Models of visual search

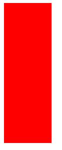
Krista A. Ehinger

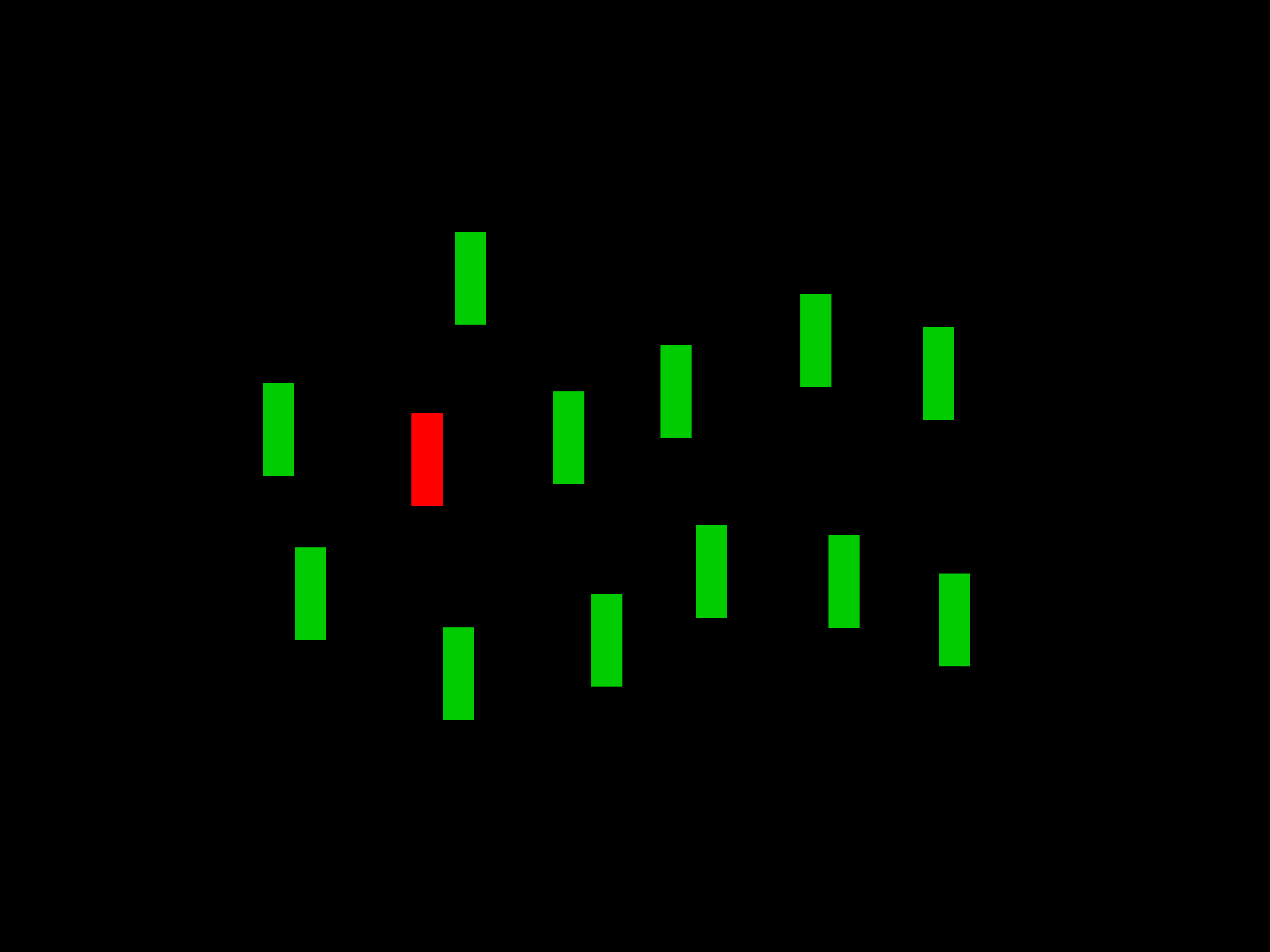
PSYC 6229 Statistical Modelling of Perception and Cognition
March 12, 2019

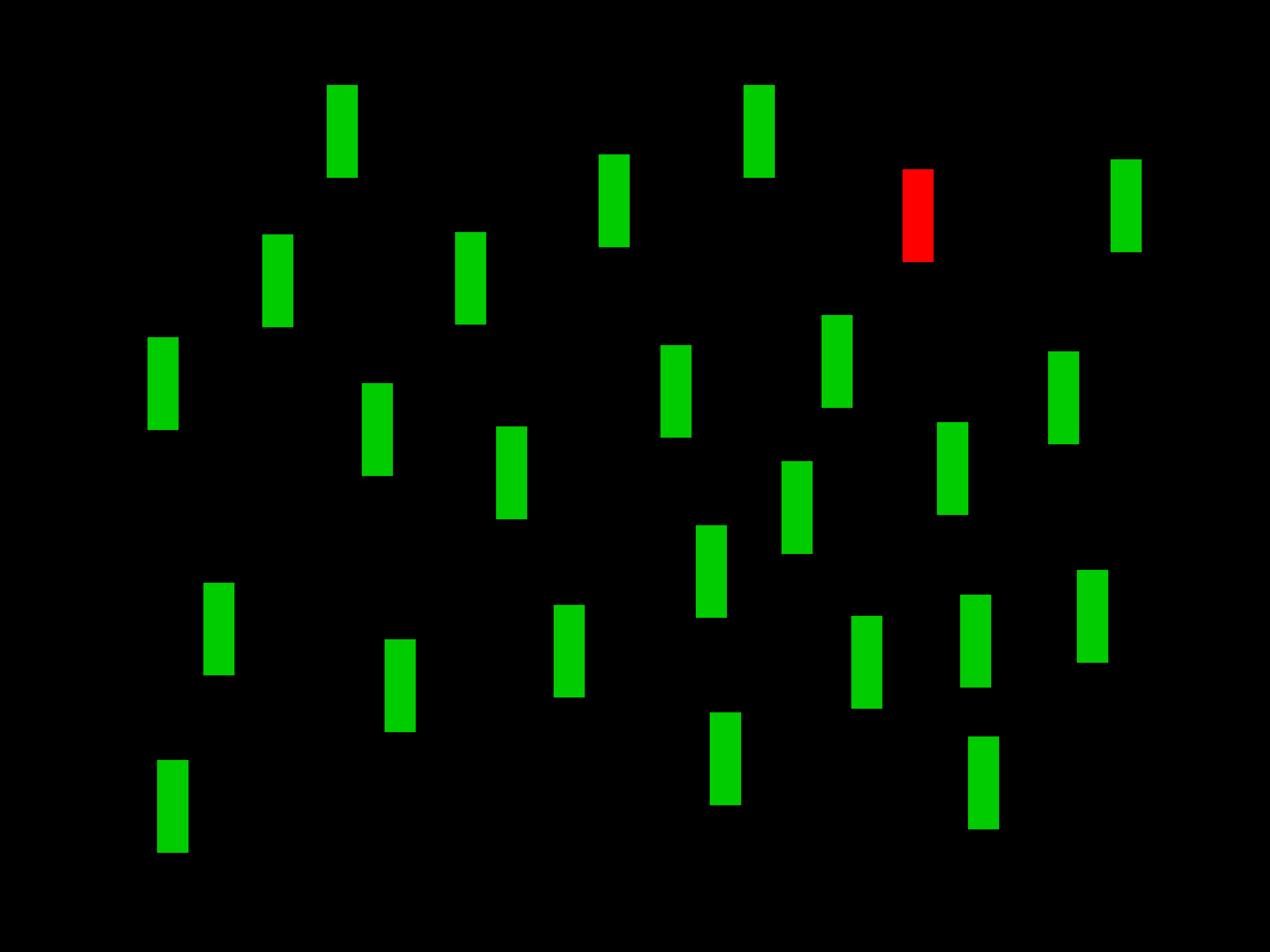
Visual search

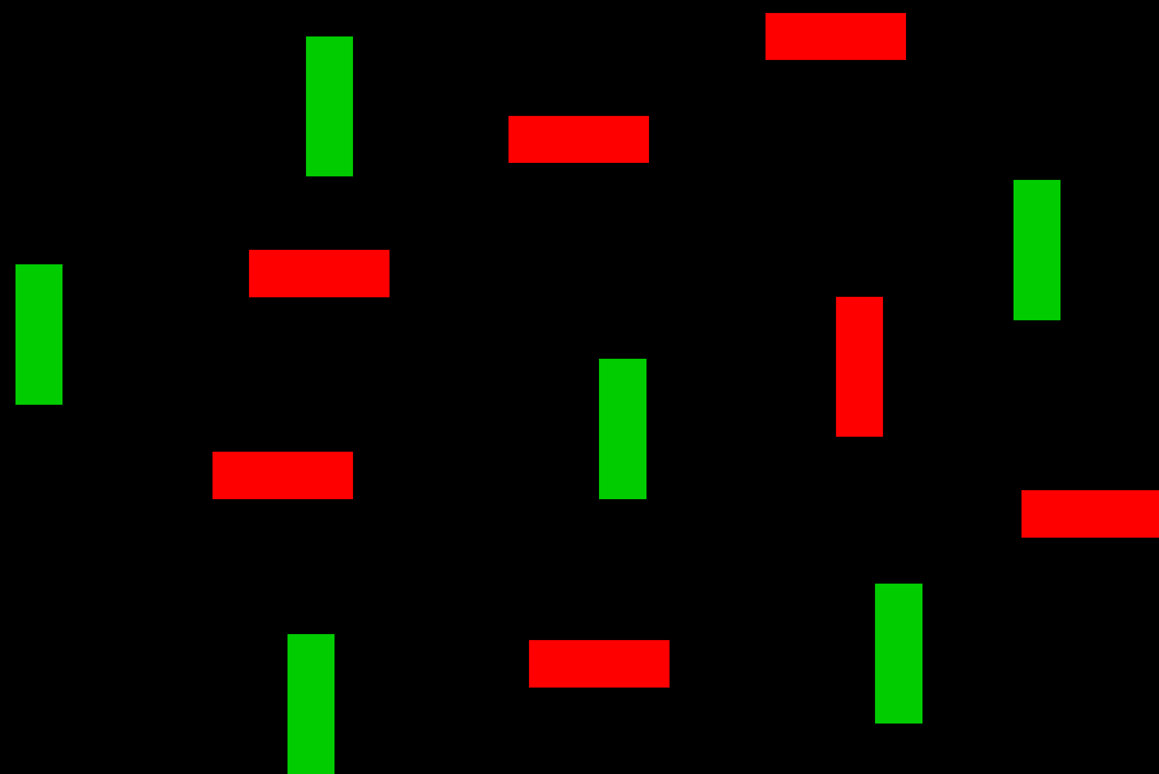
- Task: find a target object in a visual display
- Measure reaction times and/or errors
- Why is it interesting?
  - How easy/hard the search is tells us something about visual encoding – some targets just “pop out” of the display but others don’t
  - Important real-world applications: security, medical screening, search and rescue

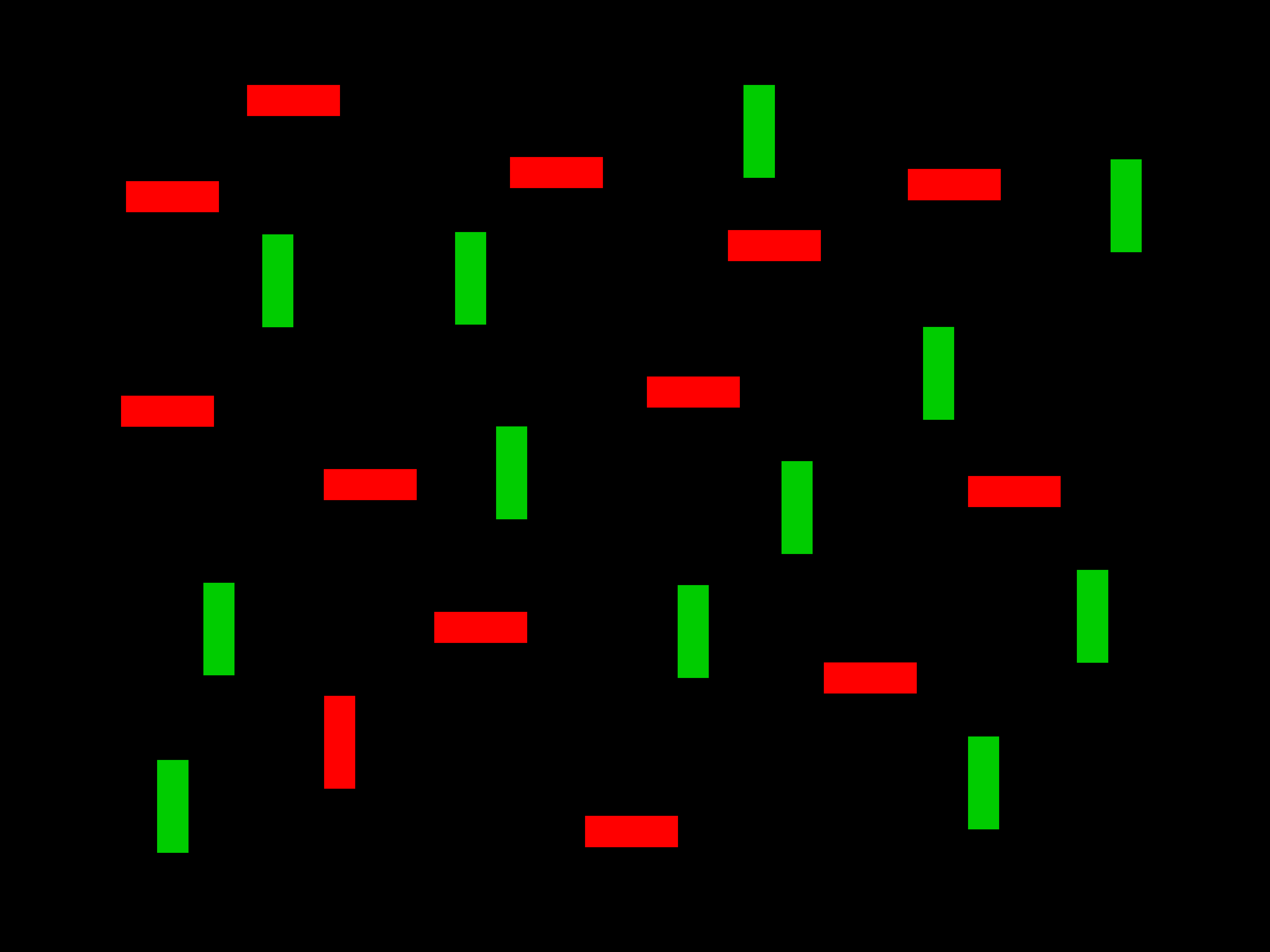
Clap when you find this:









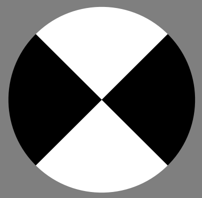


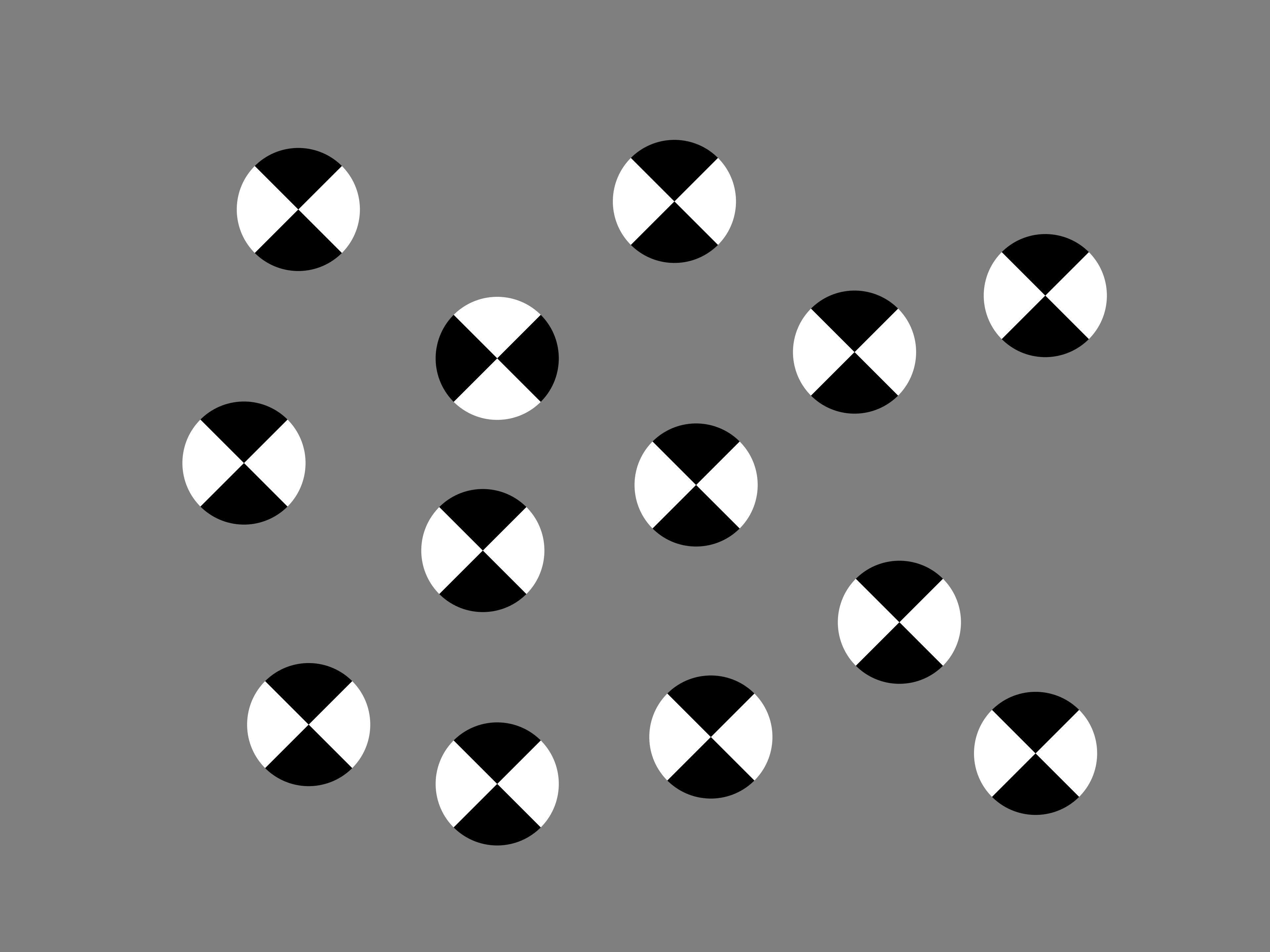
Clap when you find this:

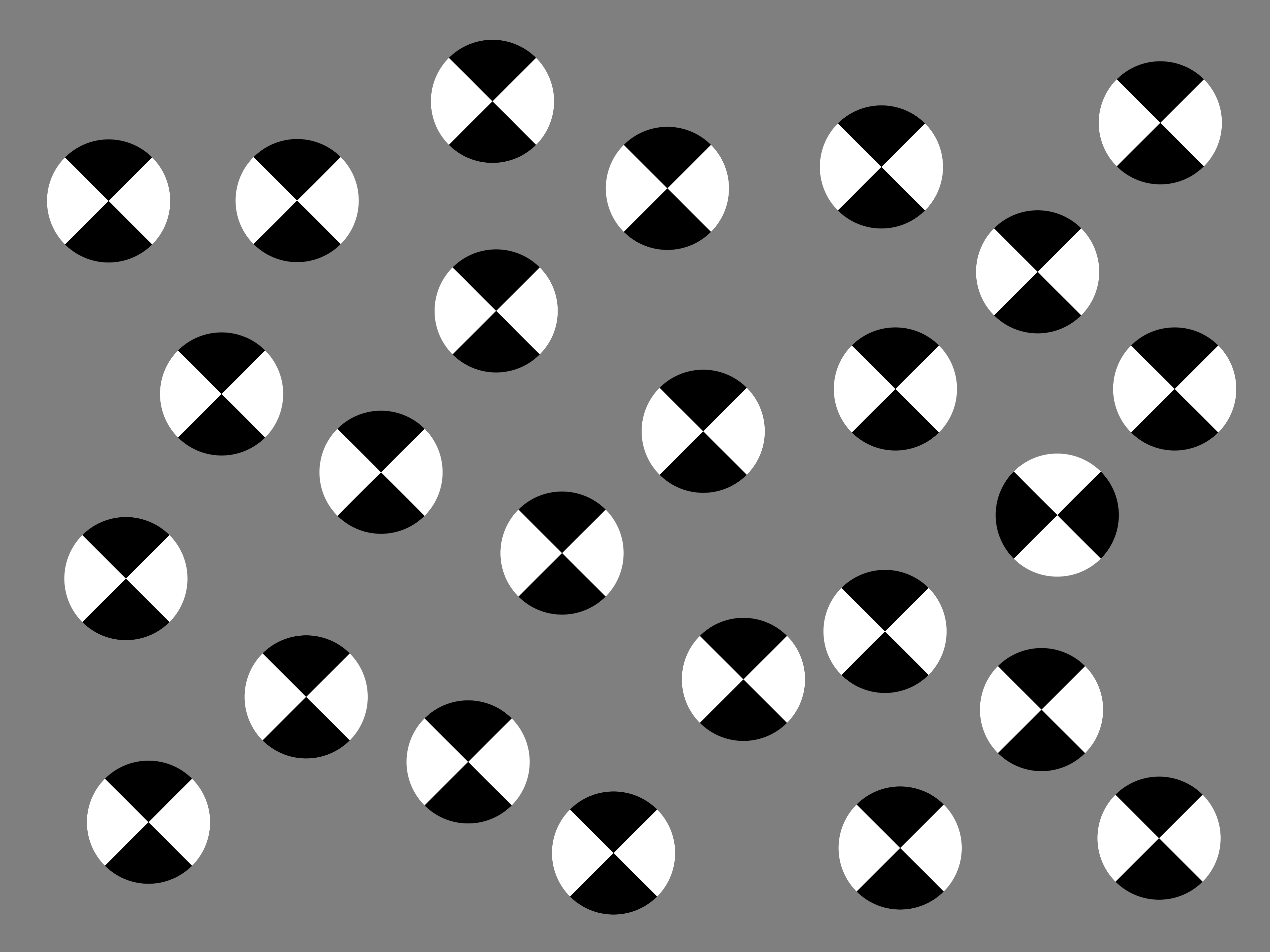
an elephant


P
HORODATEUR
P

Clap when you find this:

