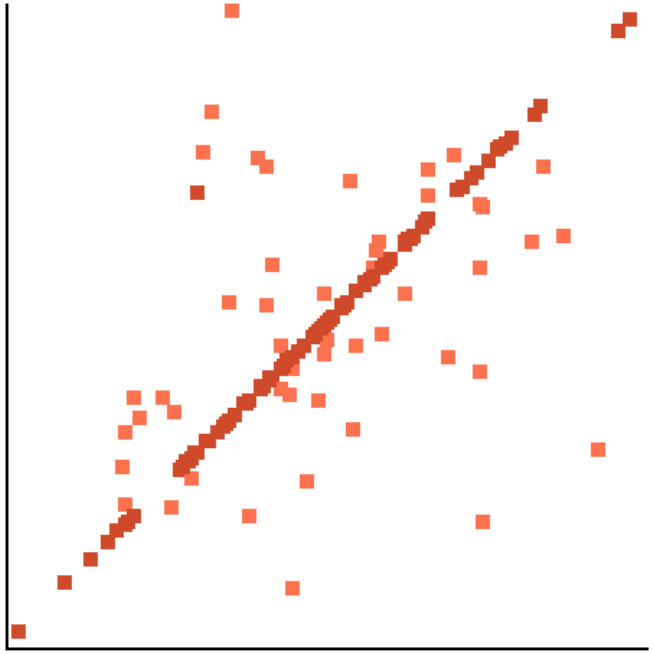
Attentional Selection of Multiple Correlation Ensembles



Madison Elliott & Ronald Rensink
The University of British Columbia
Vision Sciences Society | May 19, 2018

Ensemble Coding

- Rapidly and accurately extract structural regularities from our visual environment

(Haberman & Whitney, 2012;
Alvarez & Oliva, 2009)

Ensemble Coding

- Rapidly and accurately extract structural regularities from our visual environment

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Ensemble Coding

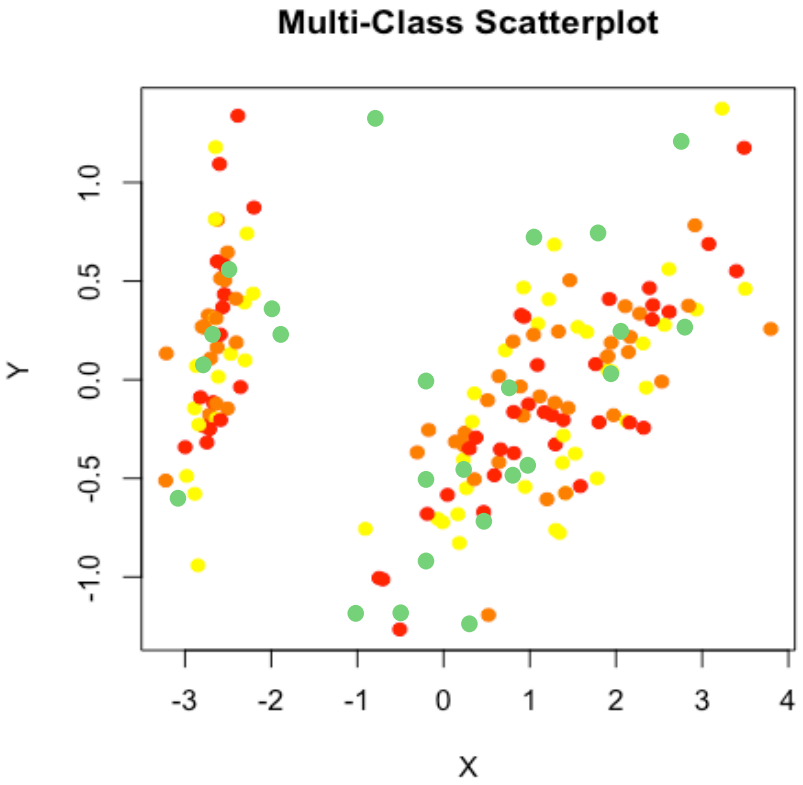
- How do we select or understand information about just the green leaves?

Multiple Ensembles: Unknown

What drives attentional selection?

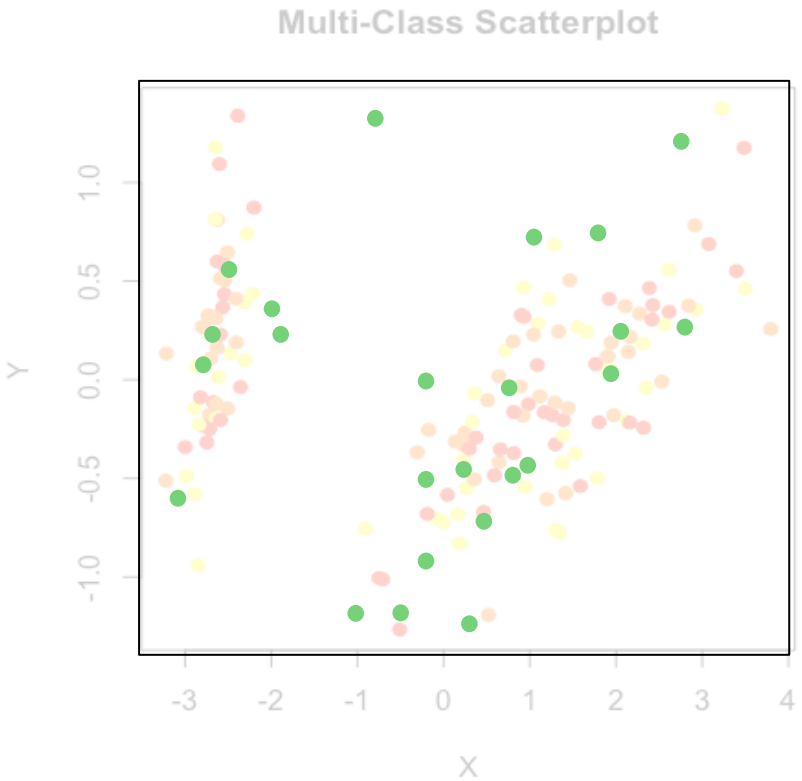
- Does combining features boost selection? (Moore & Egeth, 1997)
- Do color-category differences affect selection? (Nagy & Sanchez, 1990)

Correlations are Ensembles



- Rensink (2017)

Correlations are Ensembles

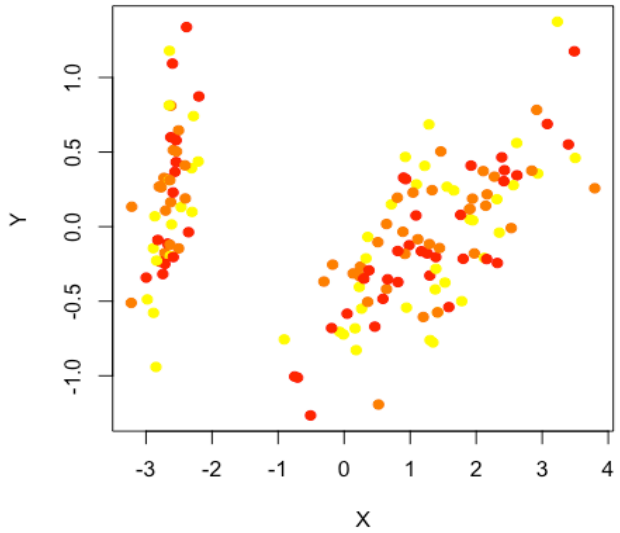


- Rensink (2017)

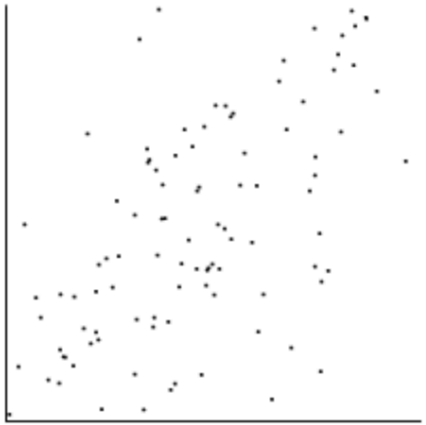
We can ask the same kinds of questions with scatterplots, like how we ignore these red things and attend to the green things. (Just like the leaves).

