

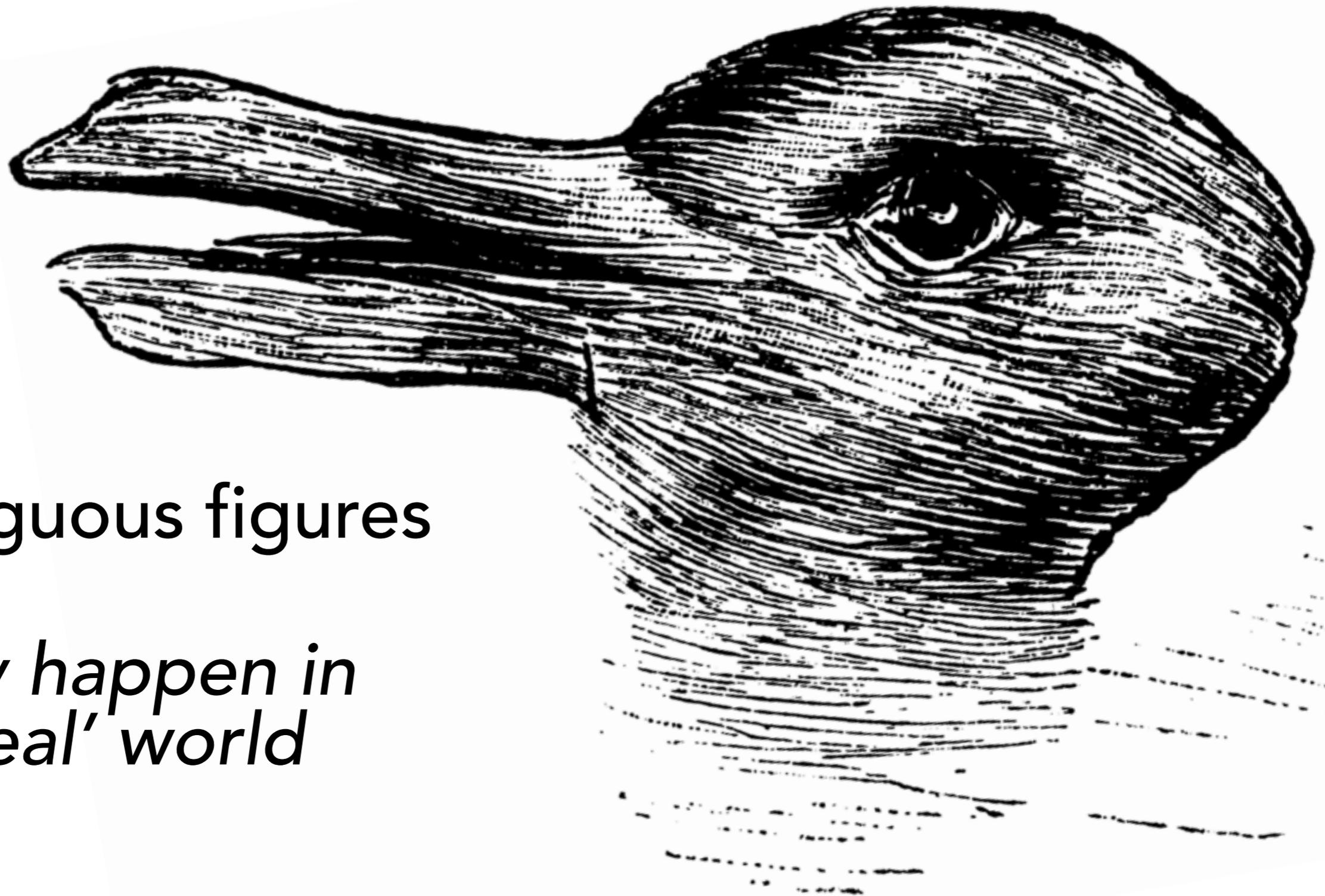
Visualizations are ambiguous figures



Steve Franconeri
Psychology, Kellogg,
& Design/Engineering
Northwestern University

 [@SteveFranconeri](https://twitter.com/SteveFranconeri)





Ambiguous figures

*Rarely happen in
the 'real' world*



Hannah Murphy

my mother was giggling at this and told me to "take a look at that adorable dachshund, he's sleeping", she was looking at a purse:



8:15 AM - 30 Jul 2017

45,323 Retweets 132,891 Likes

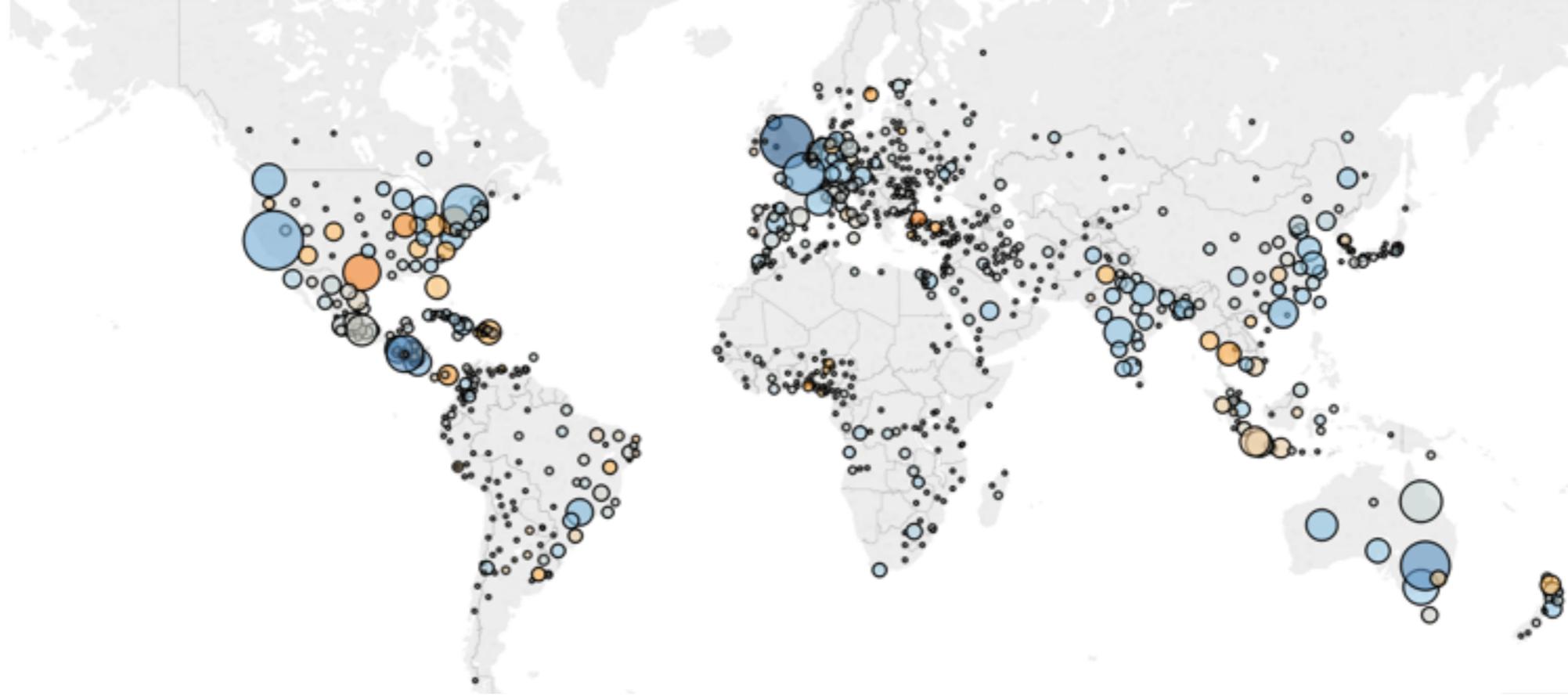


But in visualizations,
multi-stable interpretation
is **ubiquitous**

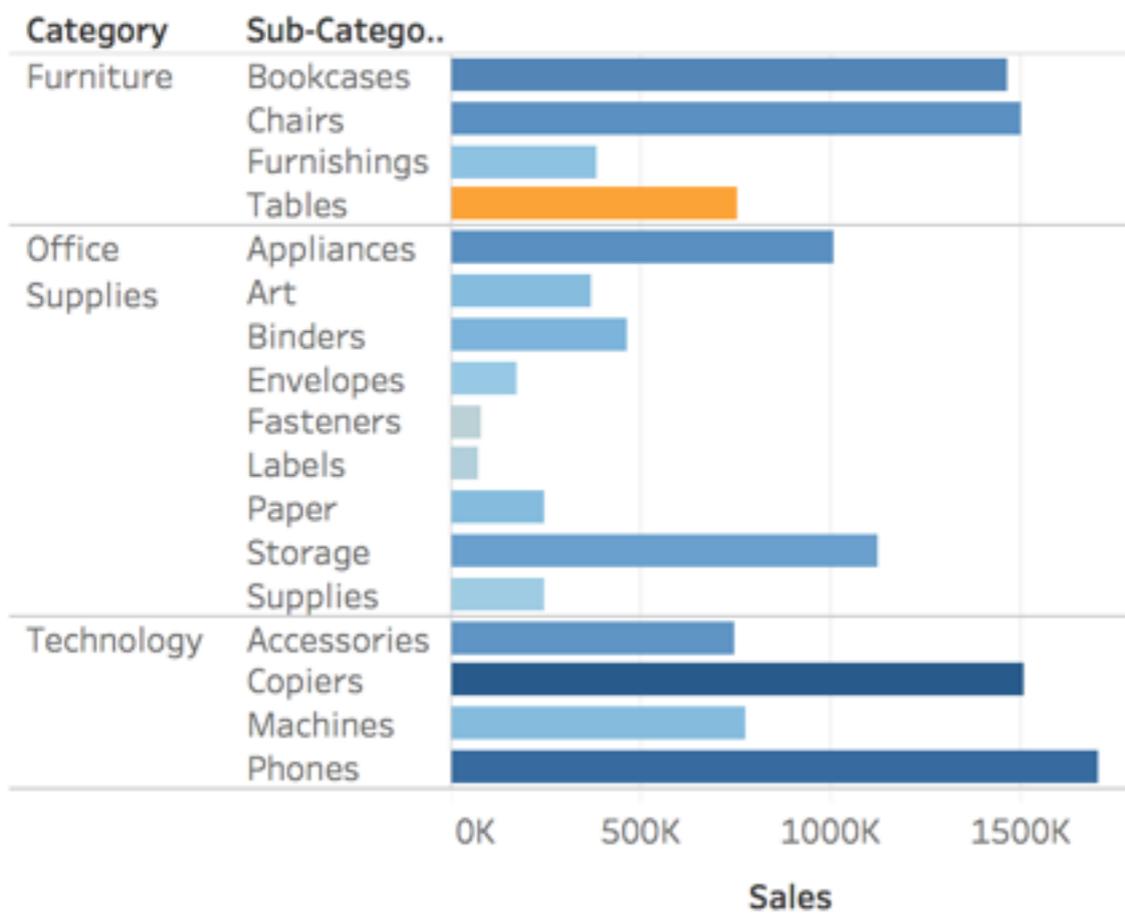
Visualizations are ambiguous figures

Three visual tools
for seeing differently

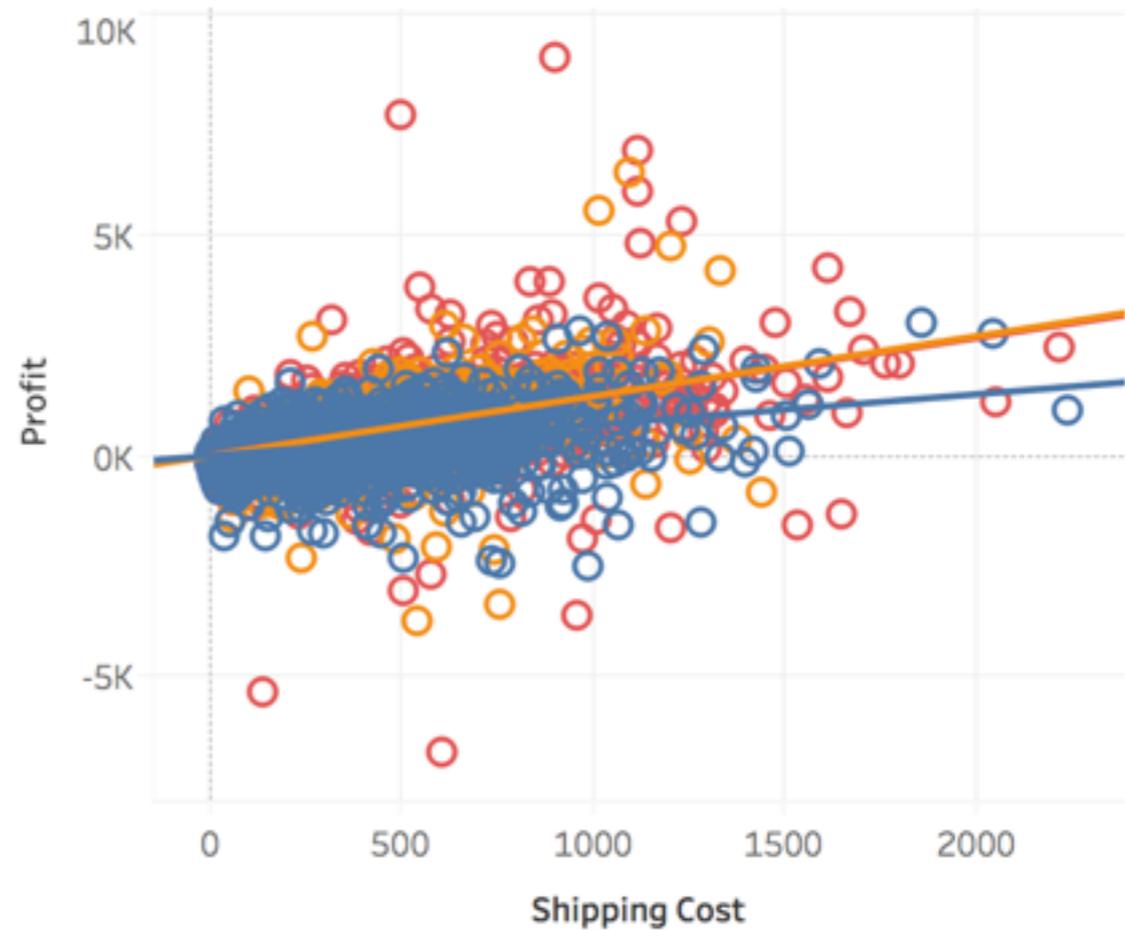


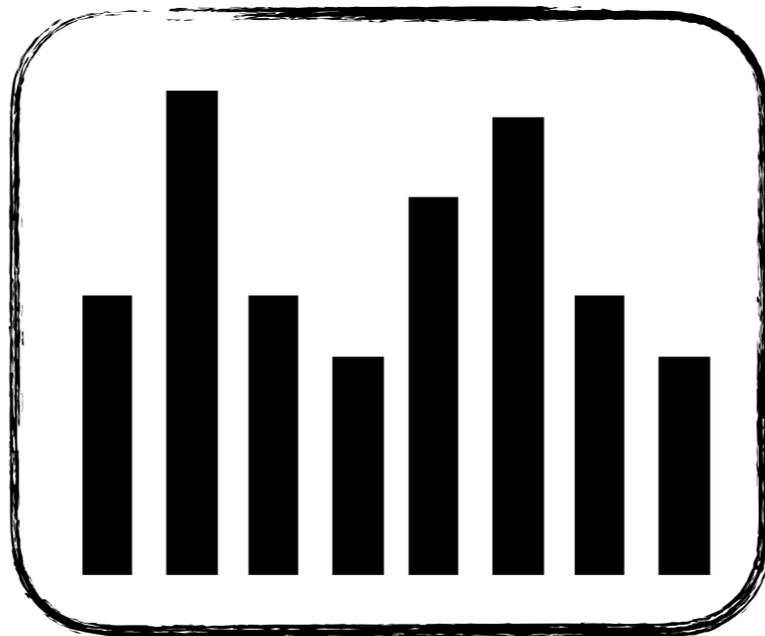


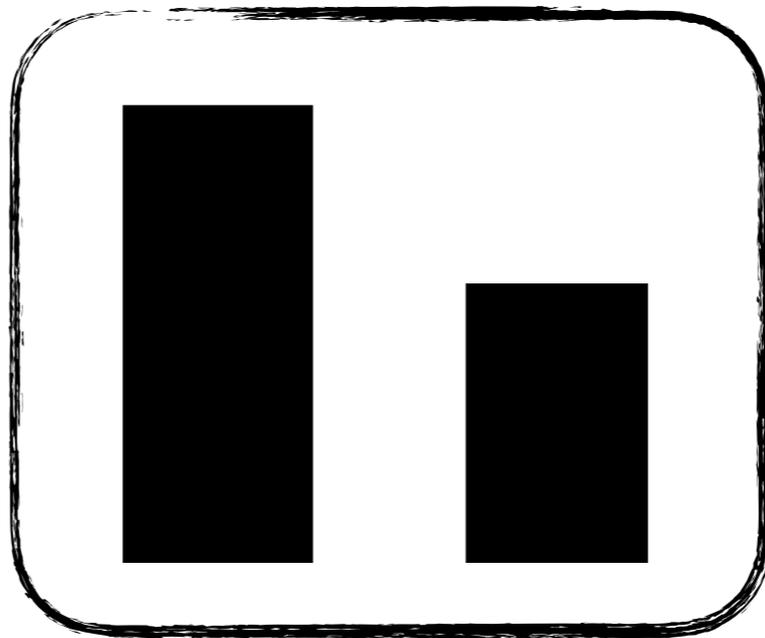
Sales By Category

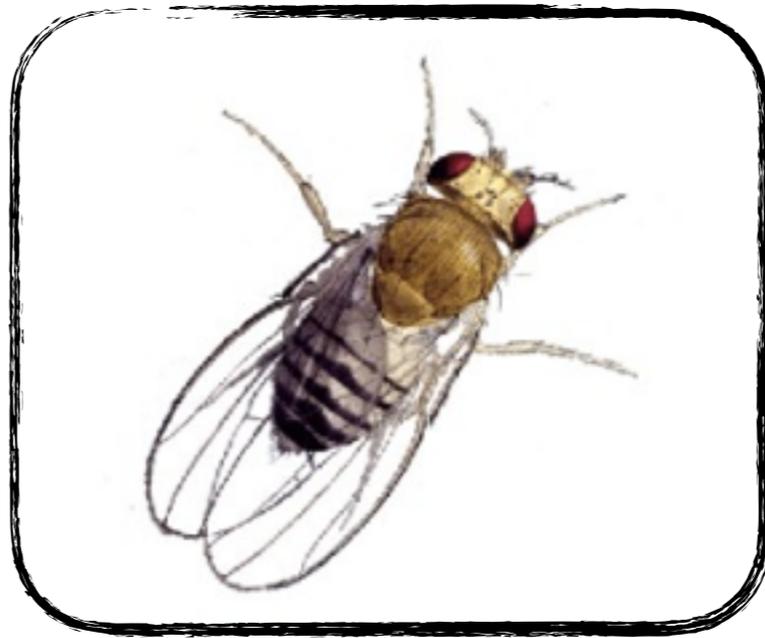


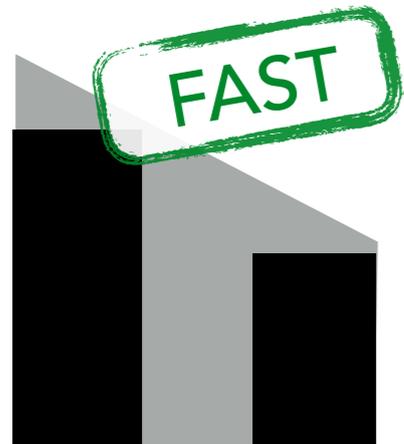
Customer Breakdown











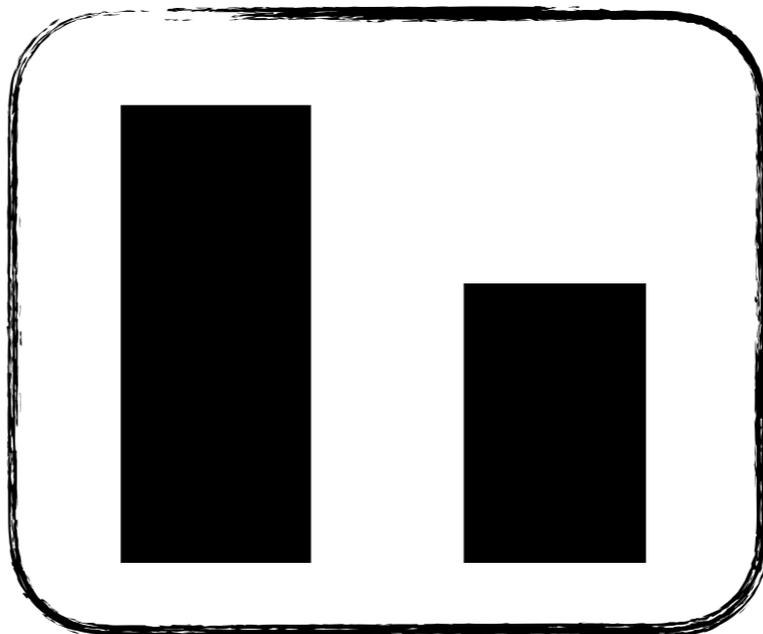
< 100ms

Shape recognition
(Sloped roof)



< 100ms

Histograms
(Different sizes)

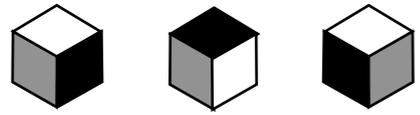


~seconds



Comparisons
(Left bigger; Right smaller; Right lighter...)

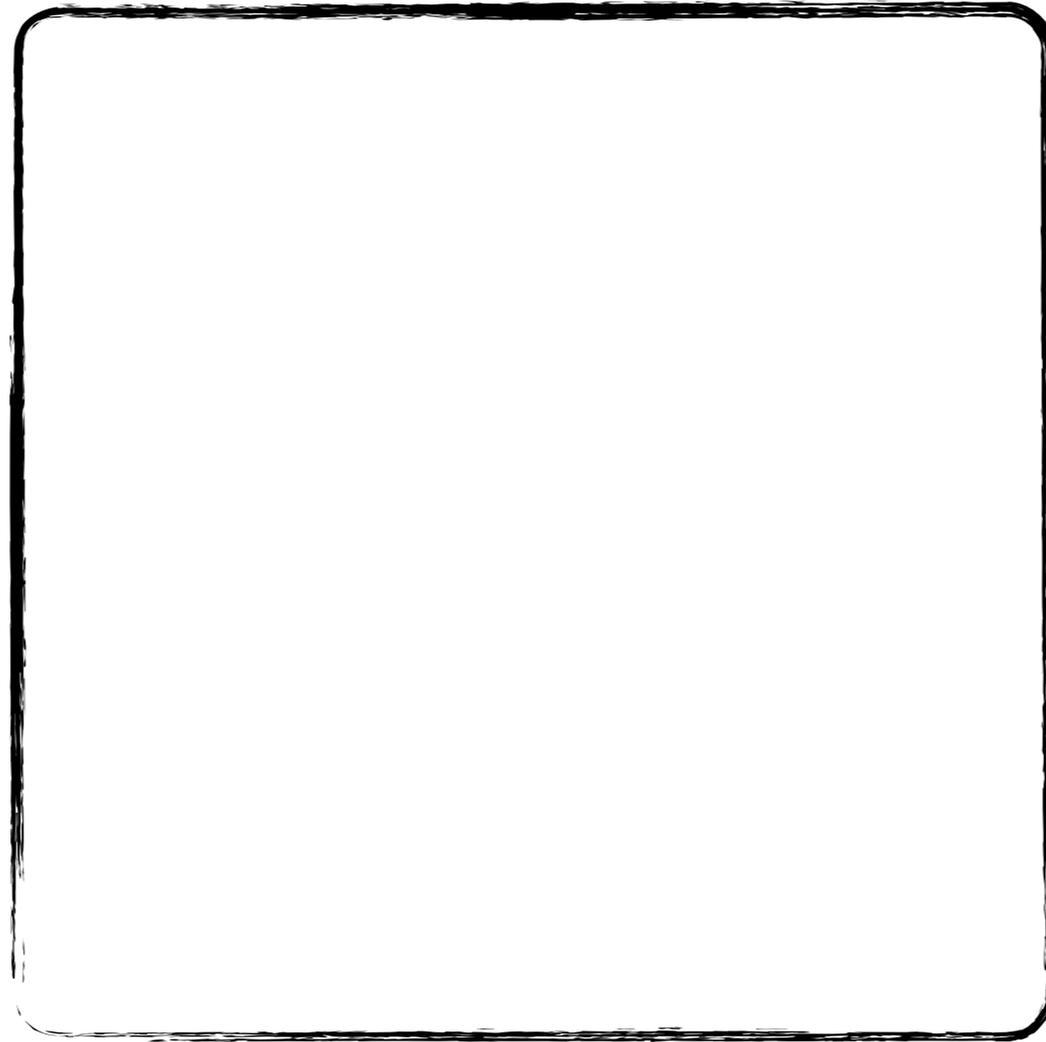
object recognition

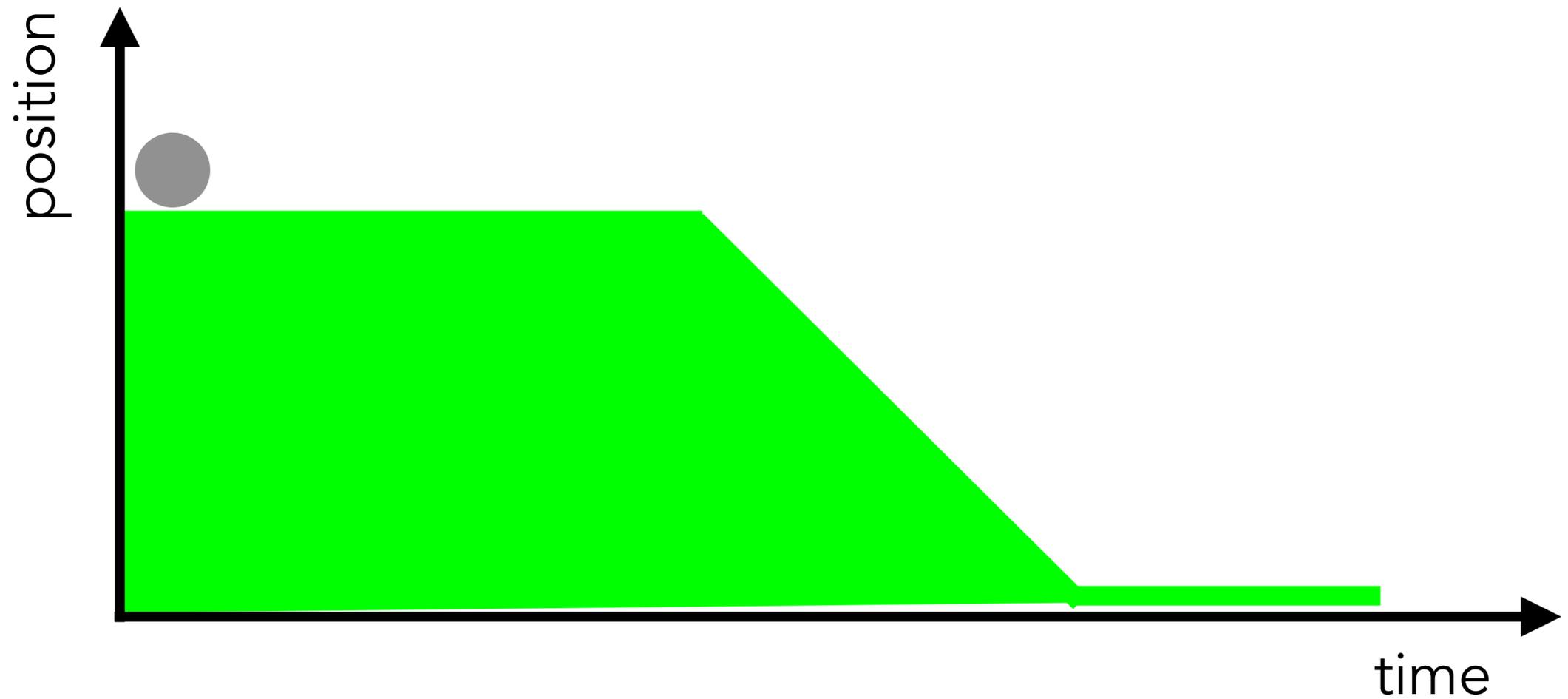


A B C

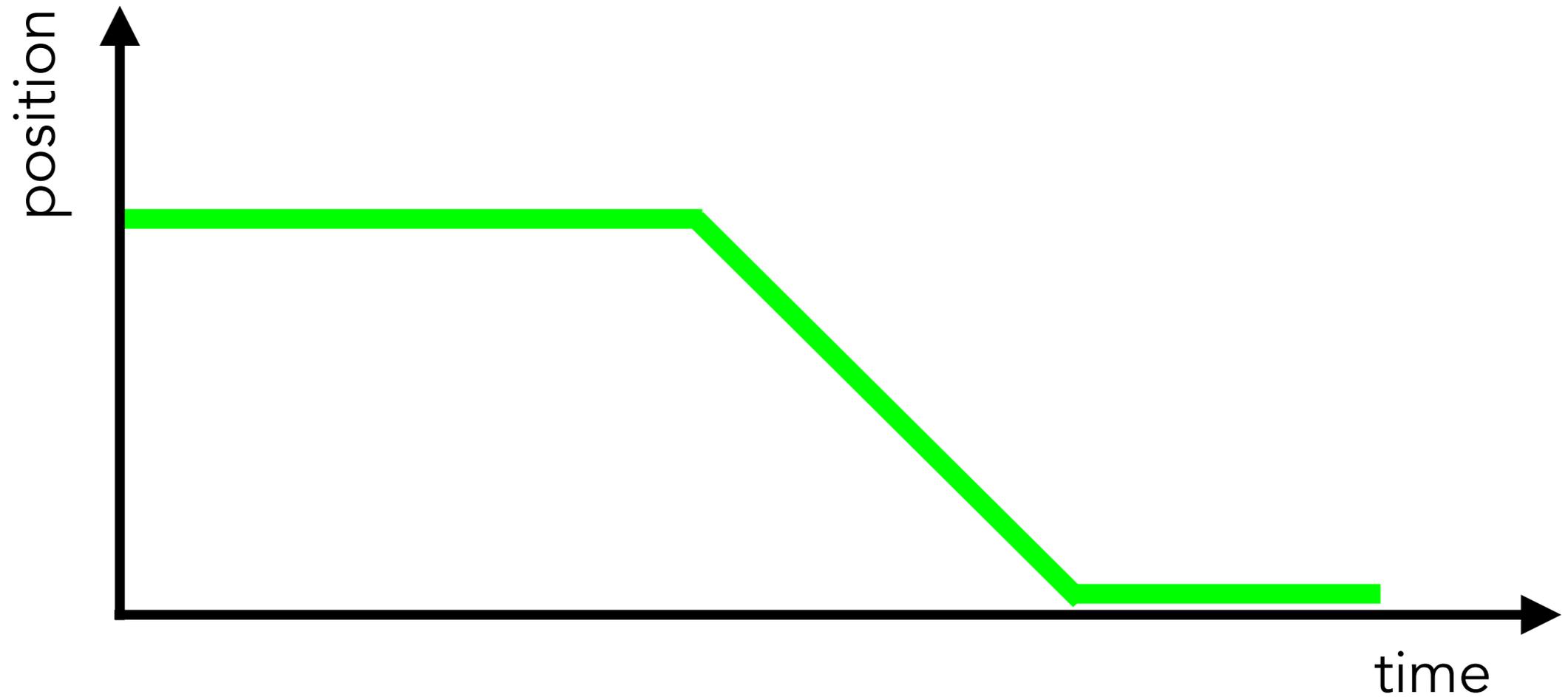


the world

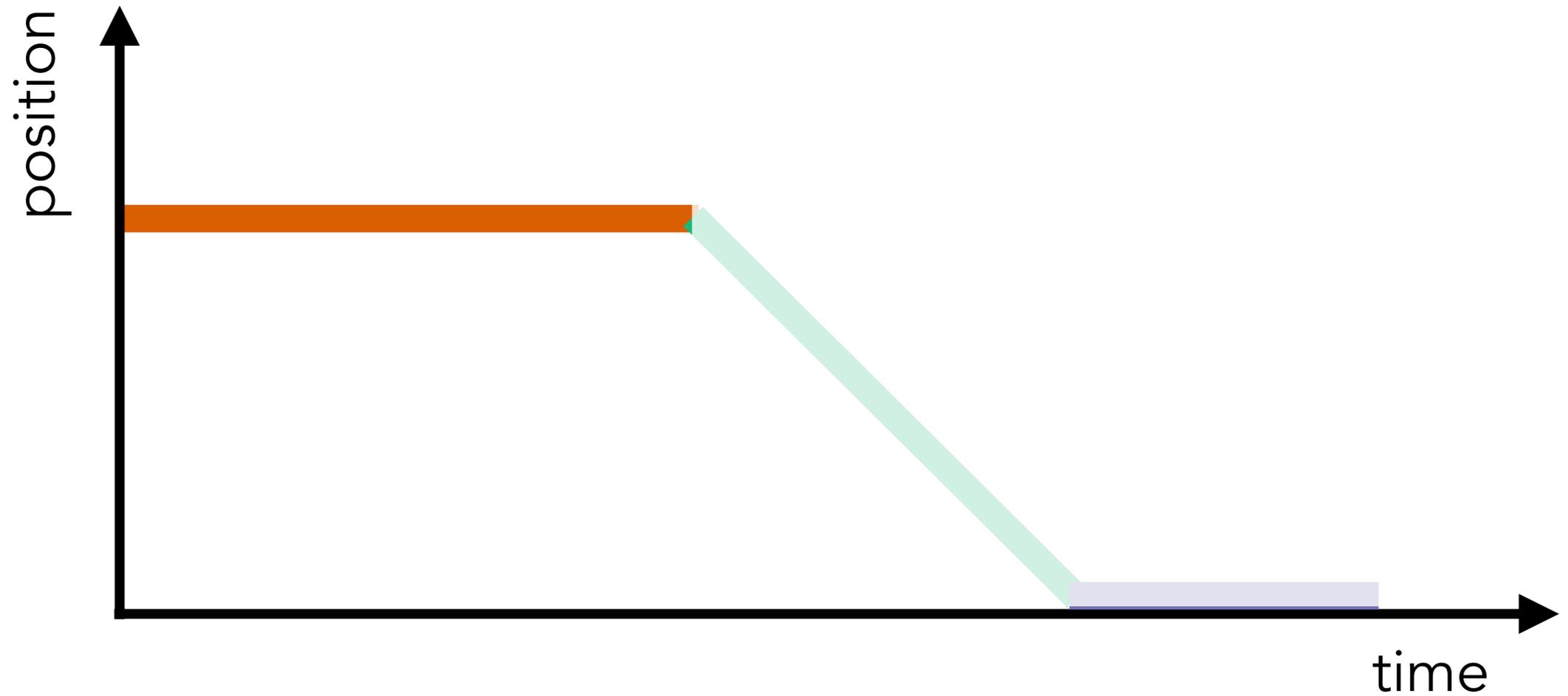




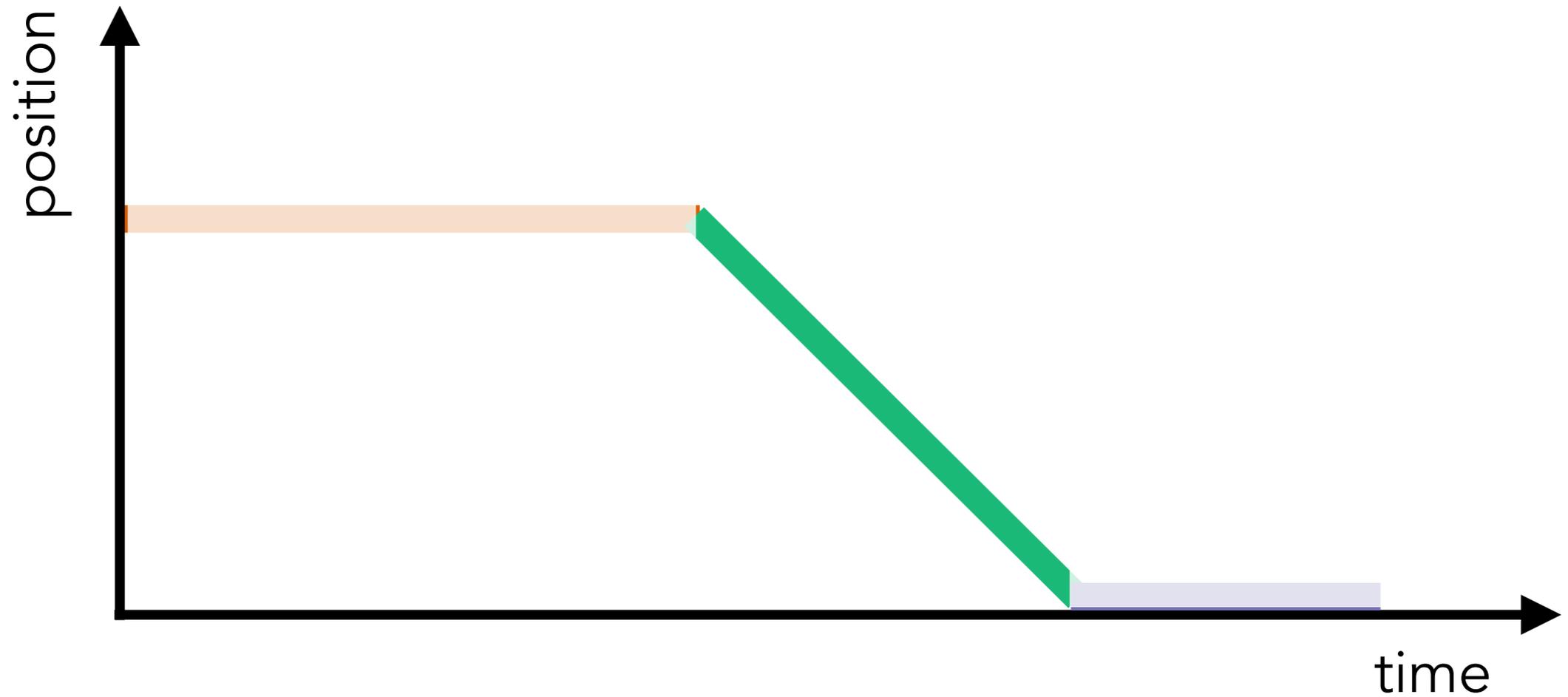
Here is a graph of an object's motion.
Imagine some real situation depicted on the graph



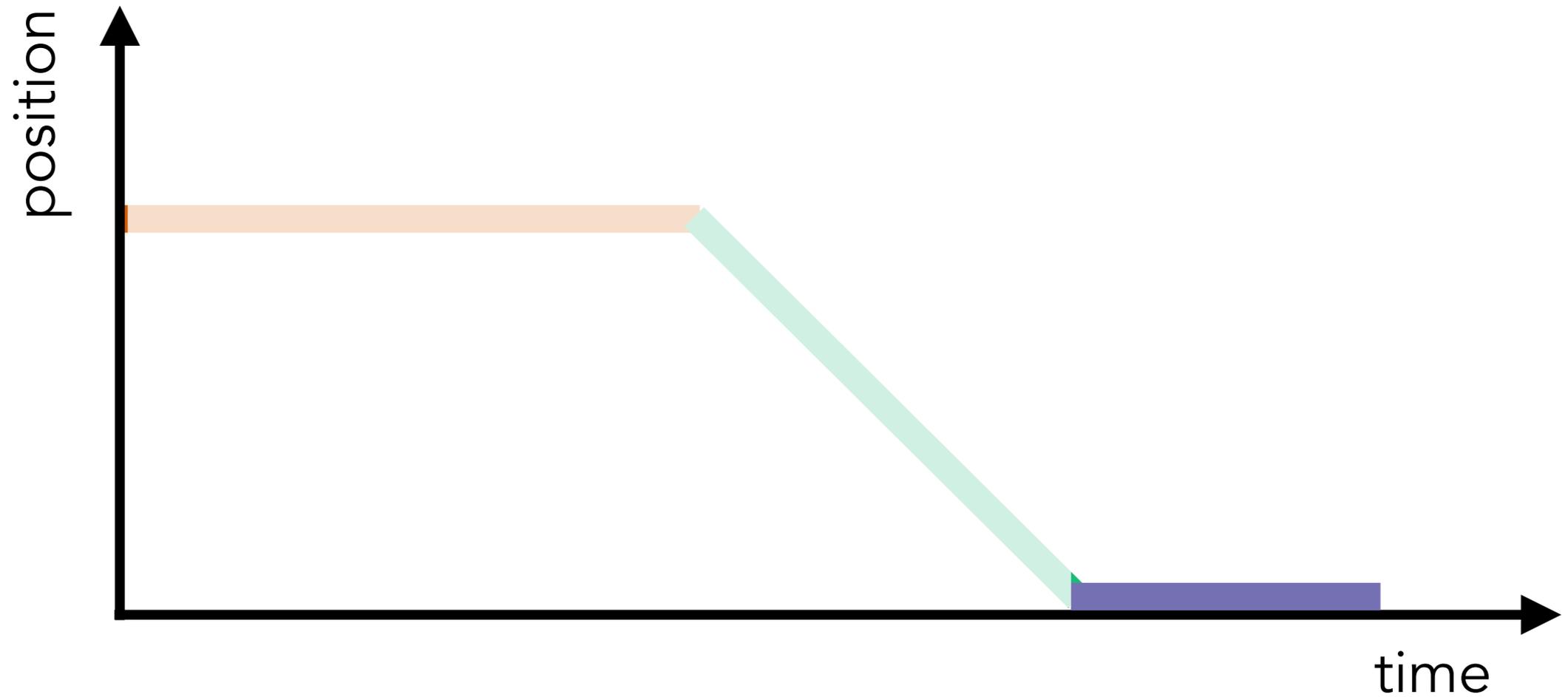
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Imagine some real situation depicted on the graph



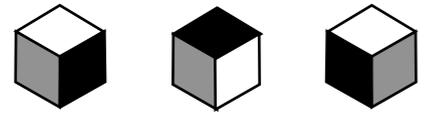
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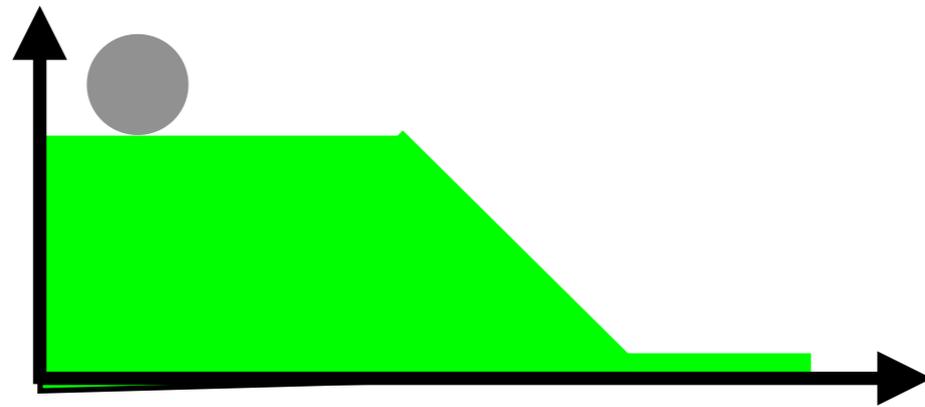
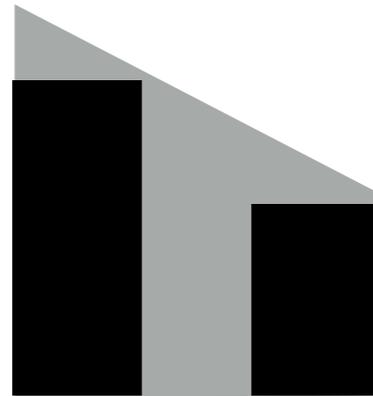
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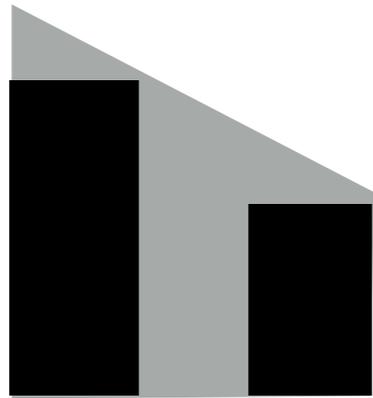
object recognition

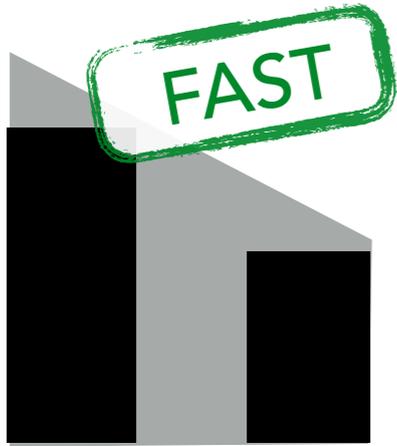
< 100ms



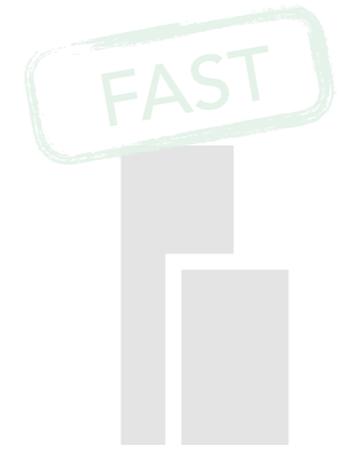
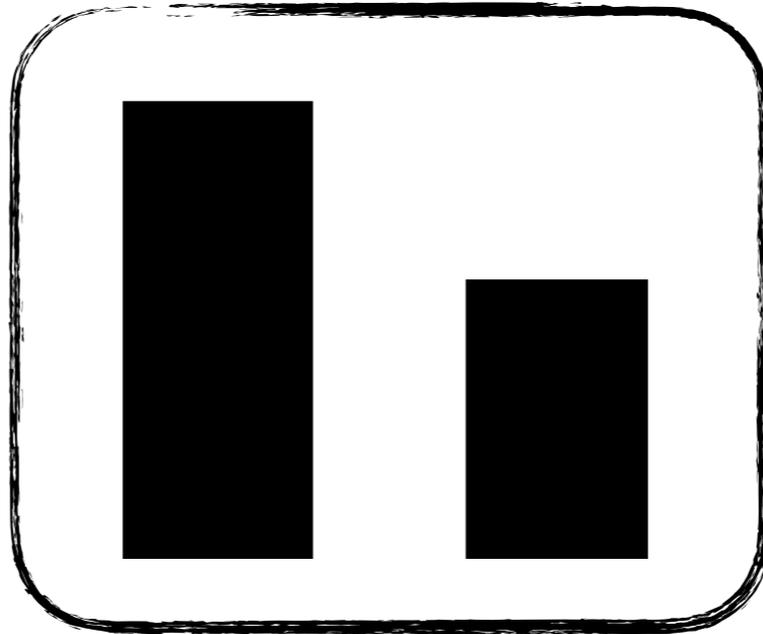
A B C



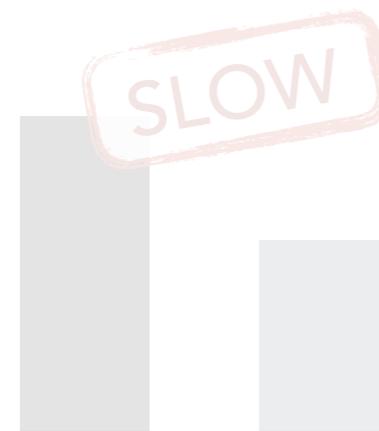




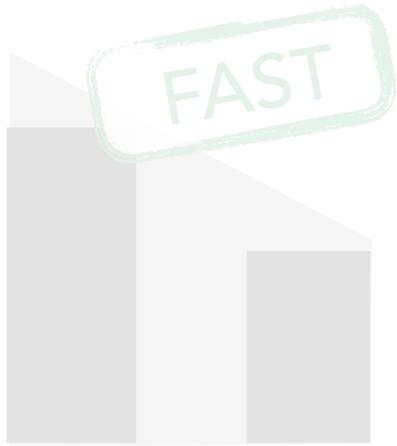
Shape recognition
(Sloped roof)



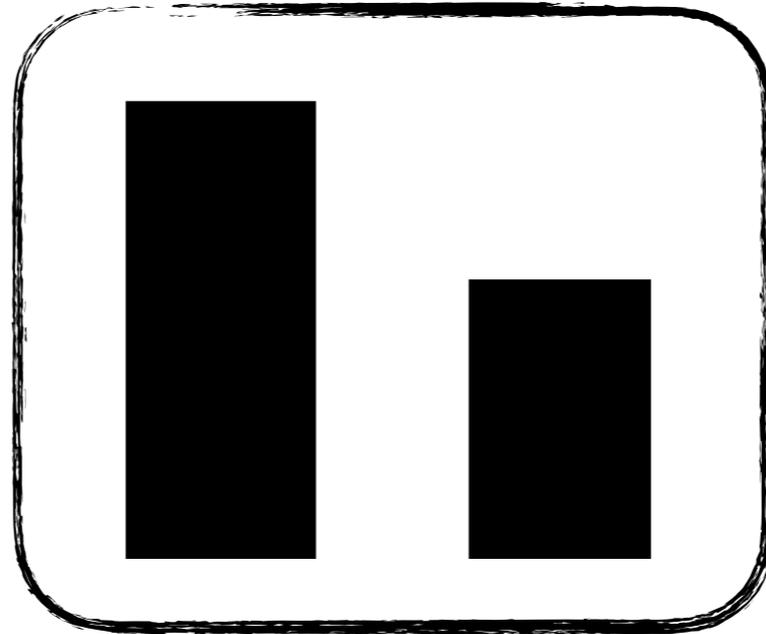
Histograms
(Different sizes)



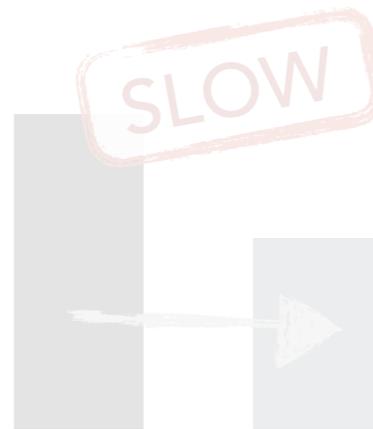
Comparisons
(Left bigger; Right smaller; Right lighter...)



Shape recognition
(Sloped roof)



Histograms
(Different sizes)

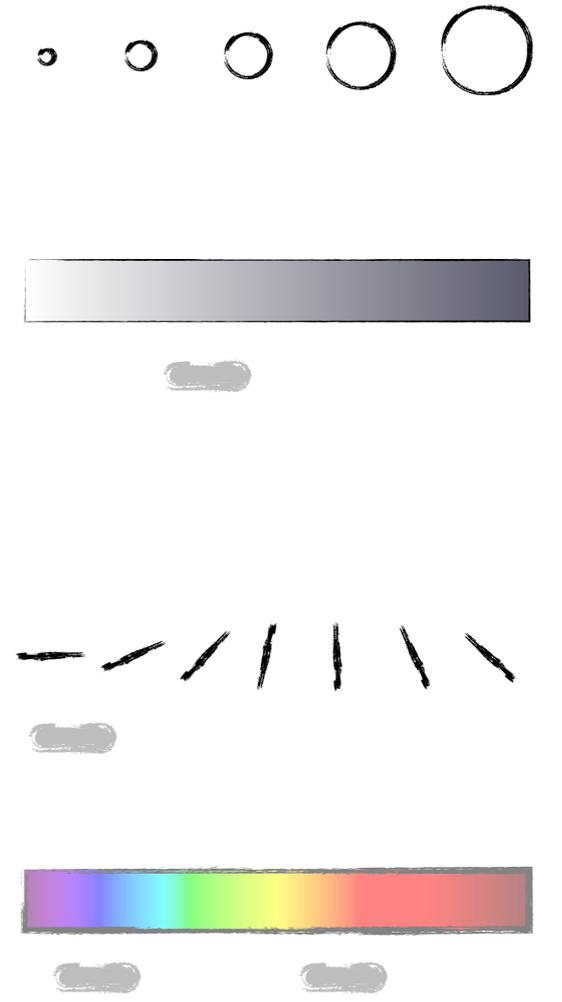
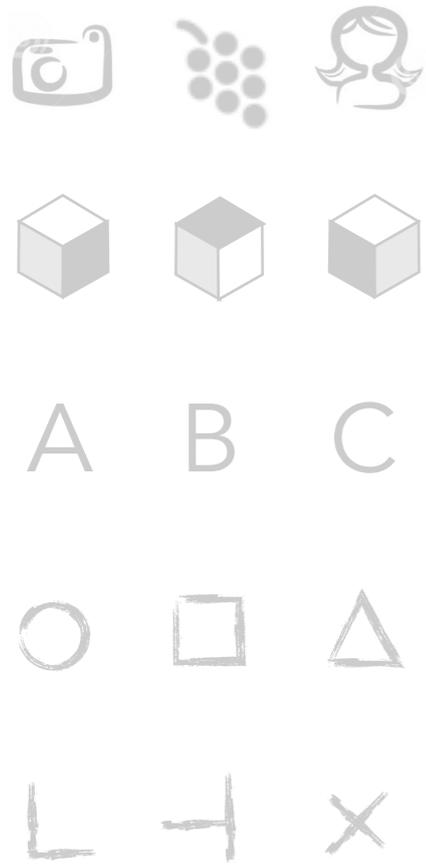


Comparisons
(Left bigger; Right smaller; Right lighter...)

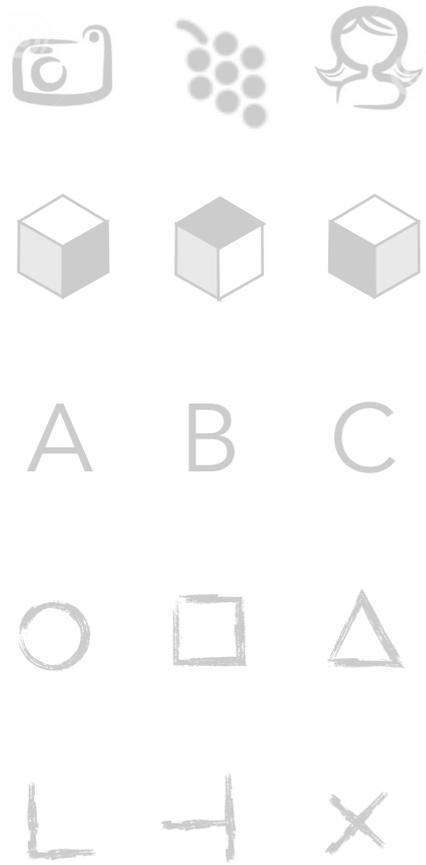


A B C



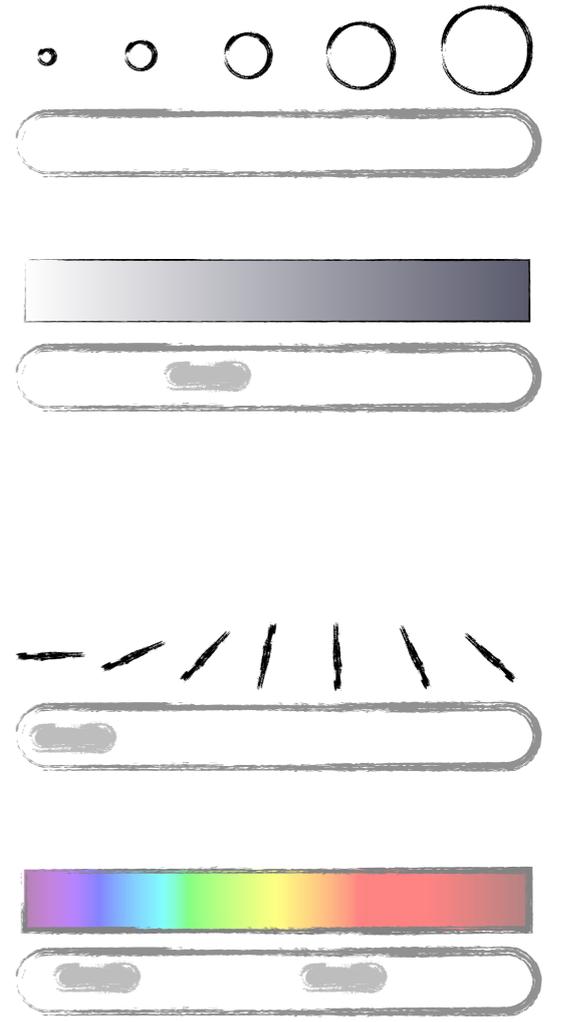


Oliva & Torralba, 2001; Alvarez, 2011;
Whitney, Haberman, & Sweeny, 2014



Beach

< 100ms



object recognition



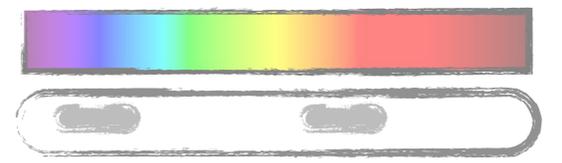
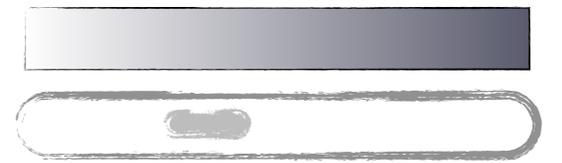
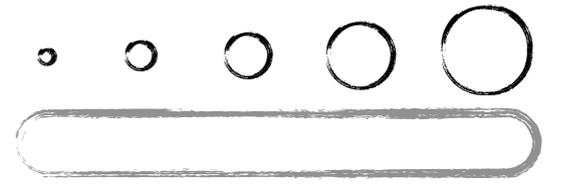
A B C

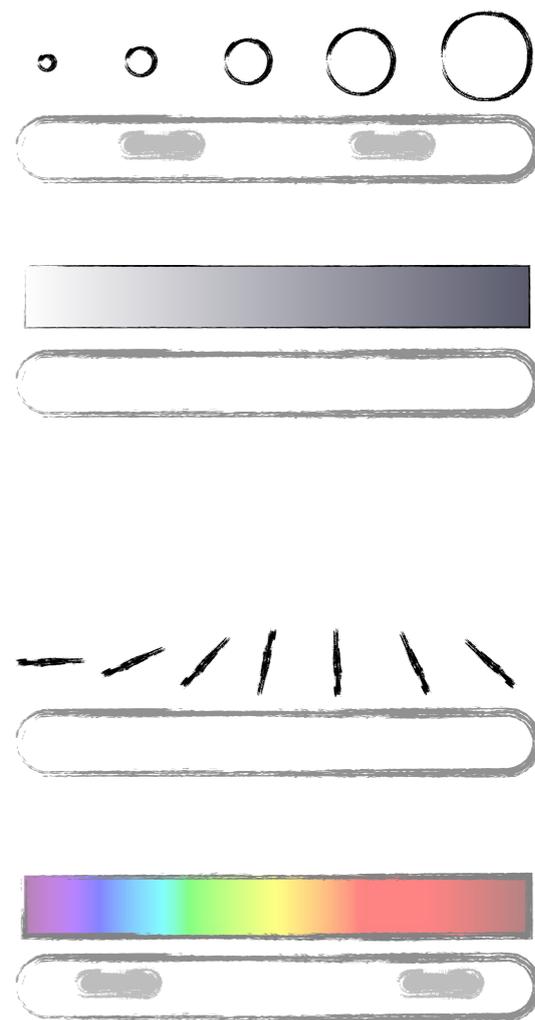
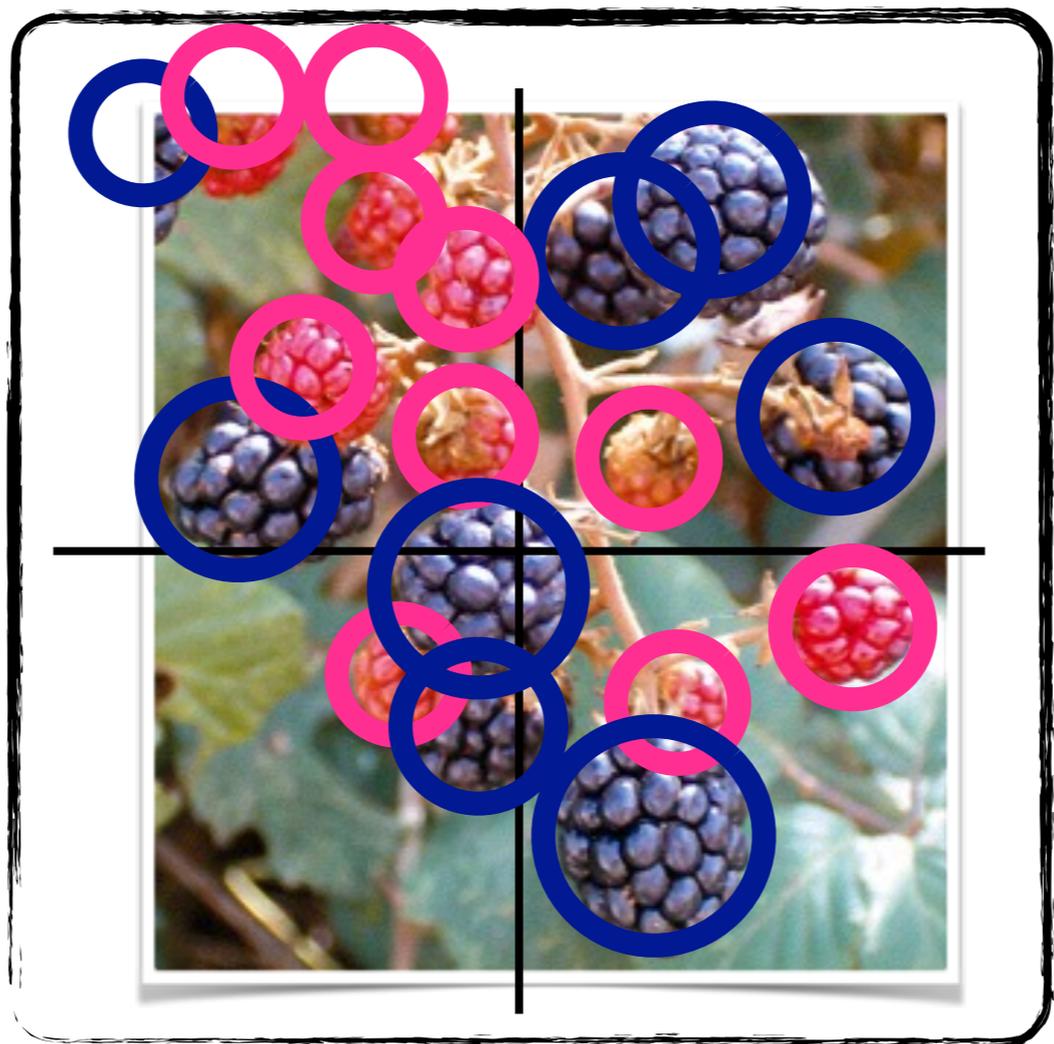
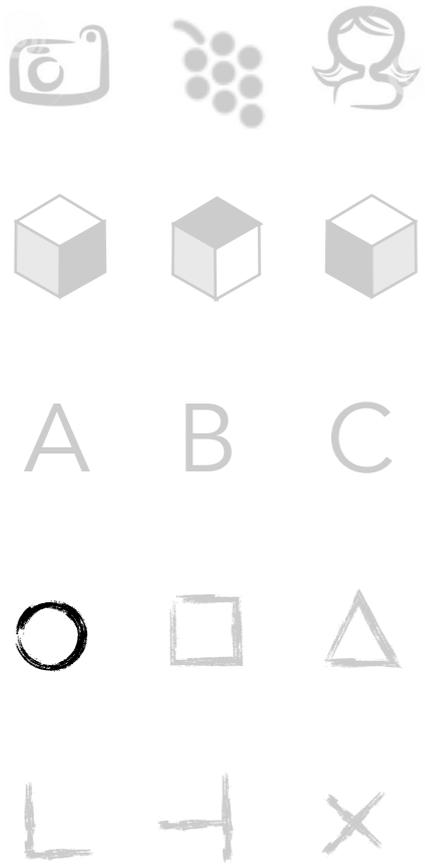


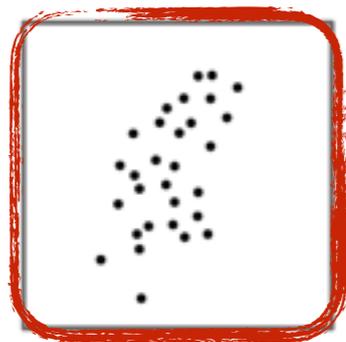
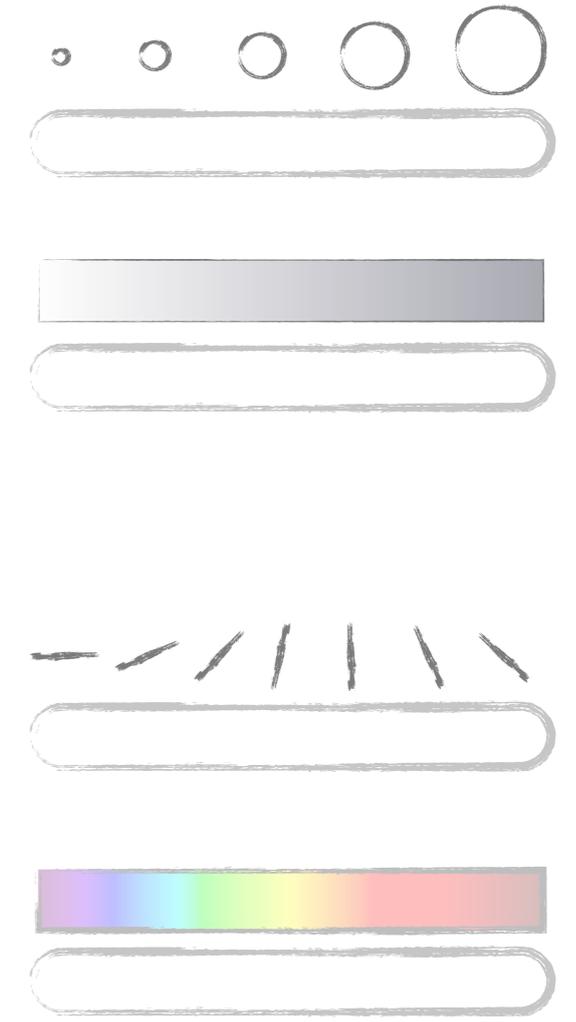
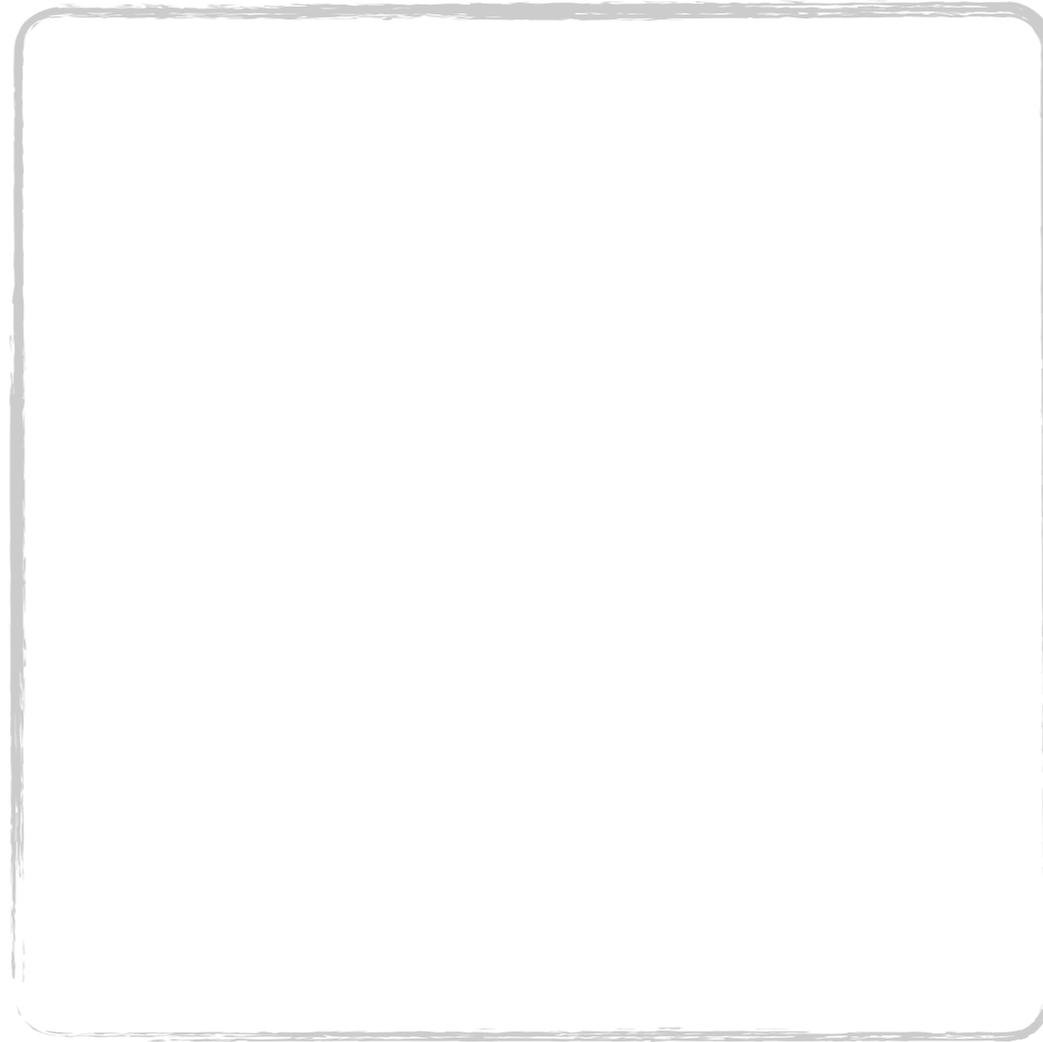
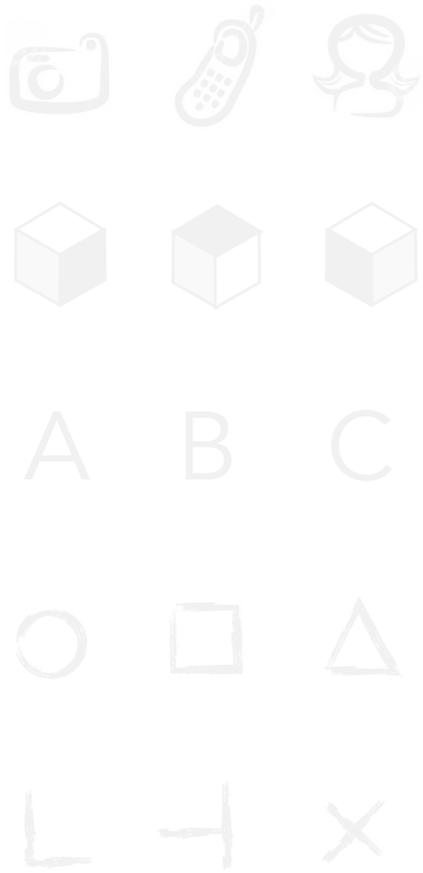
the world



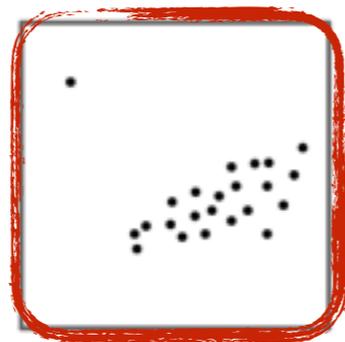
histograms



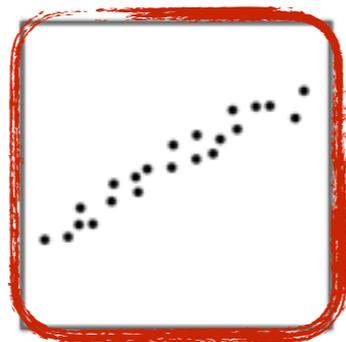




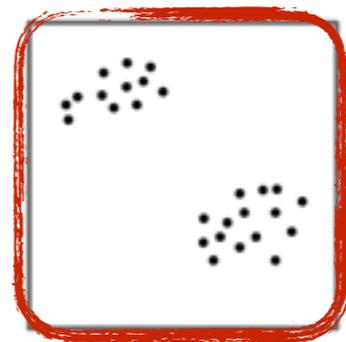
Summary
(Mean)



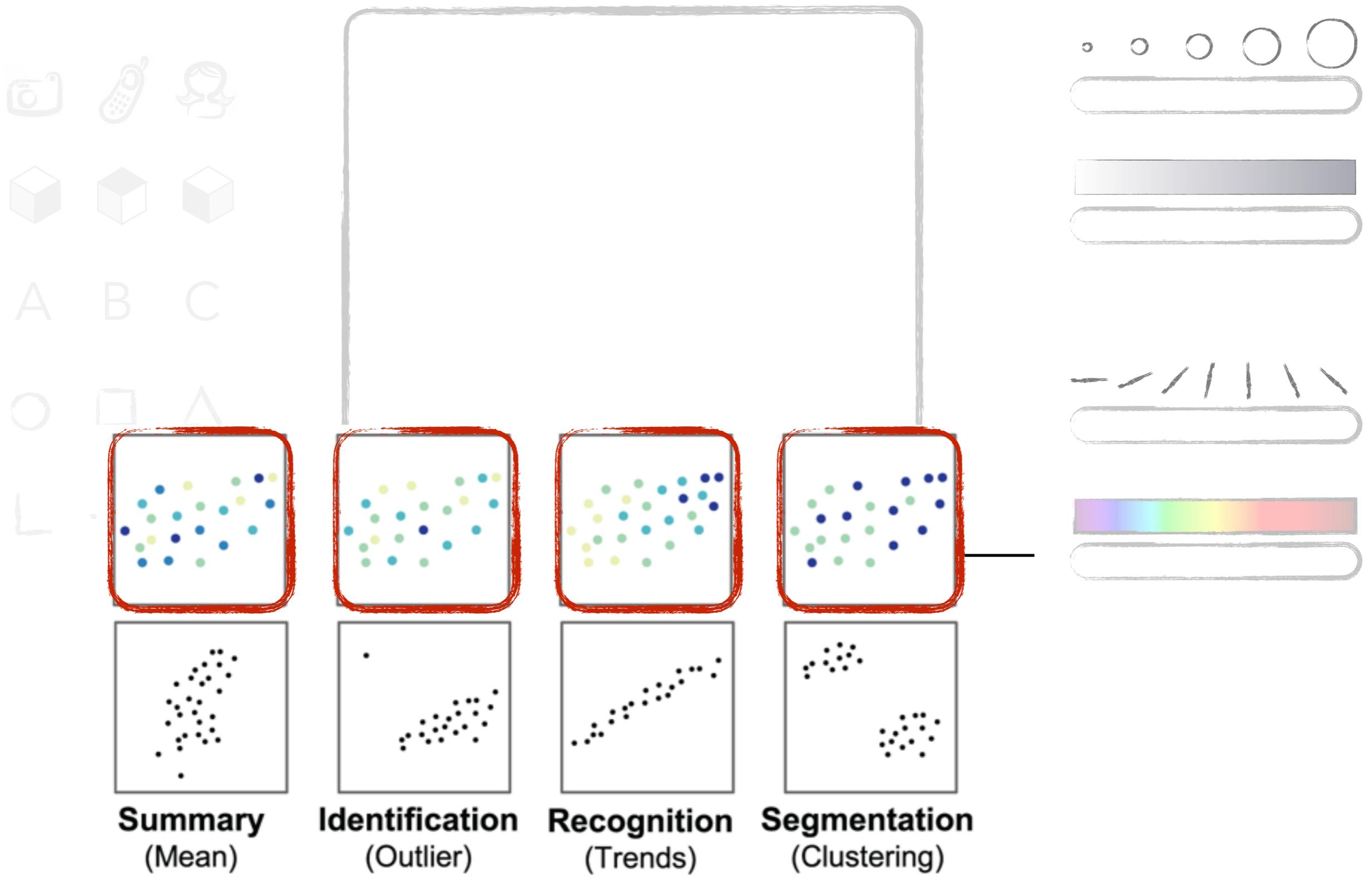
Identification
(Outlier)



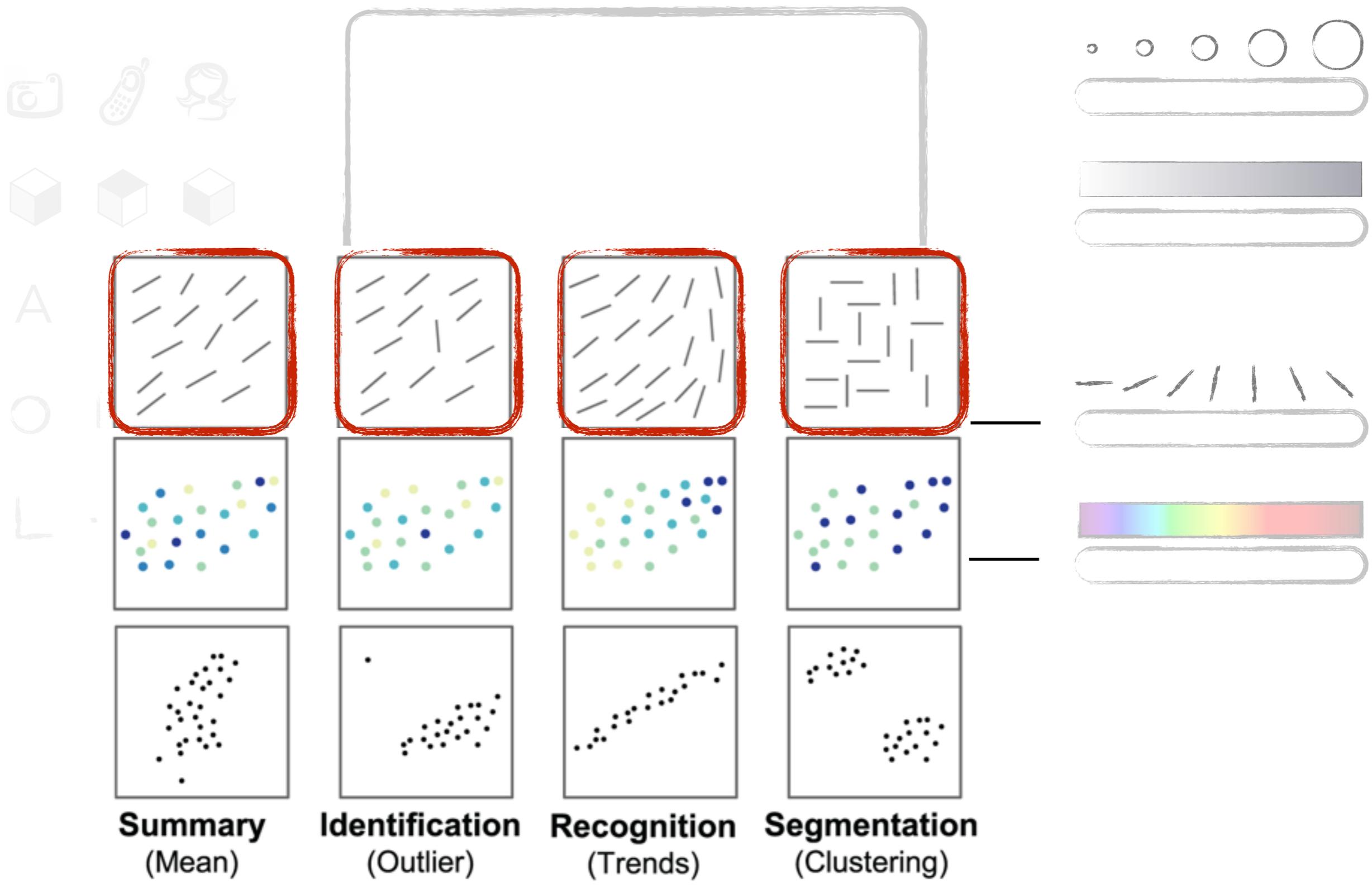
Recognition
(Trends)