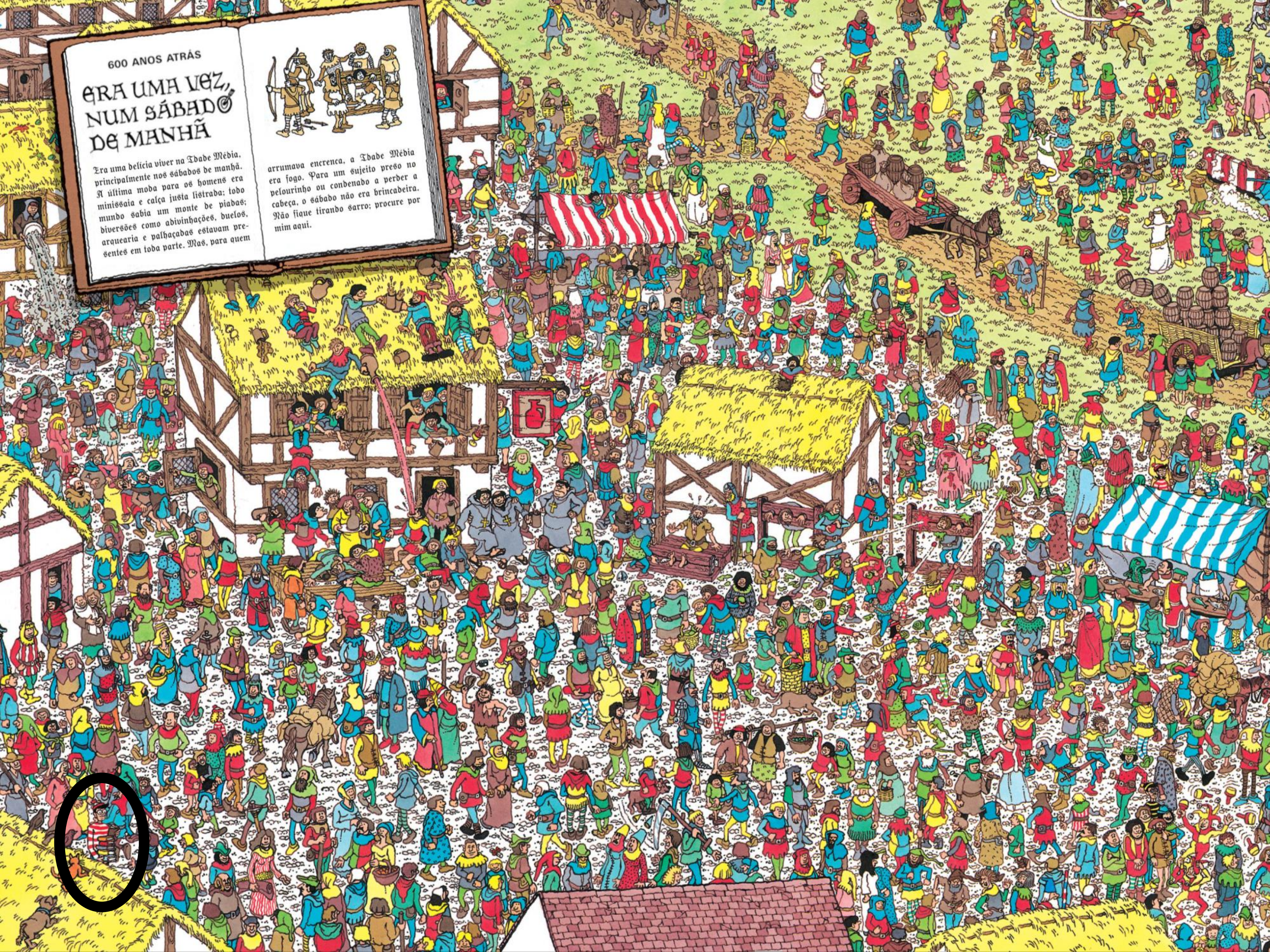






Search is harder if…

- The distractors are more similar to the target
- The distractors are more heterogeneous



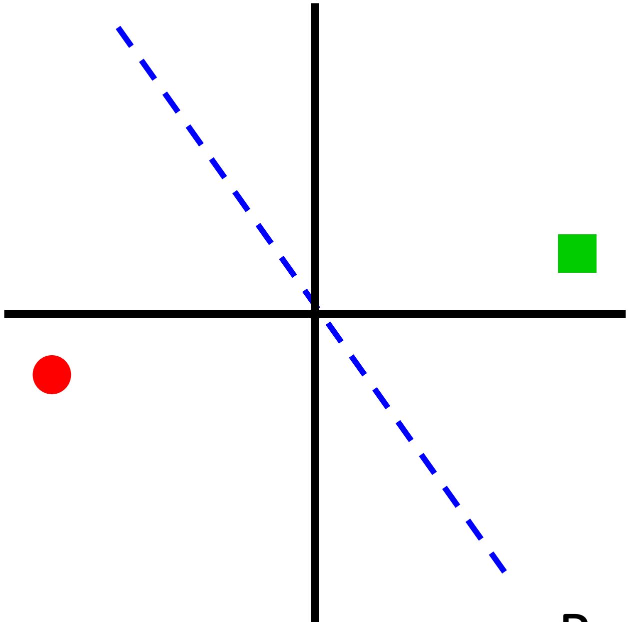
600 ANOS ATRÁS
ERA UMA VEZ, NUM SÁBADO DE MANHÃ
Era uma delícia viver na Idade Média, principalmente nos sábados de manhã. A última moda para os homens era minissaia e calça justa listrada; todo mundo sabia um monte de piadas; diversões como adivinhações, duelos, arquearia e palhaçadas estavam presentes em toda parte. Mas, para quem arrumava encrenca, a Idade Média era fogo. Para um sujeito preso no pelourinho ou condenado a perder a cabeça, o sábado não era brincadeira. Não fique tirando sarro; procure por mim aqui.

Slide from:
R. Rosenholtz

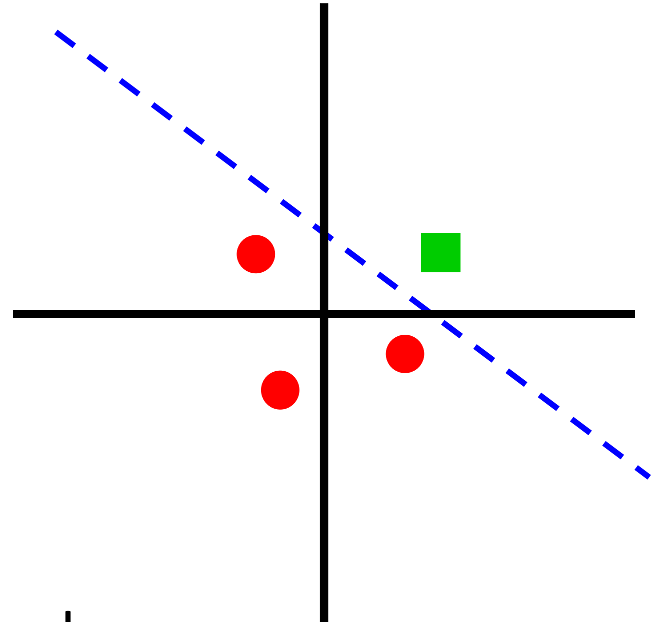
Search is harder if…

- The distractors are more similar to the target
- The distractors are more heterogeneous
- The distractor distribution (in some feature space) is less separable from the target distribution (in the same feature space)

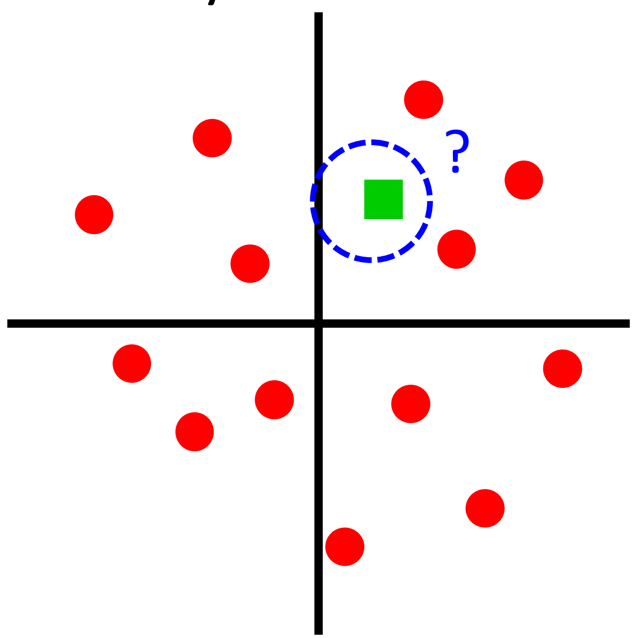
Easy search:



Harder search:



Really hard search:



Search efficiency

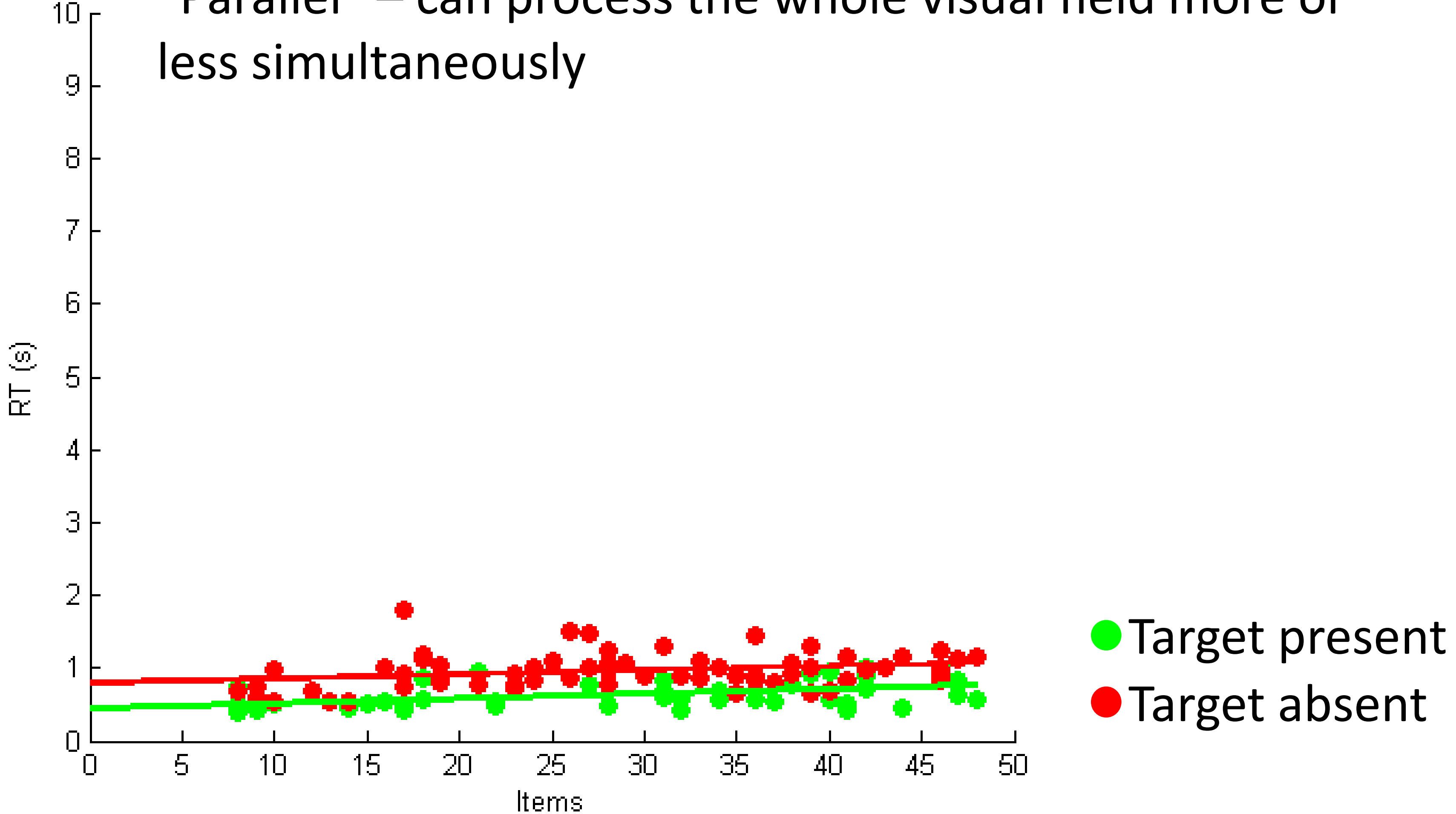
- Search efficiency = how much slower search becomes as you add more distractors to the display
- Measured as search slope: msec/item
- Simplistically, you can group search tasks into two categories:
    - Efficient = flat slope = search time does not depend on number of distractors
    - Inefficient = steep slope = search time increases with number of distractors

2AFC task

- Task: Is the target present? (yes/no)
- 50% of displays include one target, 50% of displays have no target
- Number of items in display (set size) varies
- Measure response time and/or accuracy

Efficient search

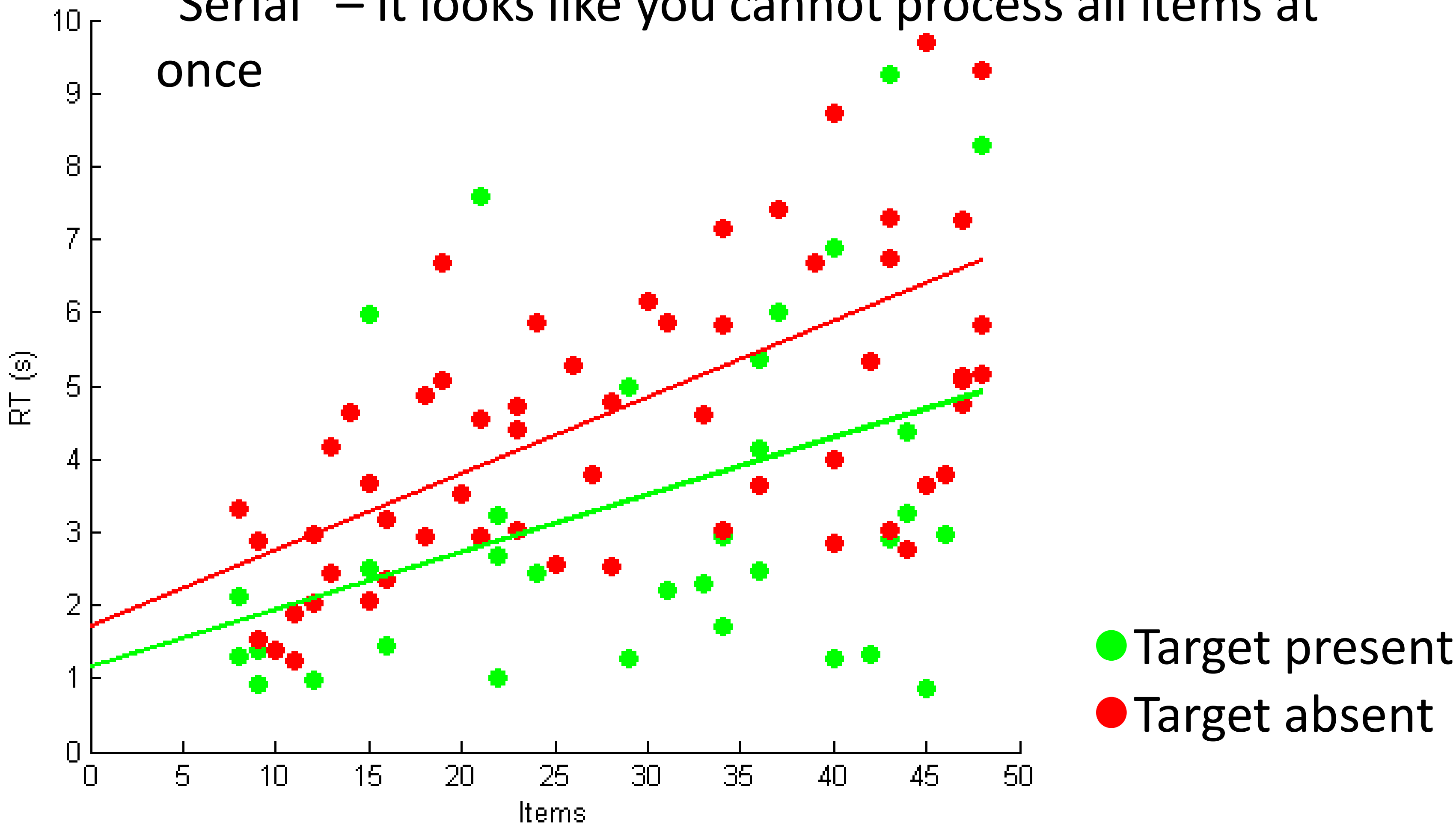
Number of distractors doesn't really affect search time
"Parallel" – can process the whole visual field more or less simultaneously