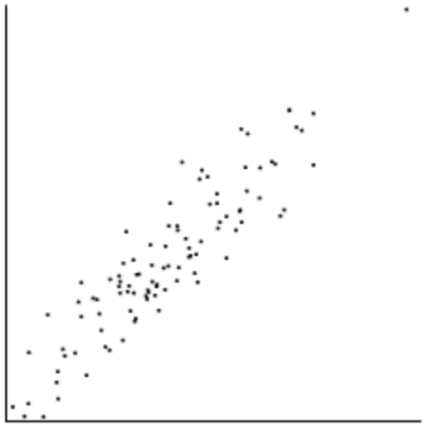
Implications for New Research

- Scatterplots are a useful, controlled stimuli for investigating multiple ensembles in attention



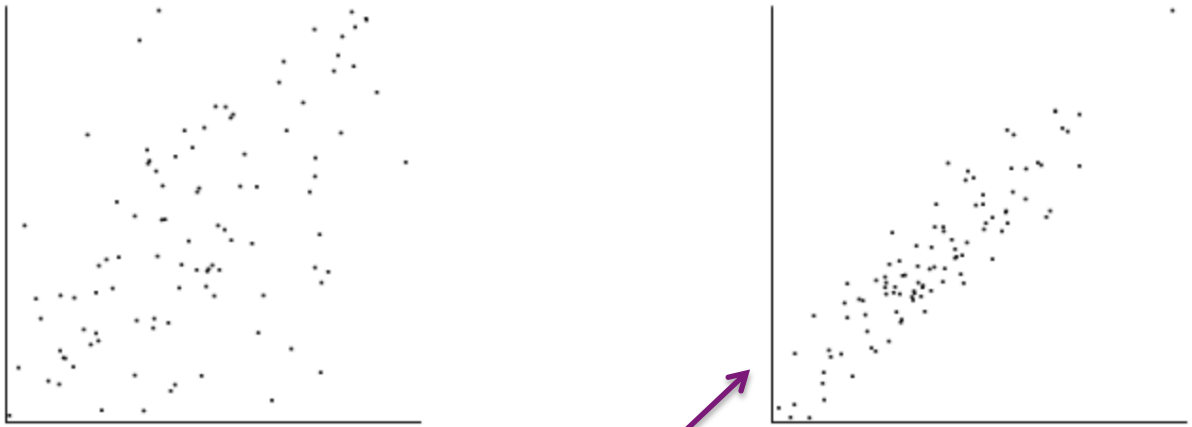
General Methods



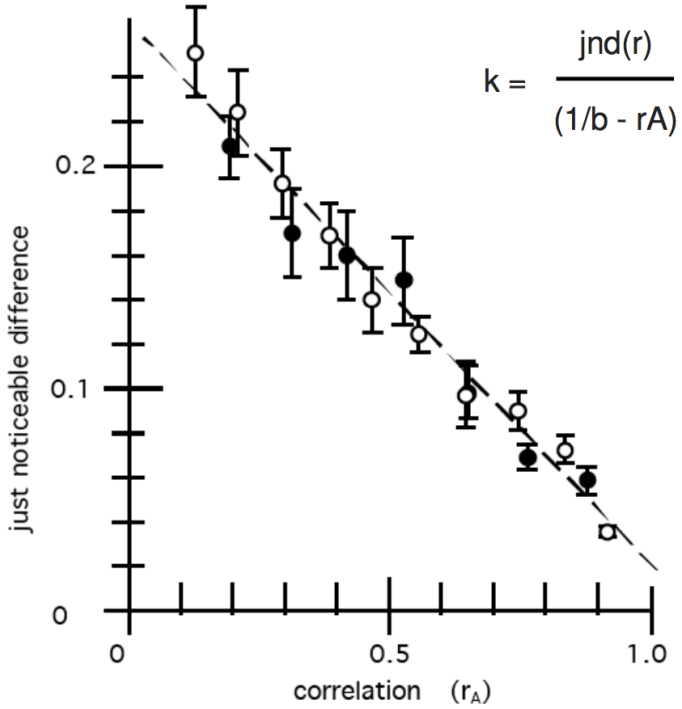


Which scatterplot has a higher correlation value?

General Methods



Which scatterplot has a higher correlation value?



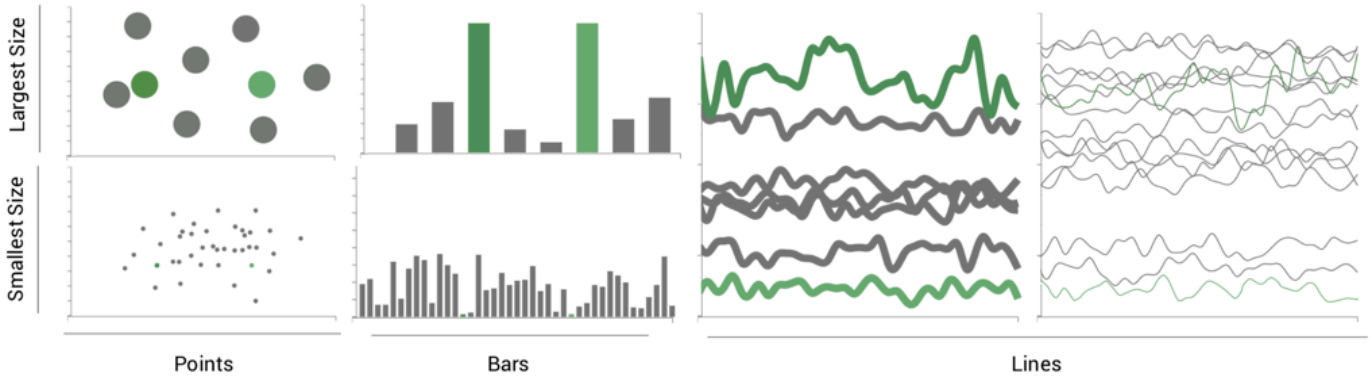
k (slope) = precision

- **JNDs exhibit clear linear behavior**
  - Instance of Weber's Law
- **Exact same behavior as other low-level visual quantities**
  - Luminance, size, length, etc.

Rensink & Baldridge (2010)

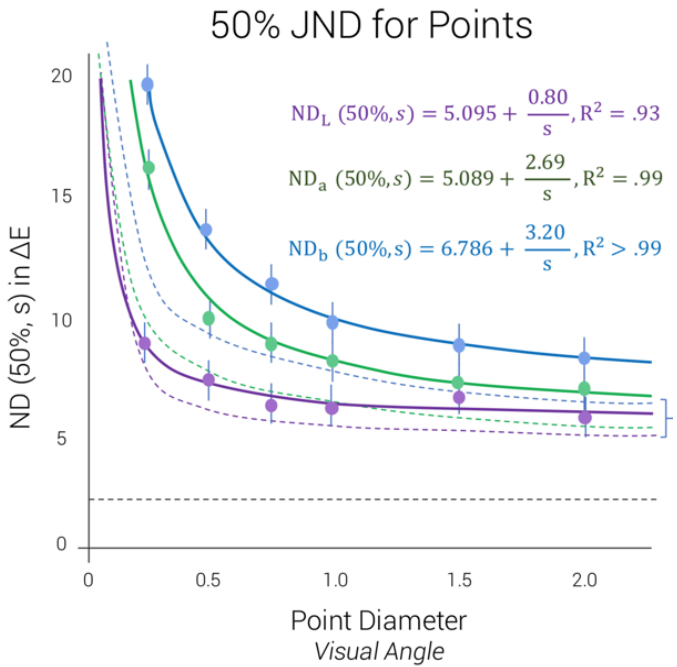
Scatterplots as Visual Stimuli

- People's abilities to perceive color differences varies significantly across mark types and sizes



