



UNIVERSITY OF SAN FRANCISCO  
CHANGE THE WORLD FROM HERE

# Perception

What We See vs What We Perceive

# MOTIVATION



**How many letter B's  
are on the next slide?**



E L V I O H A N B D I D H T C H P A E  
P B T A Q F A C N J Y G R A S Q D  
M A B Q A U A K P G A B X Z A G  
A I D E V A D U G A C E Y A J G A  
R F S C T A C A F O J G Q  
A Z A P W X A A F A B F Z



**How many letter B's  
are on the next slide?**







# Motivation

- How much can we remember?
- How quickly can we process information?
- How effectively can we process information?
- What do we automatically infer?



# MEMORY



# Memory

- **Long-Term Memory**

- Lasts for years or a life-time
- Quick to retrieve, difficult to store

- **Short-Term Memory**

- Lasts between a few seconds and a minute\*
- Limited storage capacity (5 to 7 elements)
- Conscious, focused, attentive processing

\* Rehearsed, short-term memory can last for hours.



# Memory

- **Sensory Memory**

- Impressions of sensor signals  
(*e.g. vision, hearing, smell, taste, and touch*)
- Lasts between 250 and 500 milliseconds

- **Iconic Memory**

- Visual sensory memory
- Pre-attentive processing  
(*e.g. precedes focused attention*)



# Pre-Attentive Processing

- Independent of conscious control
  - *You will notice whether you want to or not*
- Information processed without need for focus
  - *Viewed from corner of your eye*
- Similar to a filter being applied to iconic memory
  - *Only draw attention to what is important*





# PRE-ATTENTIVE ATTRIBUTES

# Pre-Attentive Attributes

- **Color**
  - Hue, intensity, etc.
- **Position**
  - Location, depth
- **Form**
  - Length, shape, etc.
- **Movement**
  - Blink, jitter, etc.

<http://www.csc.ncsu.edu/faculty/healey/PP/>



# Pre-Attentive Attributes

- Carefully map data to pre-attentive attributes
  - *Use strongest attribute wisely*
- Do not DISTRACT from data
  - *Do not abuse these attributes!*
- Keep in mind short-term memory
  - *Too many mappings will become confusing*





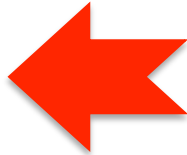


# Color

- Unique colors should represent unique data
- Similar colors should represent similar data
- Never use more colors than can be stored in short-term memory (5 to 7)
- Be mindful of color blindness



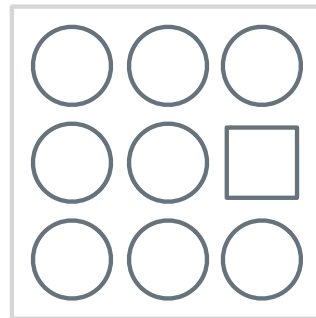
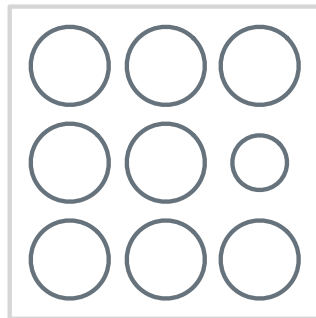
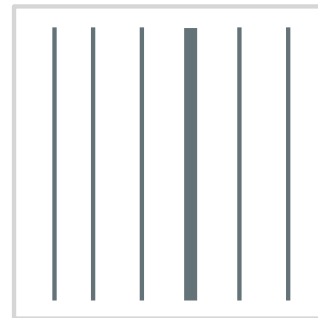
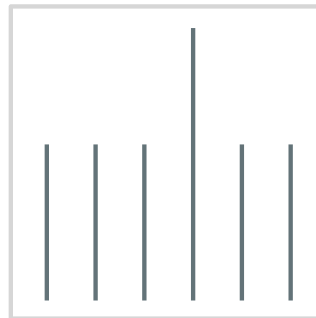
# Color Resources

- "A Field Guide to Digital Color" by Maureen C. Stone, 2003.
- Choosing Colors for Data Visualization  
<http://www.b-eye-network.com/newsletters/ben/2235>
- Color Advice for Cartography   
<http://colorbrewer2.org/>
- Colorblind Vision Simulator  
<http://www.vischeck.com/>