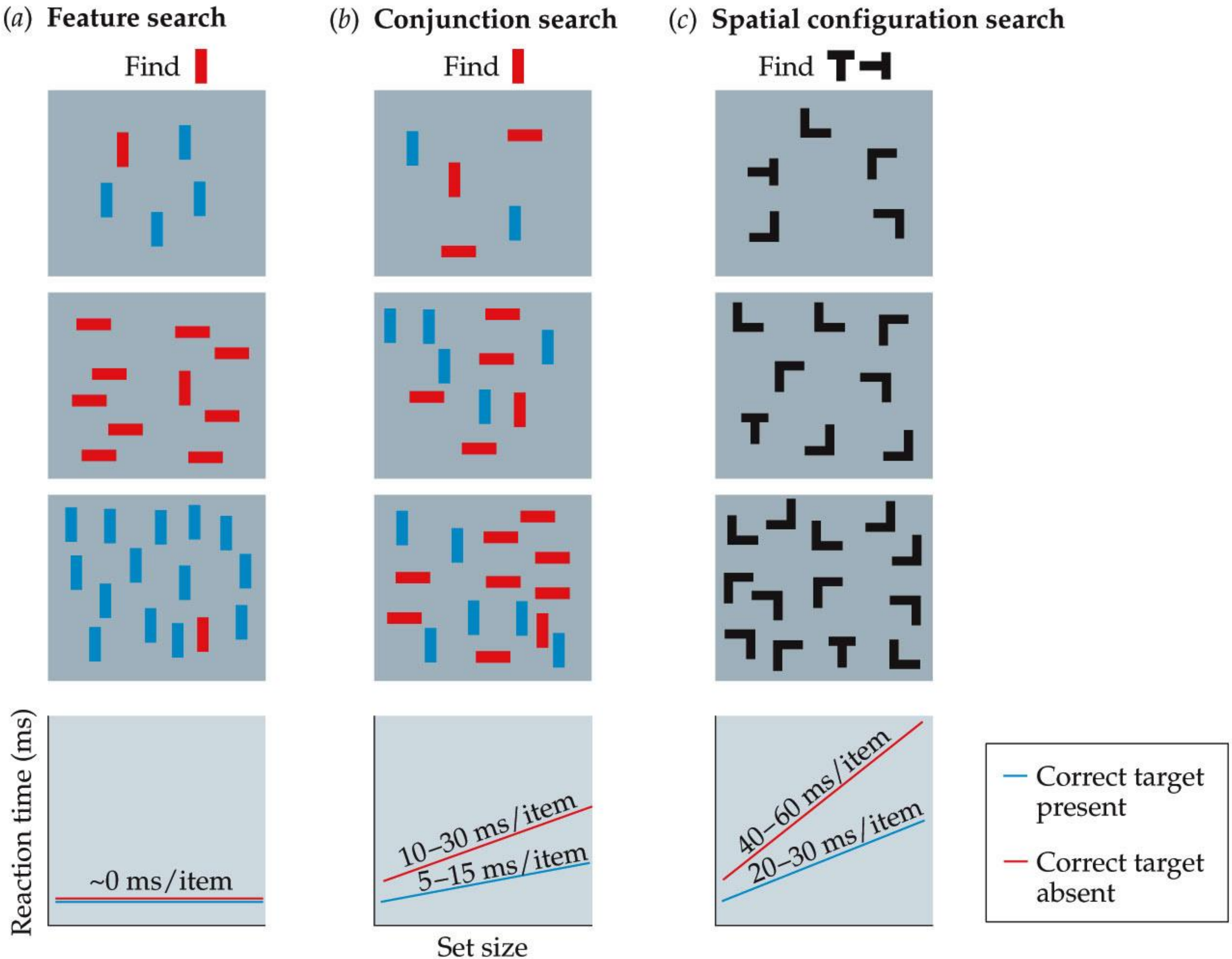


Inefficient search

More distractors -> takes longer to find the target

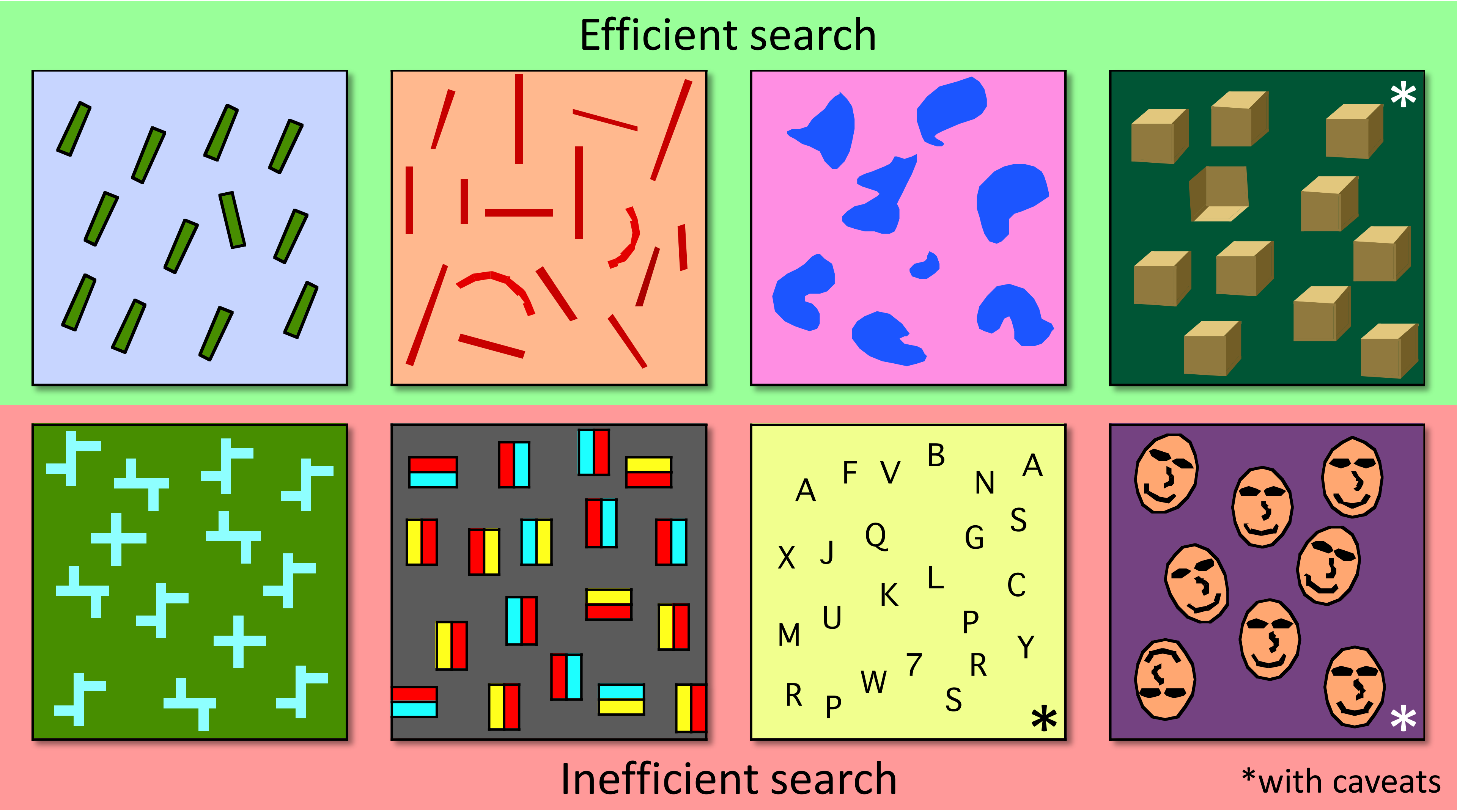
"Serial" – it looks like you cannot process all items at once





SENSATION & PERCEPTION 2e, Figure 8.6

Search efficiency



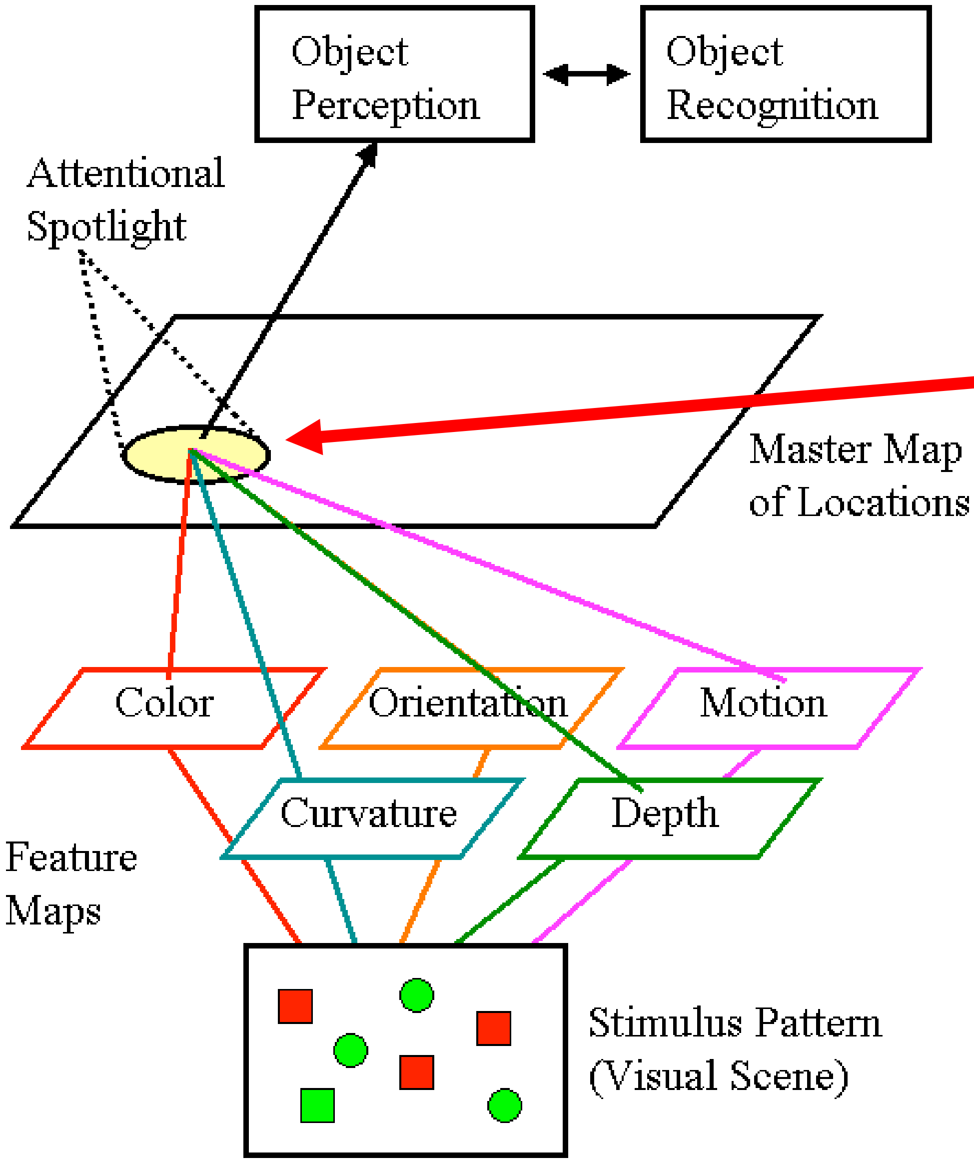
J. Wolfe

Models of visual search

Model 1: Two-stage processing

- Examples: Feature Integration Theory (Treisman); Guided Search (Wolfe)
- Visual information is processed in two stages
- The first stage processes the whole image in **parallel**; sometimes this step alone is sufficient to find the target (= efficient search)
- Harder search tasks require a second processing stage which is **serial**: you move your eyes/attention through the display and process each item (or small groups of items) one at a time (= inefficient search)

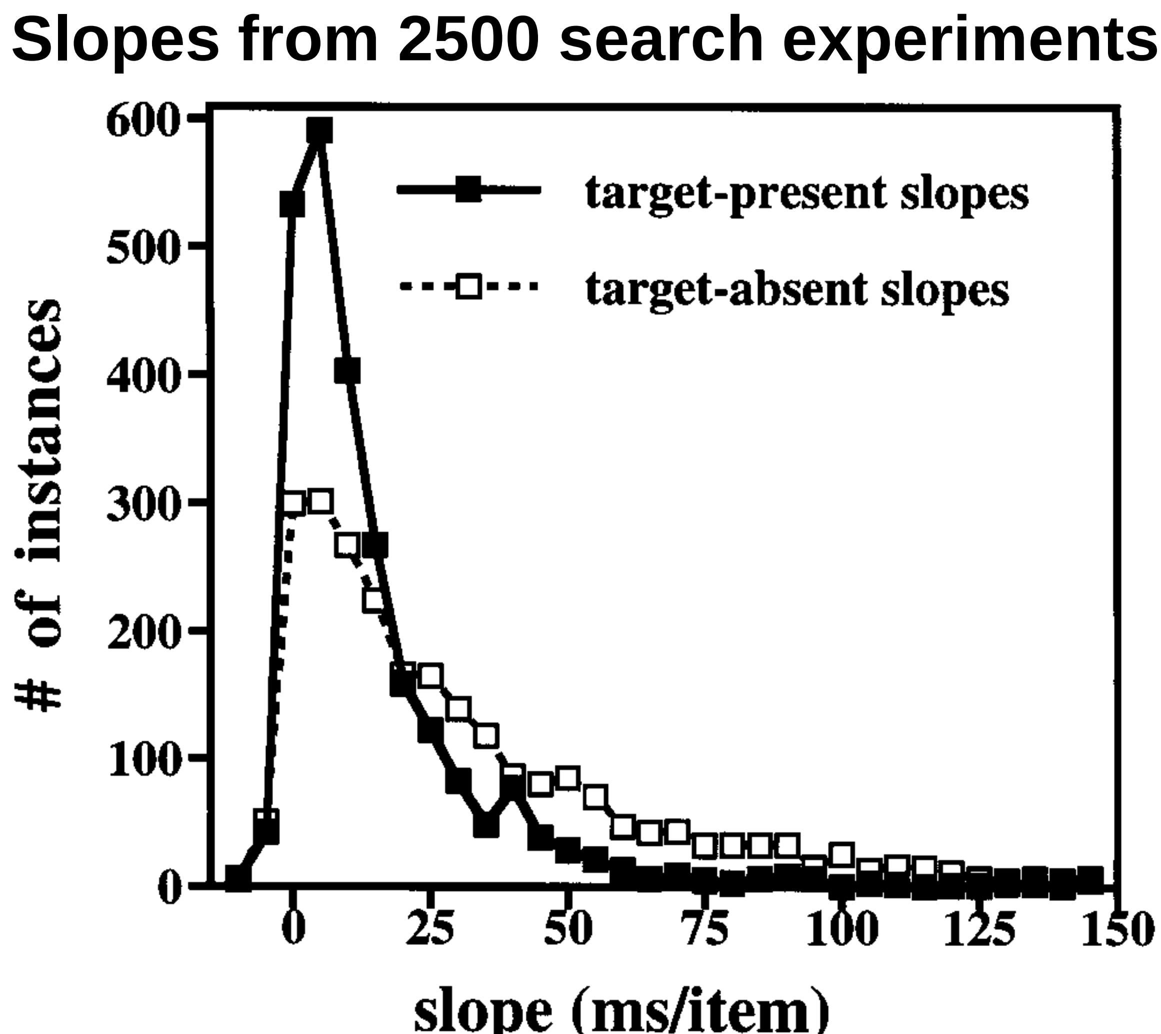
Feature Integration Theory



Serial processing of one location at a time

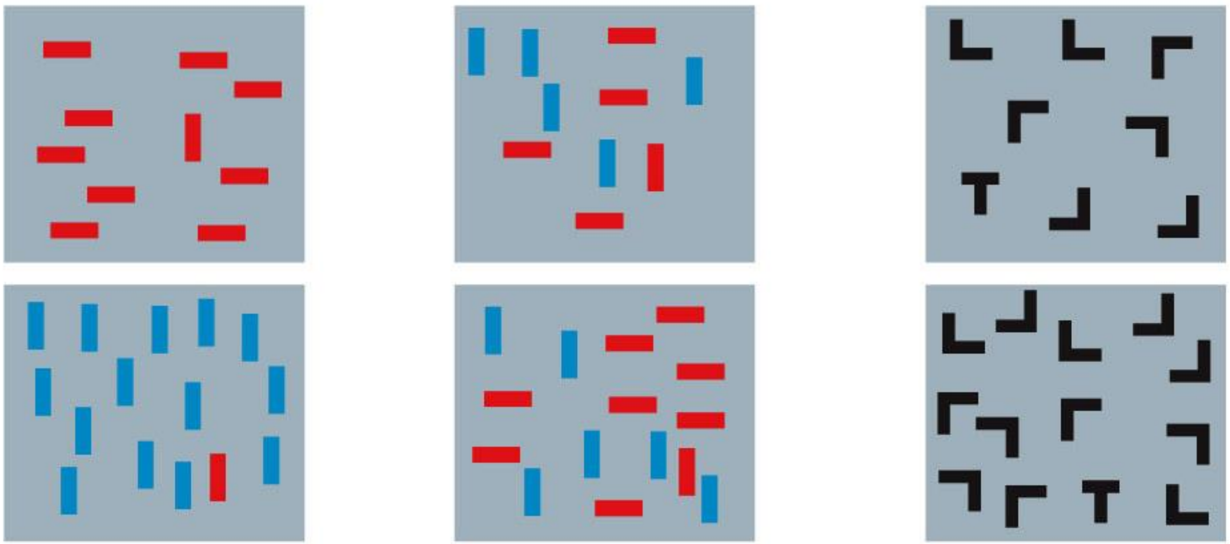
"Preattentive" parallel processing of the whole image

Serial vs. parallel



Wolfe (1998)

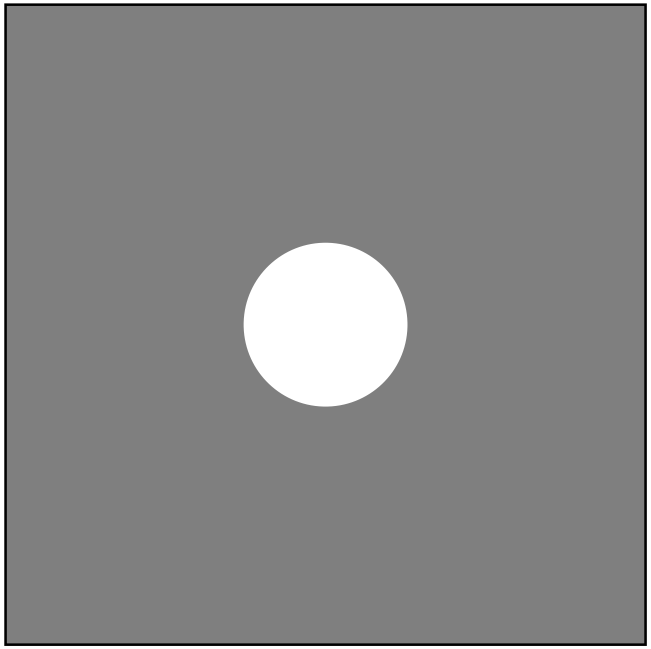
What affects search efficiency?



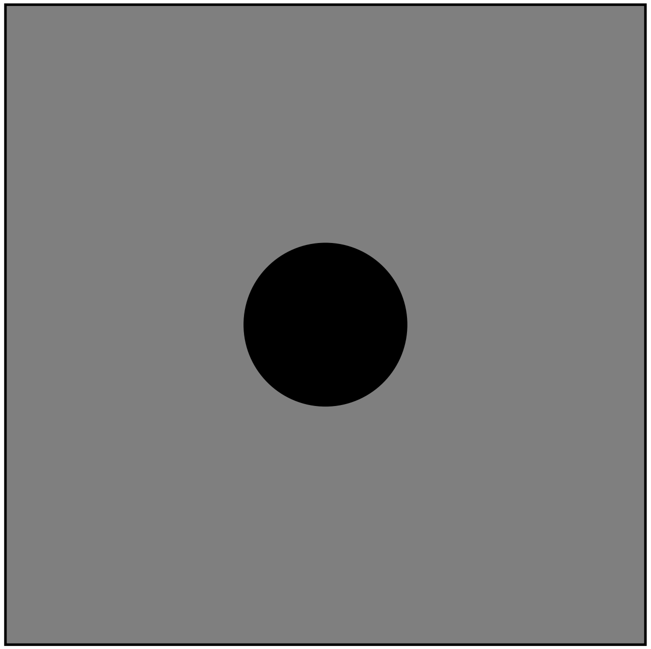
- Presence of a “basic” feature
- Conjunctions are easier than configurations
- Early vs. later stages of visual processing

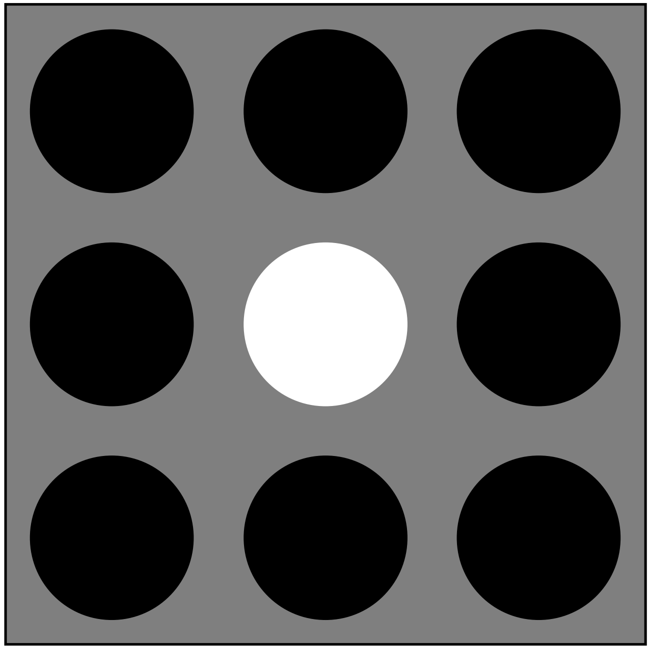
Model 2: Parallel processing (SDT)

- Examples: Palmer et al. (1993); Verghese (2001)
- Most search tasks involve parallel processing, and increased errors (or slower responses) with set size are a natural consequence of distinguishing between larger sets of items in a signal-detection framework
- If the discrimination is trivially easy, difficulty will not increase much with set size (= efficient search)
- If the discrimination is difficult, set size will have more impact (= inefficient search)

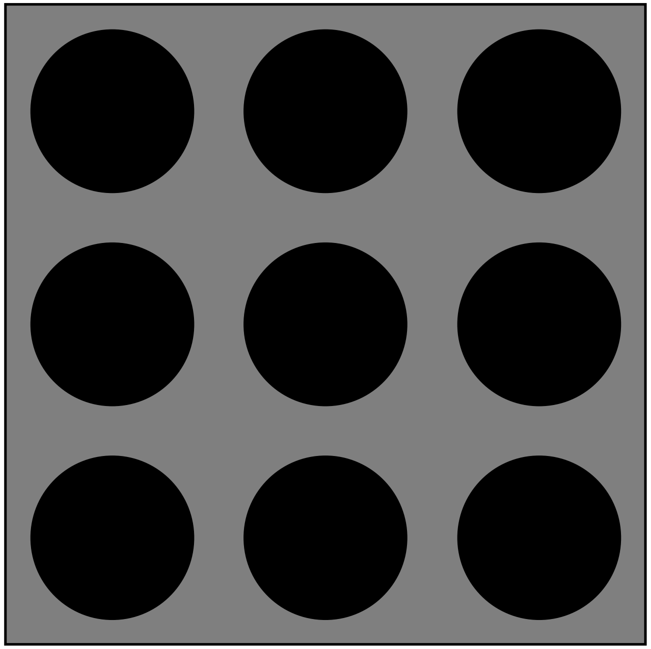


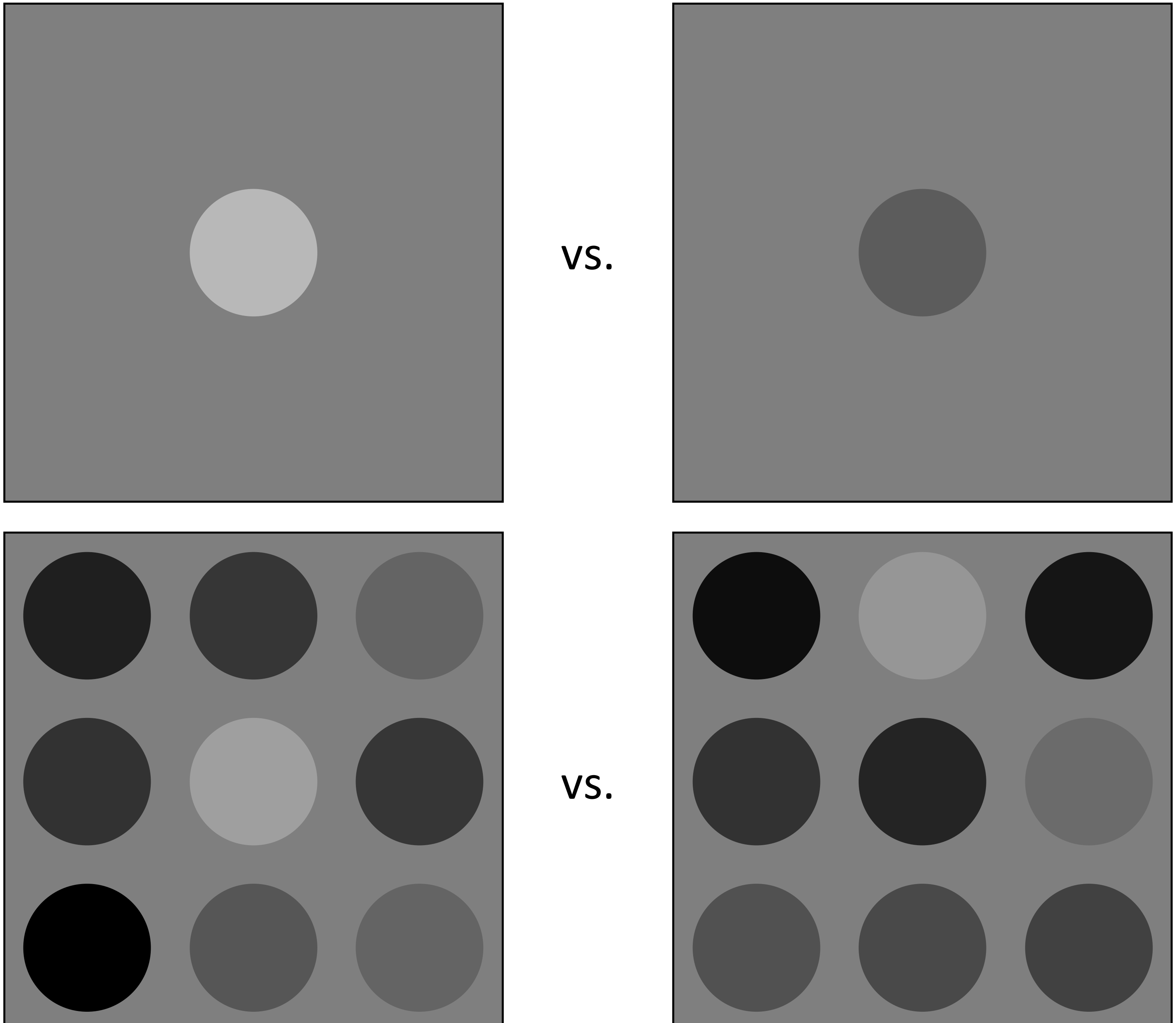
vs.