(Szafir, 2017)

Color JNDs Differ by Stimuli Size



$$ND_L(p,s) = \frac{p}{0.0937 - \frac{0.0085}{diameter}}$$

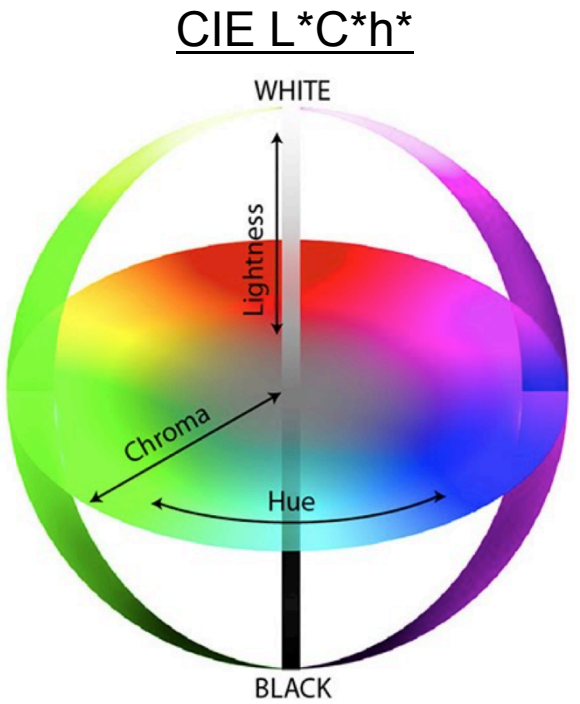
$$ND_a(p,s) = \frac{p}{0.0775 - \frac{0.0121}{diameter}}$$

$$ND_b(p,s) = \frac{p}{0.0611 - \frac{0.0096}{diameter}}$$

(Szafir, 2017)

Color Difference with Δ*E*

Color difference is the distance Δ*E* between two values in color space.



Current Study

- Extend methods from Rensink & Baldridge (2010) to investigate perception of multi-class scatterplots

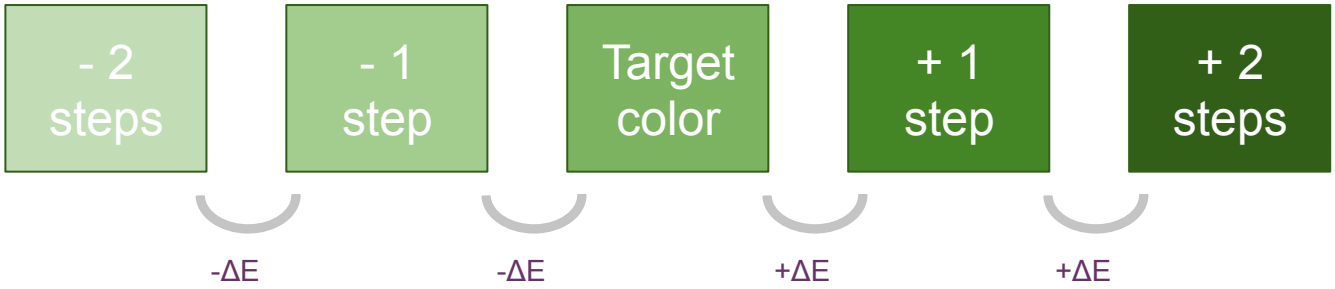
Experiment 1: Color & Shape

Experiment 2: Color Only

Color and Shape Stimuli

- Mark Size: **.35°** (**8px** on 27" iMac)
- Mark Shape: **Squares** and **diamonds** (orientation difference)
- Color Space: **CIE L*C*h*** / **CIE L*a*b***
- Colors: **Red**, **green**, **blue**, and **yellow**