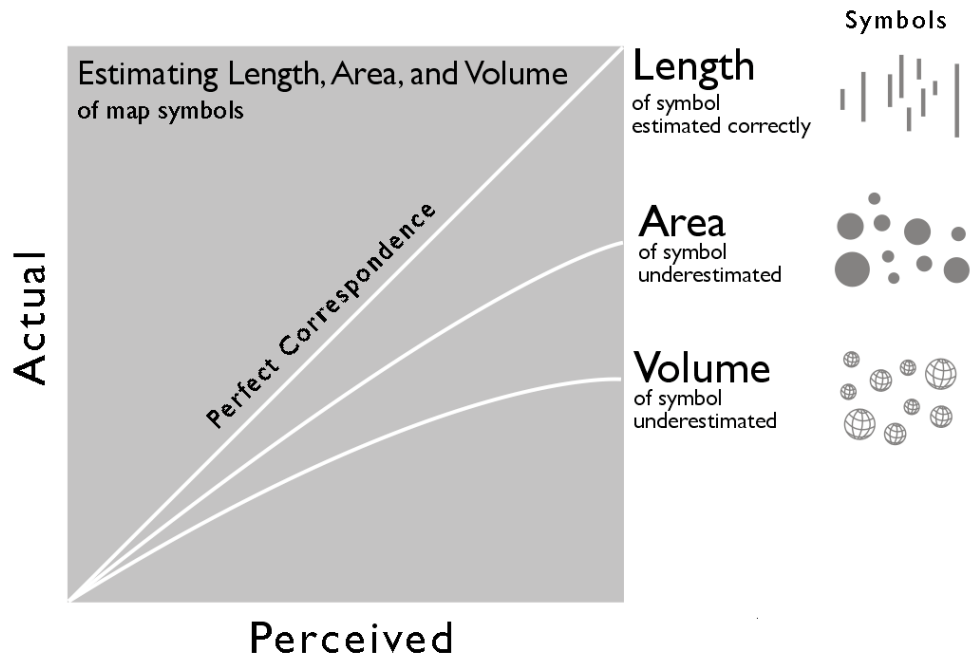


# Form

- Orientation
- Length
- Width
- Size
- Shape
- Curvature

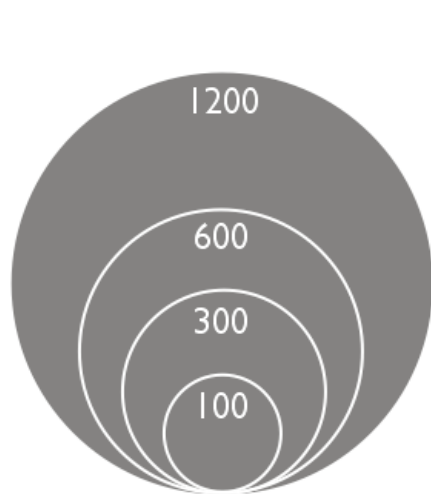


# Form: Shape and Size

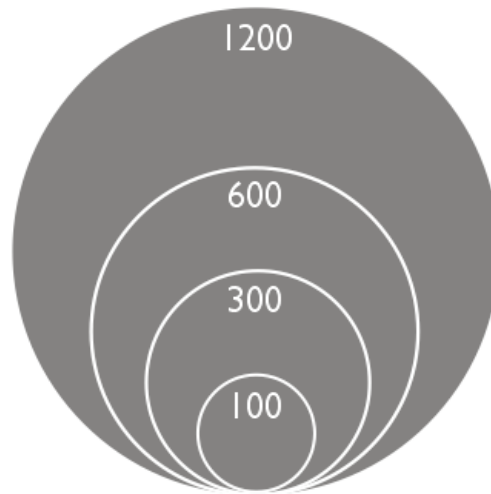


<http://makingmaps.net/2007/08/28/perceptual-scaling-of-map-symbols/>

# Form: Shape and Size



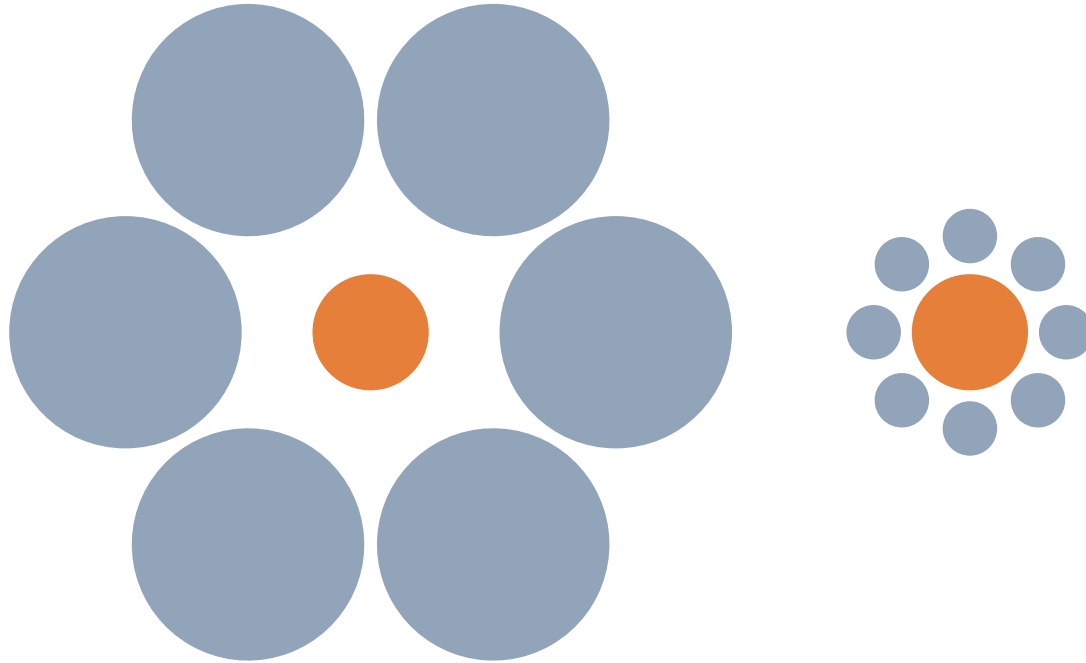
**Absolute Scaling**



**Apparent Scaling**  
(Flannery's Compensation)

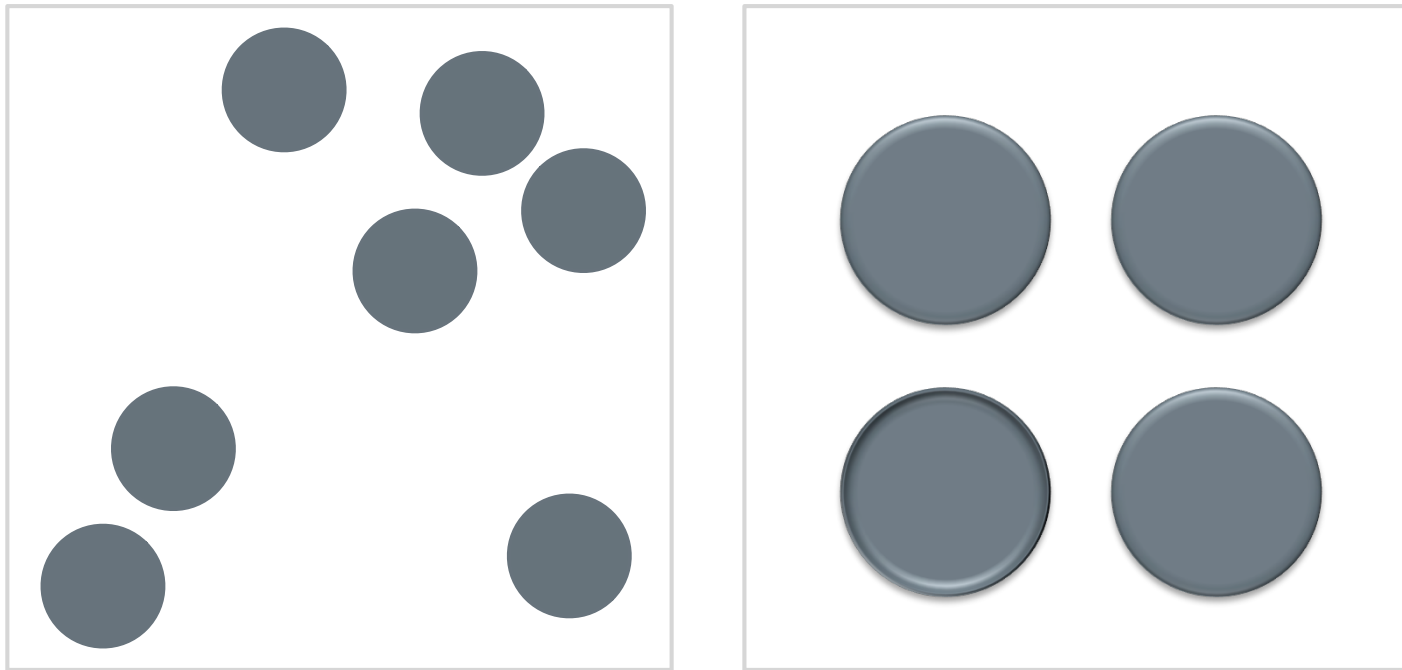
<http://makingmaps.net/2007/08/28/perceptual-scaling-of-map-symbols/>

# Form: Shape and Size



[http://en.wikipedia.org/wiki/Ebbinghaus\\_illusion](http://en.wikipedia.org/wiki/Ebbinghaus_illusion)

# Position: 2D Position and Depth





# Movement

- Two Attributes