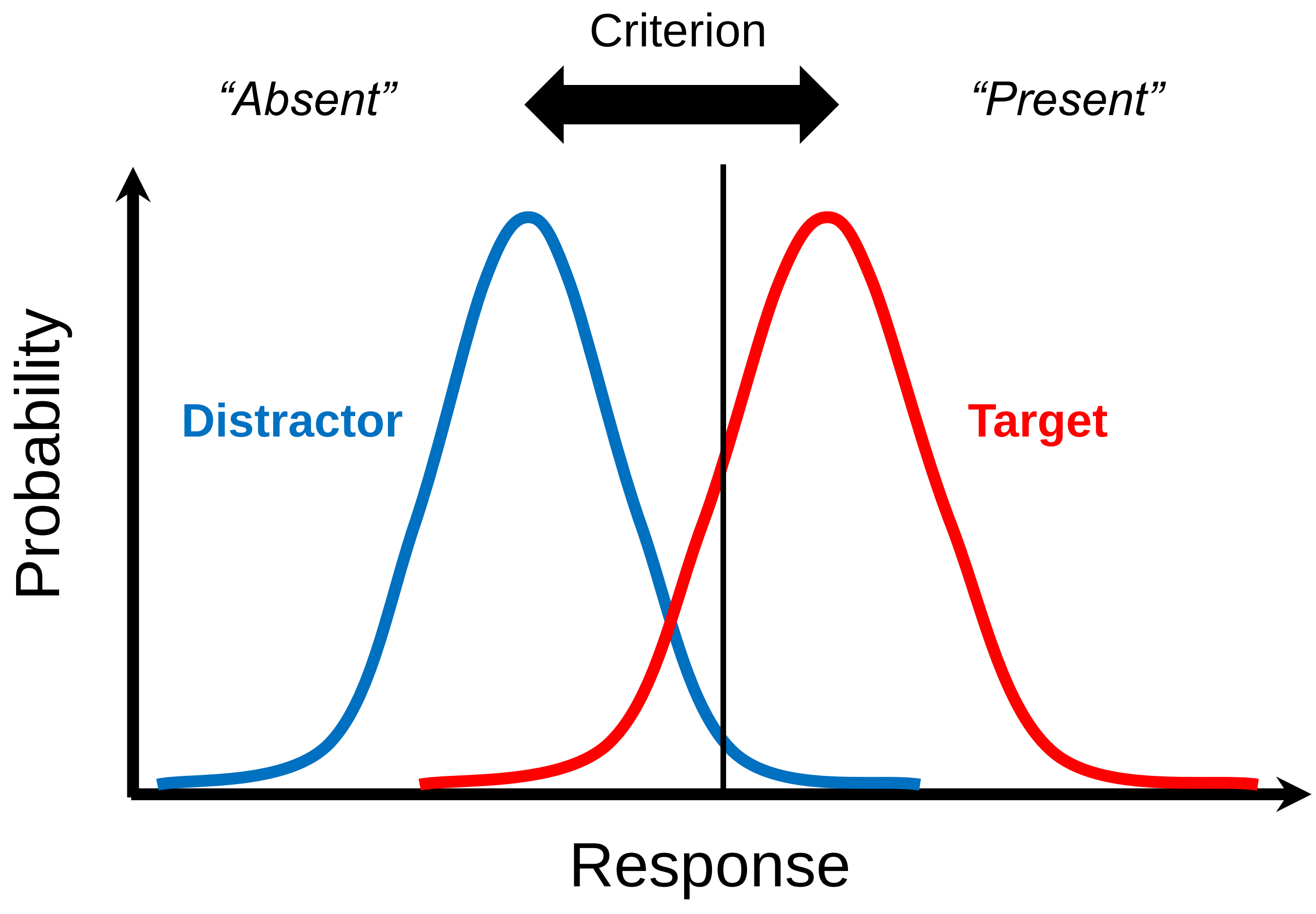


vs.



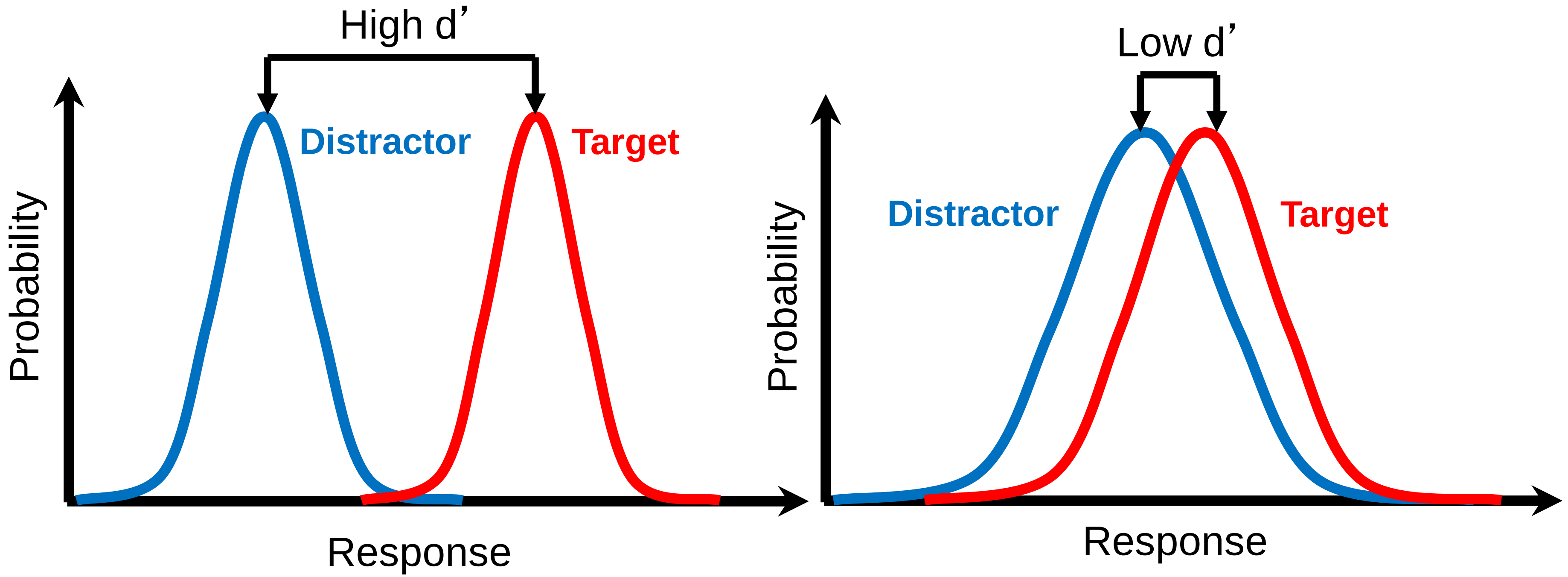

vs.
vs.

Signal-detection theory

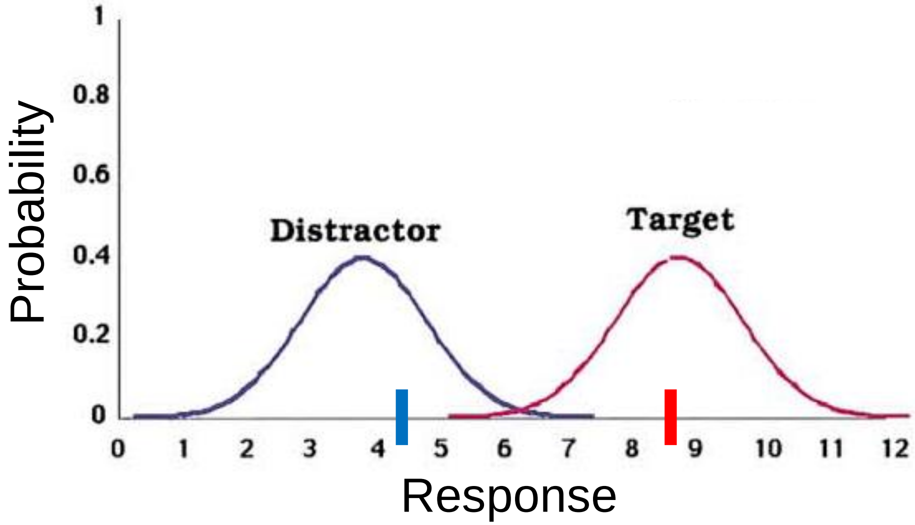


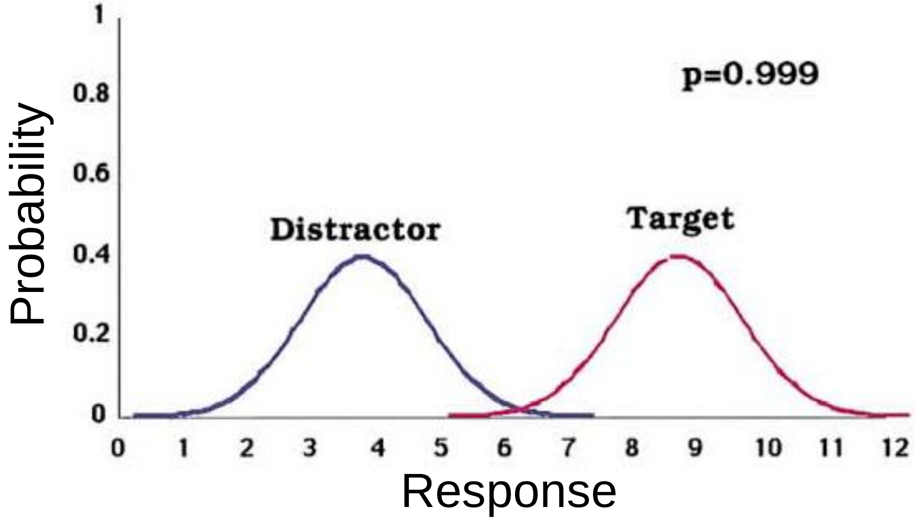
Discriminability

- D prime (d') = $\dfrac{\mu_T - \mu_D}{\sqrt{\frac{1}{2}(\sigma_T + \sigma_D)}}$ = Z(hit) – Z(FA)

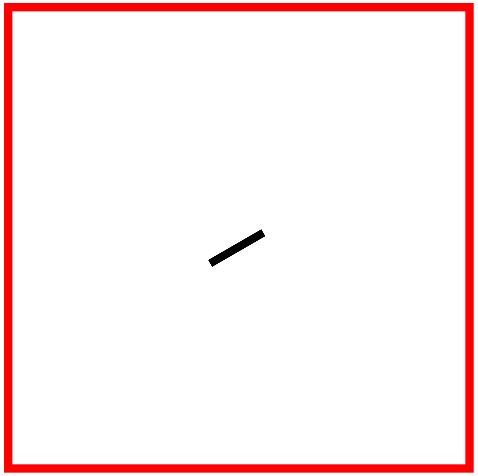


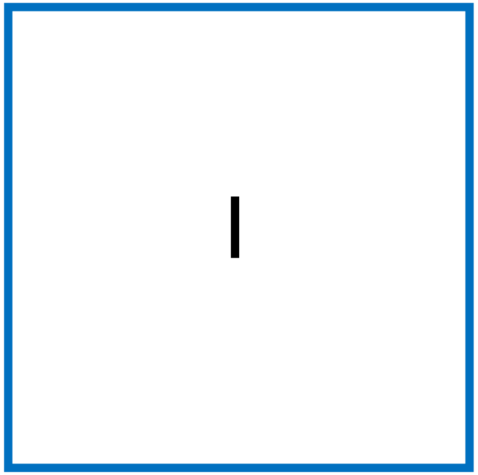
SDT and search: Maximum Rule





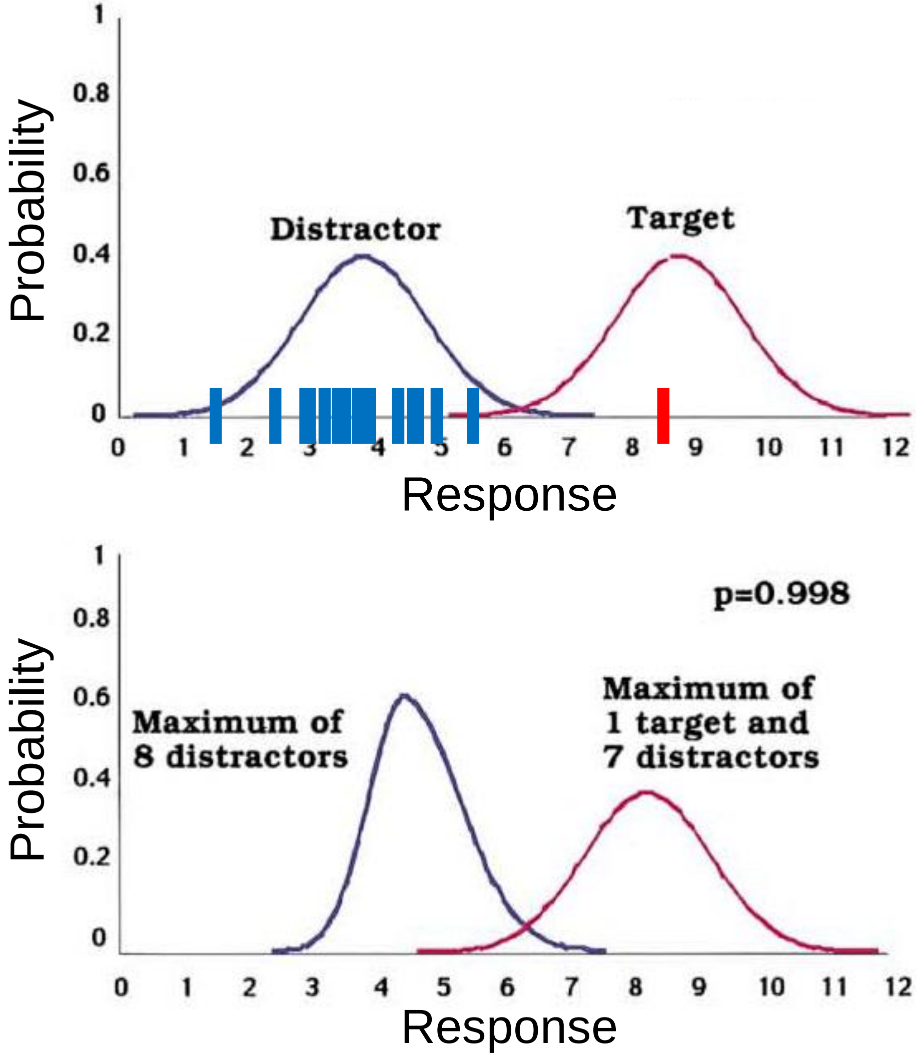
Target present?





Verghese (2001)

SDT and search: Maximum Rule



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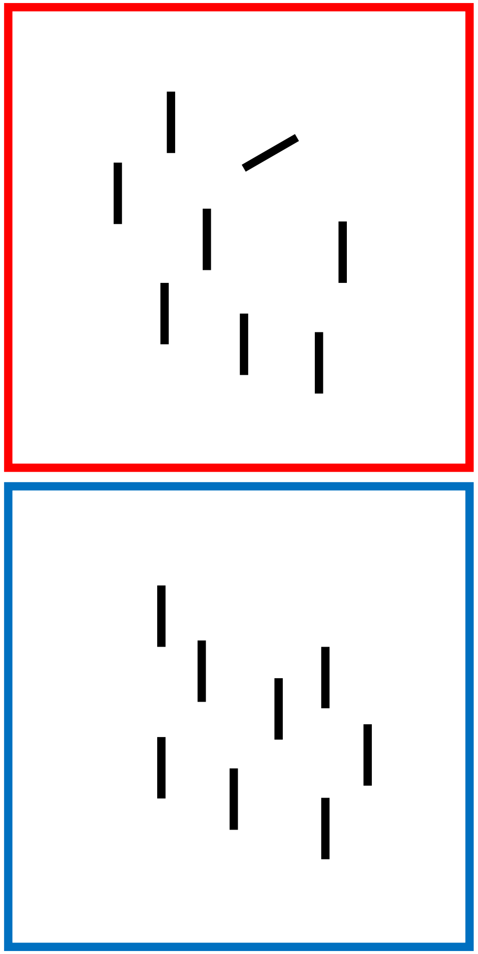

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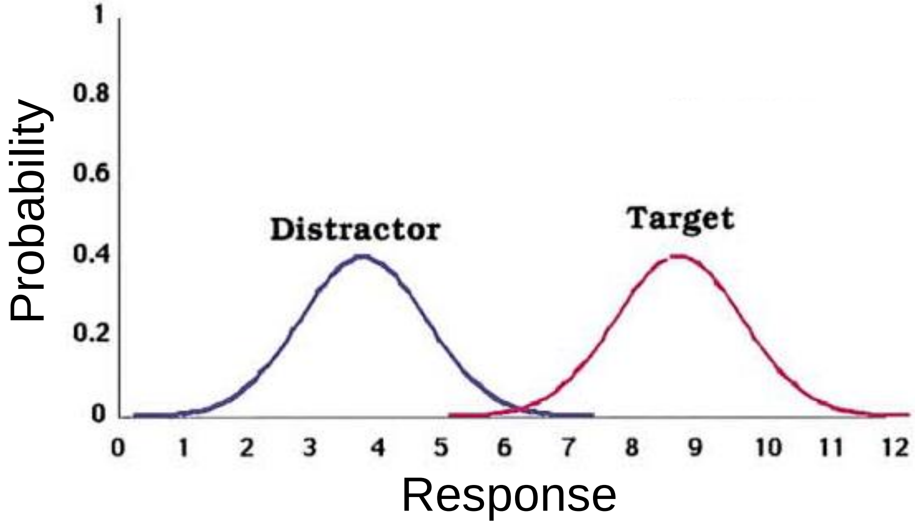

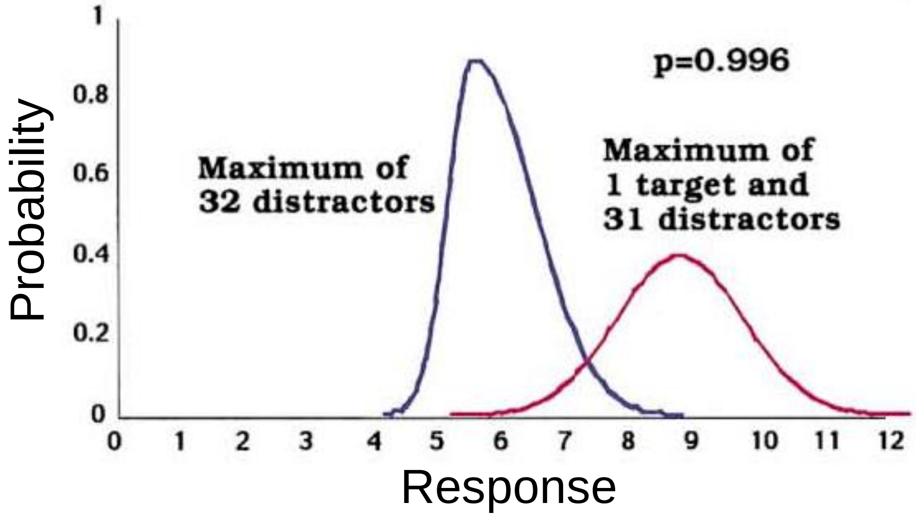

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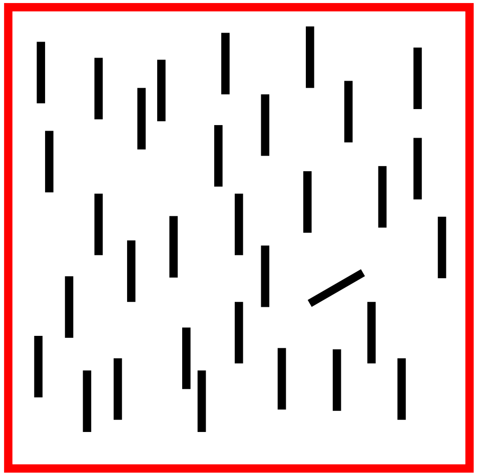