Defining our Experiment Colors



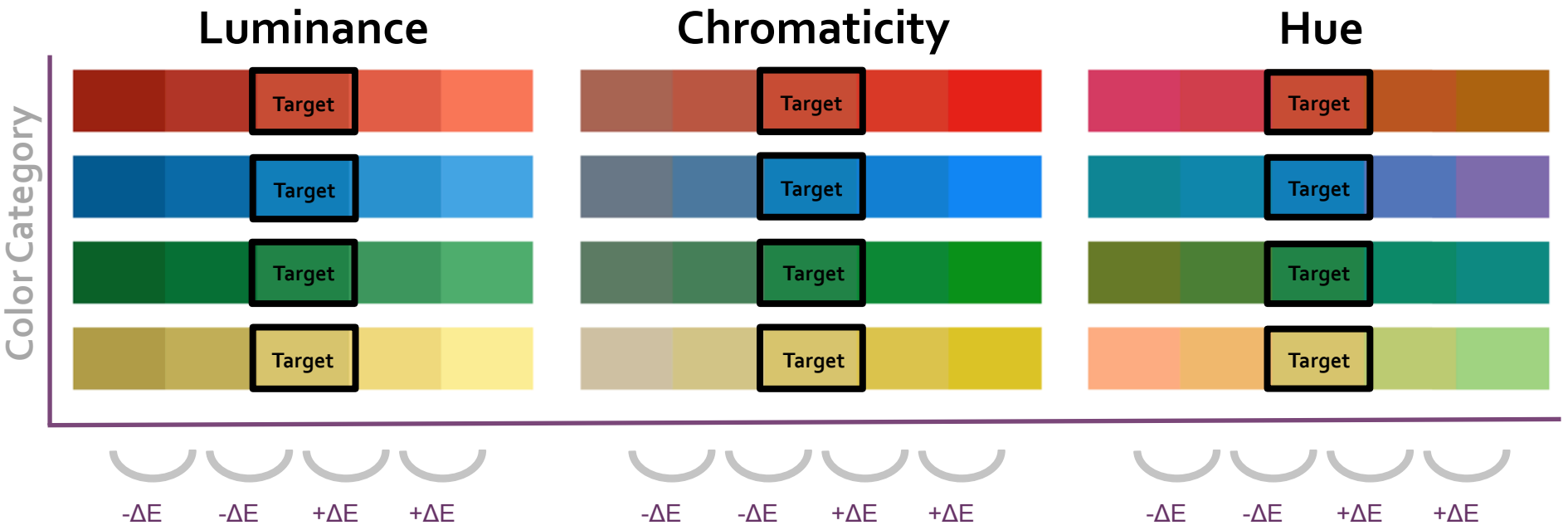
1 JND

$\Delta E_L = 7.33$

$\Delta E_C = 15.48$

$\Delta E_h = 15.48$

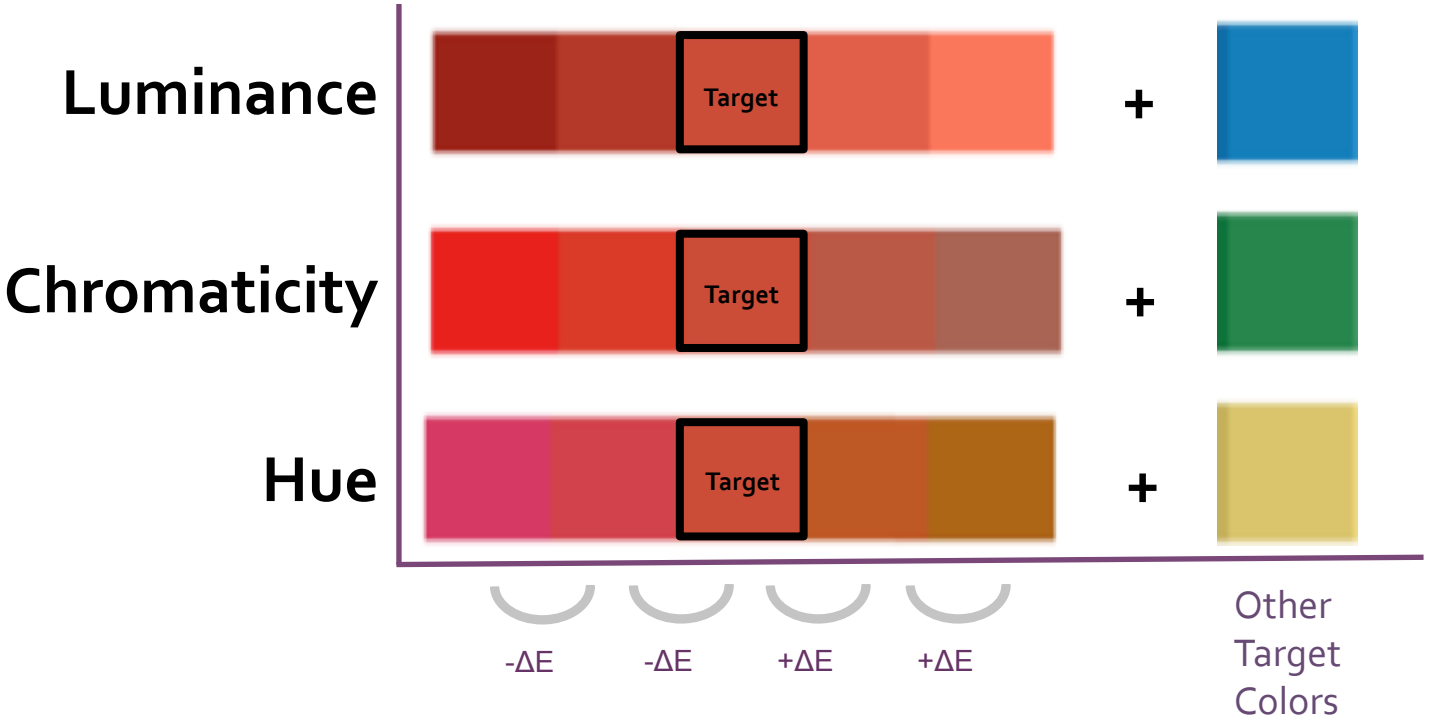
Final Colors for Experiments



Experiment 1: Color & Shape

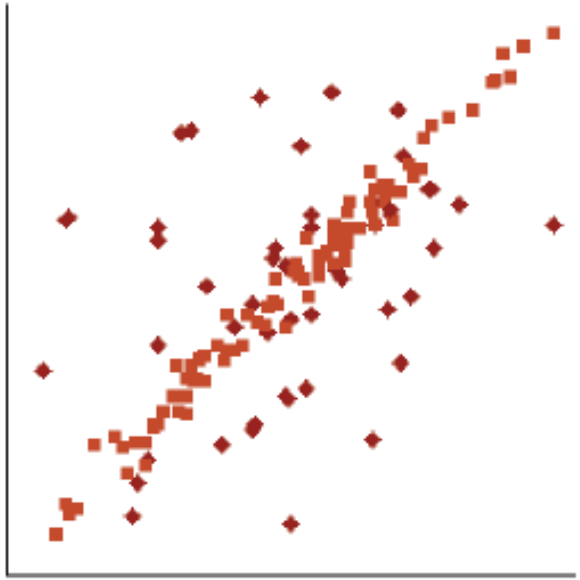
- Scatterplots contain both a "target" ensemble and an irrelevant "distractor" ensemble
- Ensembles defined by both color and shape

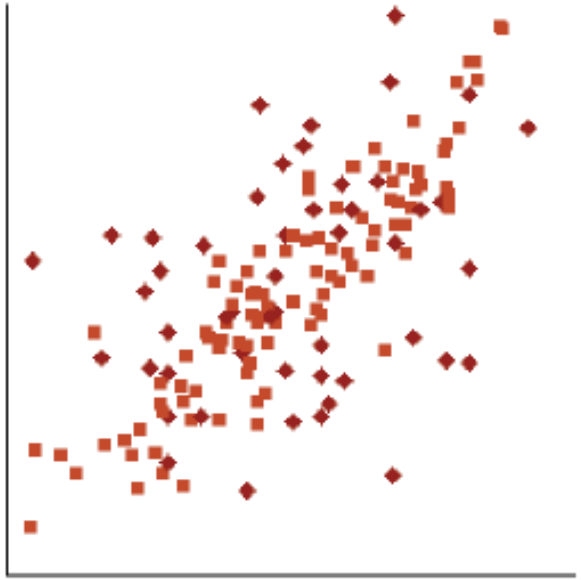
Experiment 1: Color & Shape



Experiment 1: Color & Shape

Which scatterplot has a higher correlation value of **red squares**?





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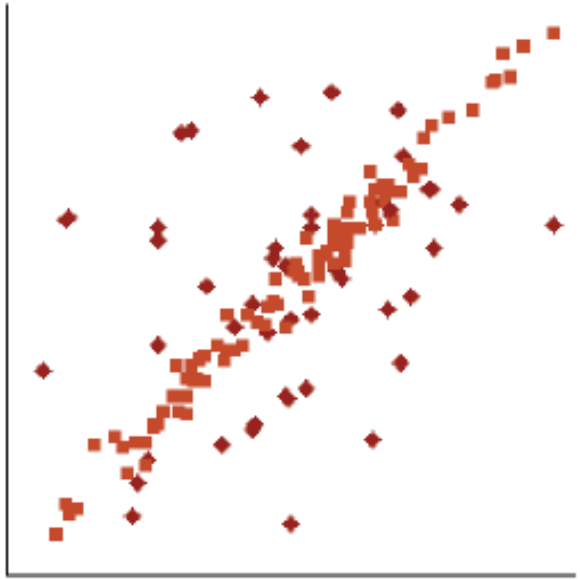
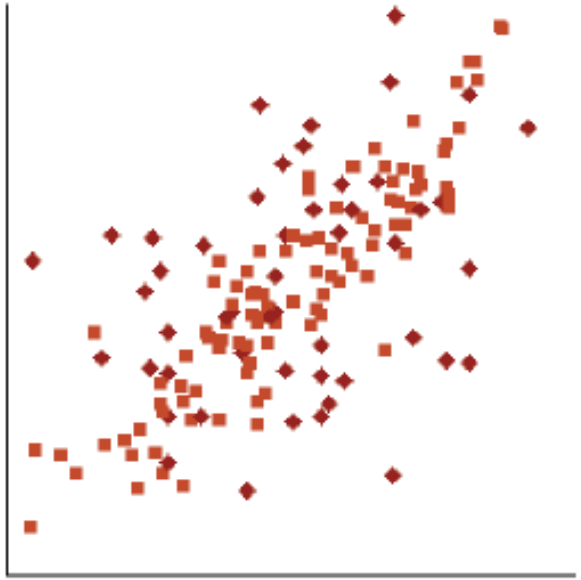
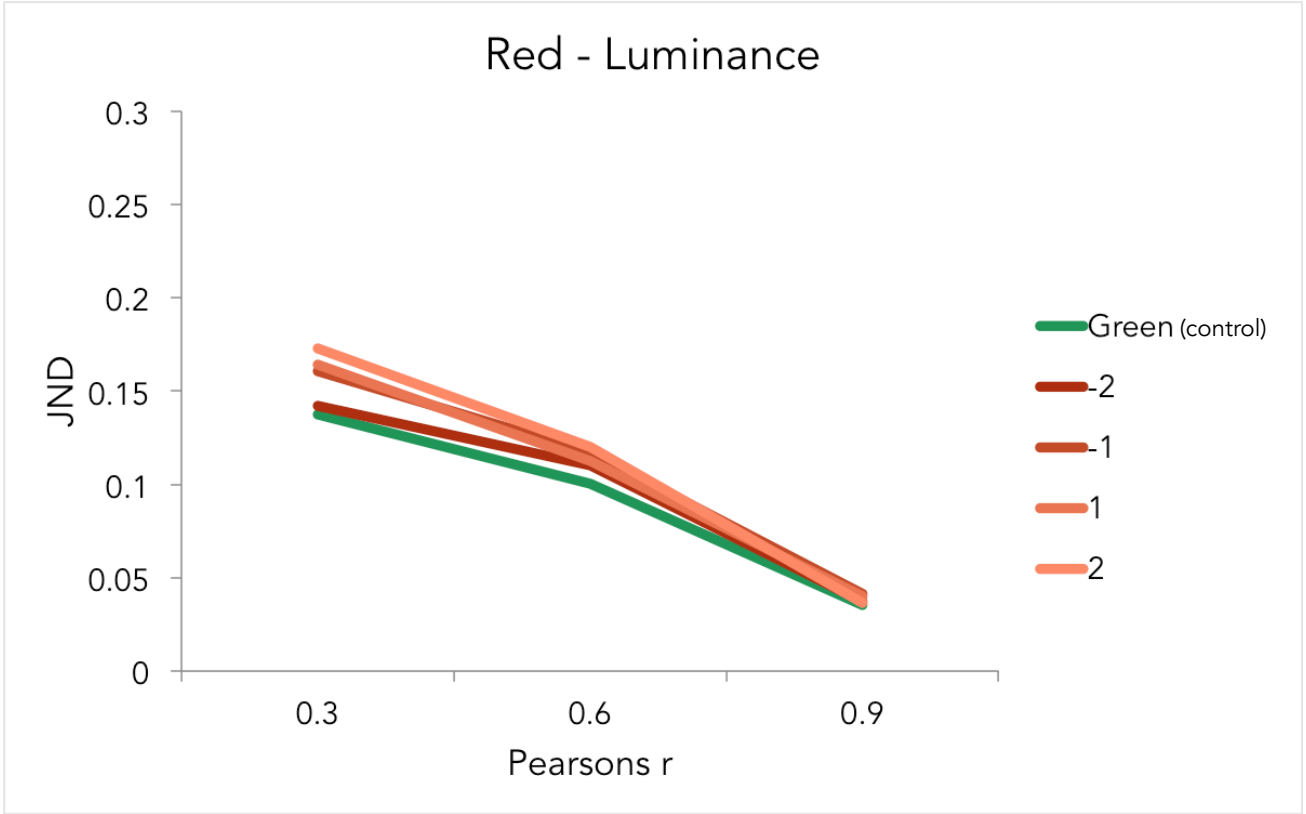