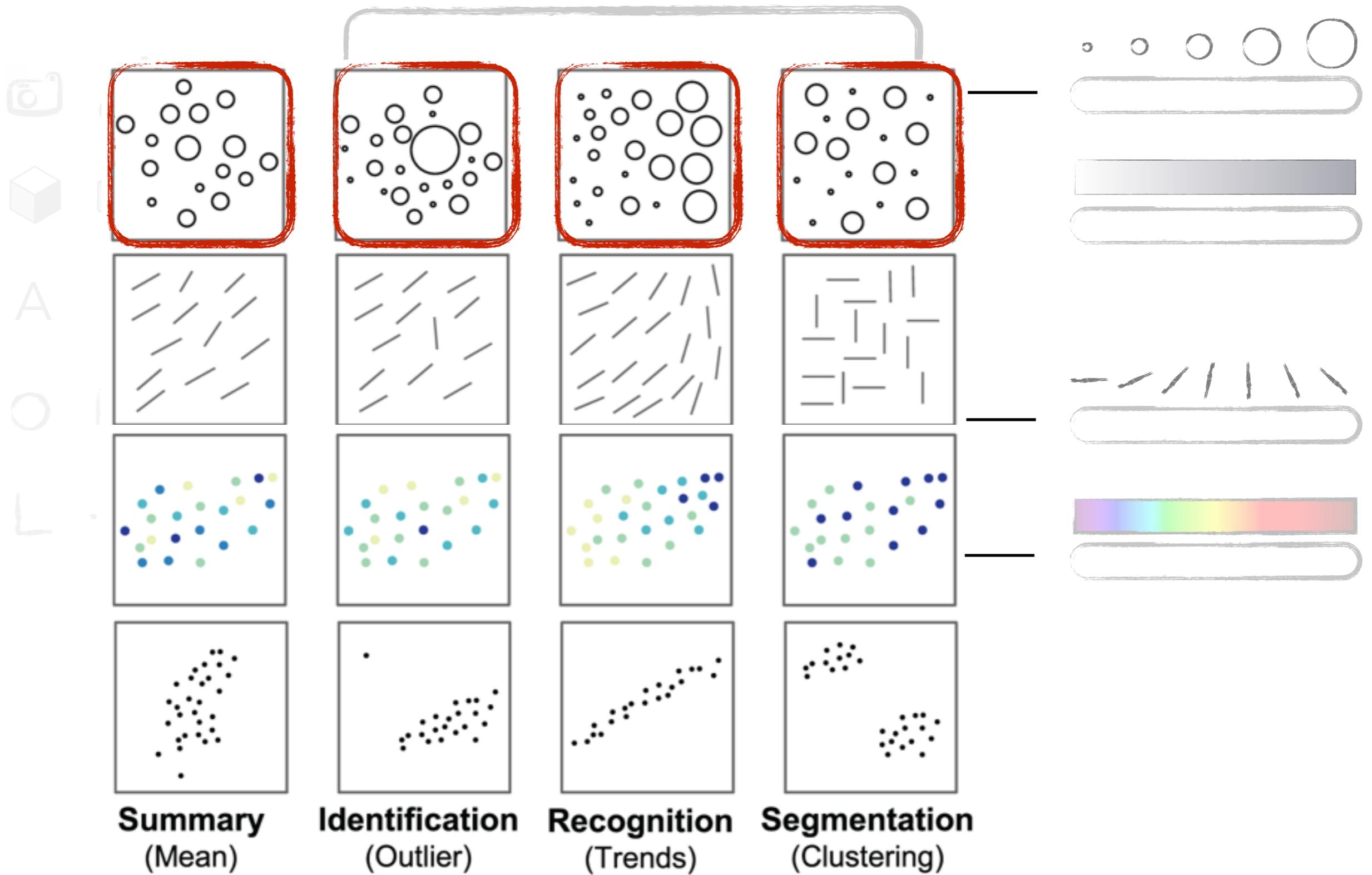
Segmentation
(Clustering)



Szafir, Haroz, Gleicher, & Franconeri, 2015, *Four types of ensemble coding in data visualizations:*



Szafir, Haroz, Gleicher, & Franconeri, 2015, *Four types of ensemble coding in data visualizations:*



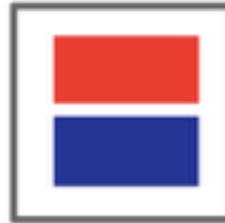
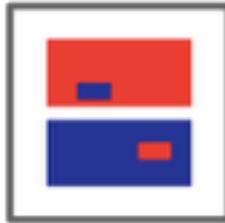
Szafir, Haroz, Gleicher, & Franconeri, 2015, *Four types of ensemble coding in data visualizations*:

Summary
(Numerosity)

Identification
(Outlier)

Pattern Recognition
(Trends)

Segmentation
(Characterization)



But, my dear friends, are you not in Danger of falling into a too thoughtful and gloomy way? By the latter Part of your Letter, we are afraid you are; and my Mamma, and Mrs Jones, and Mrs Peters, injoin me to write, to caution you on that Head. But there is the less need of it, because your Prudence will always suggest to you Reasons, as it does in that very Letter, that must out-balance your Fears. Think little, and hope much, is a good Lesson in your Case, and to a Lack of your Temper, and I hope Lady Davers will not in vain have given you that Caution. After all, I dare say, your Thoughtfulness is but symptomatical, and will go off, in proper Time. Mean time, permit me to choose you a Subject, that will certainly divert you. You must know, that I have been a diligent Observer of the Conduct of People in the married Life to each other, and have often pronounced, that there cannot be any tolerable Happiness in it, unless the one or the other makes such Sacrifices of their Inclinations and Humours, as renders it a State very little desirable to free and generous Minds. Of this I see an instance in our own Family, for though my Papa and Mamma live very happily, it is all

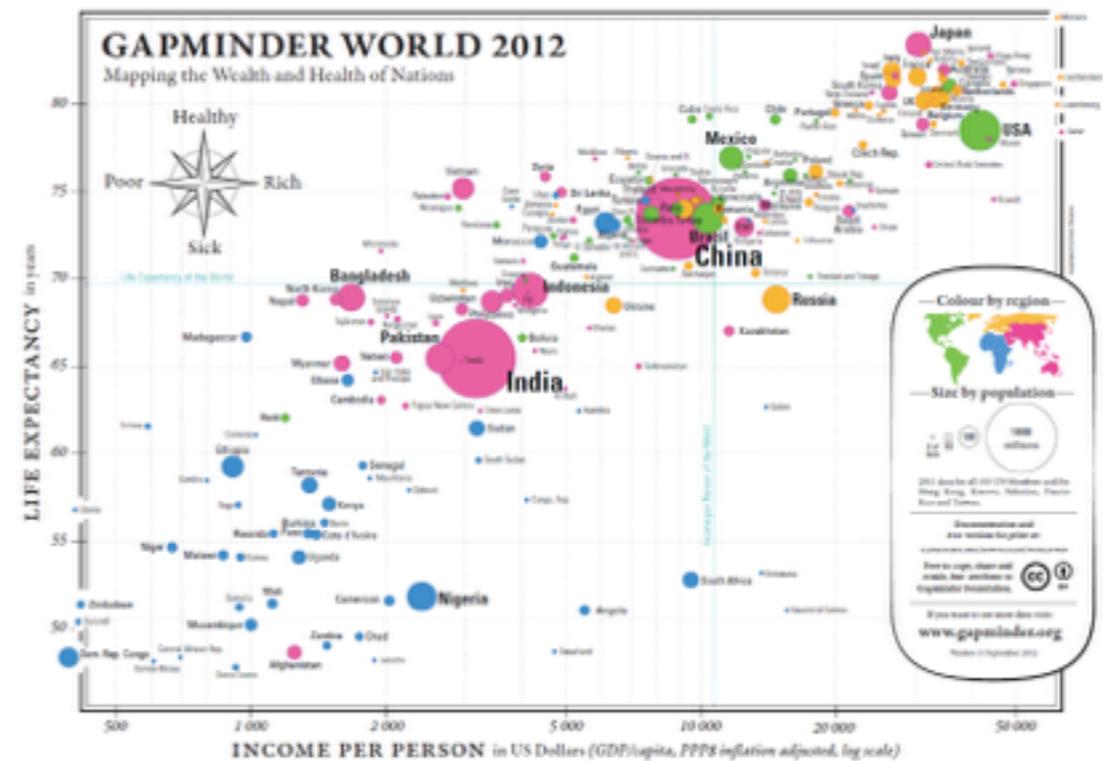
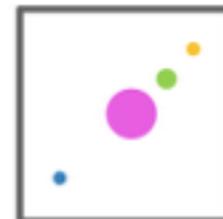
Our Contempt for the folly of the agent hinders us from thoroughly entering into the gratitude of the person to whom the good office has been done. His been-factor seems unworthy of it. As when we place ourselves in the situation of the person obliged, we feel that we could conceive no great reverence for such a benefactor, we easily absolve him from a great deal of that submissive veneration and esteem which we should think due to a more respectable character; and provided he always treats his weak friend with kindness and humanity, we are willing to excuse him from many attentions and regards which we should demand to a worthier patron. Those Princes, who have heaped, with the greatest profusion, wealth, power, and honours, upon their favourites, have seldom excited that degree of attachment to their persons which has often been experienced by those who were more frugal of their favours. The well-natured, but injudicious prodigality, of James the First of Great Britain seems to have attached no body to his person; and that Prince, notwithstanding his social and harmless disposition, appears to have lived and died without a friend. The whole gentry

Summary
(Mean)

Identification
(Maxima)

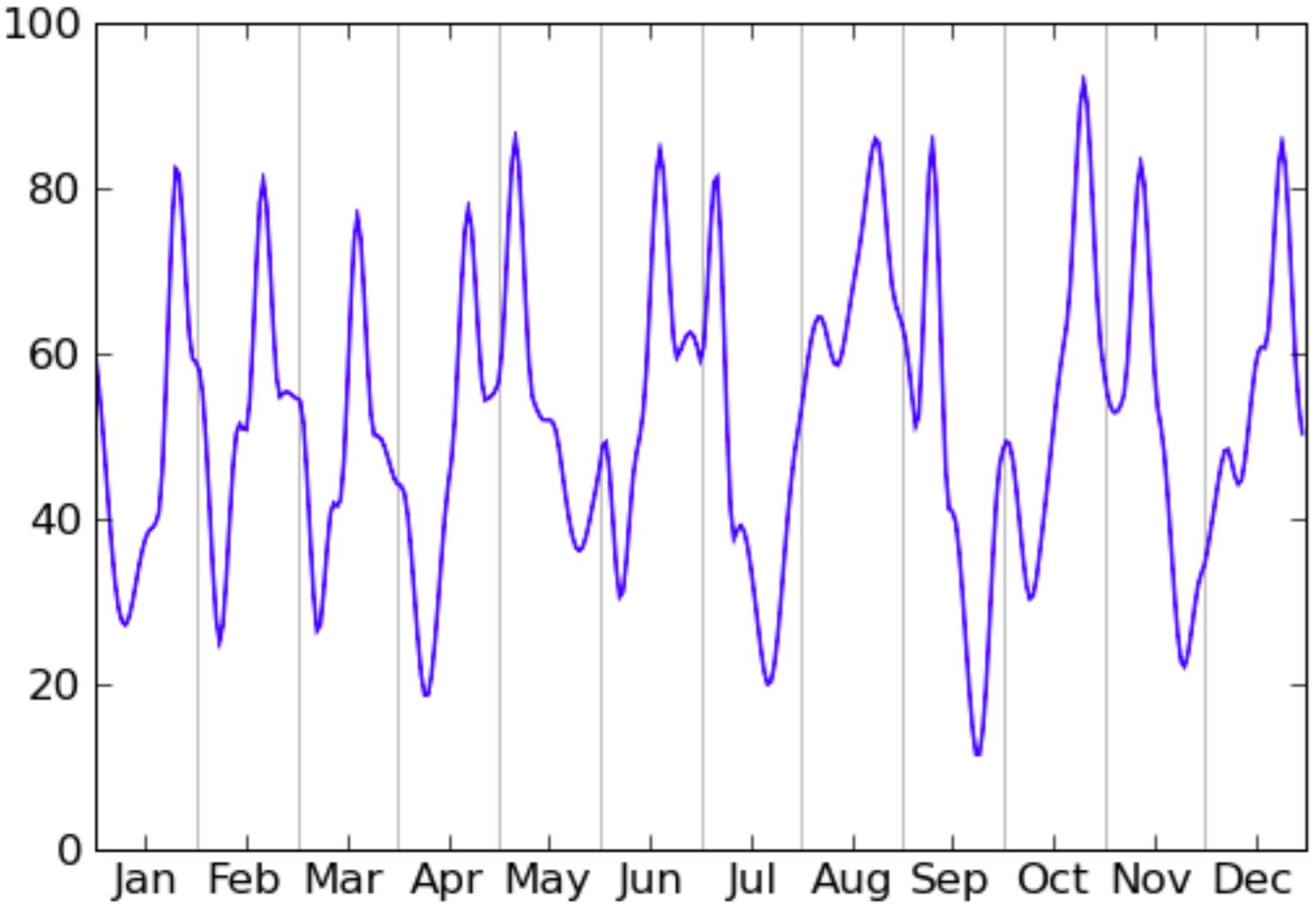
Pattern Recognition
(Correlation)

Segmentation
(Clustering)



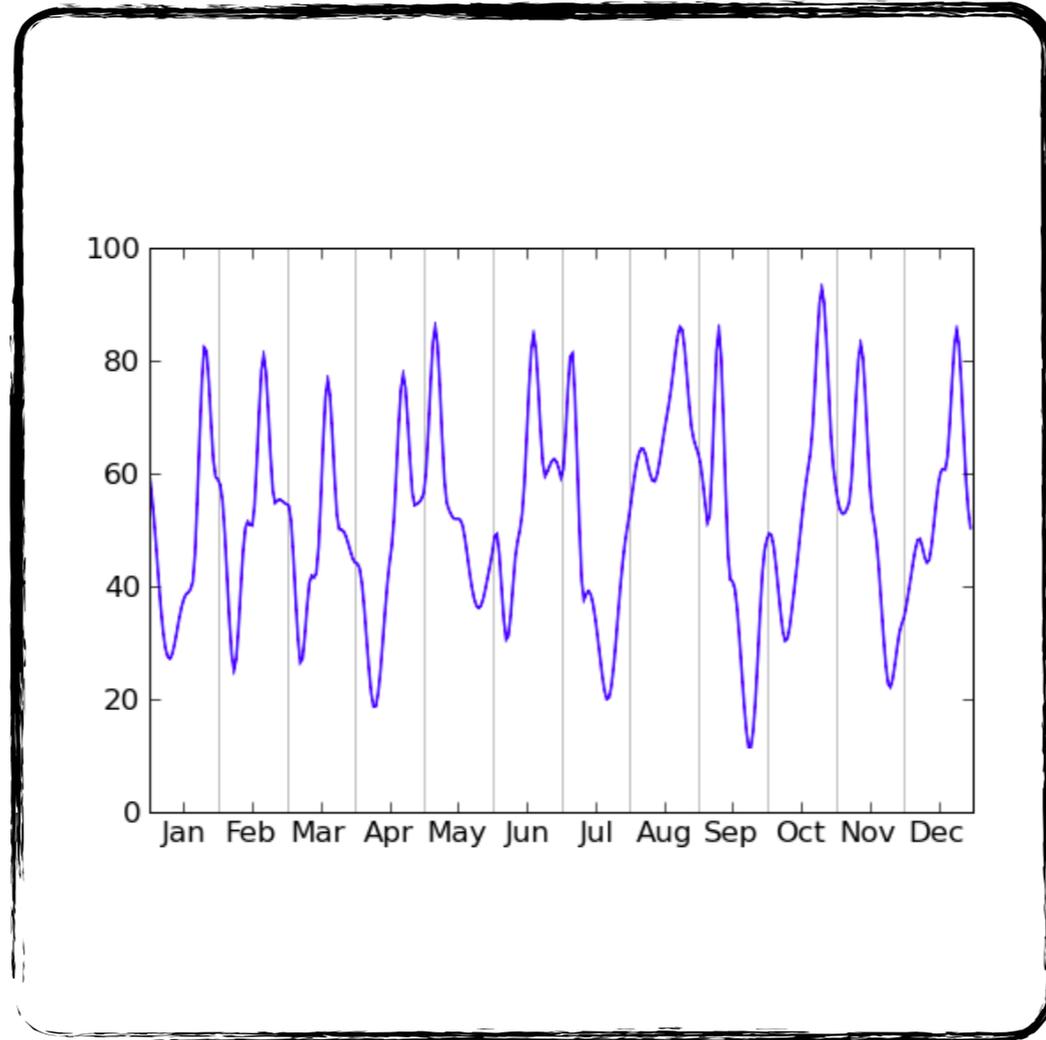


Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec





A B C



s

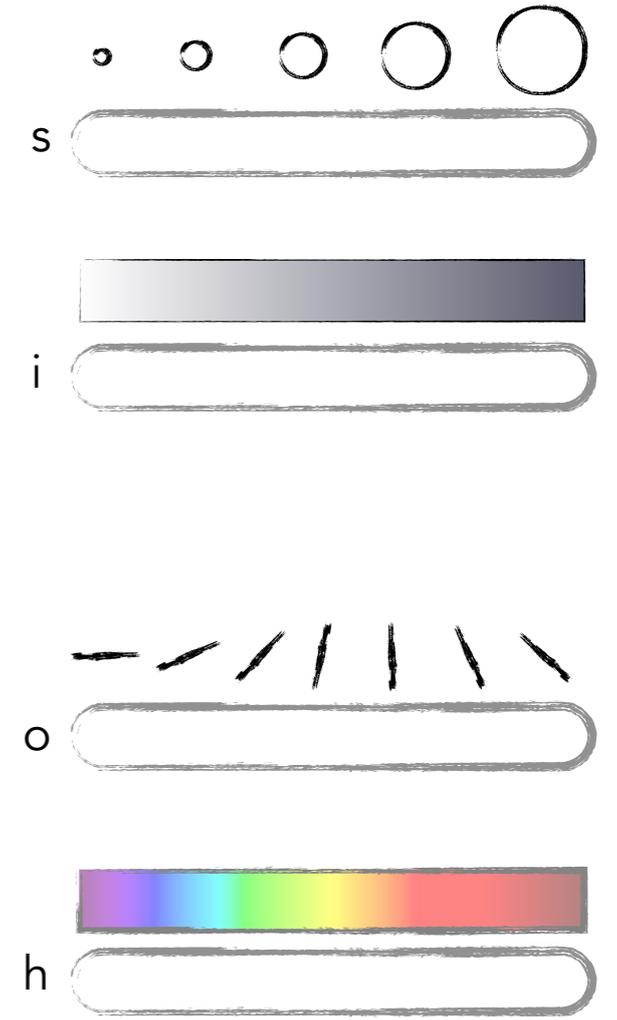
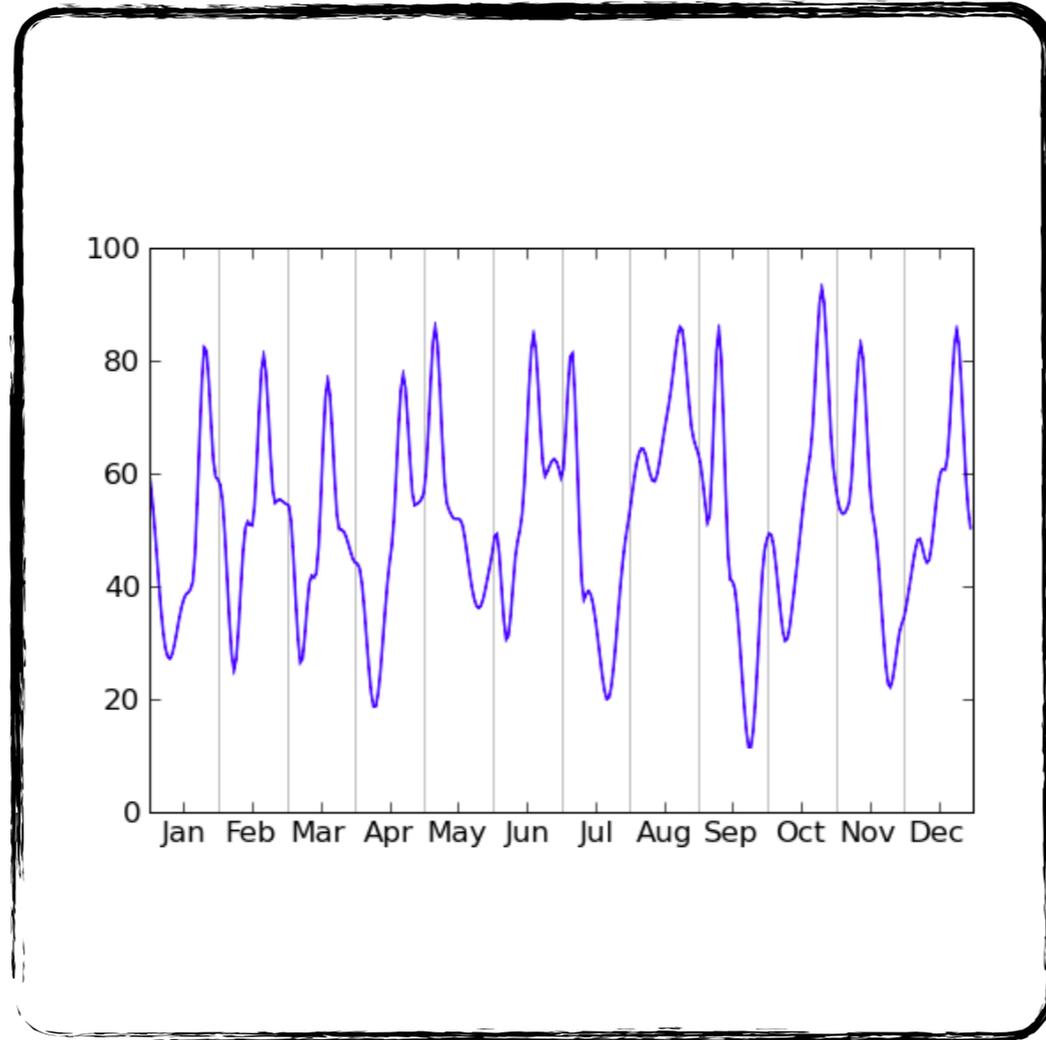
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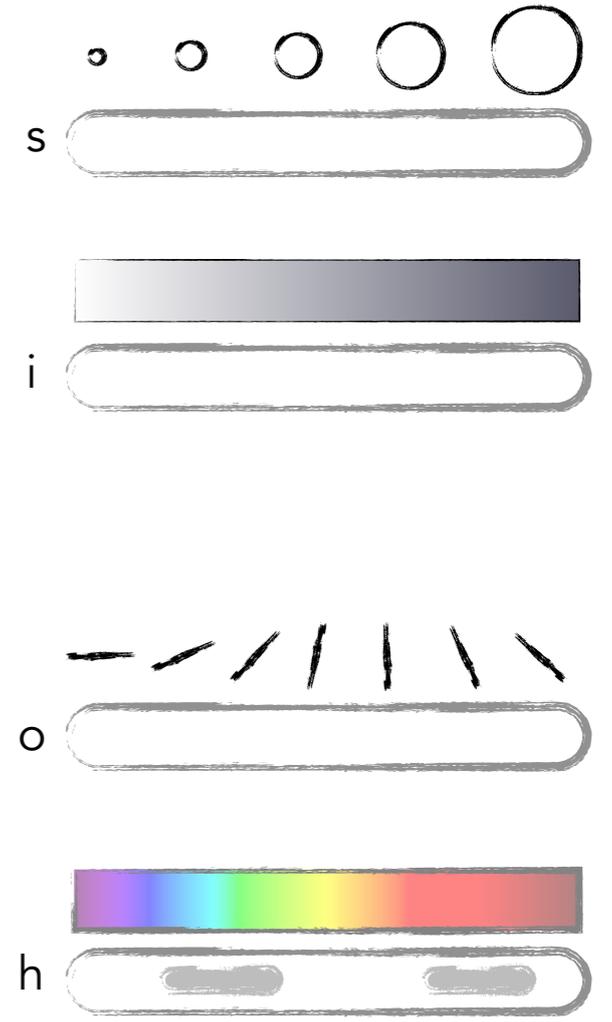
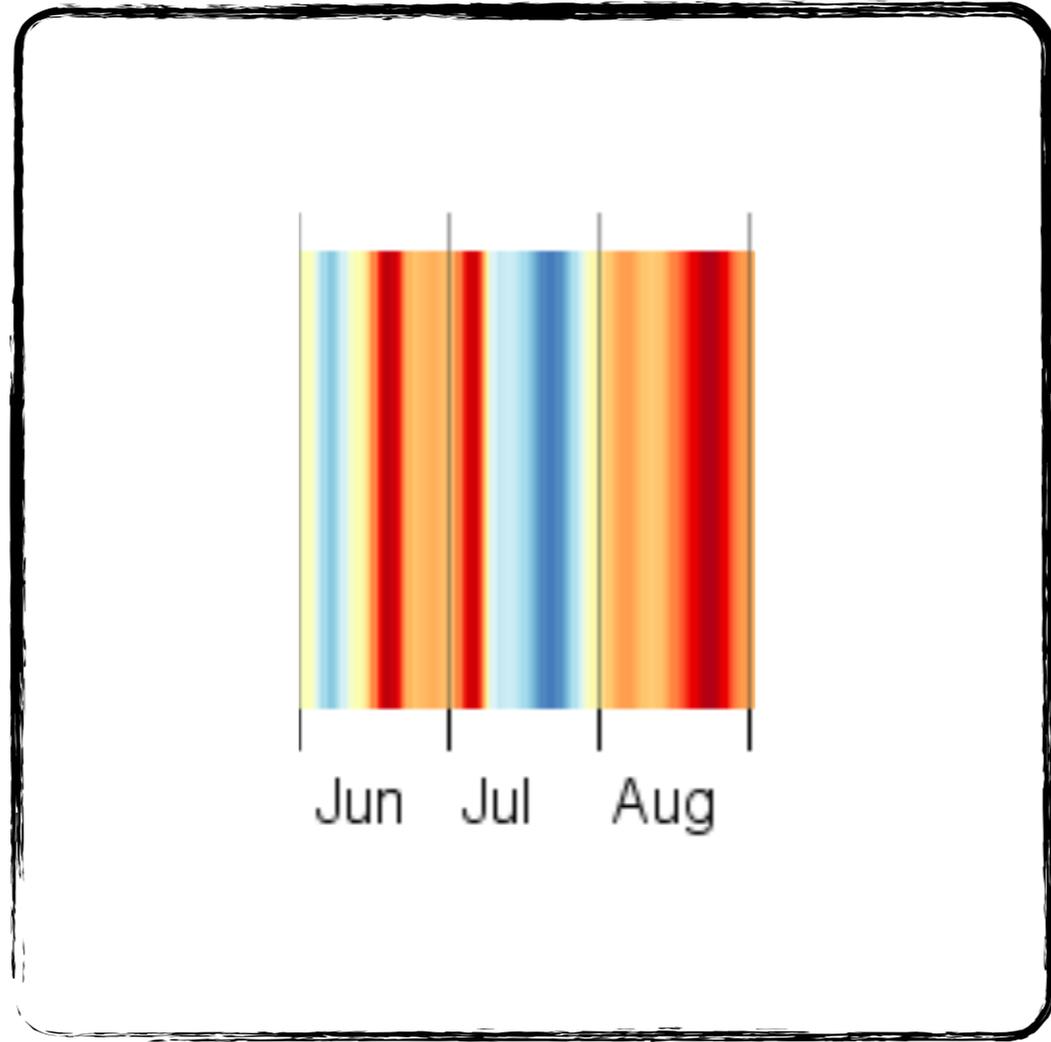
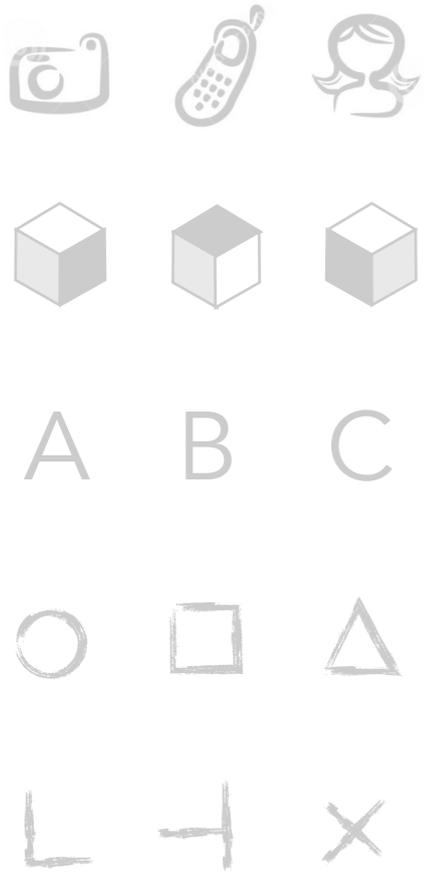
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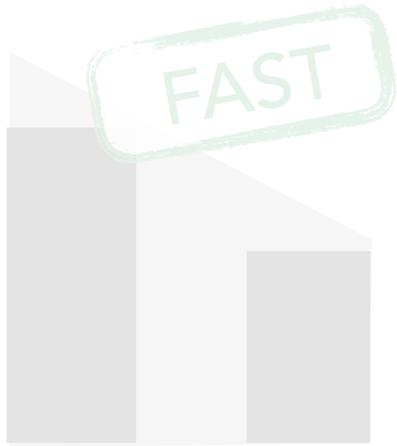
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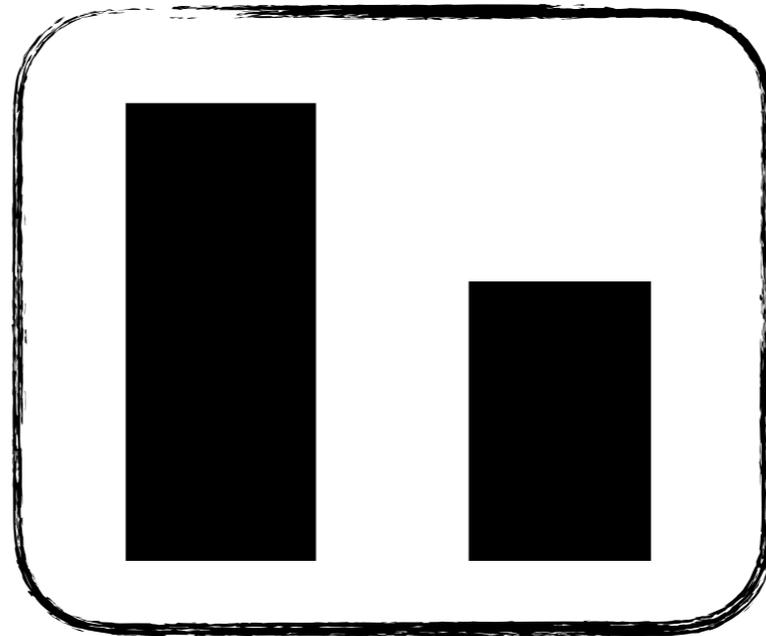
A B C



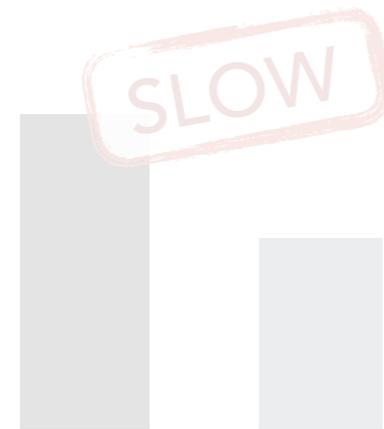




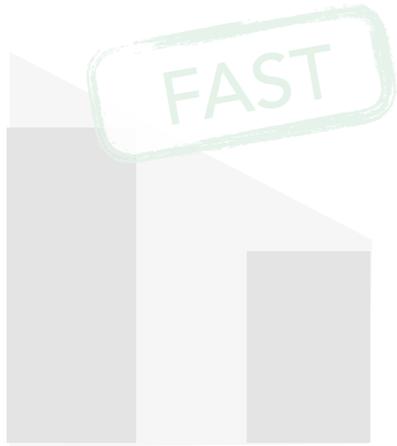
Shape recognition
(Sloped roof)



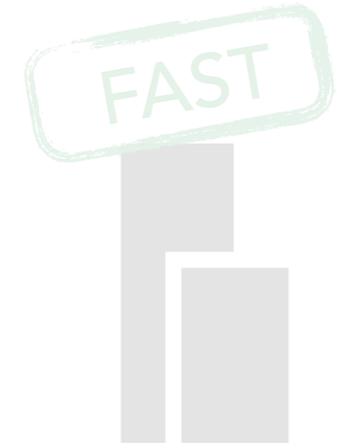
Histograms
(Different sizes)



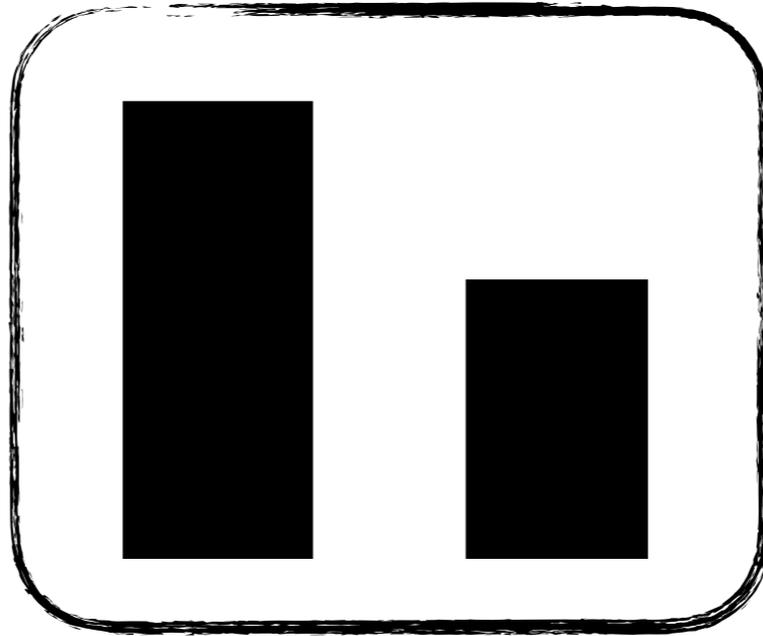
Comparisons
(Left bigger; Right smaller; Right lighter...)



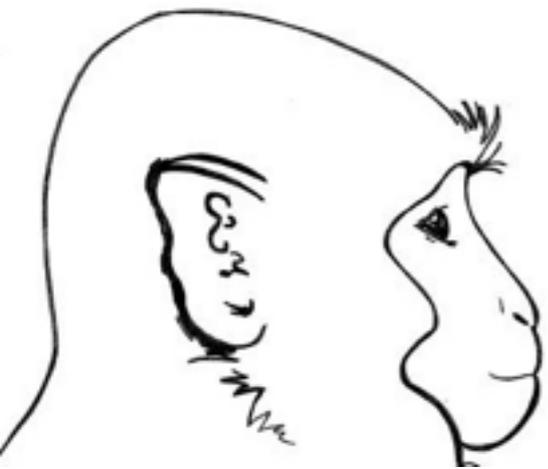
Shape recognition
(Sloped roof)



Histograms
(Different sizes)



(??)

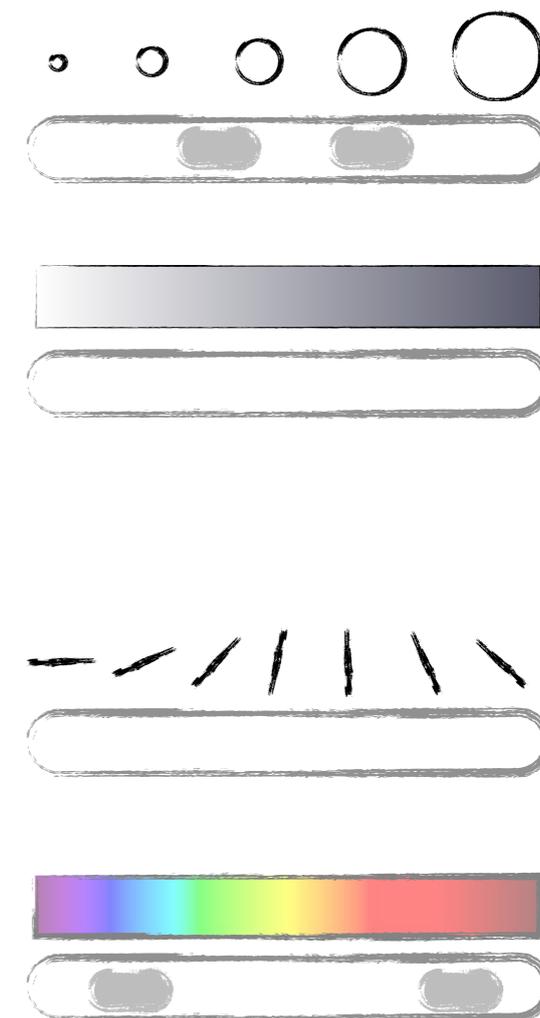
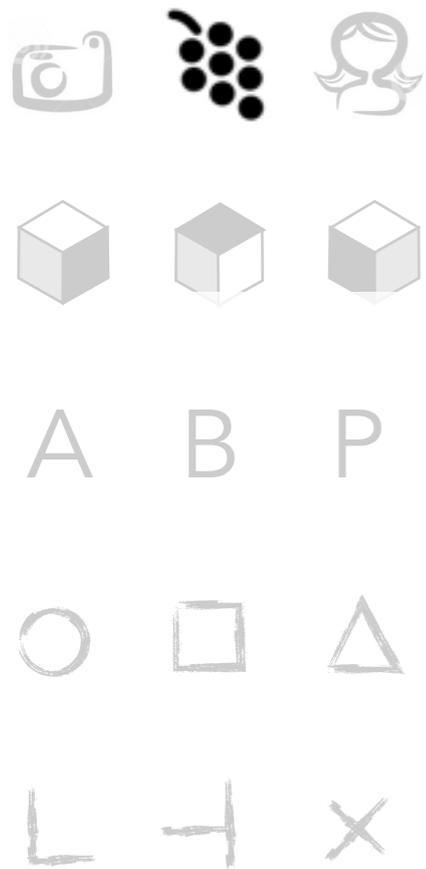


SLOW



Comparisons
(Left bigger; Right smaller; Right lighter...)

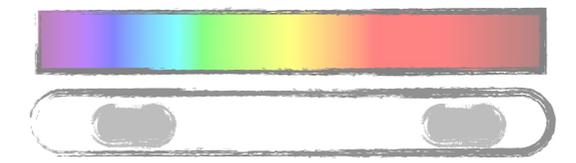
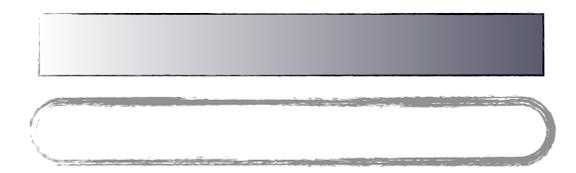
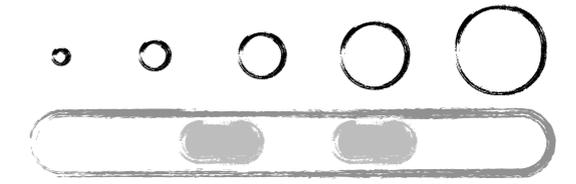




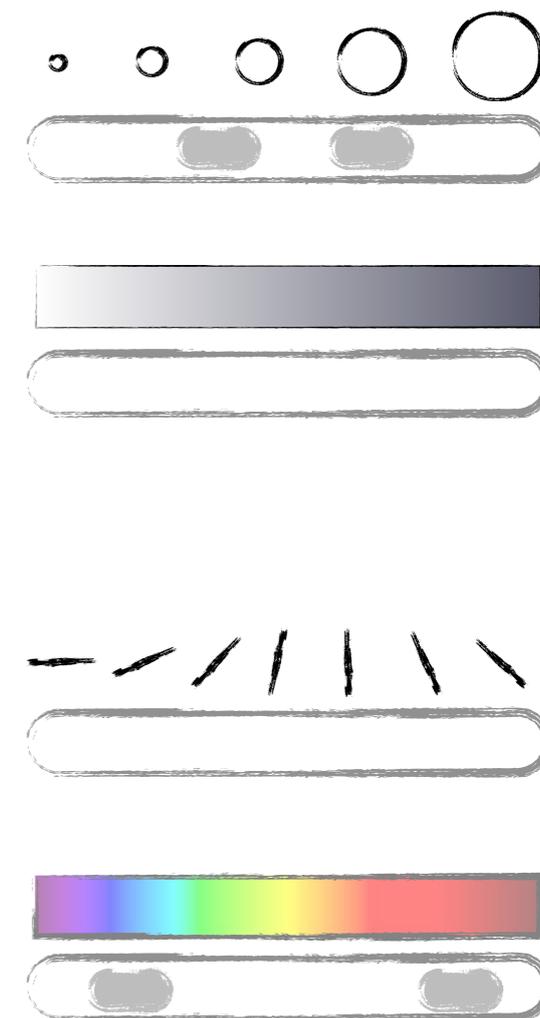
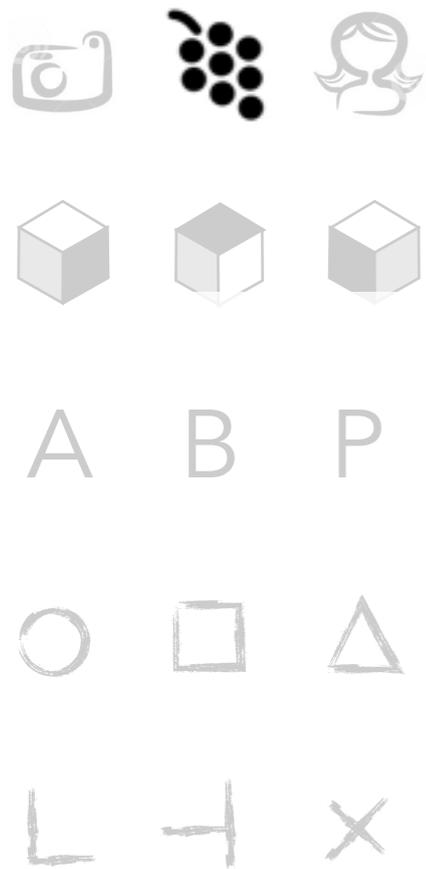
Hummel & Biederman, 1992, *Psych Review*
Holcombe, 2009, *TICS*
Hummel, 2011, *Connection Science*
Franconeri, et al., 2012, *Cognition*



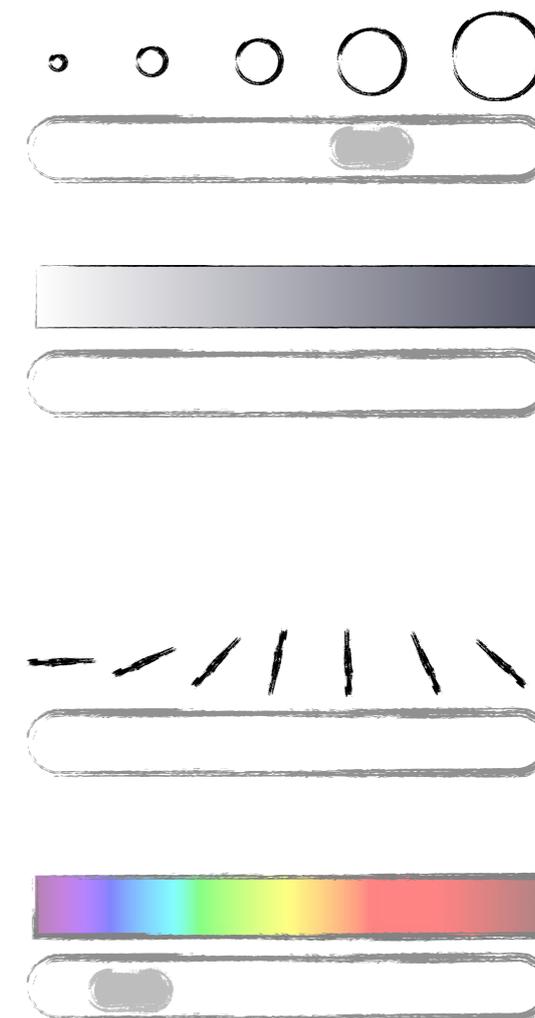
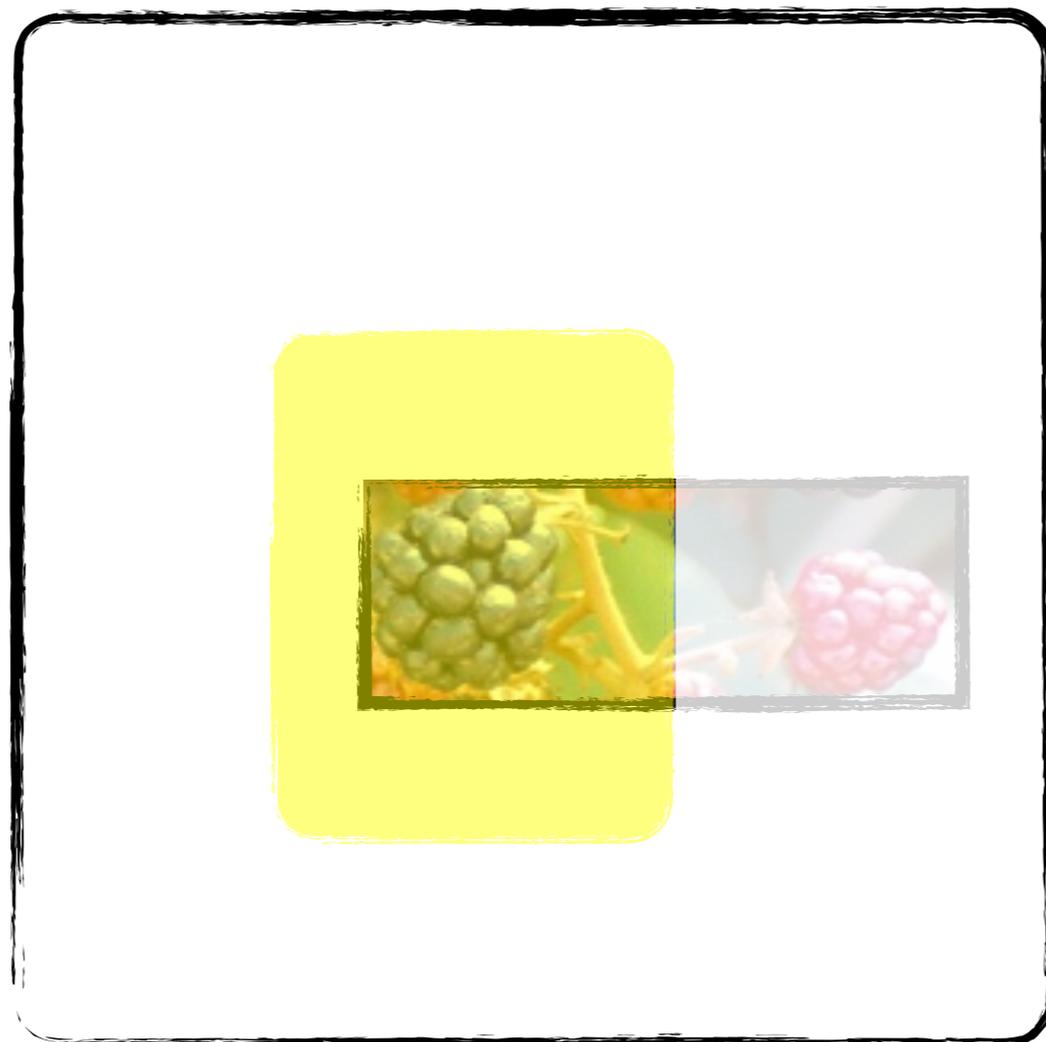
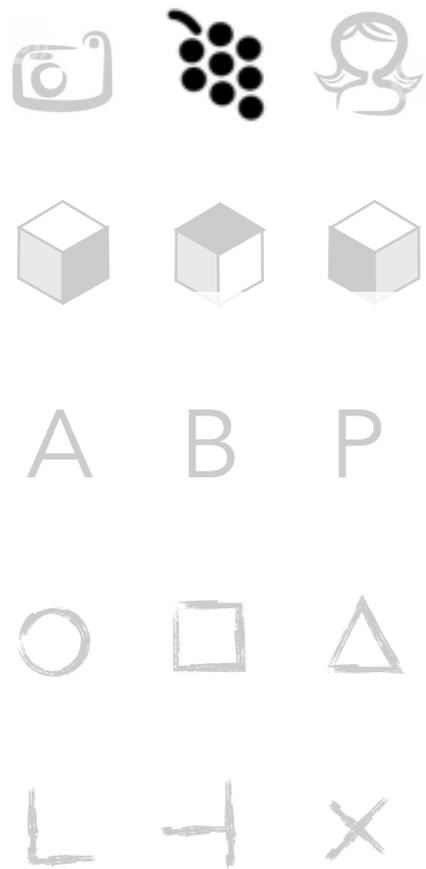
A B P



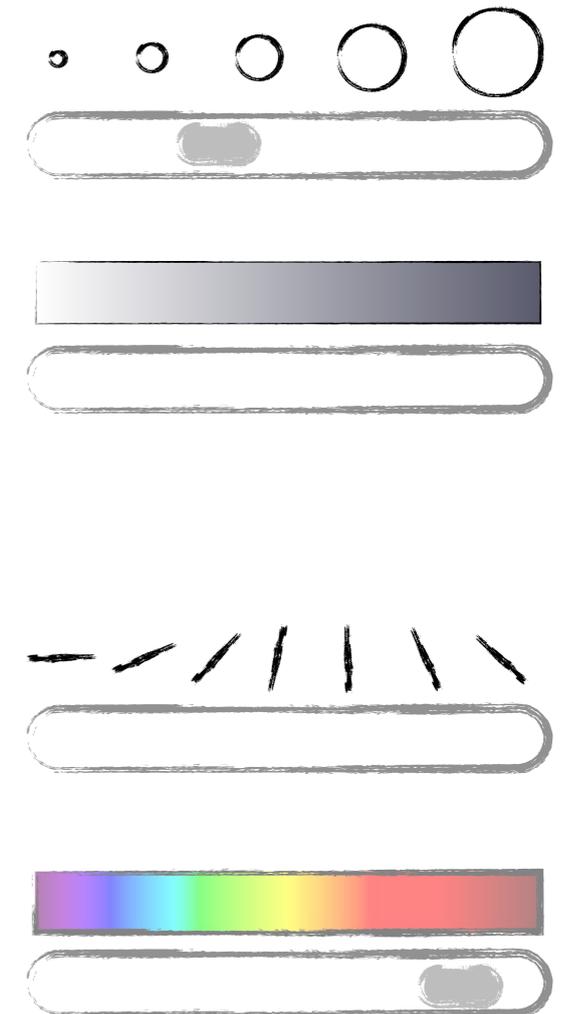
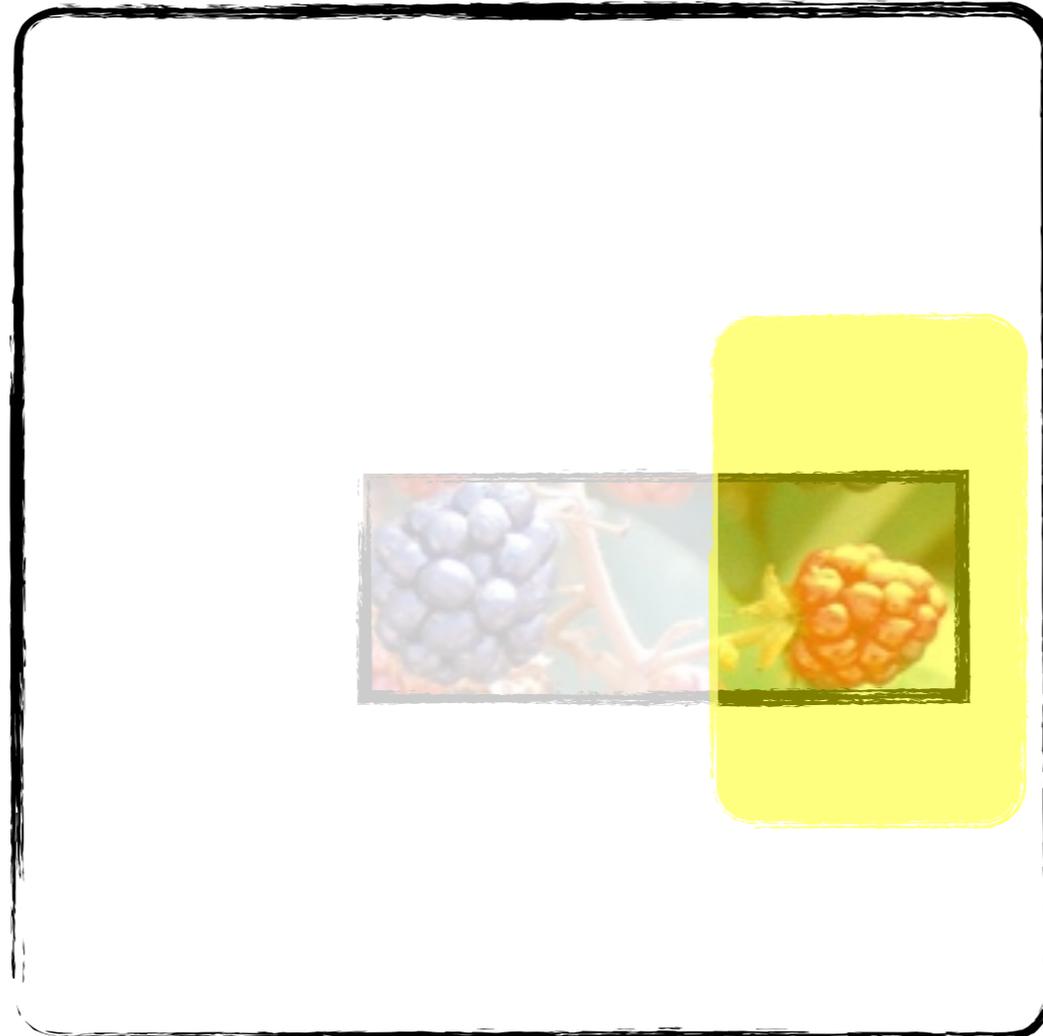
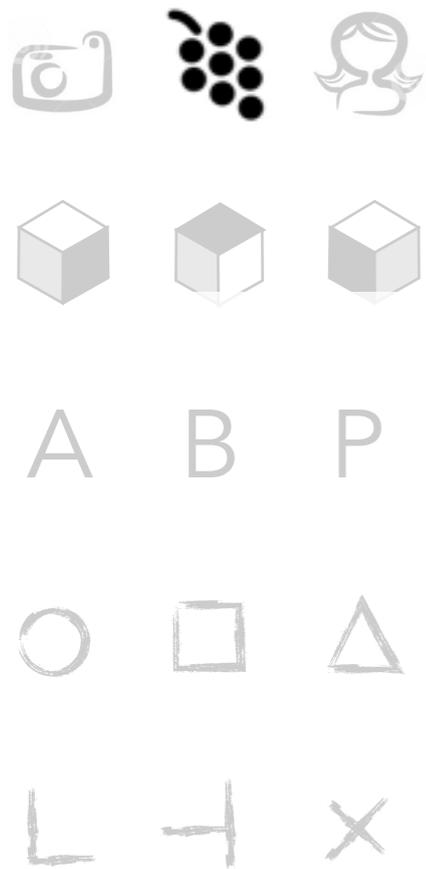
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Hummel & Biederman, 1992, *Psych Review*
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Hummel, 2011, *Connection Science*
Franconeri, et al., 2012, *Cognition*



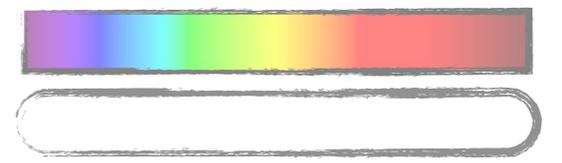
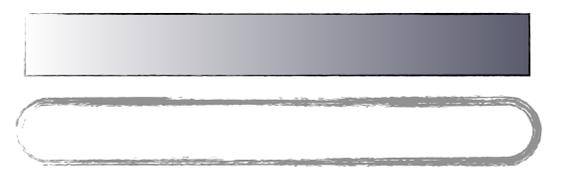
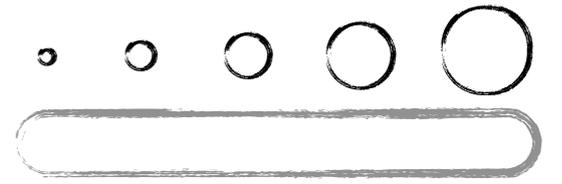
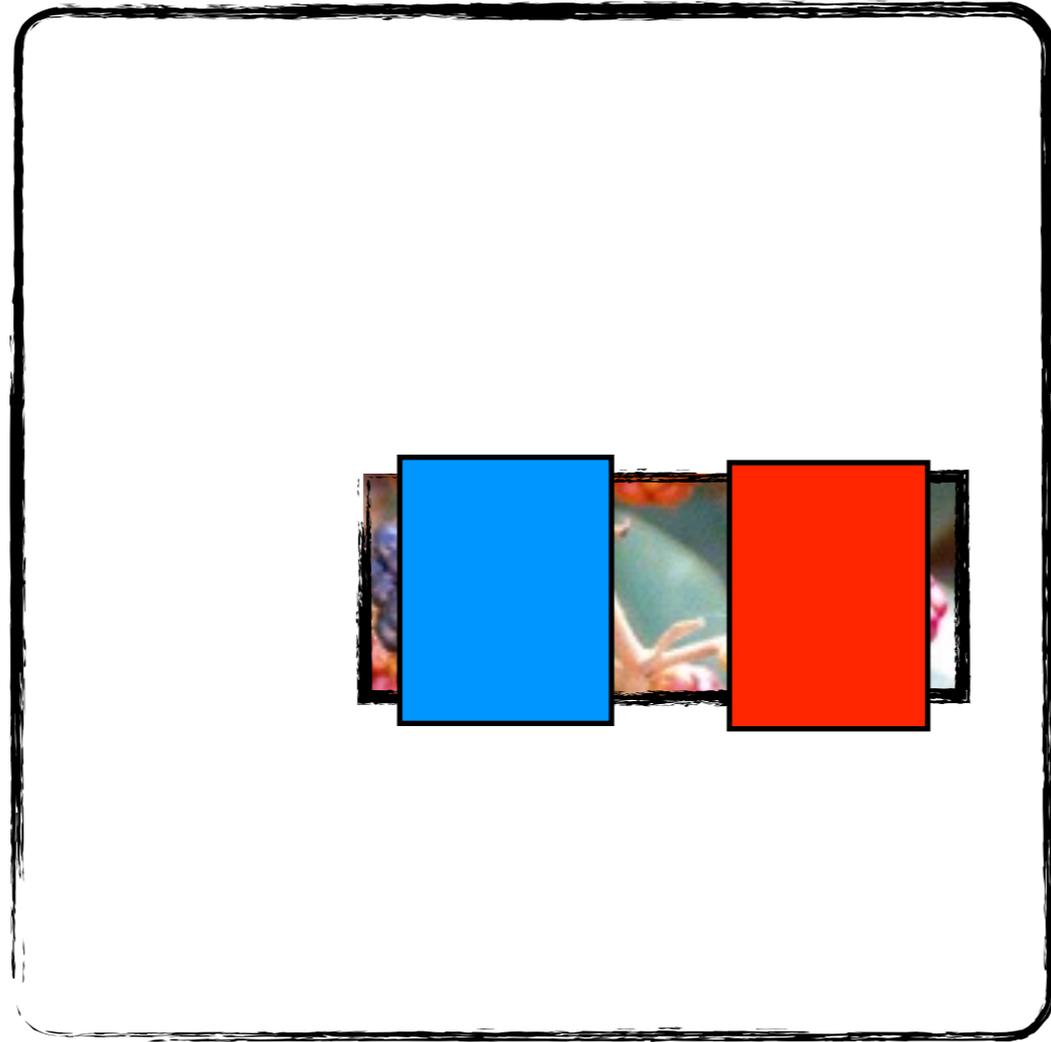
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Hummel, 2011, *Connection Science*
Franconeri, et al., 2012, *Cognition*



Hummel & Biederman, 1992, *Psych Review*
Holcombe, 2009, *TICS*
Hummel, 2011, *Connection Science*
Franconeri, et al., 2012, *Cognition*

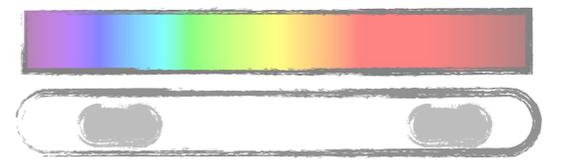
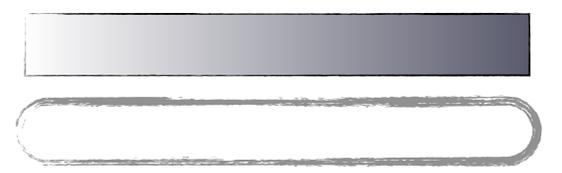
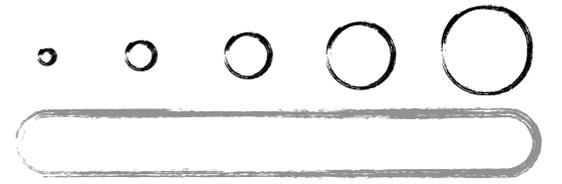
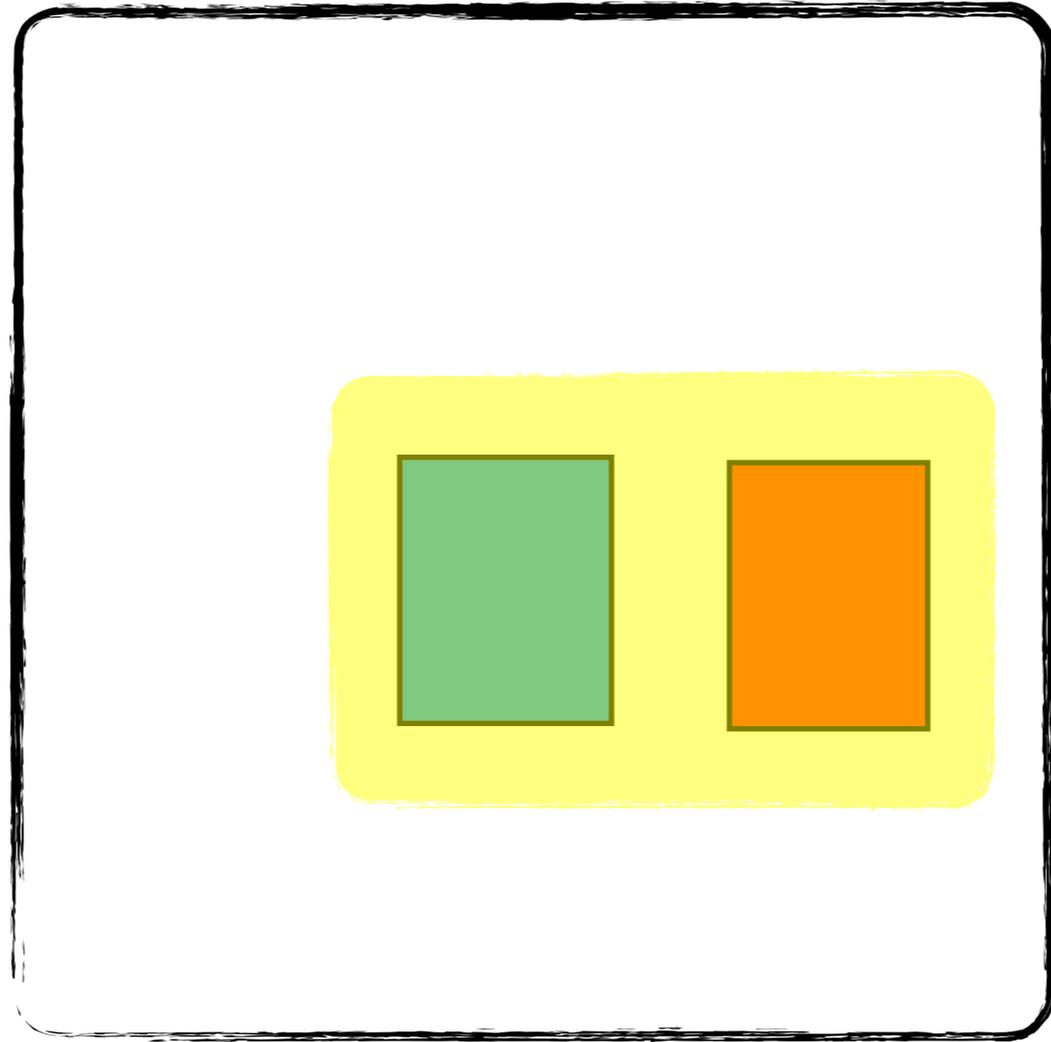


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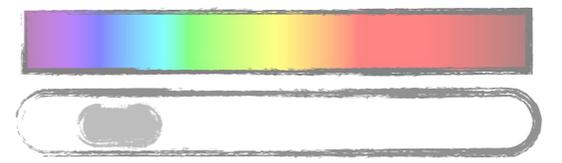
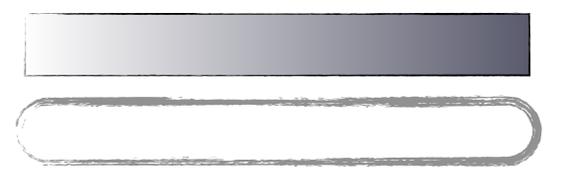
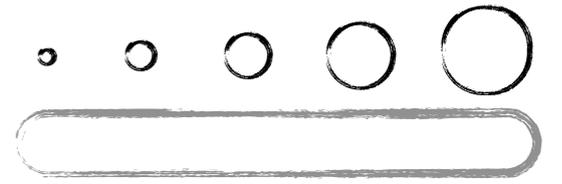
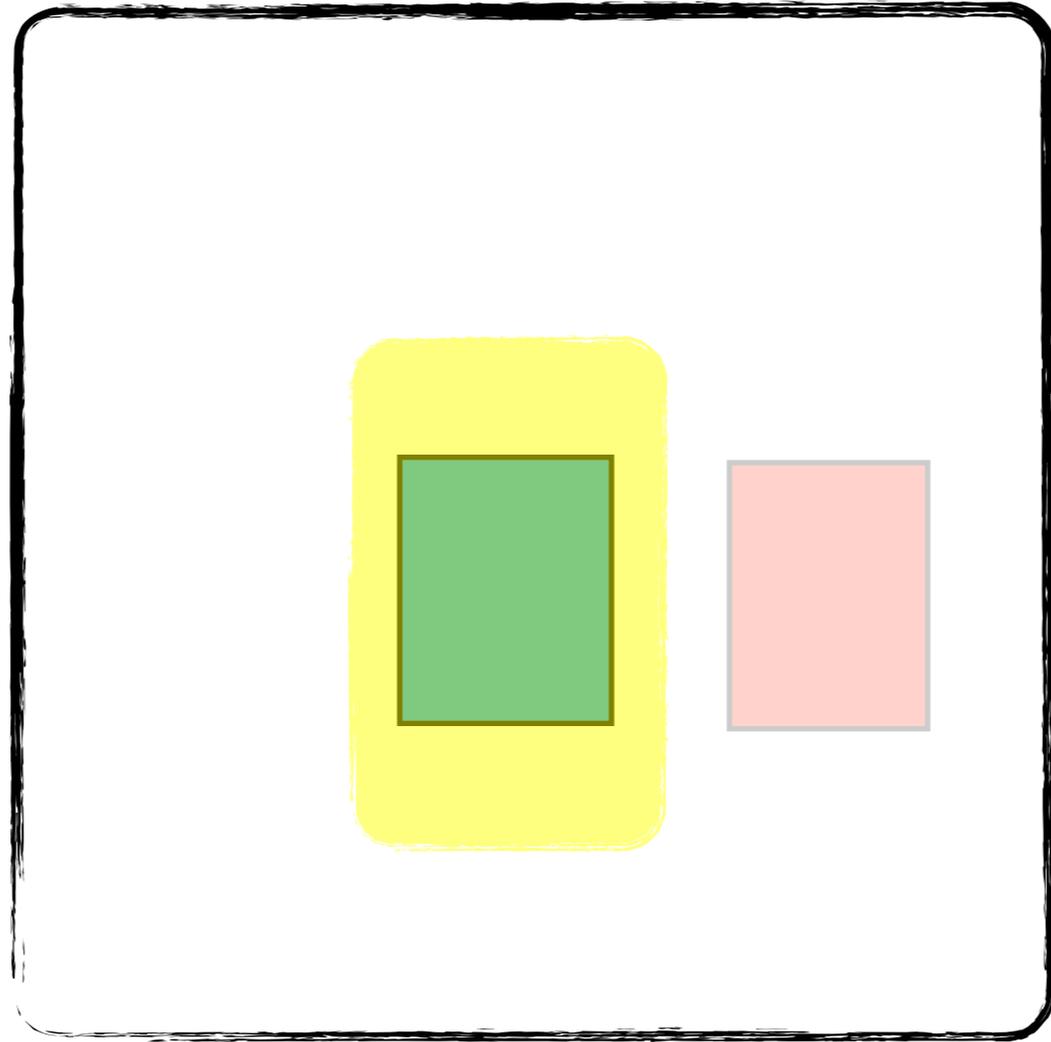


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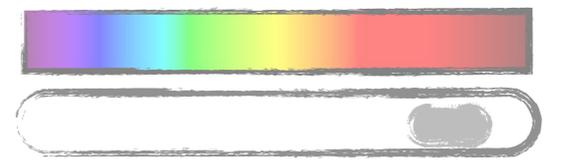
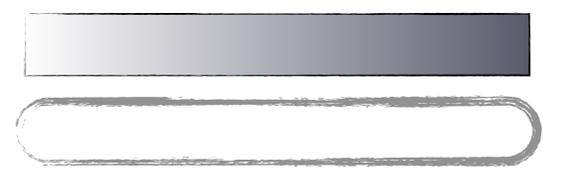
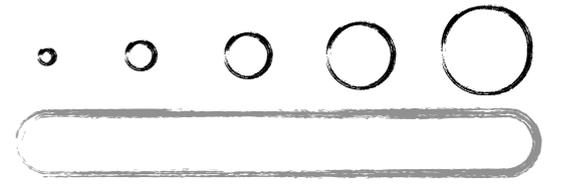
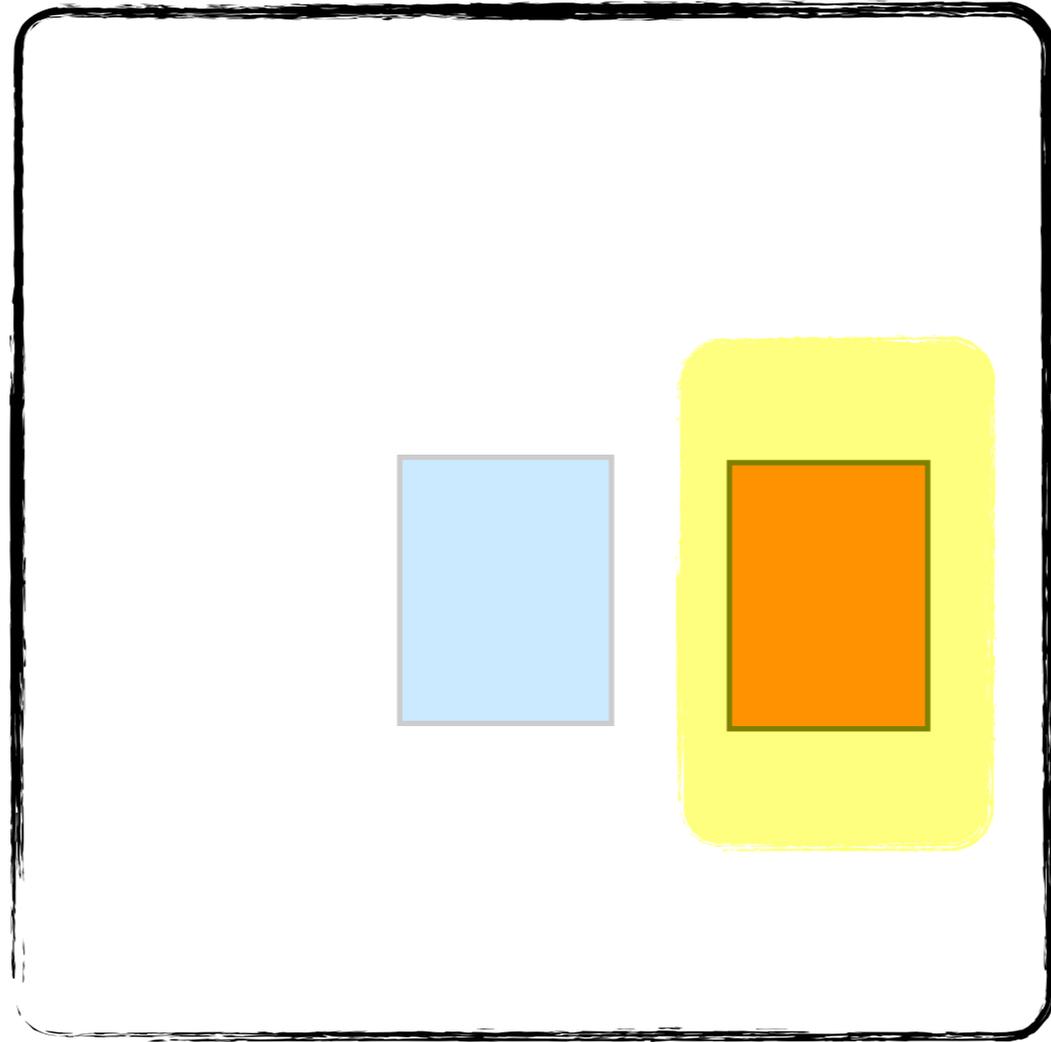


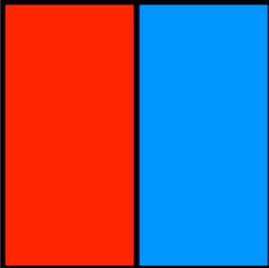
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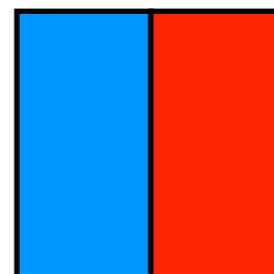
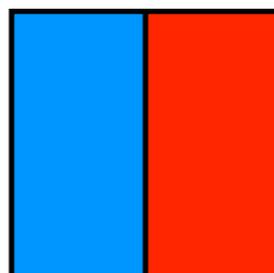
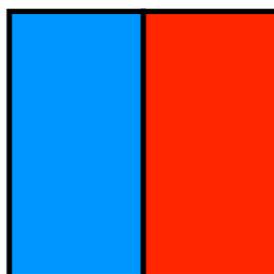
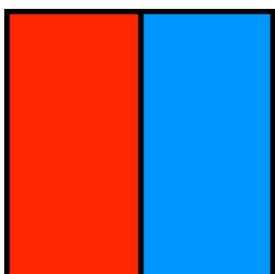
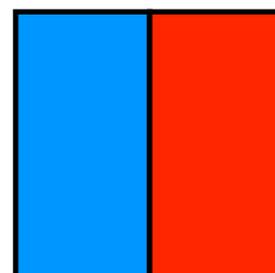
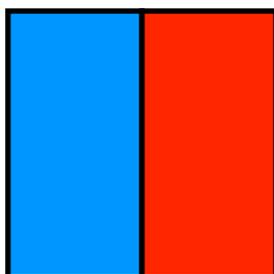
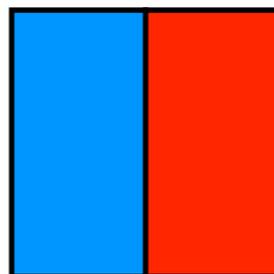
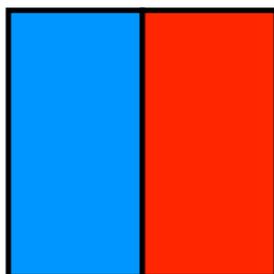
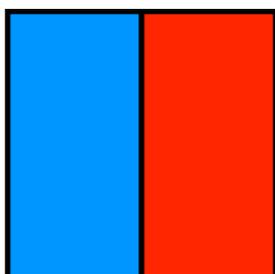
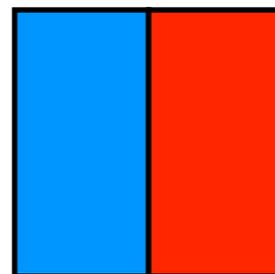
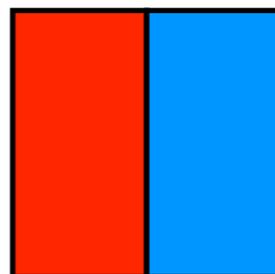
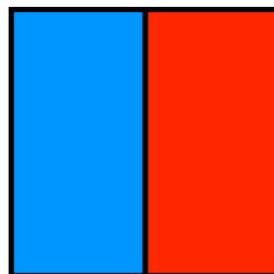
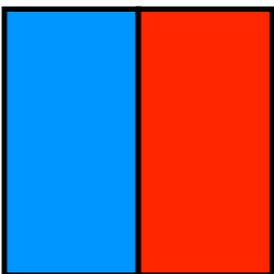
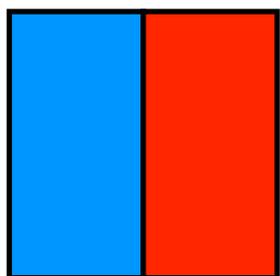