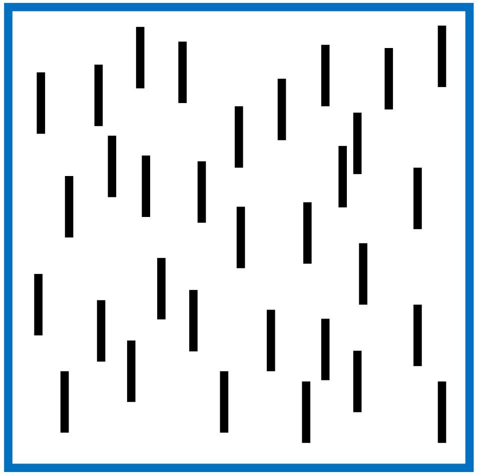

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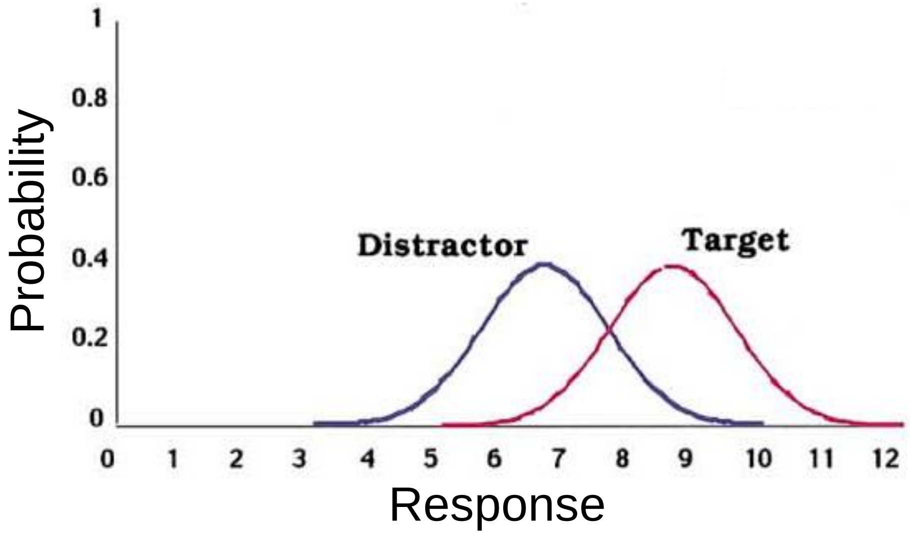

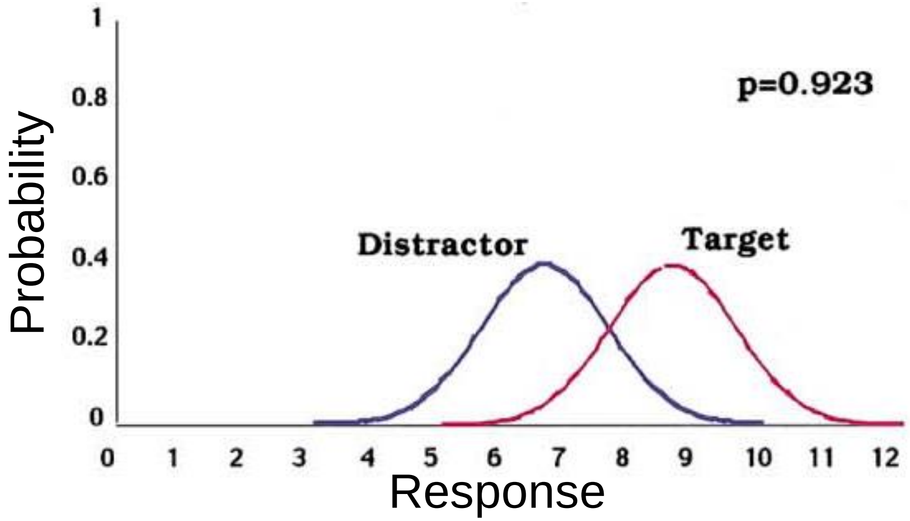

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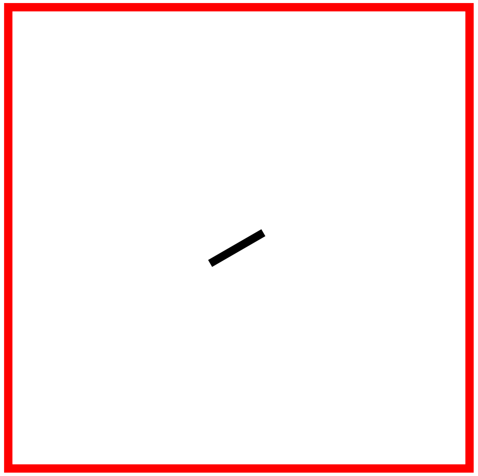

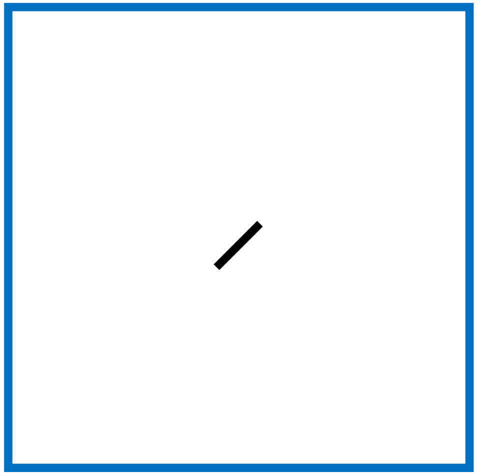

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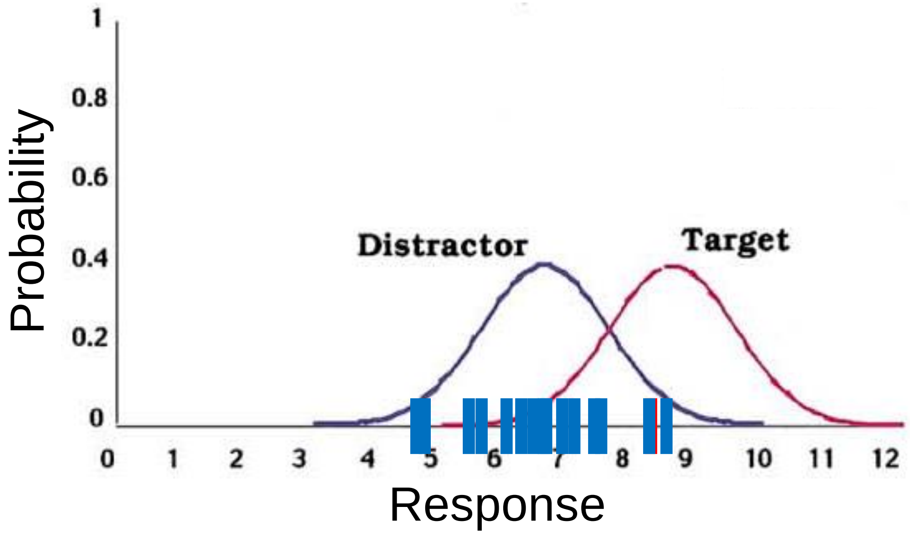

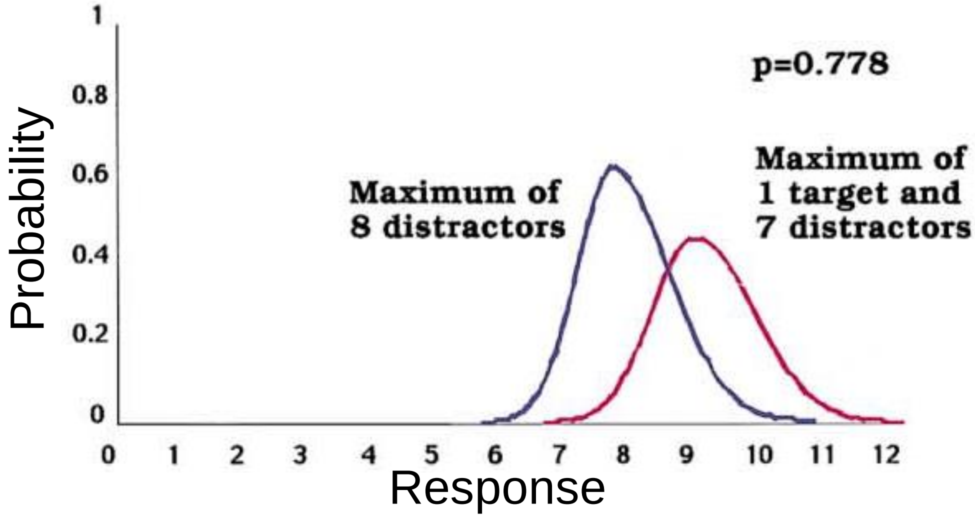

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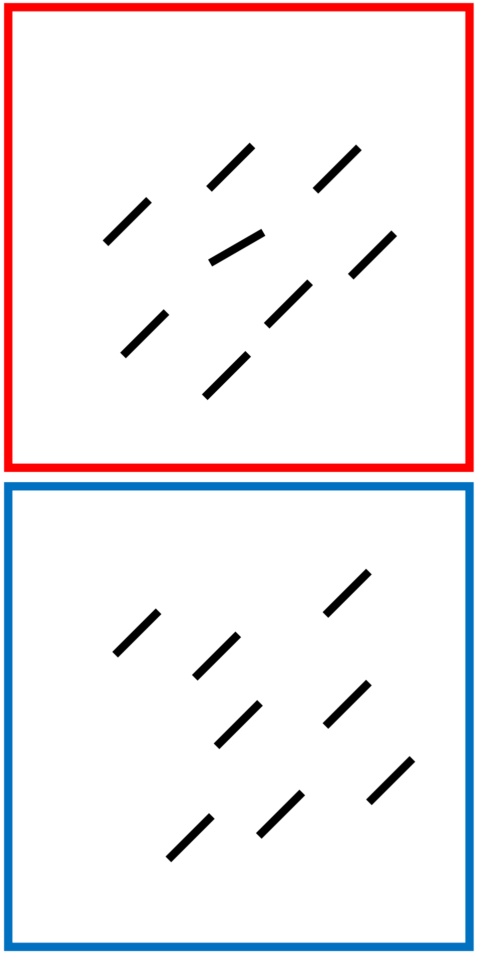

Verghese (2001)

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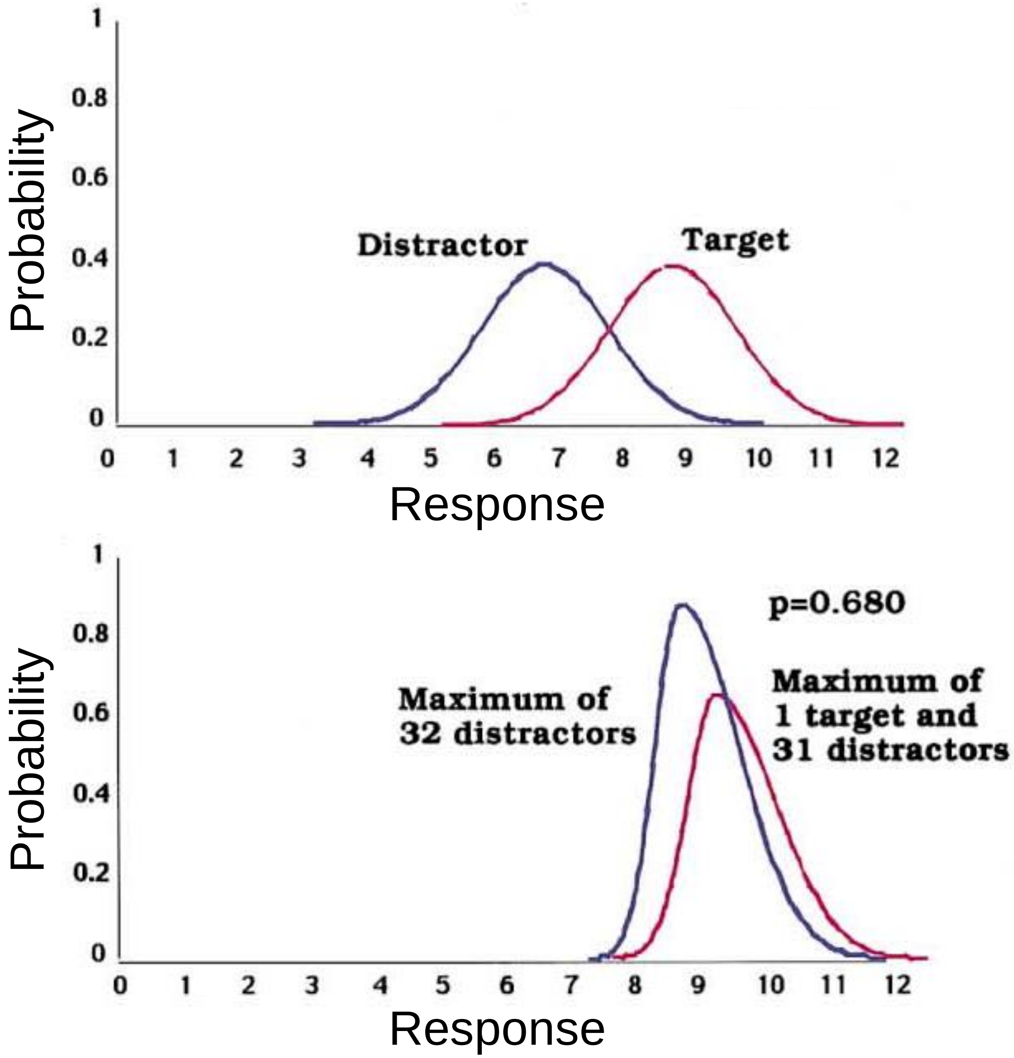

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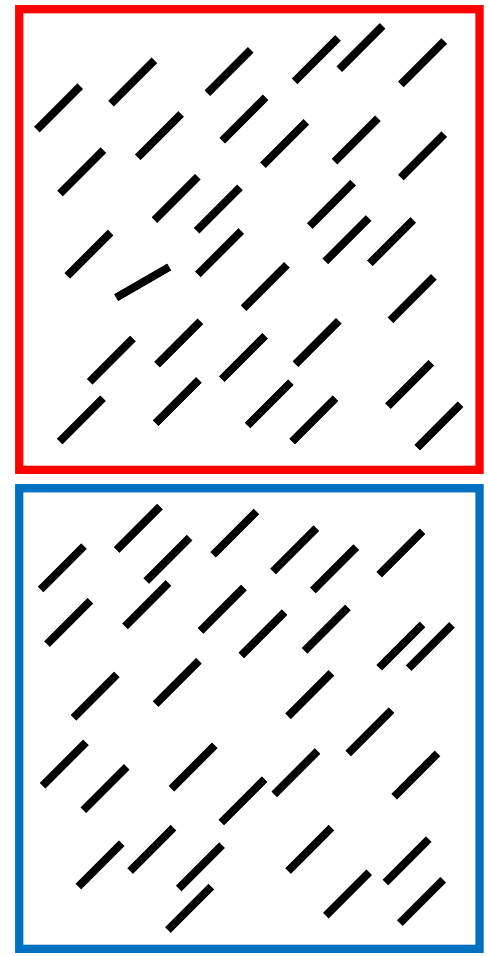
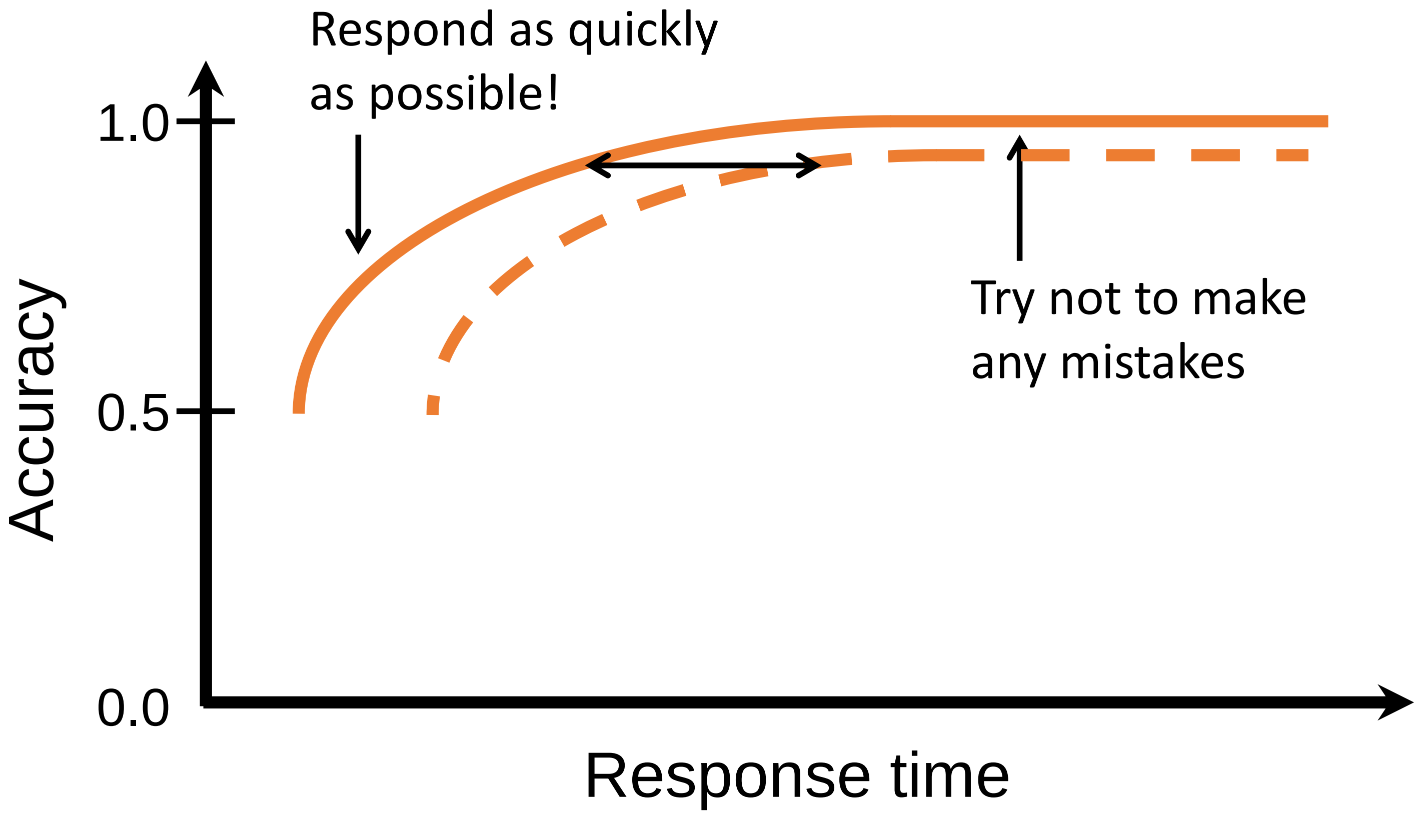
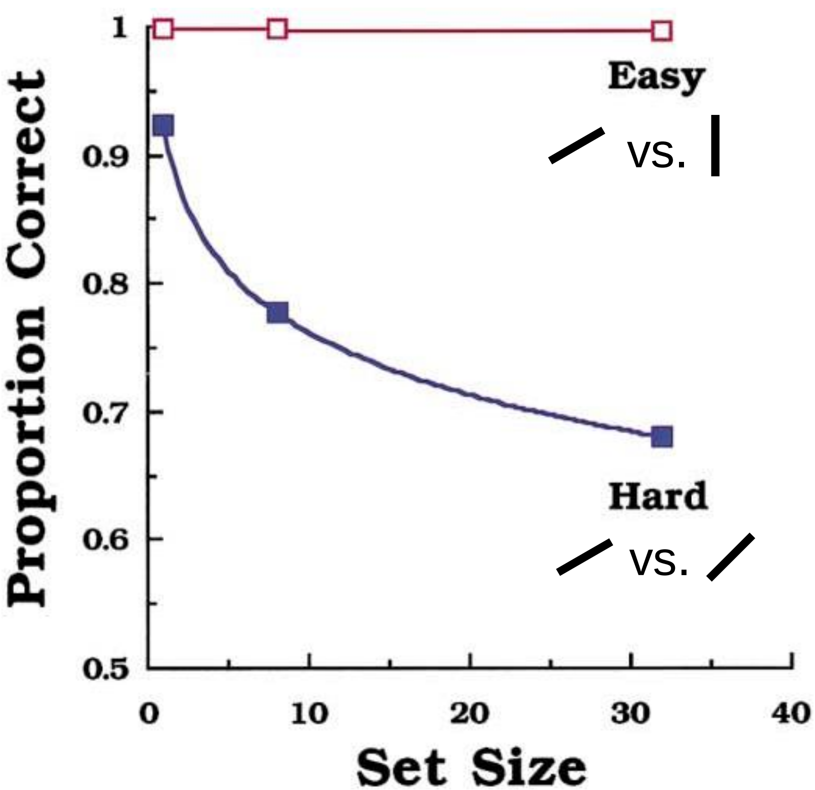


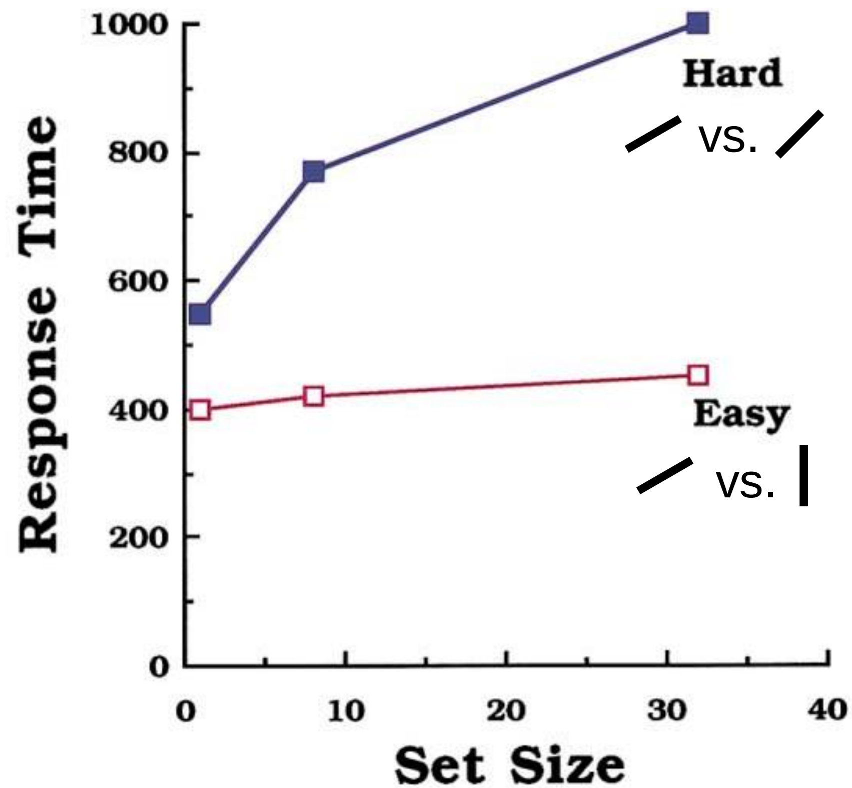
Verghese (2001)

