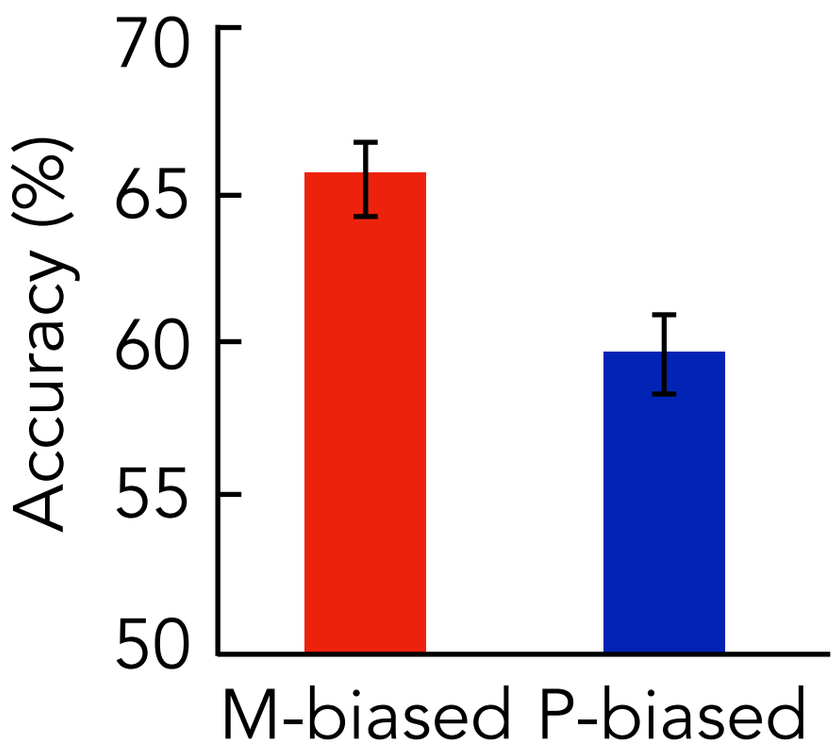
# Magnocellular bias for crowd emotion perception