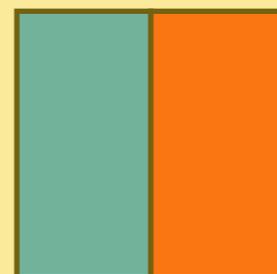
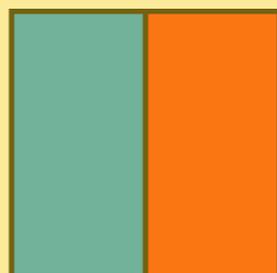
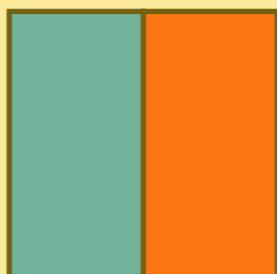
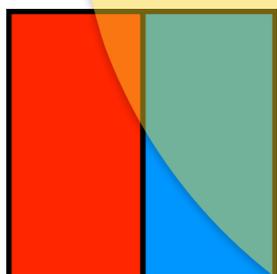
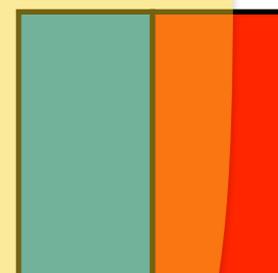
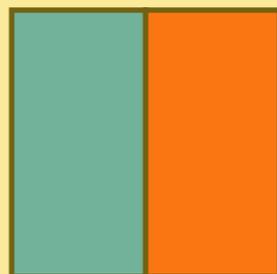
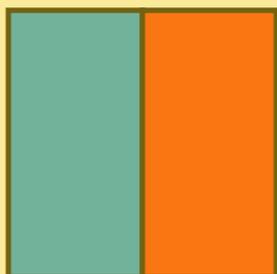
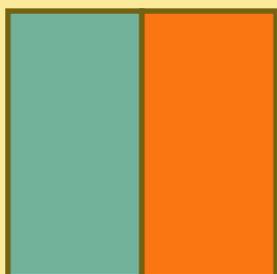
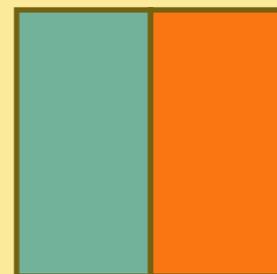
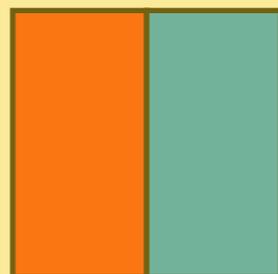
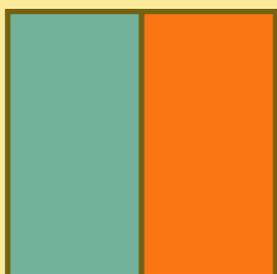
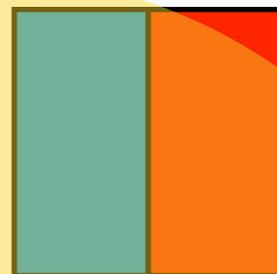
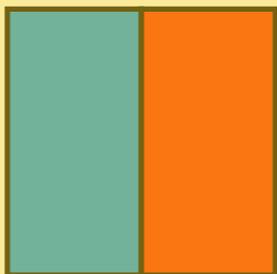


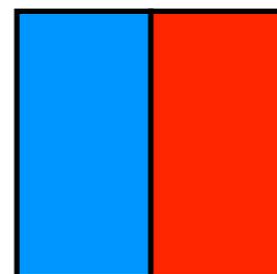
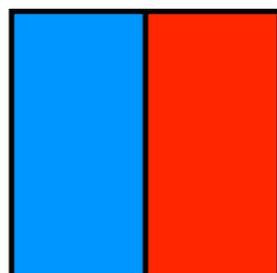
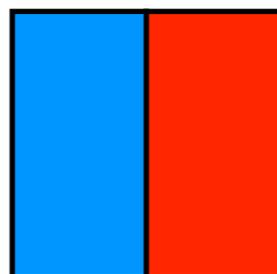
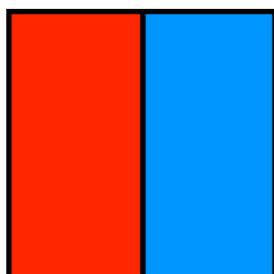
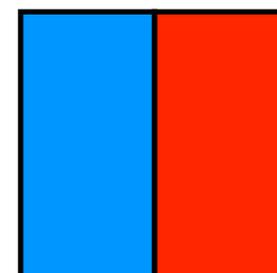
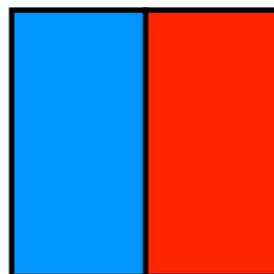
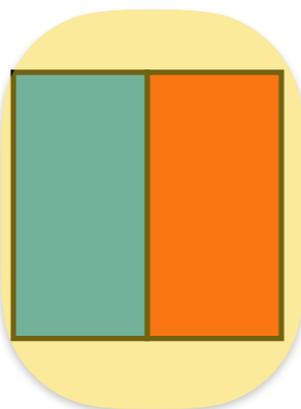
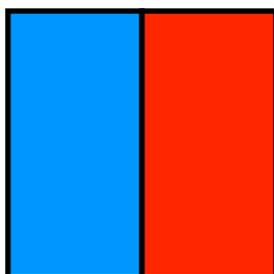
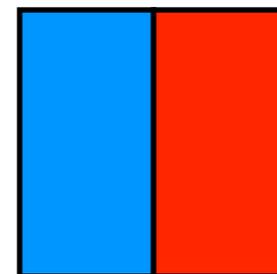
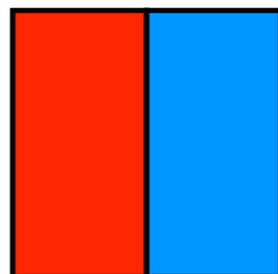
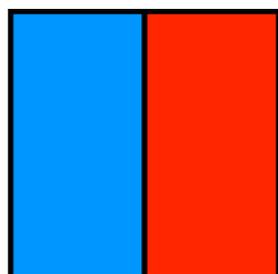
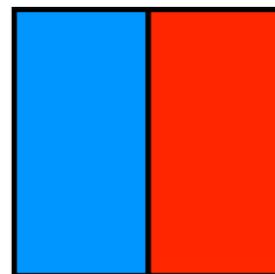
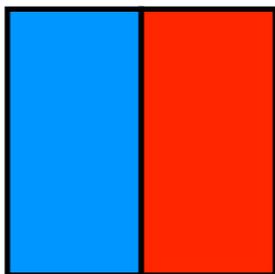
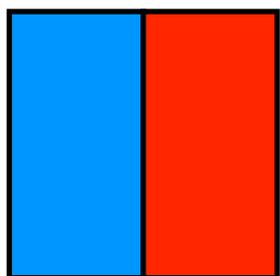
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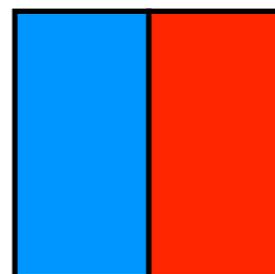
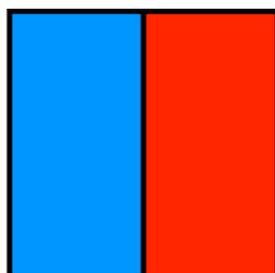
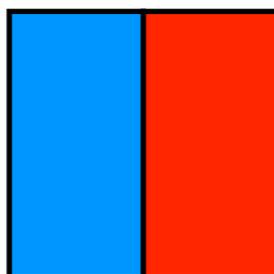
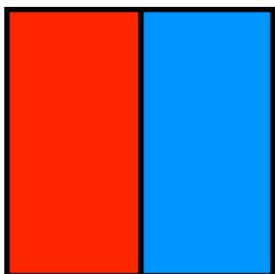
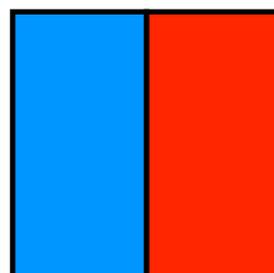
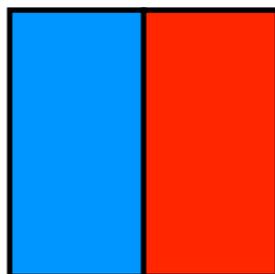
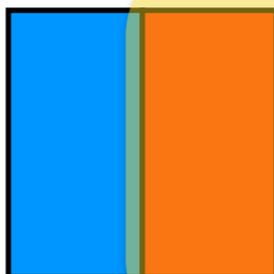
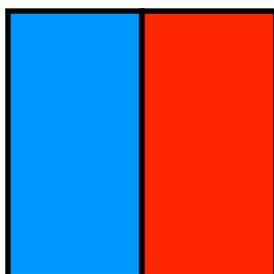
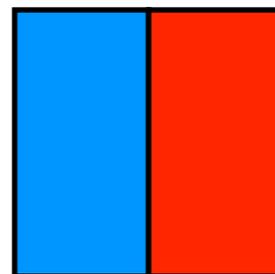
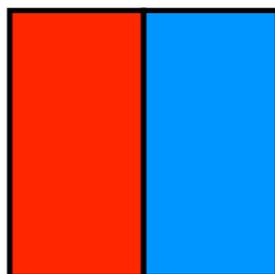
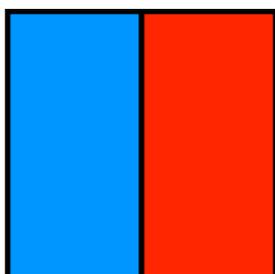
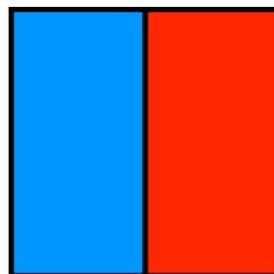
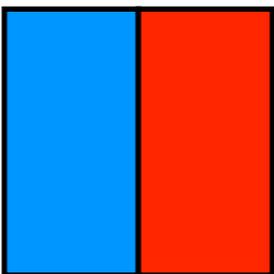
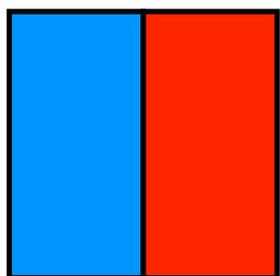


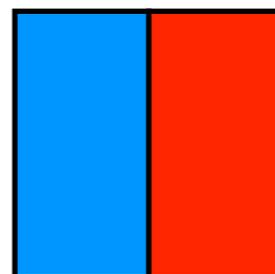
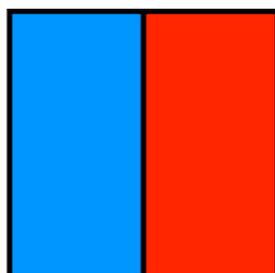
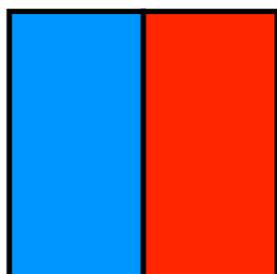
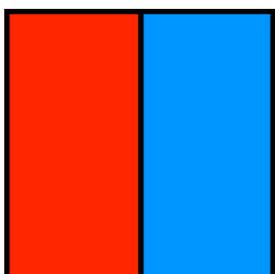
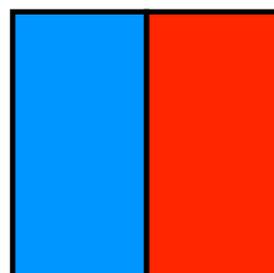
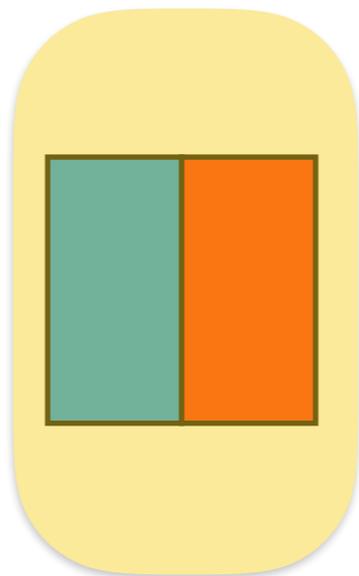
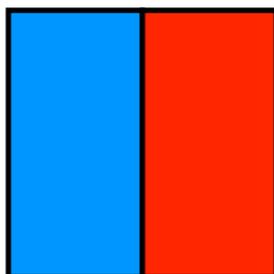
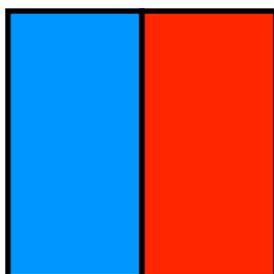
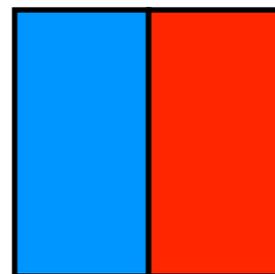
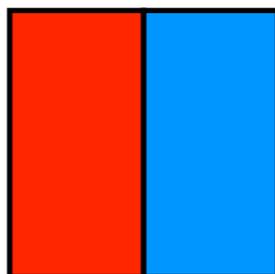
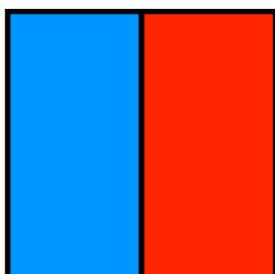
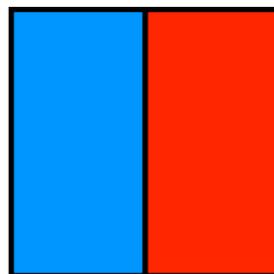
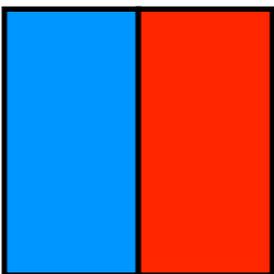
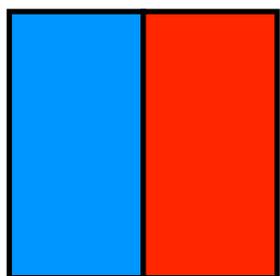


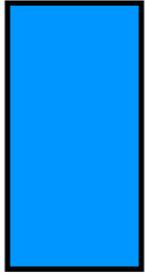


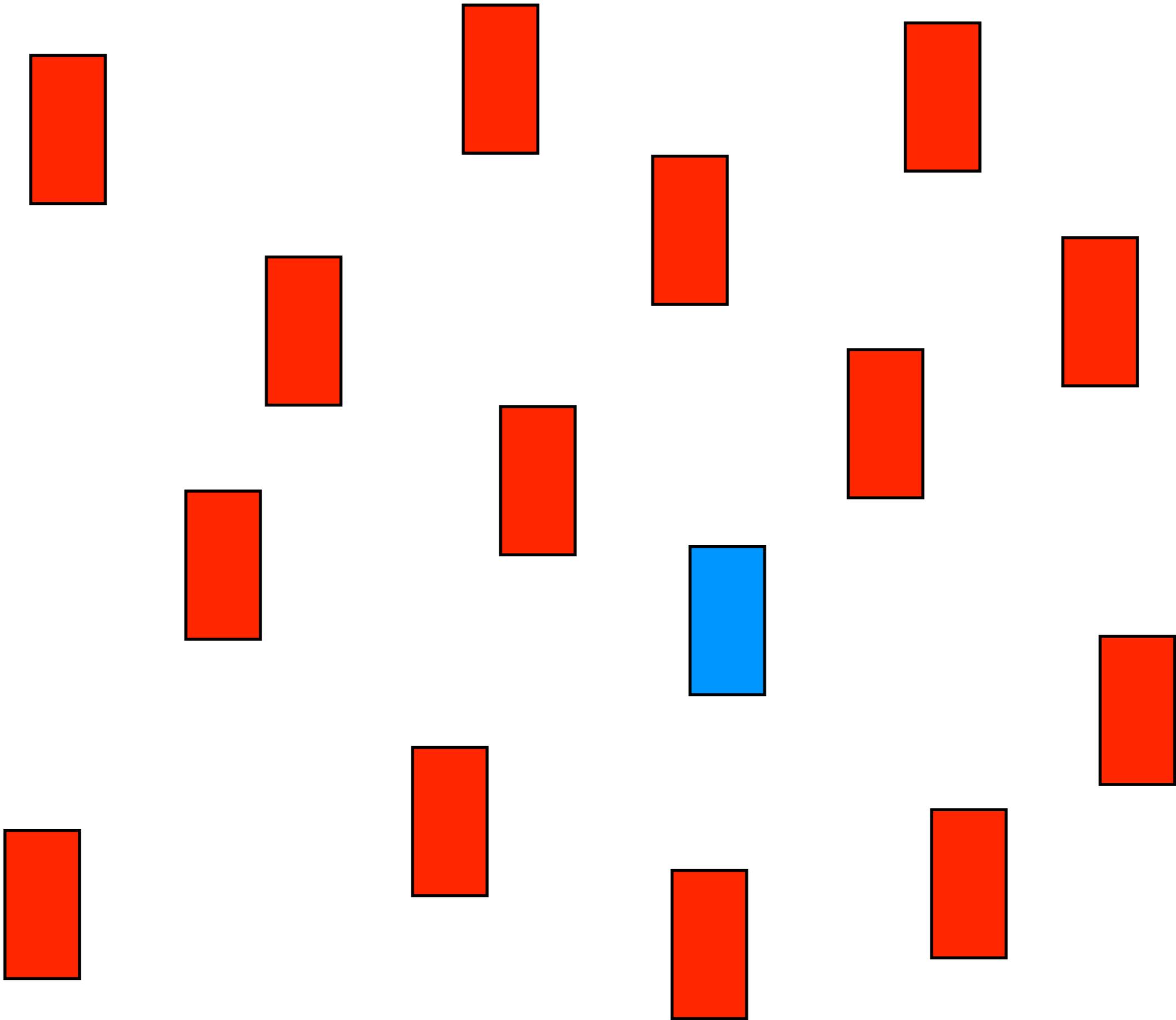


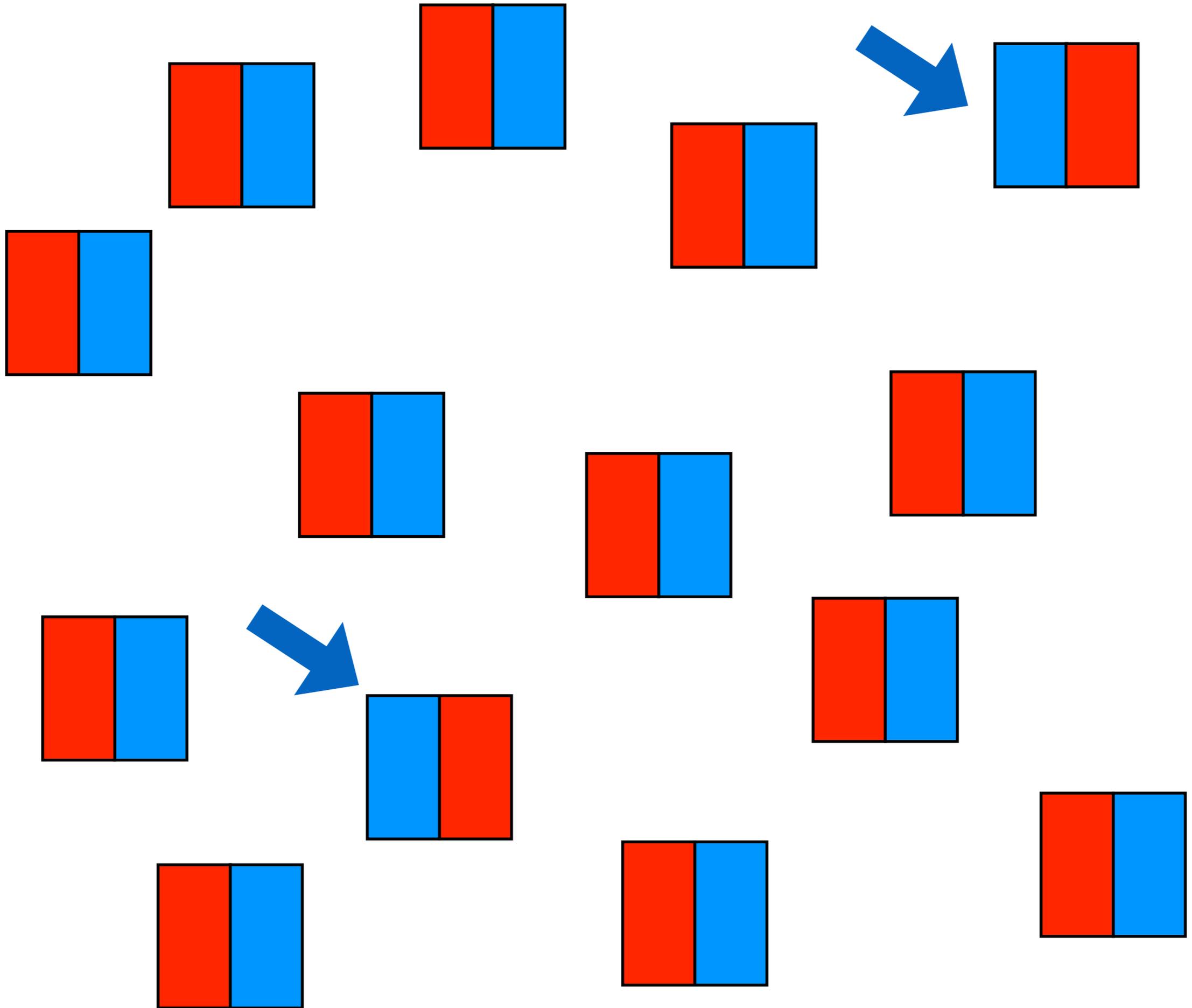


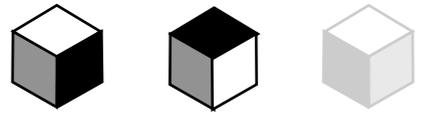




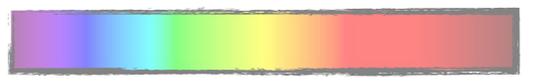
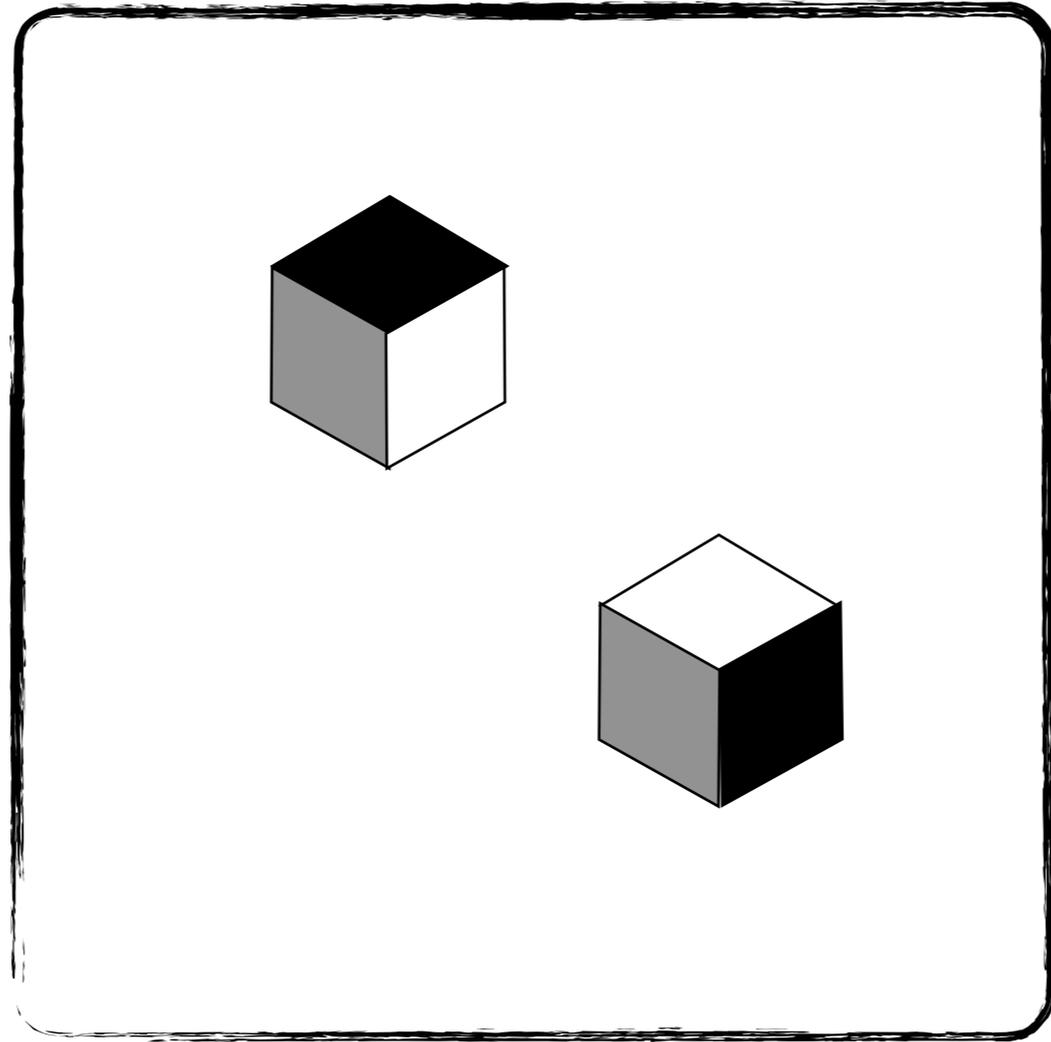


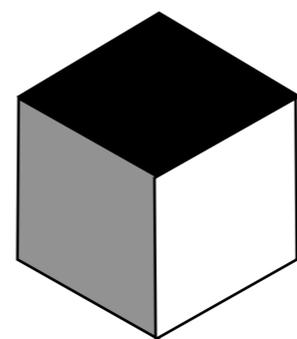




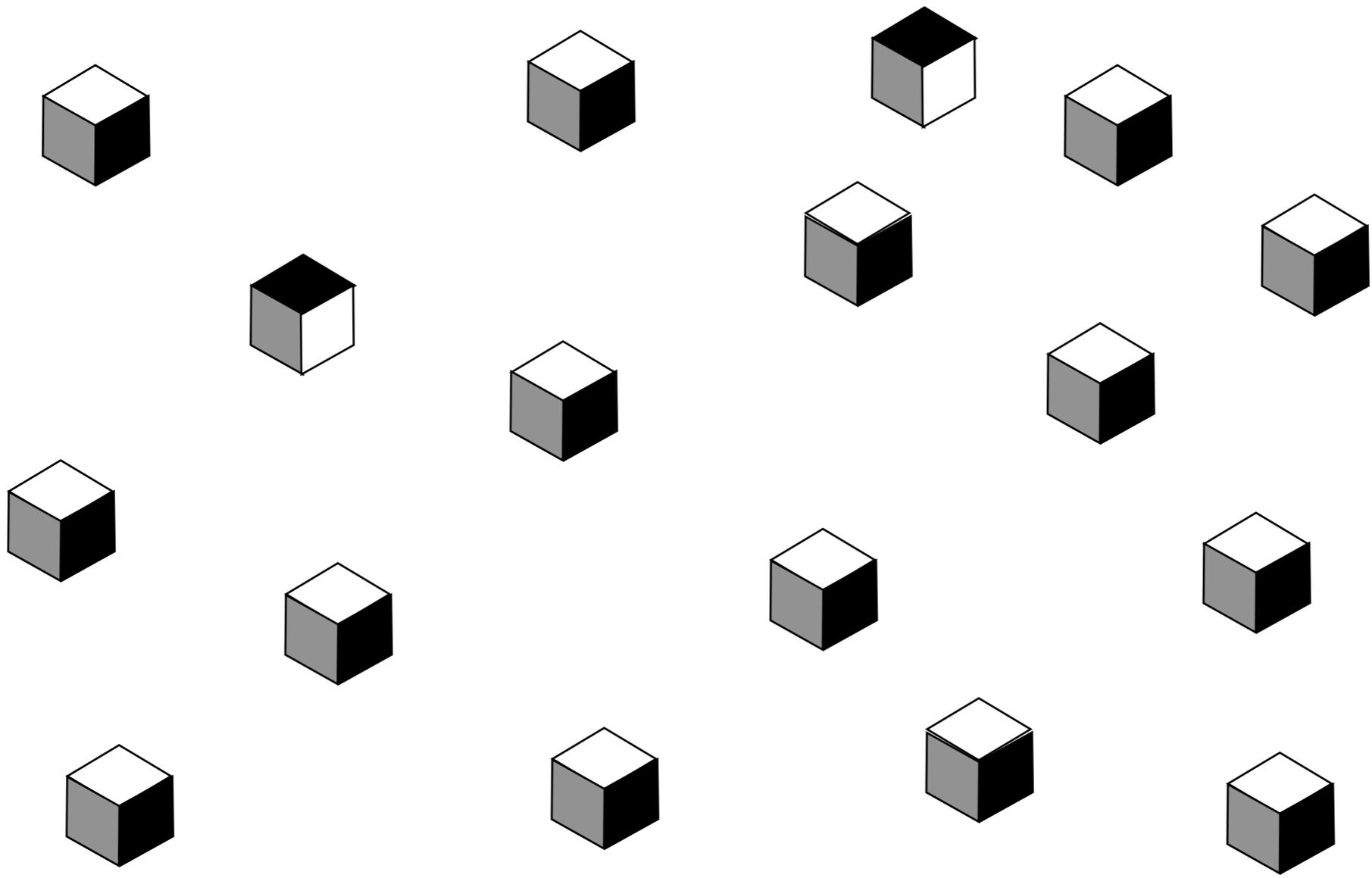


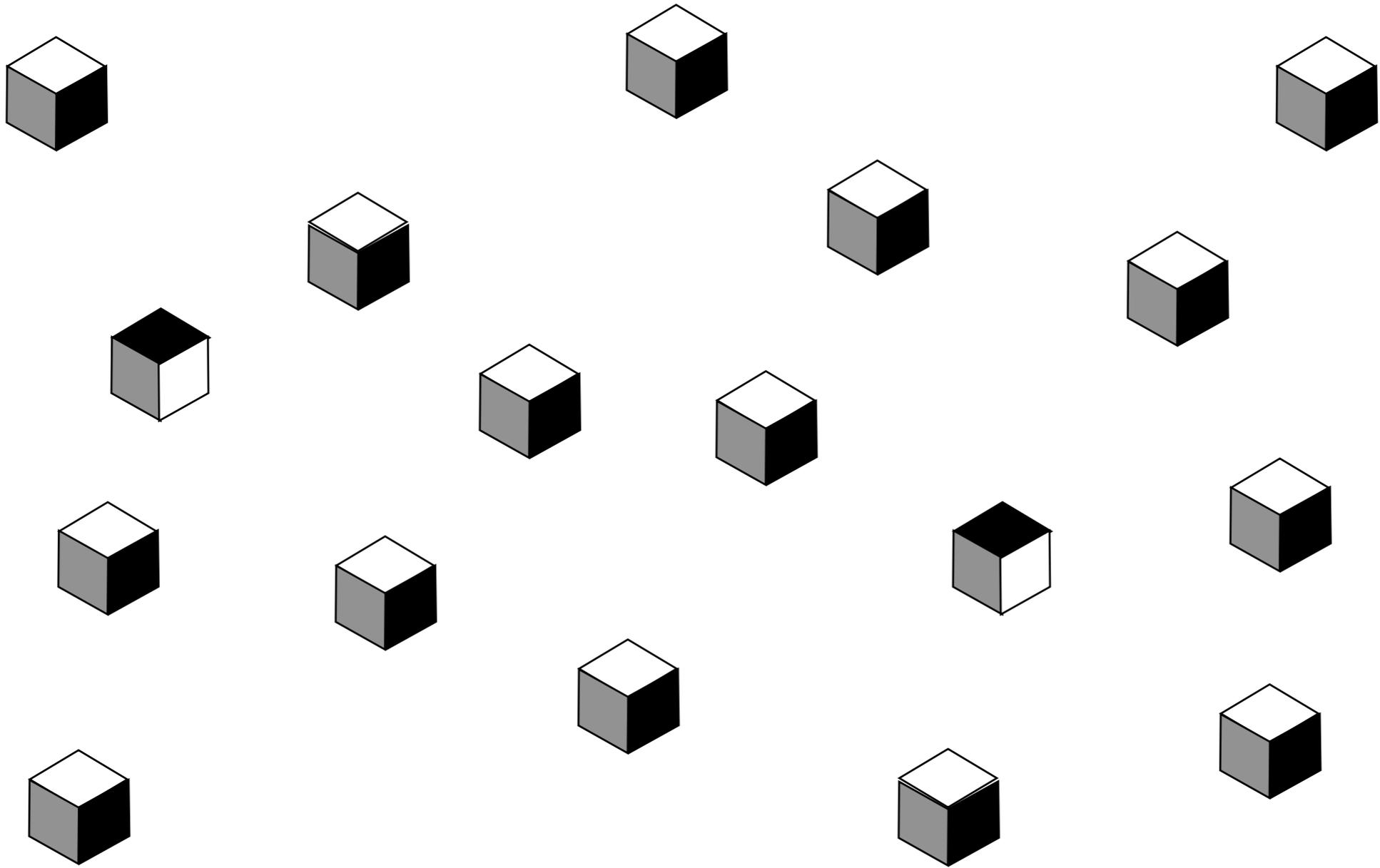
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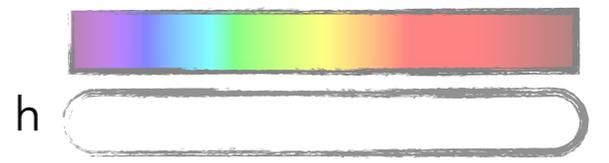
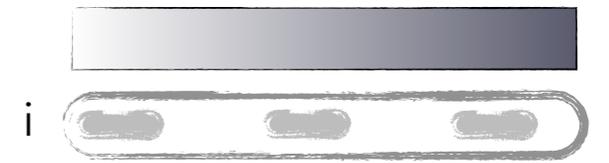
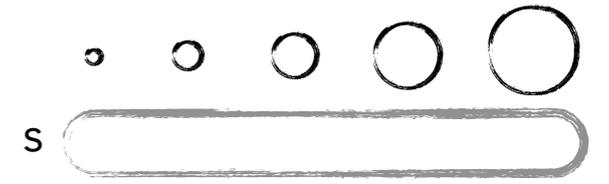
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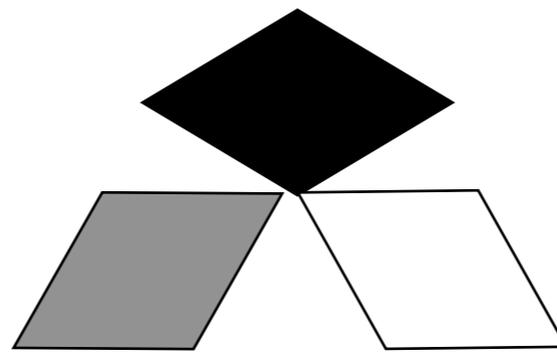




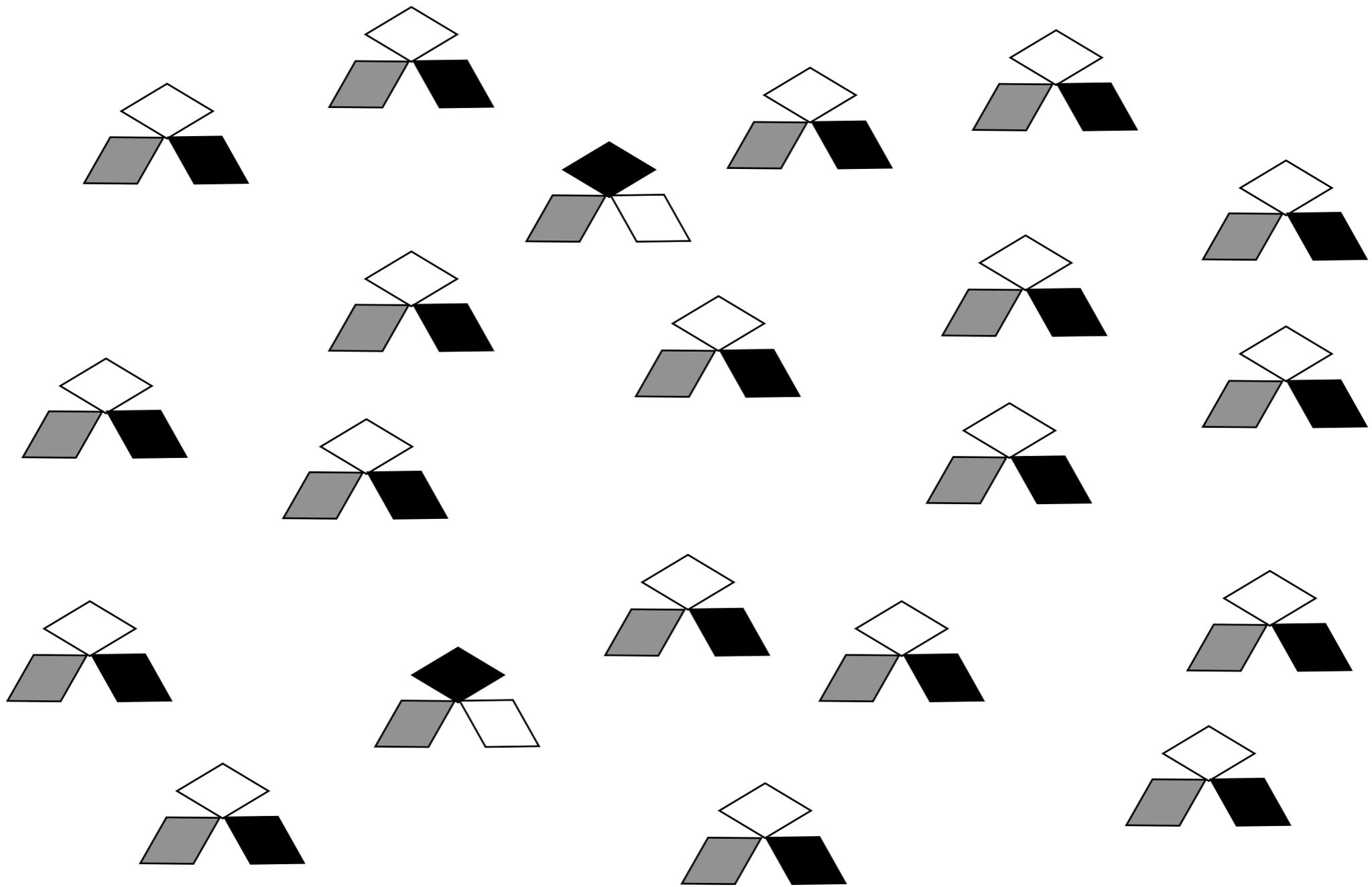


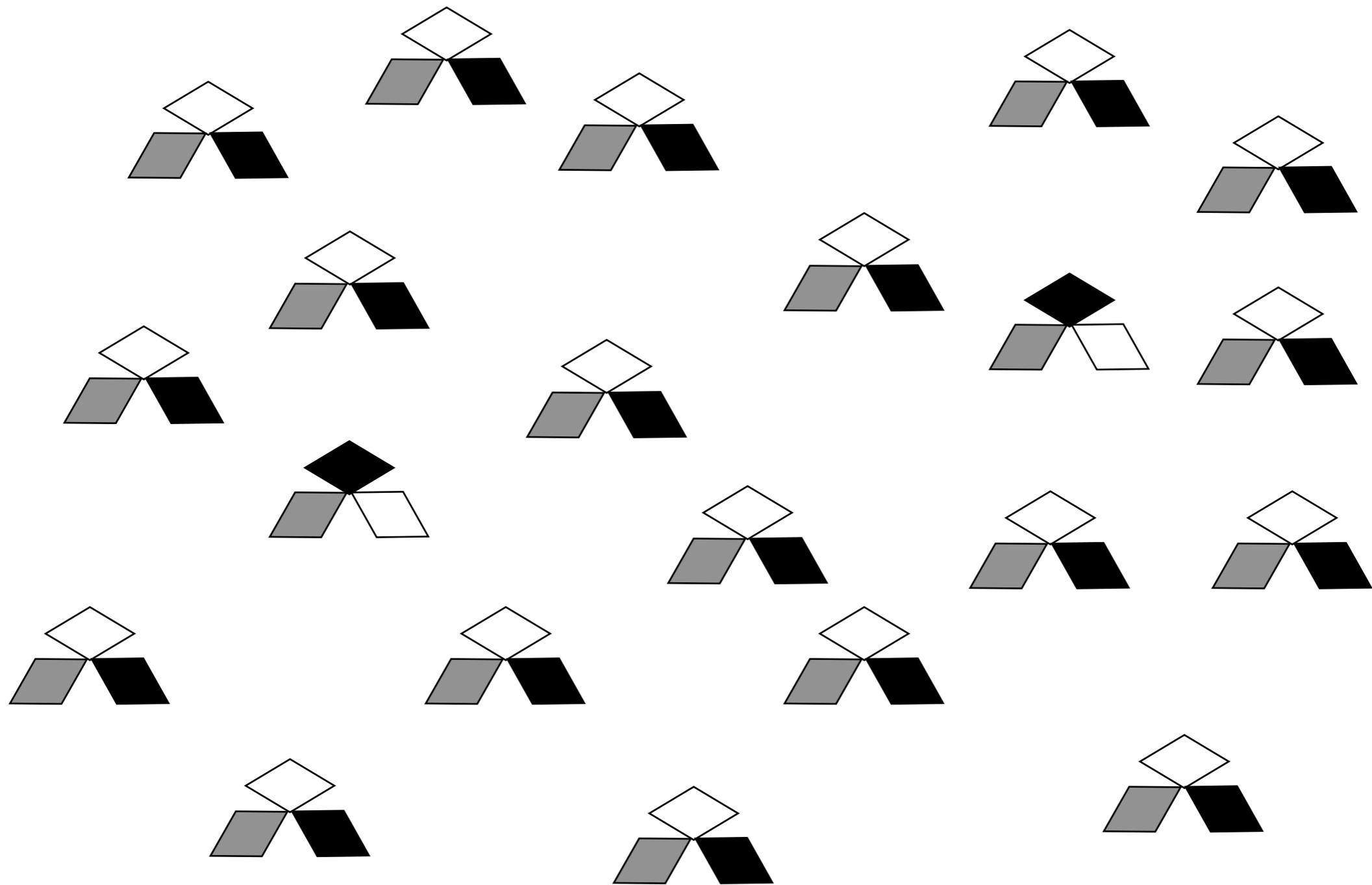
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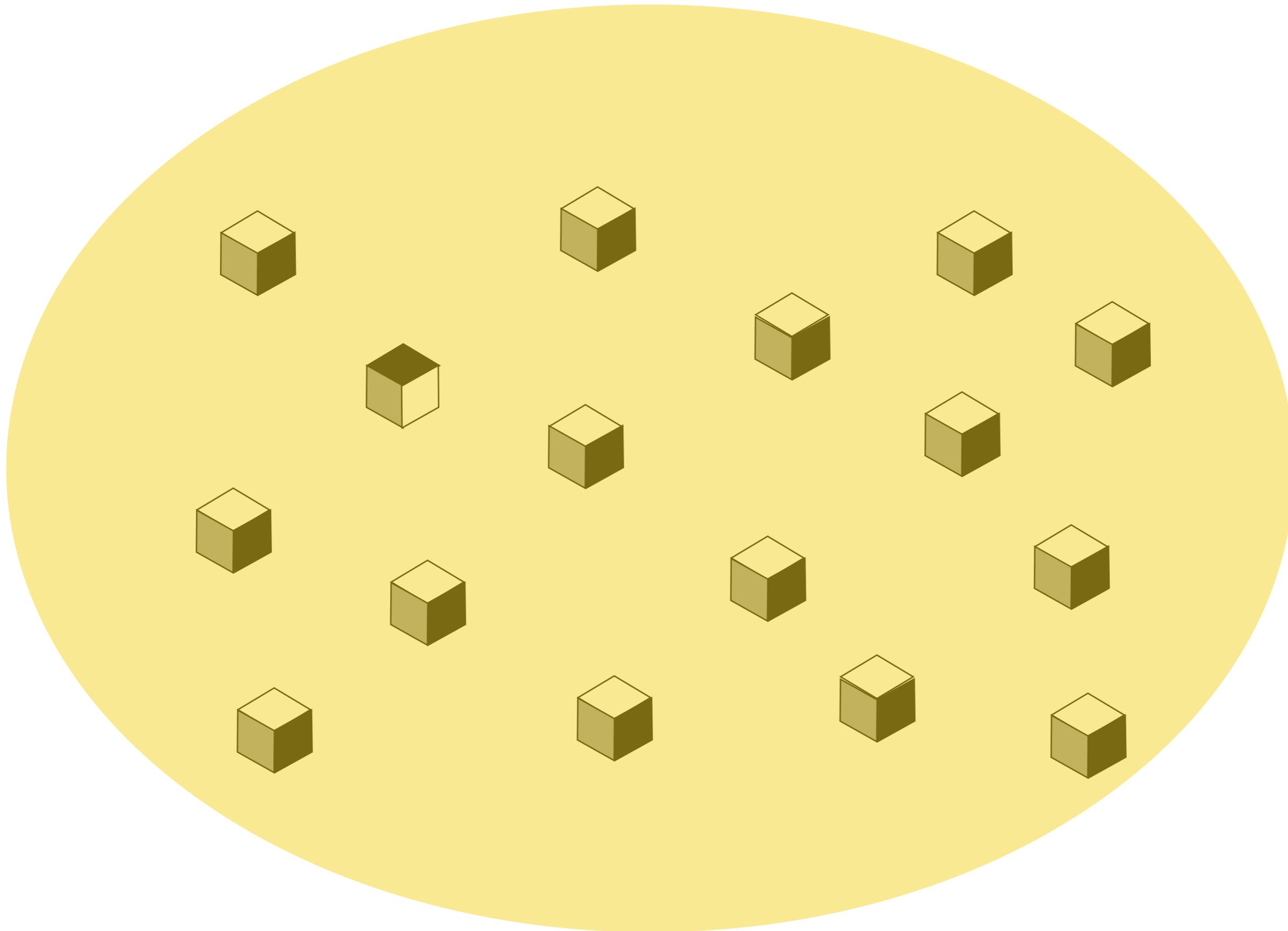


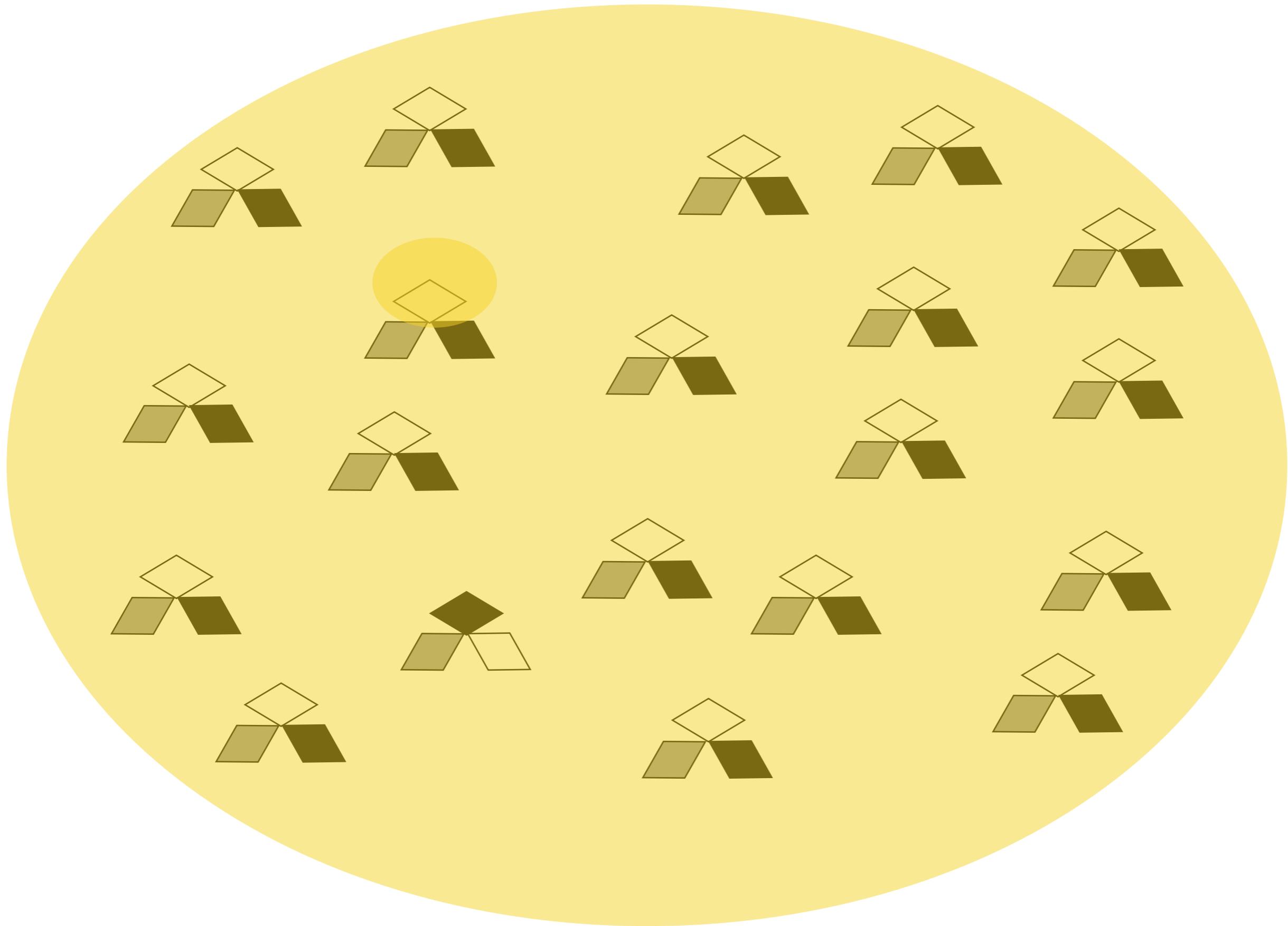
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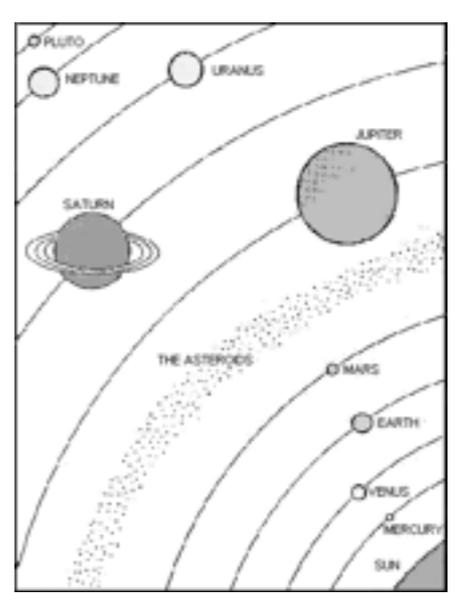
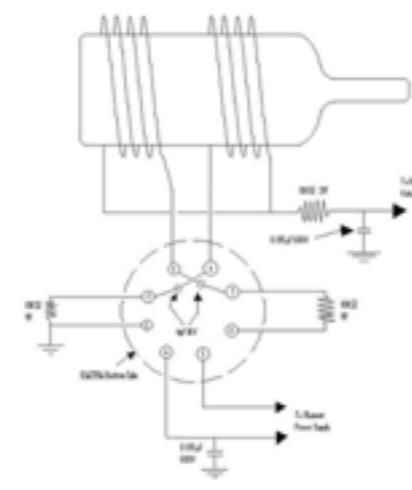
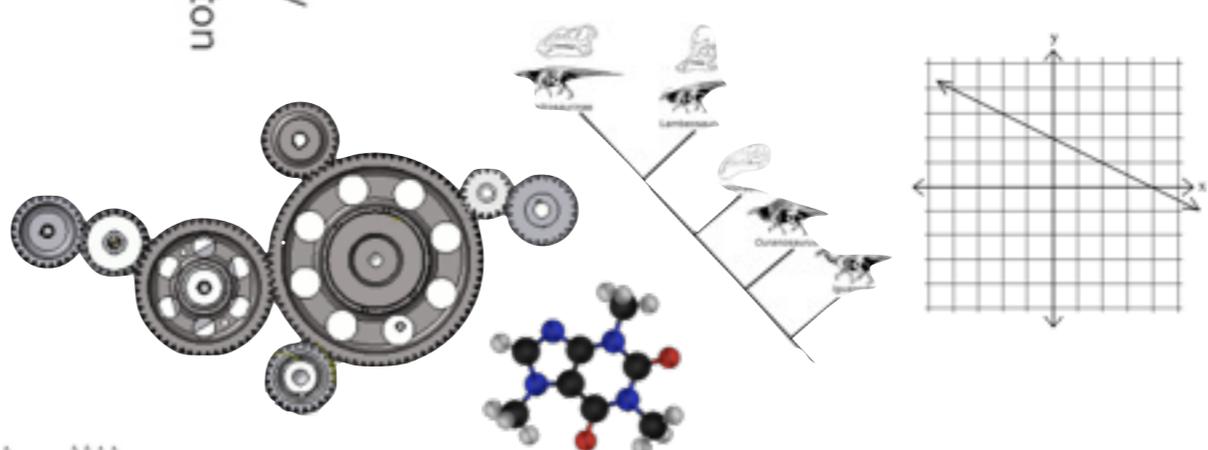
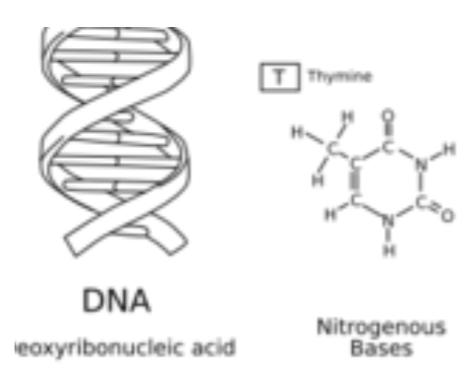
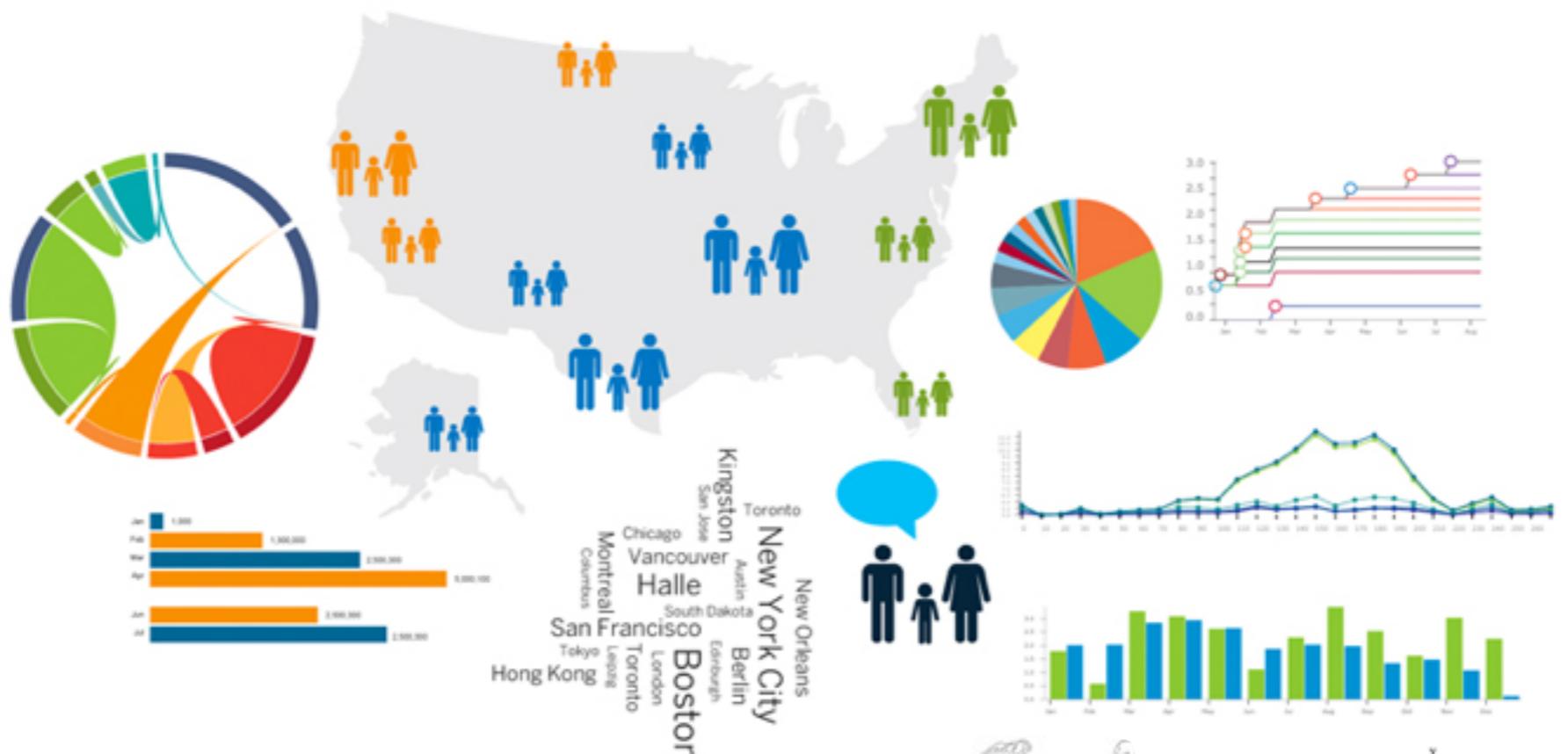




Enns & Rensink, 1990
(see also Wolfe, 1998)

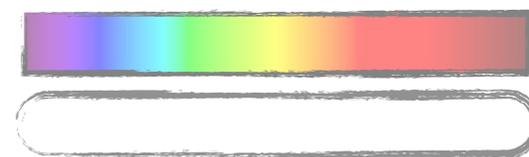
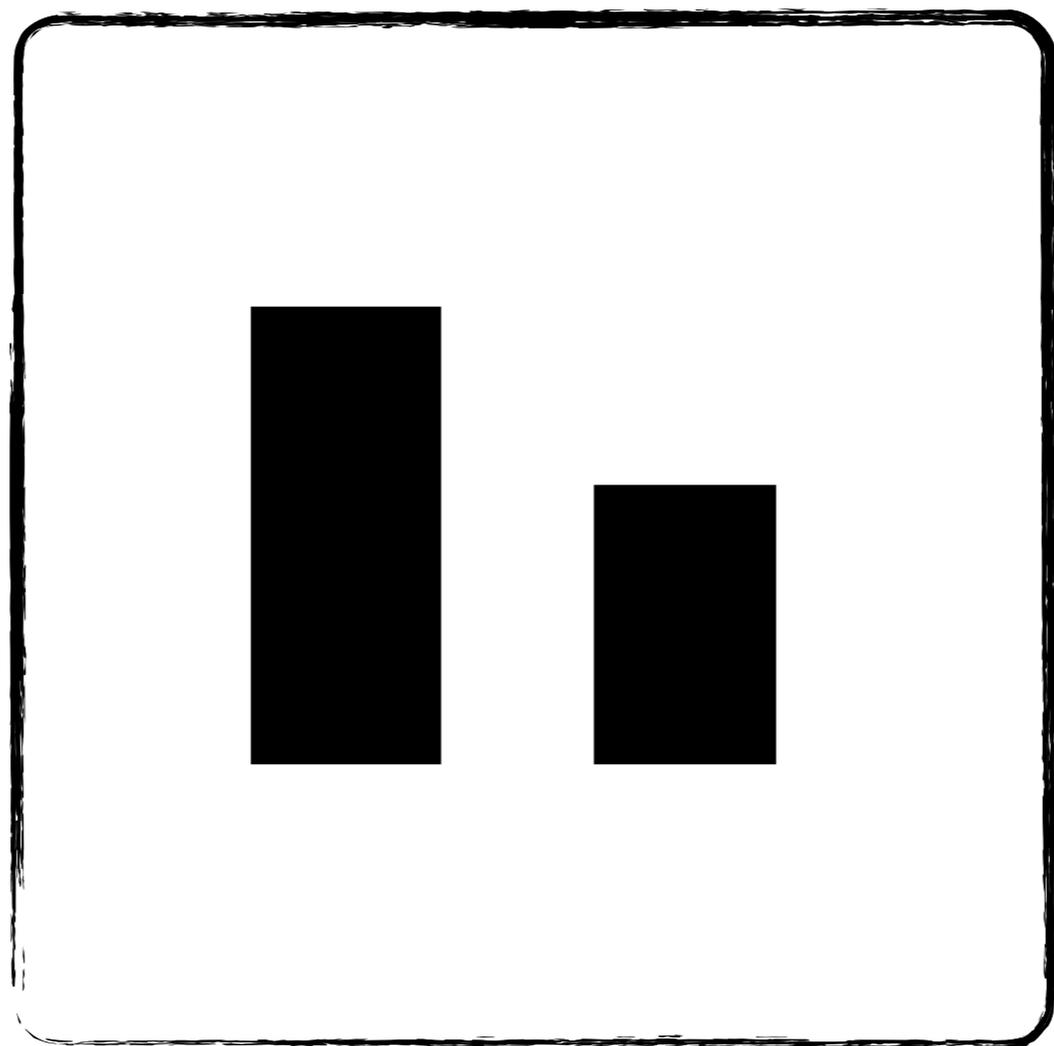


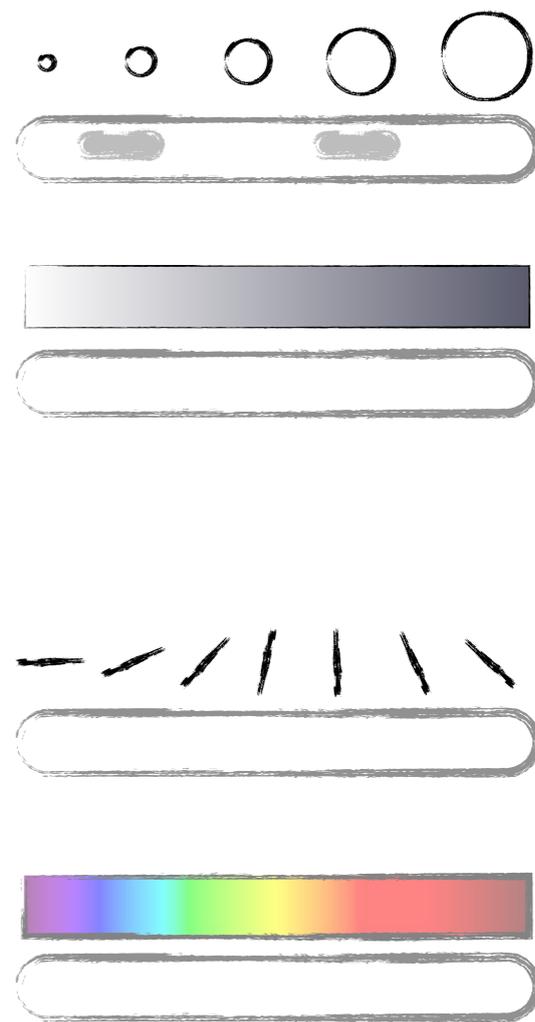
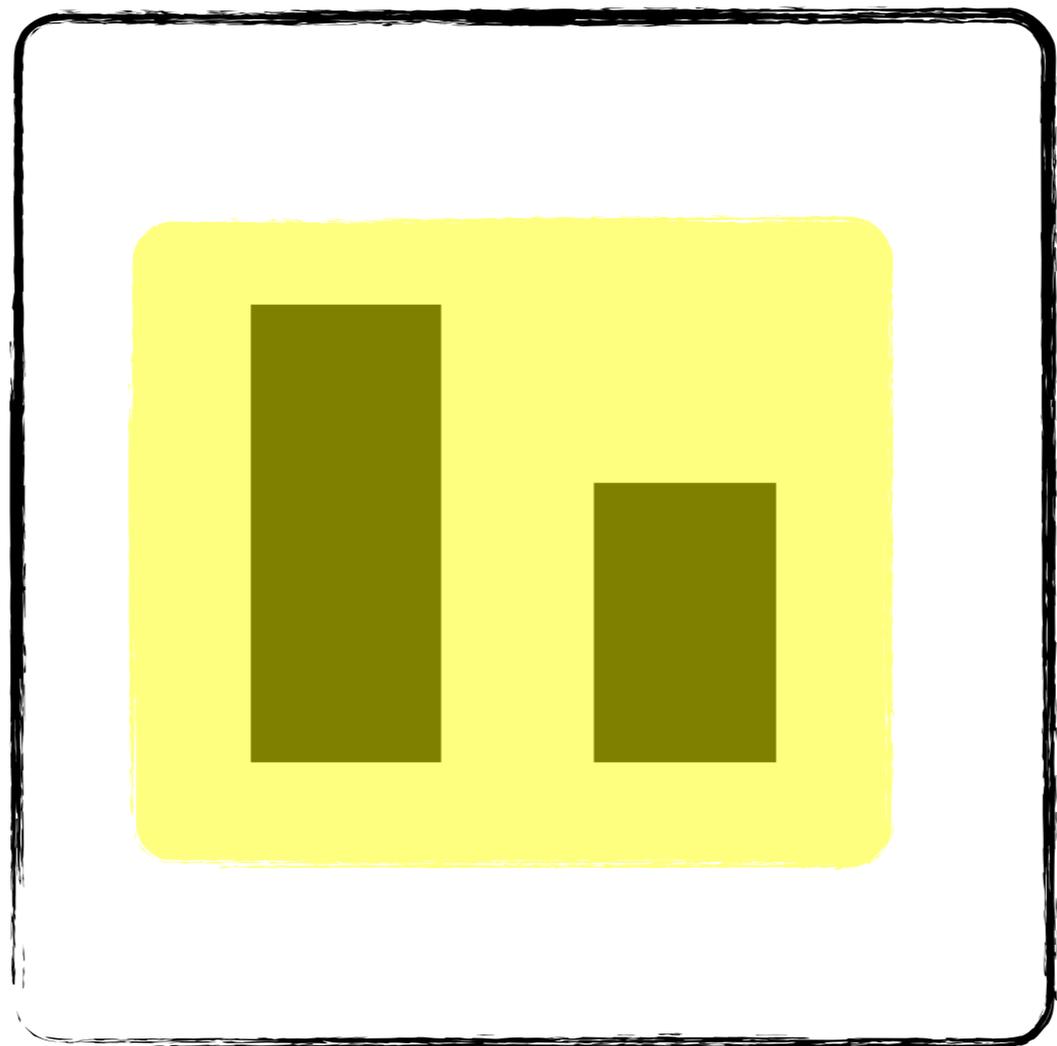
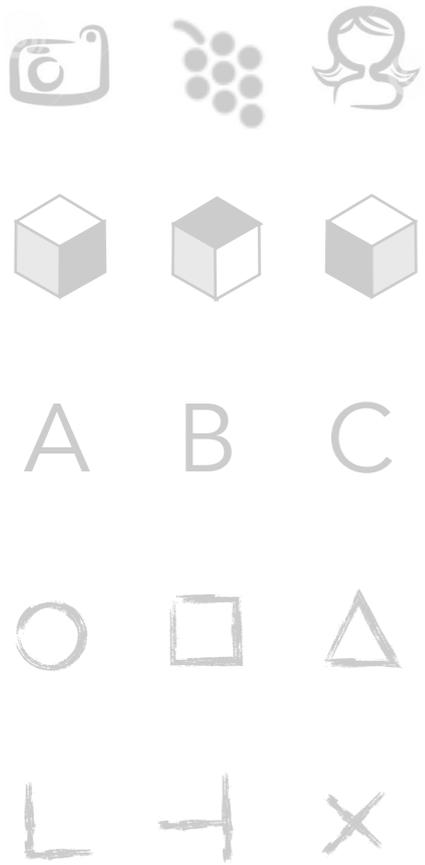


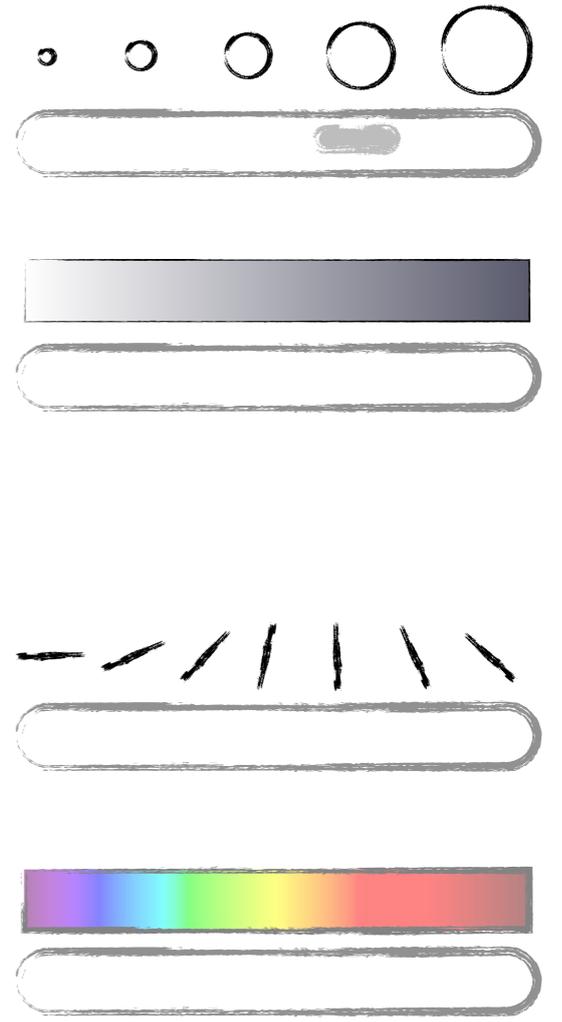
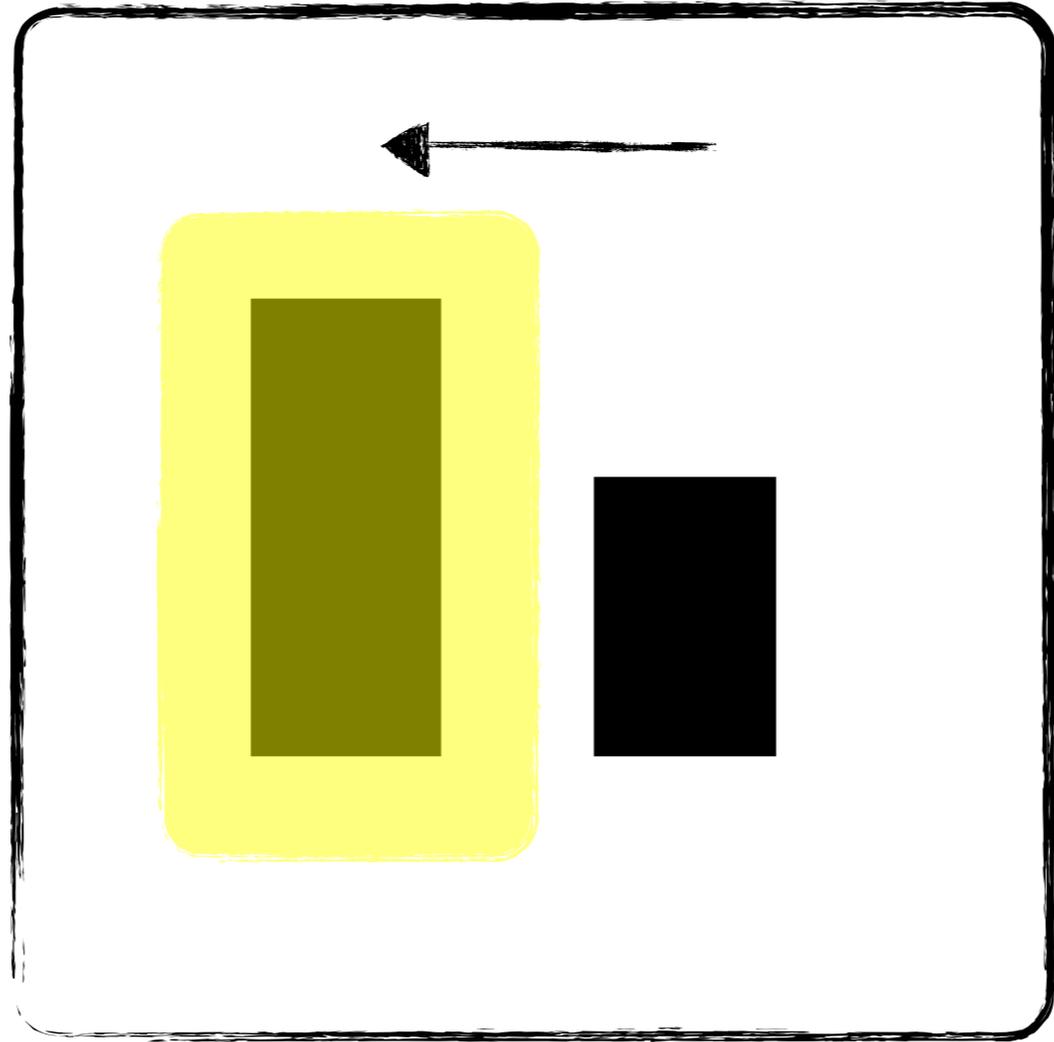
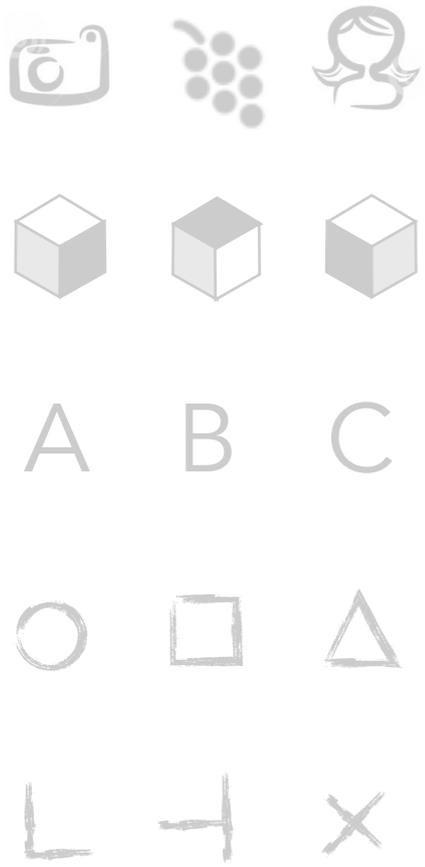




A B C





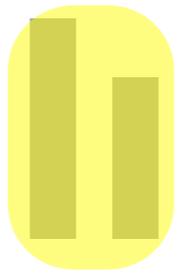




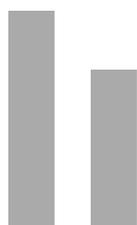


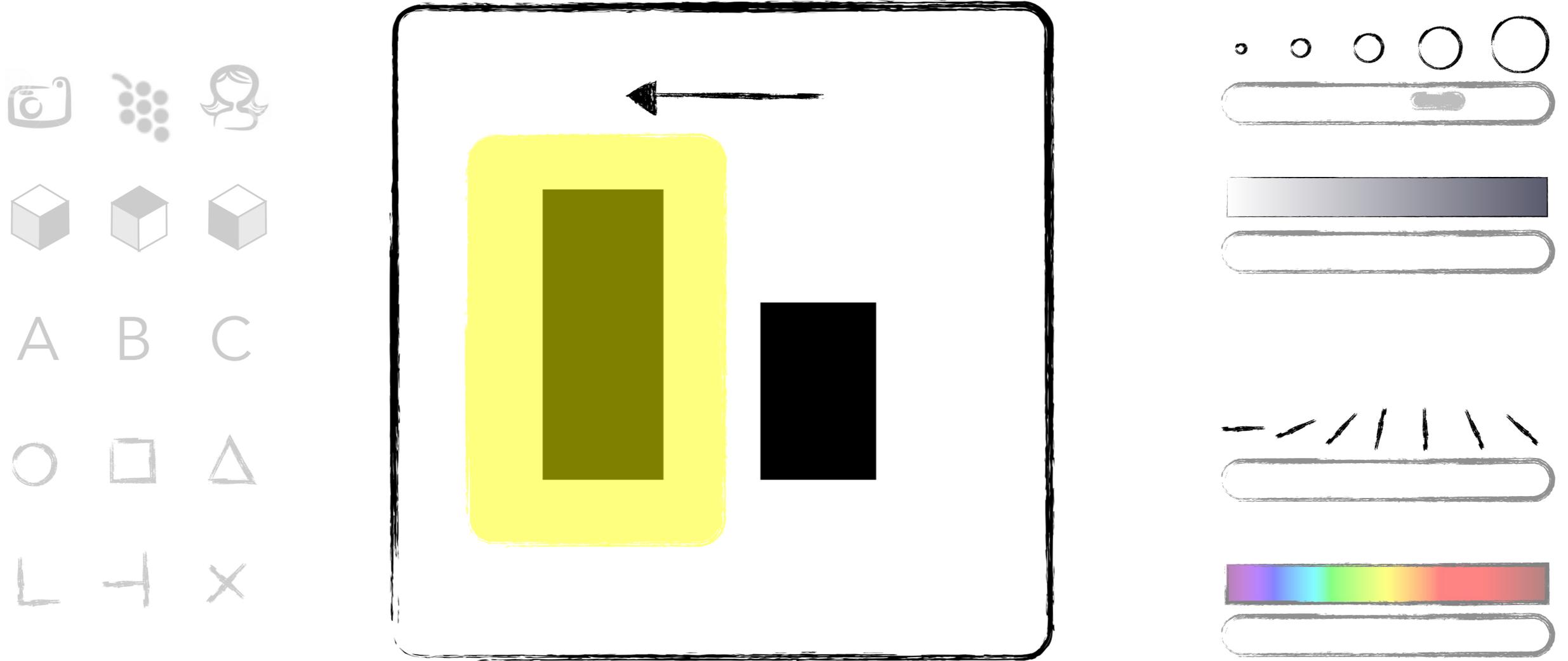


BIG small BIG small

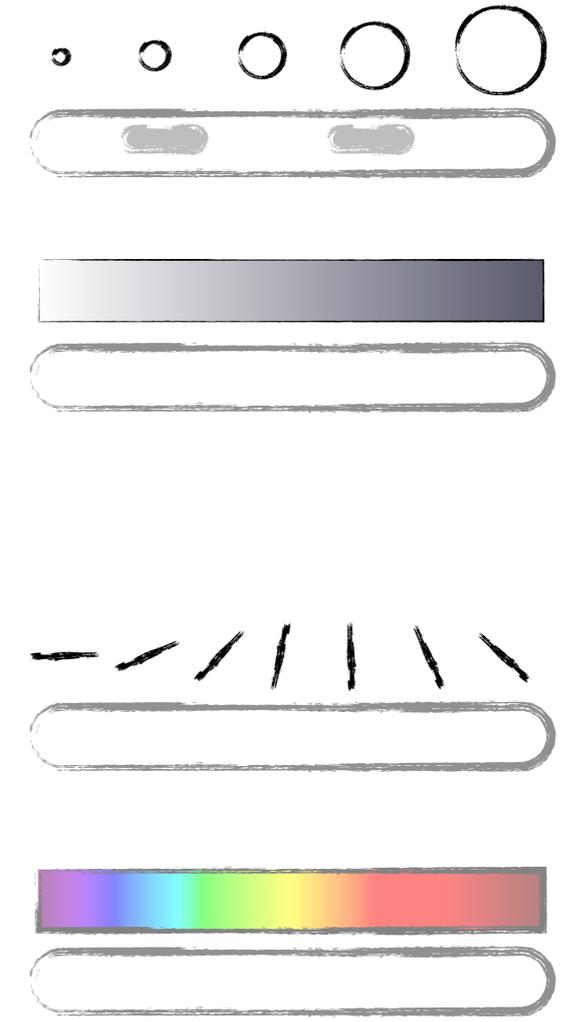
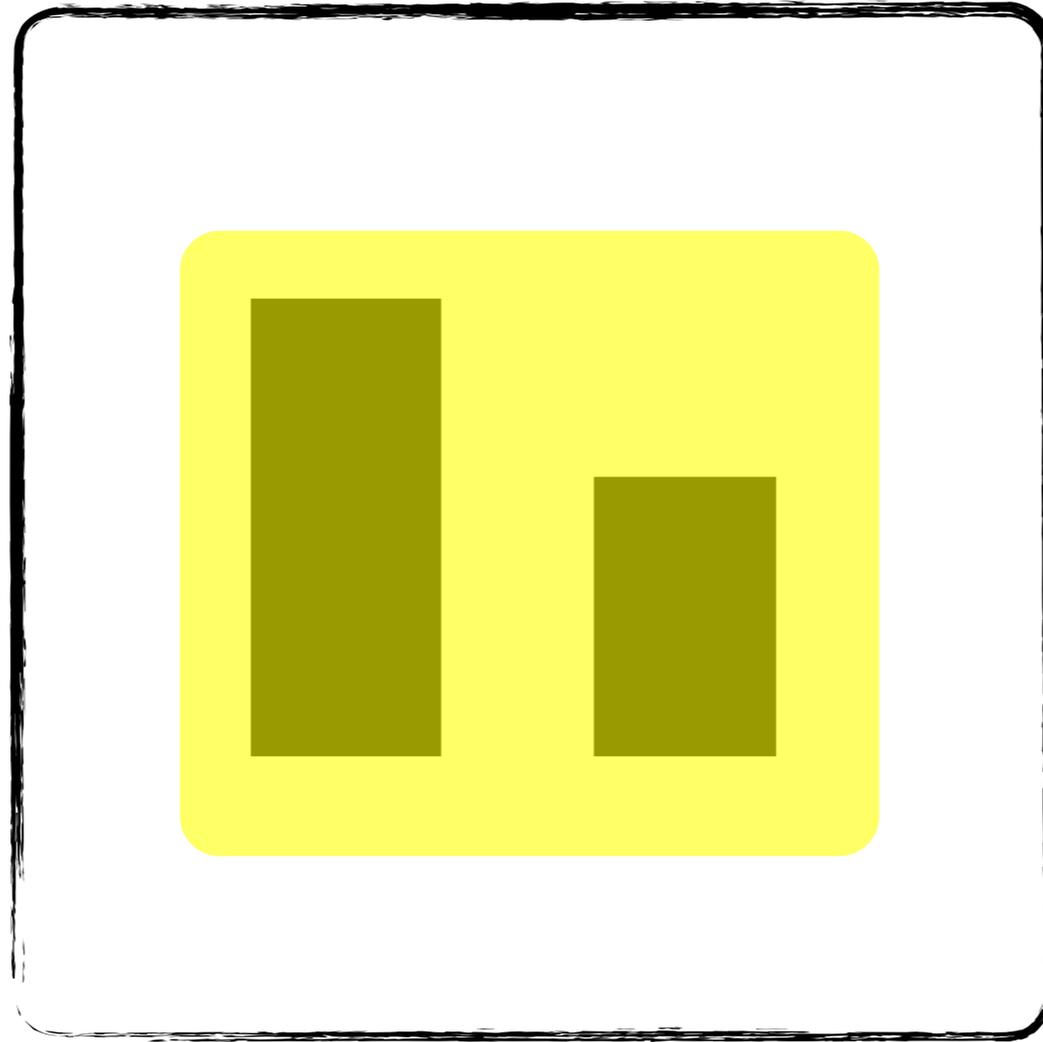
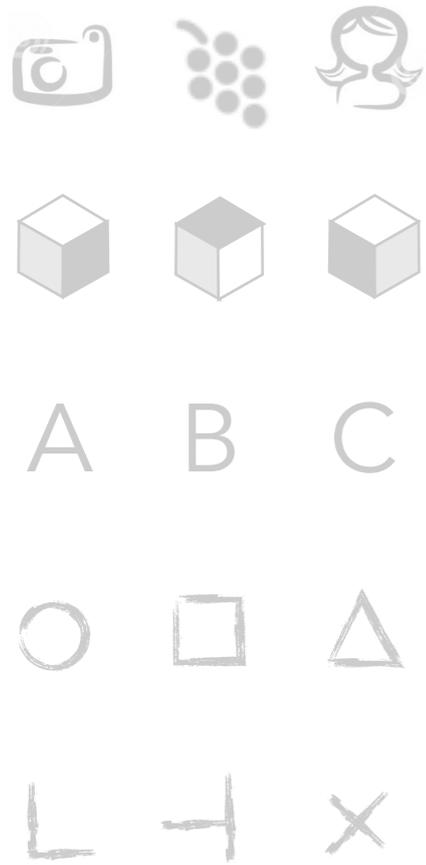


small BIG

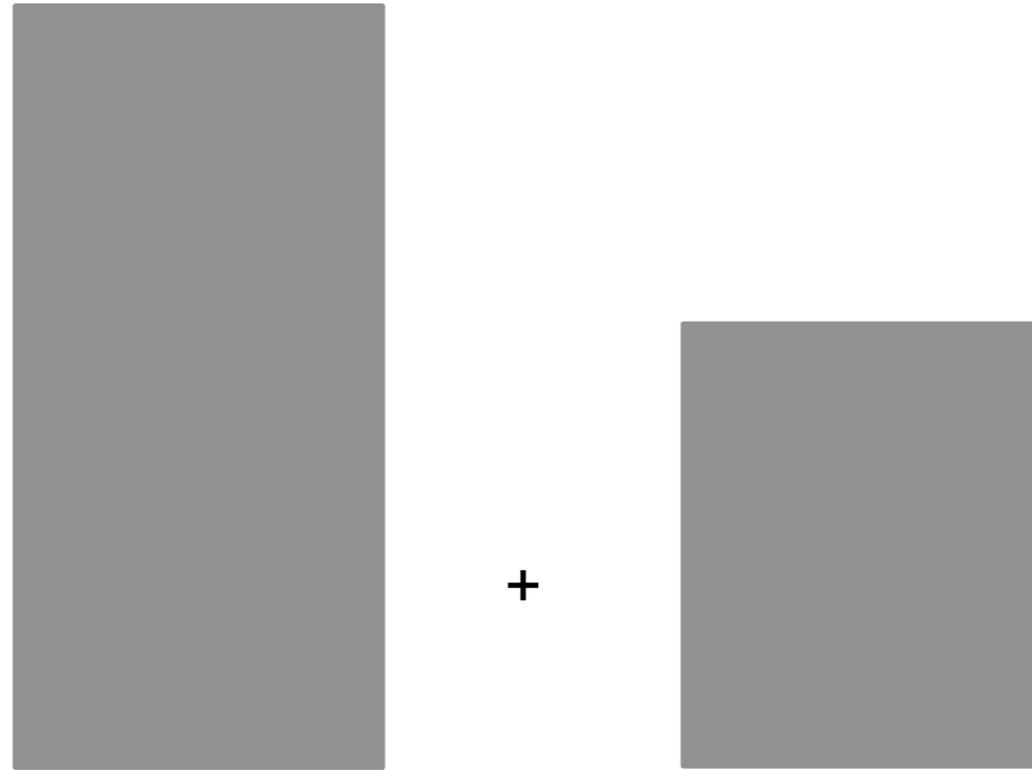




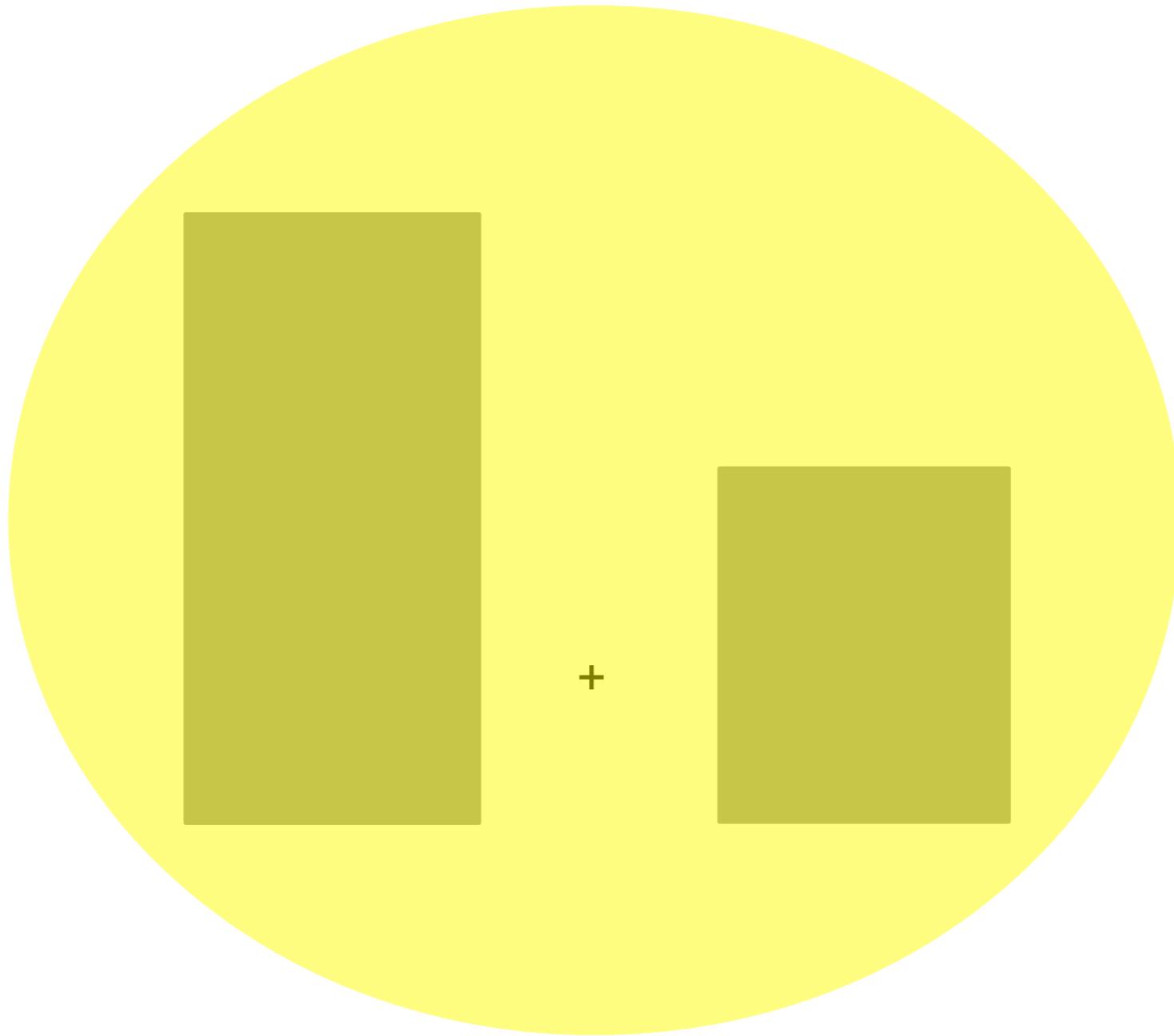
You should need to shift to
judge BIGsmall vs. smallBIG



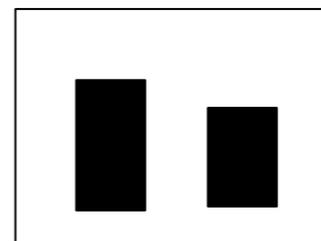
You should need to shift to
judge BIGsmall vs. smallBIG
But not same-different!