Speed-accuracy trade-off



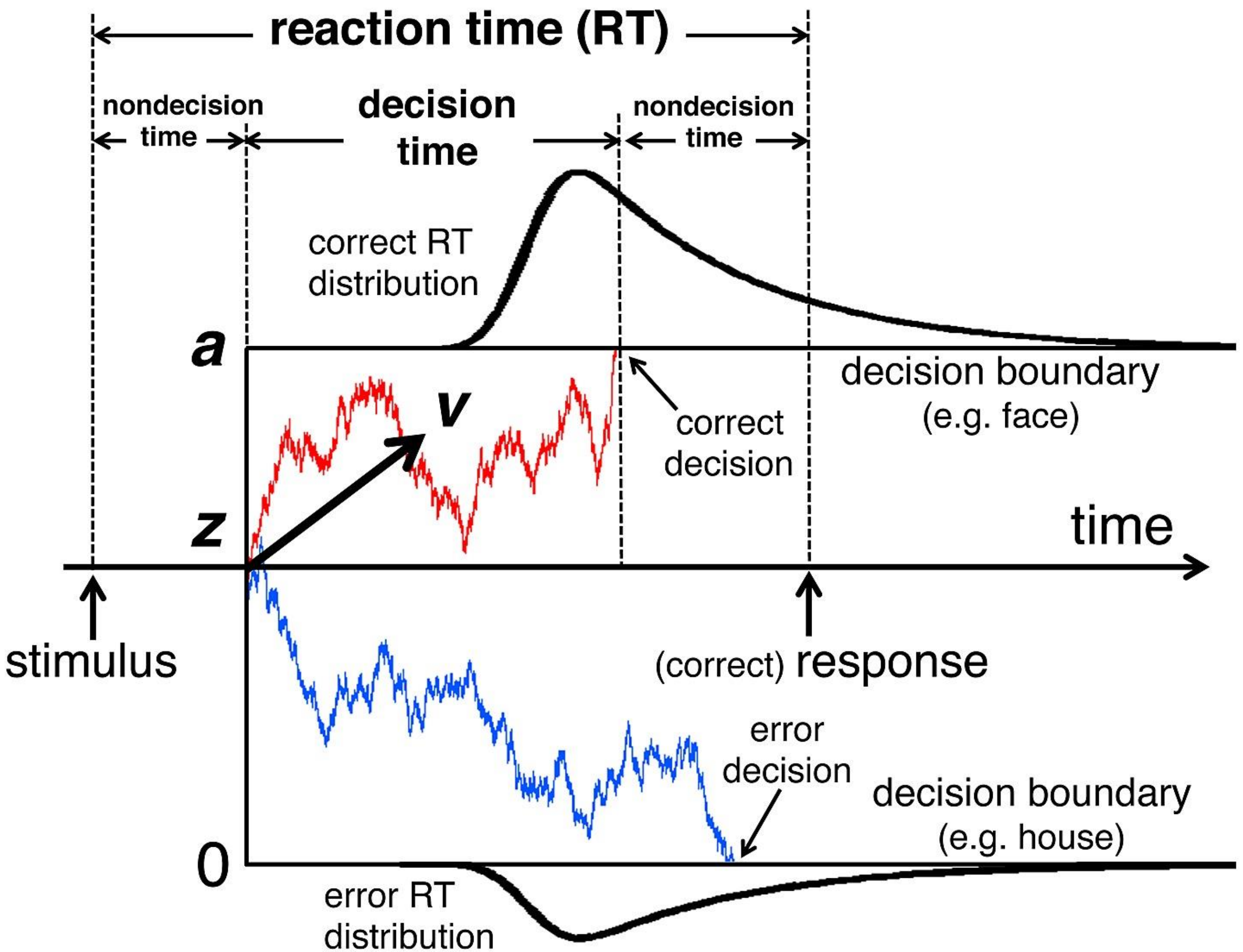
SDT and response times





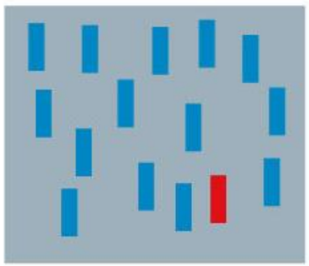
Verghese (2001)

Drift diffusion model

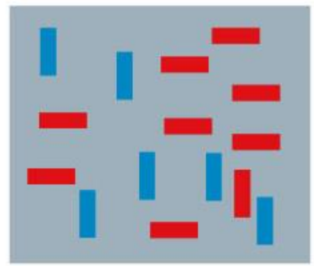


Murata et al. (2014)

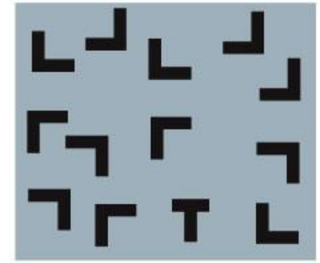
What affects search efficiency?



Feature



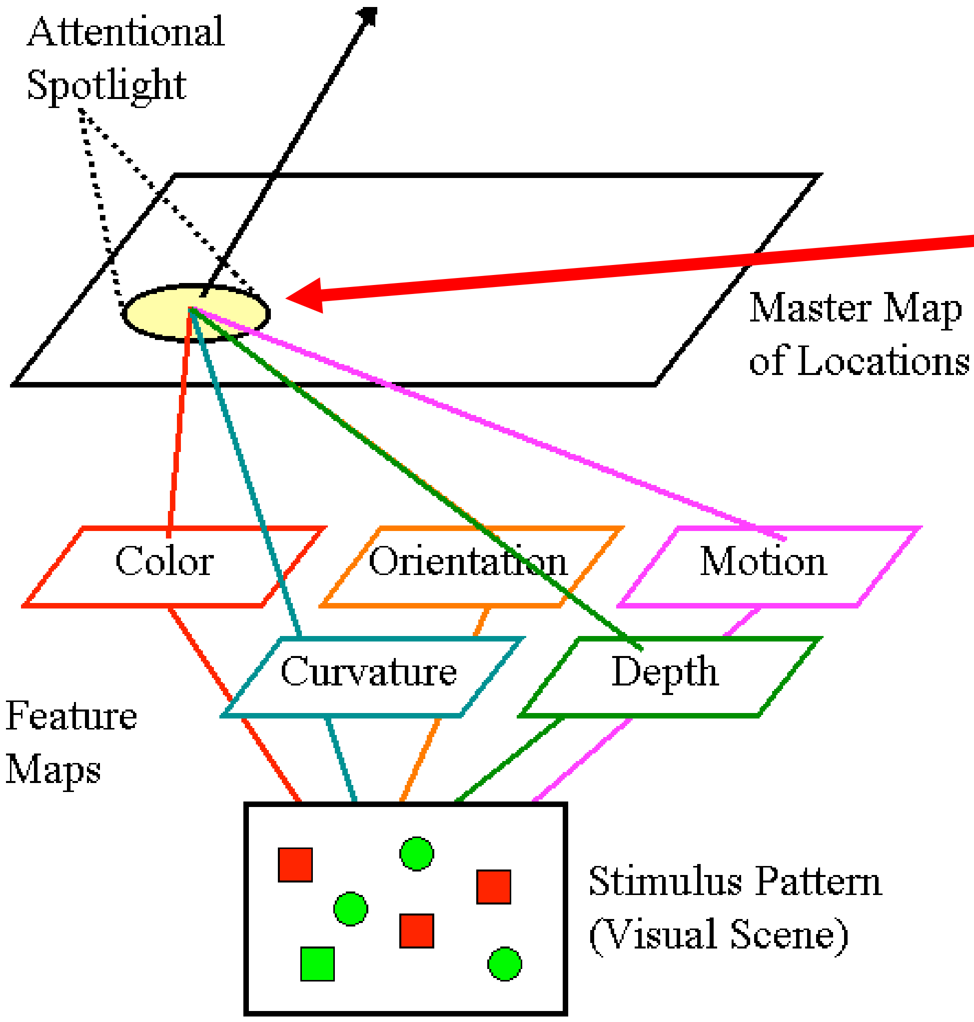
Conjunction



Configuration

- According to the two stage-model?
- According to the SDT model?

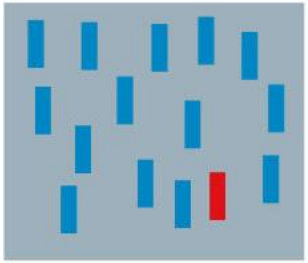
Two-stage model



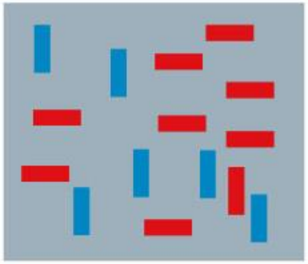
Serial processing of one location at a time

"Preattentive" parallel processing of the whole image

What affects search efficiency?



Feature



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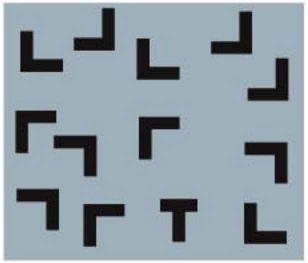
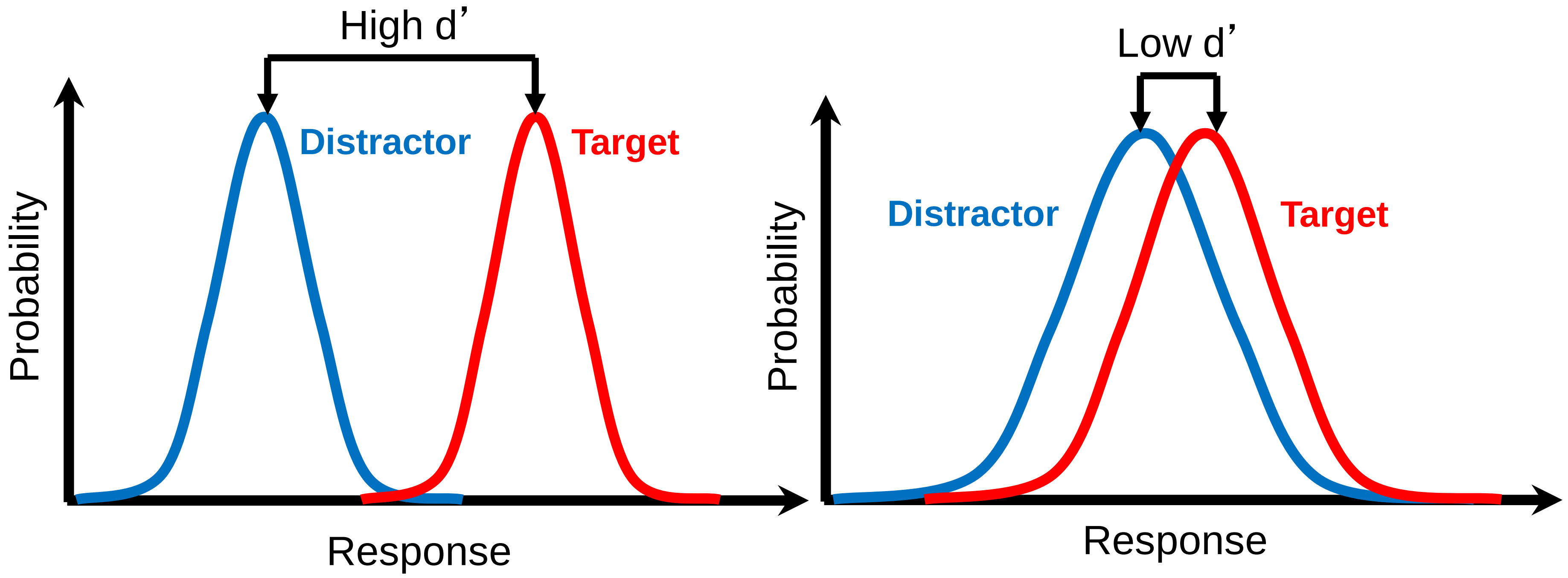


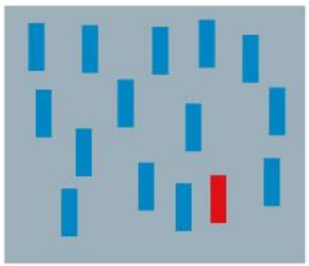
Configuration

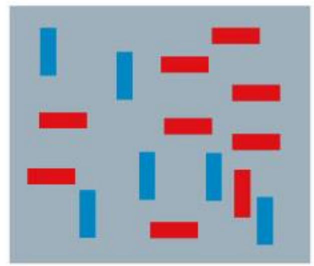
- According to the two stage-model?
    - Efficiency depends on how many preattentive maps must be combined to build the target feature
- According to the SDT model?

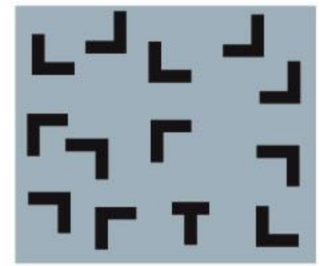
SDT model


High d'
Distractor
Target
Probability
Response
Low d'
Distractor
Target
Probability
Response

What affects search efficiency?


Feature

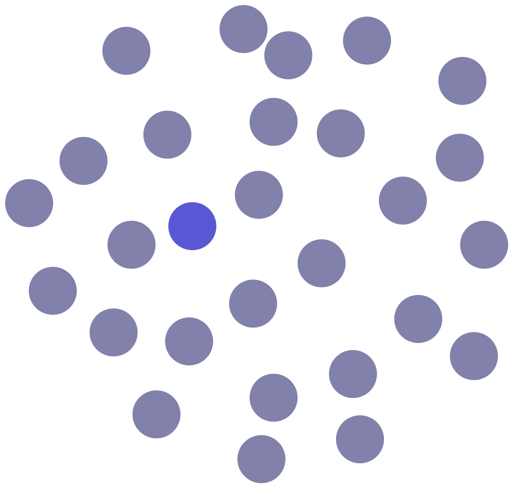

Conjunction


Configuration

- According to the two stage-model?
  - Efficiency depends on how many preattentive maps must be combined to build the target feature
- According to the SDT model?
  - Efficiency depends on the d’ of target-distractor discrimination