  - Flicker (disappear and reappear)
  - Motion (moving in position)
- One of most effective ways of getting attention
- Most often abused in marketing



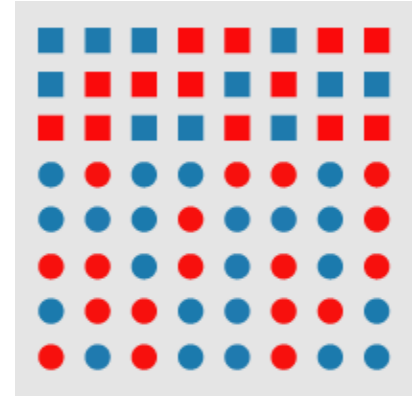
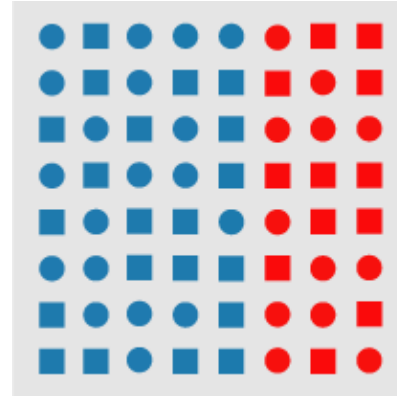
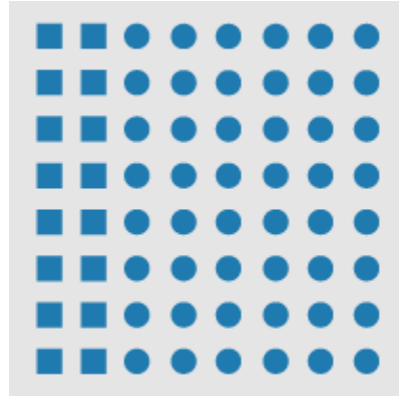
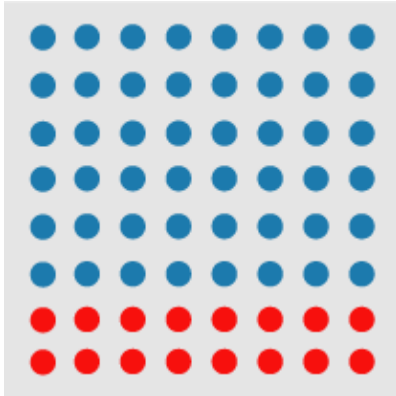
E L V I O H A N B D I D H T C H P A E  
P B T M A B Q A C N J Y G R A O Q D  
A I D E V A D U A U A K P A B X A G  
R F S C T A C A Y A O J G Q A  
A Z A P W X A A F A B F Z



E L V I O H A N B D I D H T C H P A E  
P B T A Q F A C N J Y G R A S Q D  
M A B Q A U A K P G A B X Z A G  
A I D E V D U G A C E Y A O J G A  
R F S C T A C A F A B F Z  
A Z A P W X A A A B F Z