Experiment 1: Results



Experiment 1: Results

Shape & Color Feature Task

(n = 27)

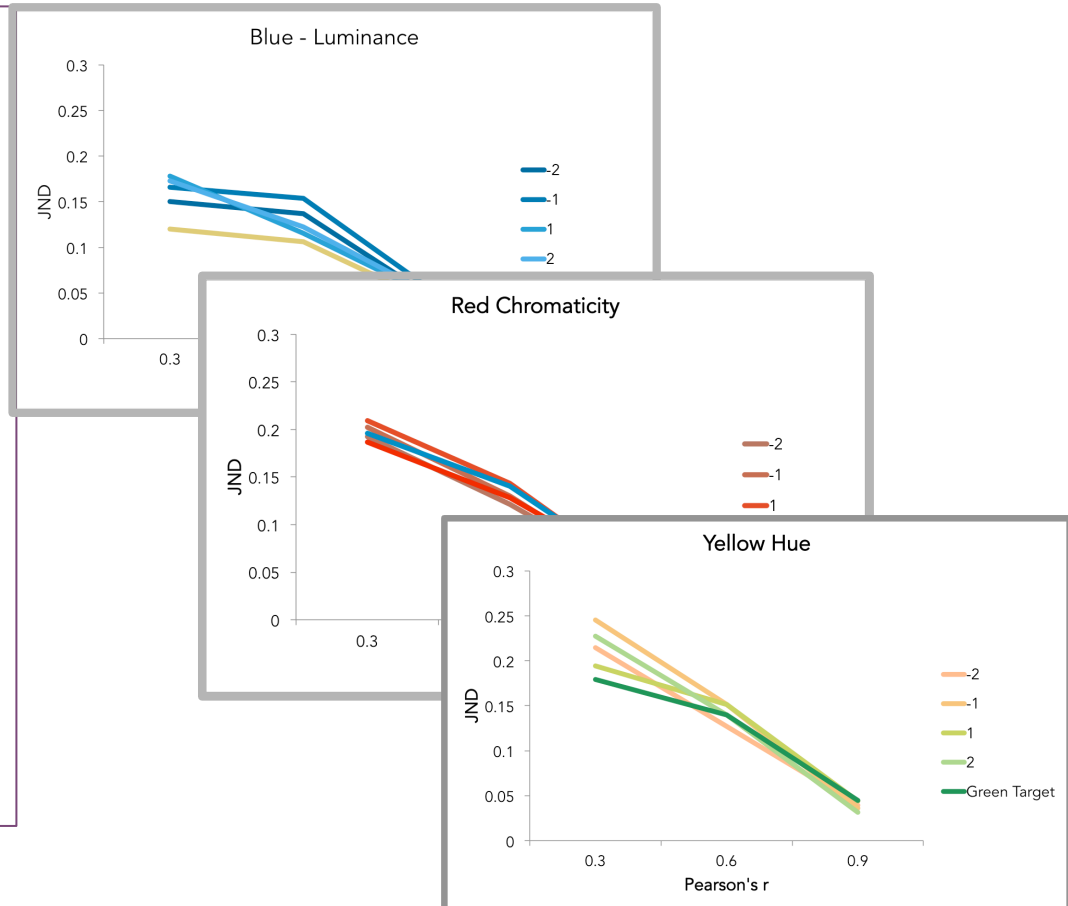
Color Difference

F(3, 51) = 1.34, p = .06

Color Difference X Correlation Value

F(3, 51) = .95, p = .58

No differences between the four colors at each level of correlation!



Experiment 1: Results

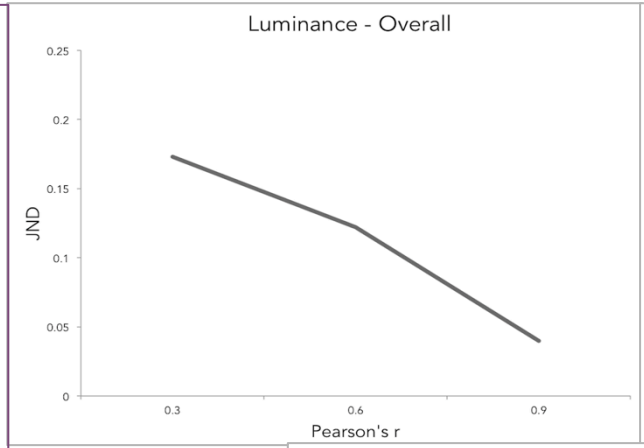
Shape & Color Feature Task

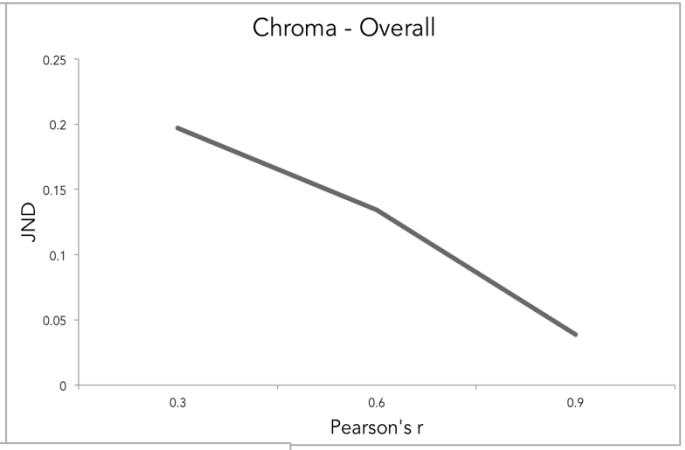
(n = 27)

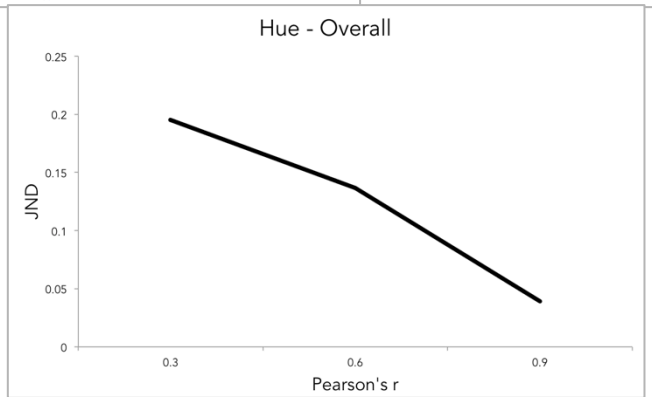
Color Axis Difference

F(2, 24) = 4.06, p = .02 *

Best performance for colors separated along luminance axis!