Example: Homogenous vs. heterogeneous distractors

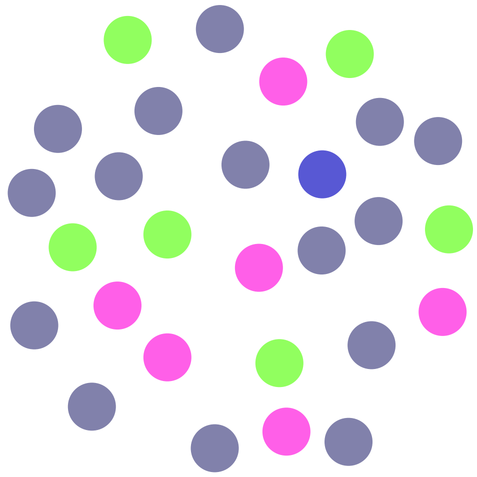
Stimuli



R Rosenholtz

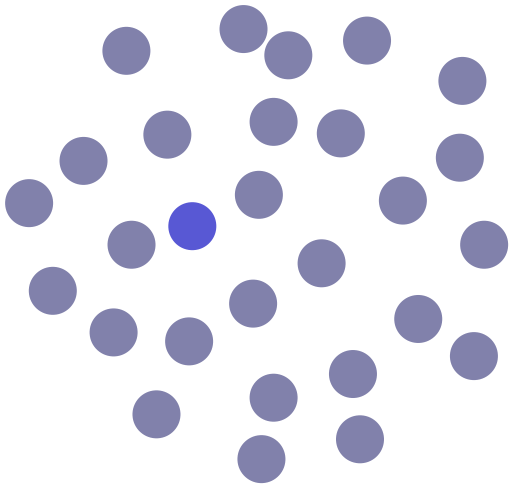
Stimuli

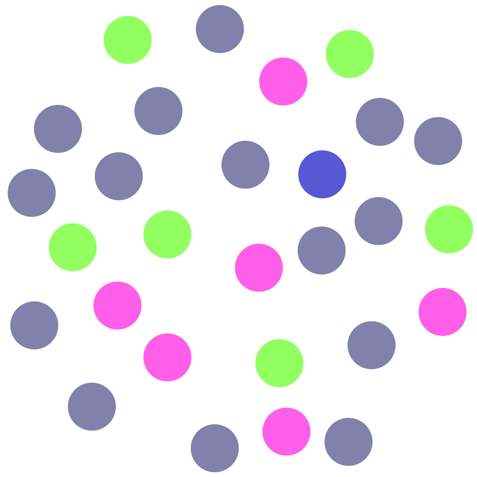
Stimuli



R Rosenholtz

Stimuli





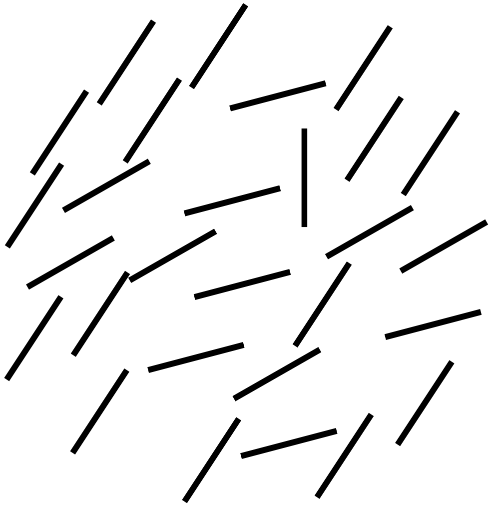
R Rosenholtz

Stimuli

R Rosenholtz

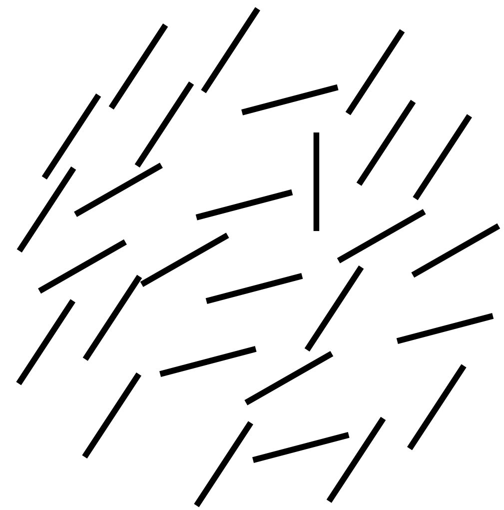
Stimuli

Stimuli

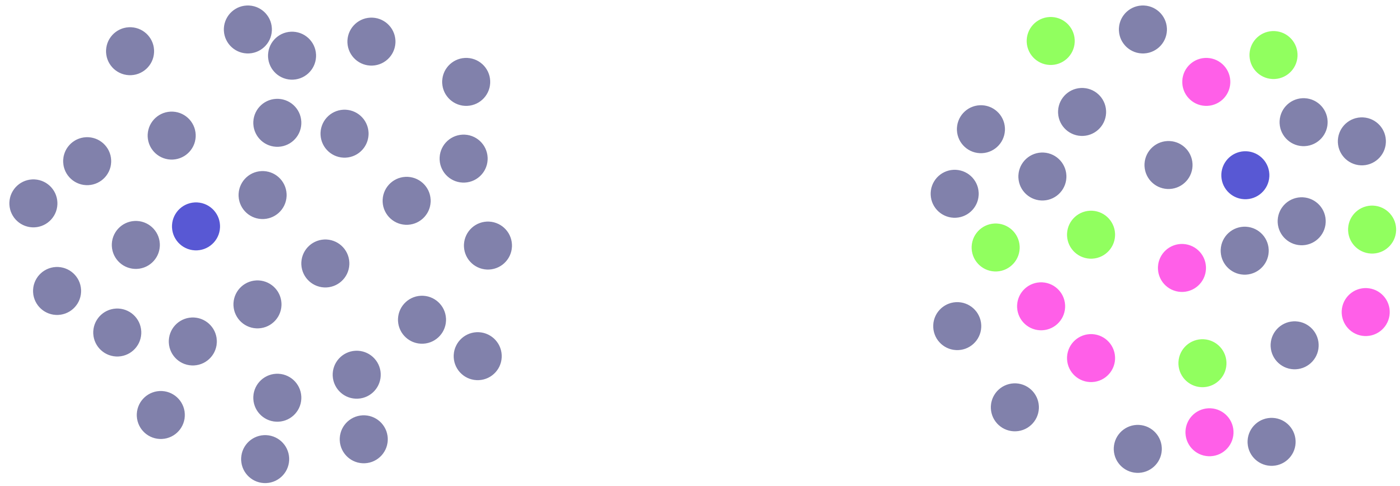


R Rosenholtz

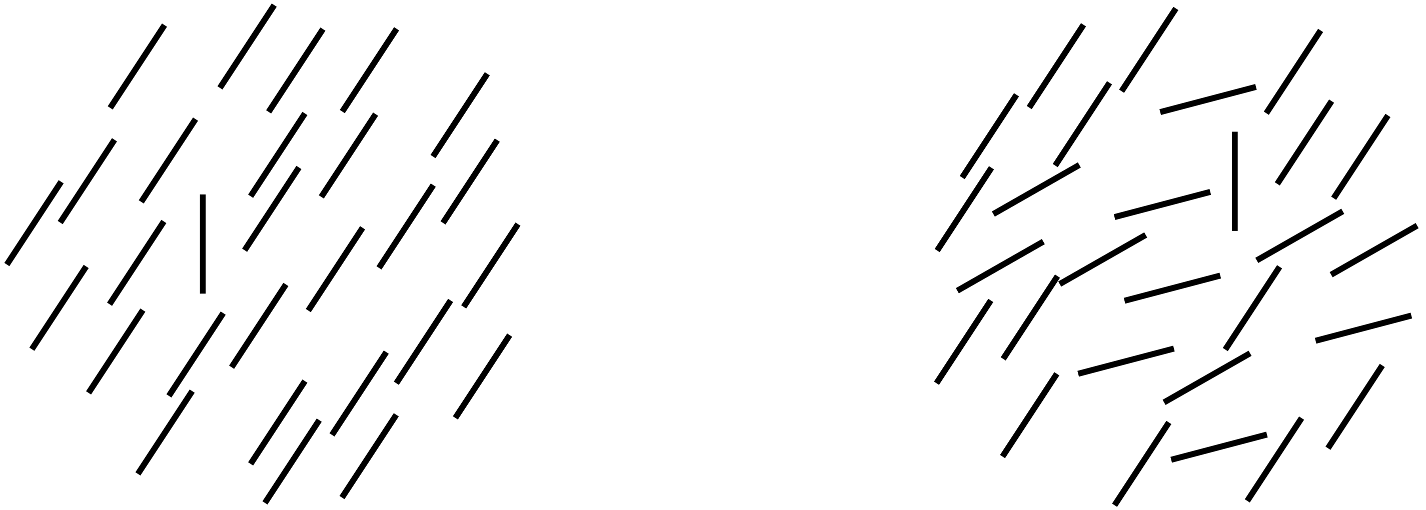
Stimuli

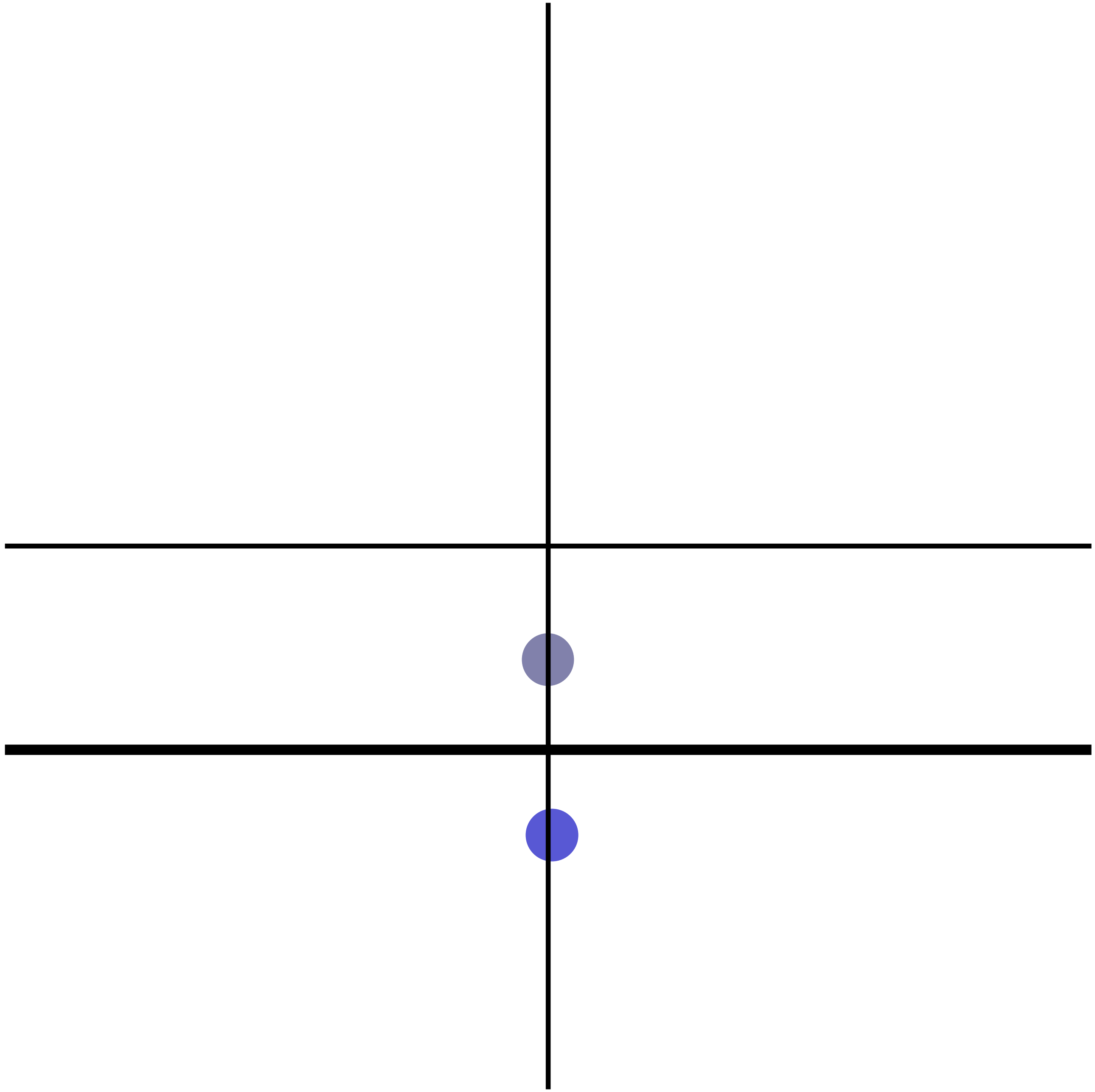


R Rosenholtz

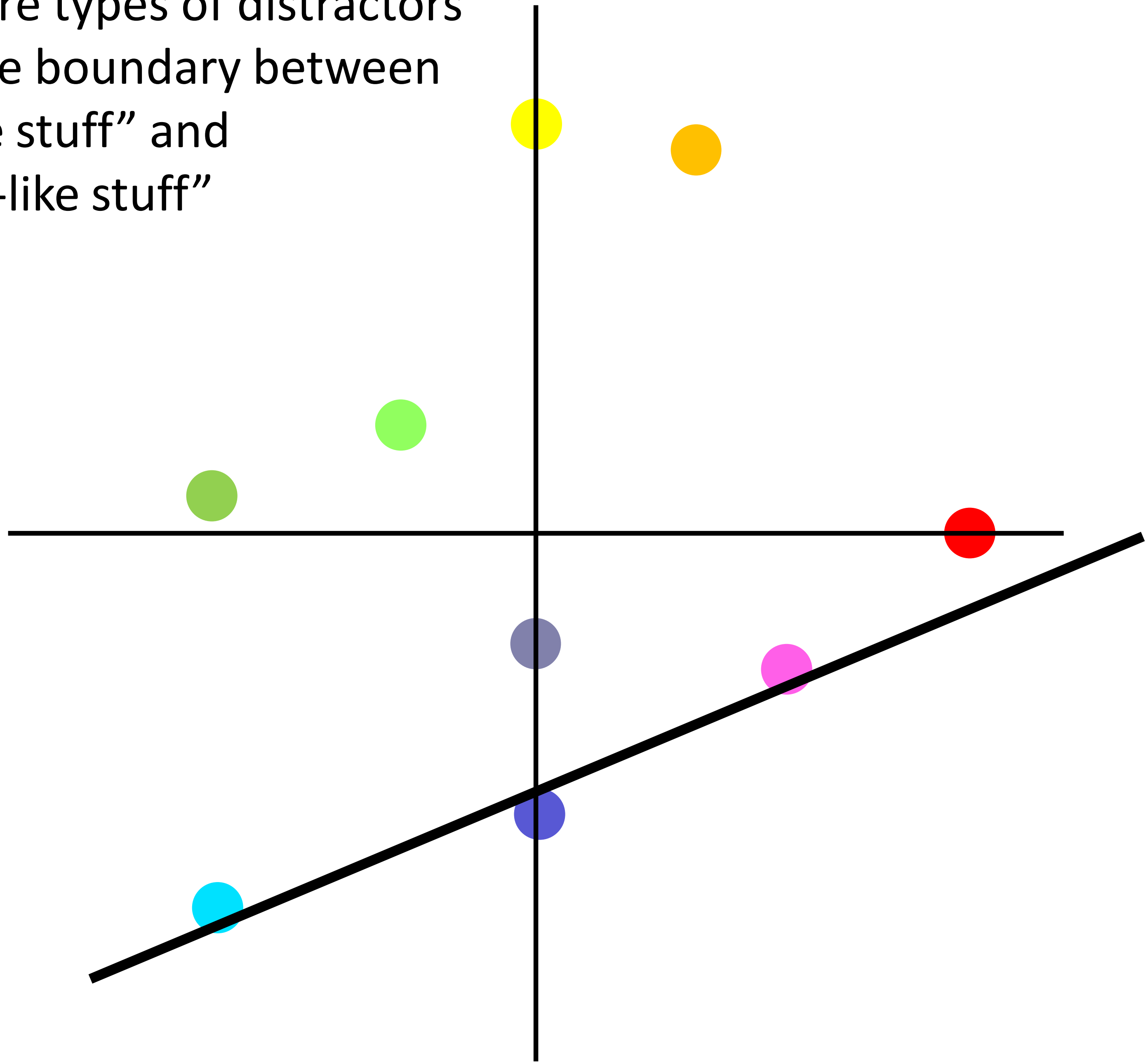


Search is easier when the distractors are homogeneous

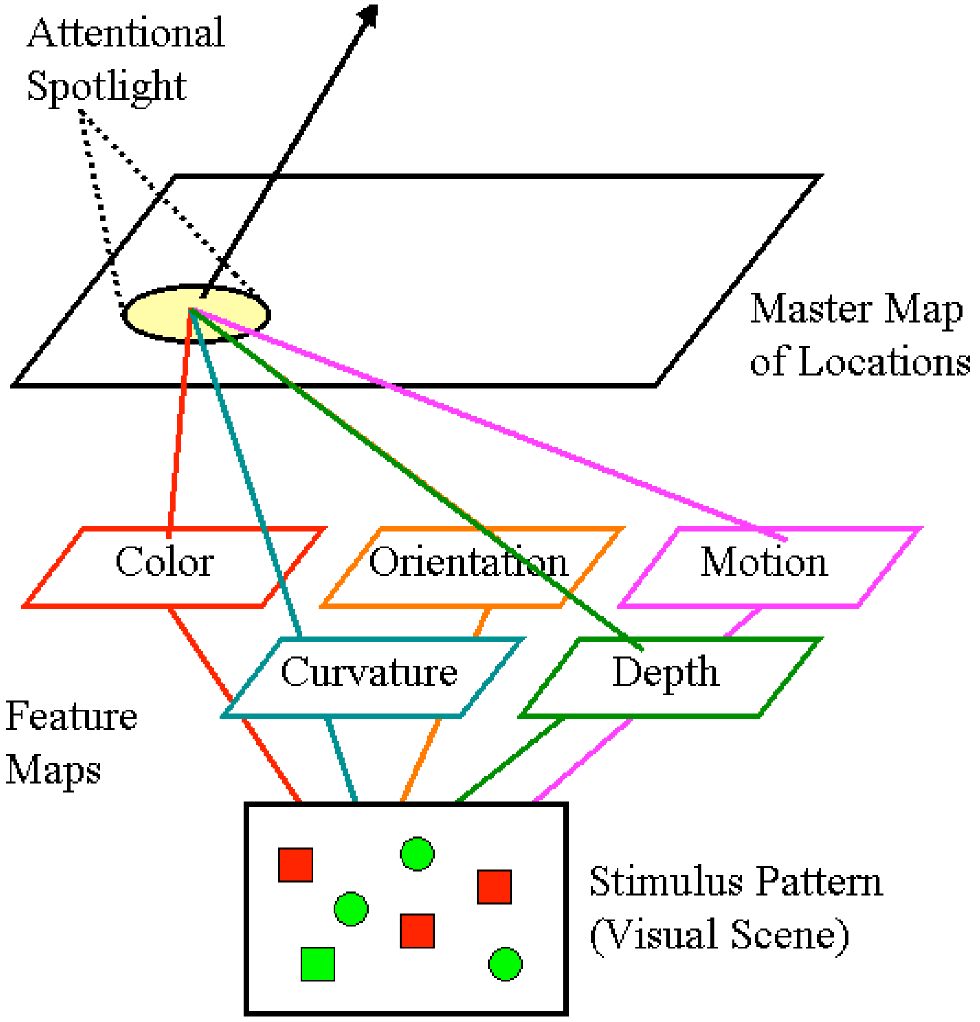




Adding more types of distractors changes the boundary between "target-like stuff" and "distractor-like stuff"

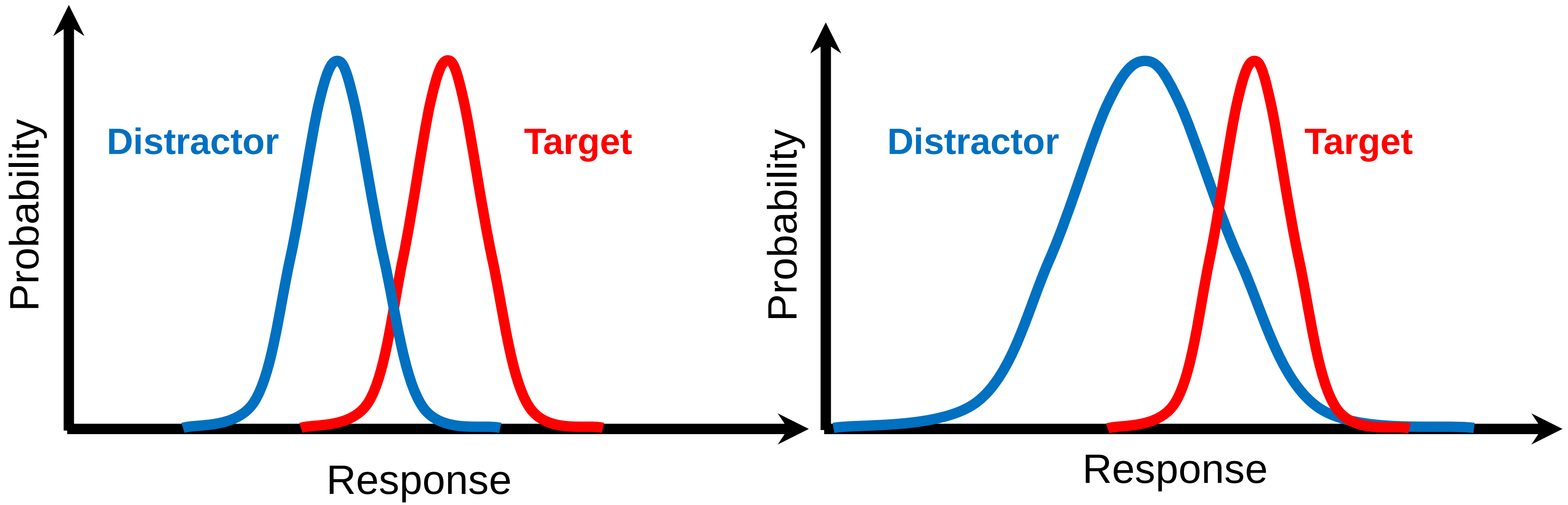


Two-stage: Distractors



Why would heterogeneous distractors be more difficult?

SDT: Distractors



What happens as set size increases?

Example: Search asymmetries

Search asymmetries

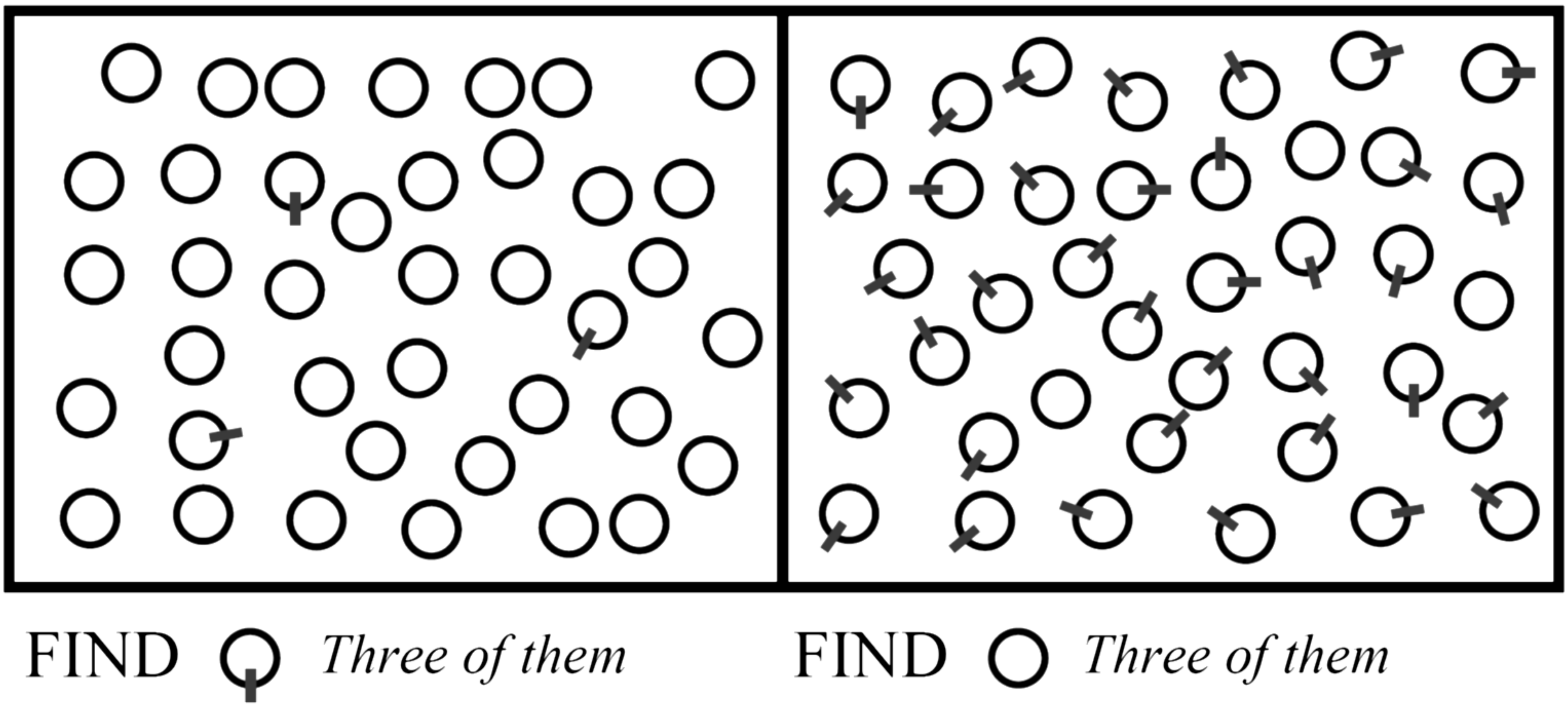
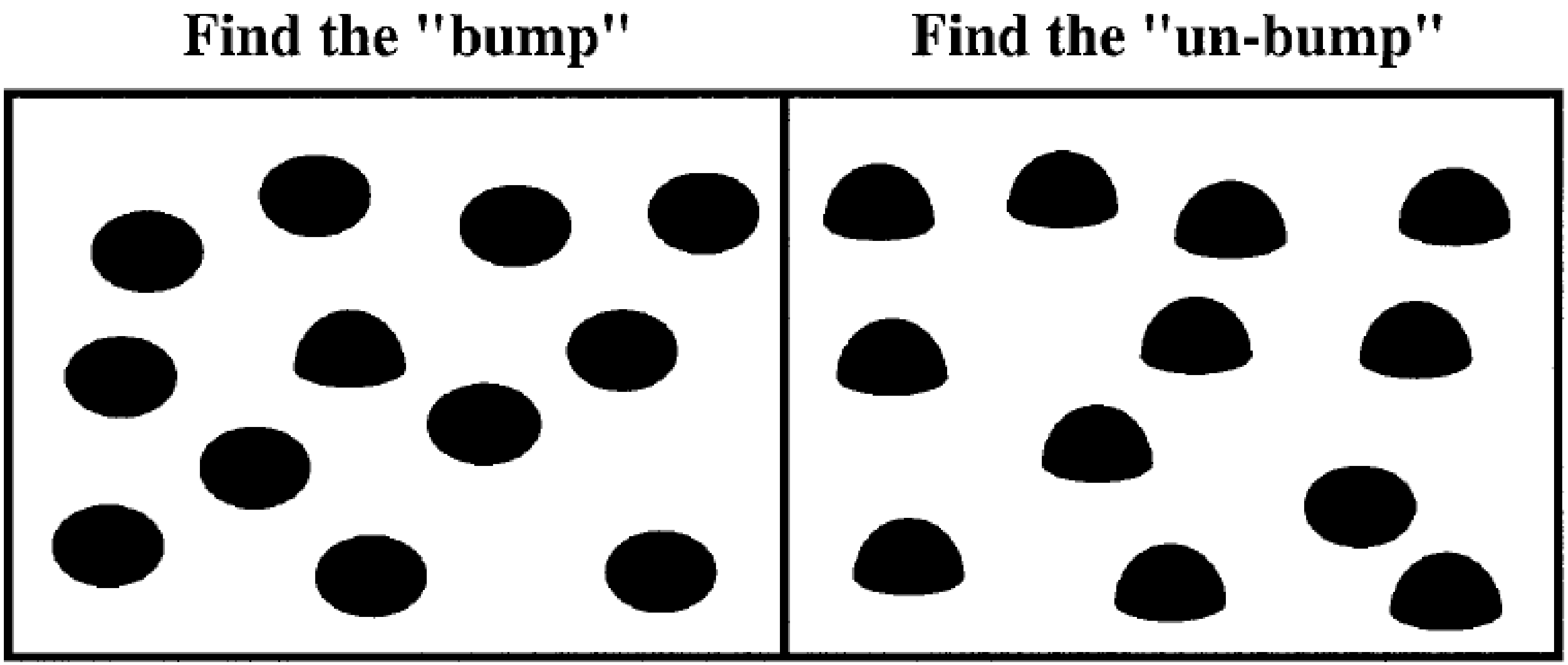