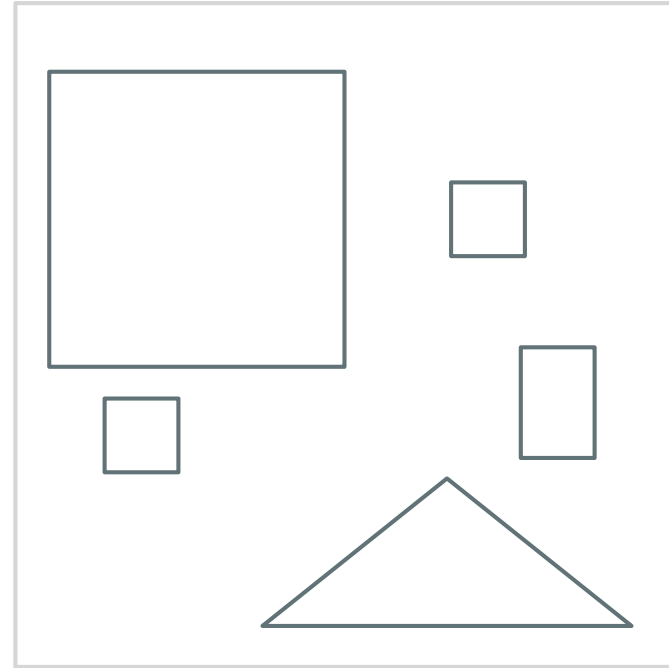
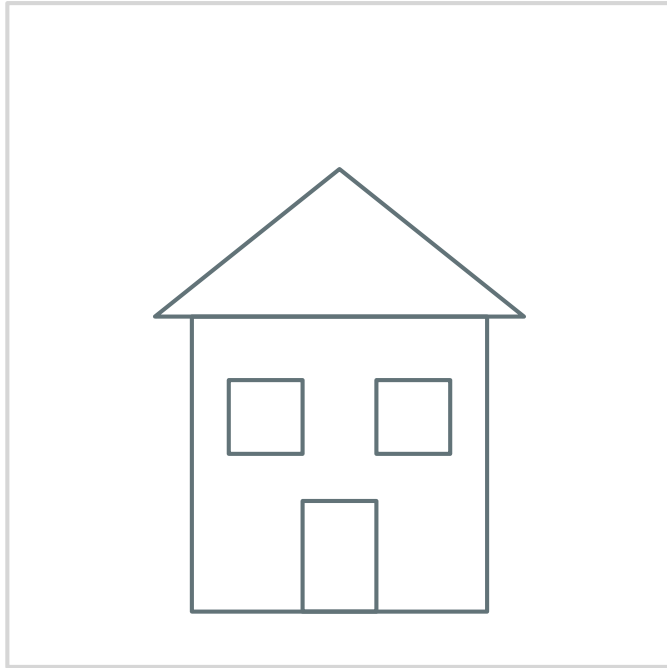
# Boundaries



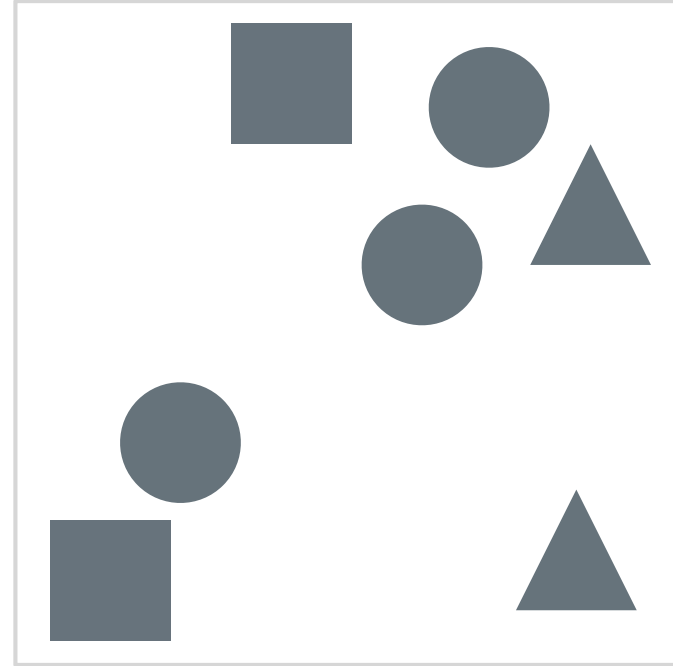
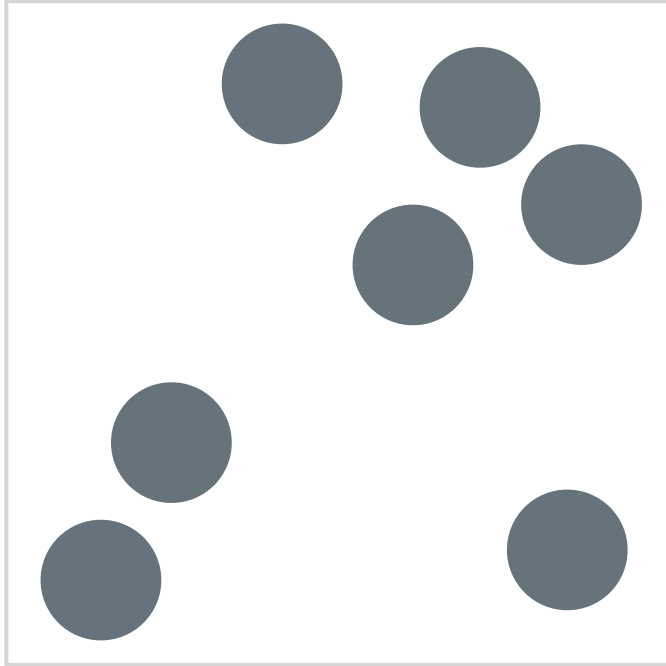
<http://www.csc.ncsu.edu/faculty/healey/PP/>

# GESTALT PRINCIPLES

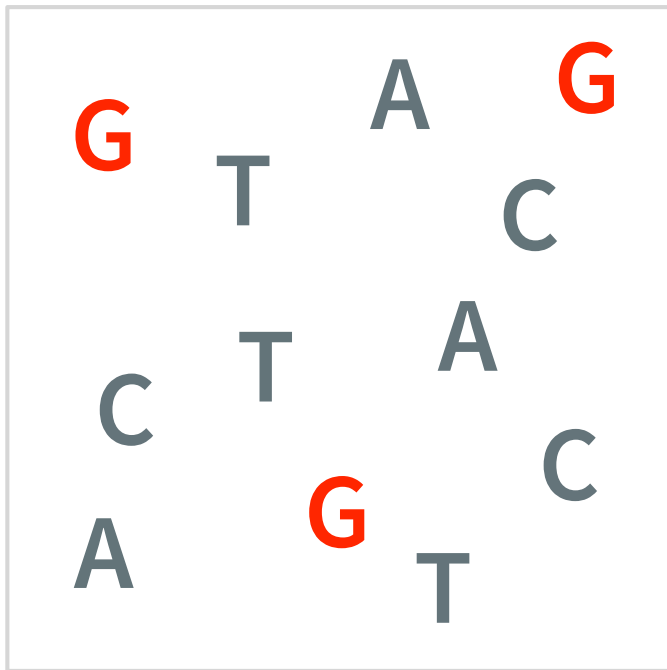
# Gestalt Principles



# Proximity



# Similarity





# Closure



# Figure and Ground



# SHORT-TERM MEMORY



# Short-Term Memory

- Attention/focus transfers information from sensory memory to short-term memory
- Lasts from a few seconds to a minute
- Limited storage capacity
  - Minimum: 5 elements
  - Average: 7 elements
  - Maximum: 9 elements