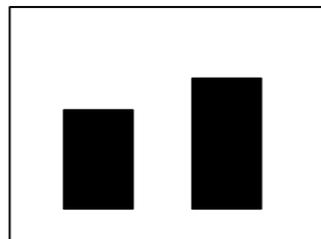
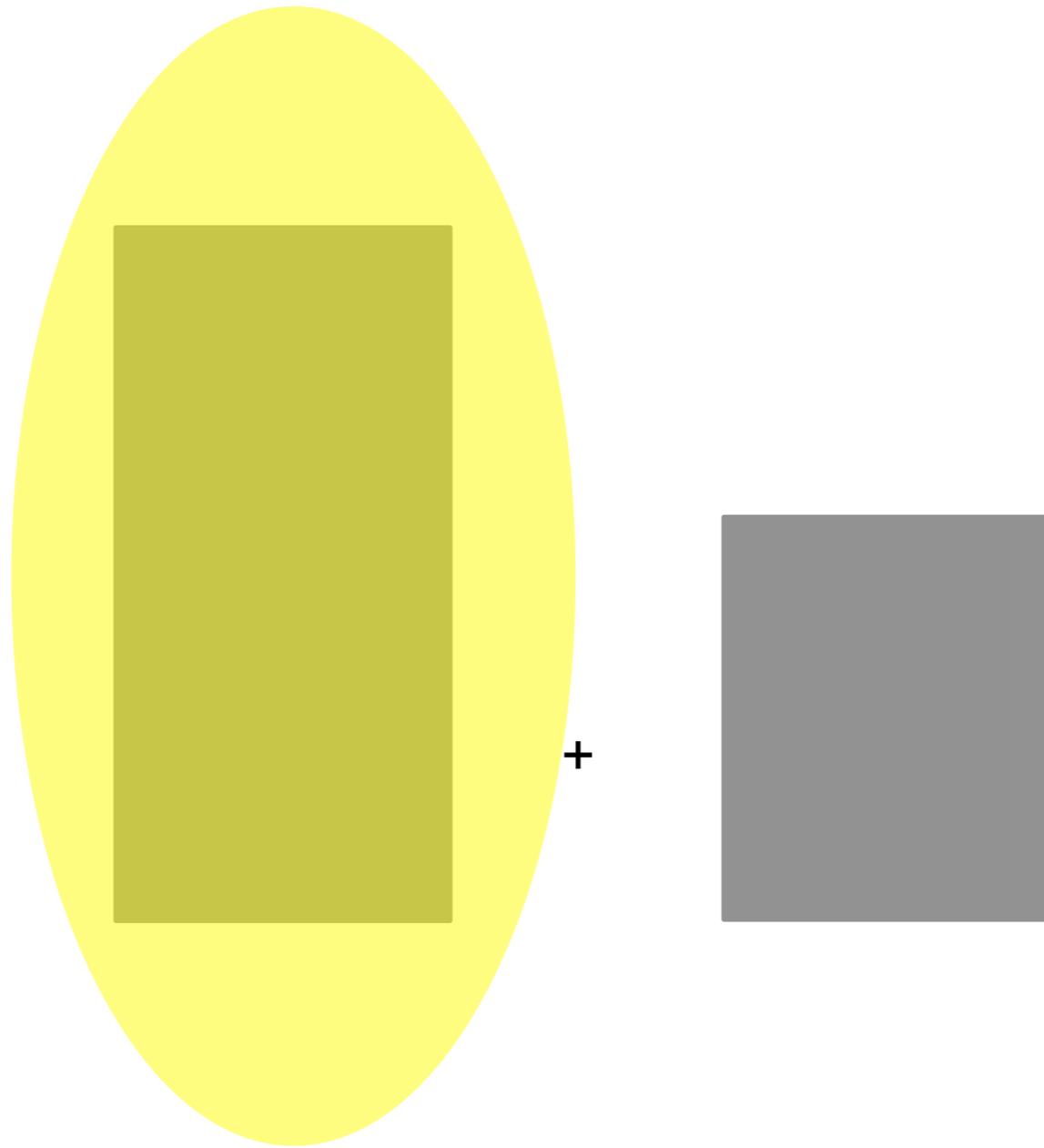
Michal, Uttal, Shah, & Franconeri (2016). *Psychological Bulletin & Review*.
Michal & Franconeri (2017). *Cognitive Research: Principles and Implications*



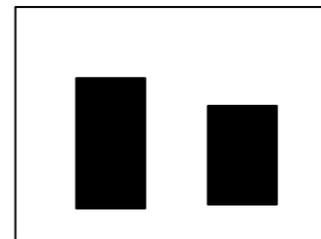
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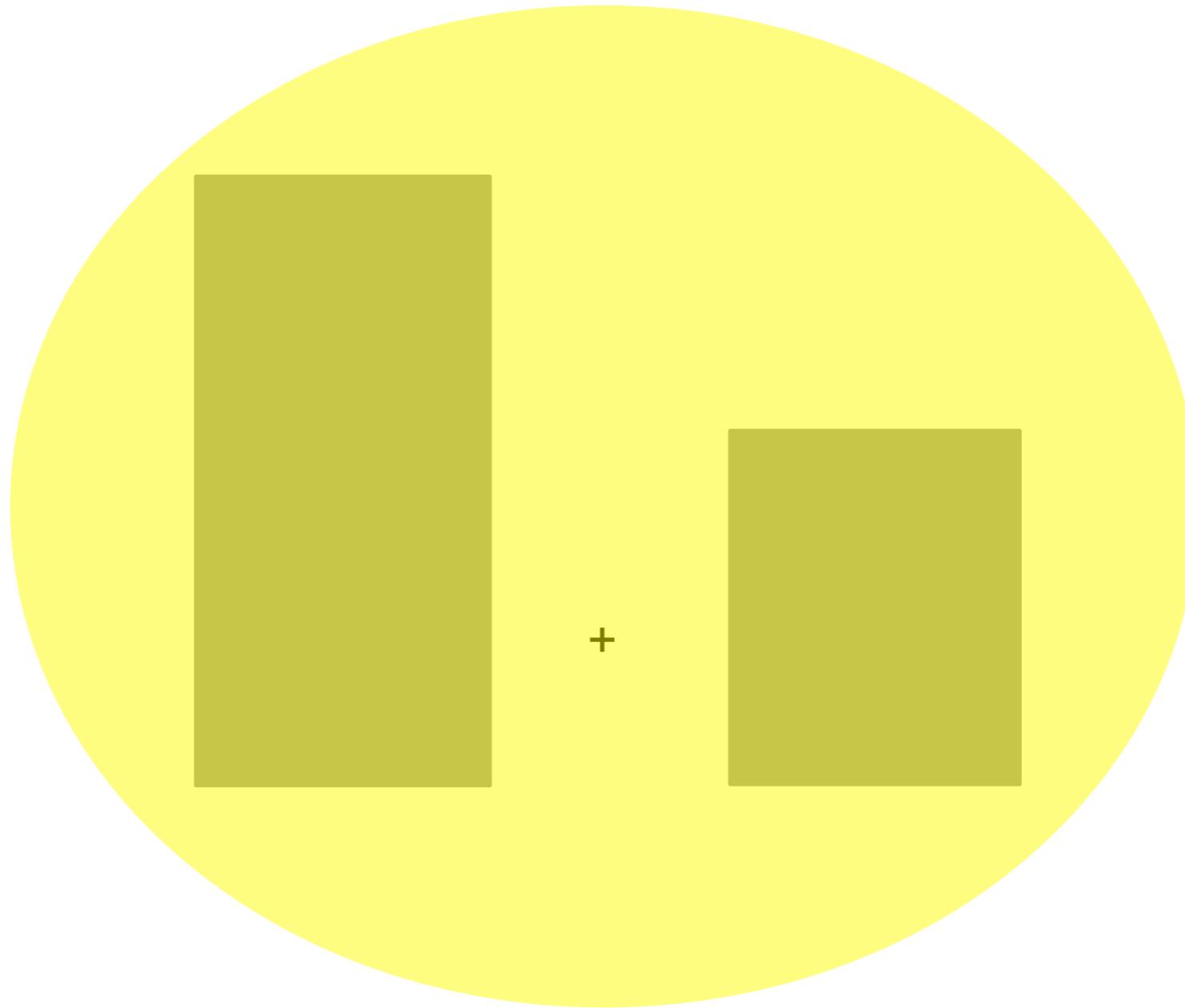
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or



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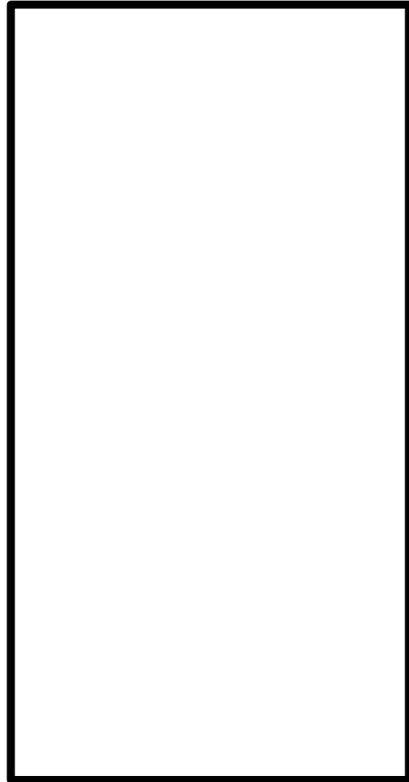


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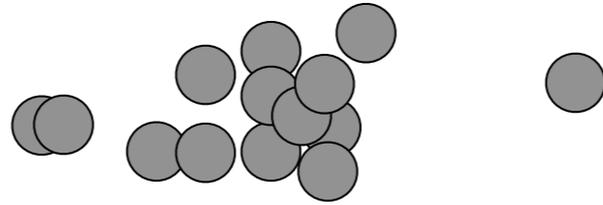
or

D

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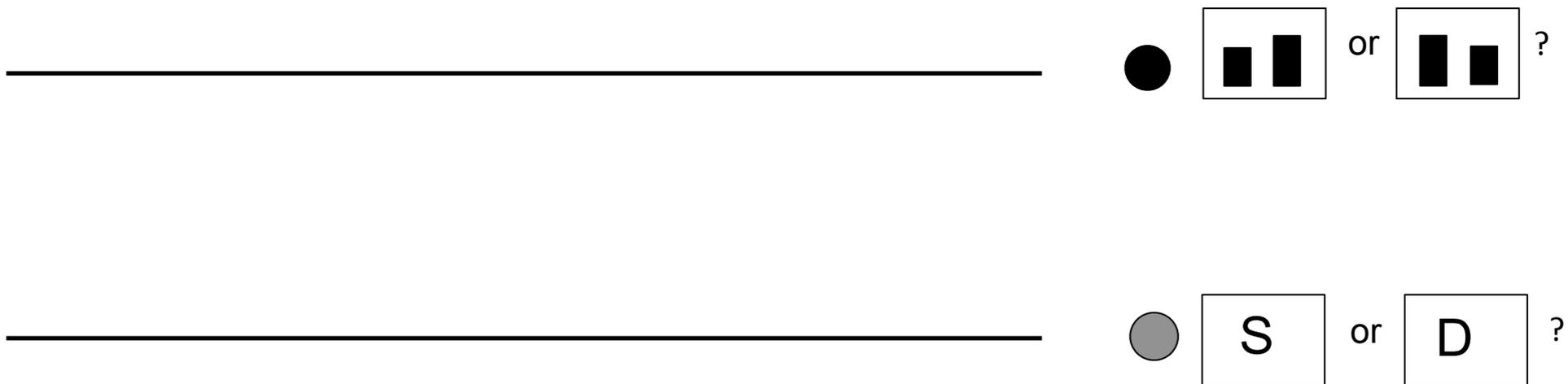
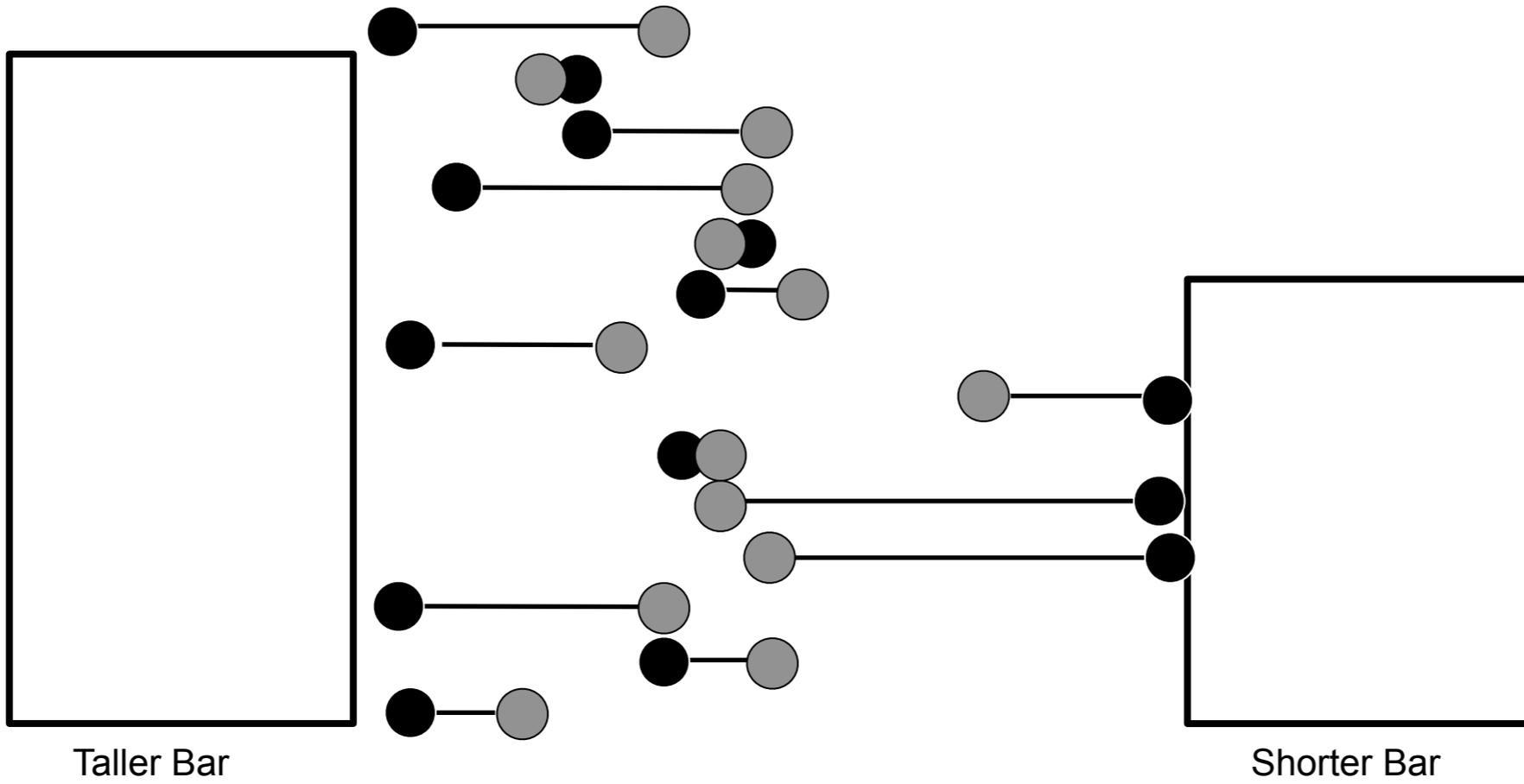


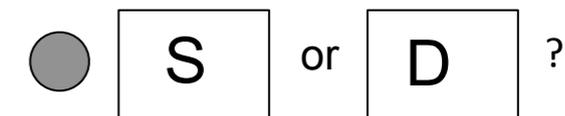
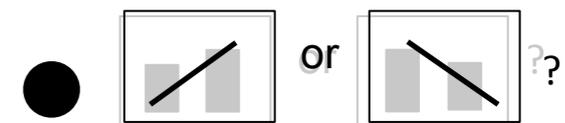
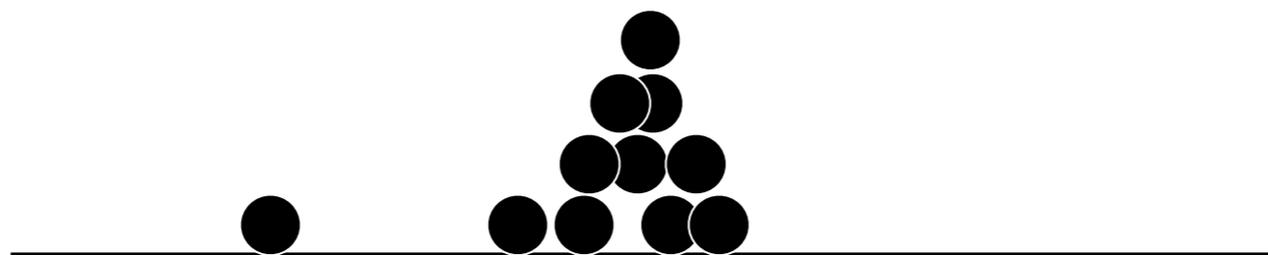
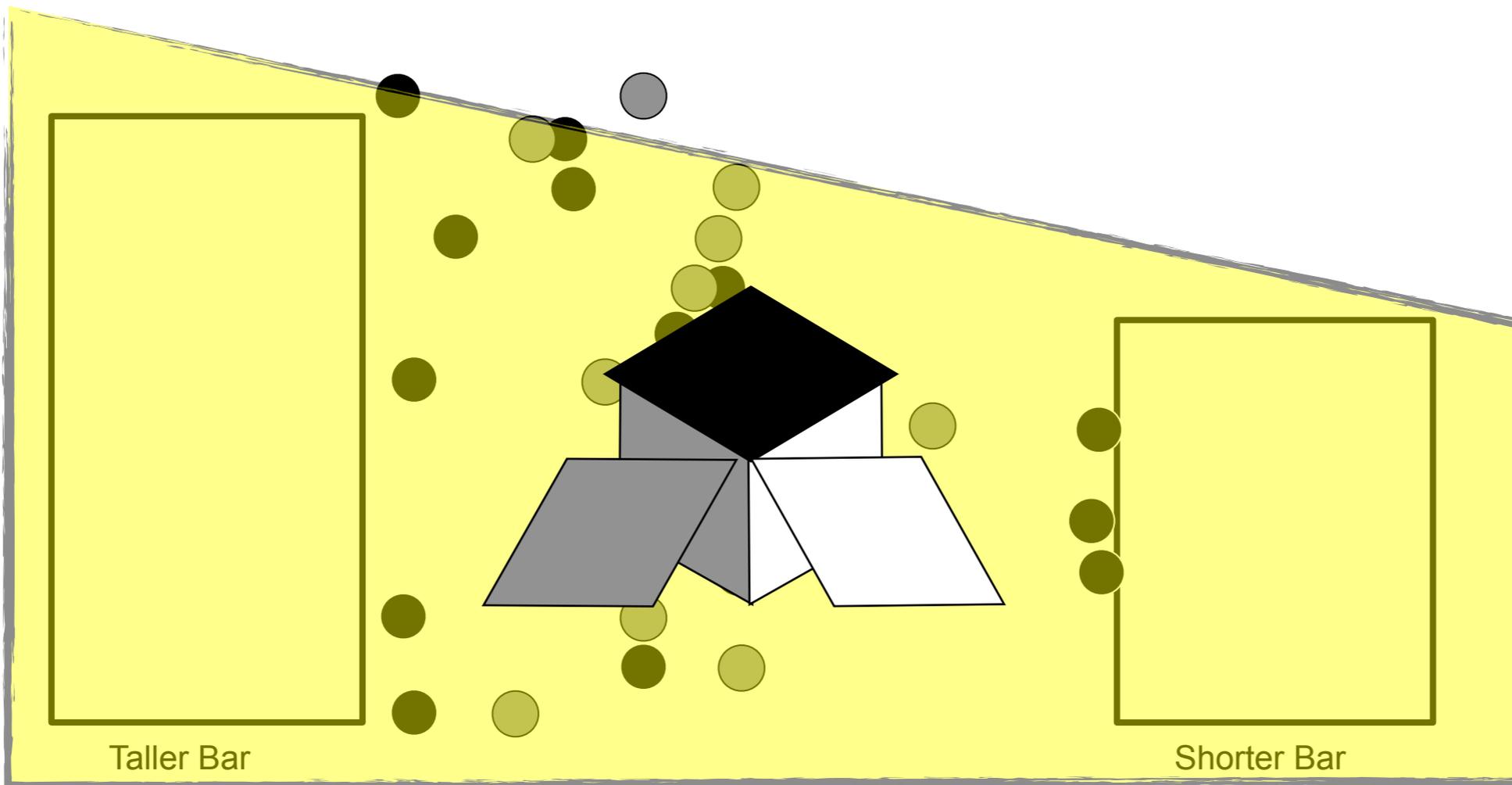
Taller Bar

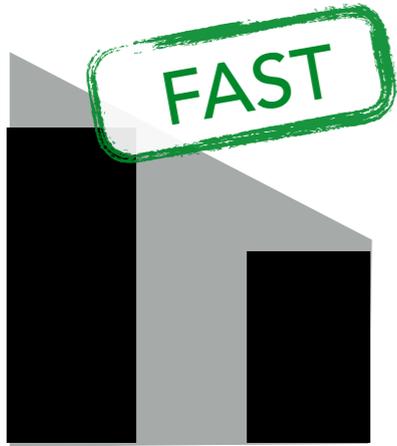


Shorter Bar

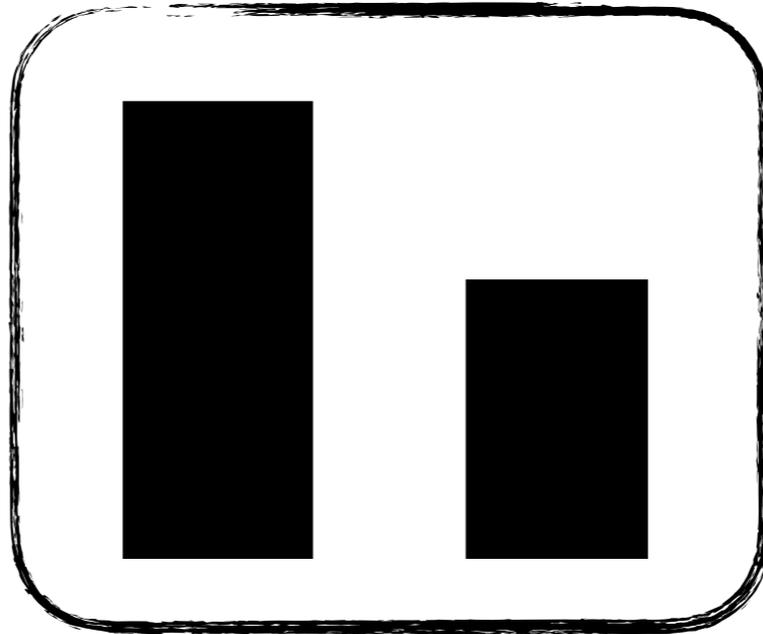
 S or D ?



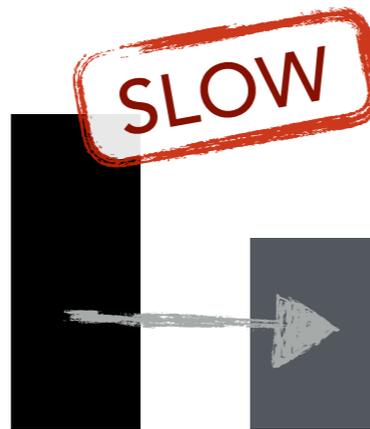




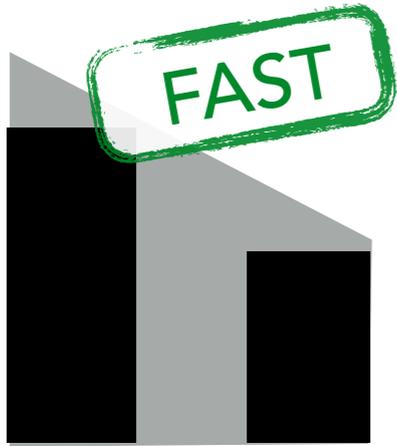
Shape recognition
(Sloped roof)



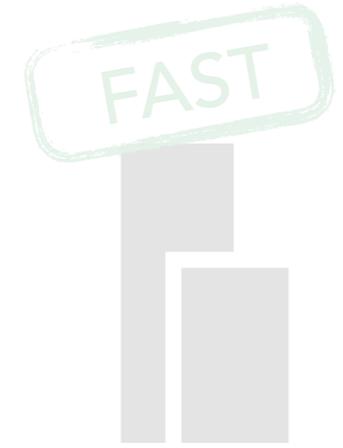
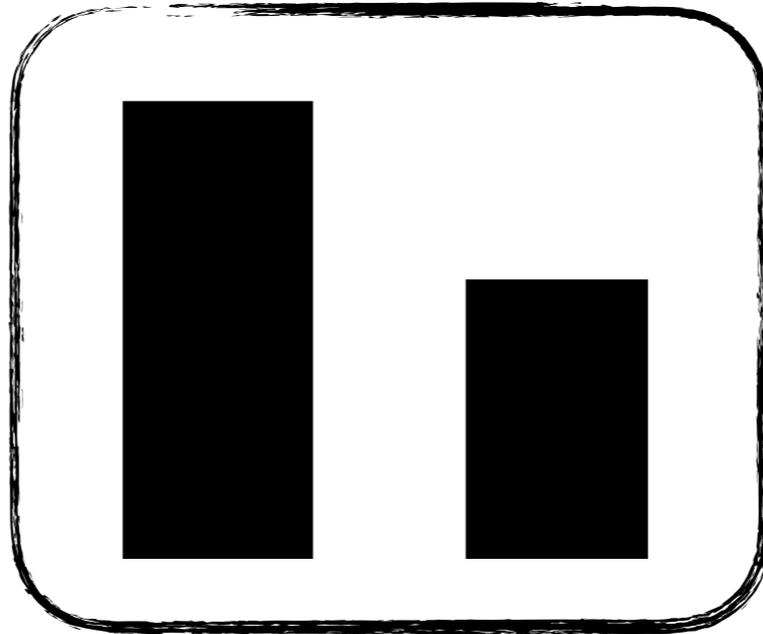
Histograms
(Different sizes)



Comparisons
(Left bigger; Right smaller; Right lighter...)



Shape recognition
(Sloped roof)



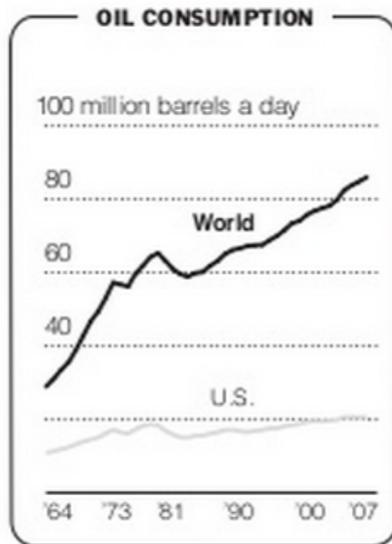
Histograms
(Different sizes)



Comparisons
(Left bigger; Right smaller; Right lighter...)

Oil's Roller Coaster Ride

This chart tracks the relationship between oil prices and oil consumption since 1964. Global oil consumption is shown on the horizontal axis and oil prices are shown on the vertical axis. So, when consumption is increasing and prices are flat, the line moves straight right. And when prices are rising and demand stops growing, the line moves straight up.



1979 and 1980
The Iranian revolution and the outbreak of the Iran-Iraq war reduce production. Prices soar.



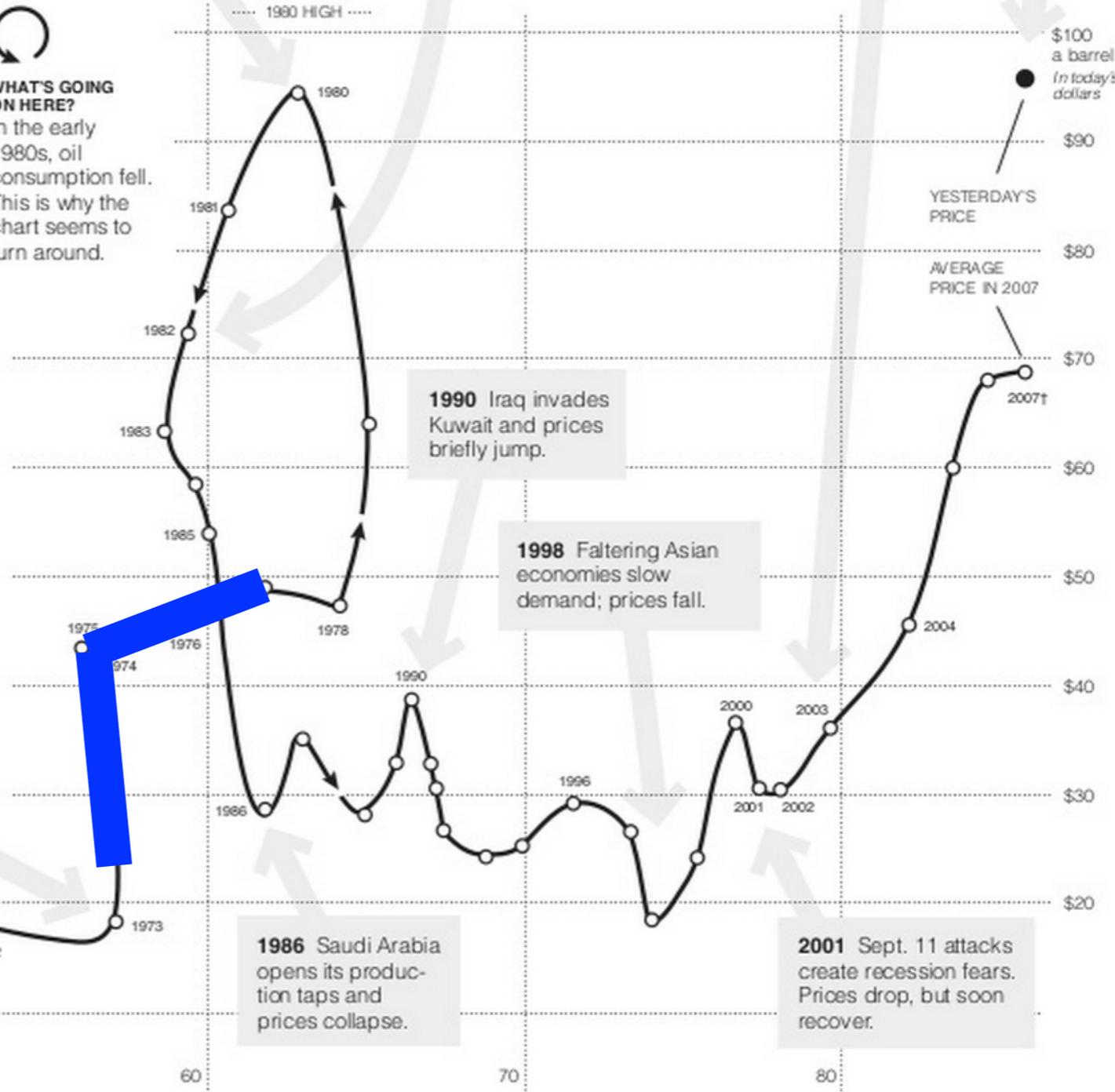
1982 Recessions in industrialized countries across the world damp demand. Smaller cars also conserve oil, and prices fall.

Early 2000s
Record demand in Asia and the United States and instability in Iraq, Venezuela and Nigeria fuel a run-up in prices.

2007 Low inventories, a weak dollar and bullish trading push oil near \$100 a barrel.



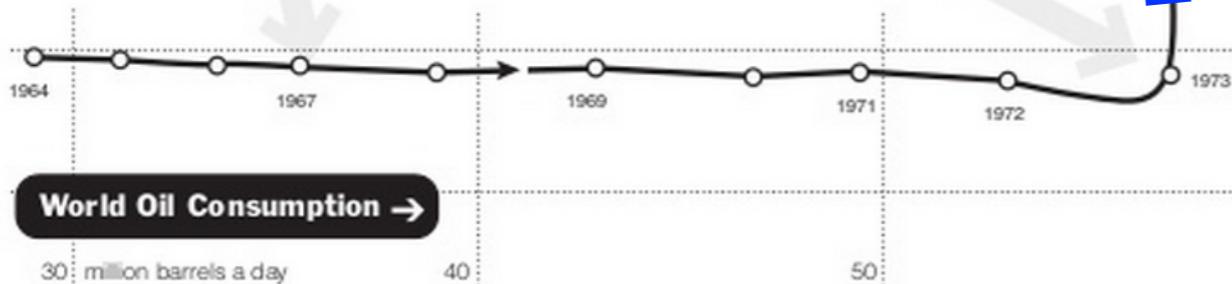
WHAT'S GOING ON HERE?
In the early 1980s, oil consumption fell. This is why the chart seems to turn around.



Late 1960s, early 1970s
Oil prices are steady and energy supplies are plentiful. World oil consumption doubles from 1964 to 1973.



1973 The Arab oil embargo causes price increases and short-term shortages. Lines form at gas stations, and consumption stalls for two years.

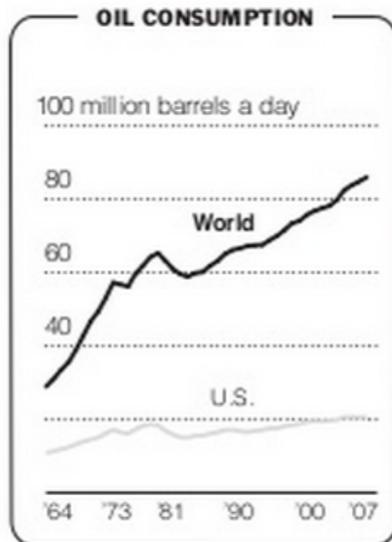


* Average annual price of West Texas Intermediate crude oil, adjusted for inflation using the Consumer Price Index. Posted prices (not spot prices) are shown before 1983.

† Consumption forecast as of Nov. 6

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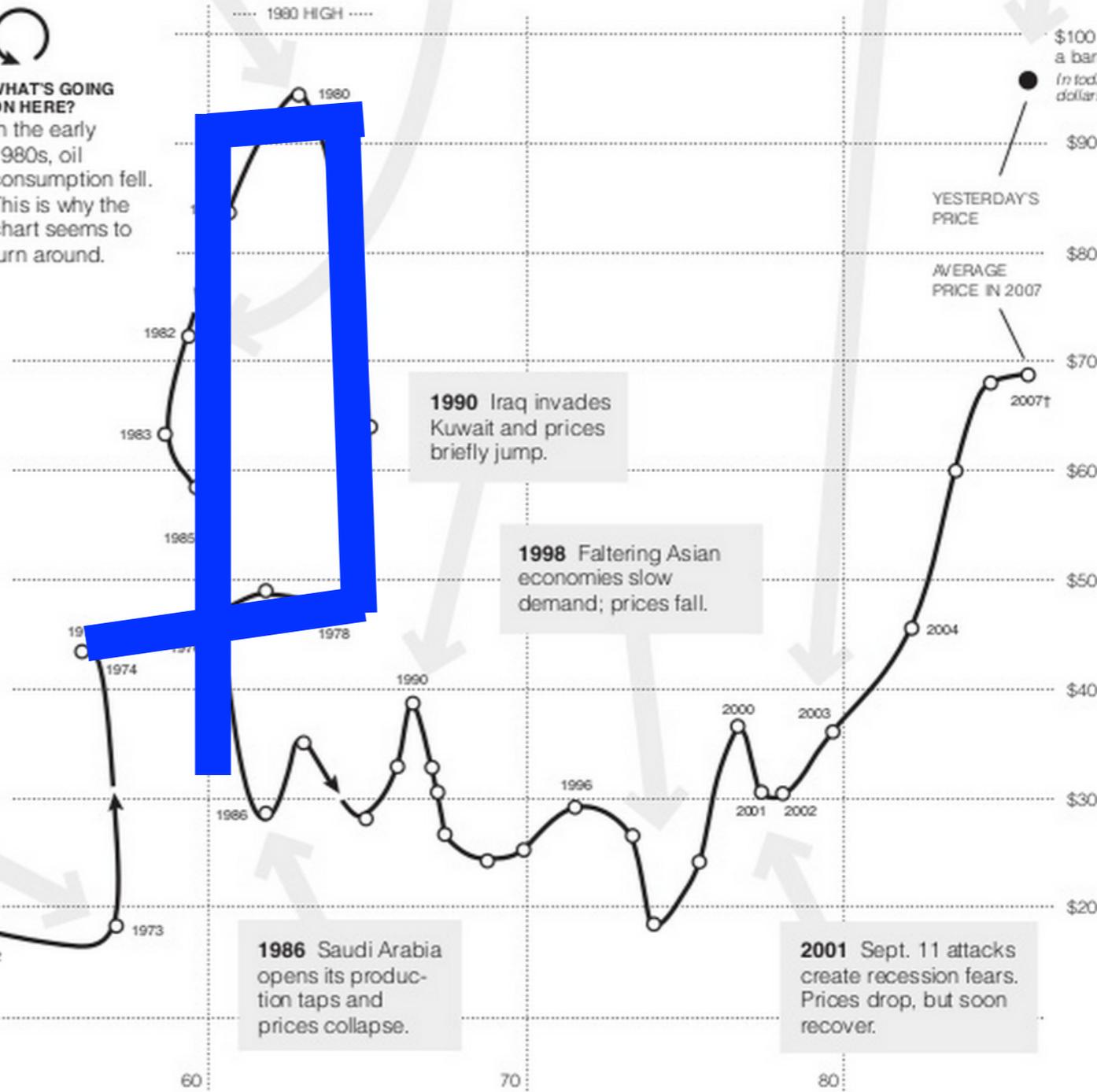
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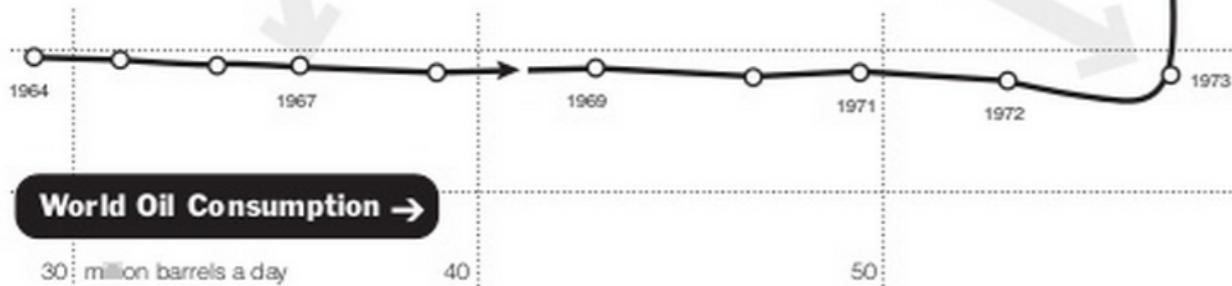
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The Connected Scatterplot for Presenting Paired Time Series

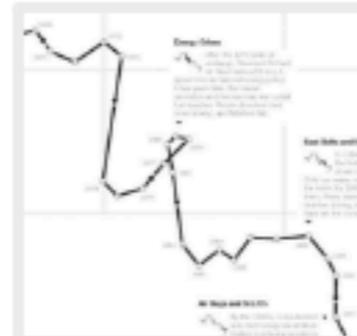
Collaborators

[Steve Haroz](#) - Psychology, Northwestern University

[Robert Kosara](#) - Tableau Research

[Steven Franconeri](#) - Psychology, Northwestern University

PDF



Hannah Fairfield, The New York Times, 2012

An effective tool for journalists?

As far back as the 1790s, the connected scatterplot was used to visualize the cycle of a steam piston. Economists have since used it to depict data about unemployment and job openings over time.

Recently, journalists have begun using the technique to convey information to readers. But how well do those readers understand this unfamiliar format?

We tested how well viewers understand what the chart depicts, whether they can translate back & forth to more traditional formats, and whether they are more likely to engage with this new chart.

Try it out: Drag the points to make your own connected scatterplot

Dataset: Figure 4 - Loops Dots Arrows Labels Grid Add samples

Flip H Flip V Rotate CW Rotate CCW

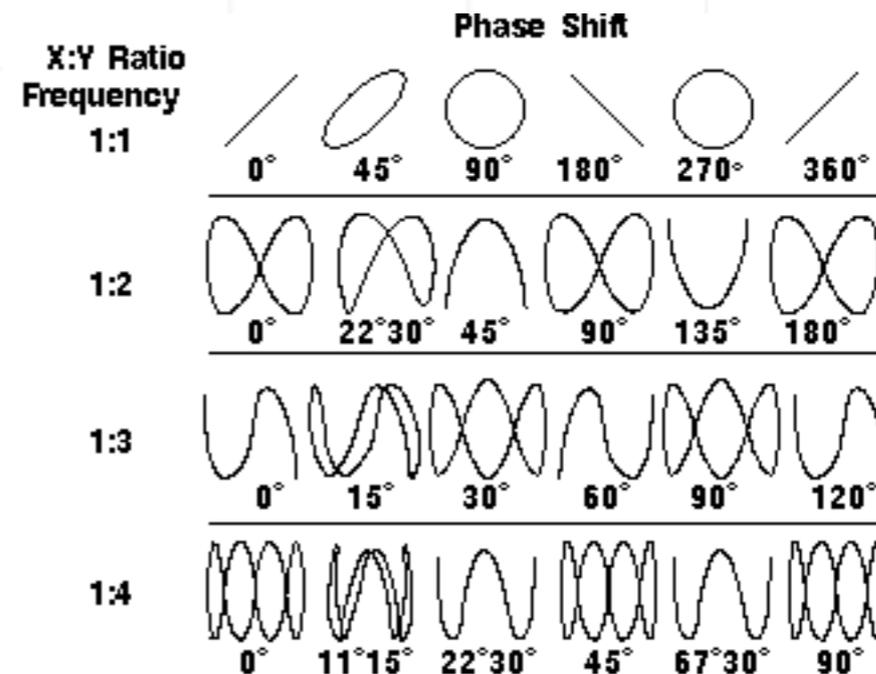
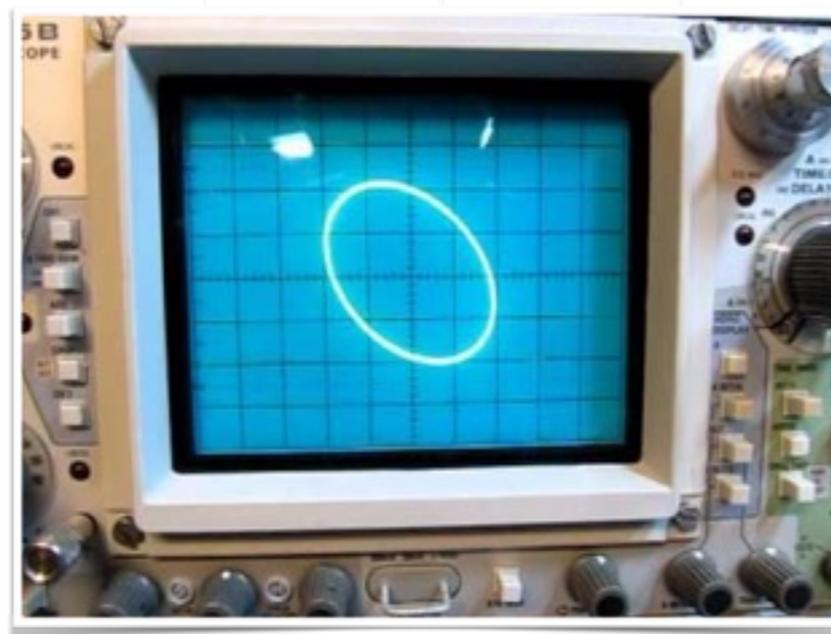
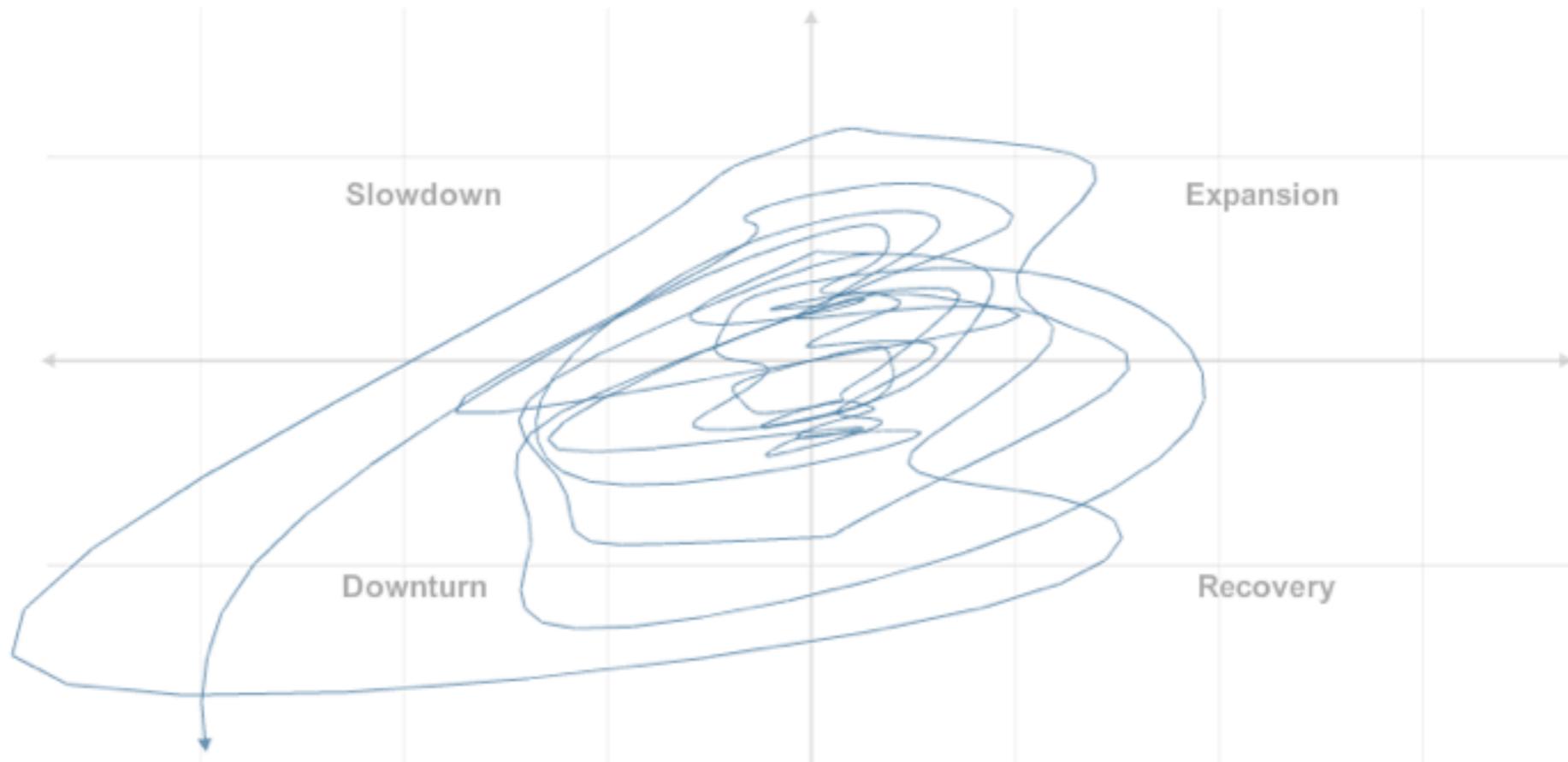
Turning a Corner?

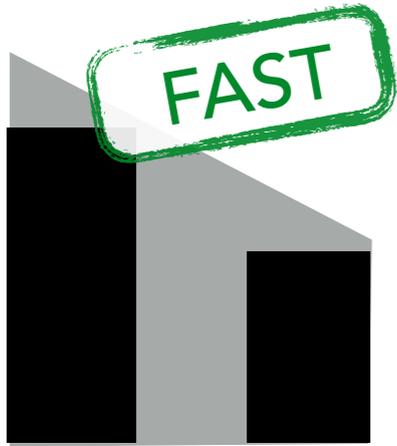
A chart of industrial production — the output of manufacturers, miners and utility companies — suggests that the economy is poised to turn around, but that the climb out of the current downturn will be a long one.

1 2 3 4 5 6 7 8 9 NEXT ▶

Looking for turning points

Economic turning points are notoriously hard to identify, especially when a parade of data can seem to contradict itself. To get a feeling for how cycles are evolving, economists at the Organization for Economic Cooperation and Development have been watching a chart that illustrates the business cycle.





Shape recognition
(Sloped roof)



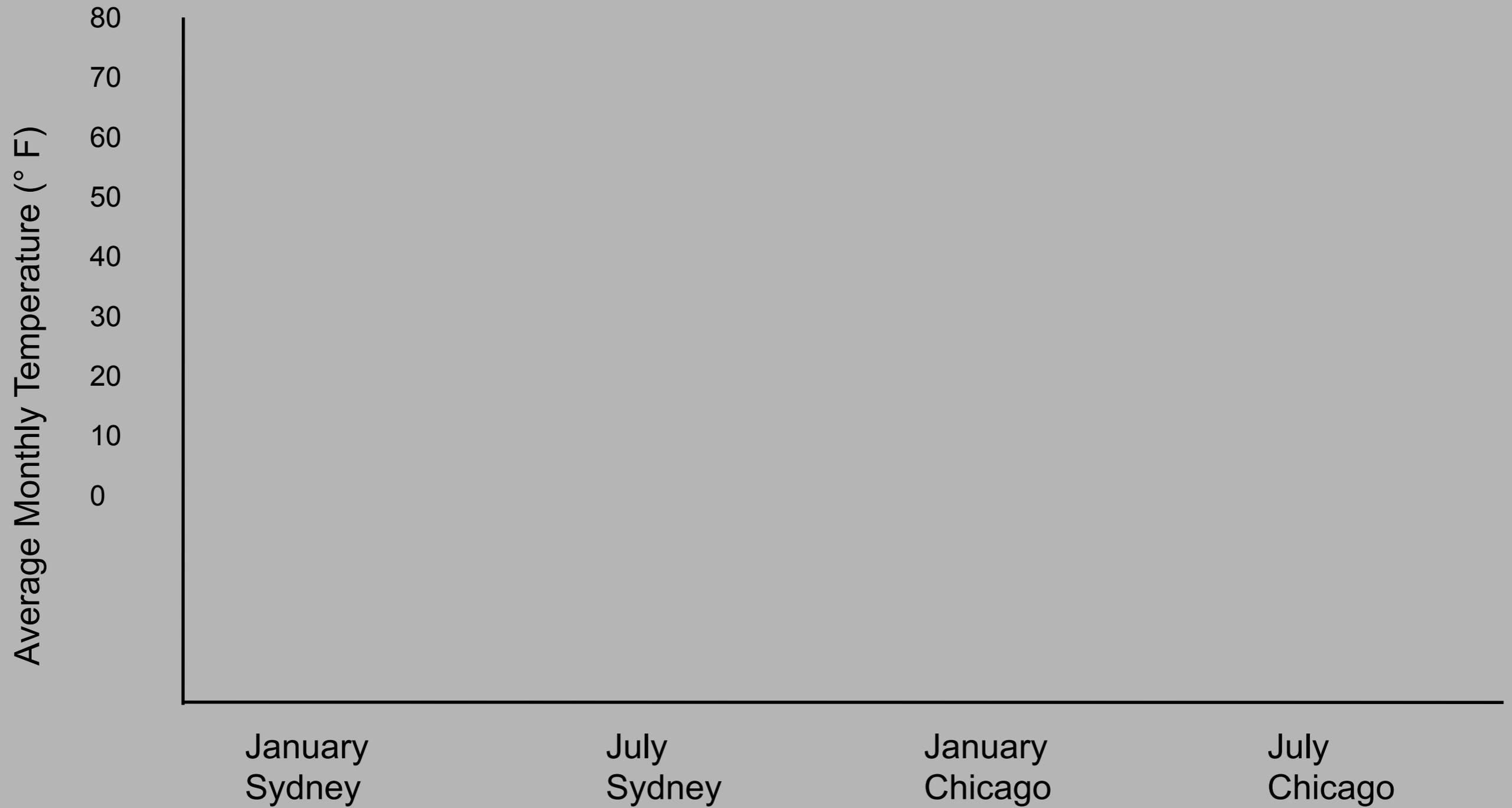
Histograms
(Different sizes)

*Students need to learn
which to use, when*

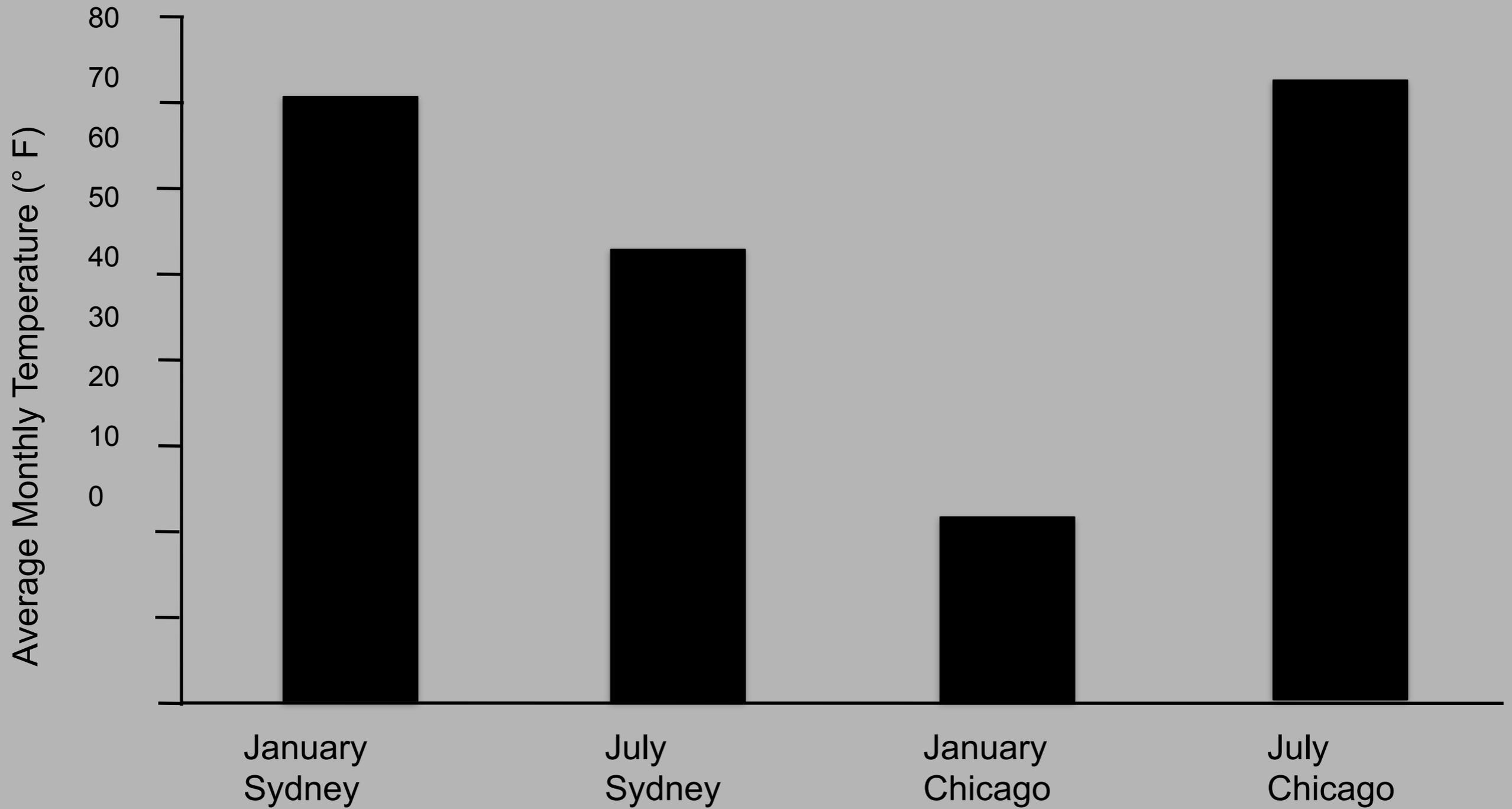


Comparisons
(Left bigger; Right smaller; Right lighter...)

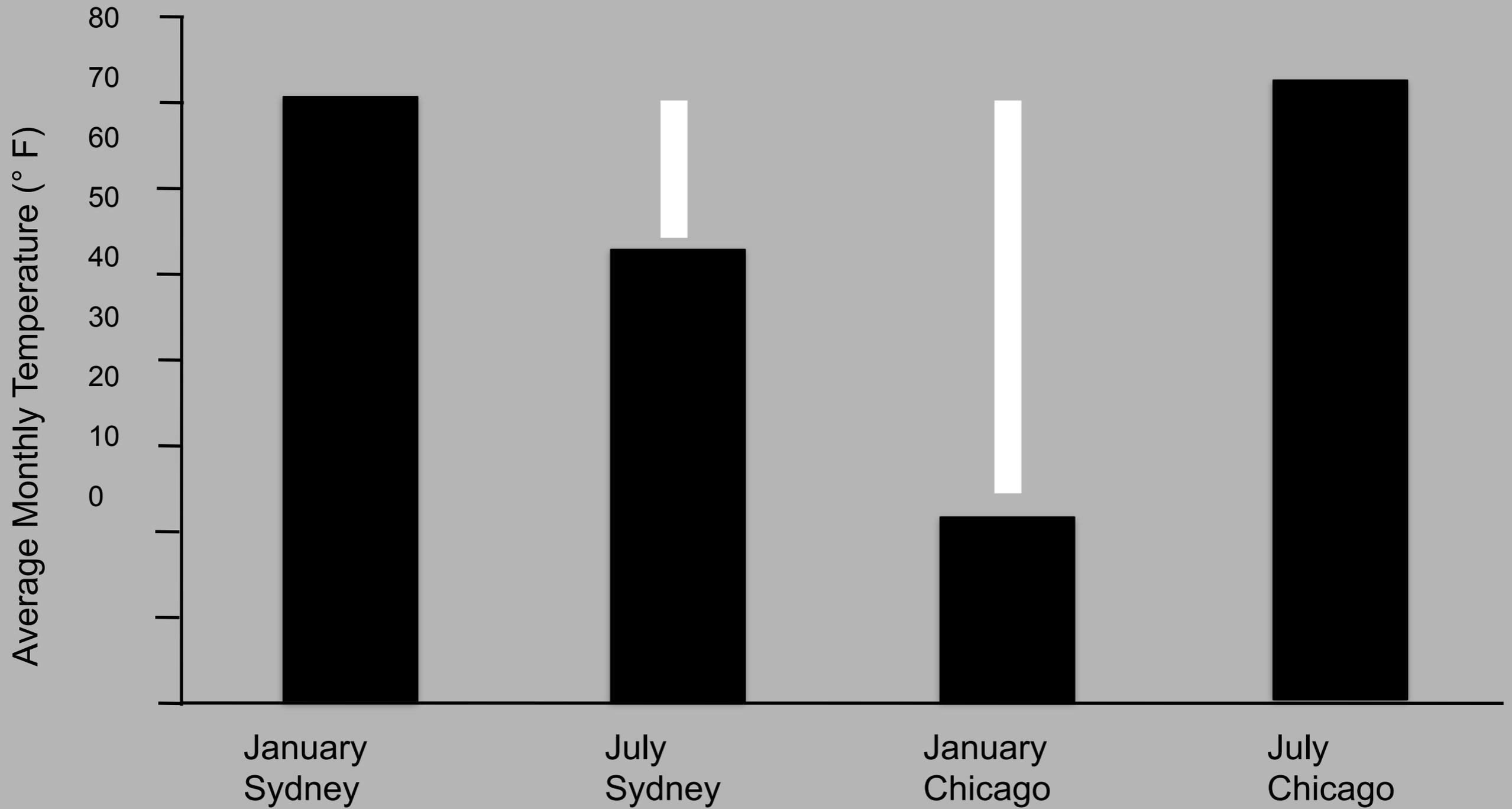
Seasonal Temperatures in Sydney and Chicago



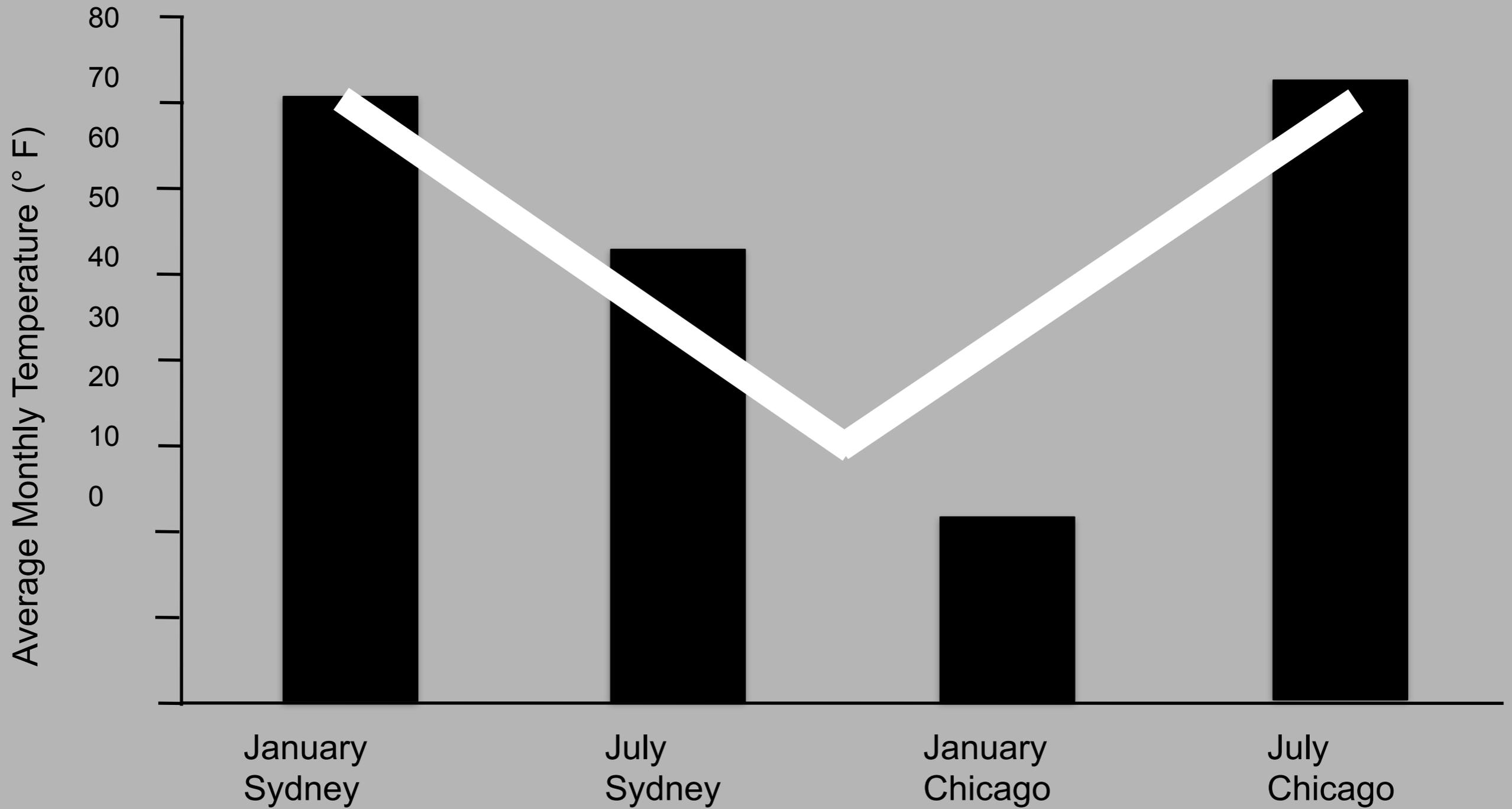
Seasonal Temperatures in Sydney and Chicago



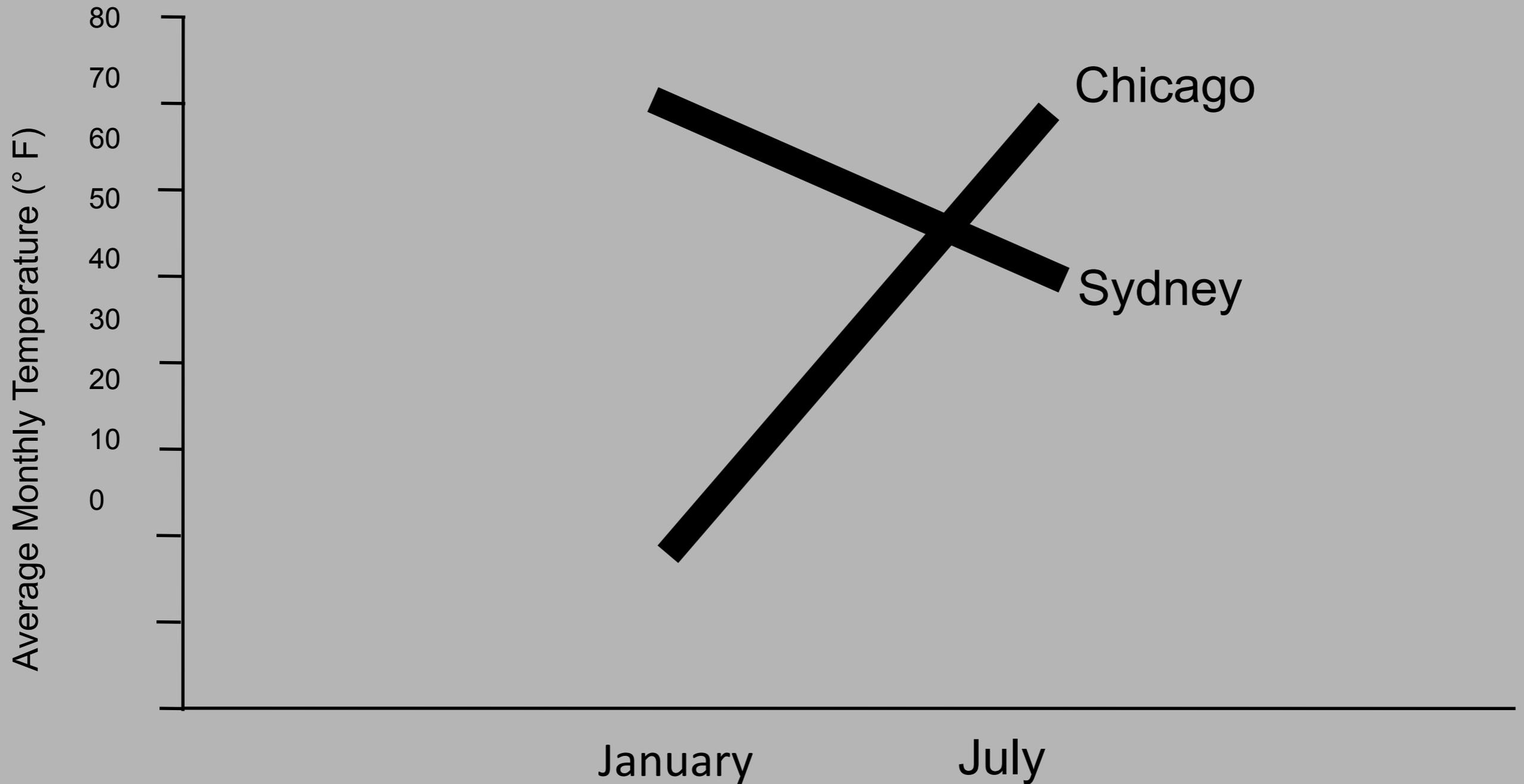
Seasonal Temperatures in Sydney and Chicago

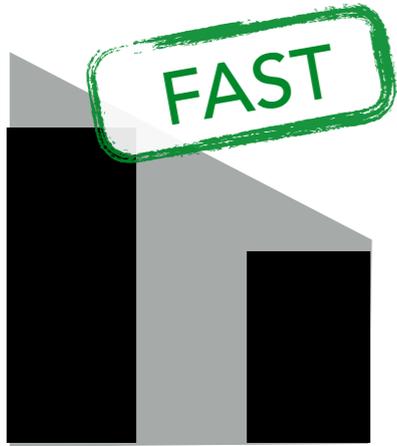


Seasonal Temperatures in Sydney and Chicago

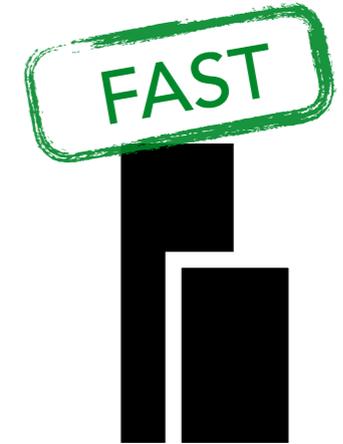
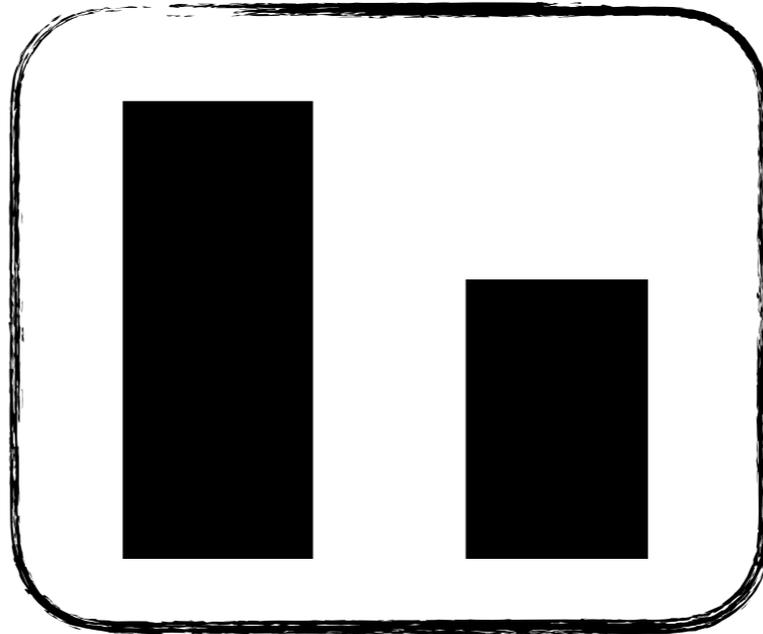


Seasonal Temperatures in Sydney and Chicago





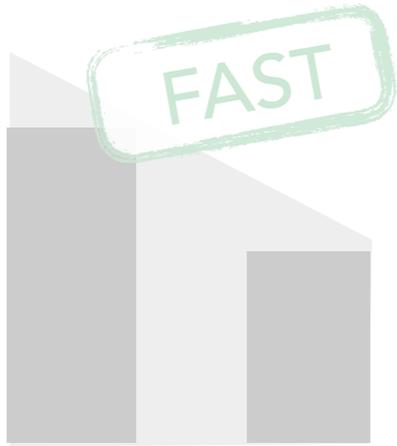
Shape Recognition



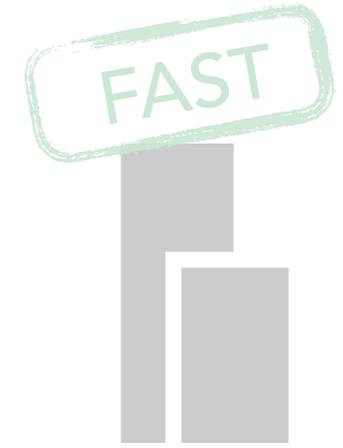
Different sizes



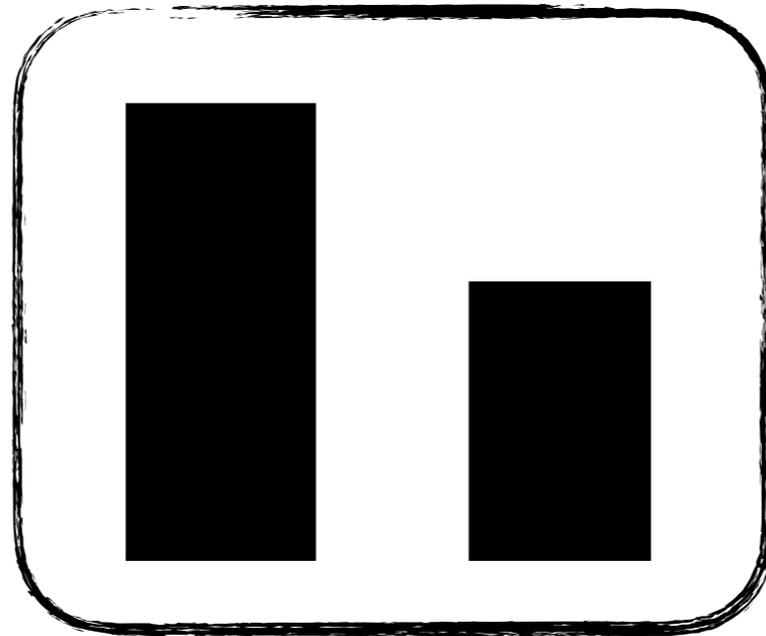
Left bigger; Right smaller; Left taller; Smaller on the right...