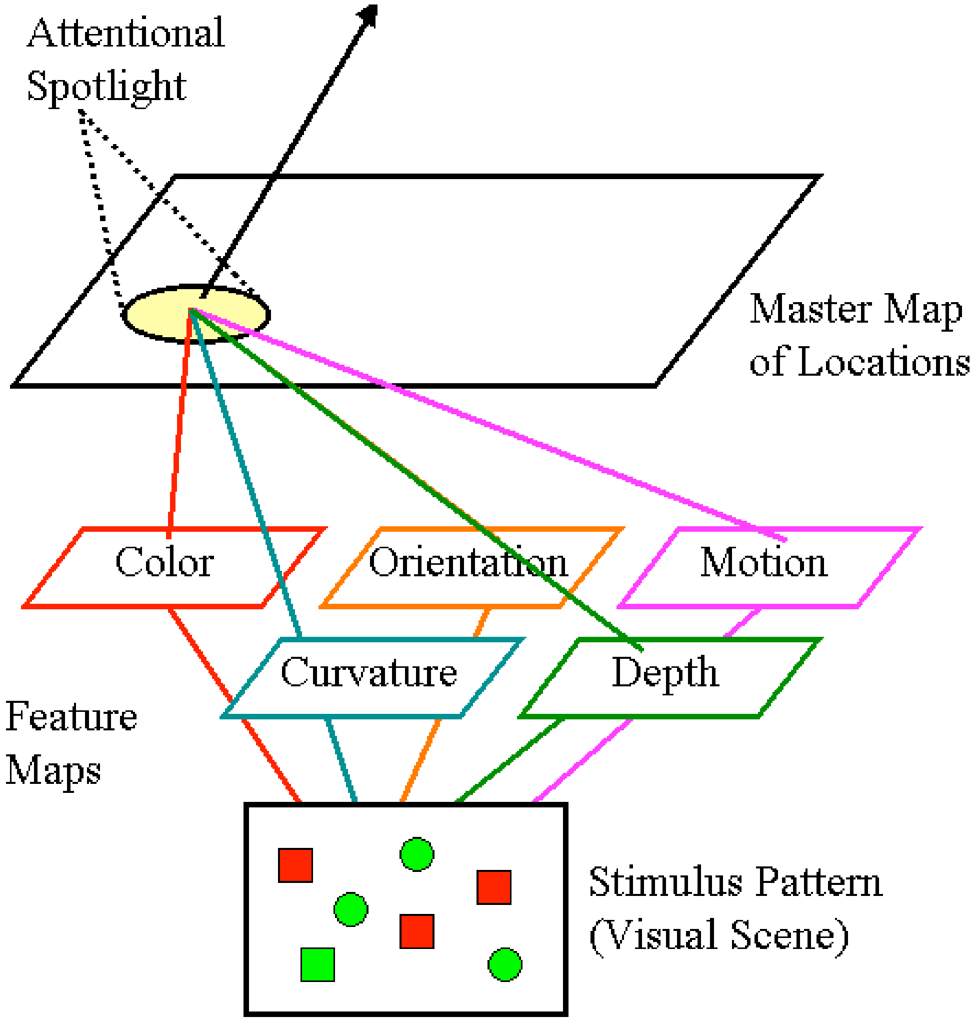
Image: J Wolfe

Search asymmetries



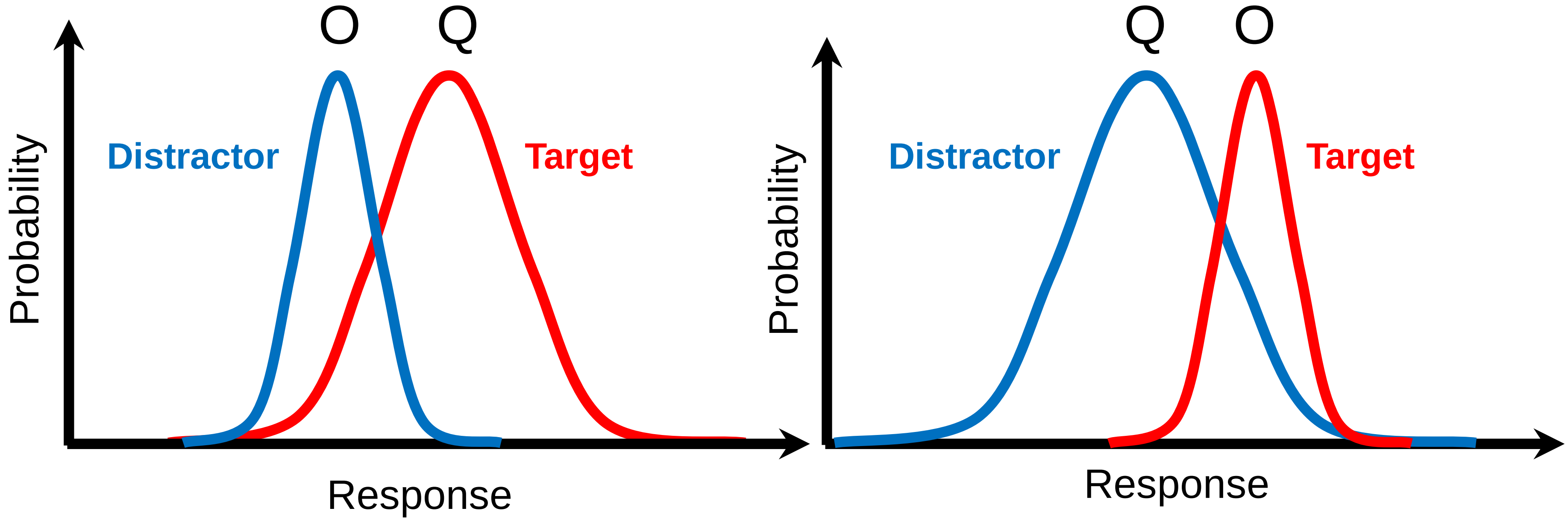
Stimuli: Kristjansson & Tse (2001)

Two-stage: Search asymmetries



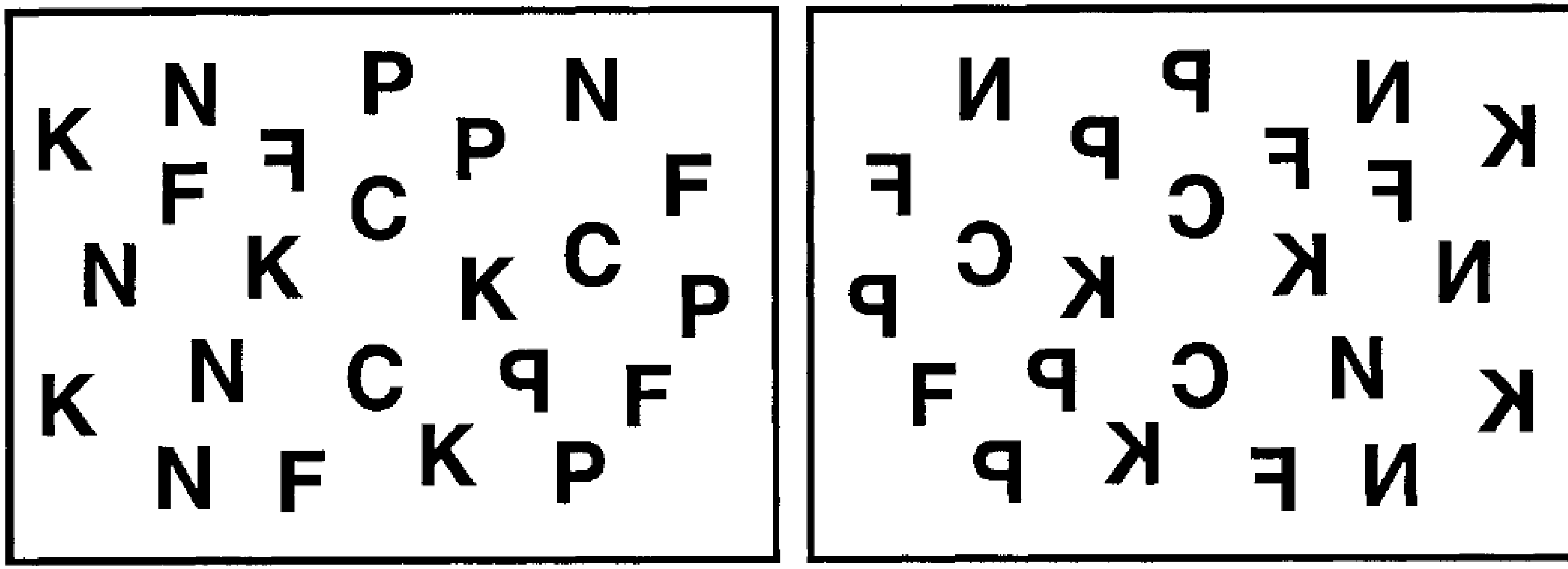
What does the asymmetry tell us?

SDT: Search asymmetries



What happens as set size increases?

Another search asymmetry



Find the mirror-reversed letters

Find the normal letters

Search for an *unfamiliar* target among familiar distractors is generally faster than the reverse – why?

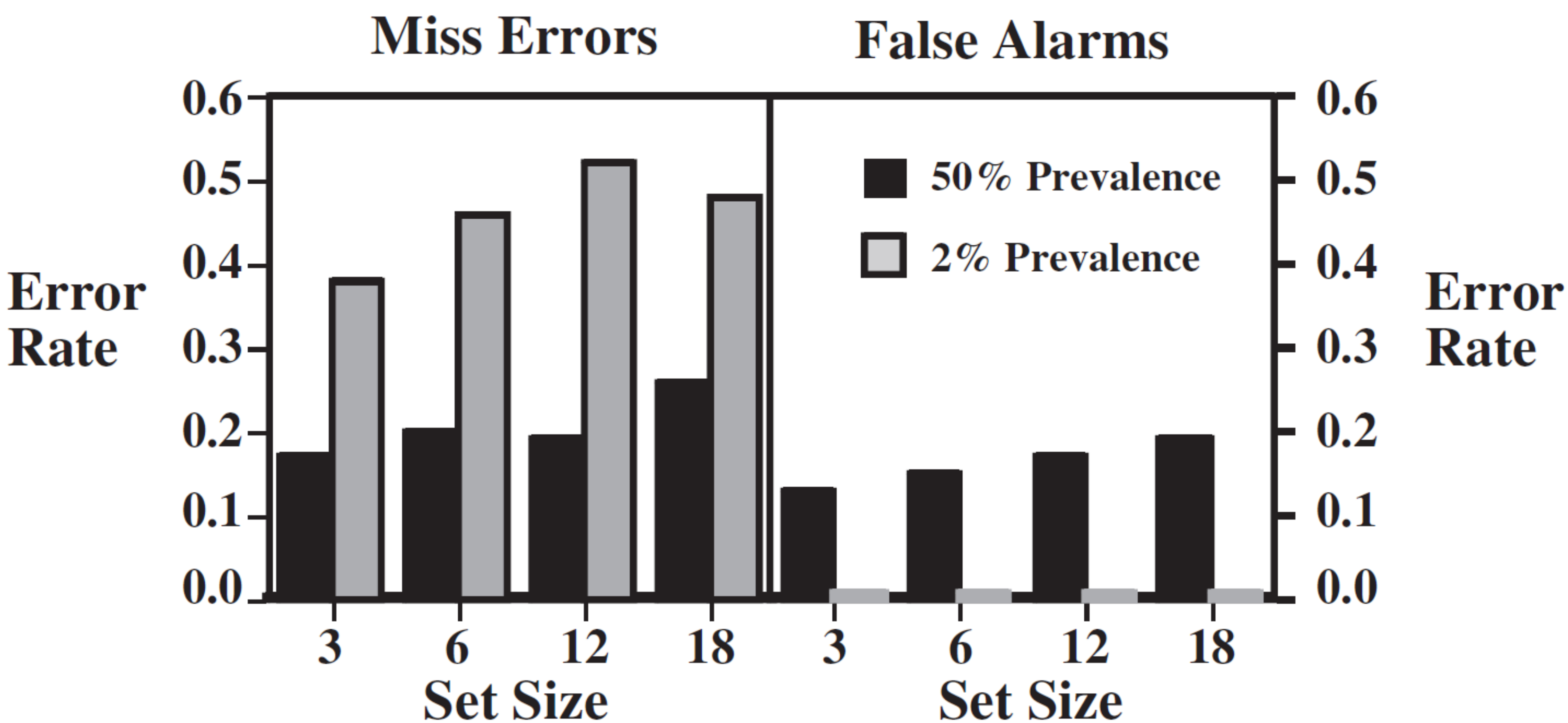
Wolfe (2001)

Example: Target prevalence

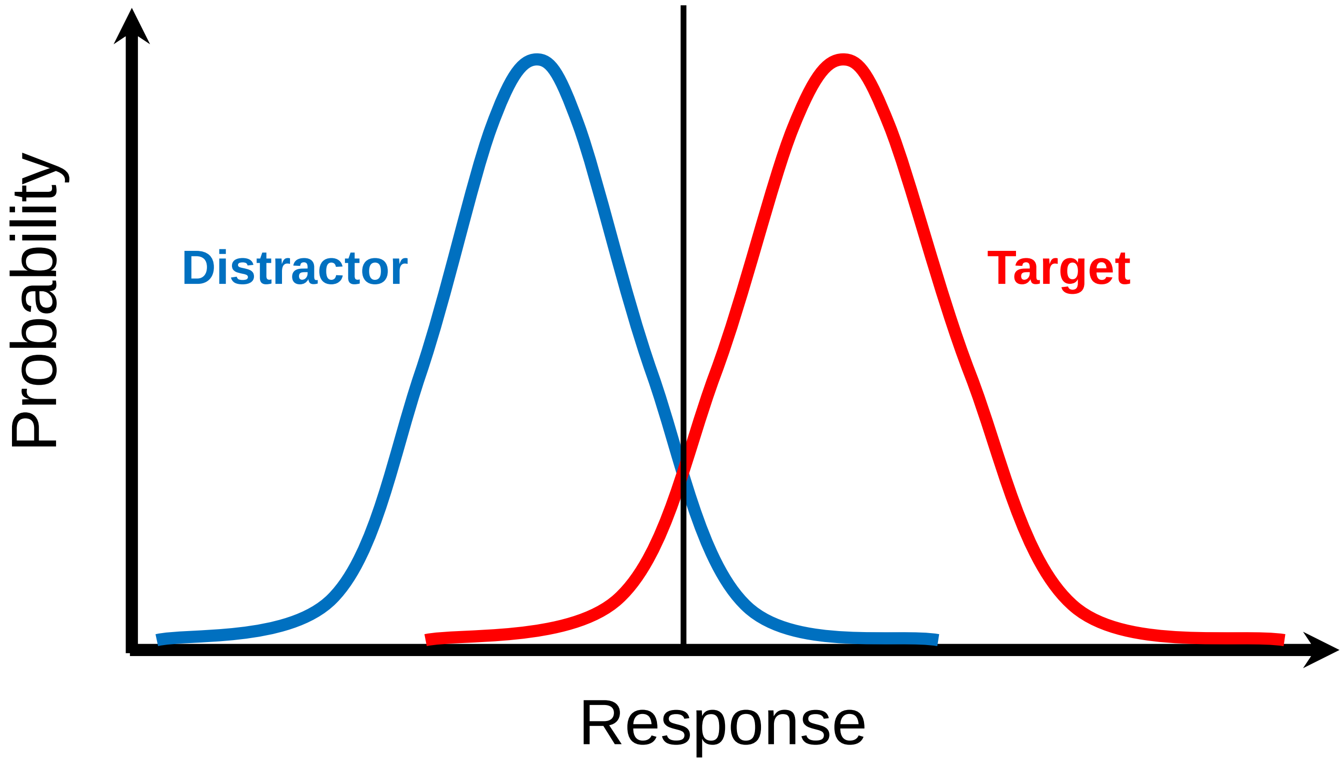
Prevalence effects

- In experiments, target is present on 50% of trials
- In real-life search, target is often much rarer:
  - Medical screening
  - Baggage screening
  - Search and rescue
- Does lower target prevalence affect search?

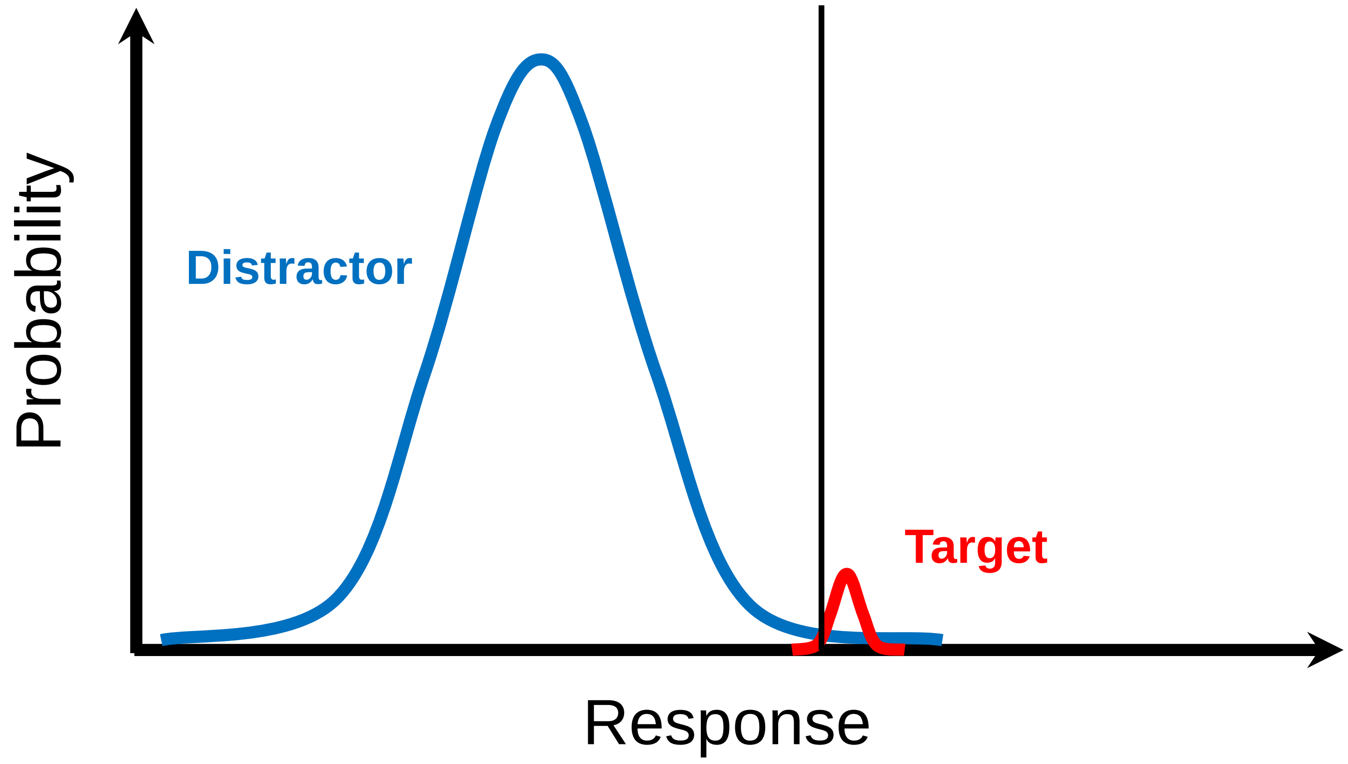
Prevalence effects



SDT: Target prevalence



SDT: Target prevalence



Conclusions

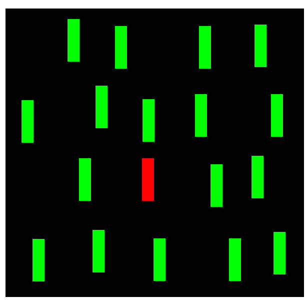
Visual search models

- Usually investigated with 2AFC tasks in which one target appears among a number of distractors
- More than one model to explain visual search:
  - Two-stage model
  - Parallel SDT model
- Many findings can be explained by both models
- Comparisons can be difficult because each model focuses on a different measure (RT vs. errors)
- Aspects of both models may be needed to fully explain search

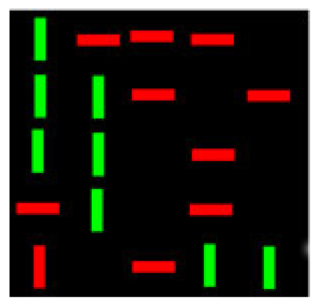
R Demonstration

Demo 1: Search slopes

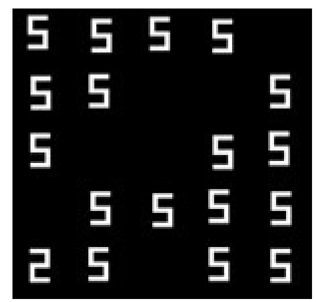
- Experiment data from: http://search.bwh.harvard.edu/new/data_set_files.html
- Three visual search tasks:



Feature



Conjunction



Configuration

Demo 2: SDT simulation

Discussion

- What are some advantages / disadvantages to each model?
- How could you interpret a negative search slope according to each model?
- If two search tasks have the same search slopes but different intercepts, what does that mean?
- What experiments could distinguish between the two models?

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