# Practical Indications

- Can reliably use 5 distinct attributes
- Should use no more than 7 to be accessible
  - *No more than 7 distinct colors or shapes*
- Attributes are cumulative
  - *3 shapes, 4 colors = 7 attributes*
- Once lose focus, forget information
  - *Distraction is costly*



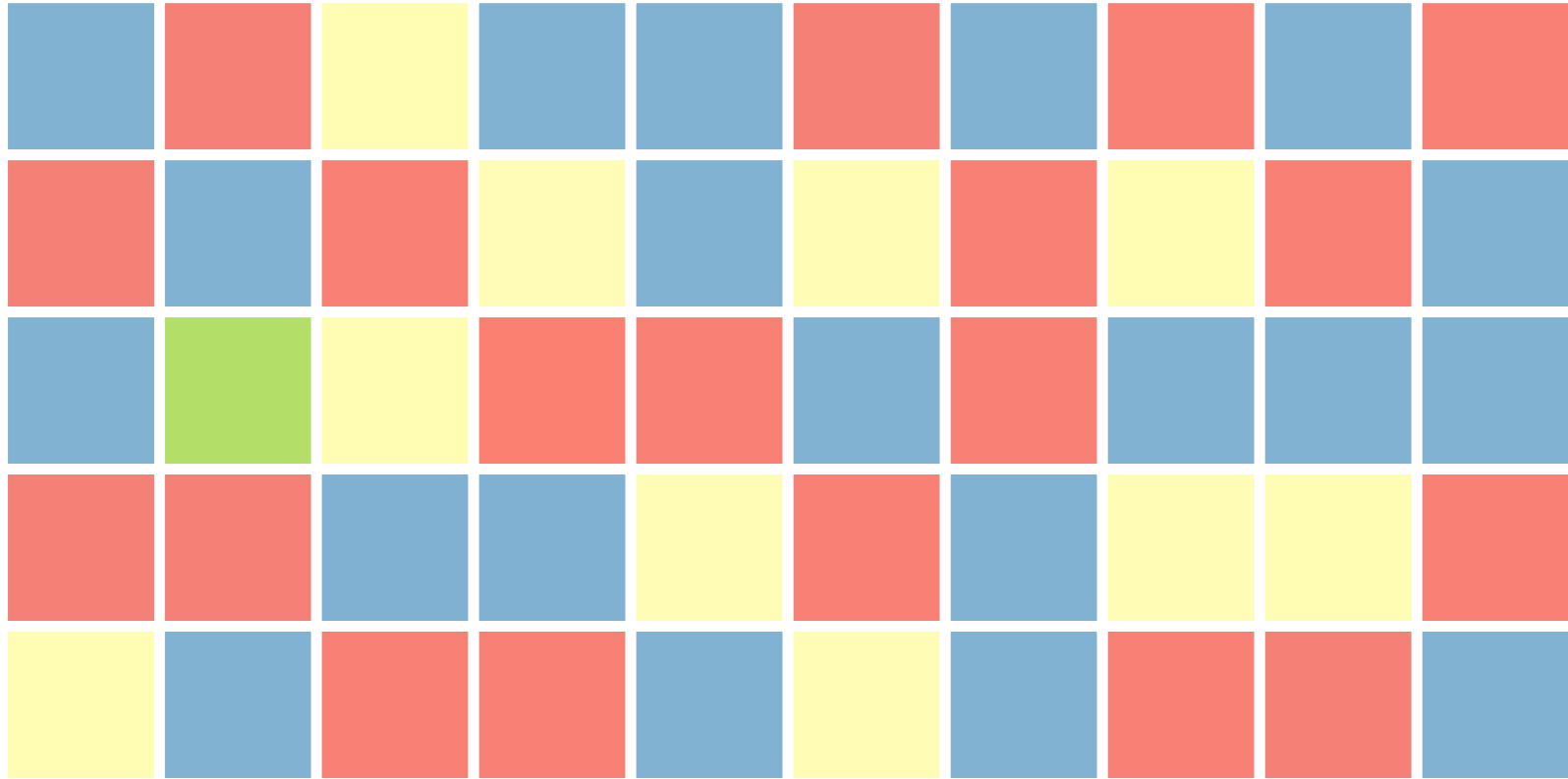
# Grouping

- Grouping/chunking can increase capacity
  - 4154224174 versus (415) 422-4174
- Group sizes must be kept small
- Grouping can also improve speed of processing