Shape Recognition



Different sizes

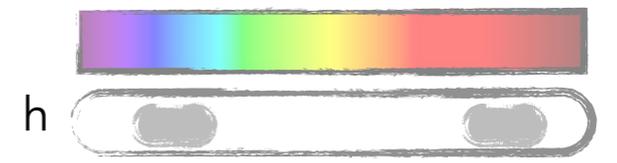
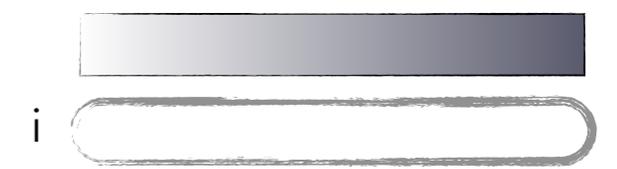
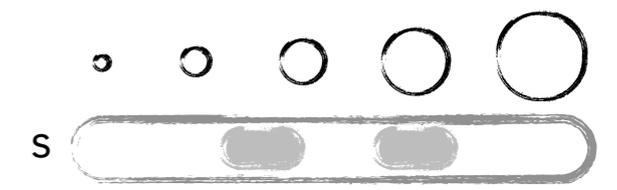


Left bigger; Right smaller; Left taller; Smaller on the right..



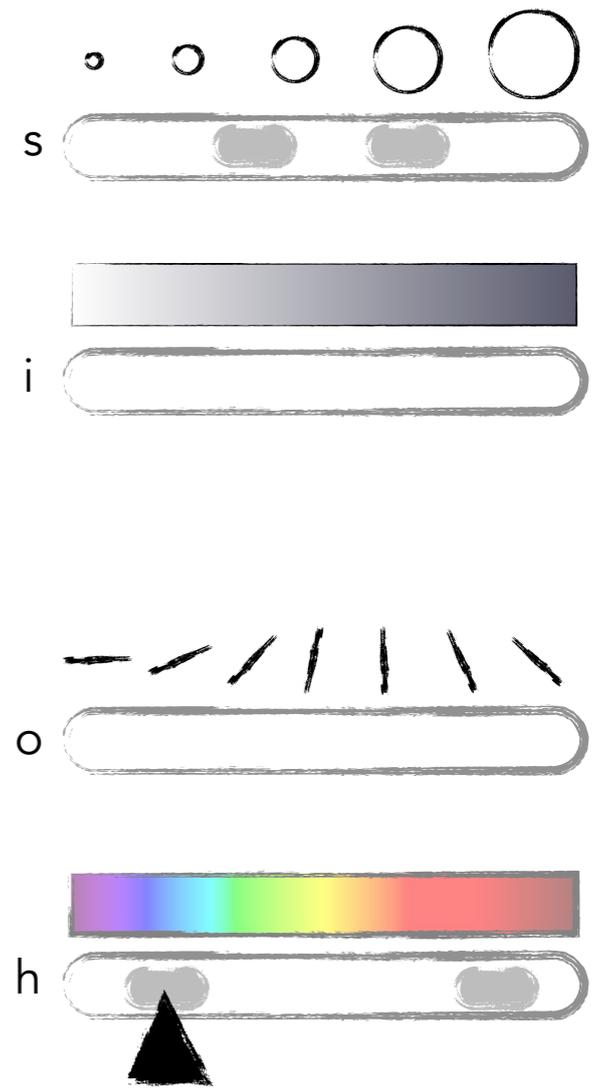
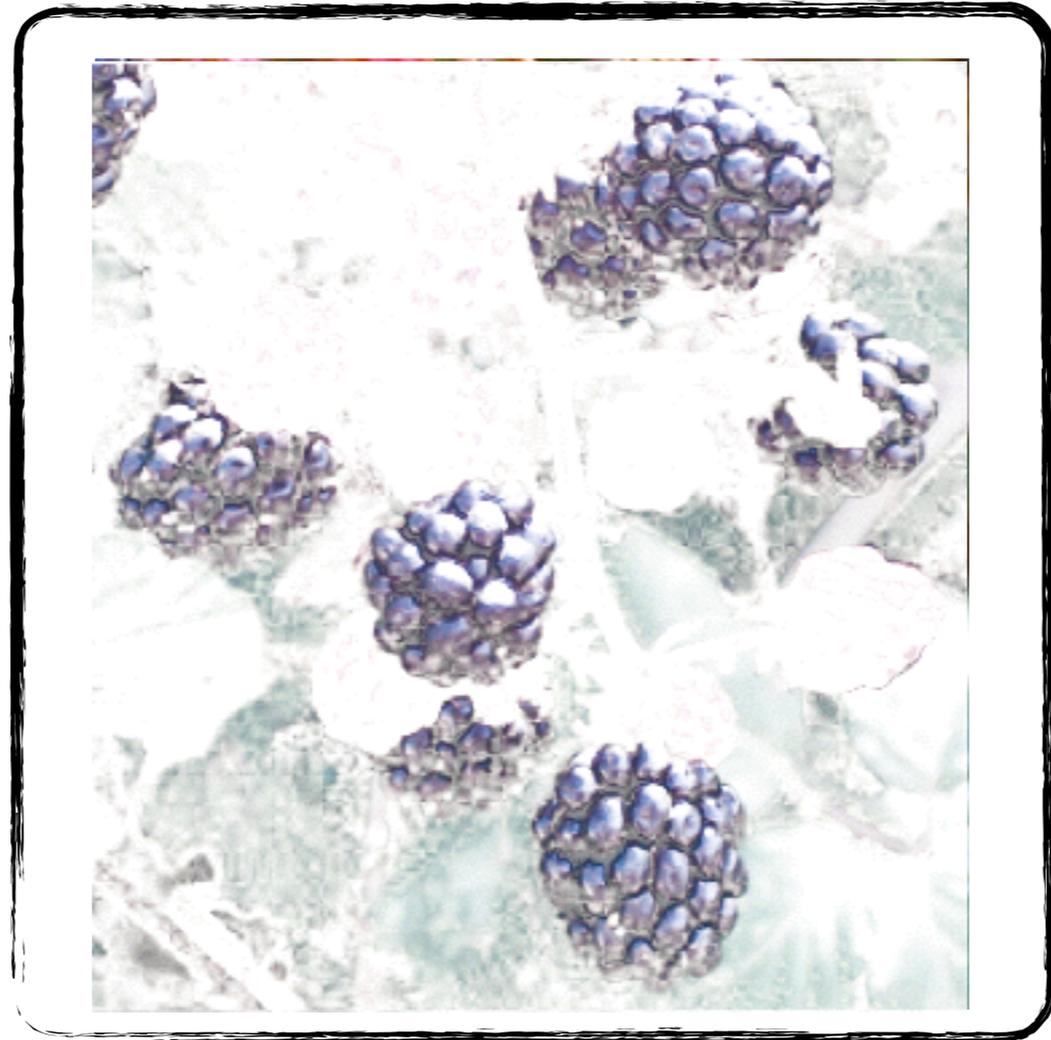


A B P



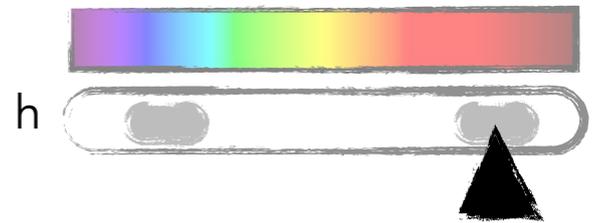
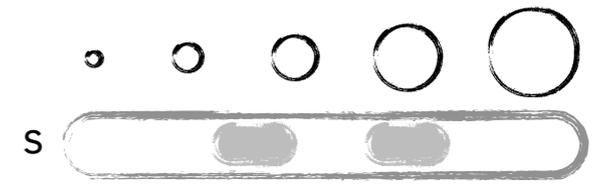


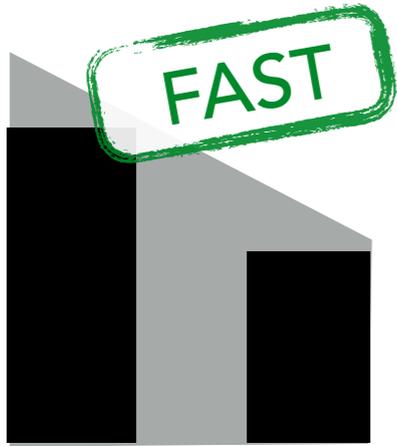
A B P



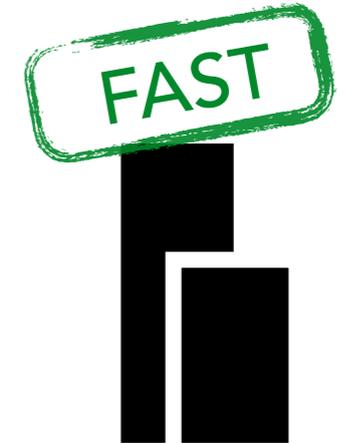
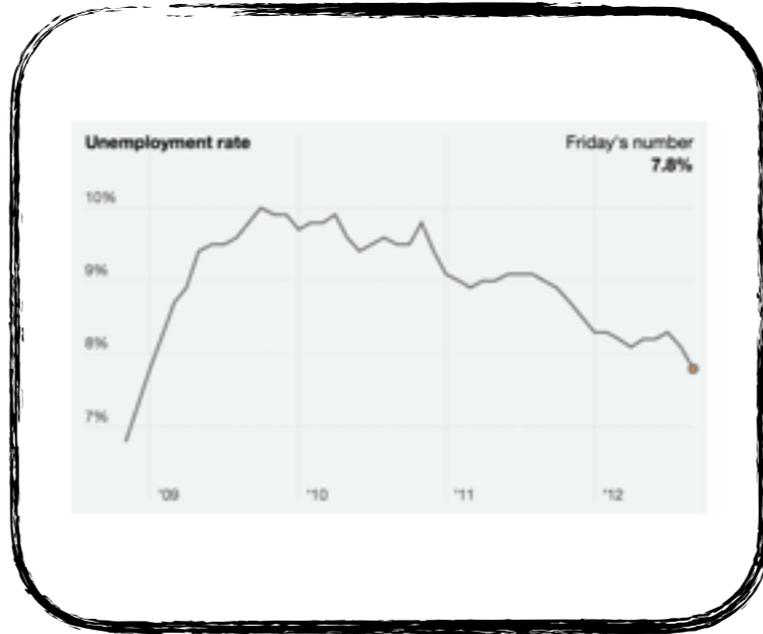


A B P





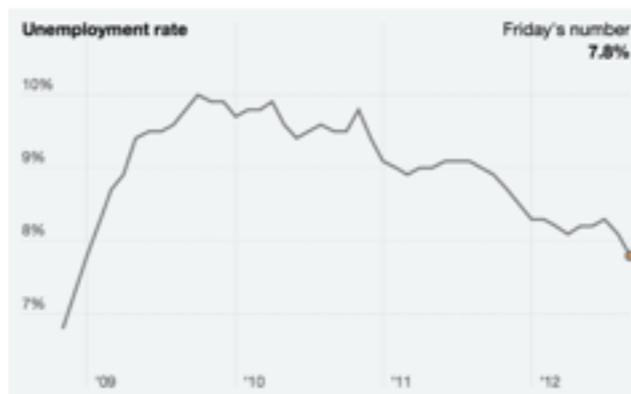
Shape Recognition



Different sizes

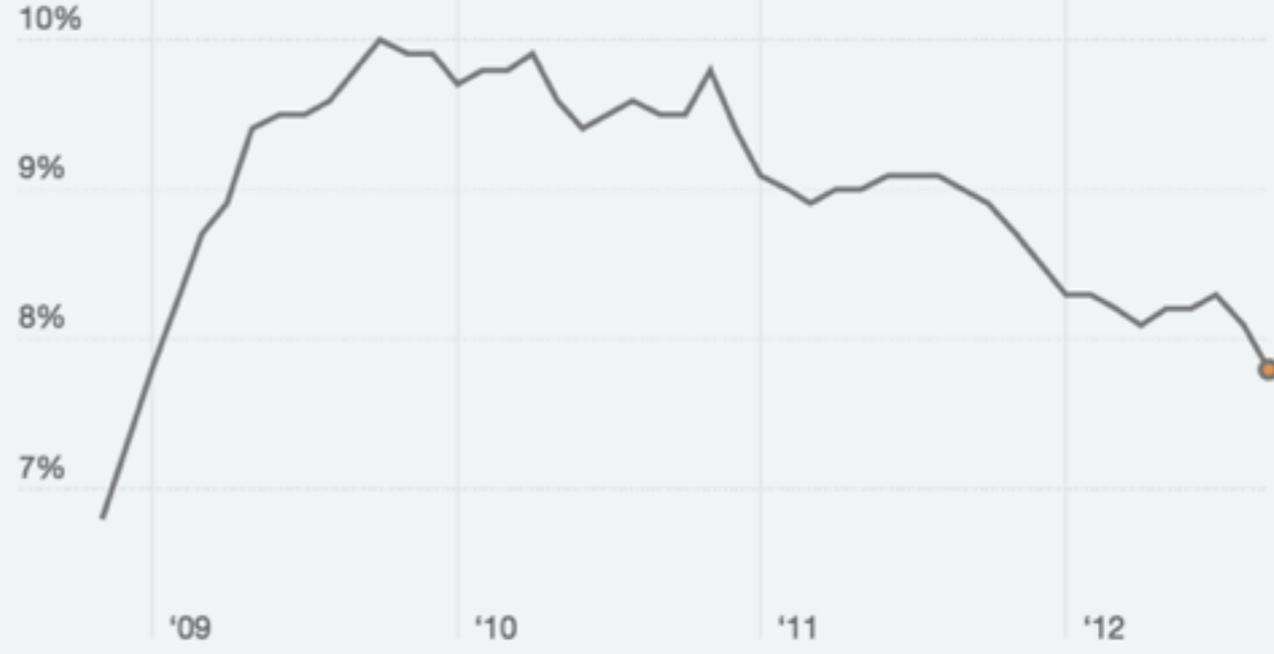


Left bigger; Right smaller; Left taller; Smaller on the right...



Unemployment rate

Friday's number
7.8%



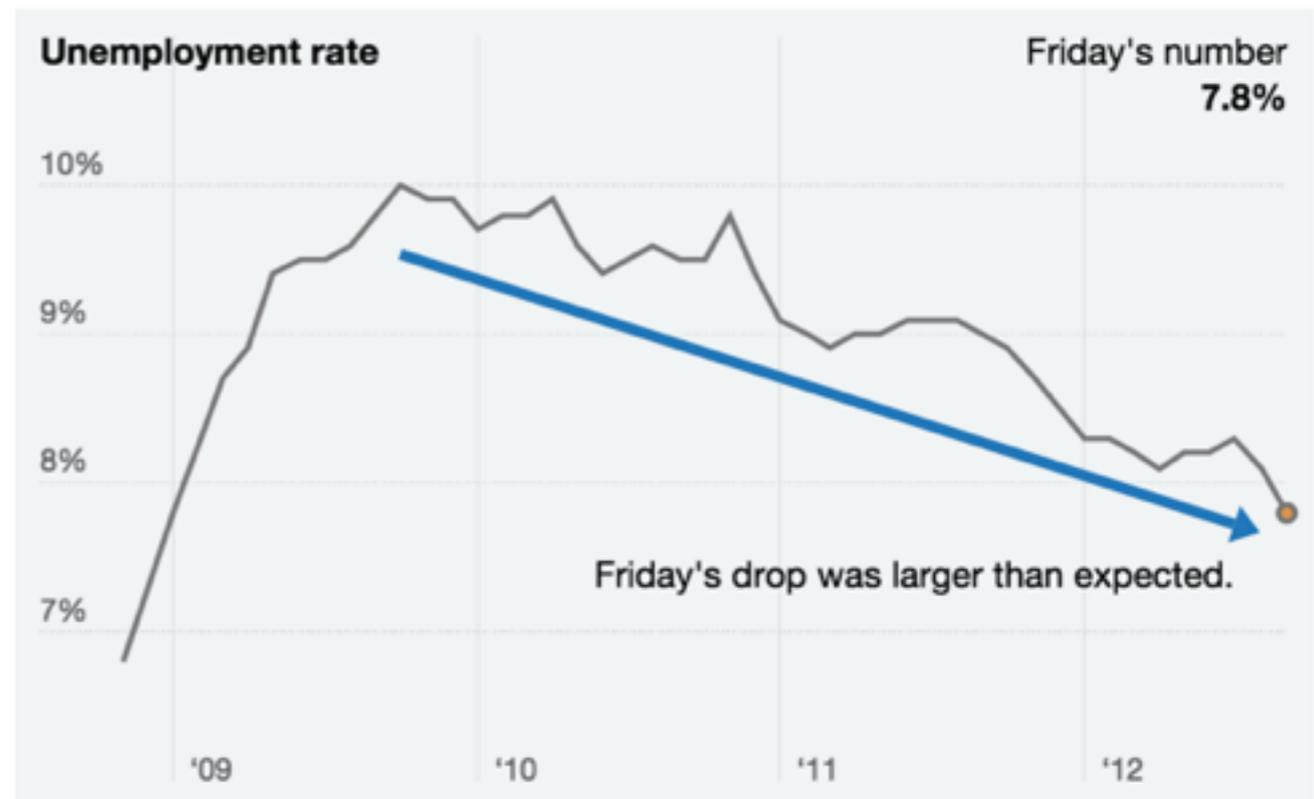
One Report, Diverging Perspectives

Friday's jobs report is the second-to-last of the presidential campaign. Each party will interpret the numbers in a way to convince voters that its policies will help economic growth. [Related Article »](#)

 <p>How a Democrat Might See Things</p>	 <p>September Jobs Report</p>	 <p>How a Republican Might See Things</p>
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There have been 31 consecutive months of job growth.

The rate has fallen more than 2 points since its recent peak.



By MIKE BOSTOCK, SHAN CARTER, AMANDA COX and KEVIN QUEALY | [Send Feedback](#)

Source: Bureau of Labor Statistics

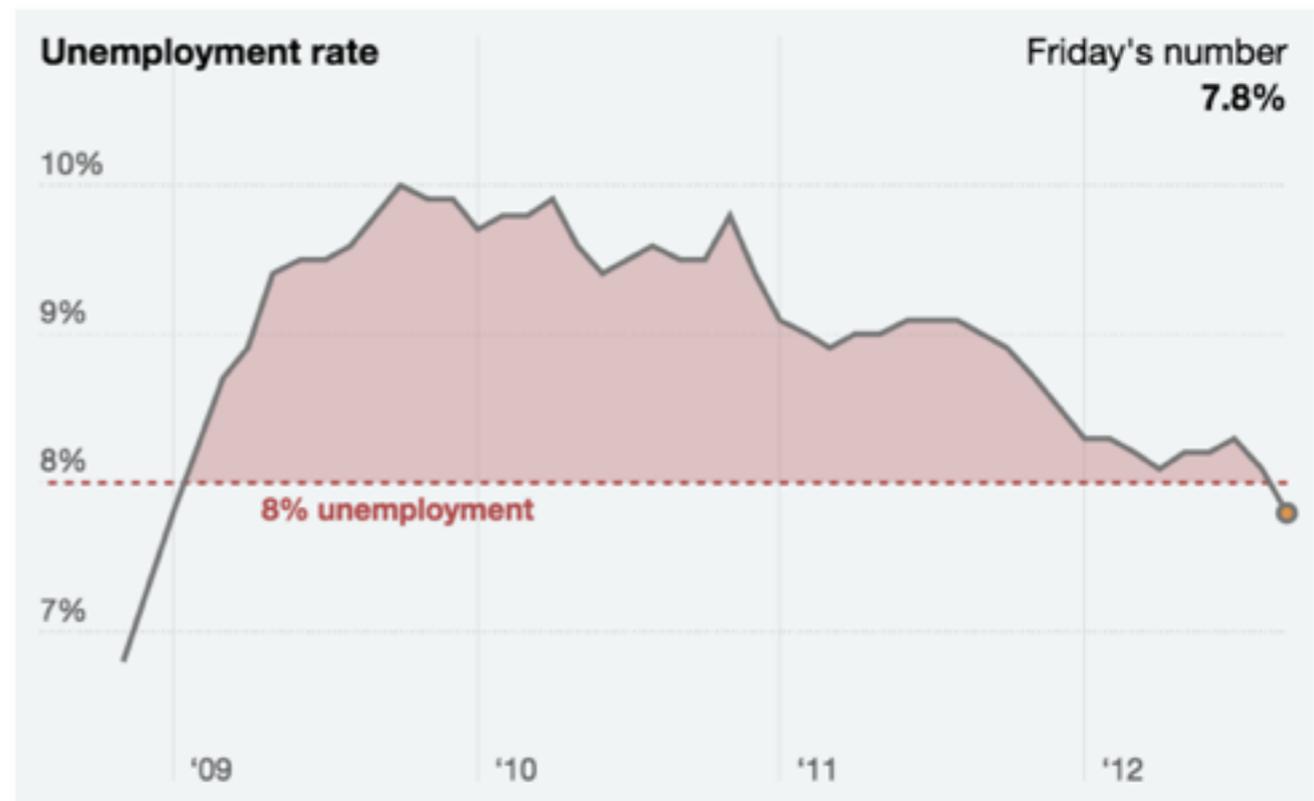
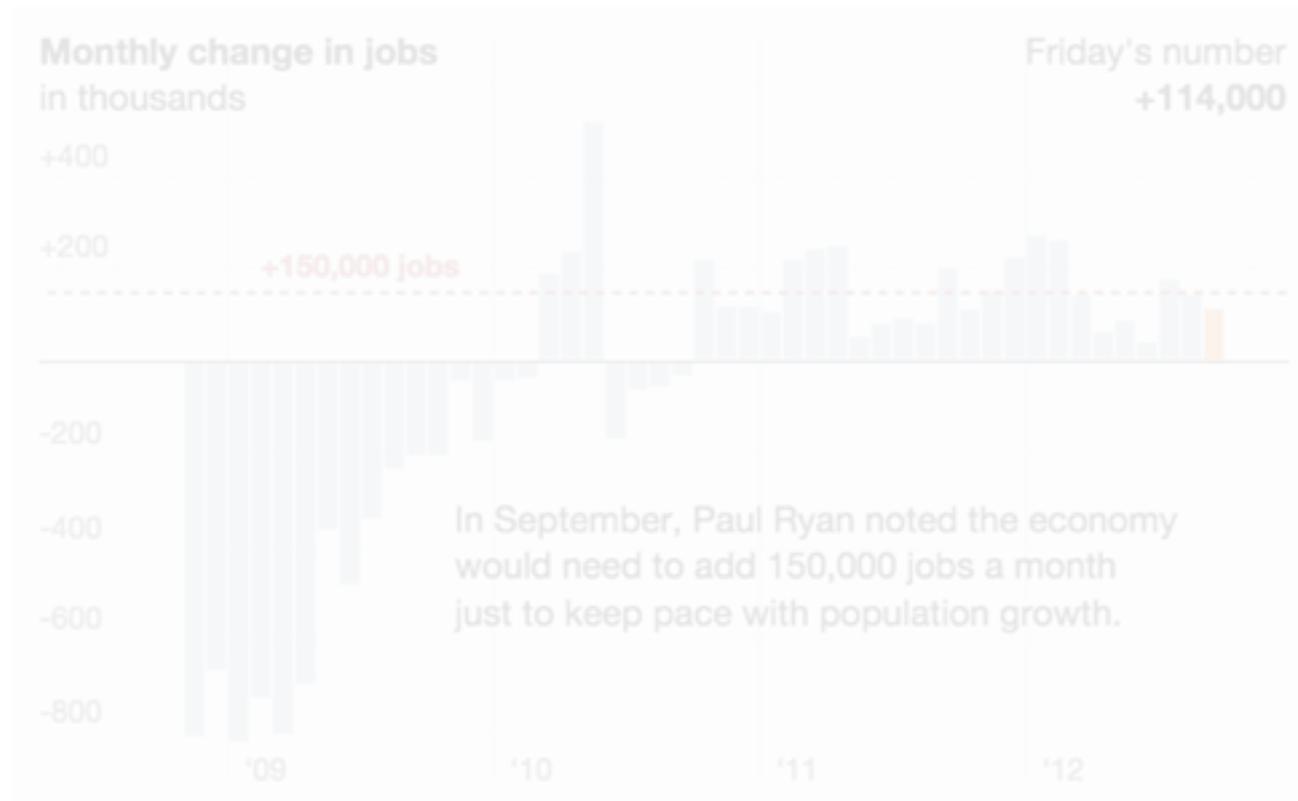
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Job growth has been weak.

The rate was above 8 percent for 43 months.

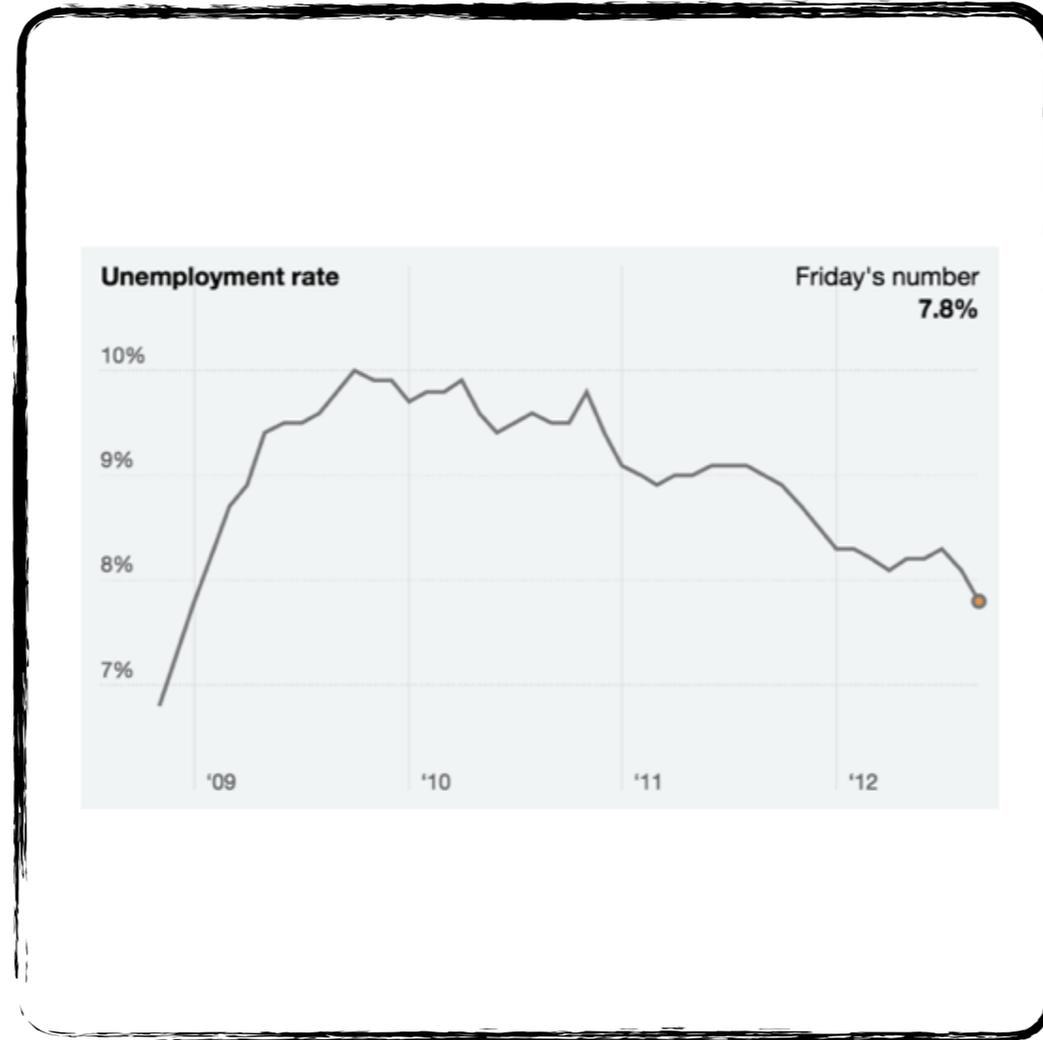


By MIKE BOSTOCK, SHAN CARTER, AMANDA COX and KEVIN QUEALY | [Send Feedback](#)

Source: Bureau of Labor Statistics

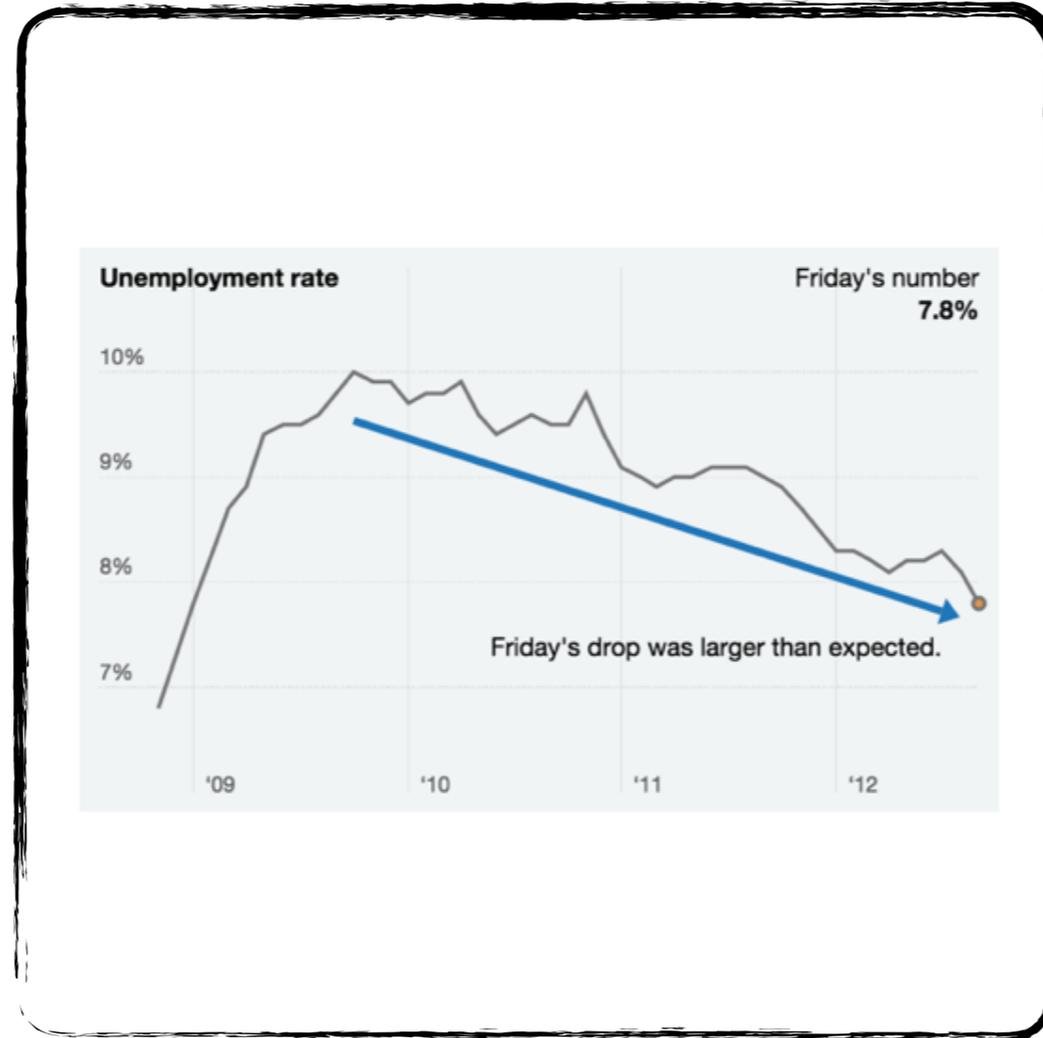


A B C



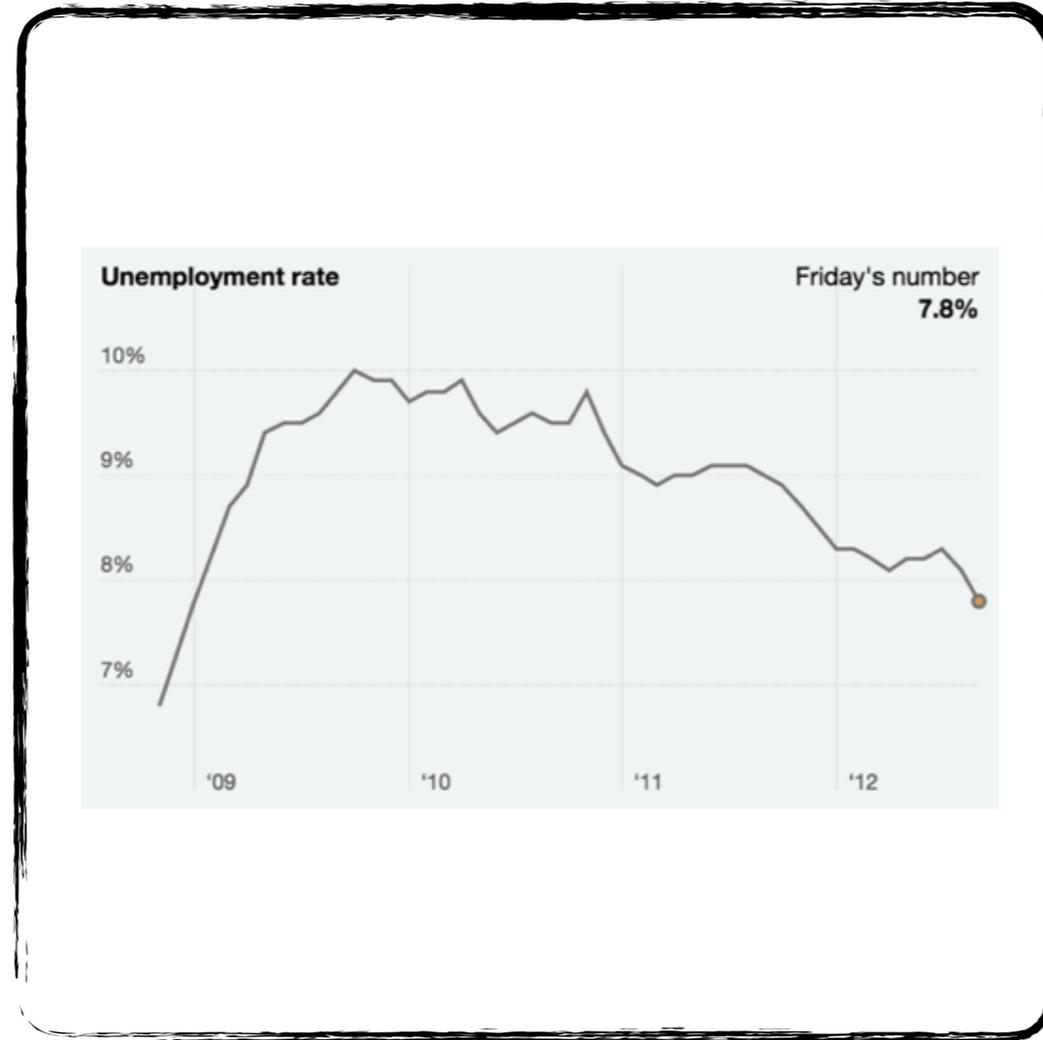
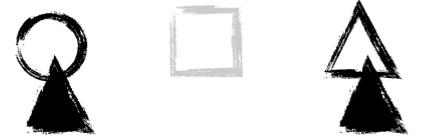


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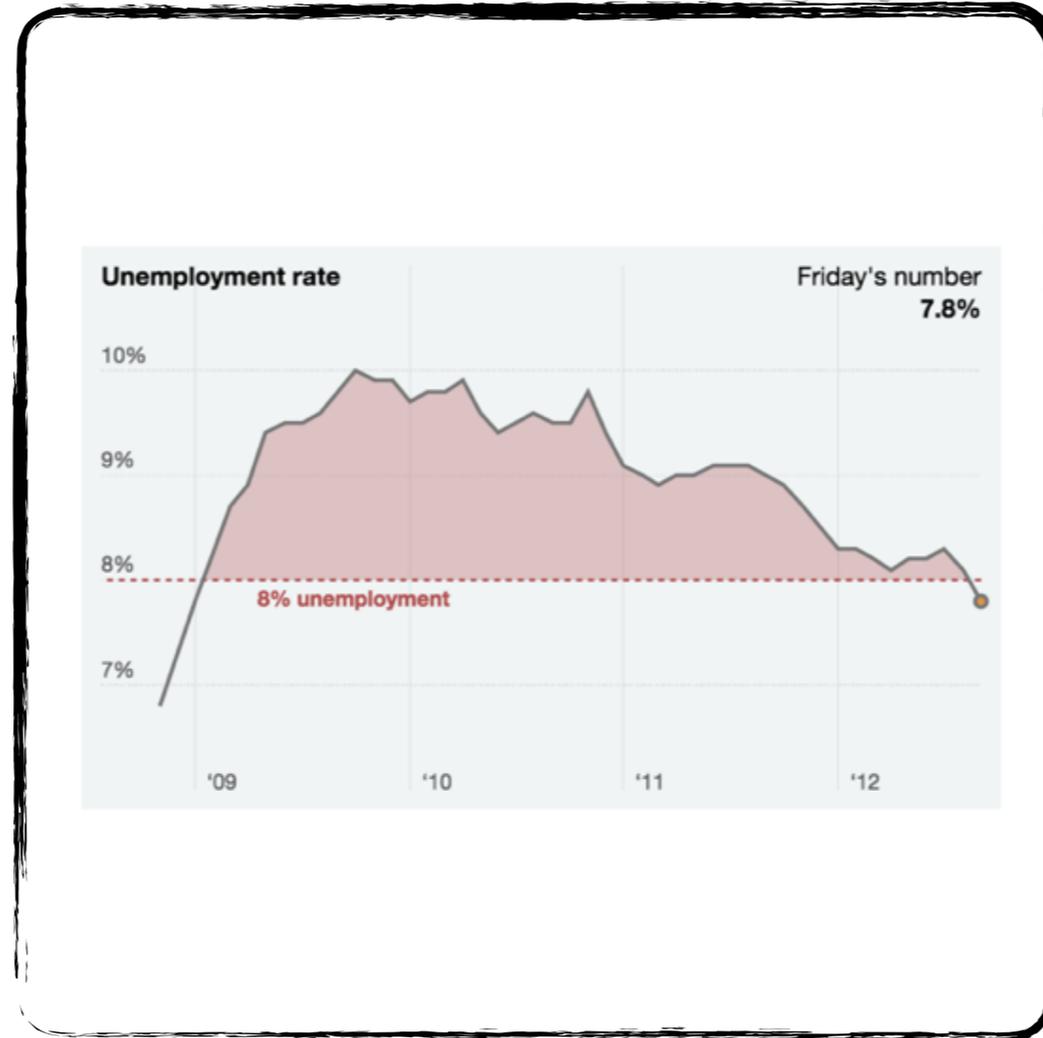
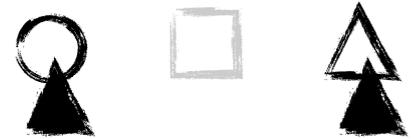


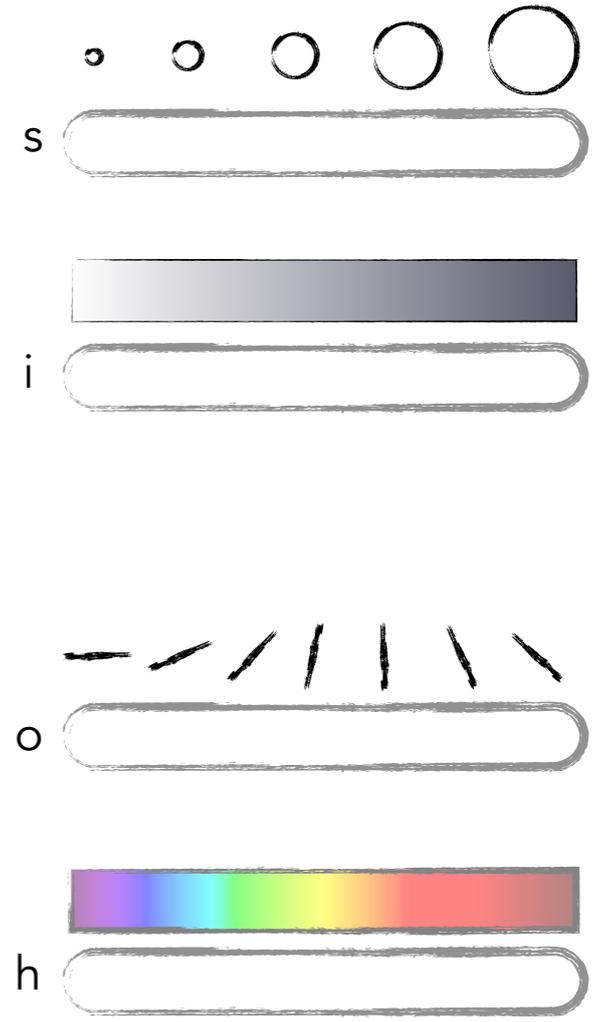
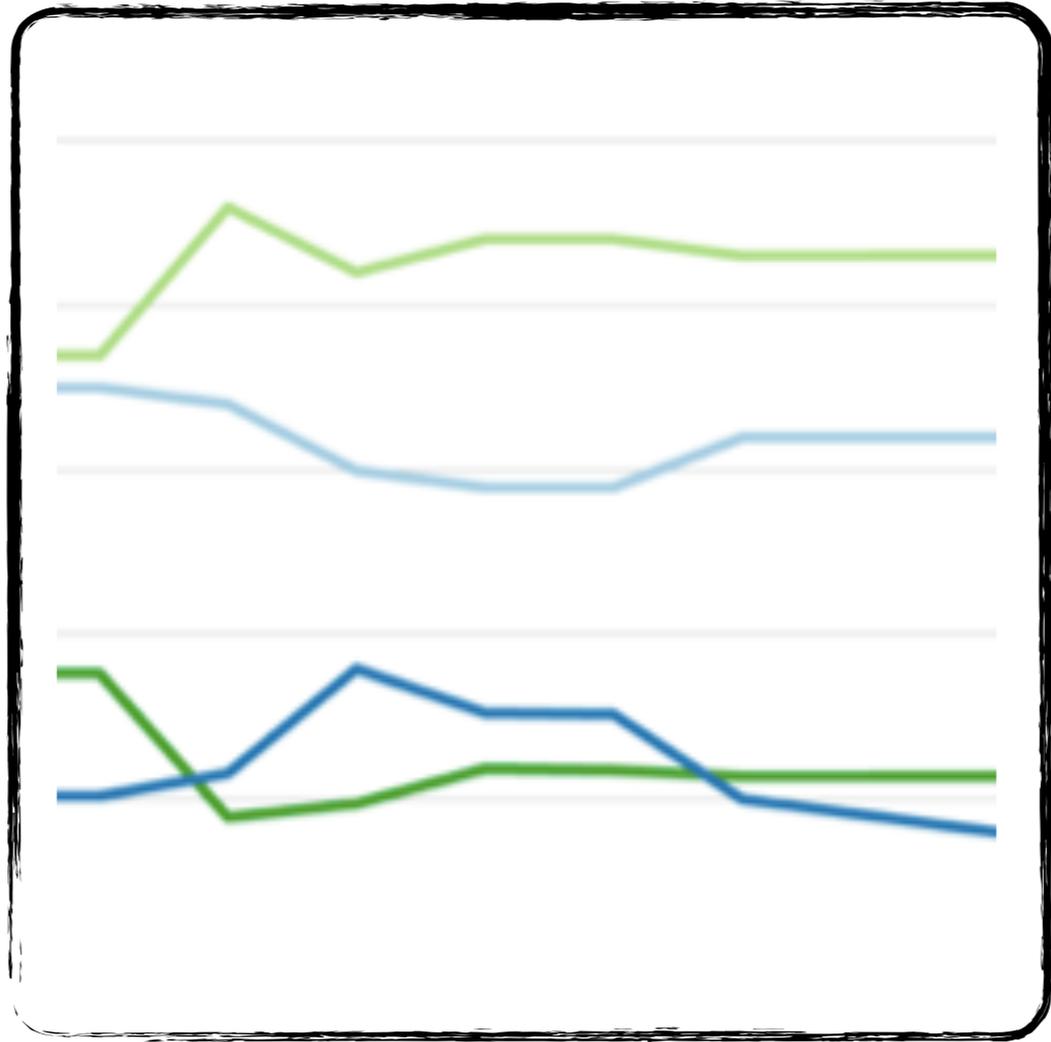
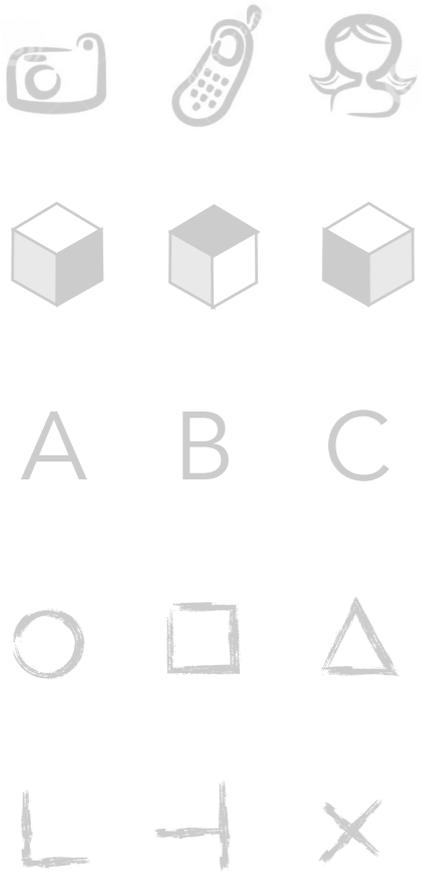
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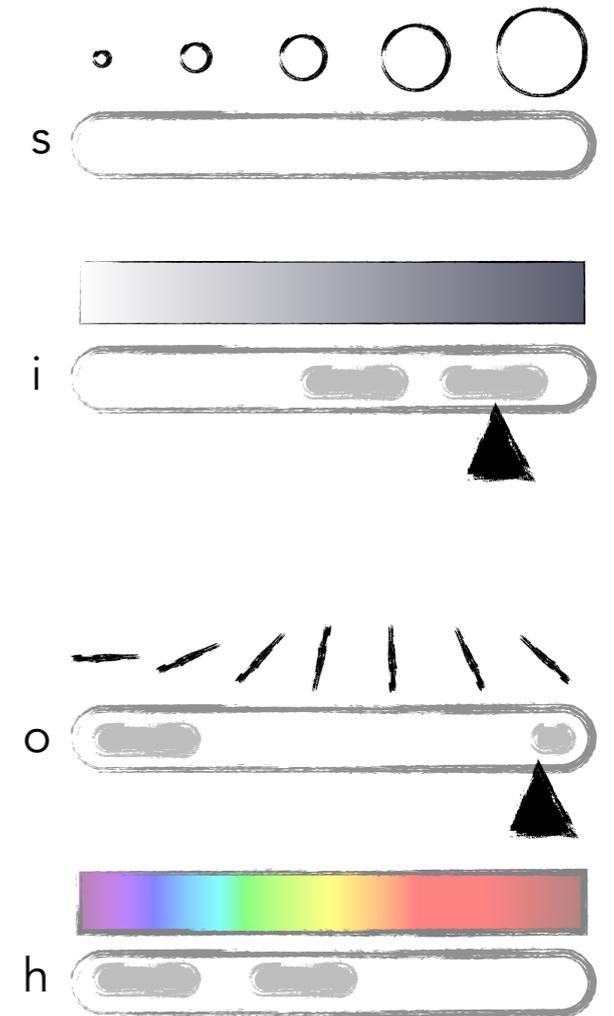
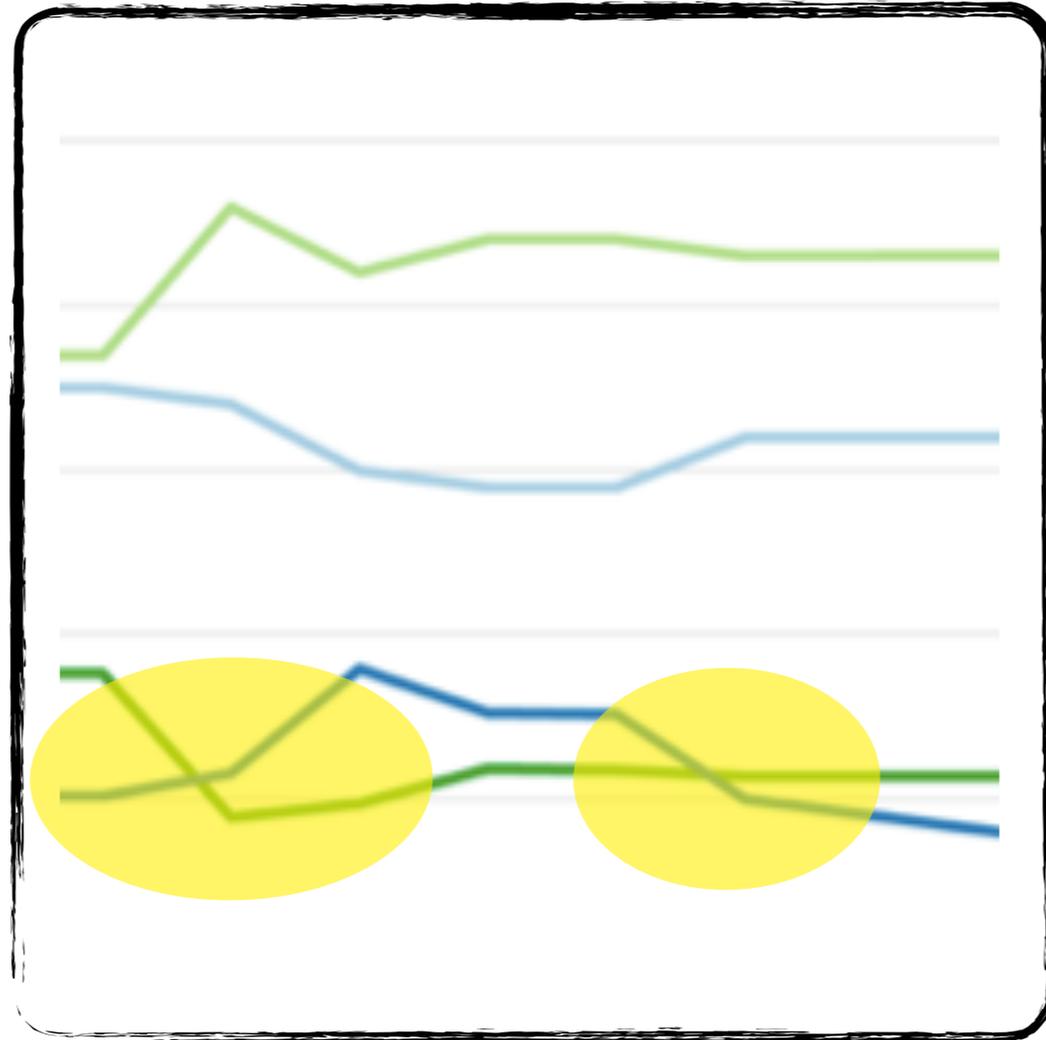
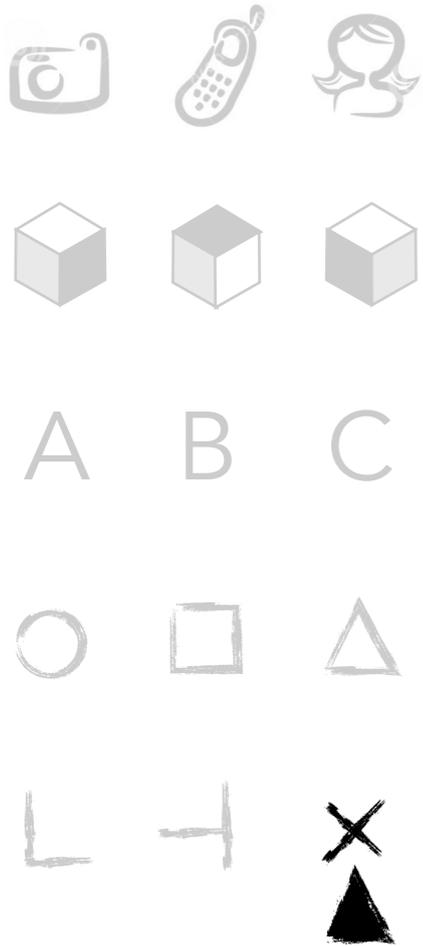




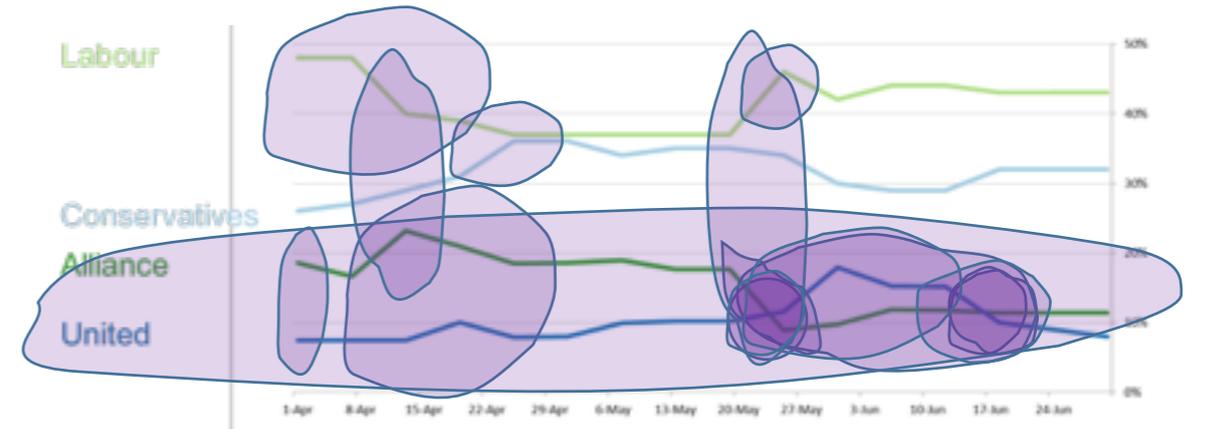
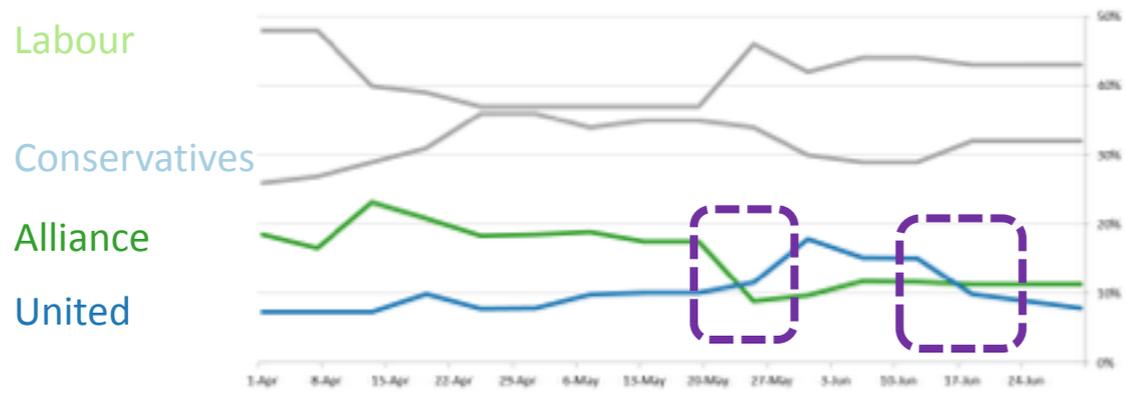
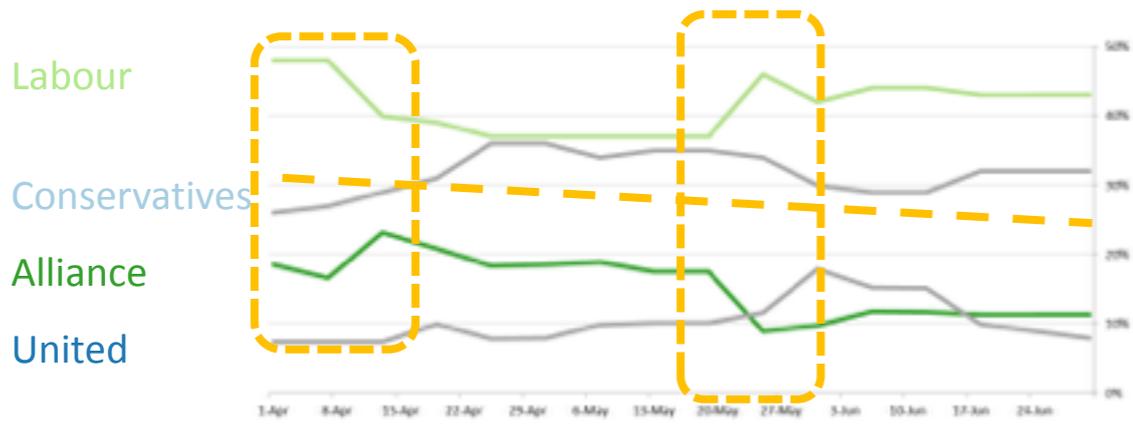
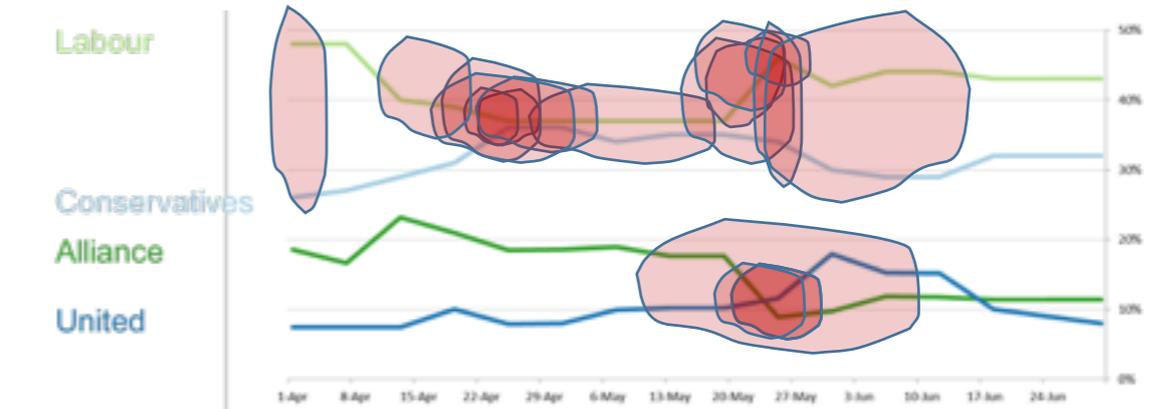
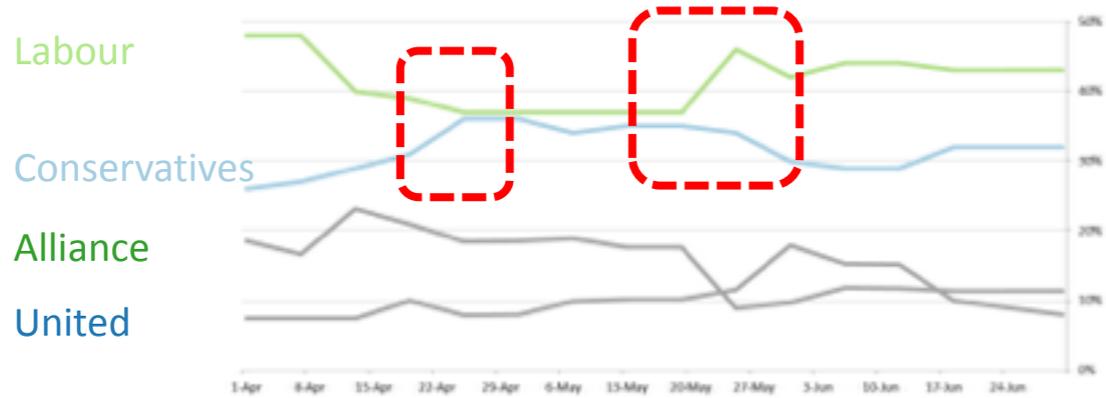
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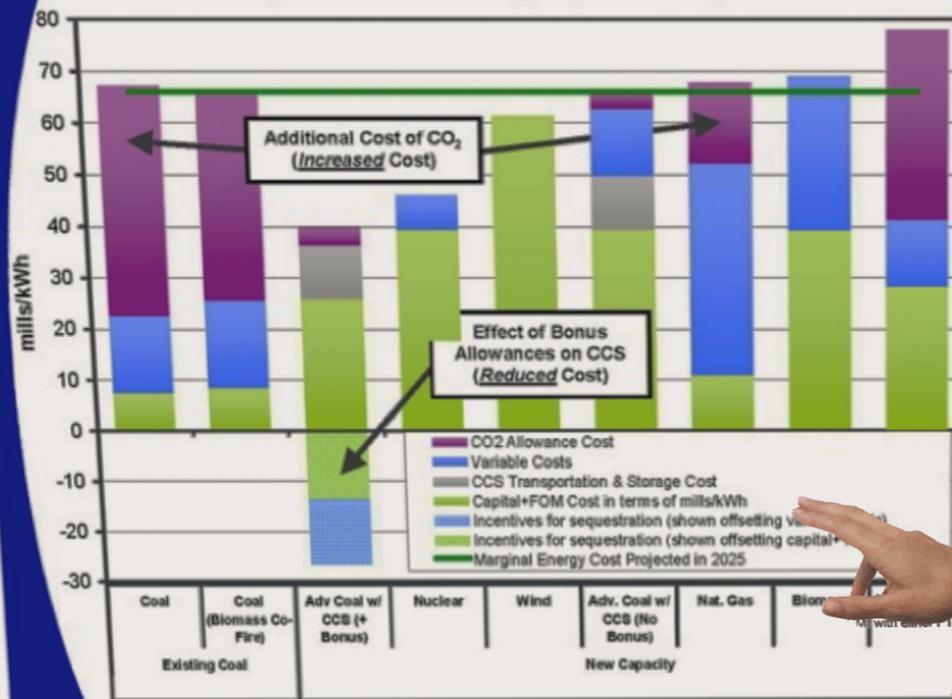
Knowledge + Expertise
changes what you see





Near-Term Power Plant Economics with CO₂ Allowance Costs

Estimated Power Plant Electricity Costs in 2025 for Various Technologies
(includes the cost of CO₂ of ~\$50/metric ton)

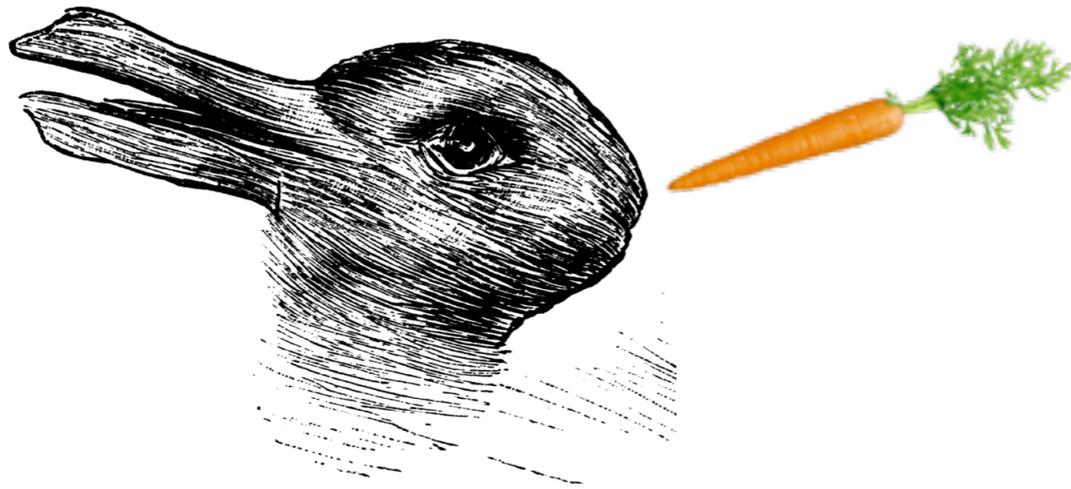


- To illustrate the economics of operating existing and new power technologies, the chart shows the cost of various technologies when the projected CO₂ allowance prices are included.
- Projected CO₂ allowance prices of roughly \$50/ton in 2025 increase variable costs of existing plants powered by fossil fuels to the point where many are likely to shut down.
- However, S. 2191 provides significant incentives for CCS technology plants in the form of bonus allowances, resulting in earlier...

Notes: For the case with bonus allowances, the variable, capital, and fixed O&M costs are actually an aggregate of the solid part and the hashed part but the net cost is only the solid part. For this illustrative calculation, EPA used a conservative efficiency metric for existing coal plants (10,500 Btu/kWh), which most plants currently meet or exceed. The marginal energy cost is defined as the cost of production of the most expensive unit operating in that region. The cost of fuel, variable O&M cost and the cost of environmental allowances. The capital costs used here are from IPM v3.01, which relies upon EIA capital cost data from AEO 2005. More recently, capital costs have increased due to increasing international demand for raw materials. It is not clear how the market will respond to these price increases and whether these increased costs will be sustained over the period of the analysis.

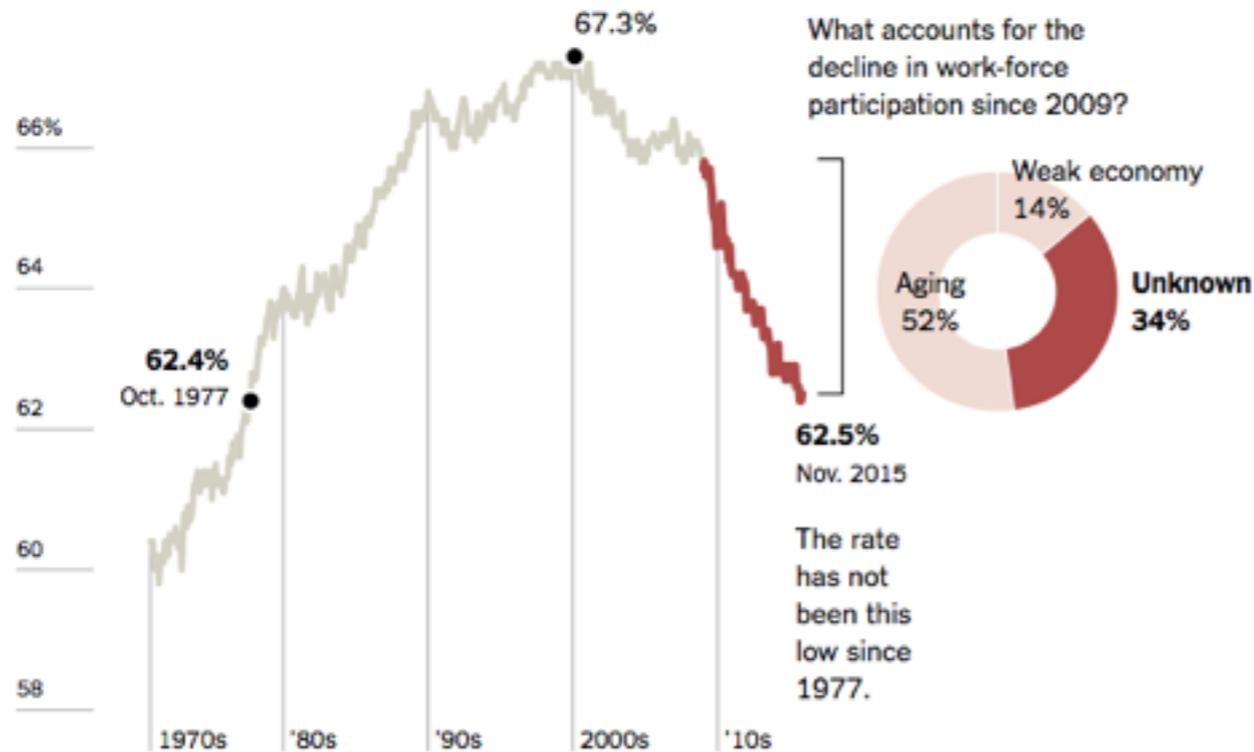
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More Are Dropping Out of Work Force

The percent of workers who have jobs or are looking for them is falling.