Experiment 1: Summary

- Color-category does not affect discrimination performance for target ensembles

- Luminance axis is weighted differently
  - Helps selection and discrimination for shape differences

Question

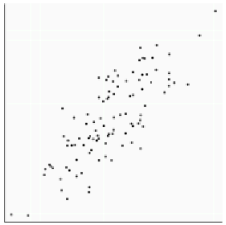
- Are participants just using shape/orientation?
  - We already know people can do this…

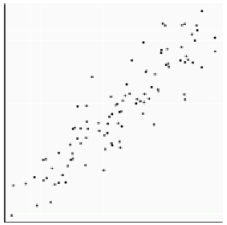
Sun et al. (2015)

Experiment 2: Color Only

- Test ensembles separated only by color

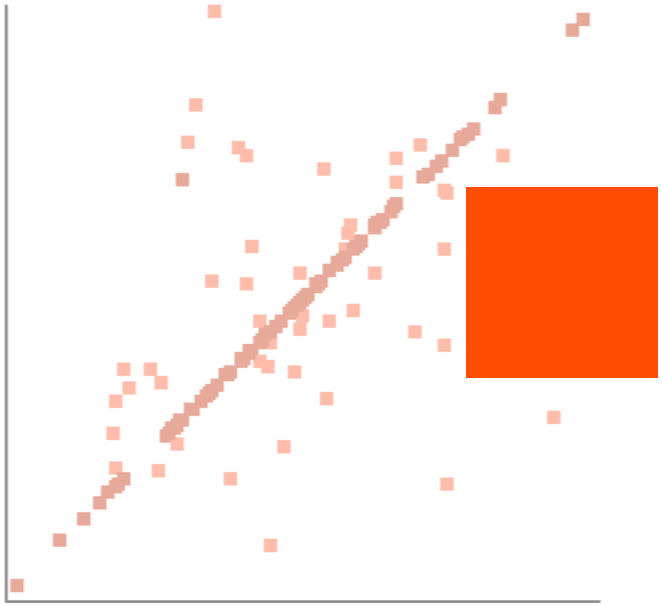
- Include a single-population condition
  - Does second population causes interference at all?

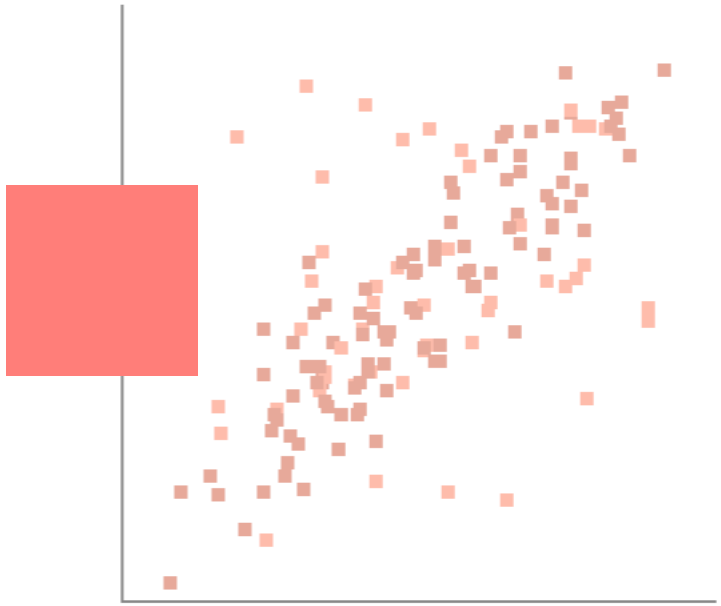




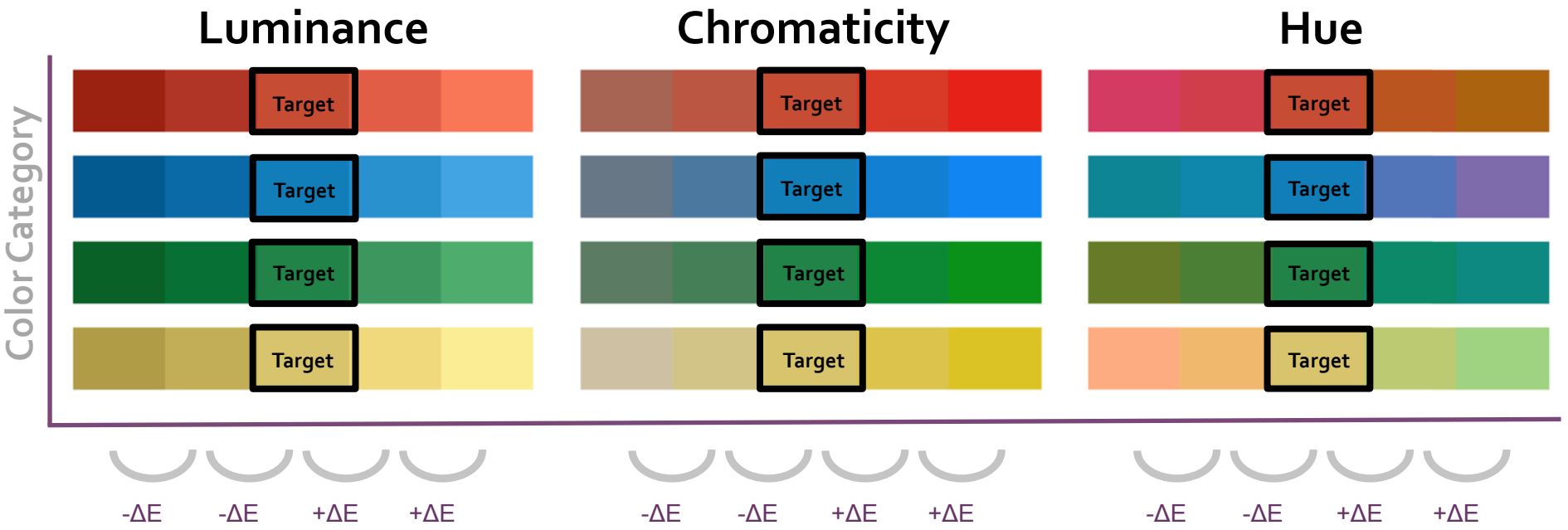
Elliott & Rensink
(VSS 2017)