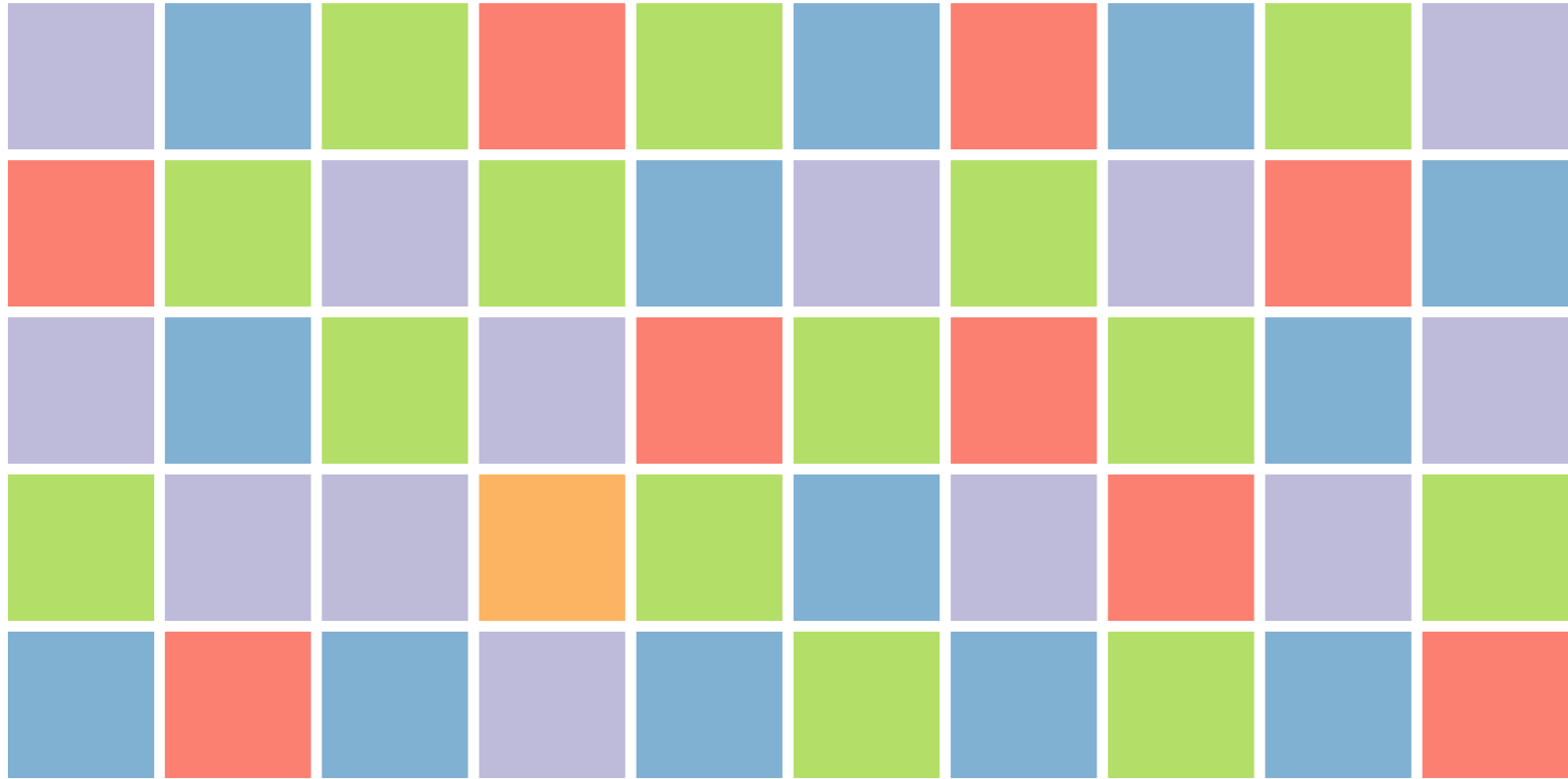
# Find the unique color.