Sources: Bureau of Labor Statistics; White House Council of Economic Advisers

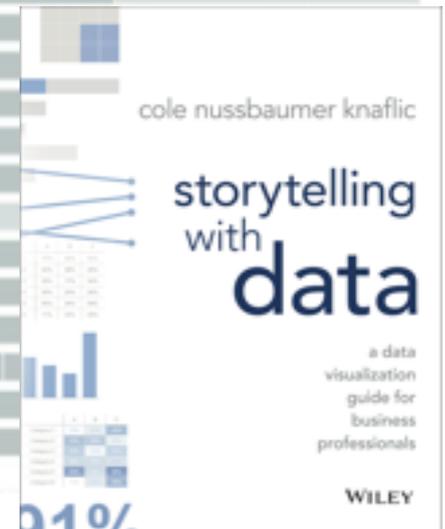
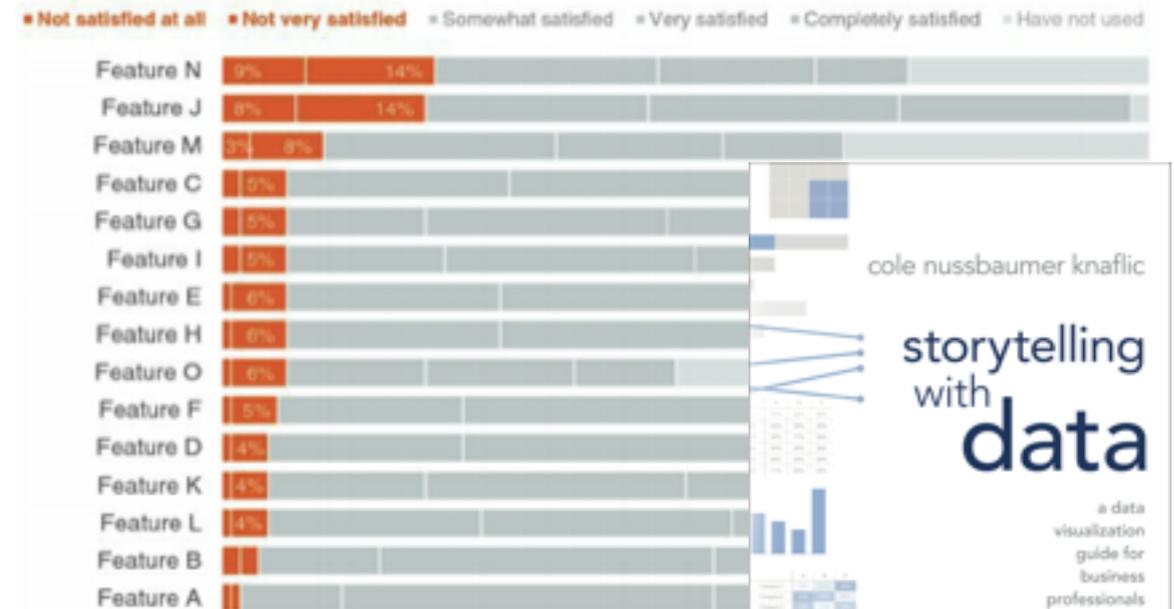
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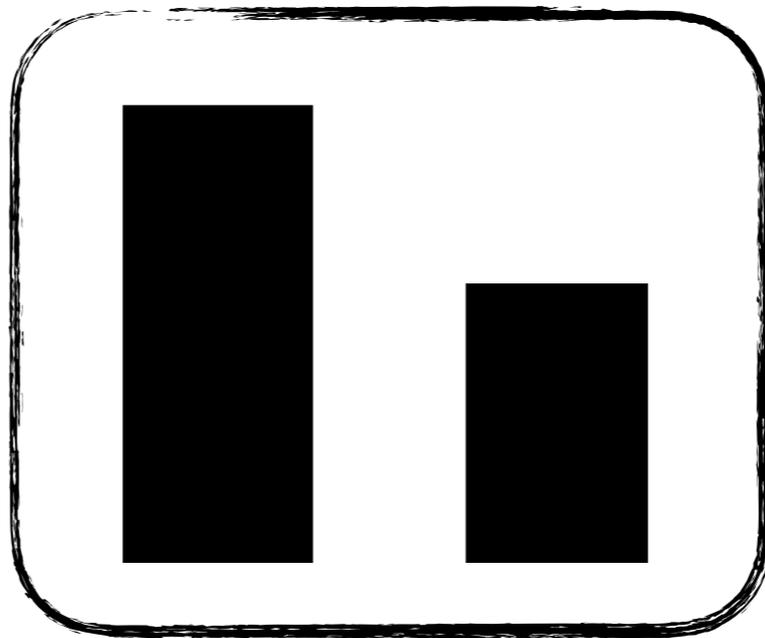


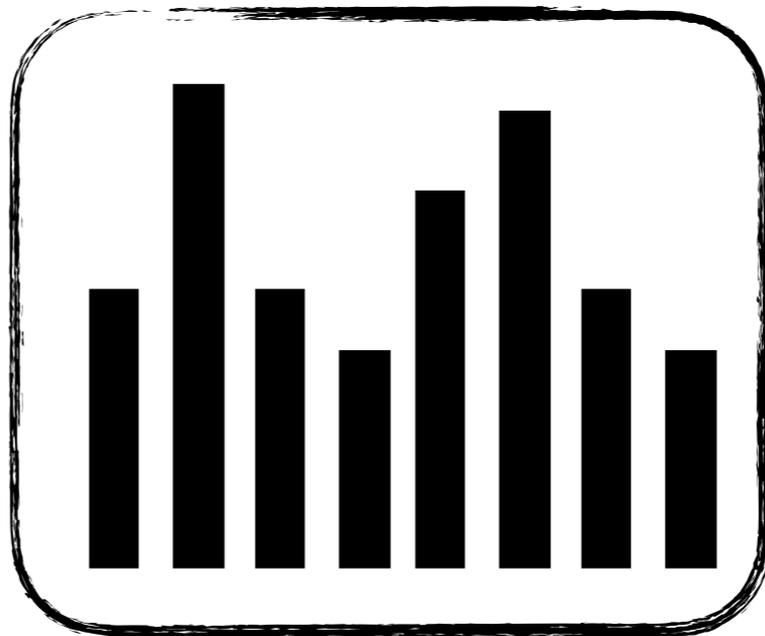
https://www.ted.com/talks/hans_rosling_shows_the_best_stats_you_ve_ever_seen

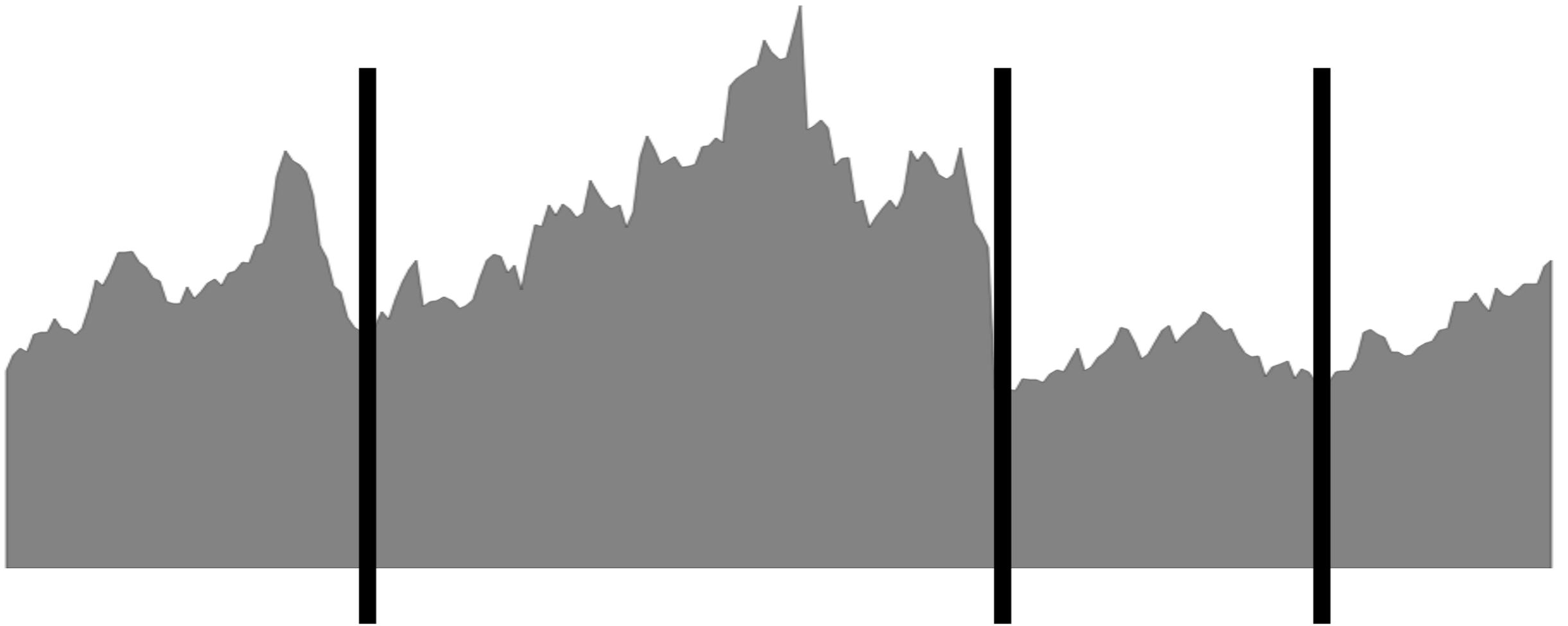
Users least satisfied with Features N & J

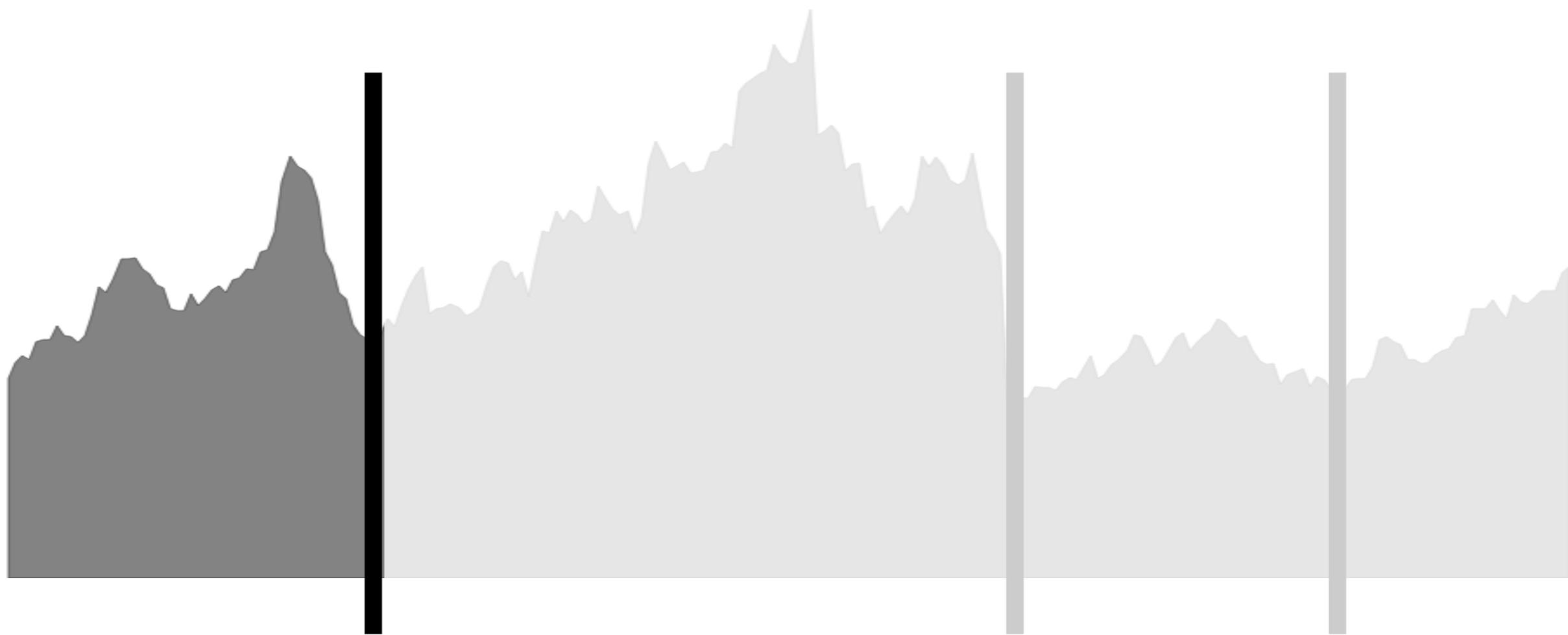
Product X User Satisfaction: Features



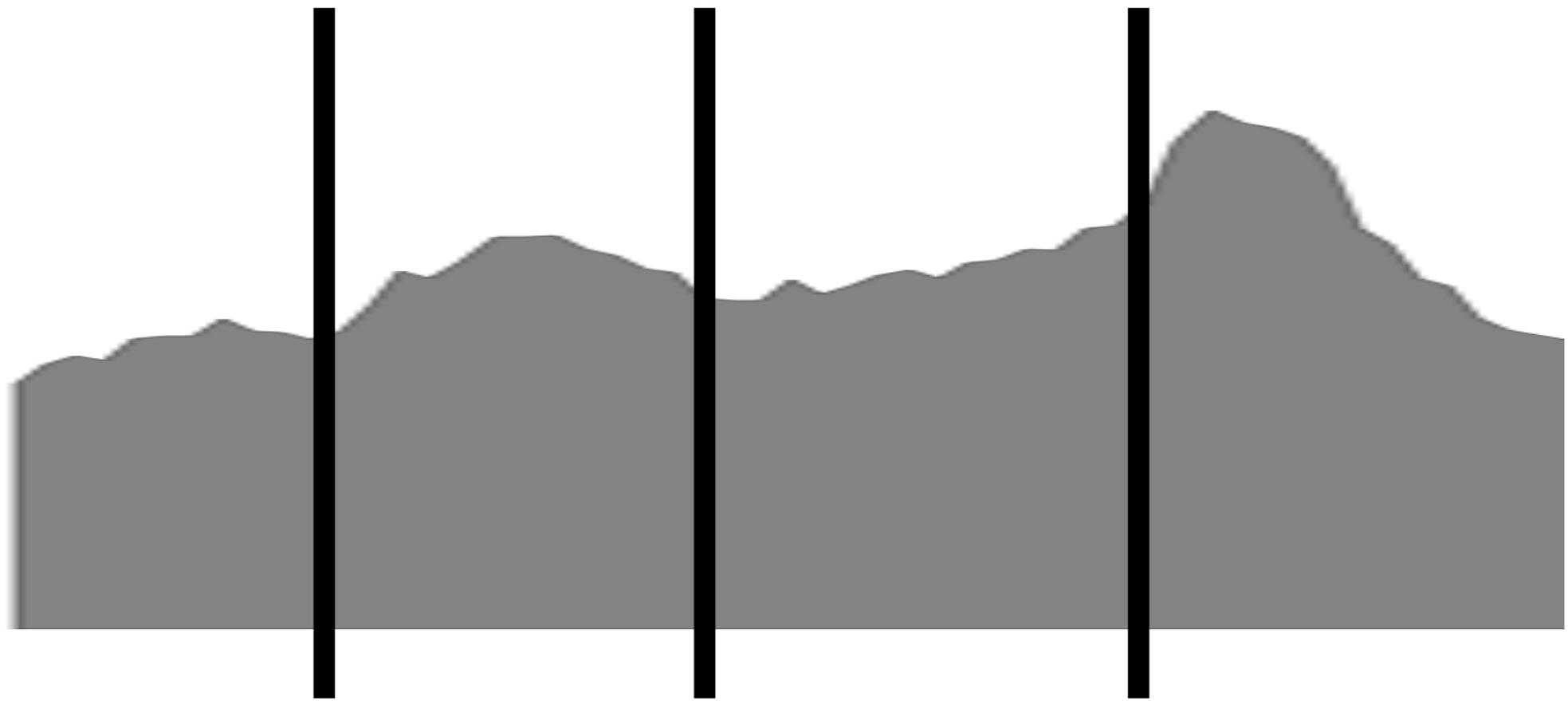


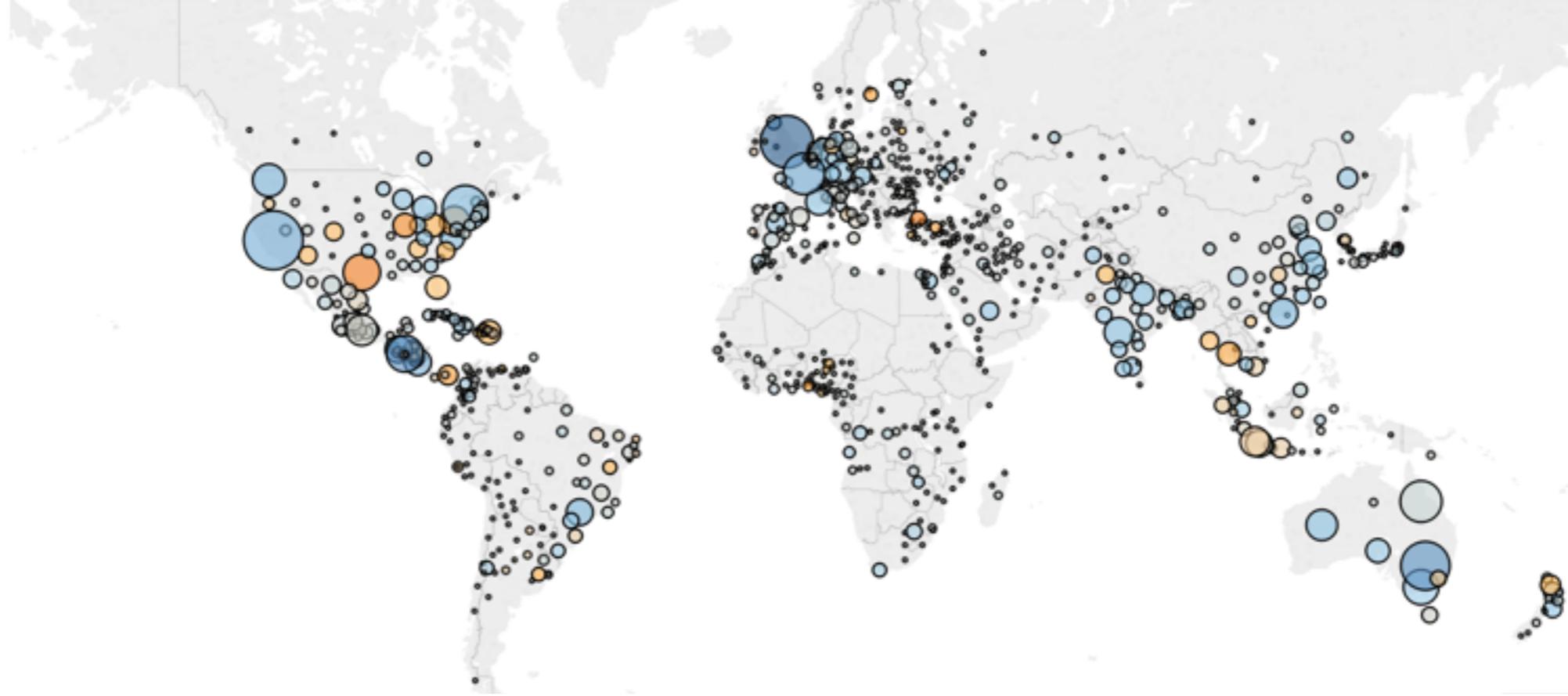




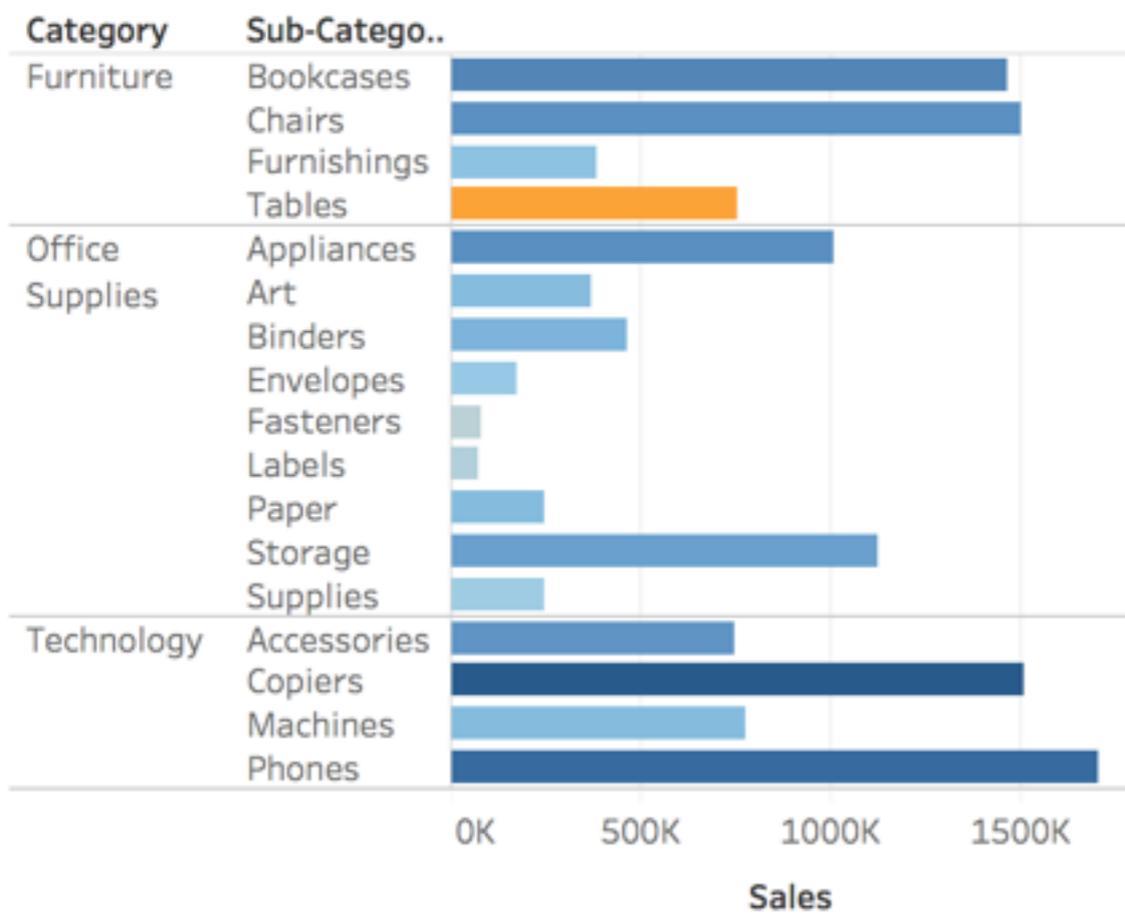




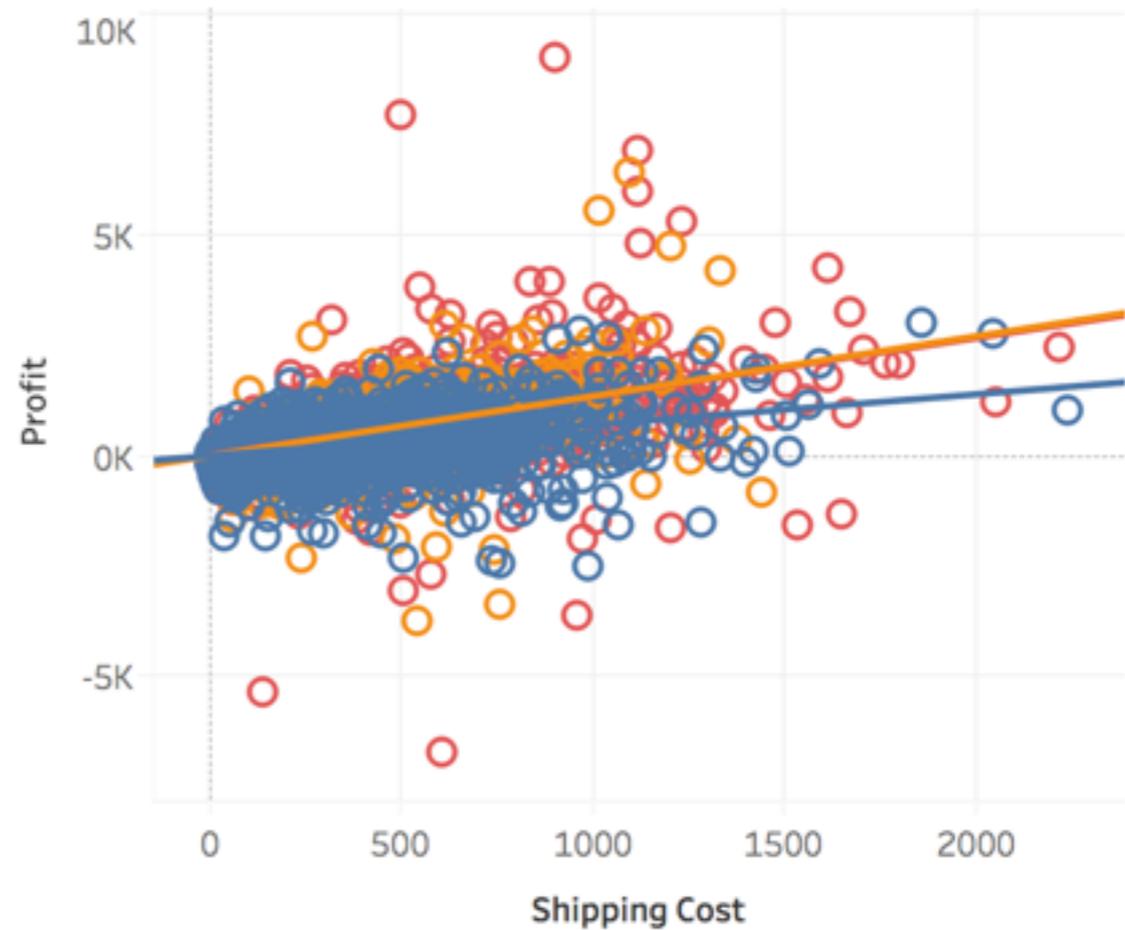




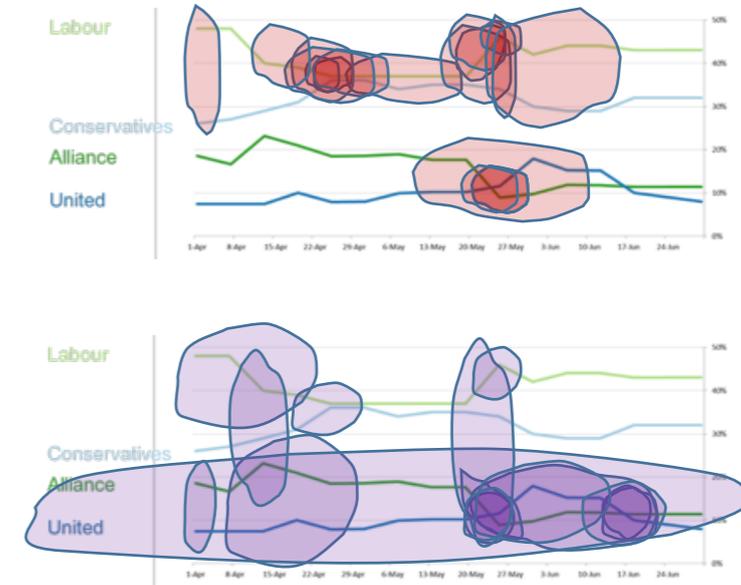
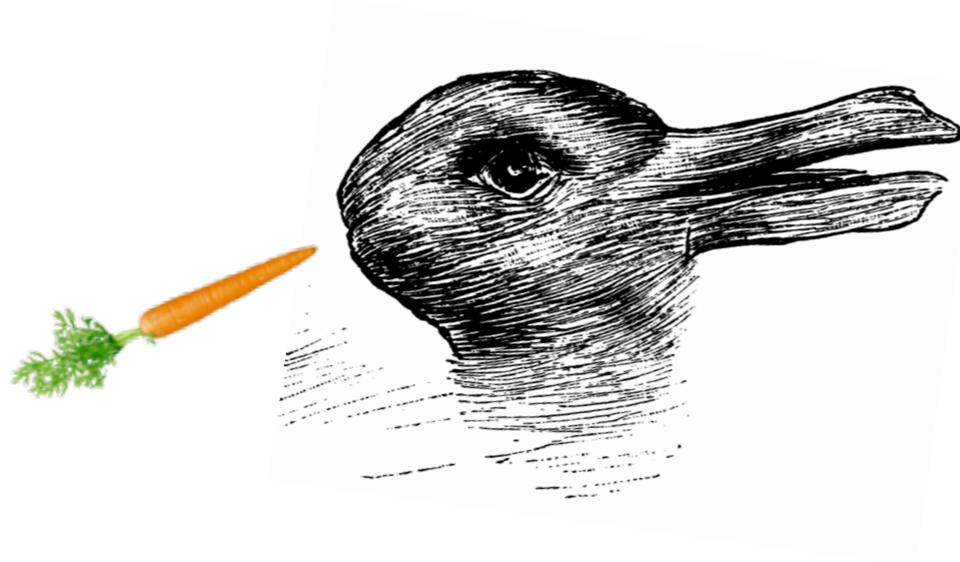
Sales By Category



Customer Breakdown



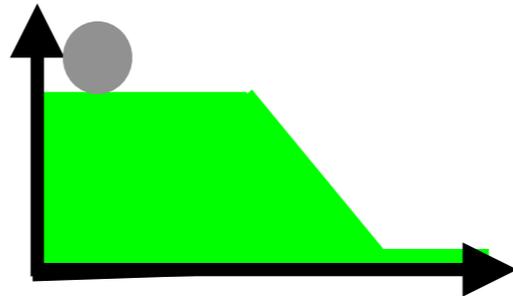
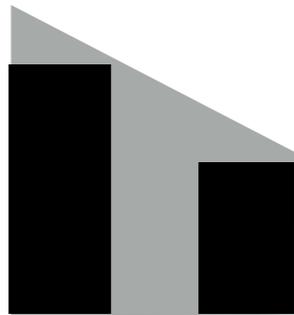
Many ways to see one visualization



Three tools

Shape

FAST



Dangerous for novices
But critical for experts

Histograms

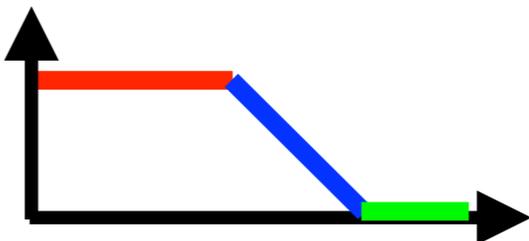
FAST



Not just 'popout',
histogram info for features

Comparisons

SLOW



Flexible, uniquely human
But slow & limited



BCS-1056730 CAREER
IIS-1162067
DRL-1661264
SBE-0541957



IES-R205A120531

The opinions expressed are those of the authors and do not represent views of the National Science Foundation or the U.S. Department of Education.

 @SteveFranconeri

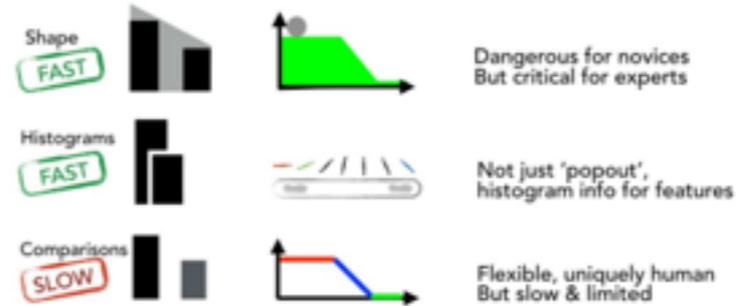
 Steve Franconeri
@SteveFranconeri

Data Visualizations are Ambiguous Figures.
Summary of my panel talk for #ieevis
InfoVis panel on Perception
visxvision.com/vis-2017/ (1/8)

Many ways to see
one visualization



Three tools



11:01 AM - 4 Oct 2017

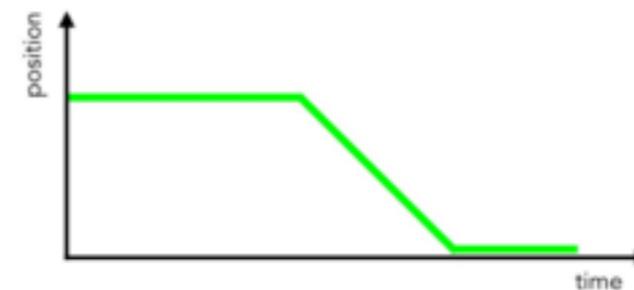
2 Likes 

 1   2 

 Tweet your reply

 Steve Franconeri @SteveFranconeri · 2m
Replying to @SteveFranconeri

Love this result. Most students say 'a ball rolling down a hill'.
Wrong. Knee-jerk shape recognition fails them here.



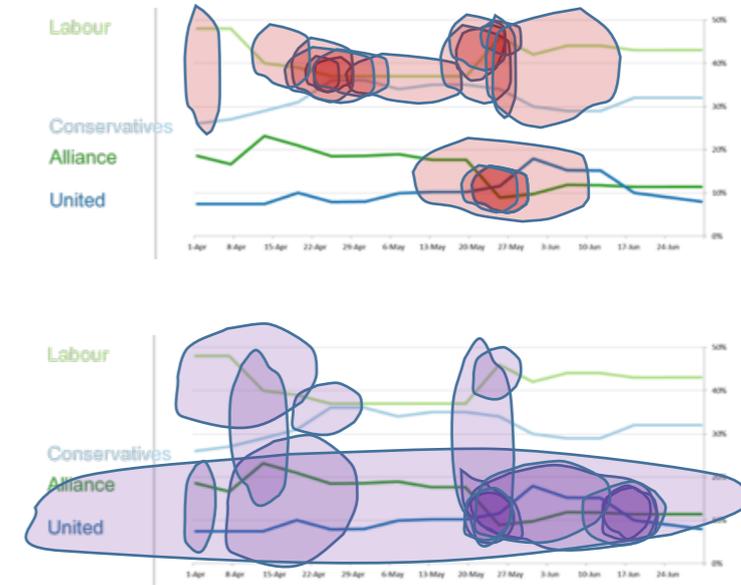
Here is a graph of an object's motion.
Imagine some real situation depicted on the graph

Kozhevnikov, Hegarty, & Mayer, 2002

 1   

 Steve Franconeri @SteveFranconeri · 1m
Data Visualizations are richly ambiguous figures. Three visual
tools for seeing differently, even the simplest 2-bar graph.

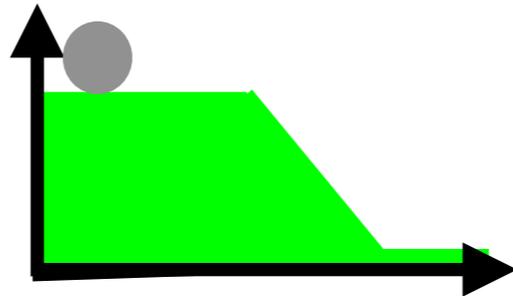
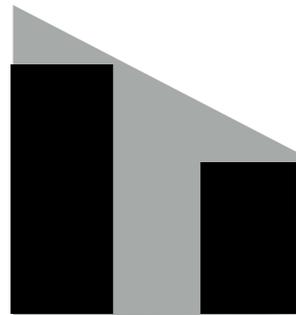
Many ways to see one visualization



Three tools

Shape

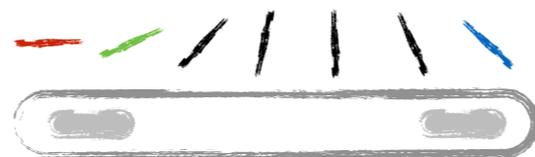
FAST



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Histograms

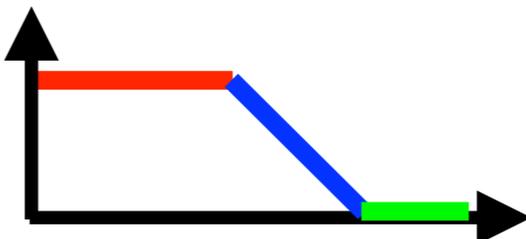
FAST



Not just 'popout',
histogram info for features

Comparisons

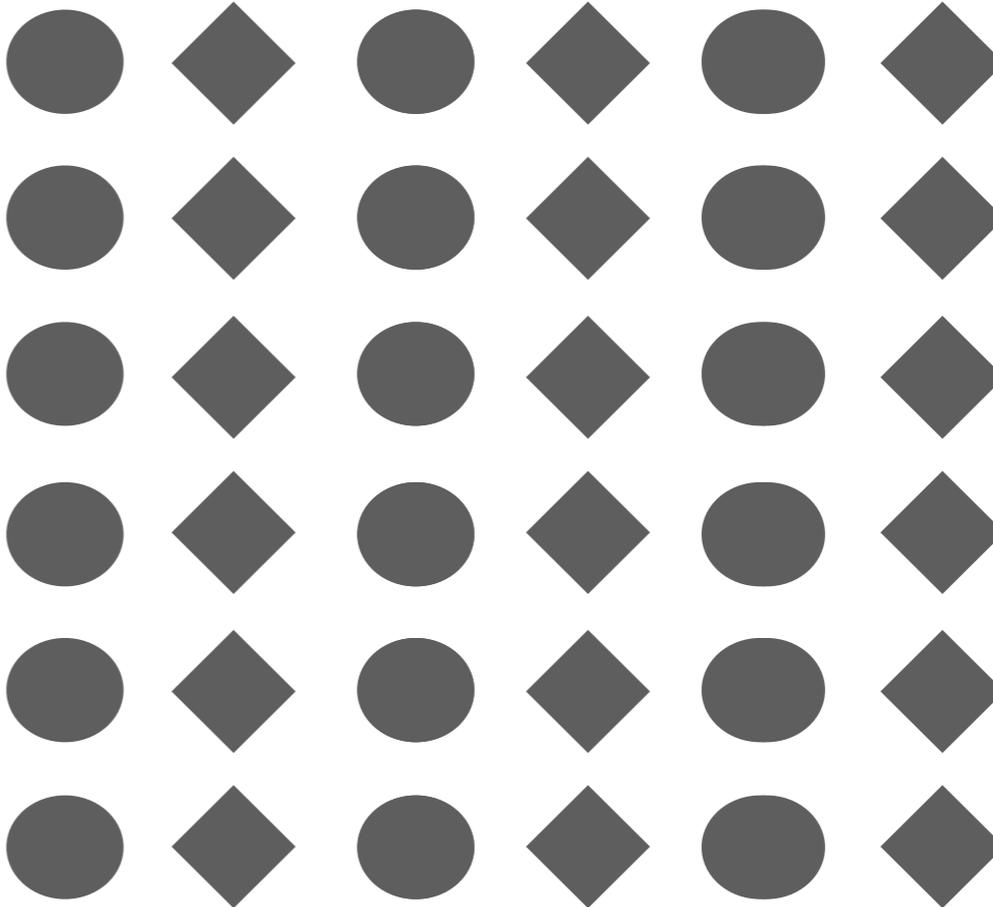
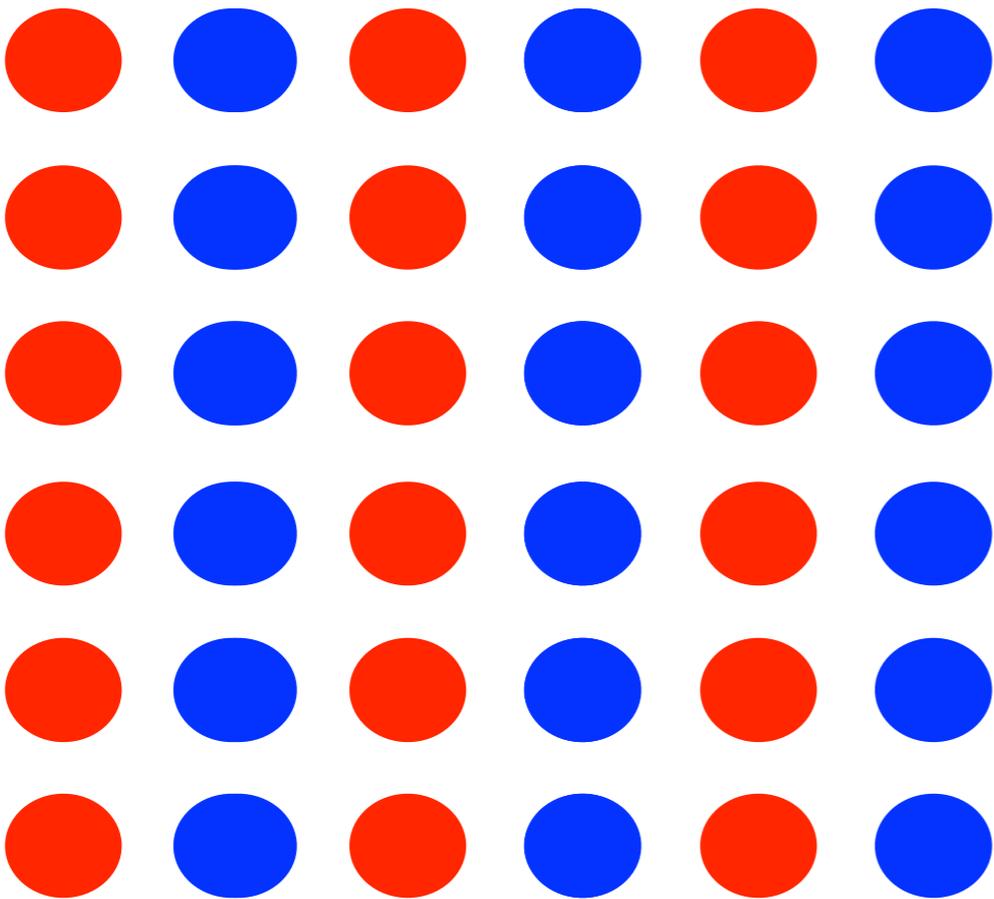
SLOW

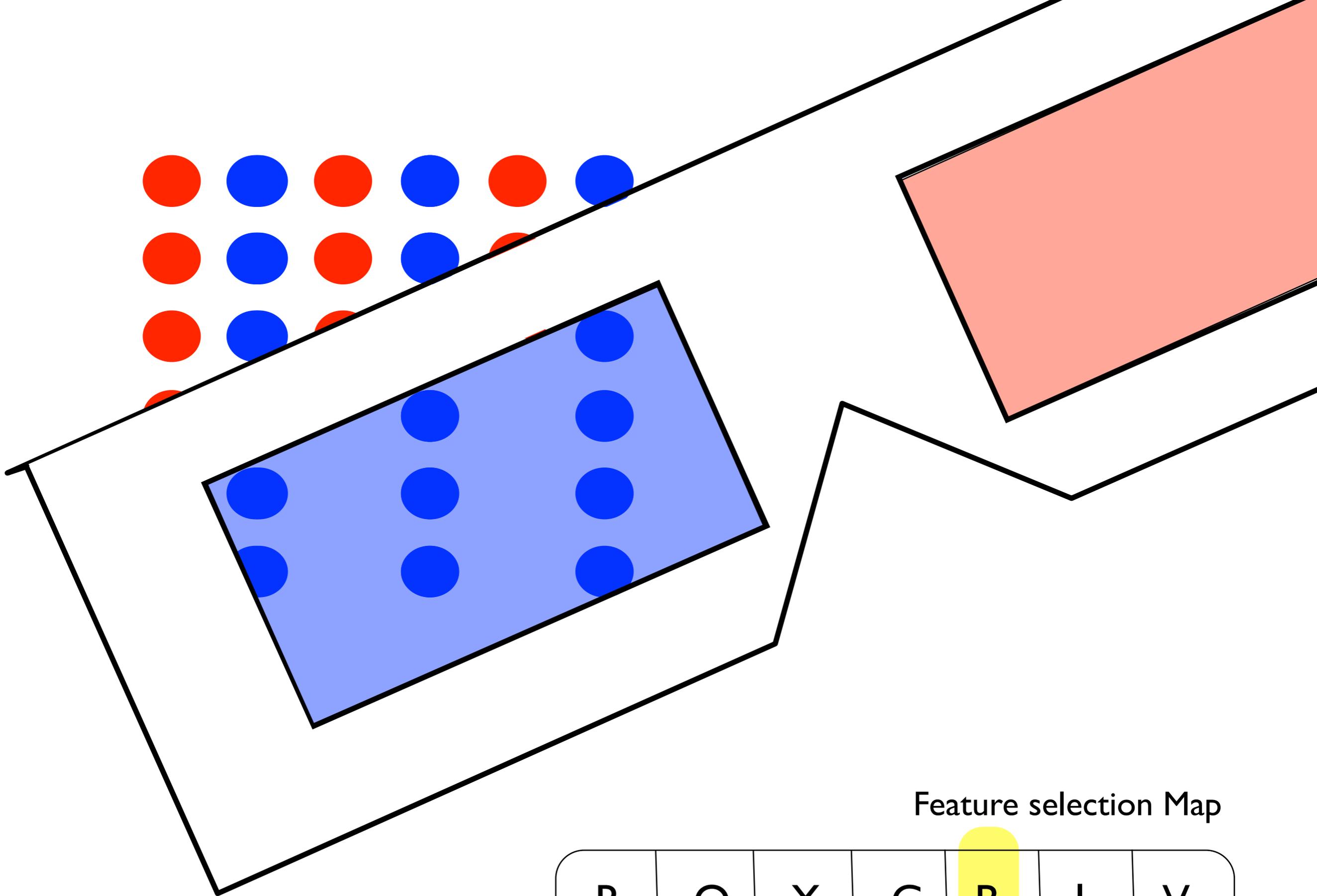


Flexible, uniquely human
But slow & limited

fin

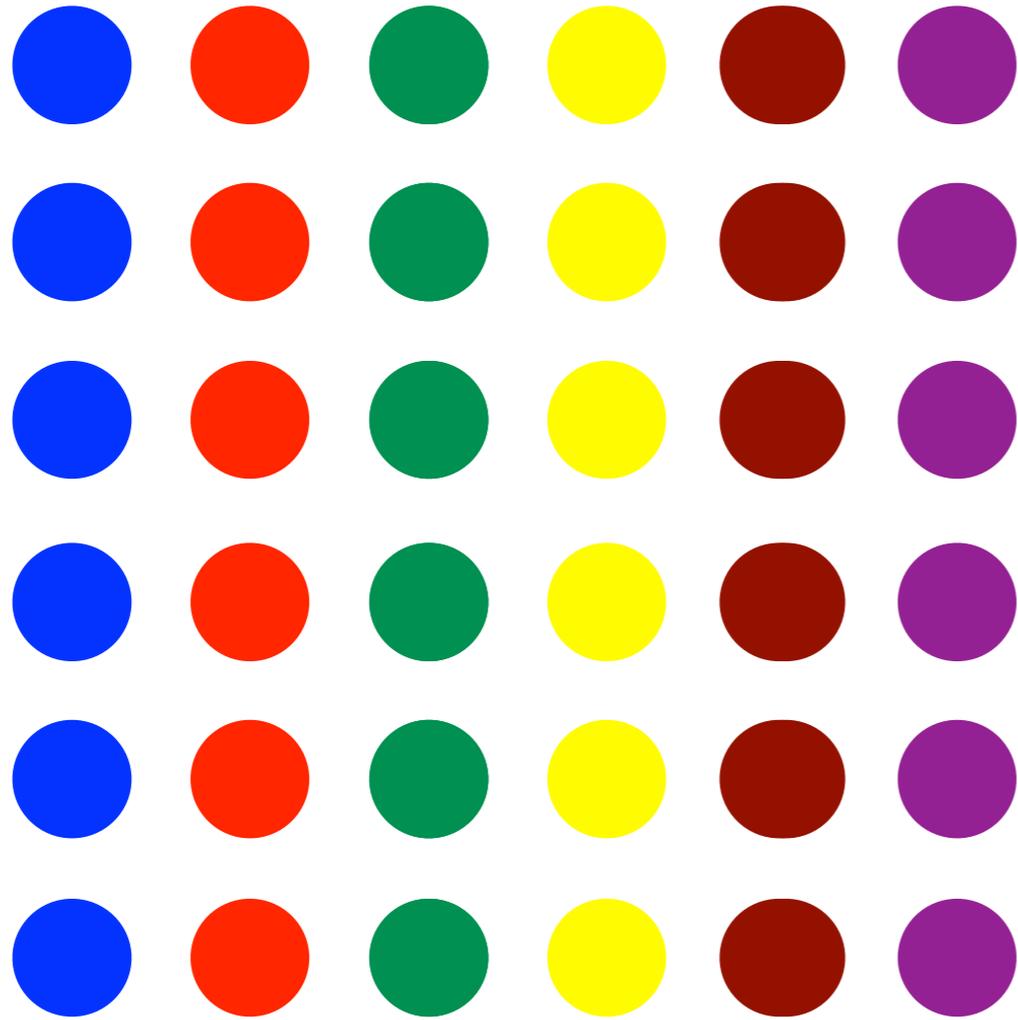
extras





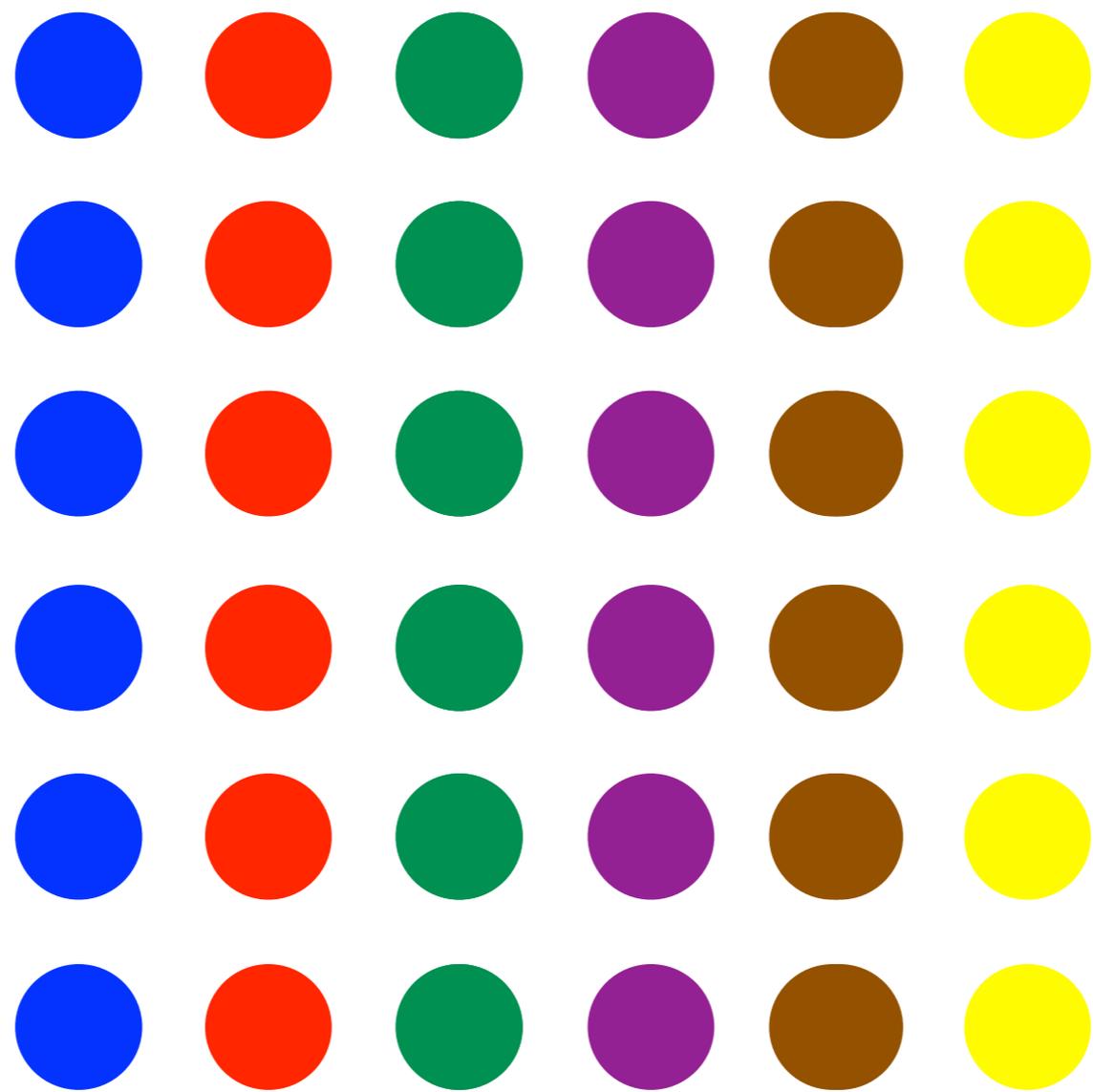
Feature selection Map

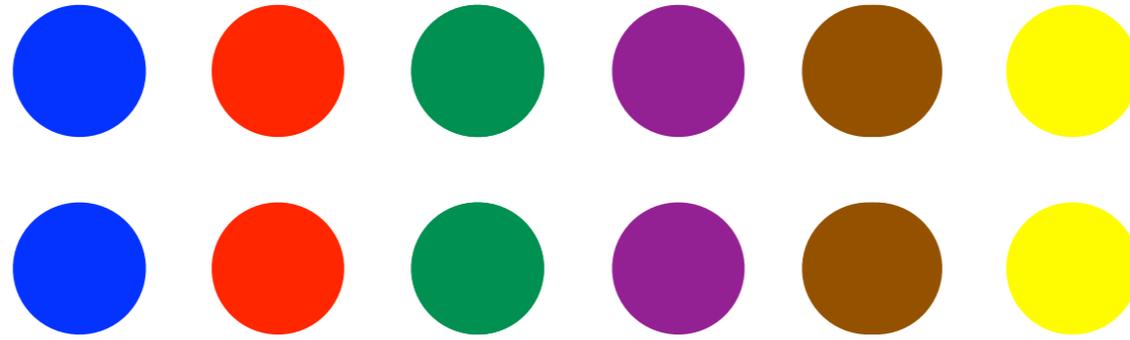
R	O	Y	G	B	I	V
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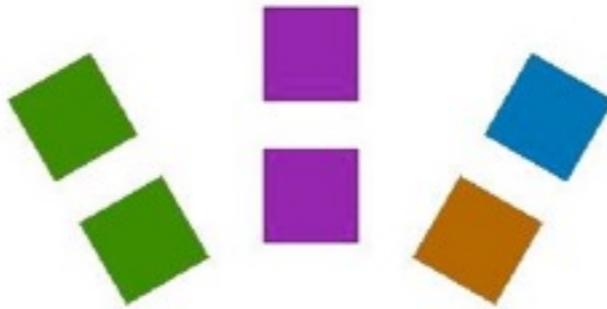
The illusion of detail



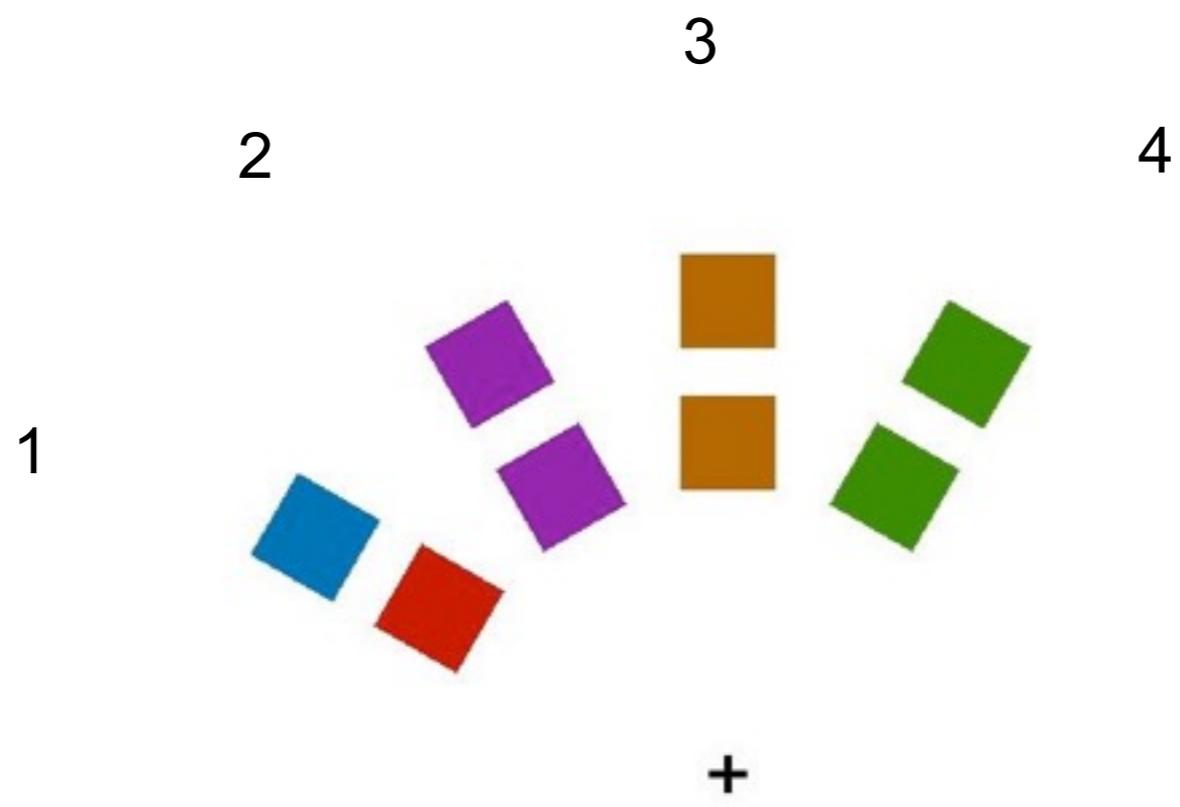


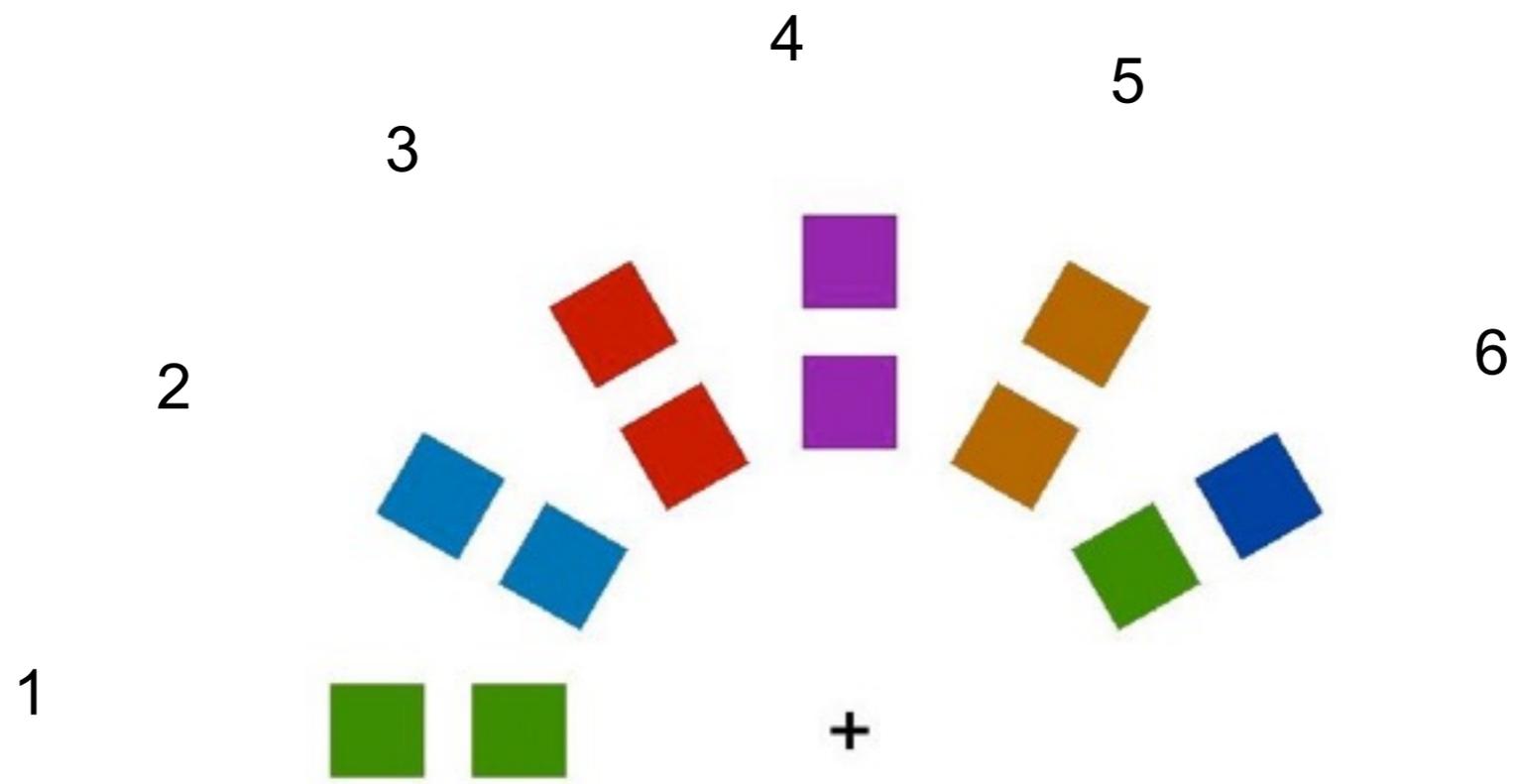


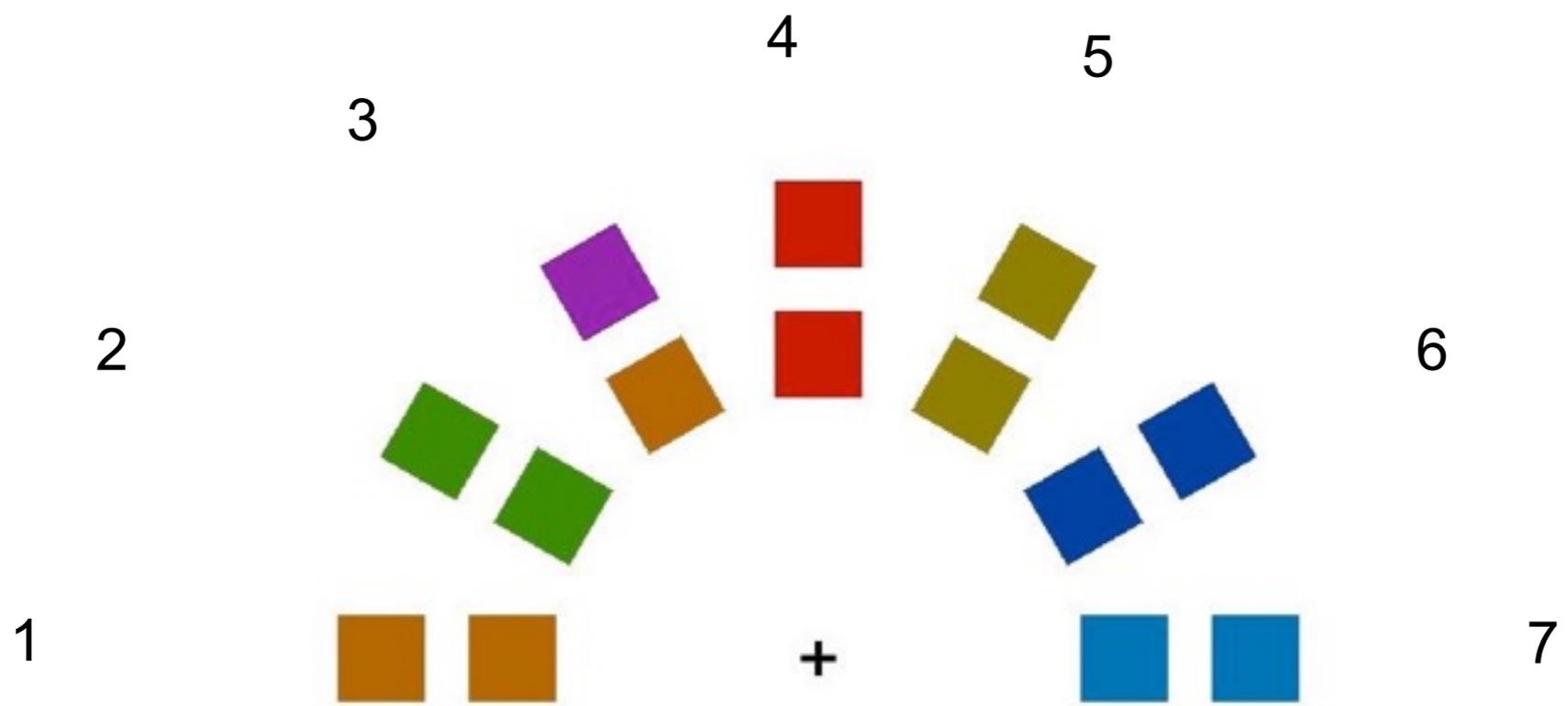
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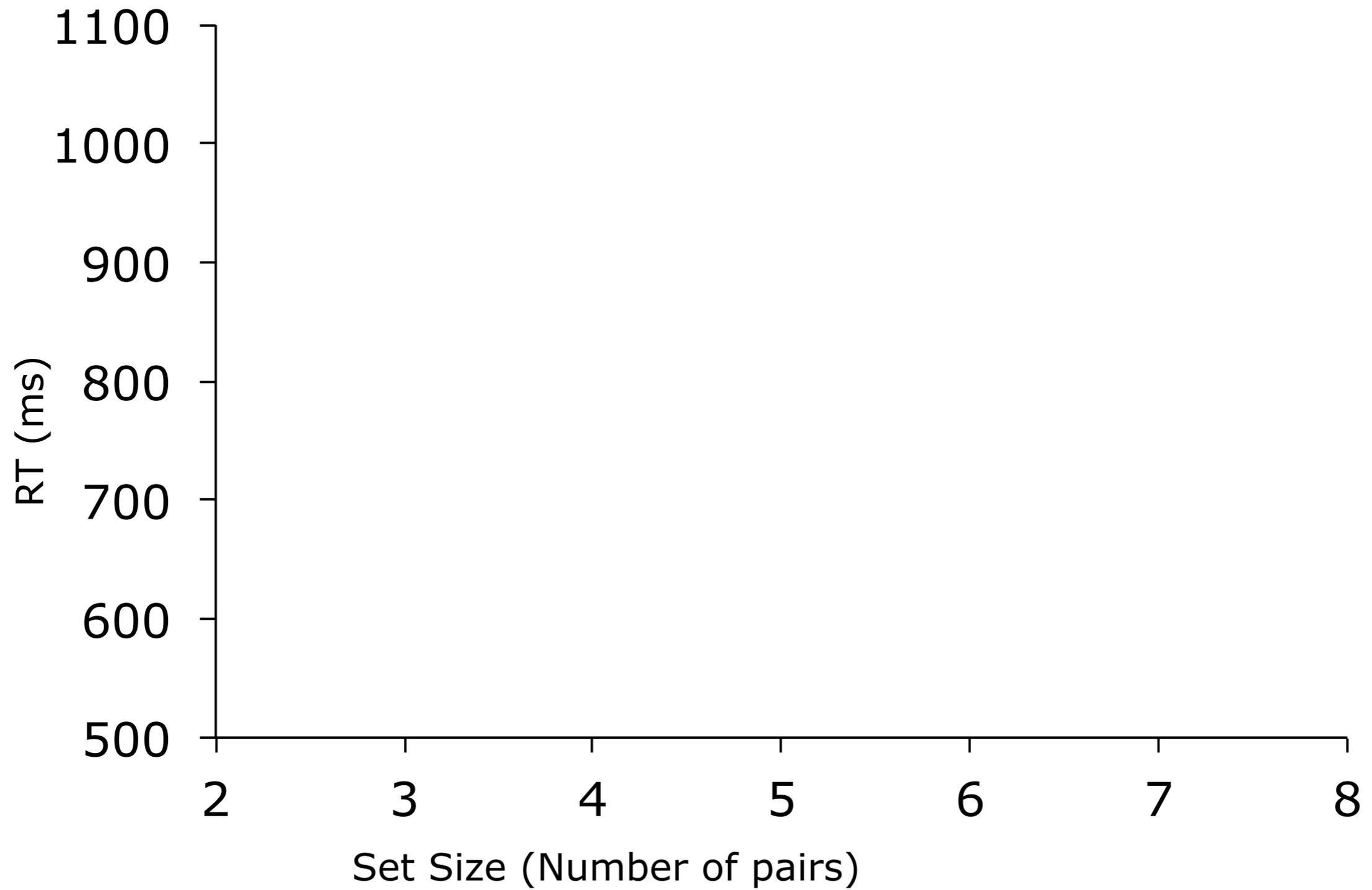


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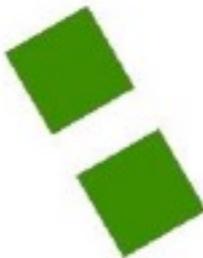








1



2



3



+

1



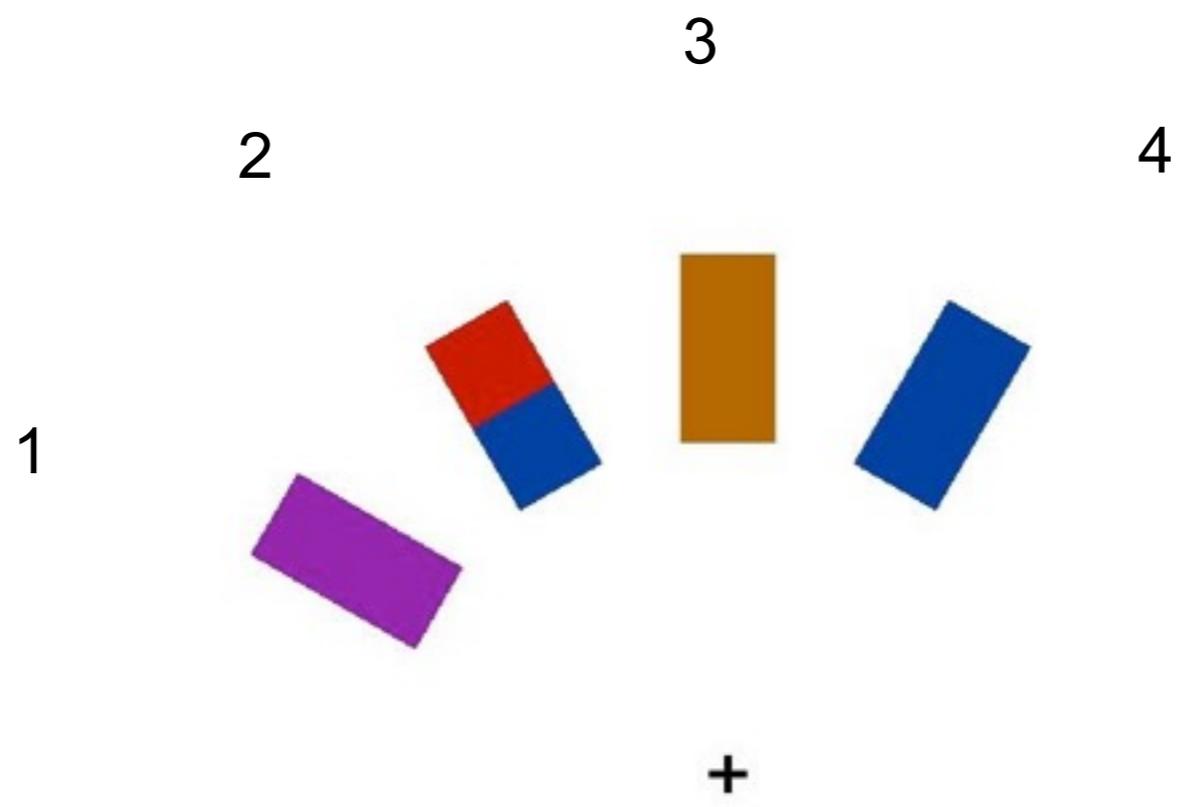
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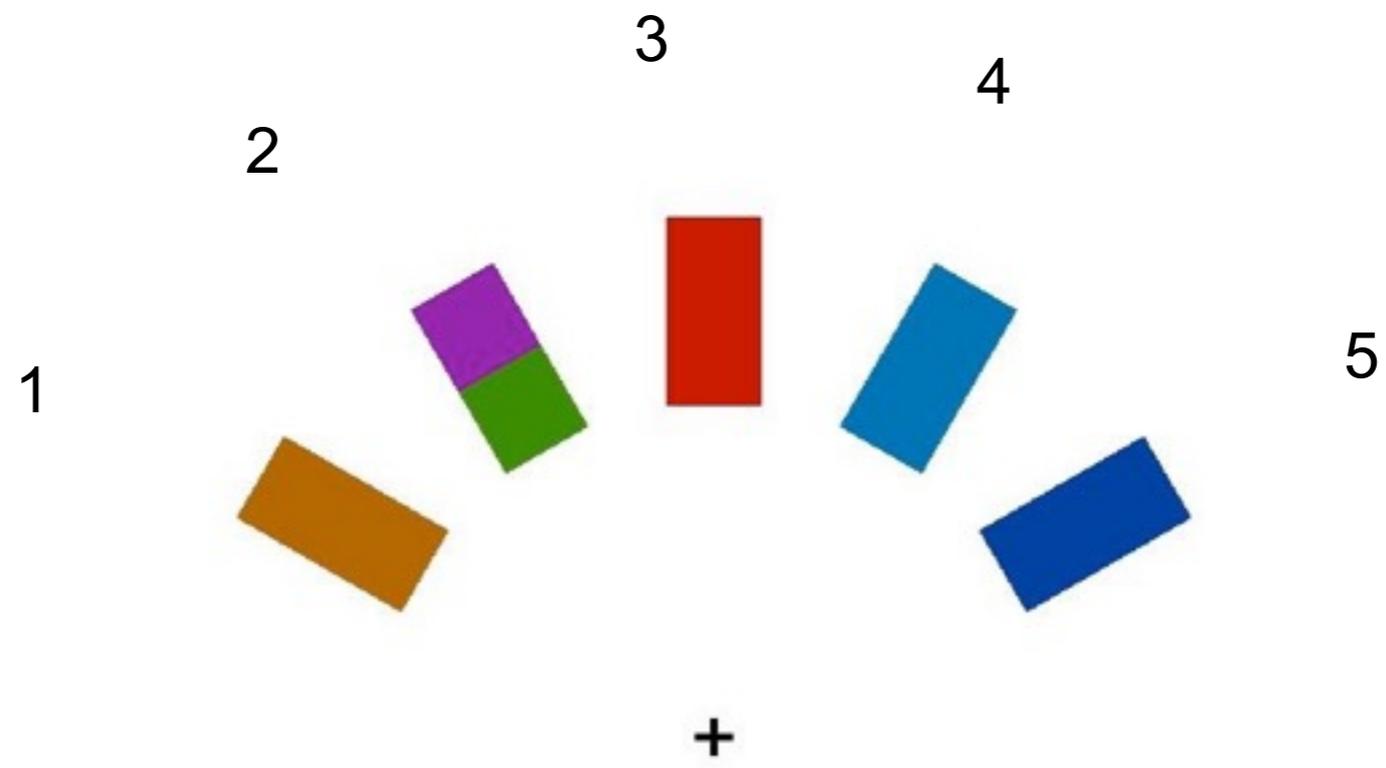


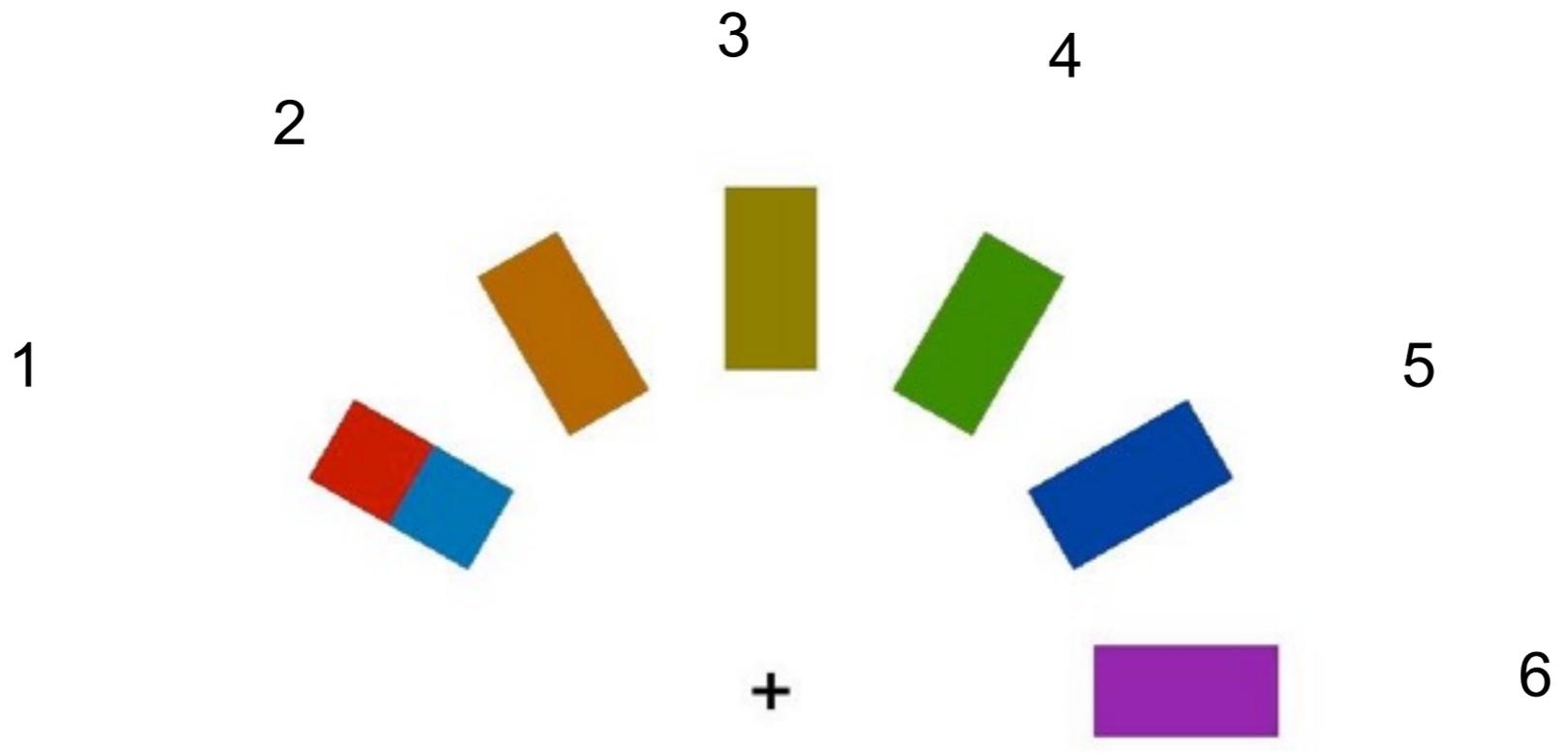
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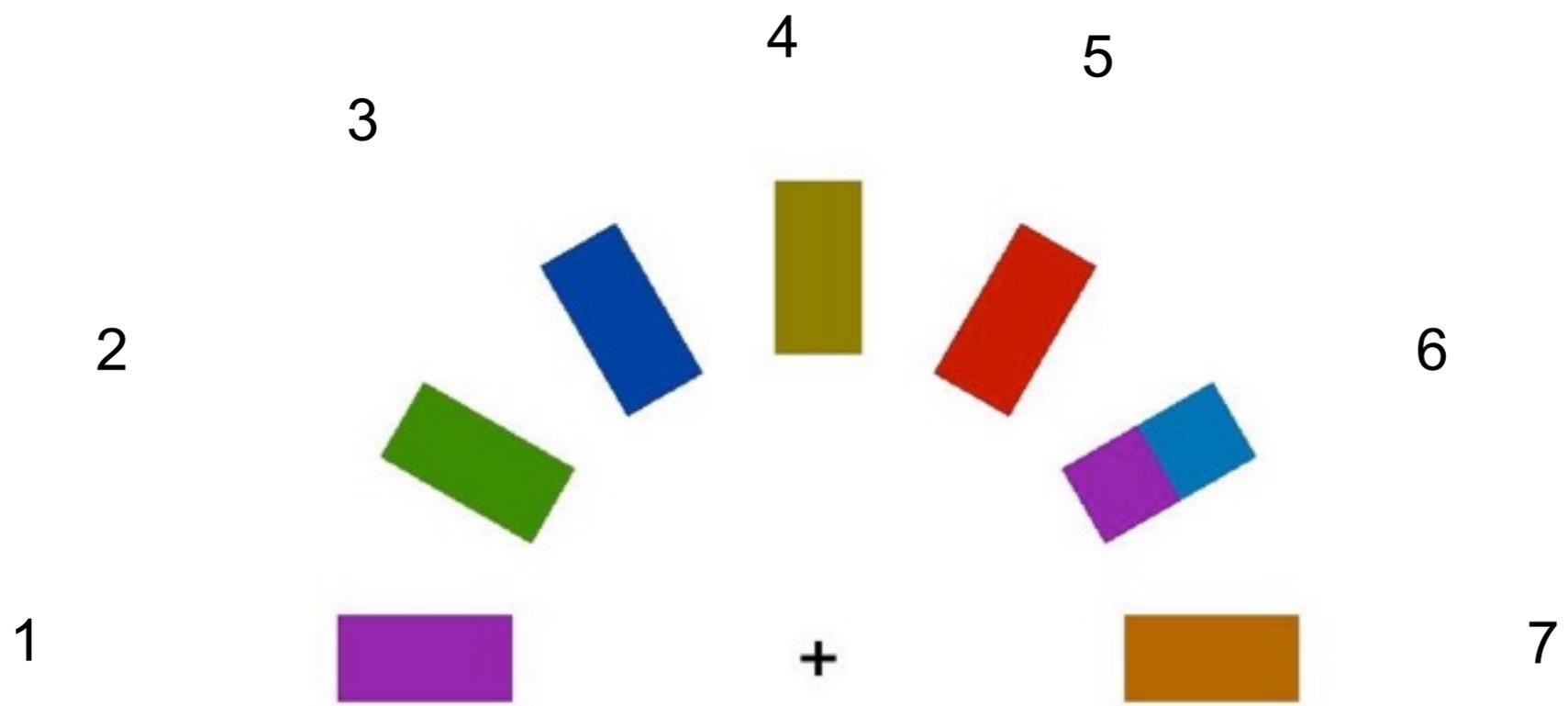