Experiment 2: Color Only



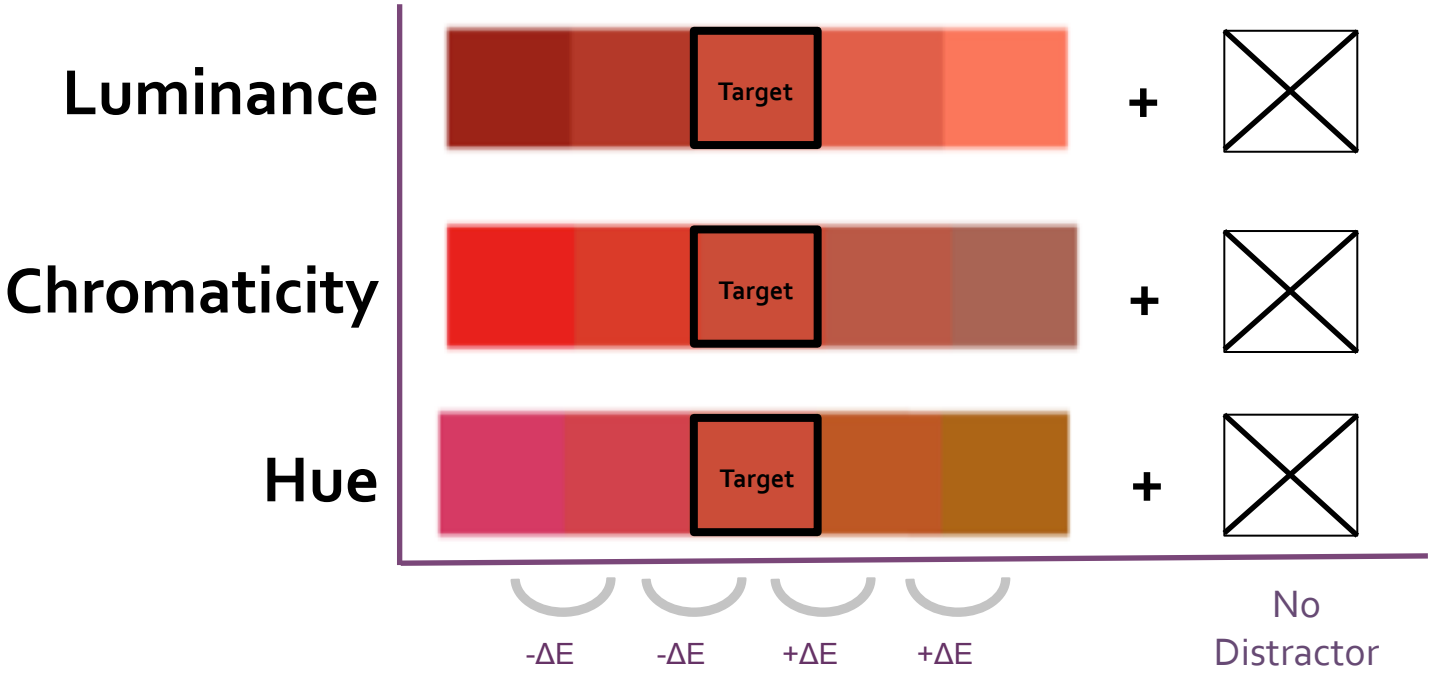


Experiment 2: Color Only



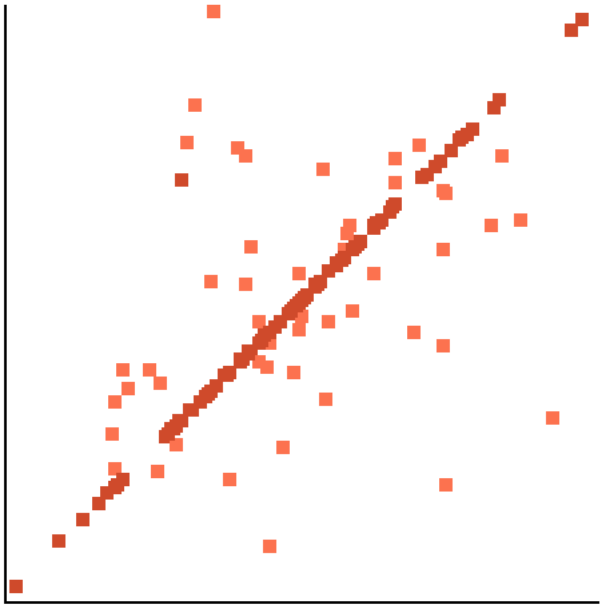
Experiment 2: Color Only

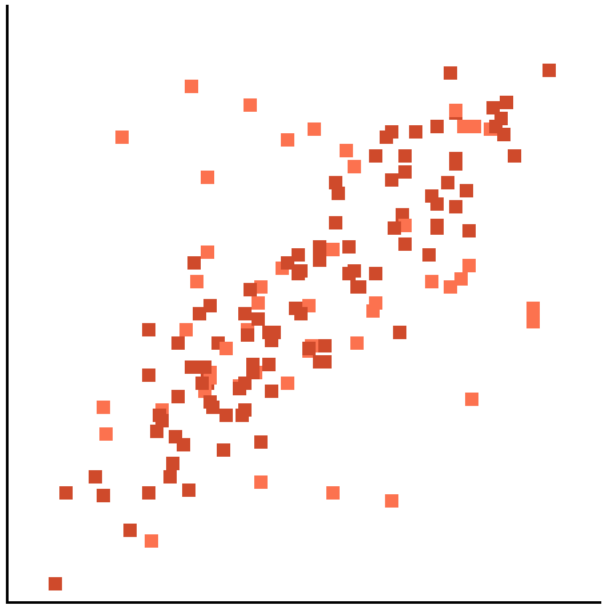
First, show participants the **target** color, as well as **distractor** colors.



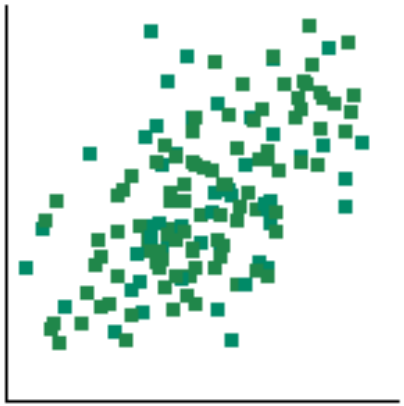
Experiment 2: Color Only

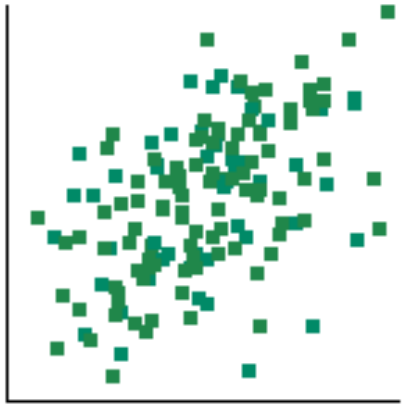
Which scatterplot has a higher correlation value of the **target** red squares?



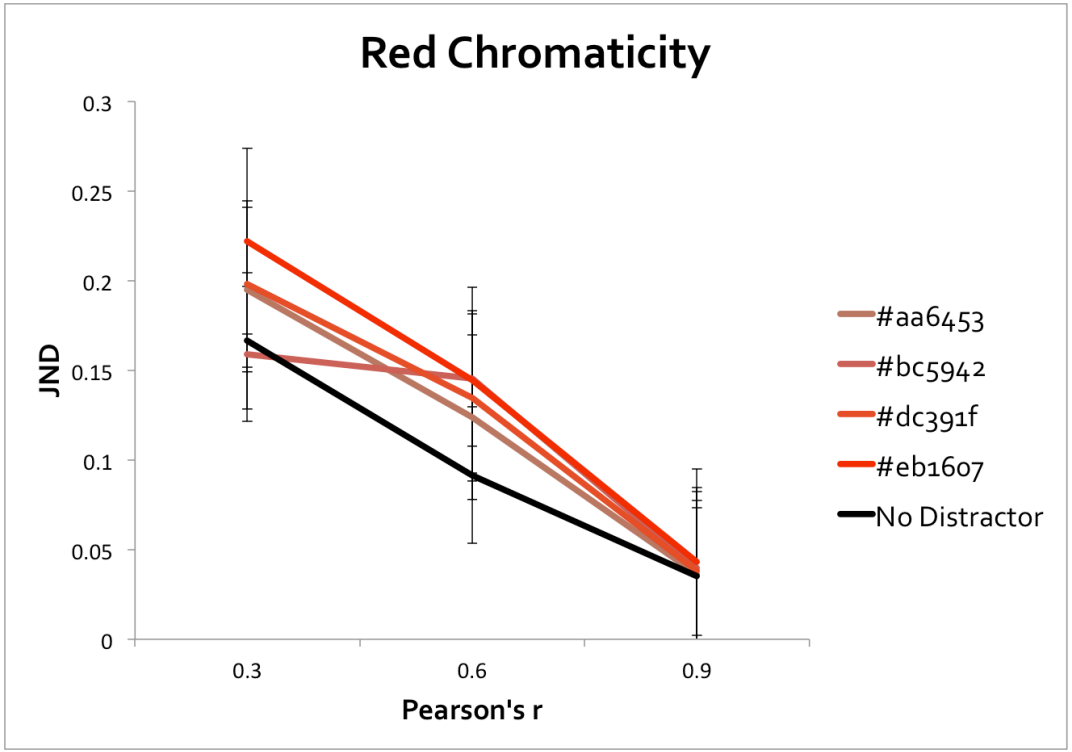


Except it looked like this…





Experiment 2: Results



Experiment 2: Results

Shape & Color Feature Task

(n = 42)