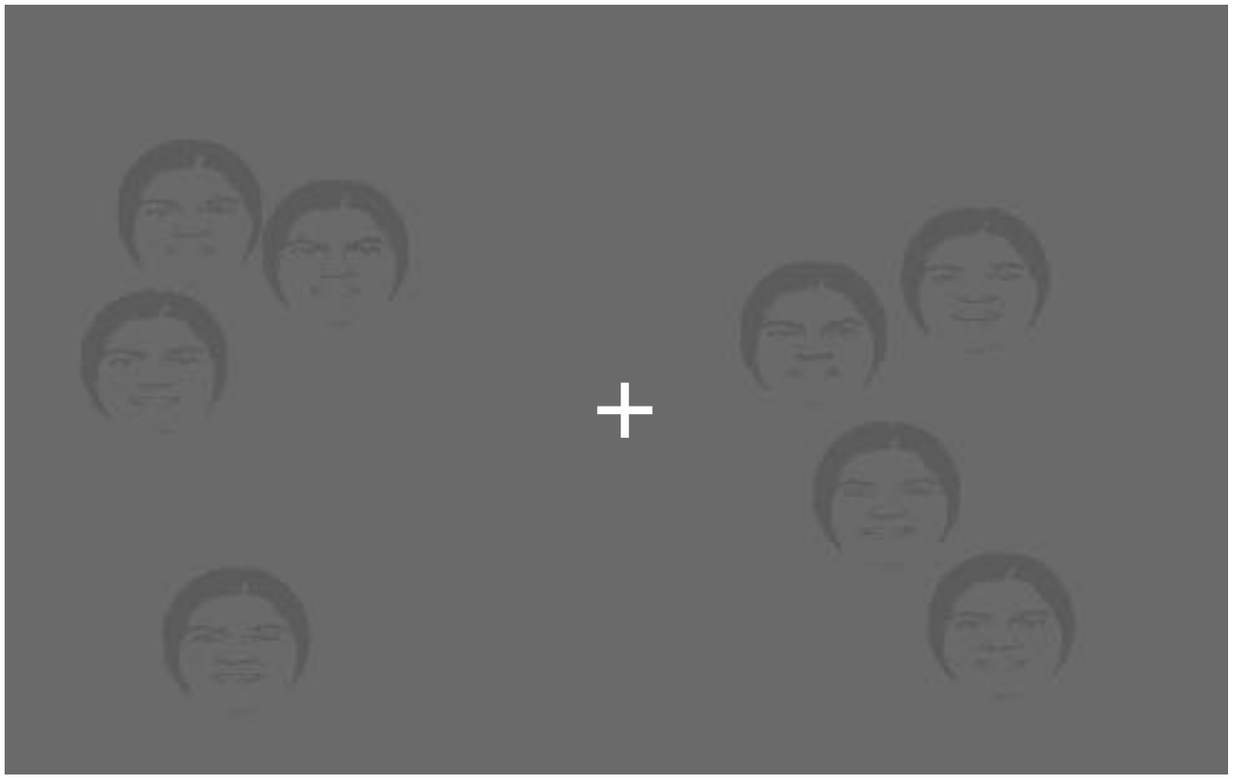
Magnocellular (M) biased

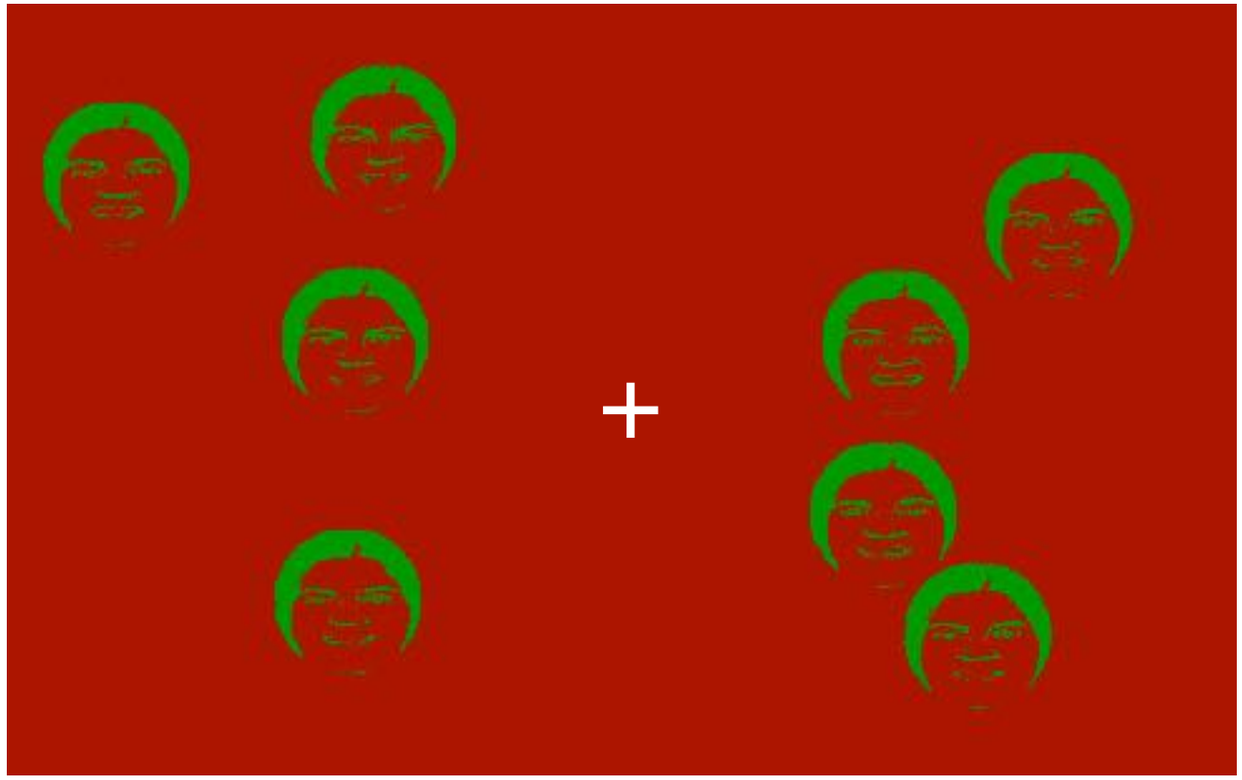
Parvocellular (P) biased



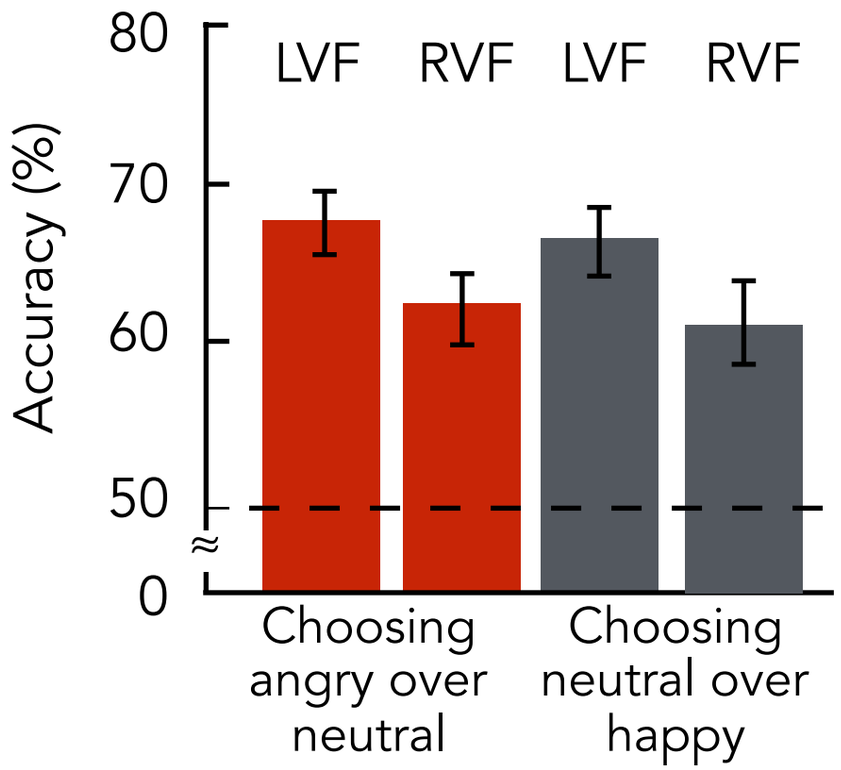

Im et al., in preparation

# Goal-dependent laterality effects for M-biased stimuli

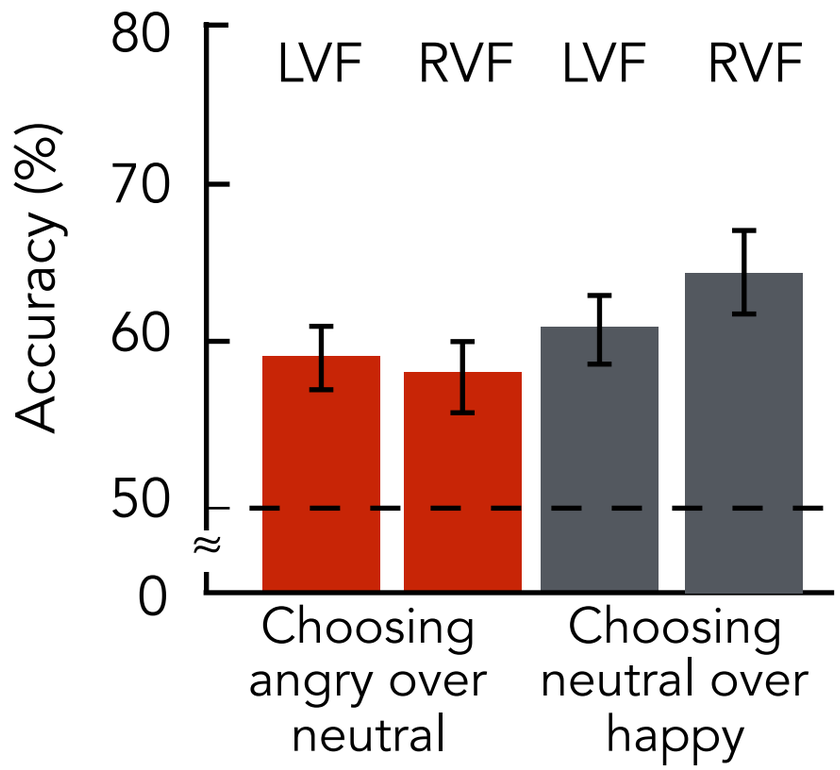




## Magnocellular (M) biased




## Parvocellular (P) biased

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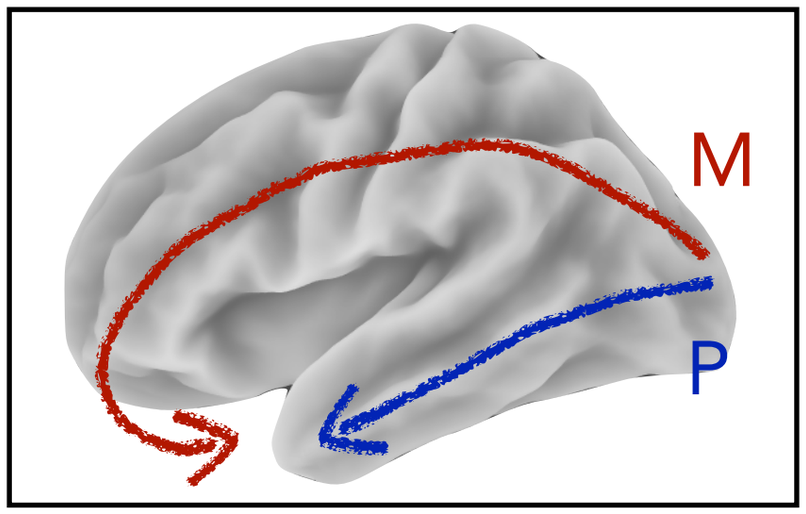
# Conclusion



- Hierarchical representation of objects, sets, and ensembles
- Interaction between the different types of representation




- Different brain pathways
- Different hemispheric lateralization

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Athinoula A. Martinos Center For Biomedical Imaging

MGH 1811

VE RI TAS

PENNSTATE 1855