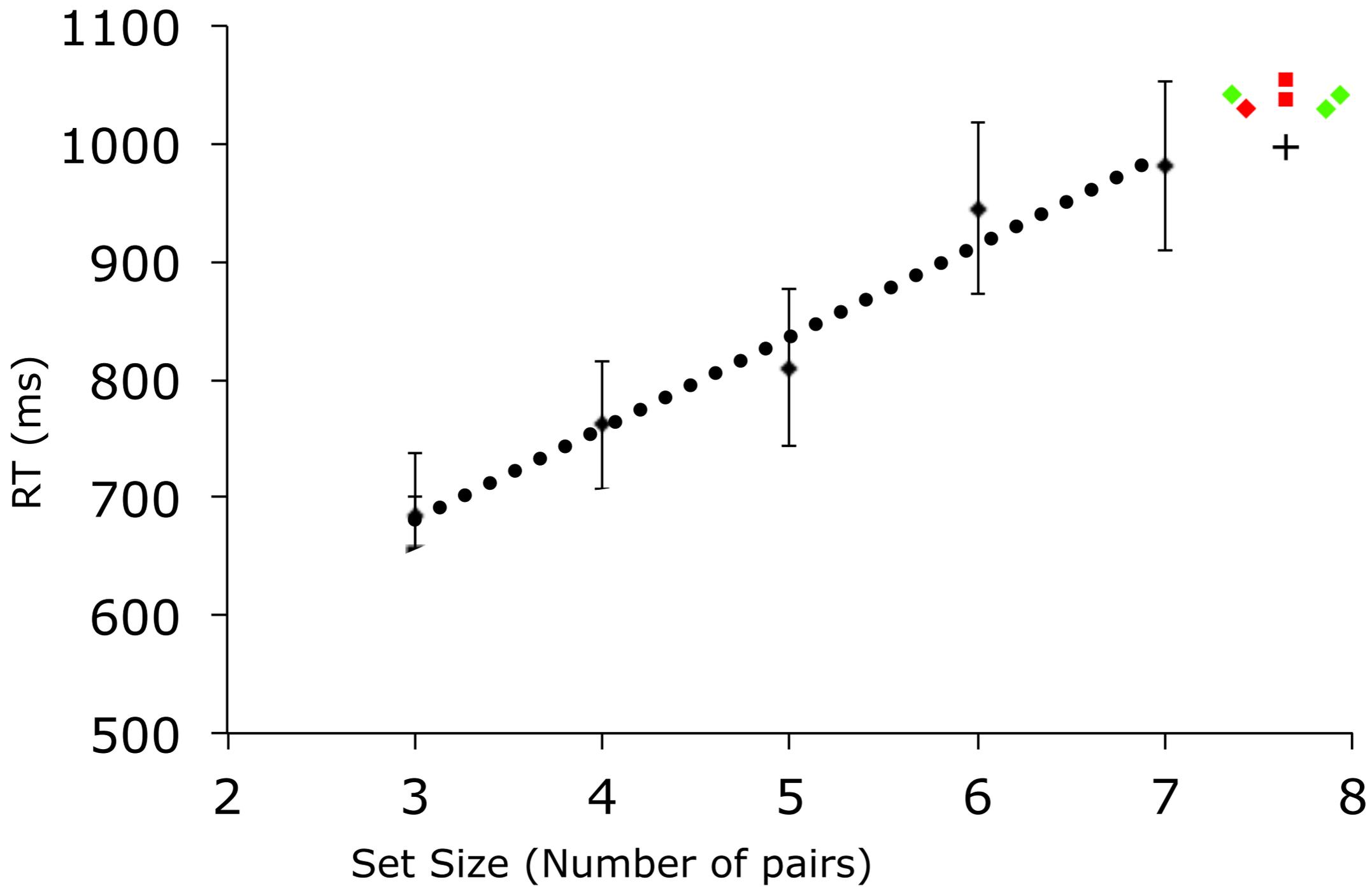
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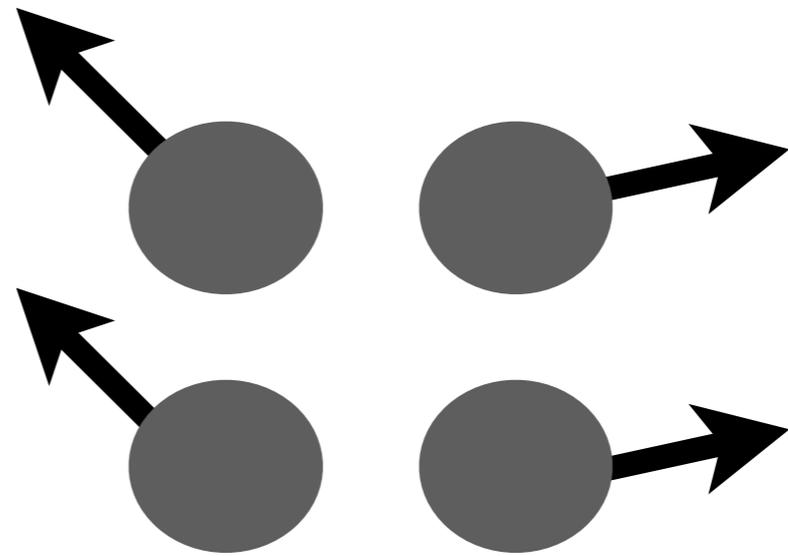
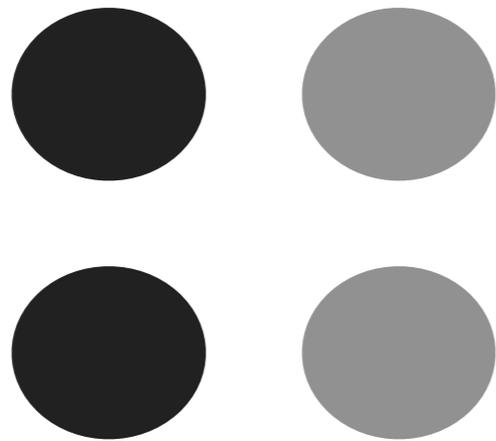
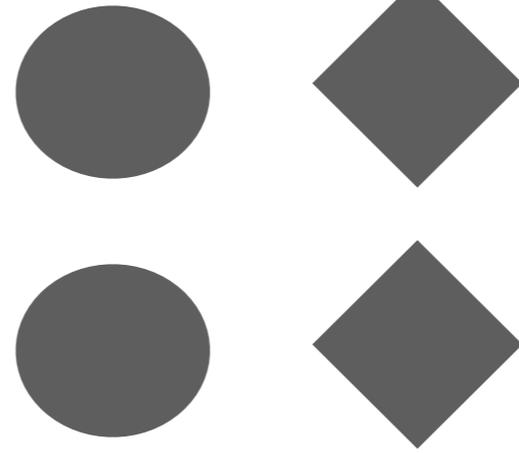
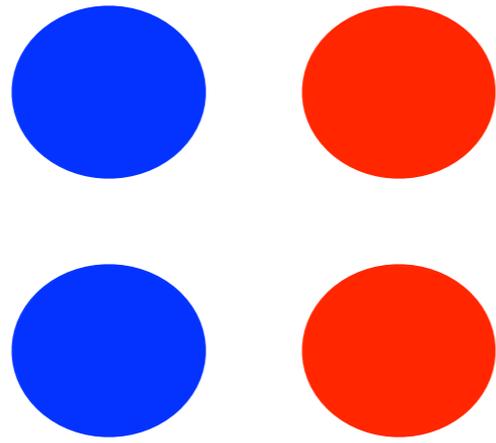




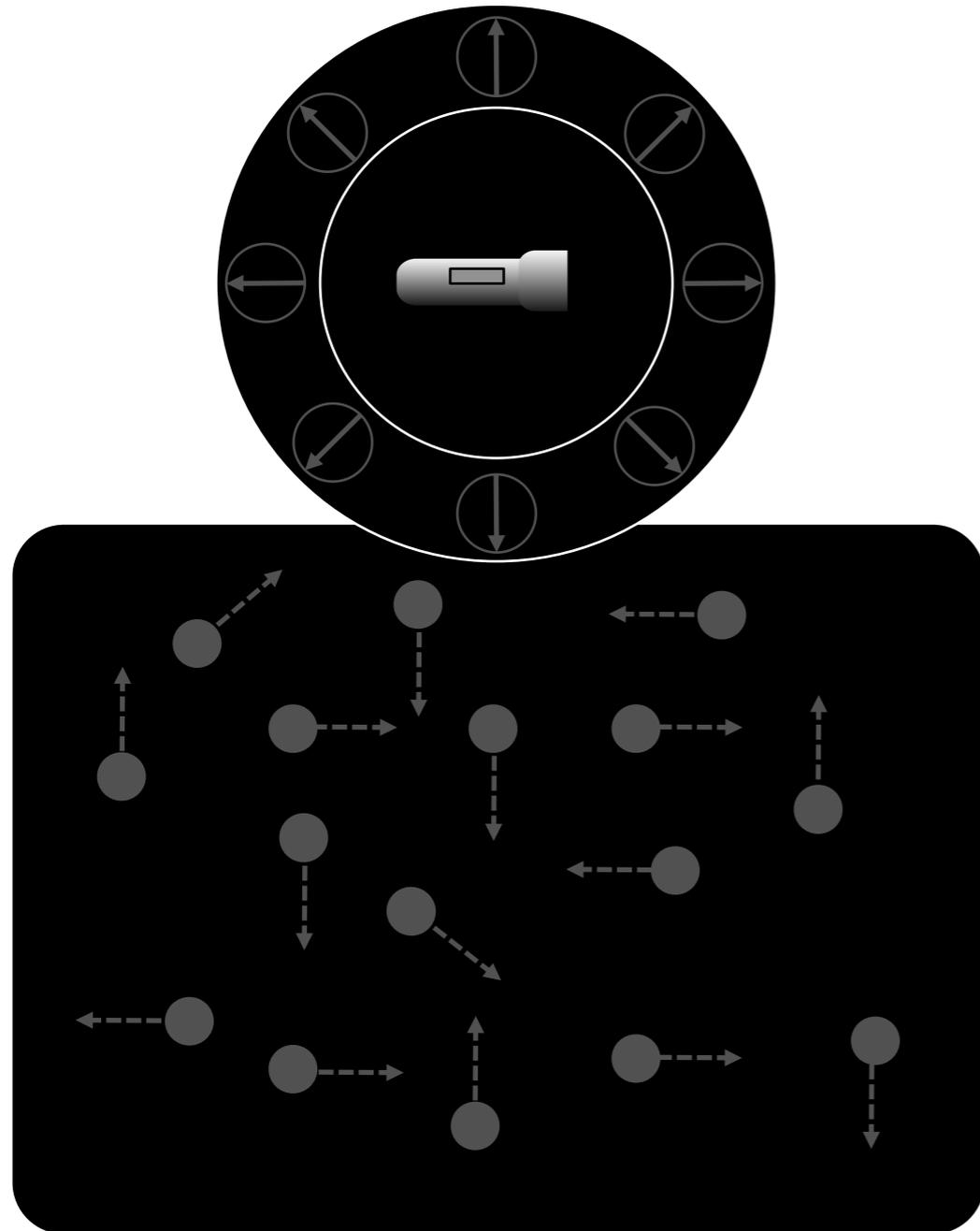




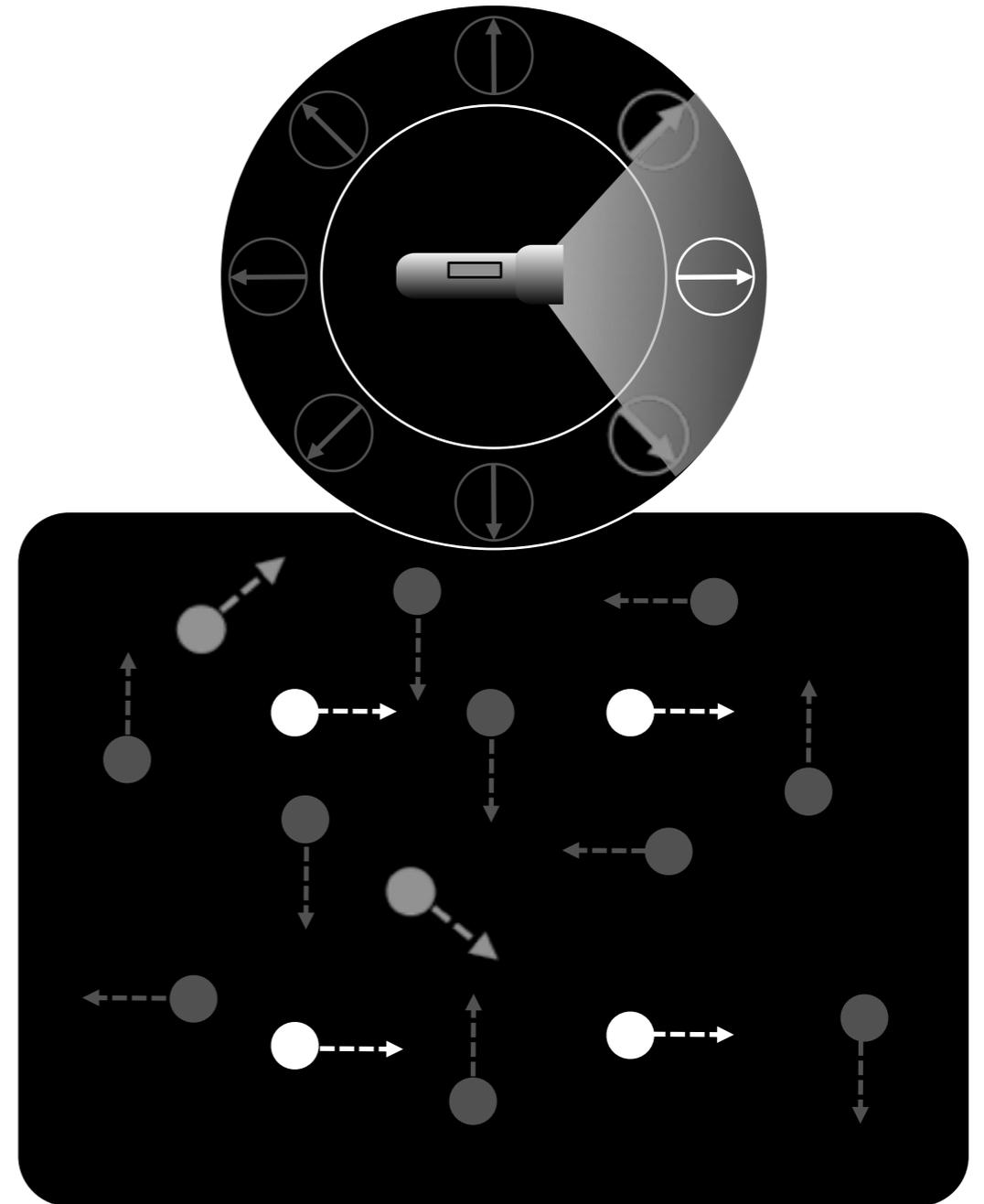


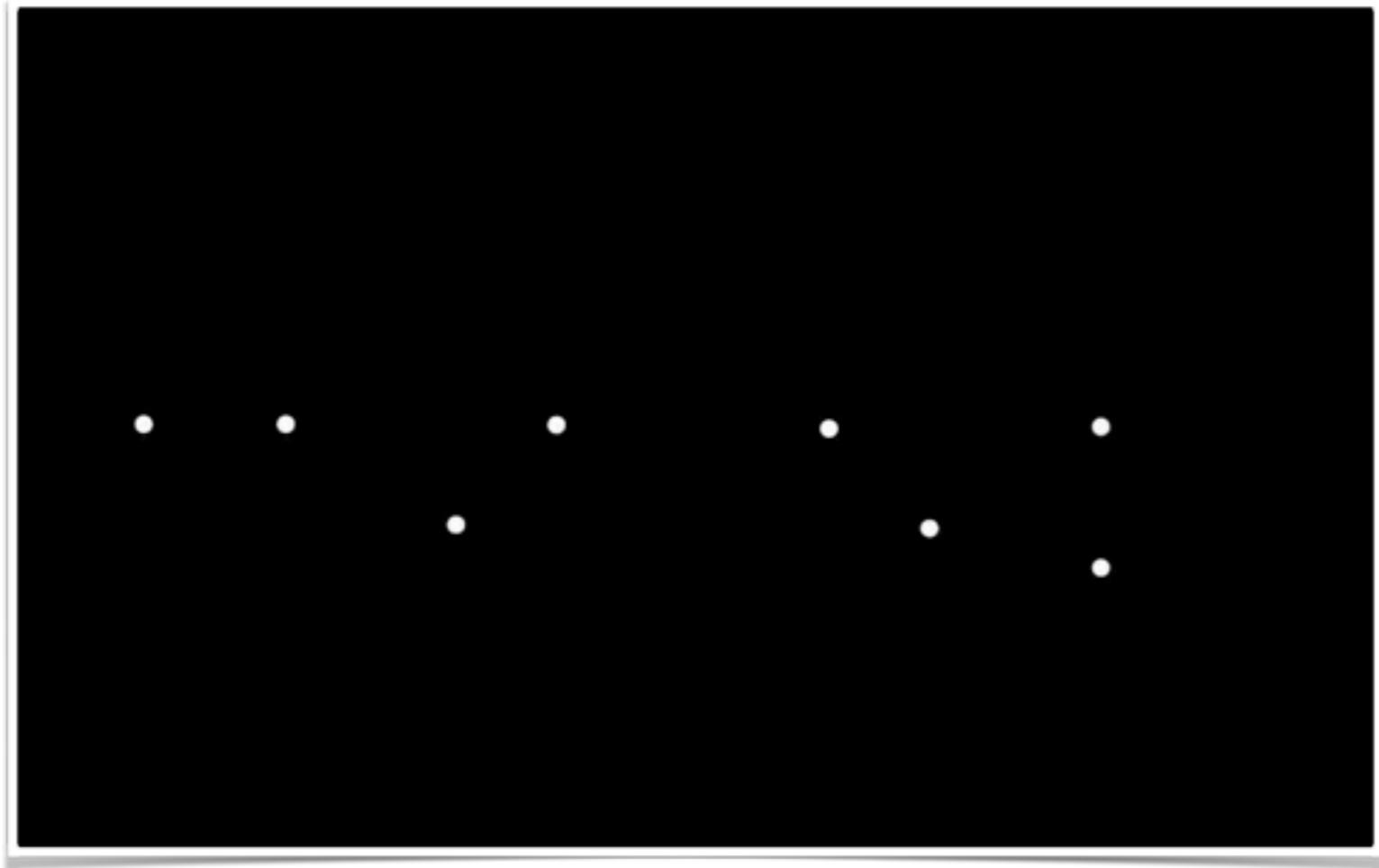


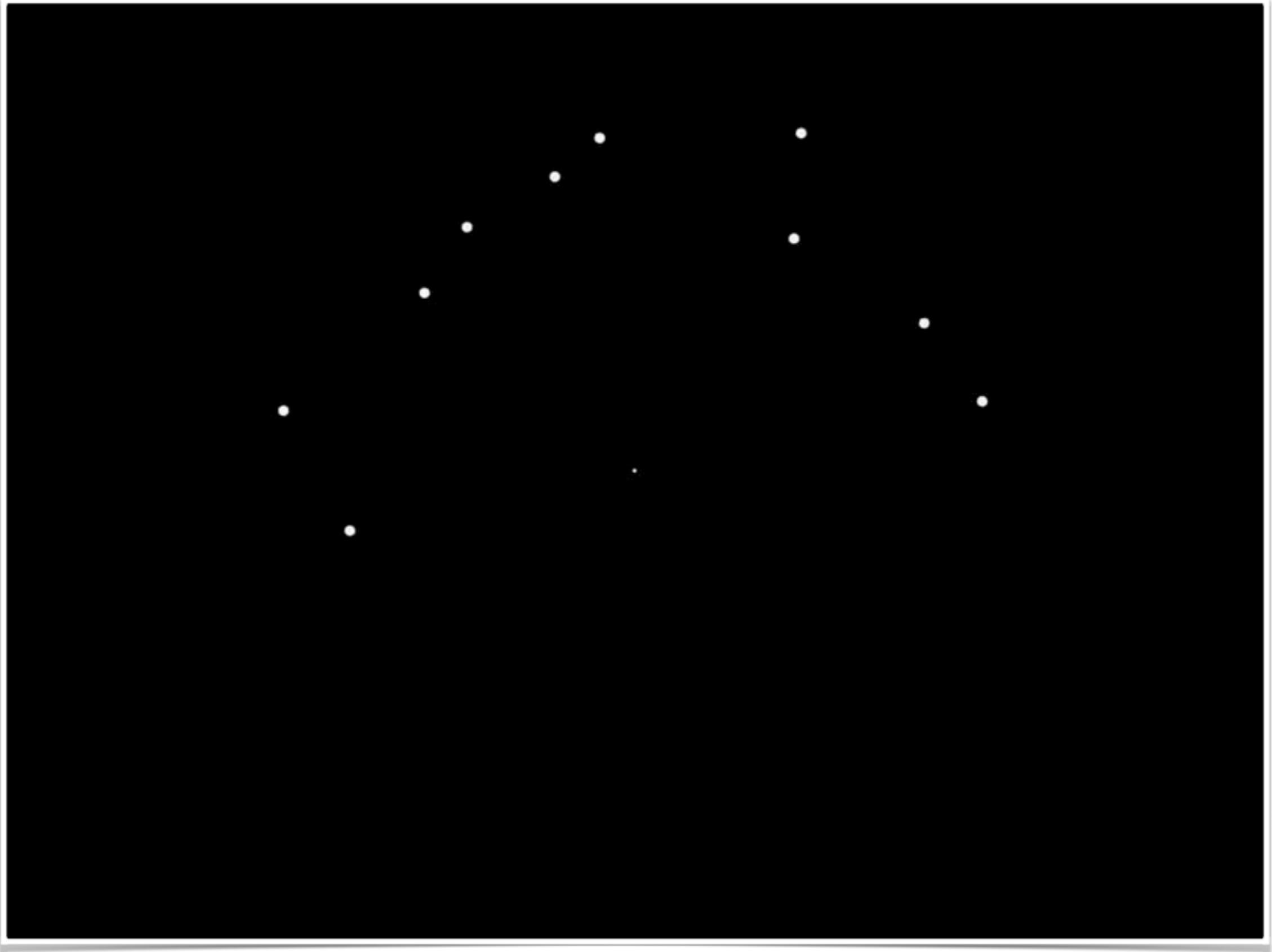
No Motion Direction Selection

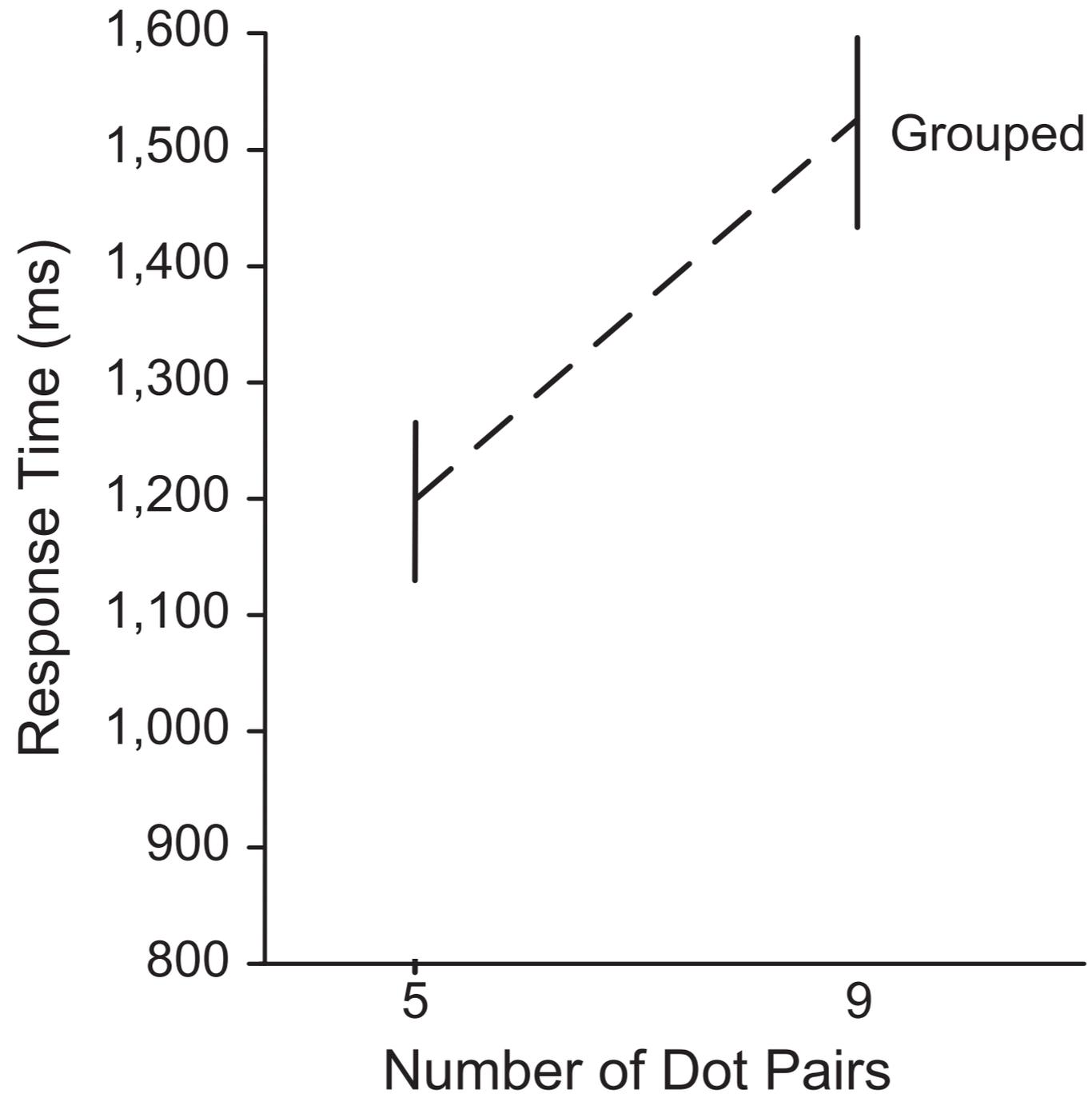


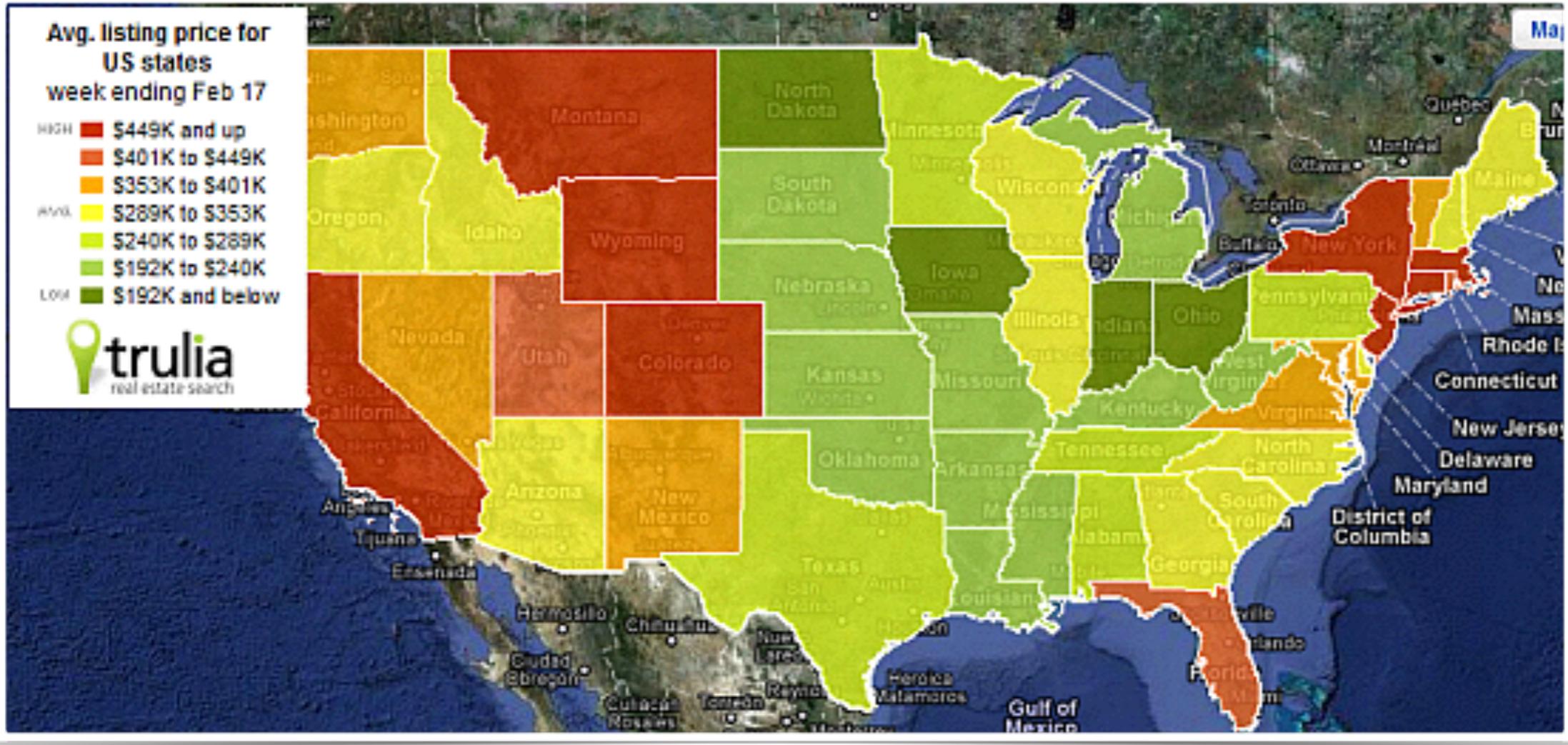
Motion Direction Selection

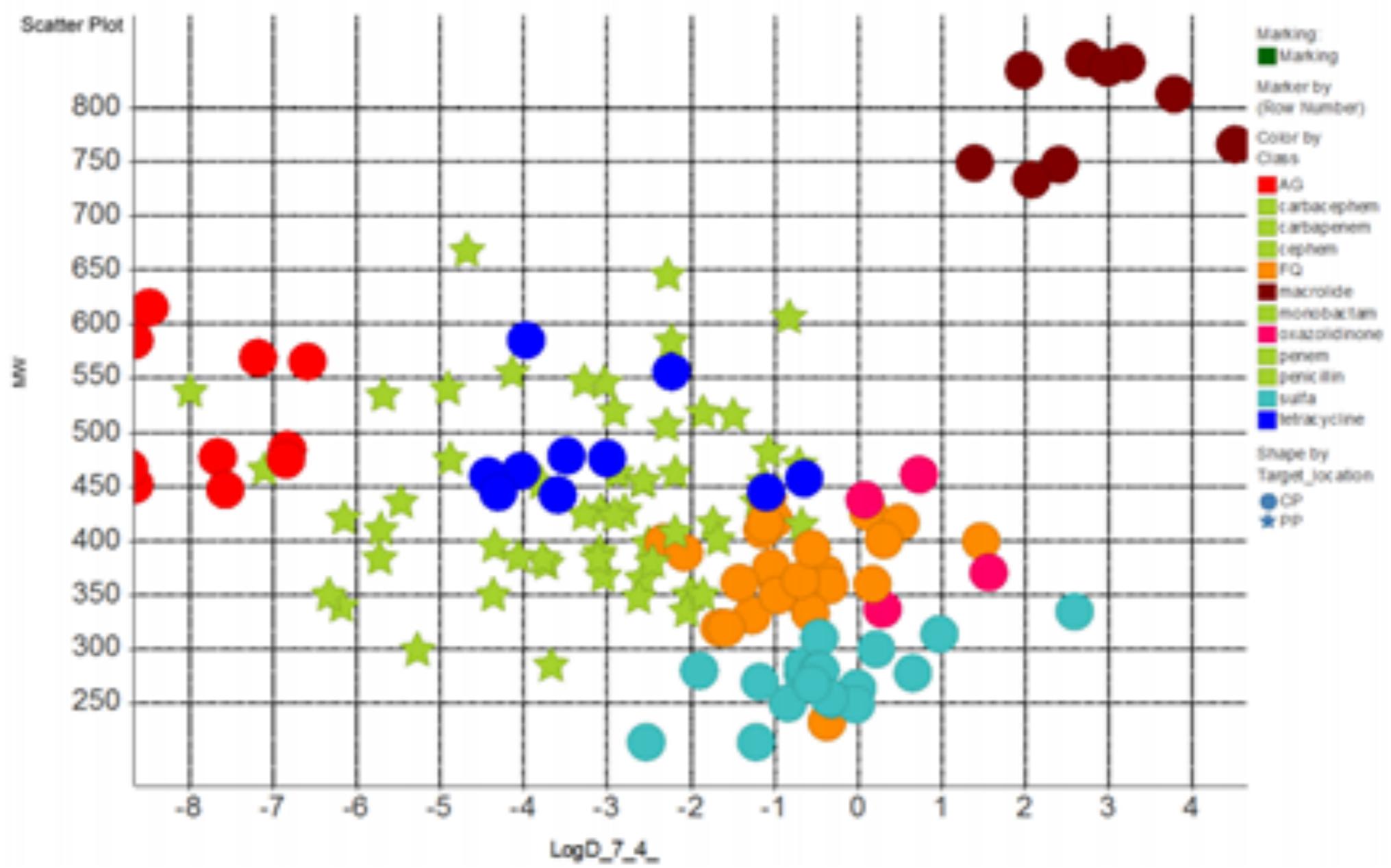




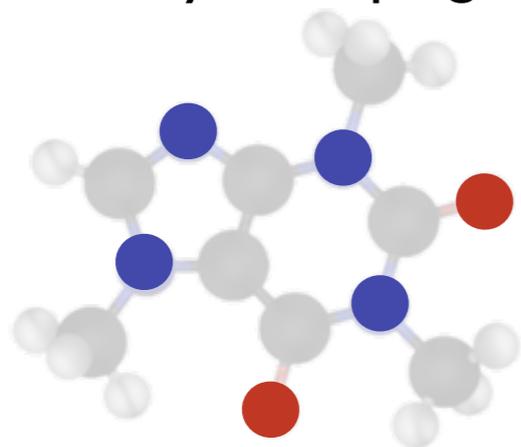




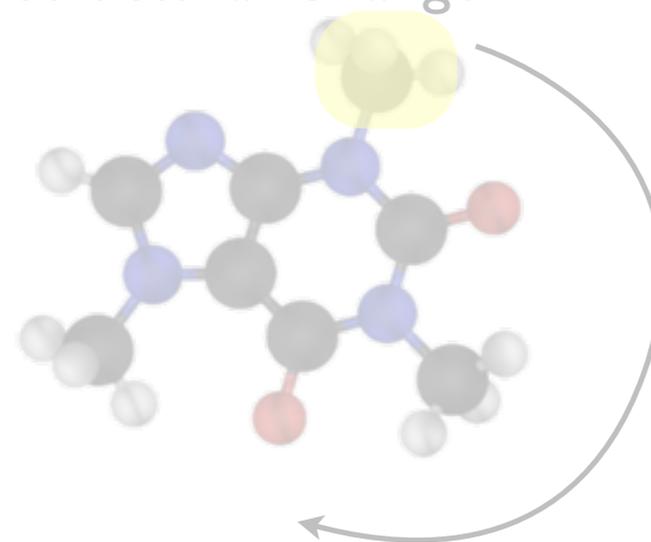




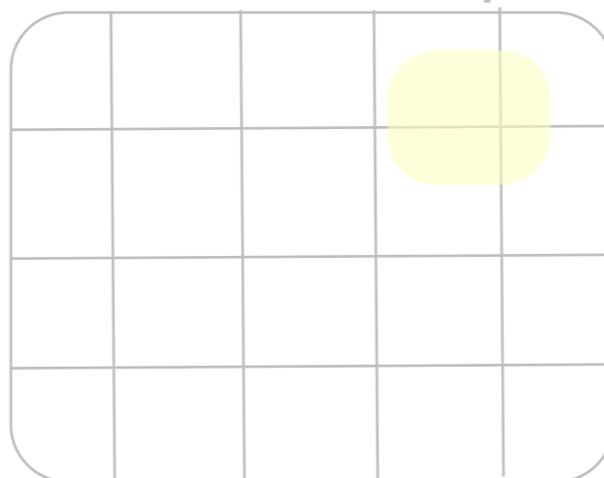
Similarity Grouping



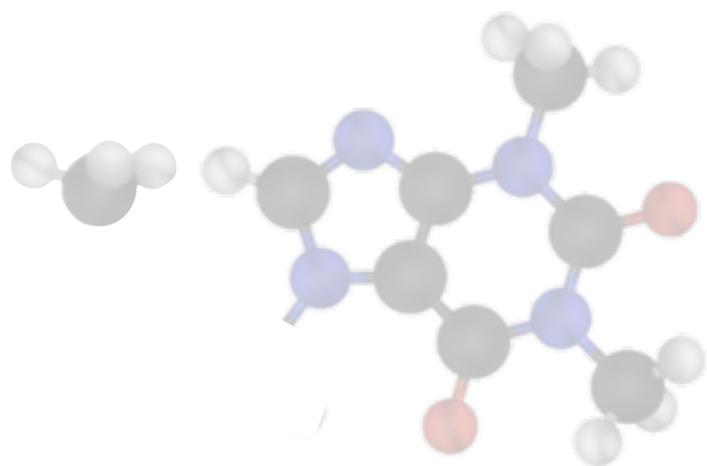
Structural Change



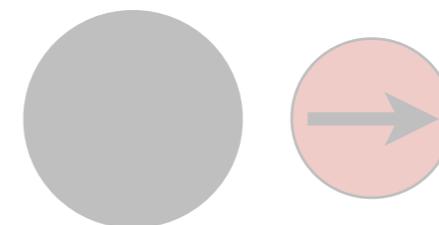
Attentional Priority Map



Object Continuity



Spatial Relations



12 pairwise relations

The smaller bar is yellow

The larger bar is blue

The left bar is blue

The right bar is yellow

The yellow bar is smaller

The blue bar is larger

The left bar is larger

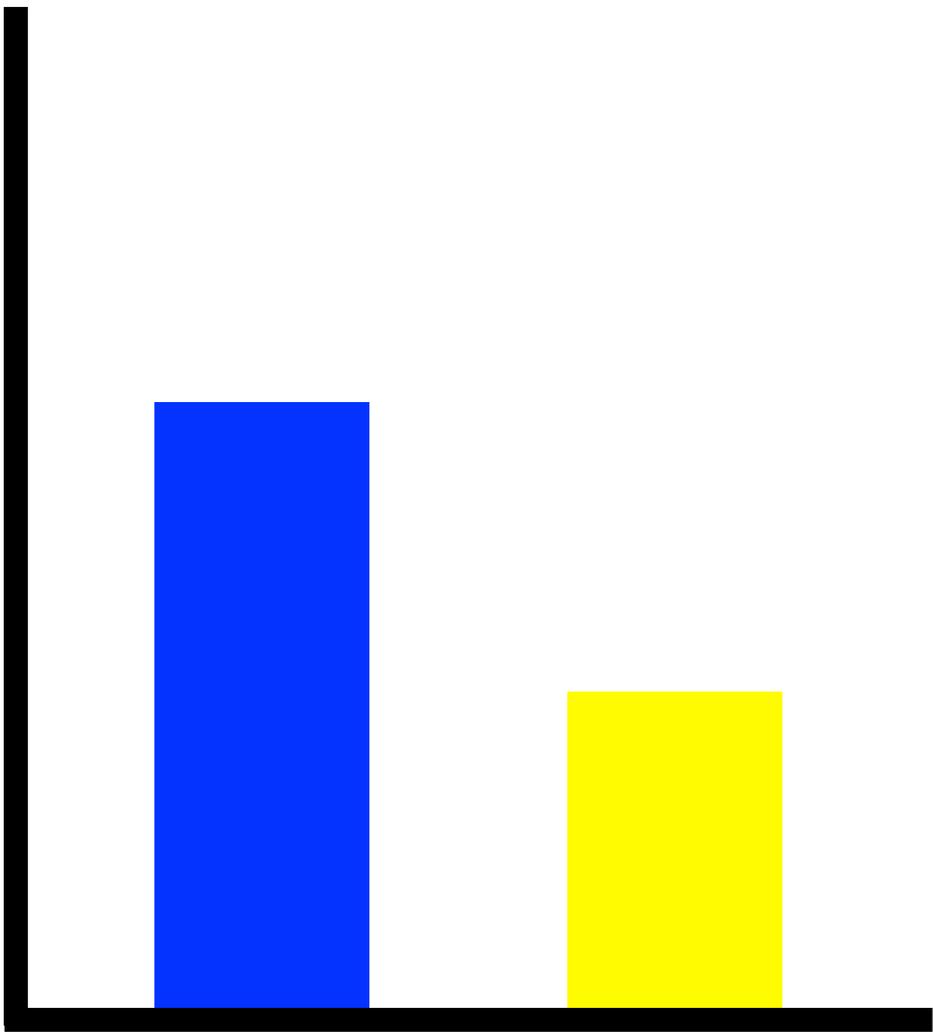
The right bar is smaller

The blue bar is on the left

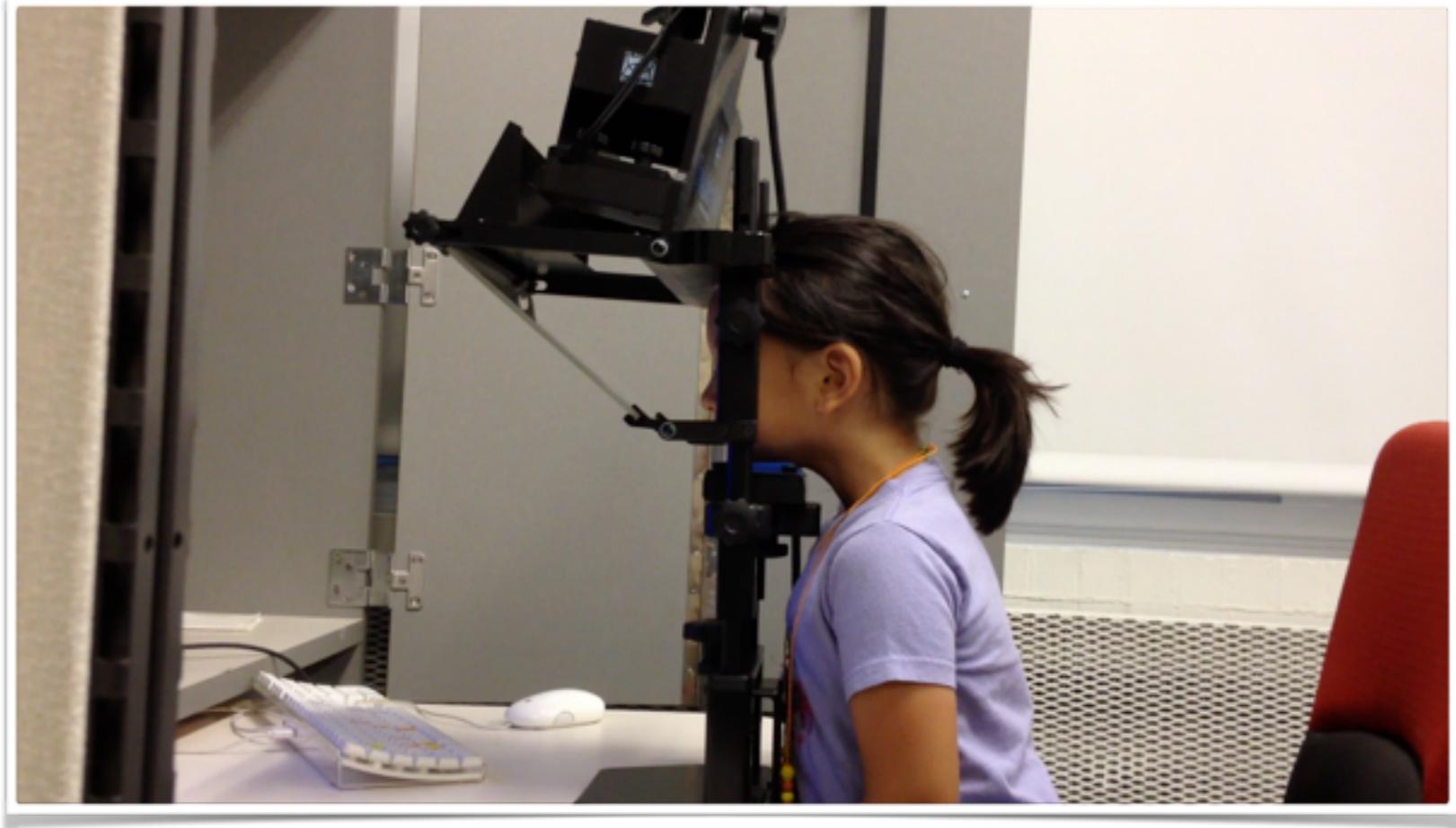
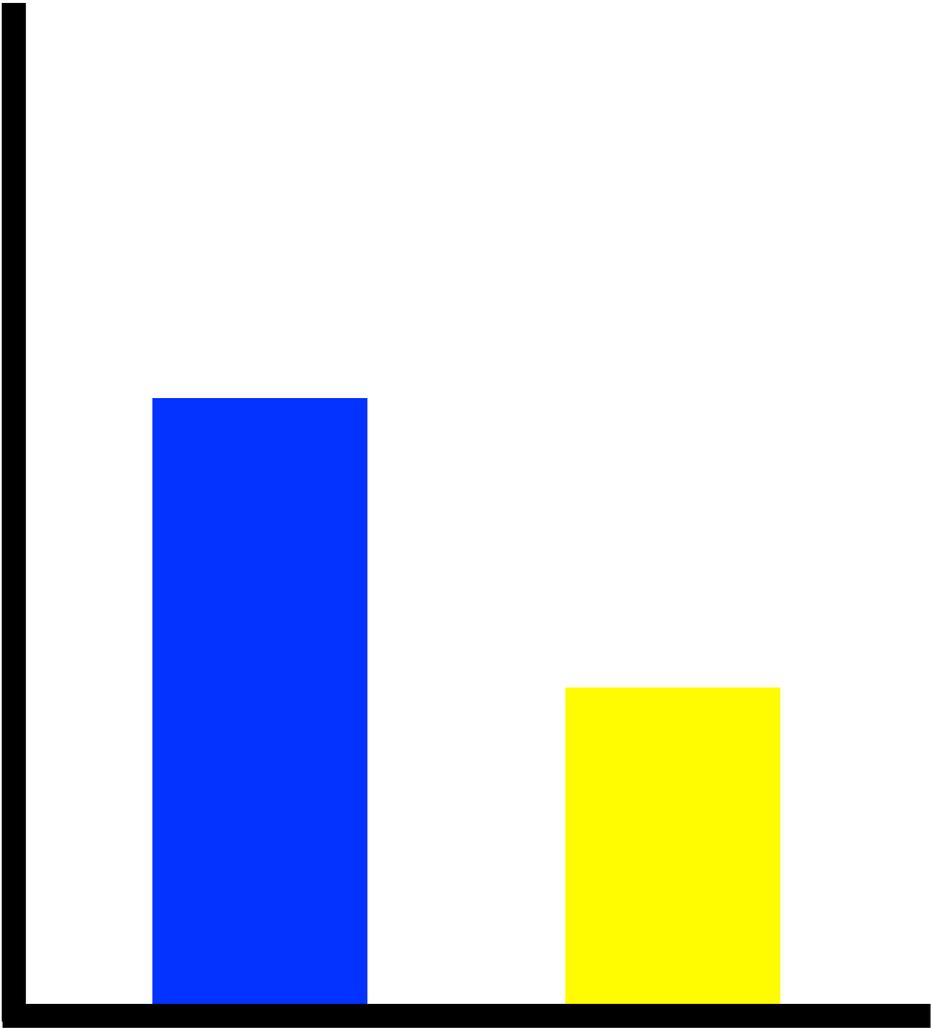
The yellow bar is on the right

The smaller bar is on the right

The larger bar is on the left

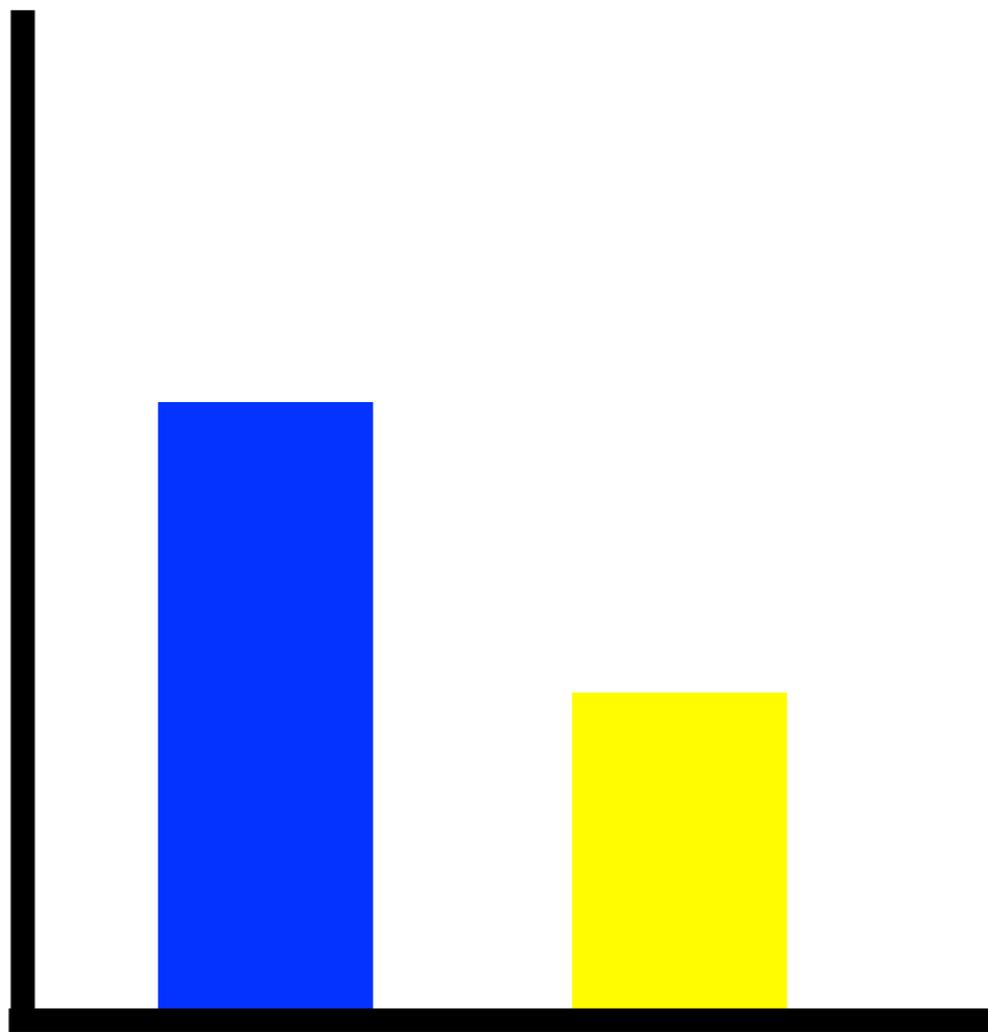


Reading a graph can be like
reading a paragraph
Carpenter & Shah, 1998

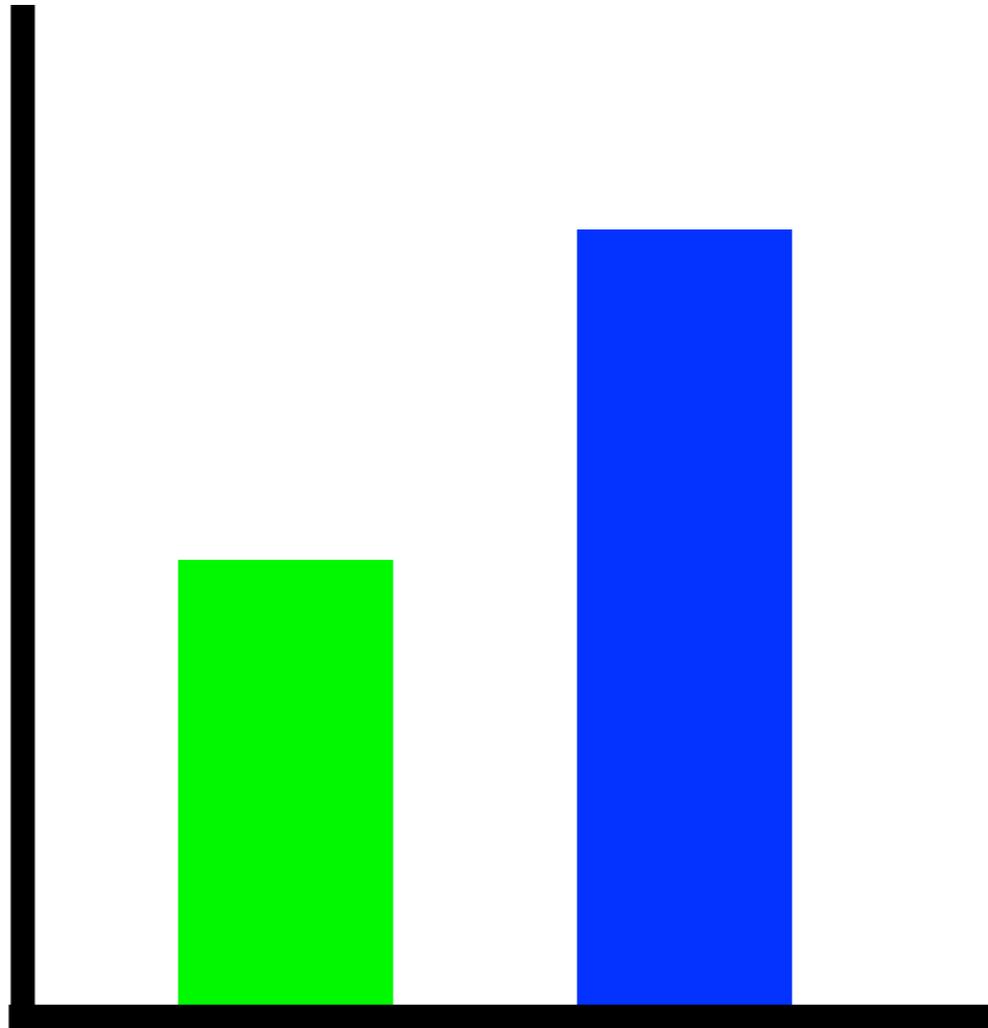


Perceptual Routines

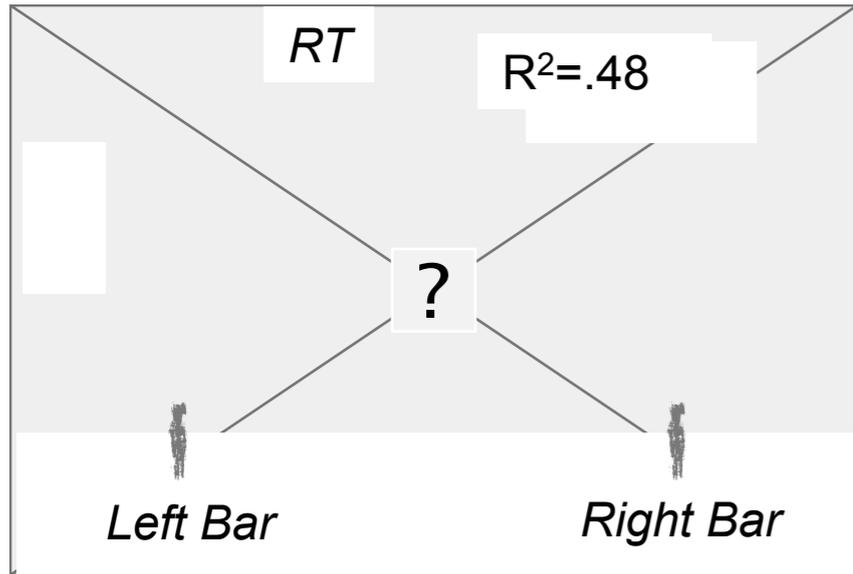
Are there fewer pears than blueberries?



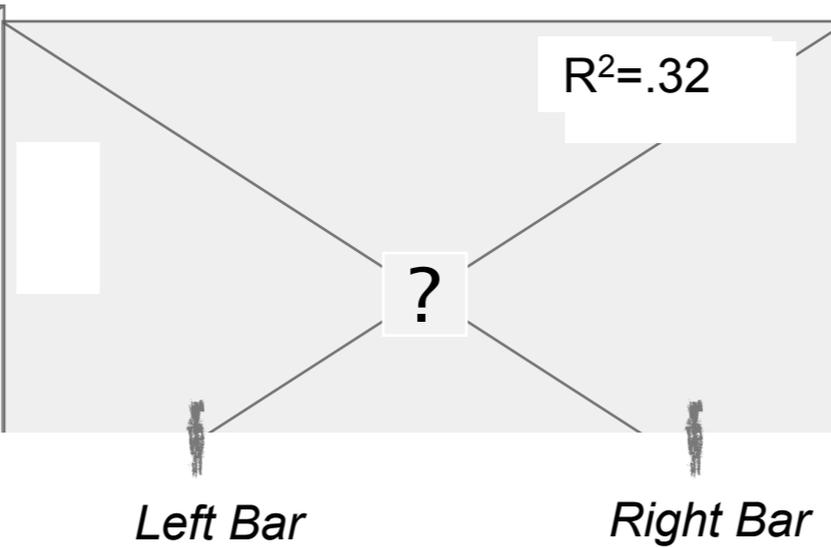
Are there more limes than blueberries?



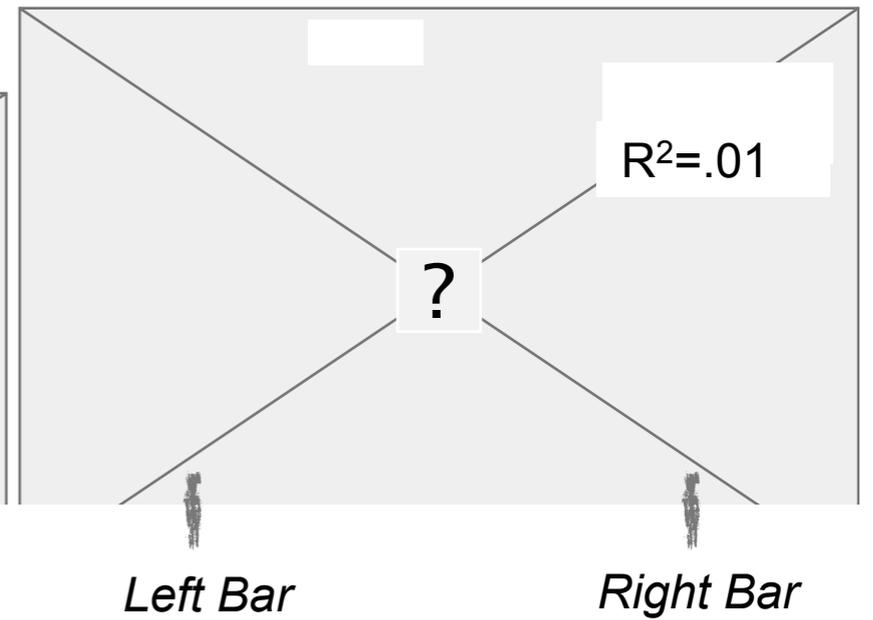
6-Year Olds



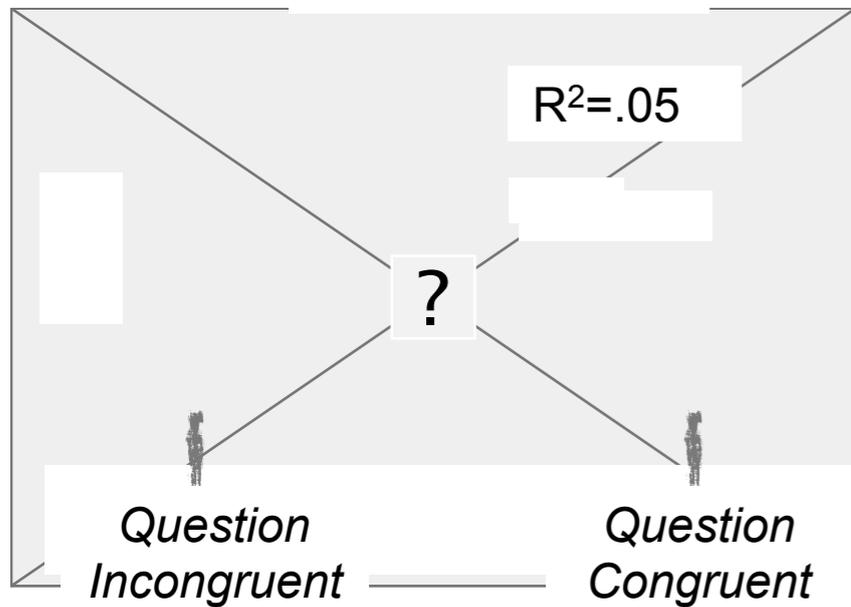
8-Year Olds



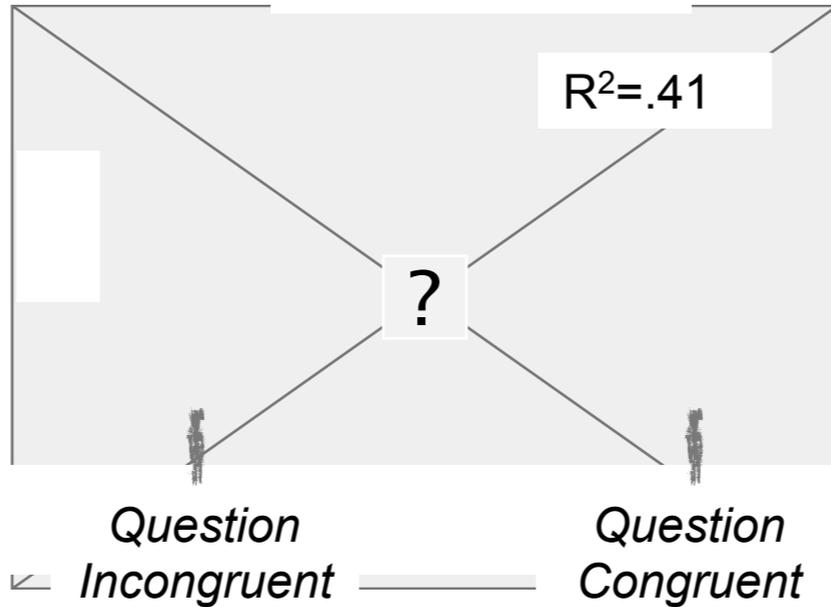
College Students



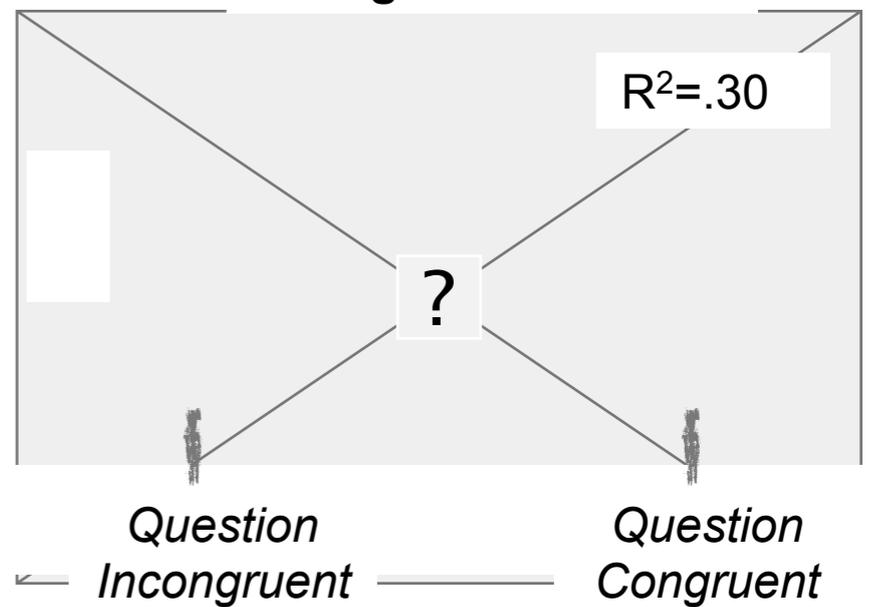
6-Year Olds



8-Year Olds



College Students



Are there more blueberries than oranges?



Slower RT 8 year-old

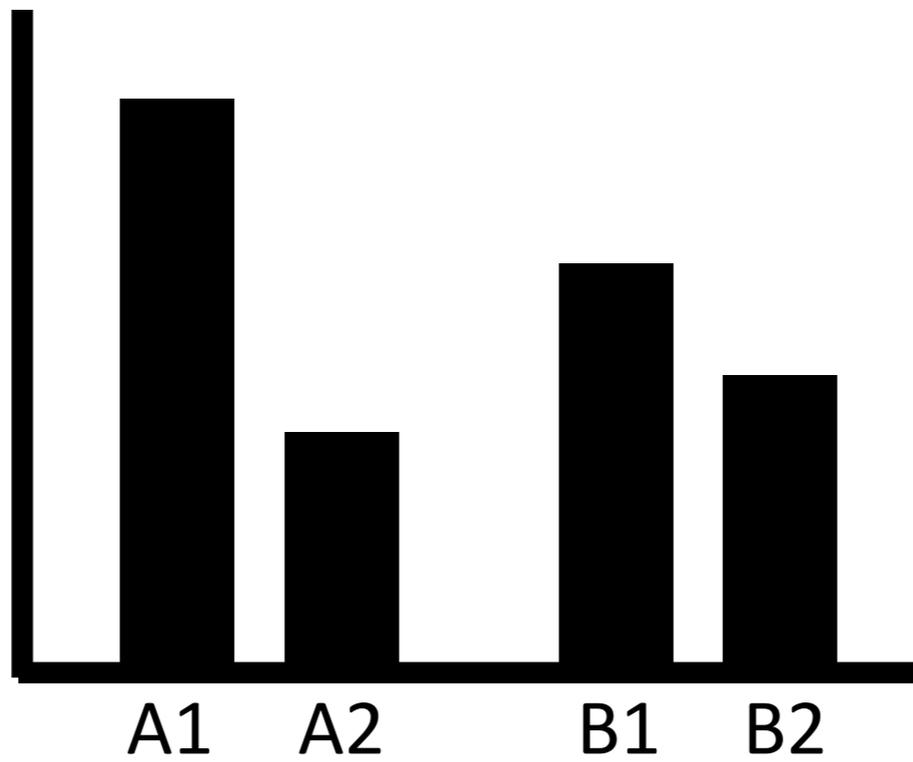
Left to right perceptual order, regardless of question

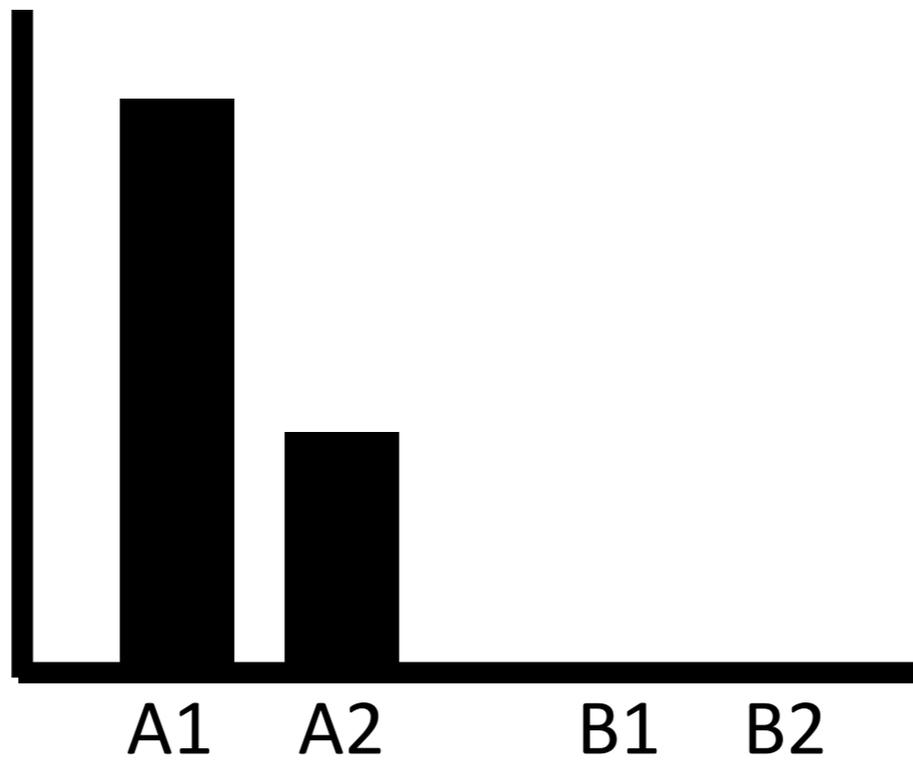
Are there more oranges than blueberries?