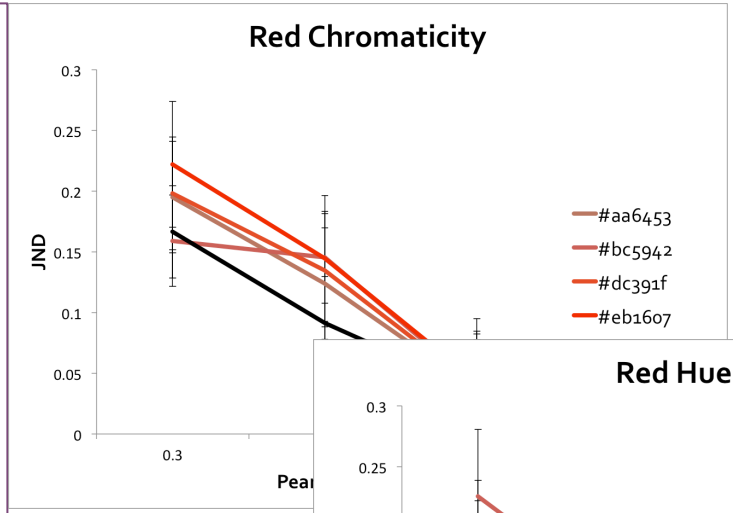
Color Difference

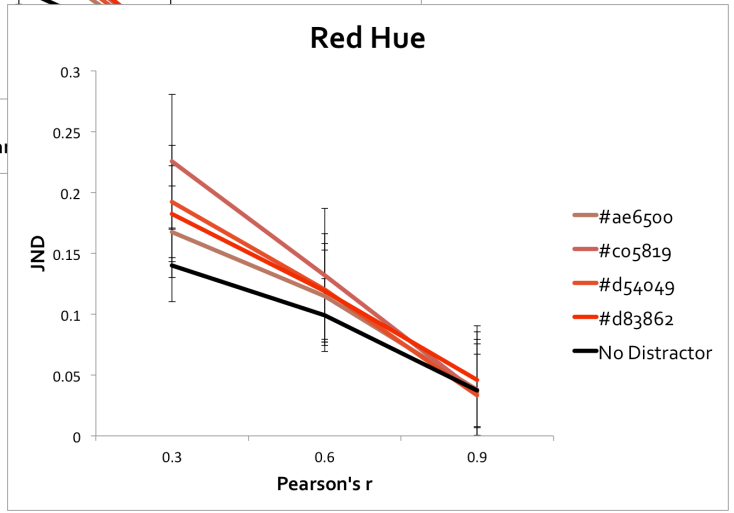
F(3, 51) = 2.38, p = .000 *

Color Difference X Correlation Value

F(3, 51) = .87, p = .70

Including a distractor population of data causes interference, no differences between colors!





Experiment 2: Results

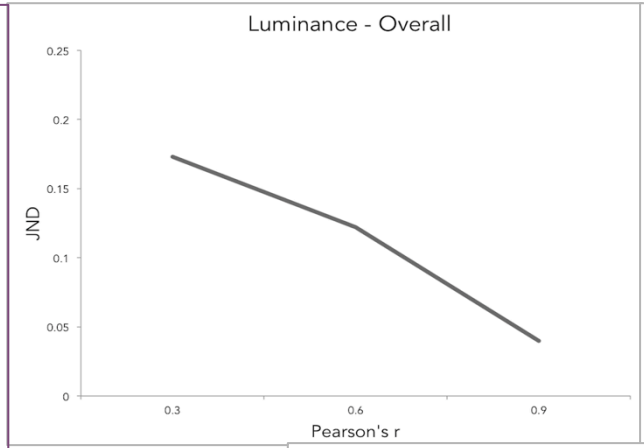
Shape & Color Feature Task

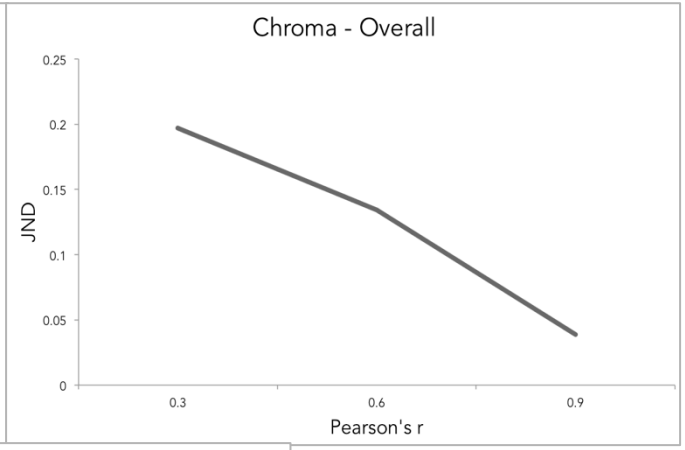
(n = 42)

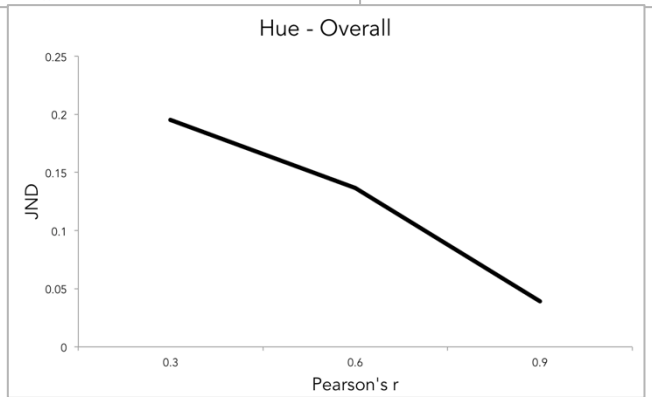
Color Axis Difference

F(2, 24) = 1.07, p = .35

No effect of color axis.







Experiment 2: Summary

- People can successfully select and discriminate ensembles defined by **color only**
  - Even when those colors are extremely perceptually similar (1 JND)

- Any color dimension can be used equally well for ensemble selection

Conclusions

- Overall performance was equally good for target ensembles defined by differences in single features and differences in two features
  - But, presence of distractors causes interference for selection of targets

- Even very small differences along each color dimension were enough to facilitate ensemble selection

- **Increasing feature differences did not boost selection performance**
  - Caveat: it does appear to help people use luminance dimension

Future Directions

- Scatterplots are convenient, well-controlled stimuli for investigating the nature of ensemble processing in attention

- Our color modeling technique can be applied to other multi-dimension discrimination and identification tasks in attention
  - Number, centroid-detection, array-density tasks…

- **Inform color palette design choices for visualization software**

Thank You!

Ronald Rensink

UBC VISUAL COGNITION

Camila Sieben **Ellen Kim** **Kouther Noureddine**

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