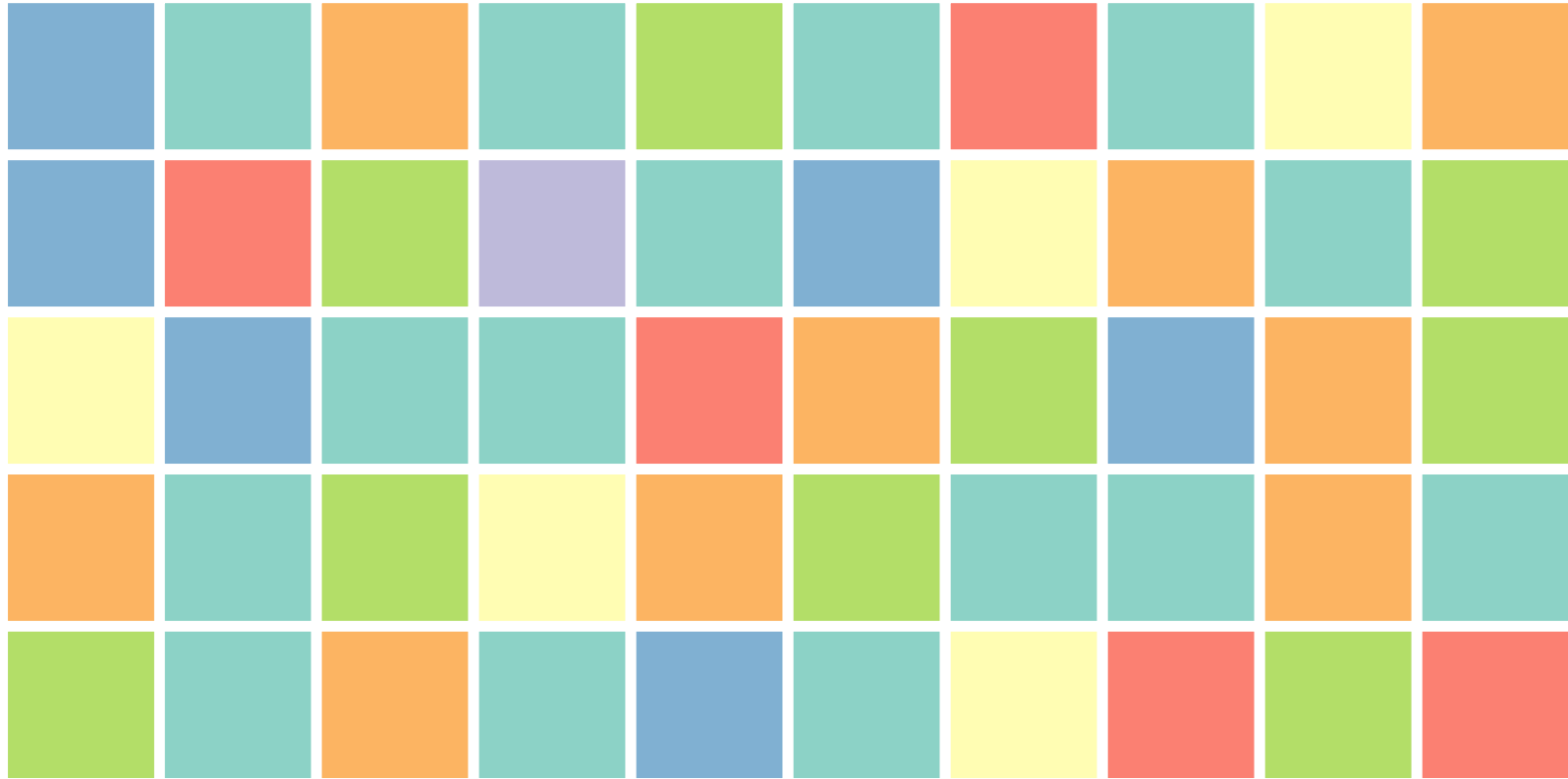


<http://steveharoz.com/research/attention/>

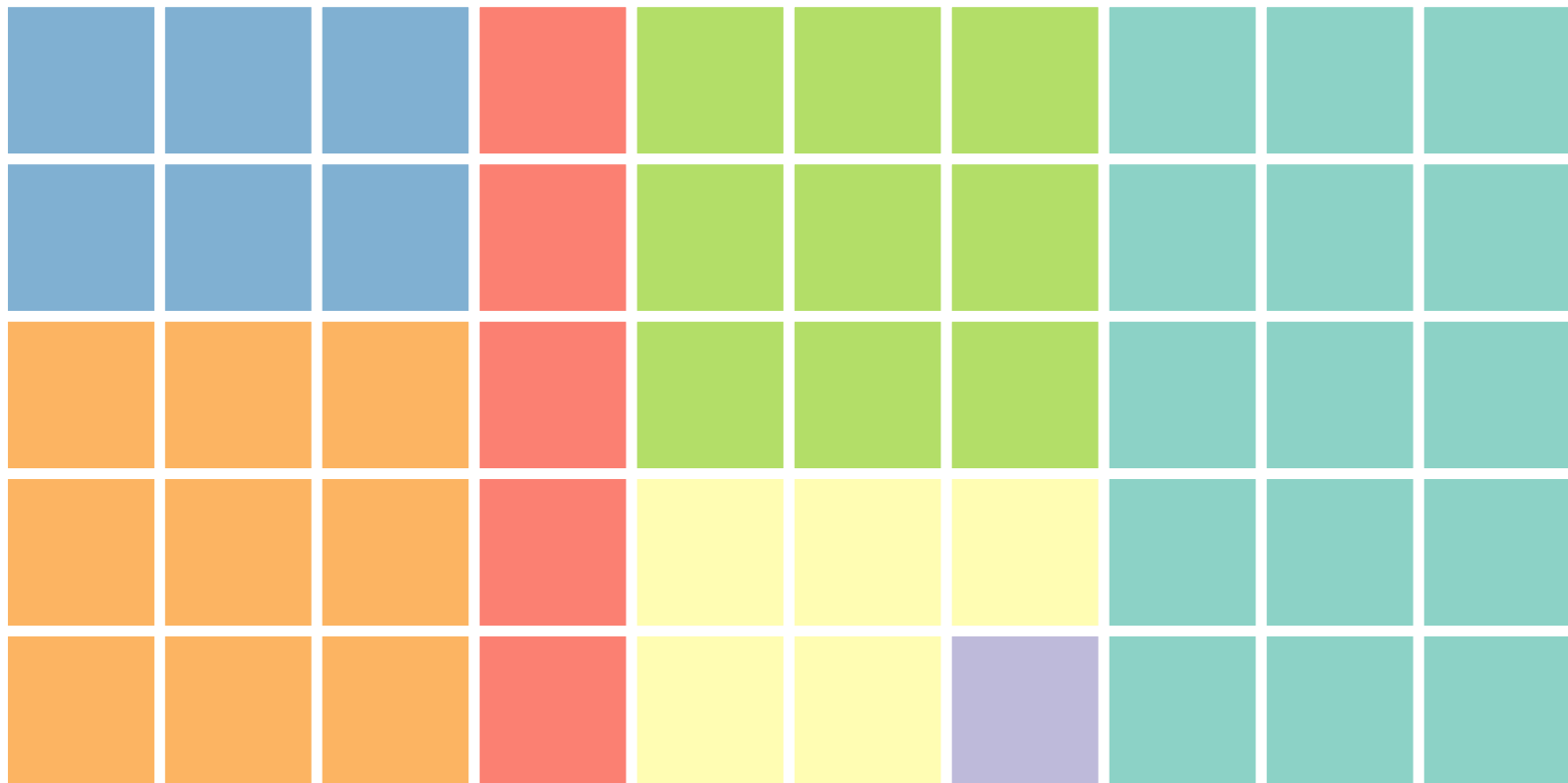




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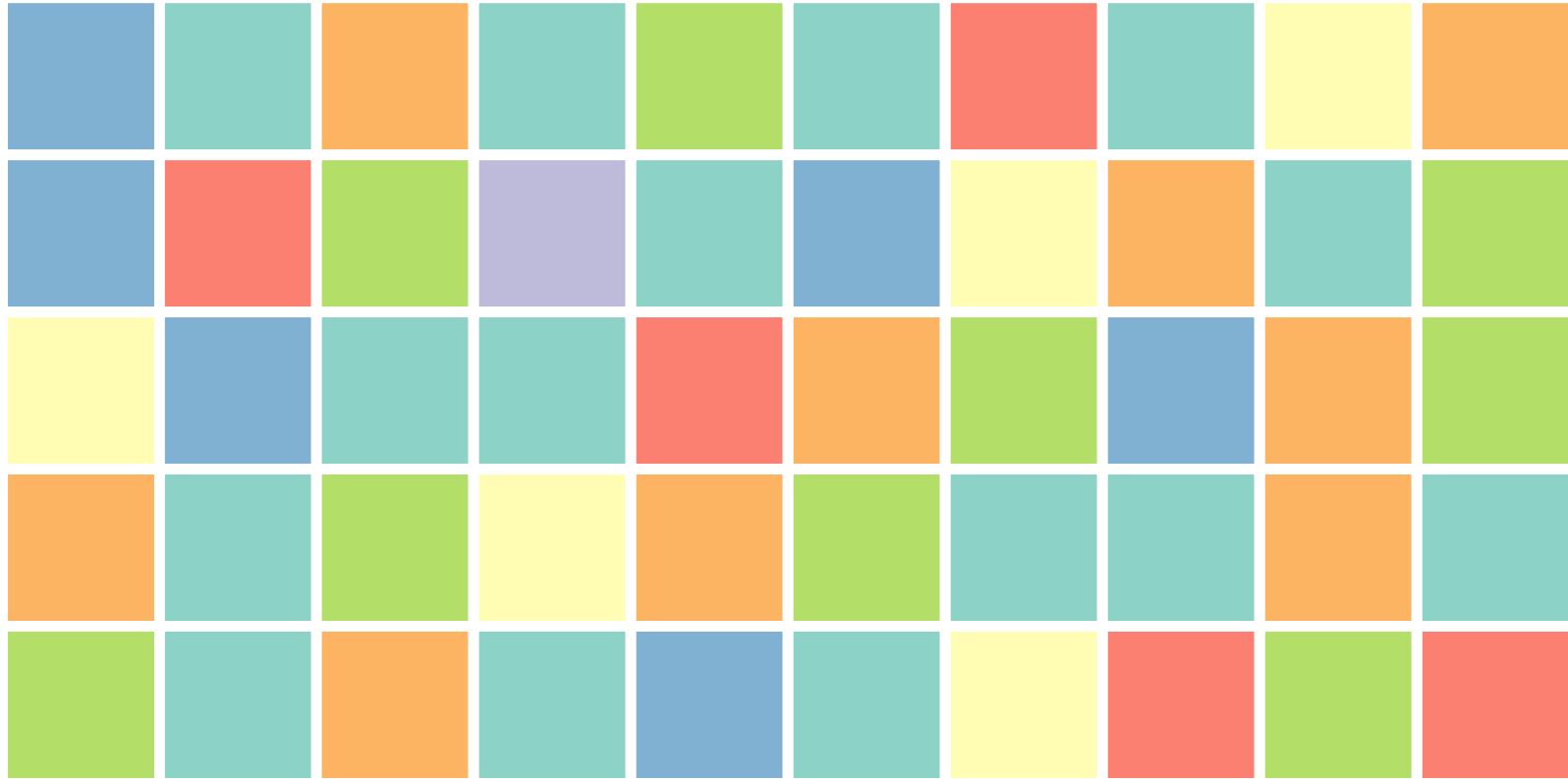
- Improves ability to detect outliers
- Especially important as short-term capacity is strained (*approaching 7 colors*)
- Works for other pre-attentive attributes (*e.g. motion video*)
- Does not seem to help with search tasks

<http://steveharoz.com/research/attention/>



# Find all of the red squares.





<http://steveharoz.com/research/attention/>



<http://steveharoz.com/research/attention/>



# Change Blindness

- To notice change, must pay attention to or focus on area of change
- Can break focus with flicker, making it difficult to detect change
- For visualization, must be careful to direct the eye where it is important

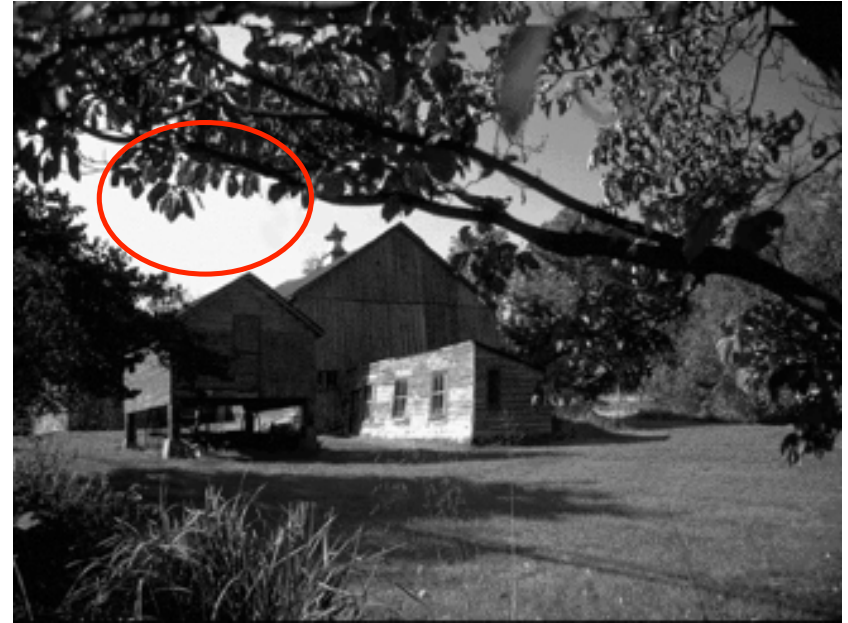






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# Change Blindness



<http://www.csc.ncsu.edu/faculty/healey/PP/>



<http://www.cogsci.uci.edu/~ddhoff/cbvenice.html>



# Change Blindness



<http://www.cogsci.uci.edu/~ddhoff/cbvenice.html>



# REFERENCES



# References

## **Attention and Visual Memory in Visualization and Computer Graphics**

Christopher Healey and James. T. Enns, in *IEEE Transactions on Visualization and Computer Graphics (IEEE TVCG)*, Volume 18, Issue 7, Pages 1170 – 1188, July 2012.

DOI: [10.1109/TVCG.2011.127](https://doi.org/10.1109/TVCG.2011.127) URL: <http://steveharoz.com/research/attention/>

## **How Capacity Limits of Attention Influence Information Visualization Effectiveness**

Steve Haroz and David Whitney, in *IEEE Transactions on Visualization and Computer Graphics (IEEE TVCG)*, Volume 18, Issue 12, Pages 2402 – 2410, December 2012.

DOI: [10.1109/TVCG.2012.233](https://doi.org/10.1109/TVCG.2012.233) URL: <http://www.csc.ncsu.edu/faculty/healey/PP/>



# QUESTIONS?

<http://sjengle.cs.usfca.edu/>