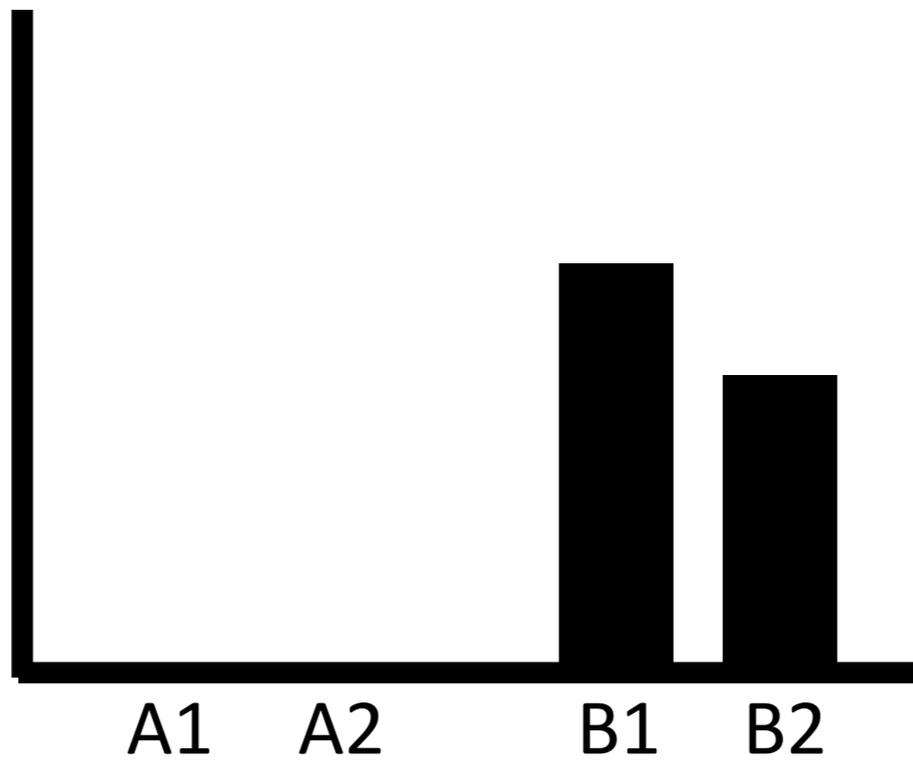


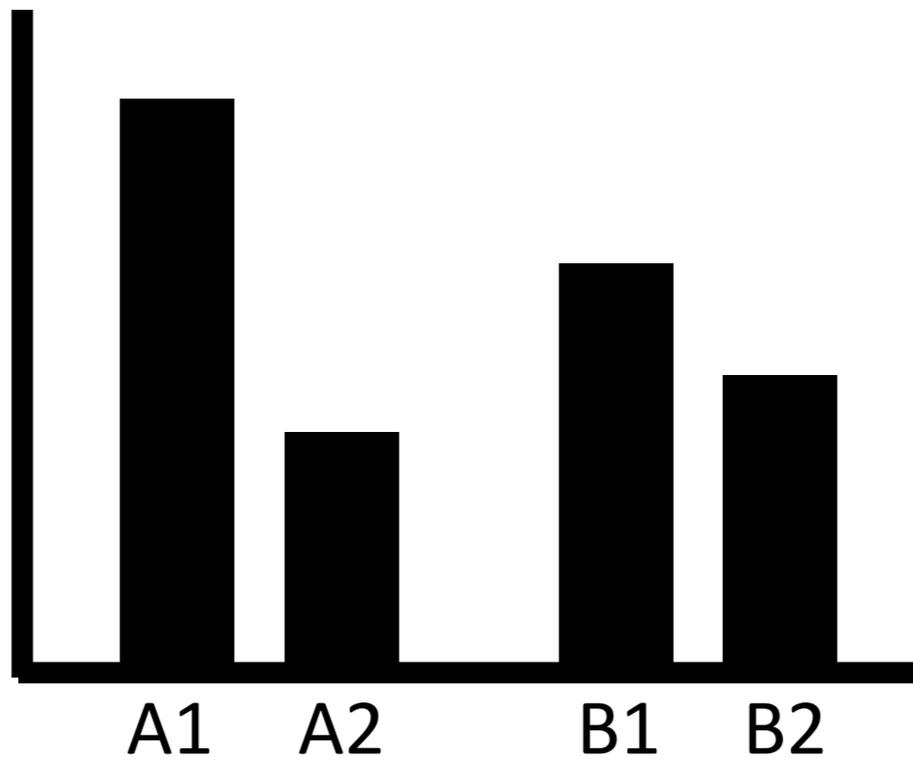
Faster RT 8 year-old

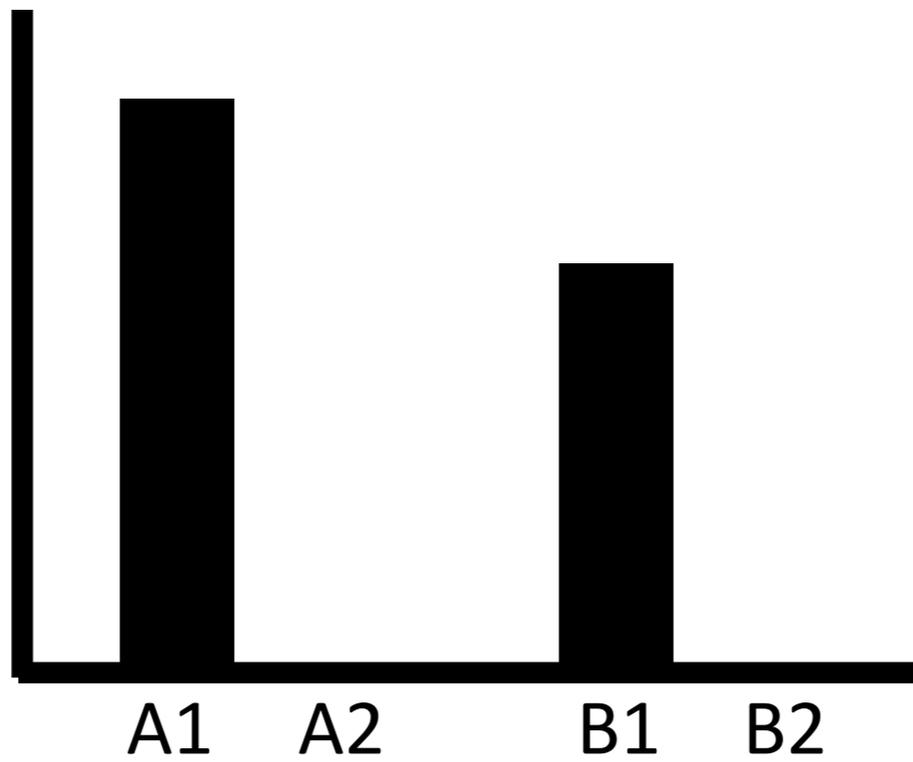
Fixation order congruent with question

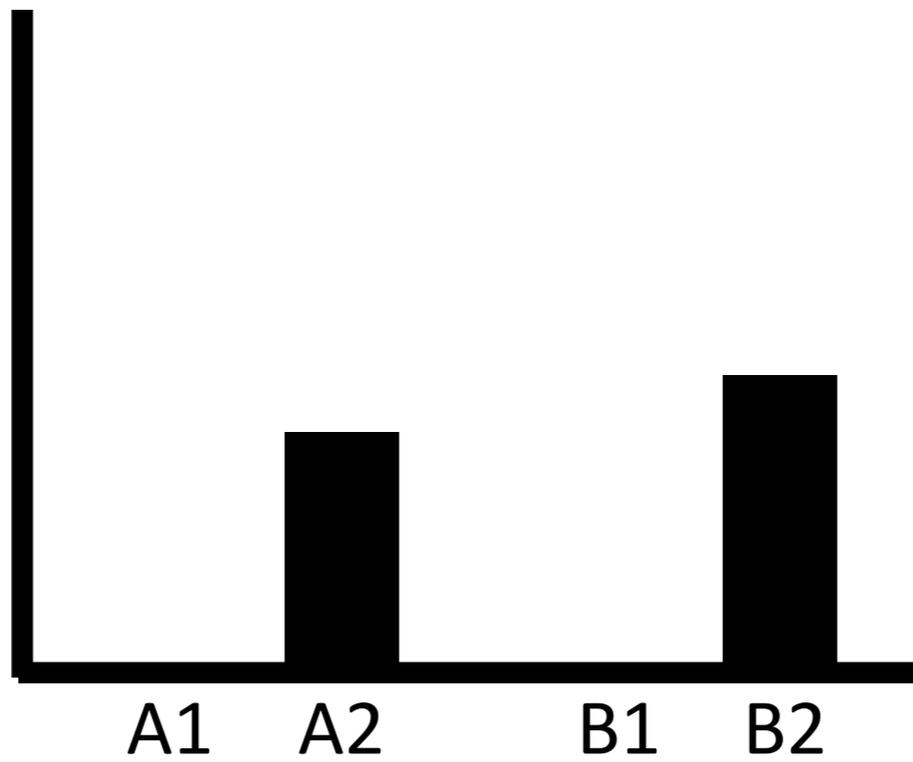


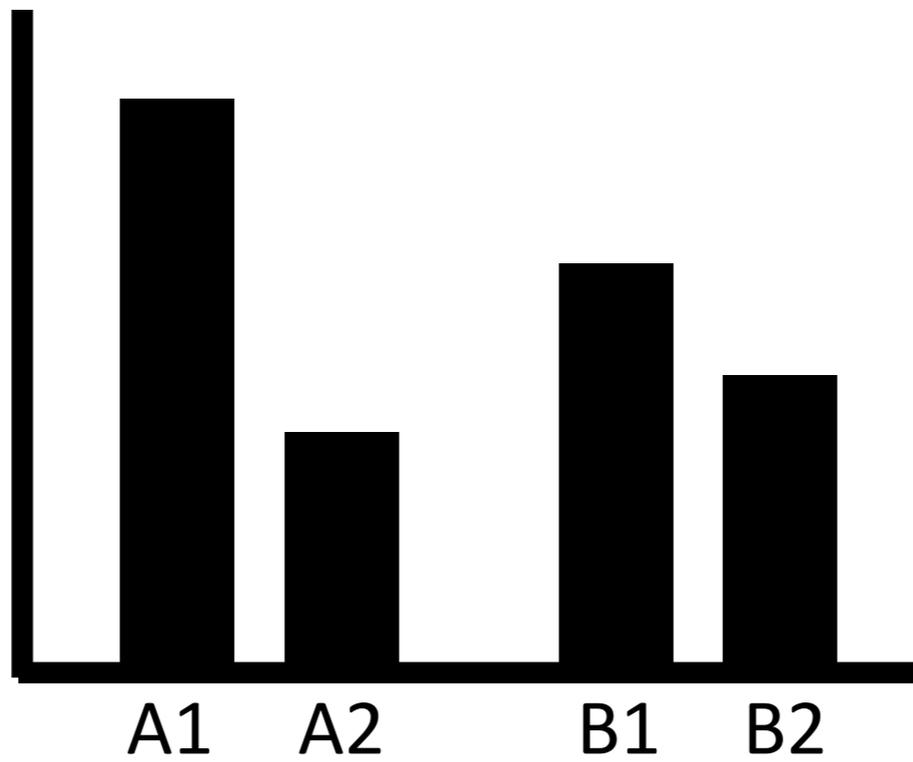


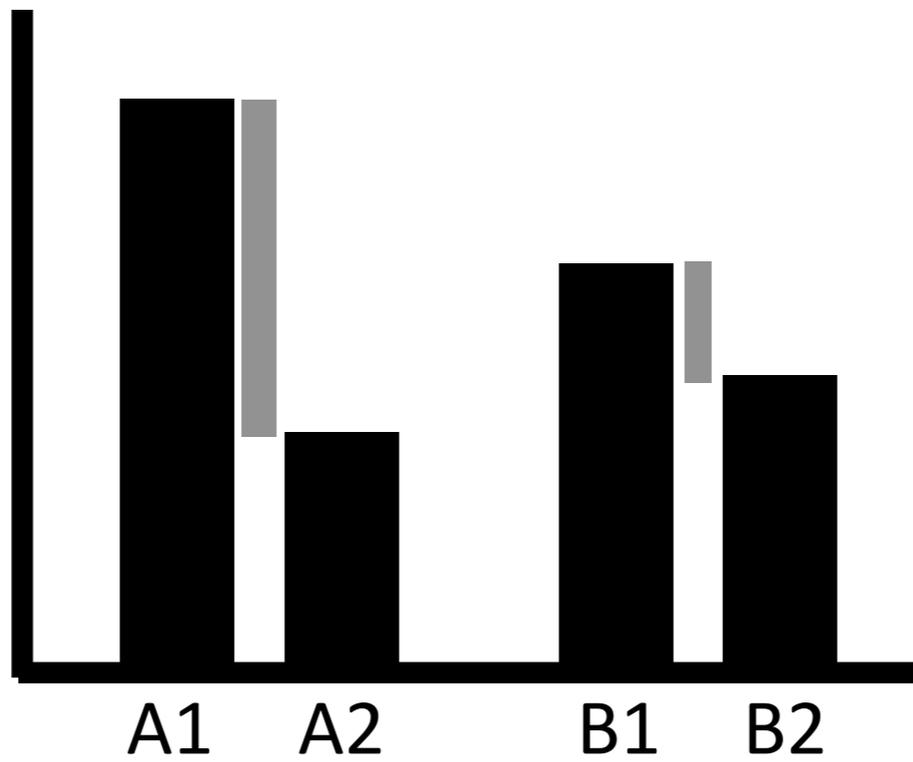


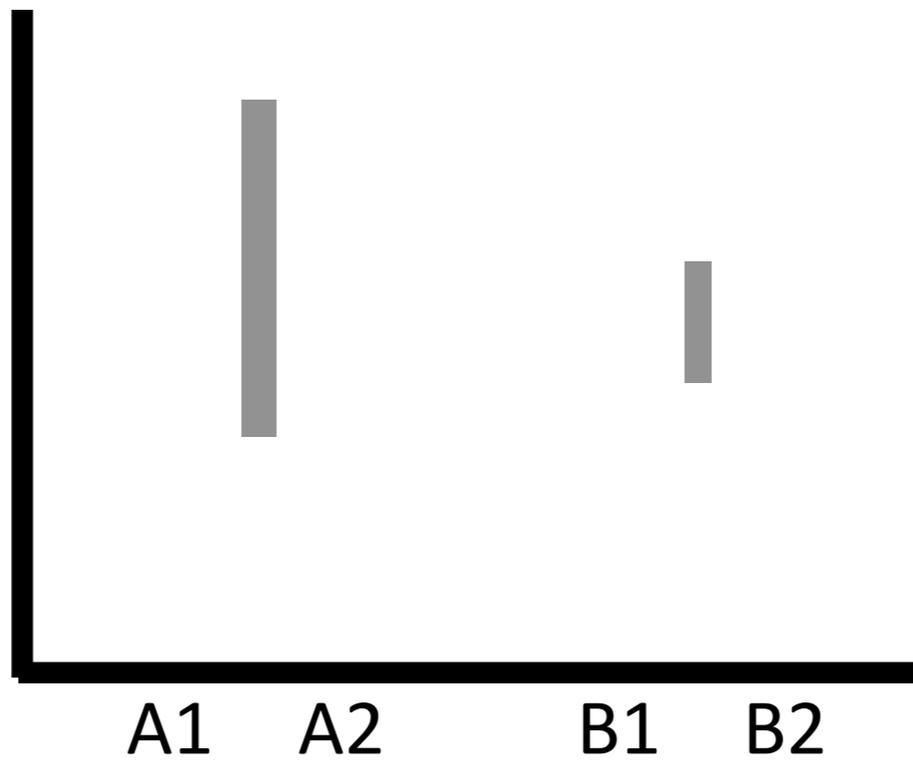


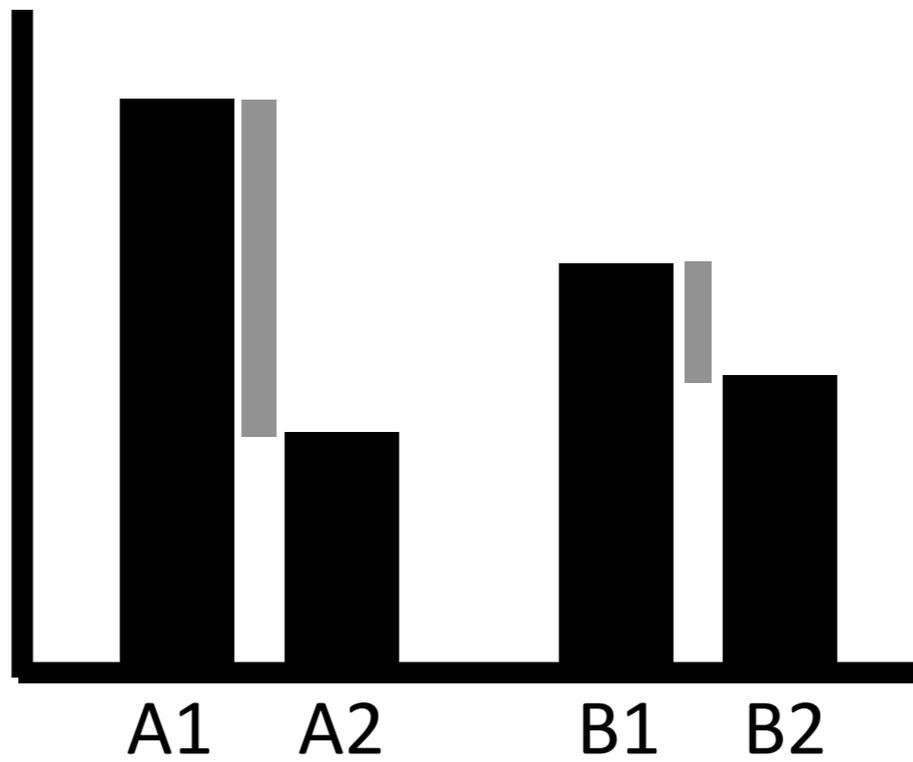


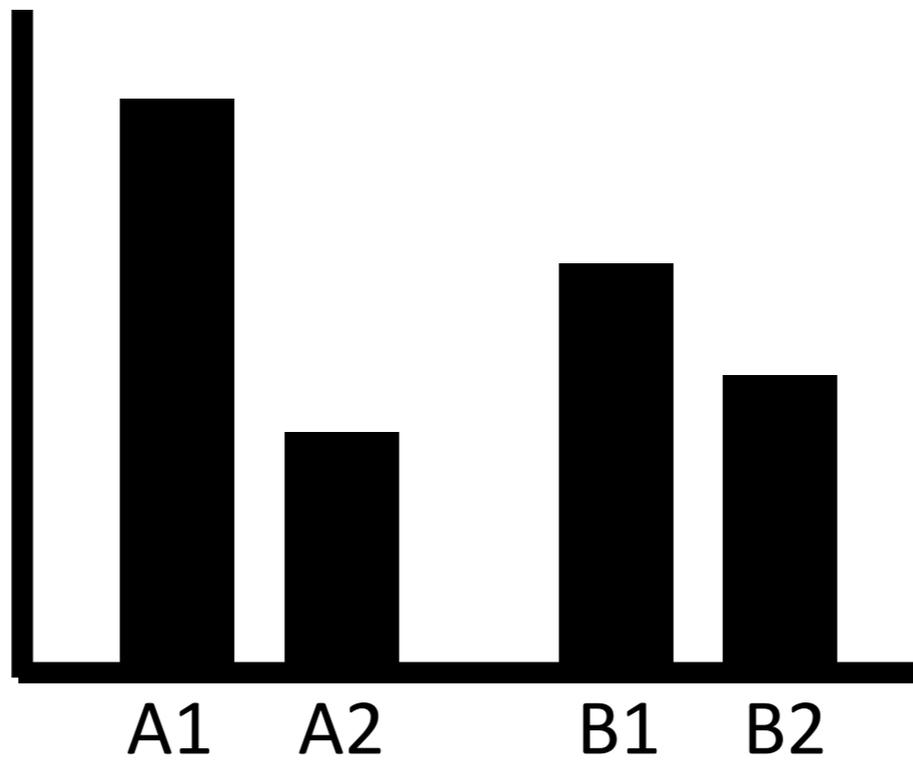


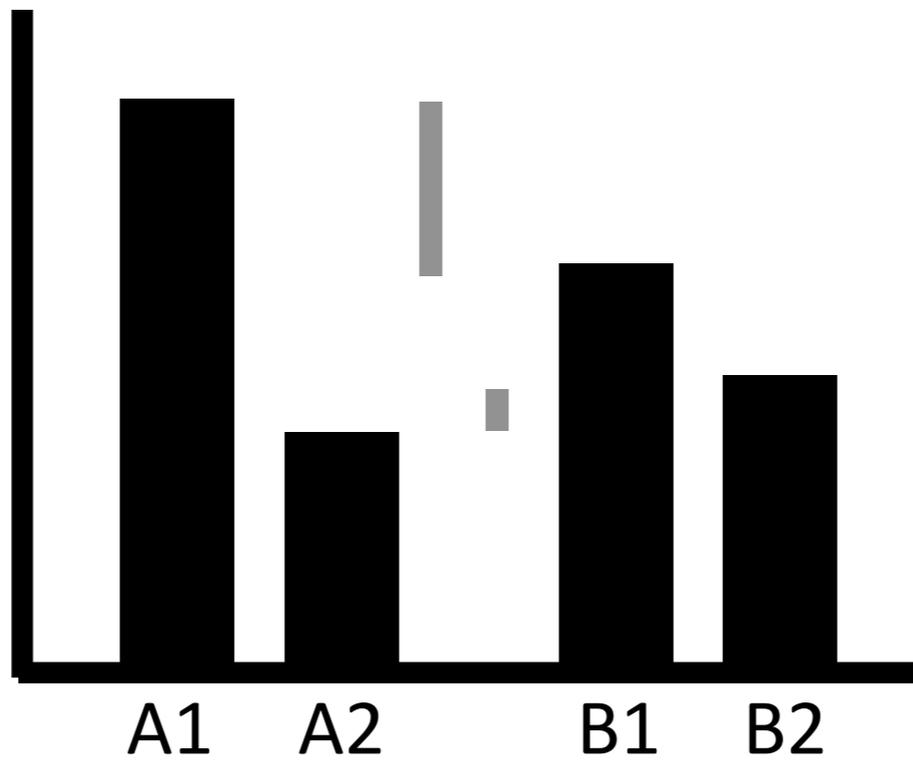


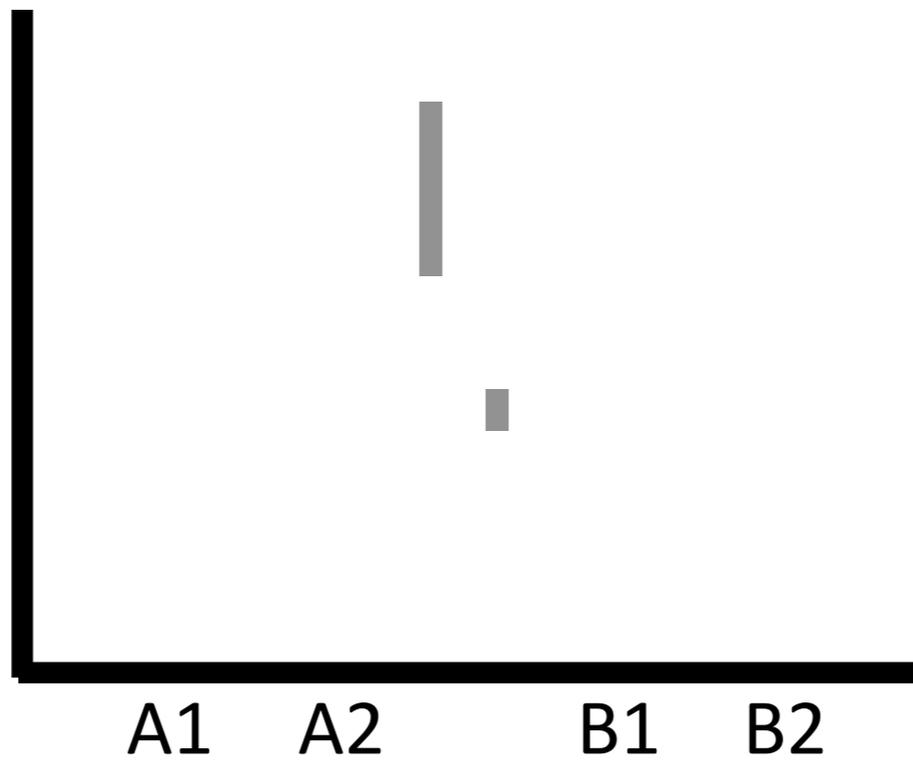


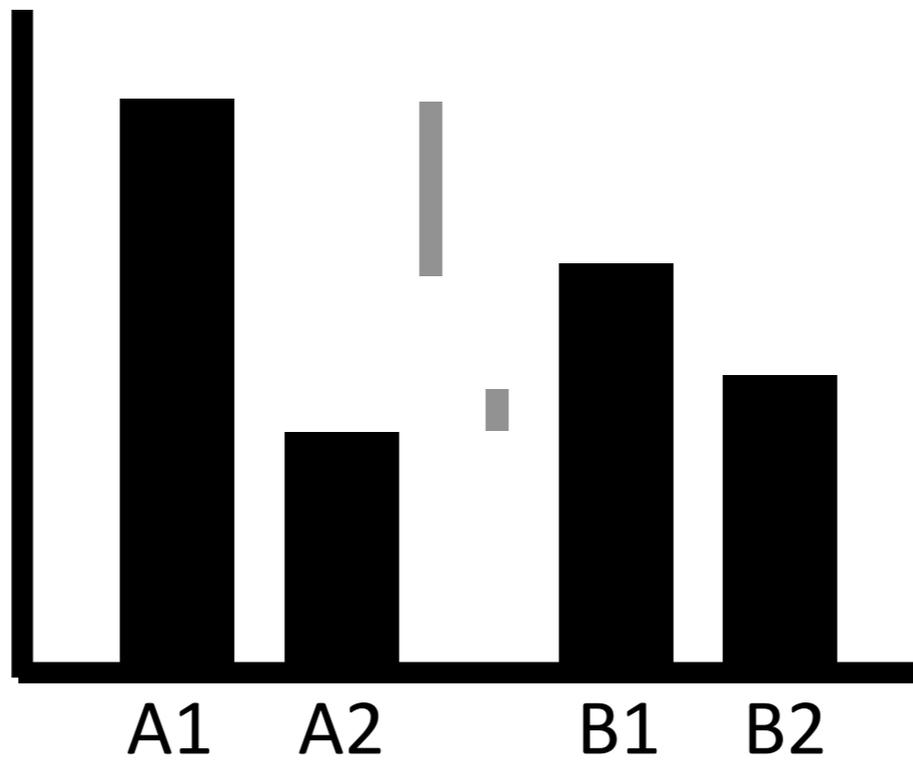


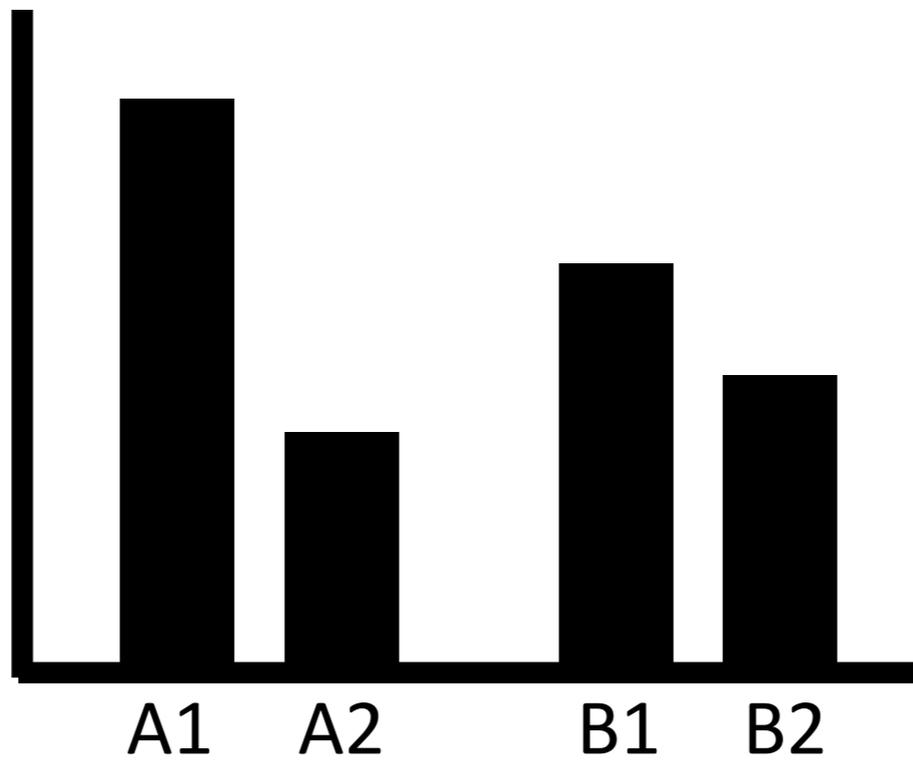


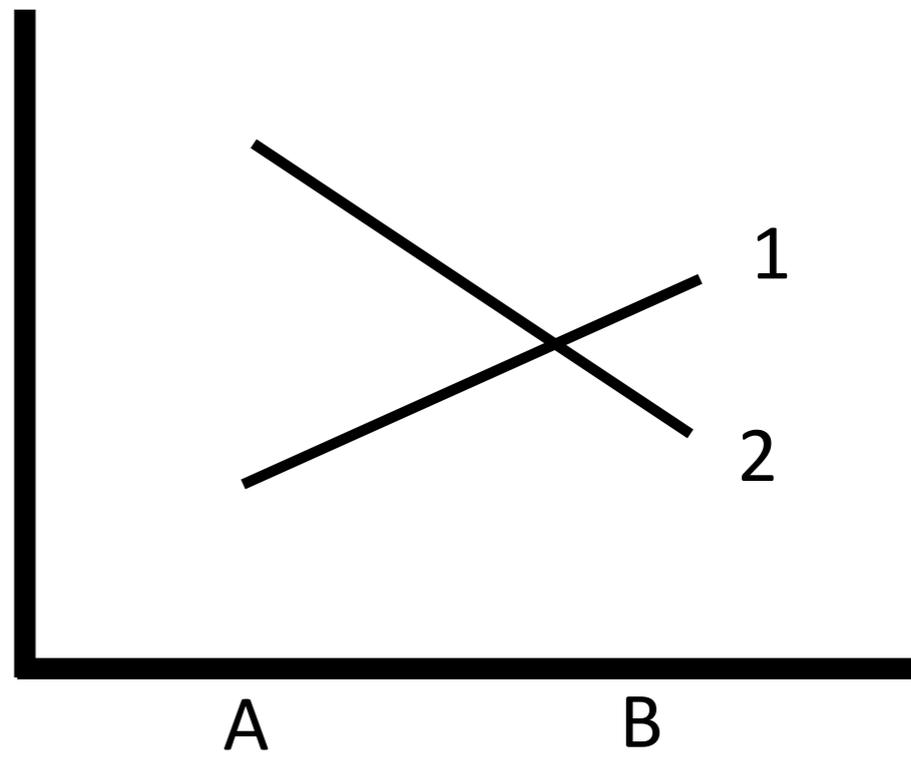
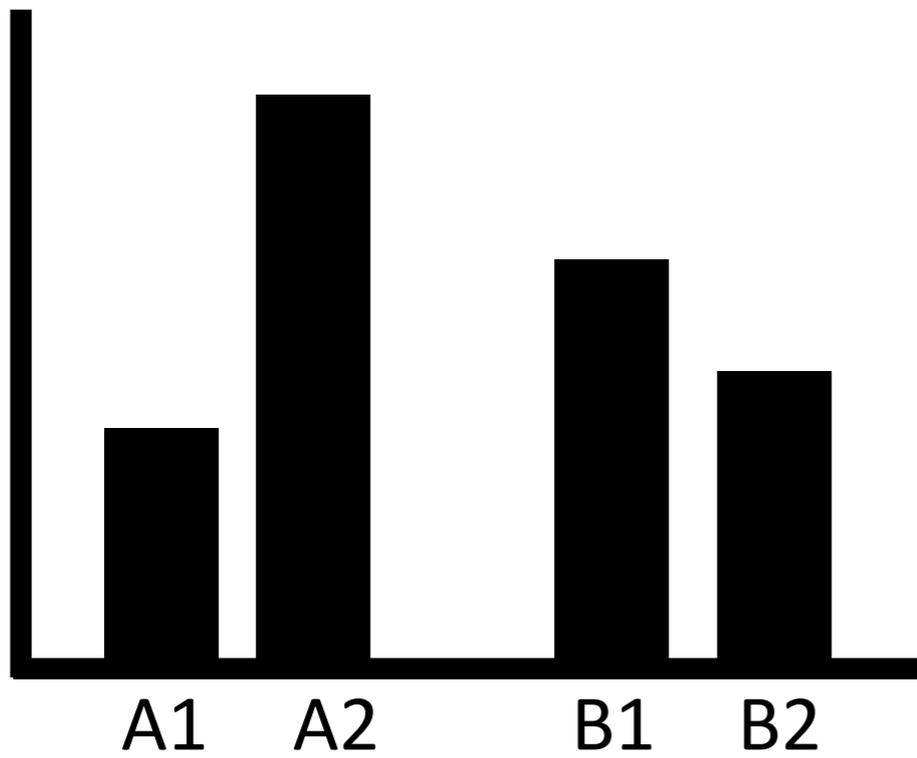


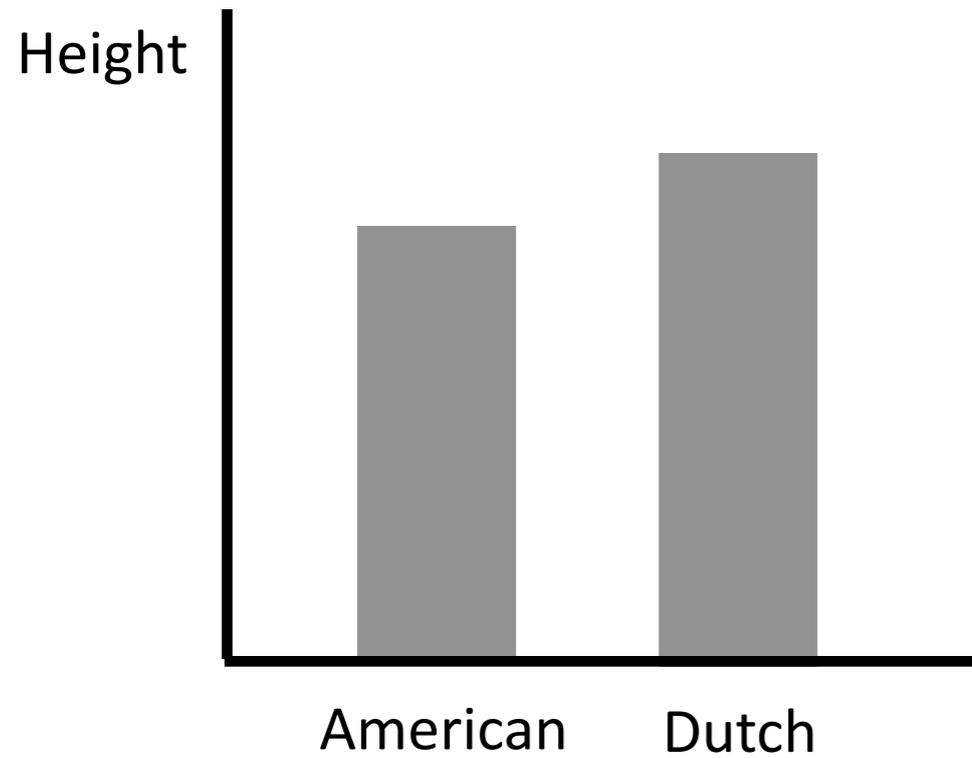




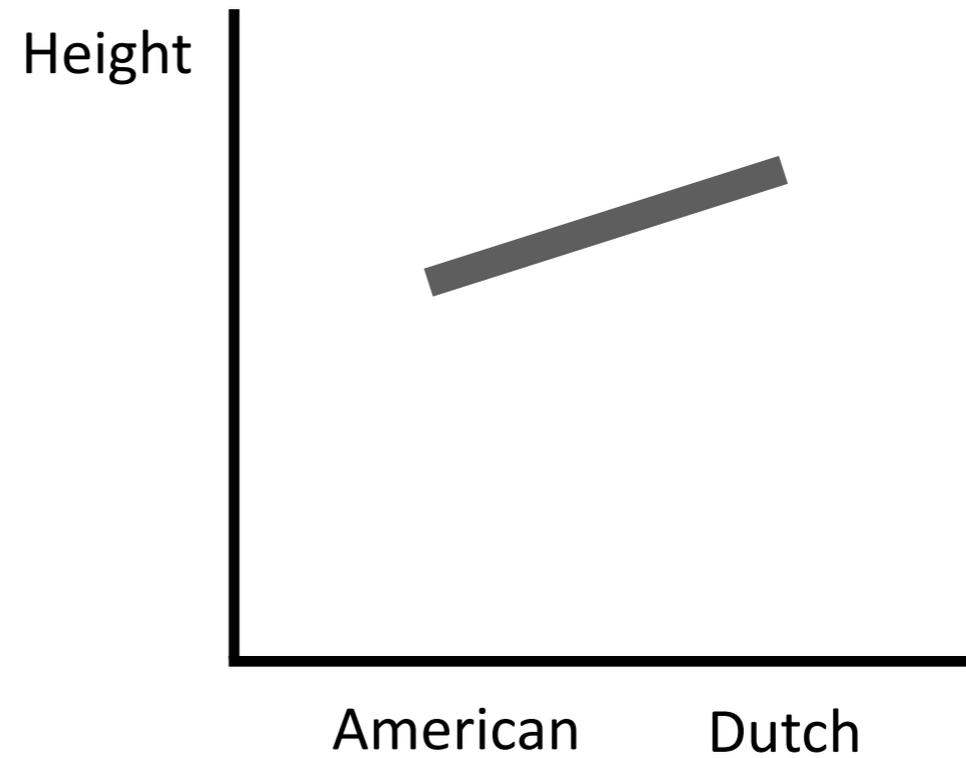








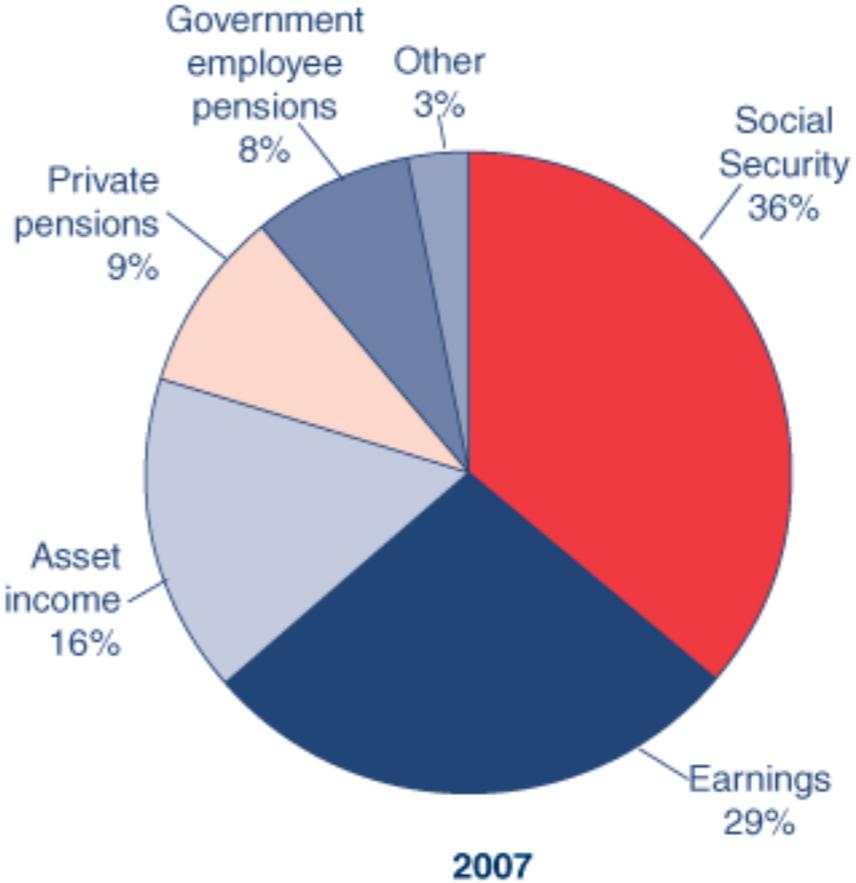
“On average,
Dutch people are
taller than Americans”



“On average, people become
taller as they become more
Dutch”

Zachs & Tversky, 1999

Aggregate income, by source



https://www.ssa.gov/policy/docs/chartbooks/fast_facts/2009/fast_facts09.html



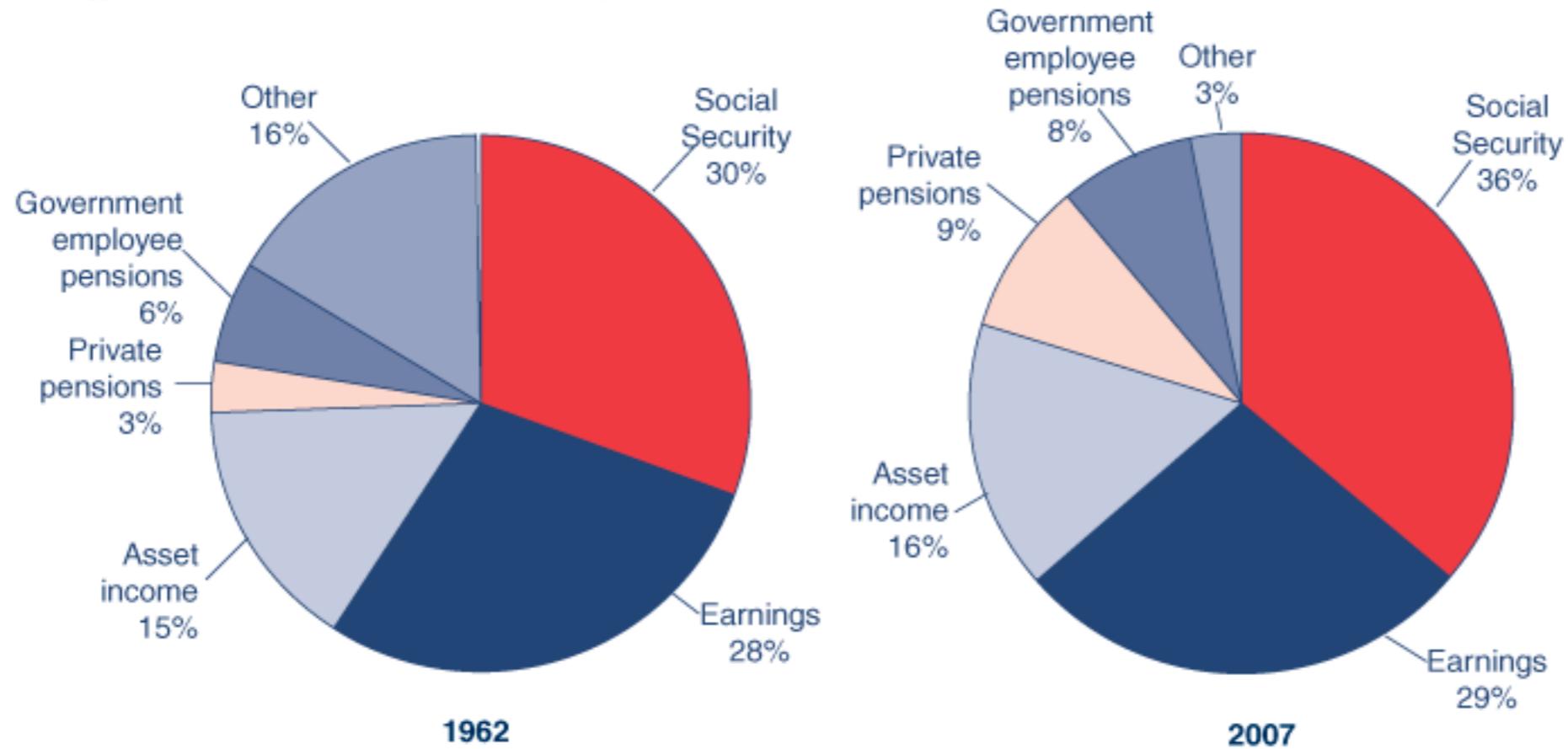
SAS Software
@SASsoftware



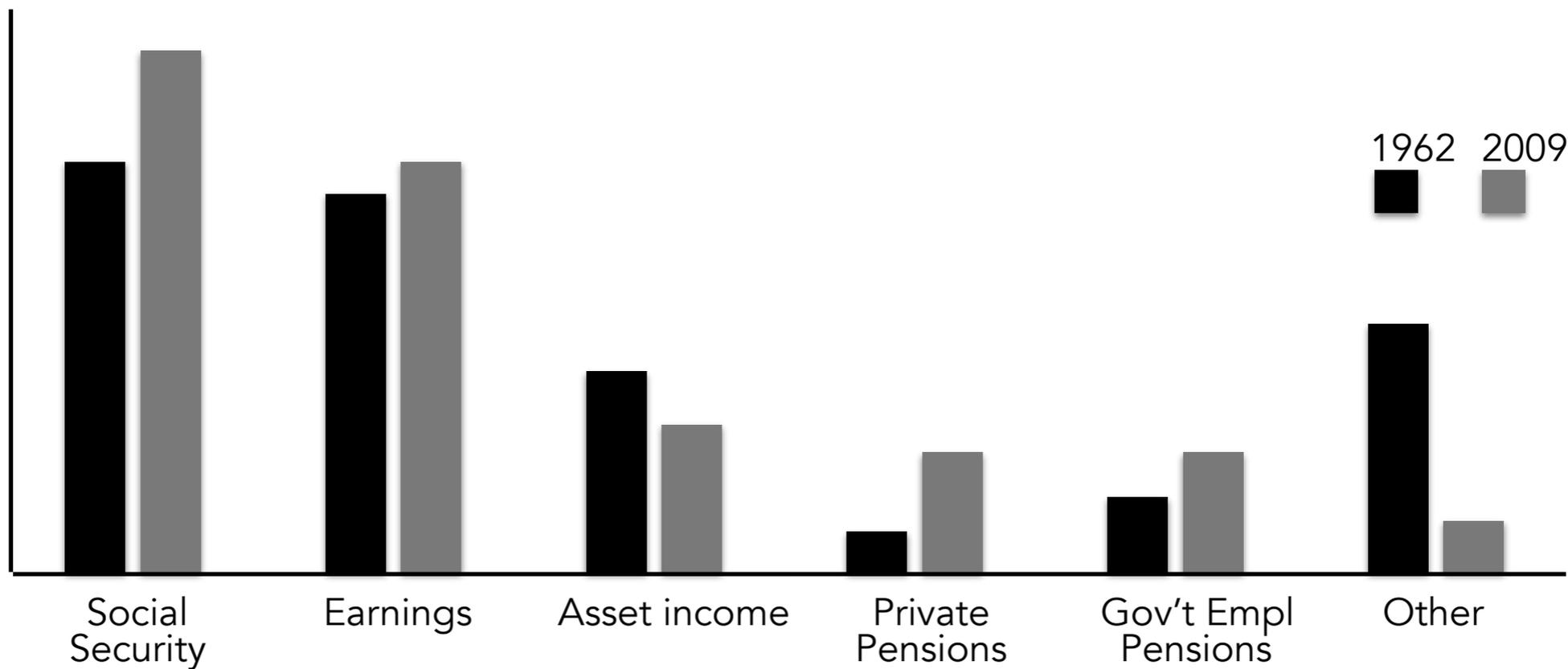
Move past the limits of spreadsheets and canned BI reports. #GartnerBI #dataviz
2.sas.com/6011BeY3c

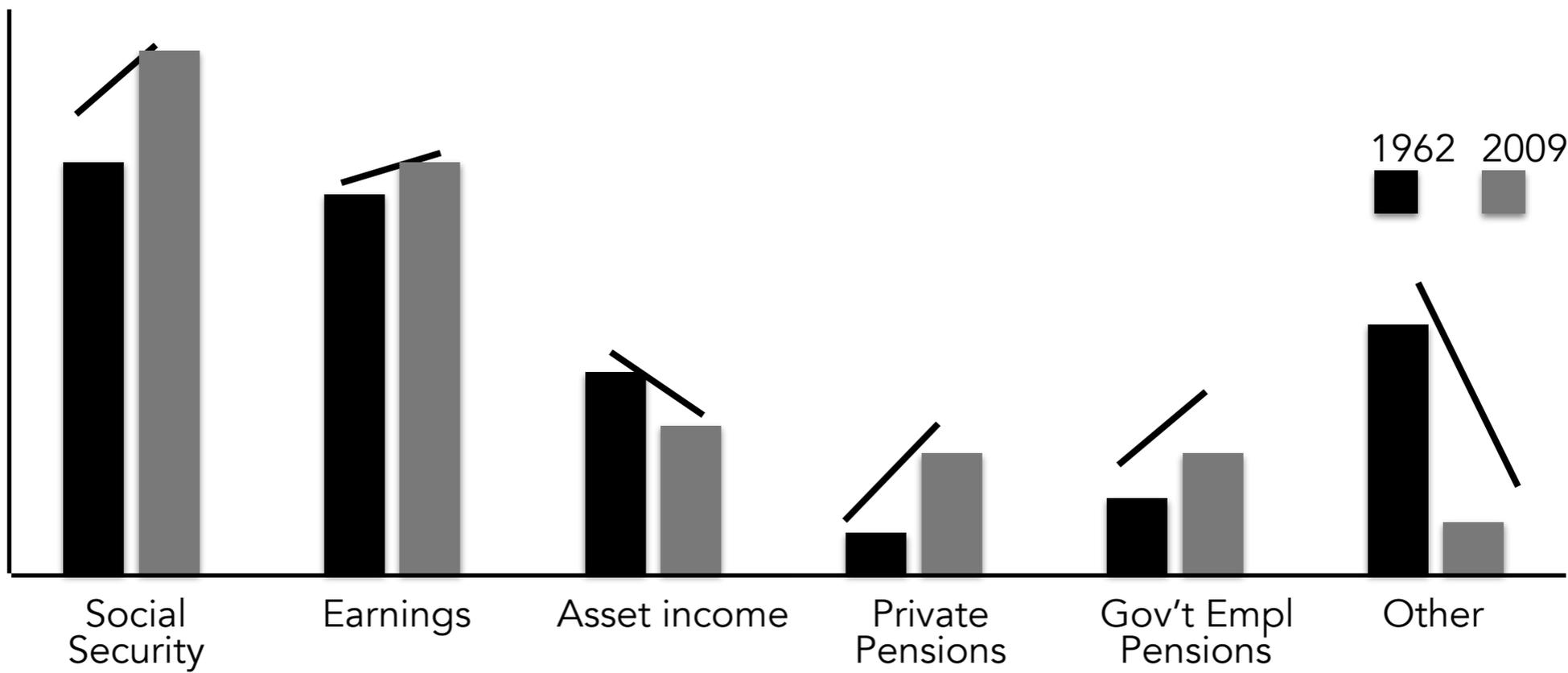


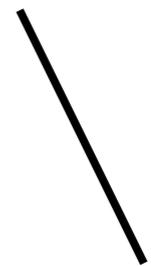
Aggregate income, by source



https://www.ssa.gov/policy/docs/chartbooks/fast_facts/2009/fast_facts09.html



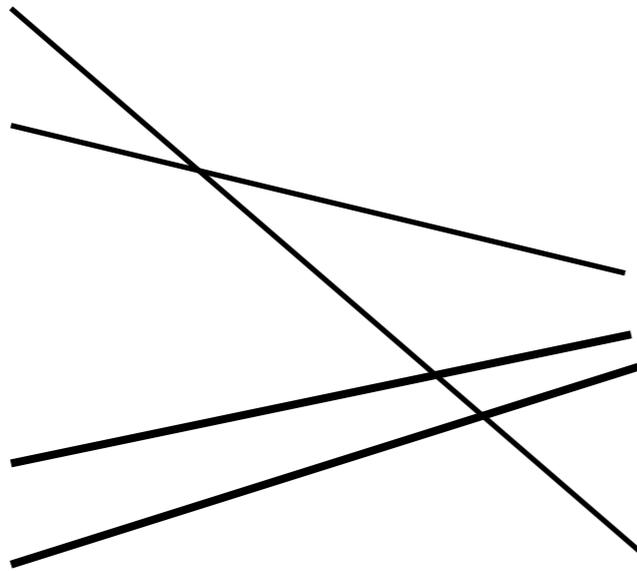
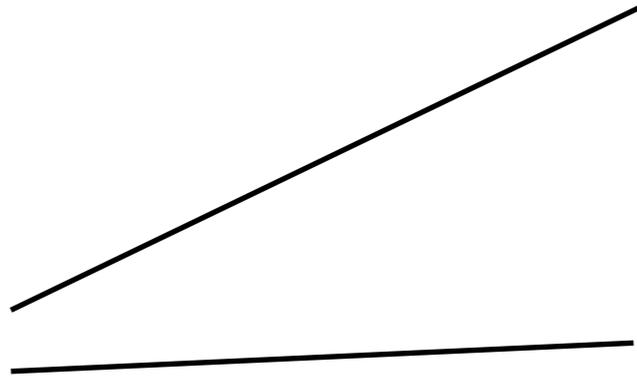




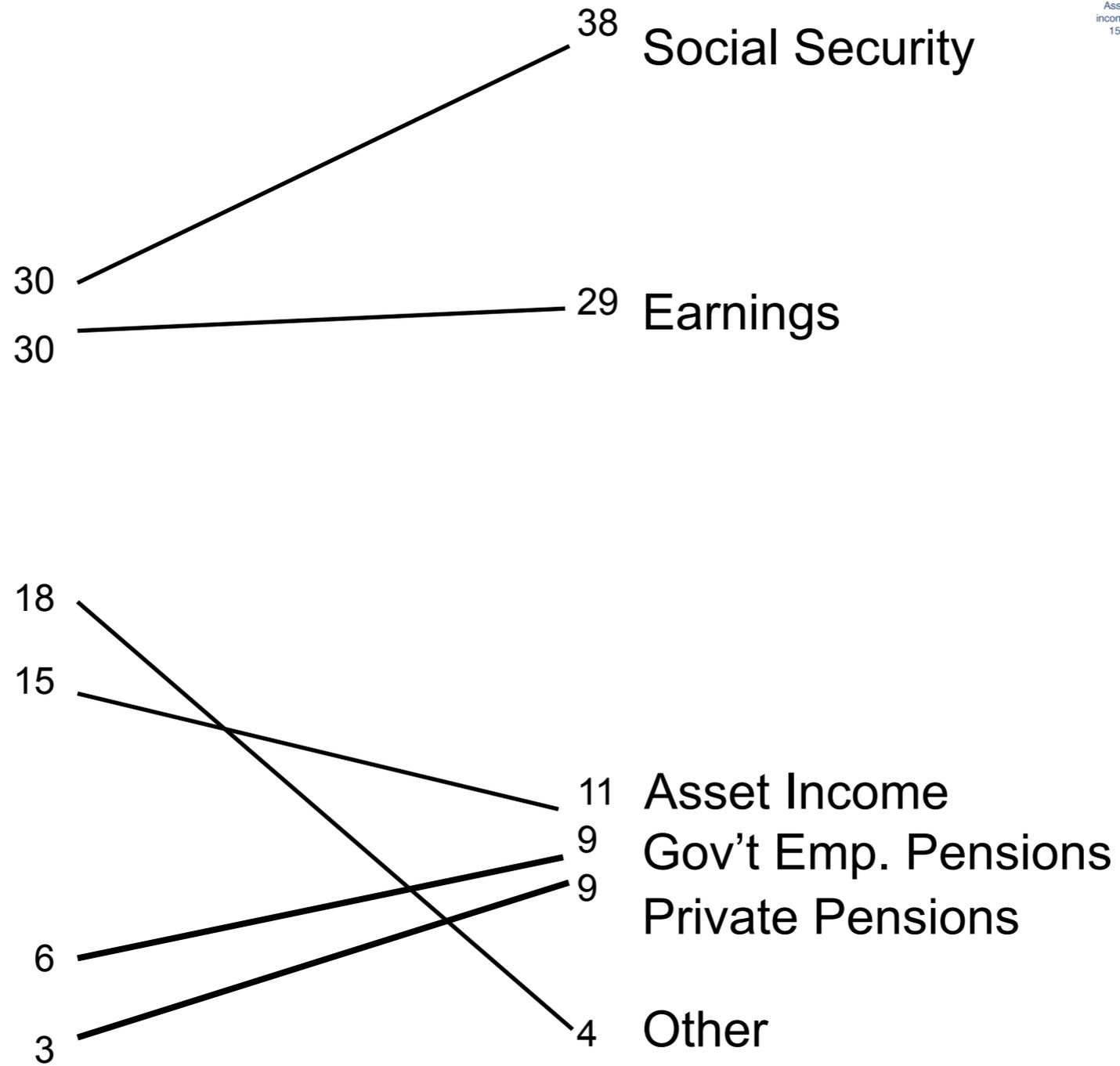
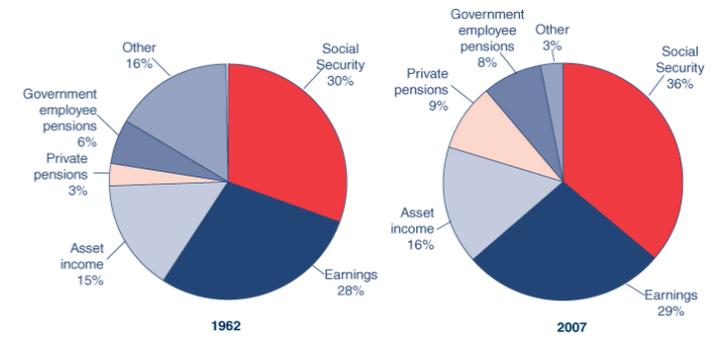
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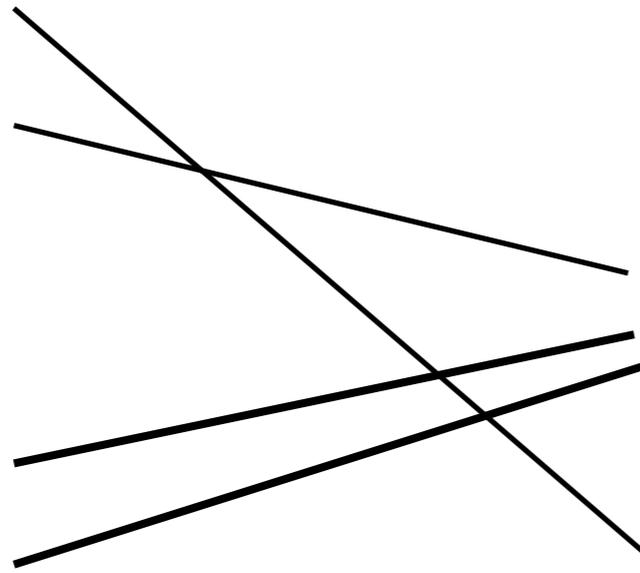
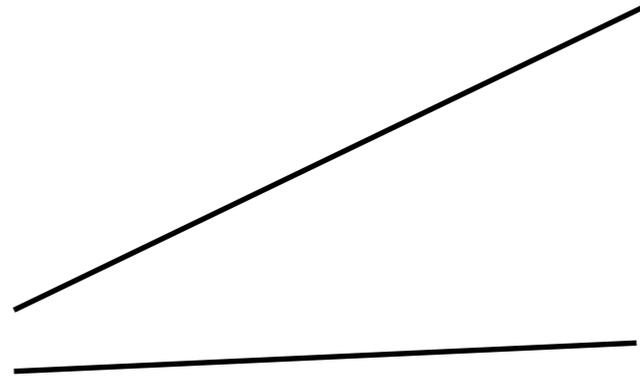
Aggregate income share

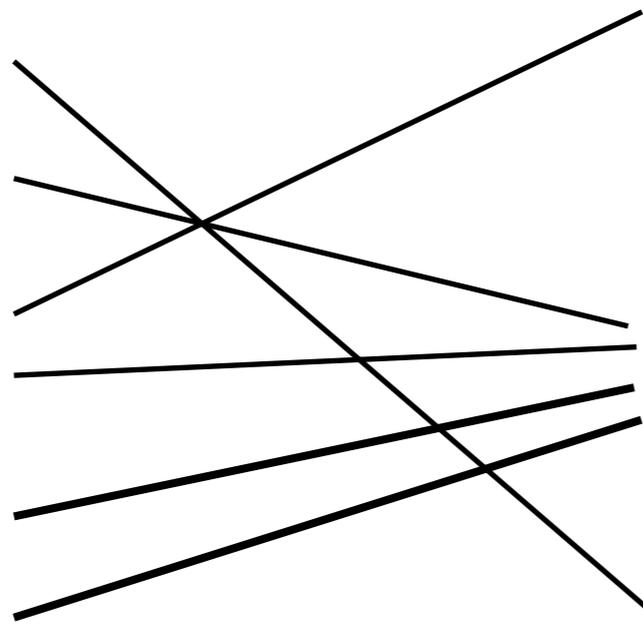


1962

2007

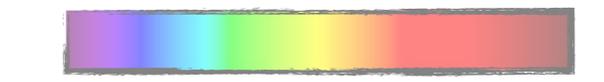
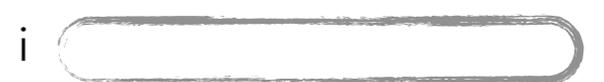
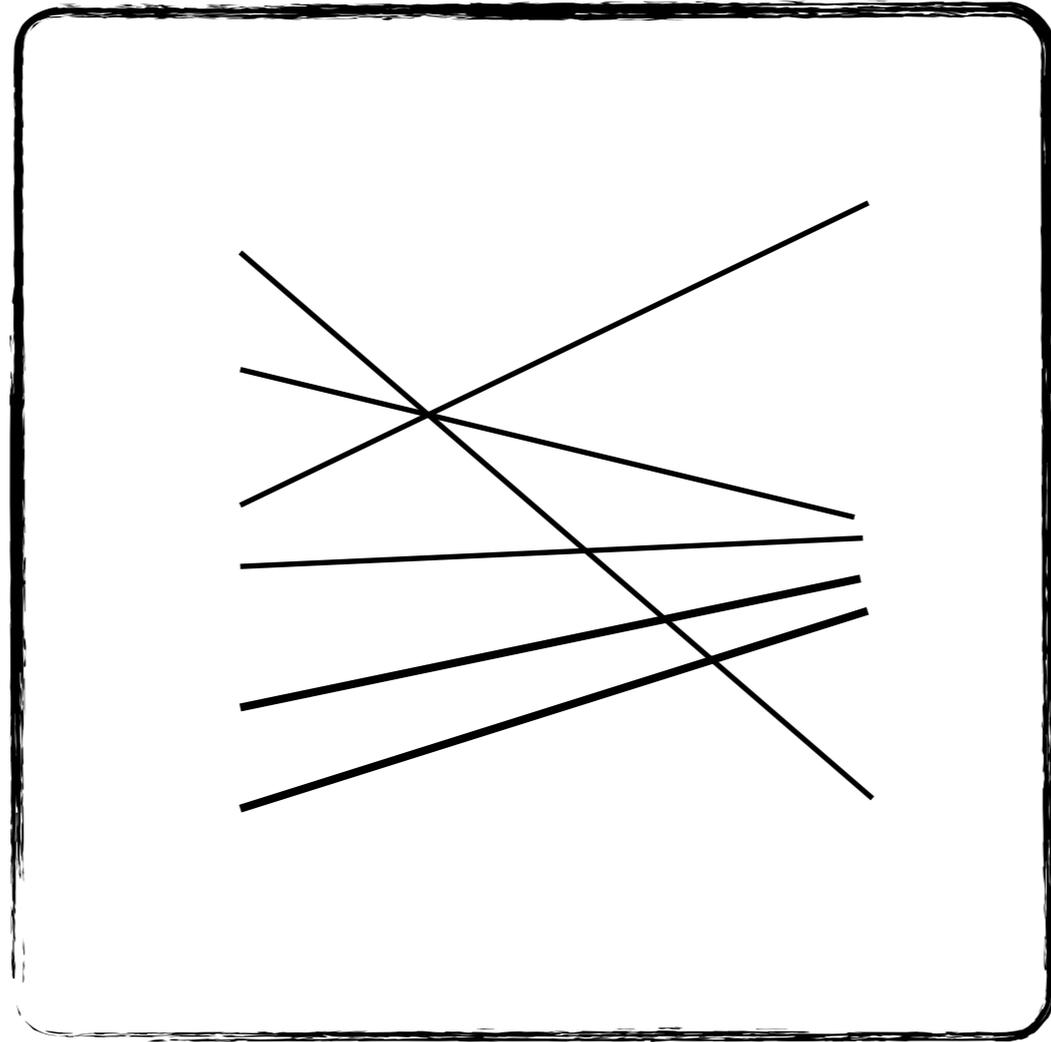
A SlopeGraph





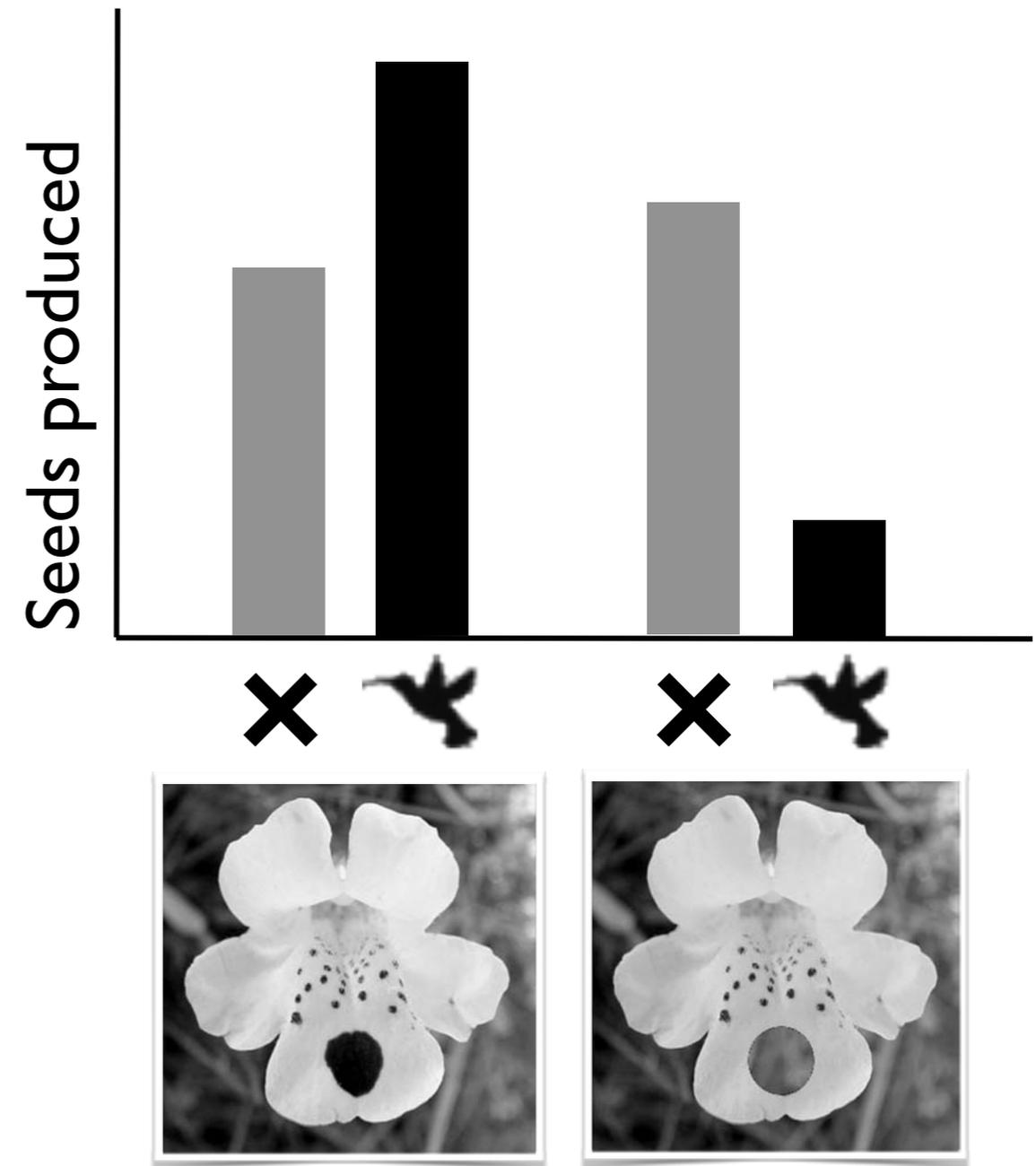


A B C



Nonadditive effects of flower damage and hummingbird pollination on the fecundity of *Mimulus luteus*

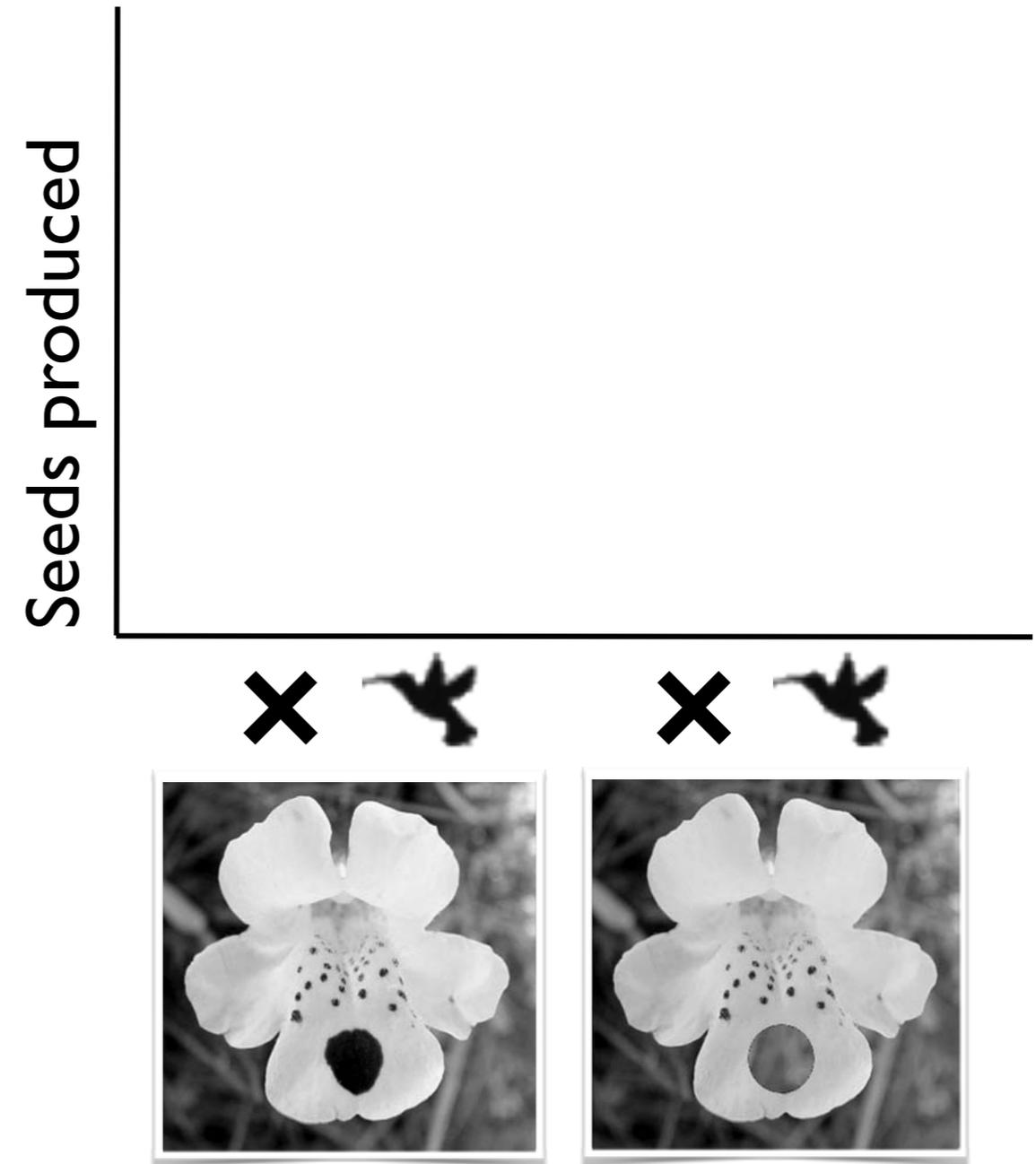
Nélida Pohl · Gastón Carvalho · Carezza Botto-Mahan ·
Rodrigo Medel



Nonadditive effects of flower damage and hummingbird pollination on the fecundity of *Mimulus luteus*

Nélida Pohl · Gastón Carvalho · Carezza Botto-Mahan ·
Rodrigo Medel

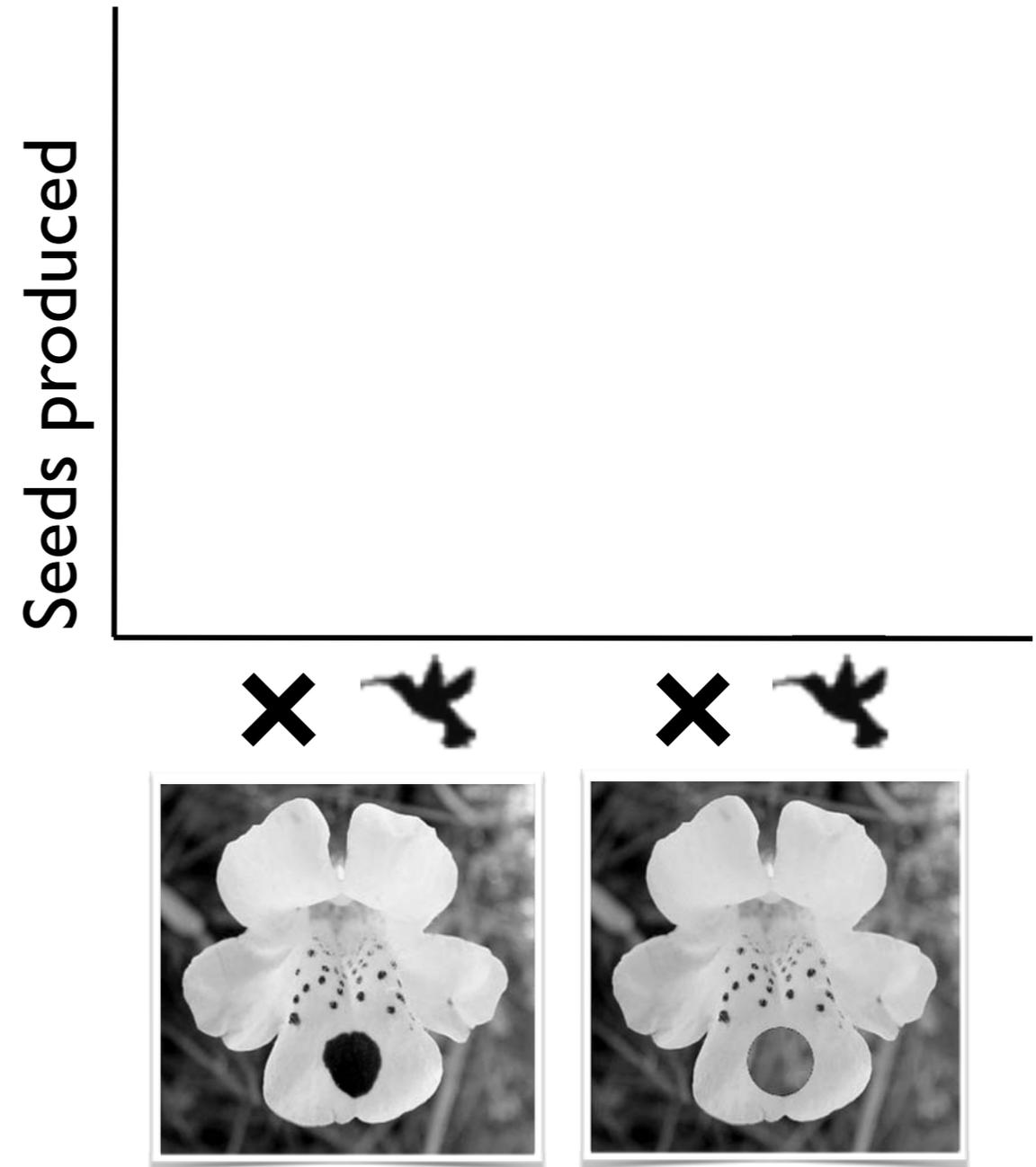
- Main effect of damage



Nonadditive effects of flower damage and hummingbird pollination on the fecundity of *Mimulus luteus*

Nélida Pohl · Gastón Carvalho · Carezza Botto-Mahan ·
Rodrigo Medel

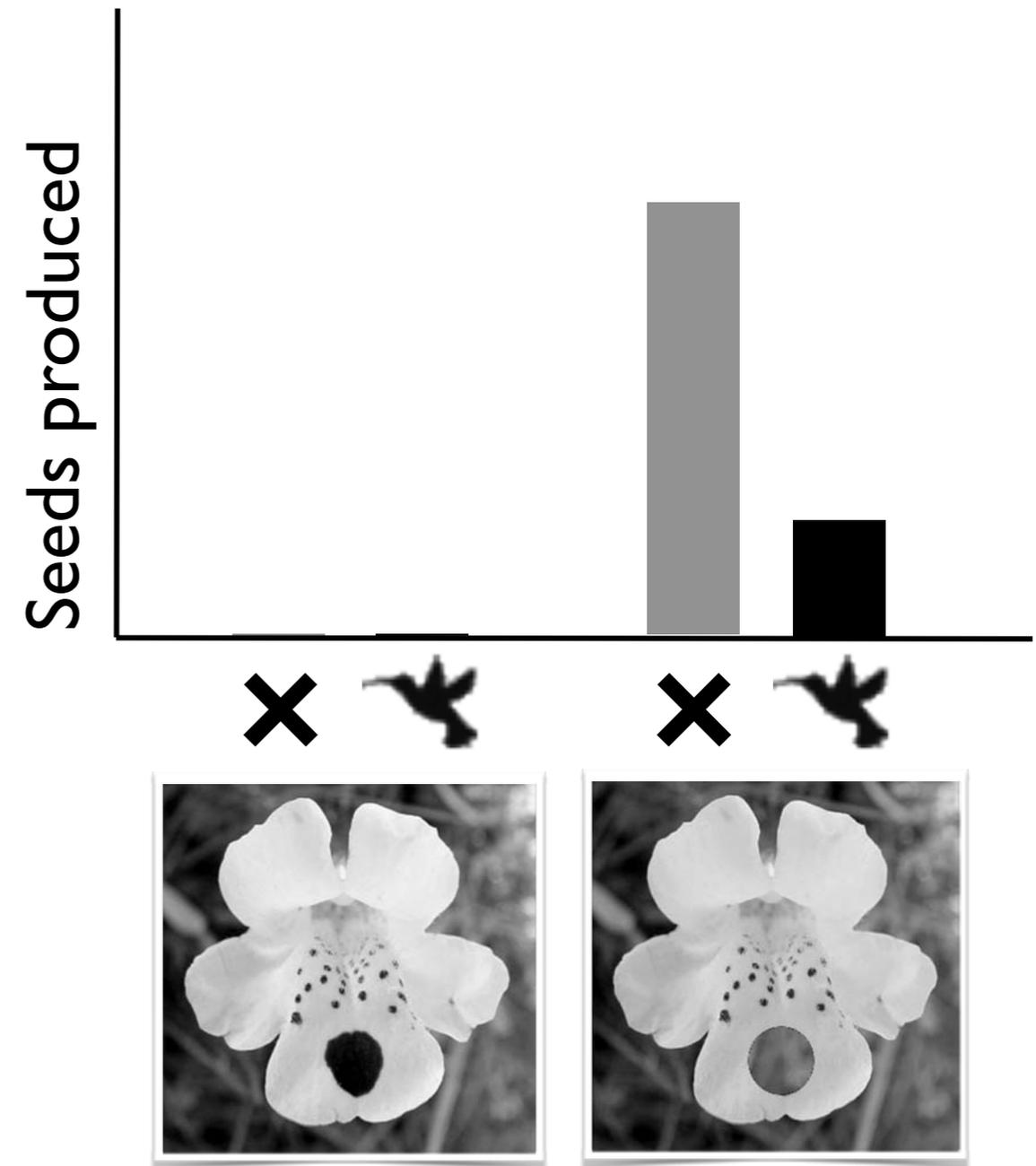
- Main effect of damage
- But not whole story - seed impact not from damage per se.
 - Hummingbirds show a big impact
 - No hummingbirds = no impact



Nonadditive effects of flower damage and hummingbird pollination on the fecundity of *Mimulus luteus*

Nélida Pohl · Gastón Carvalho · Carezza Botto-Mahan · Rodrigo Medel

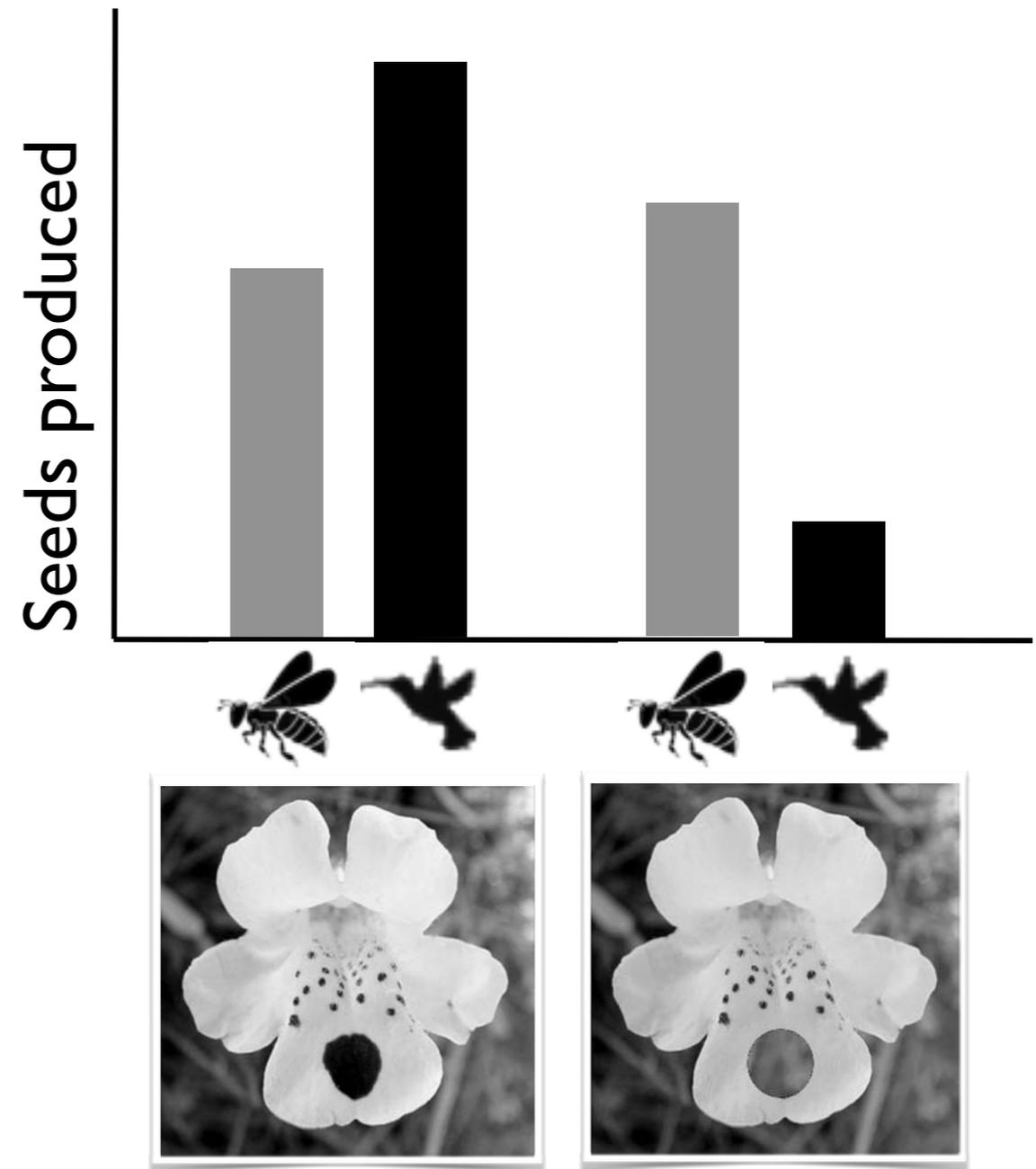
- Main effect of damage
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- But why are *damaged* flowers better off with no hummingbirds around?



Nonadditive effects of flower damage and hummingbird pollination on the fecundity of *Mimulus luteus*

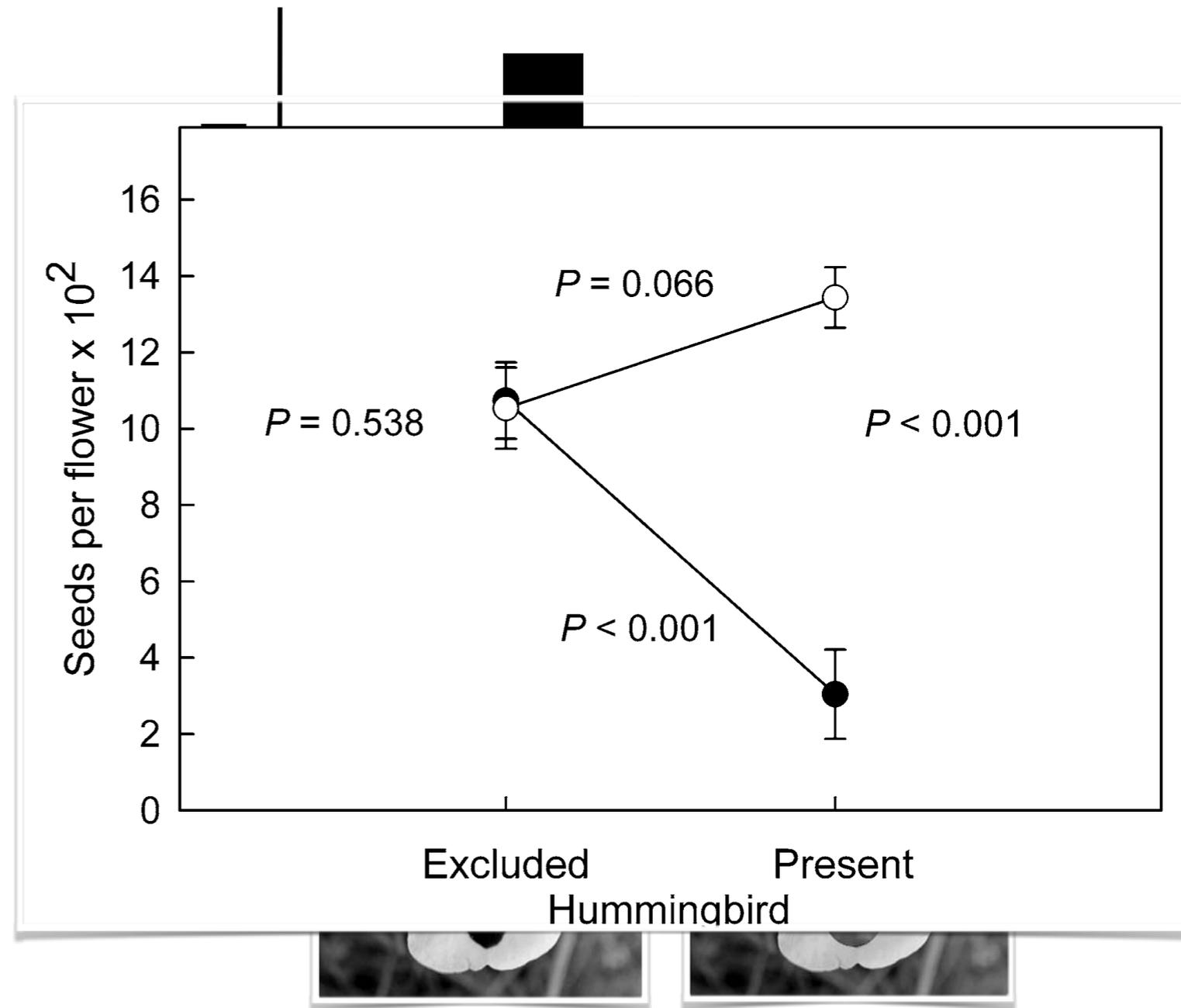
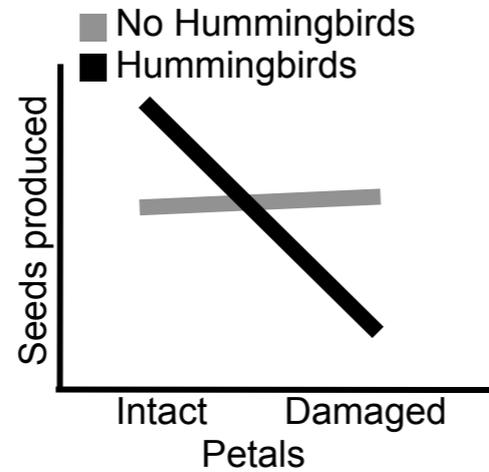
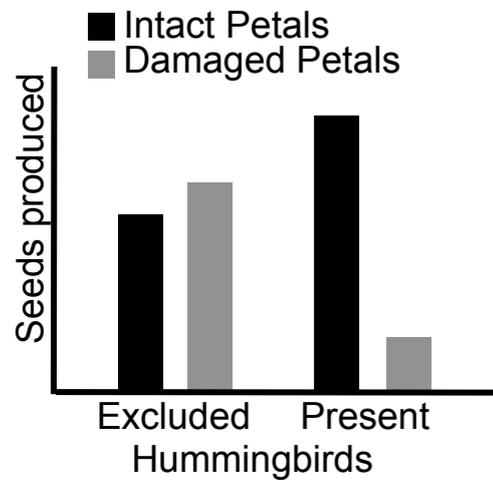
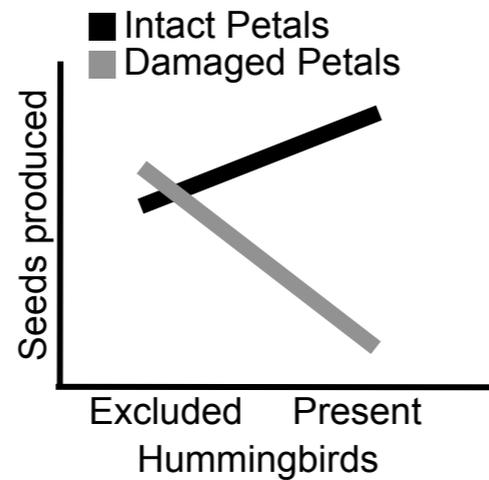
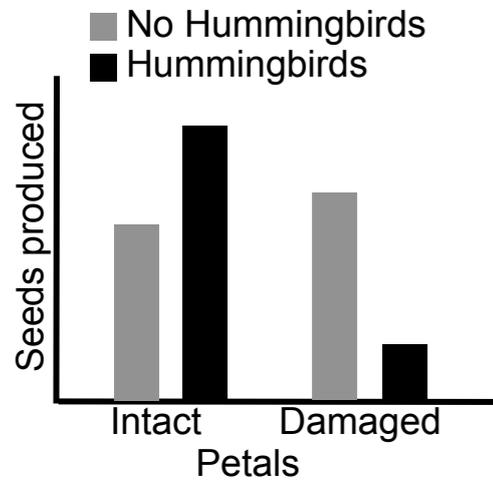
Nélida Pohl · Gastón Carvalho · Carezza Botto-Mahan · Rodrigo Medel

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Nonadditive effects of flower damage and hummingbird pollination on the fecundity of *Mimulus luteus*

Nélida Pohl · Gastón Carvalho · Carezza Botto-Mahan · Rodrigo Medel



Pounds of Newspapers Recycled by
Abraham Lincoln Elementary School Students

