Animation

Maneesh Agrawala

CS 448B: Visualization
Fall 2020

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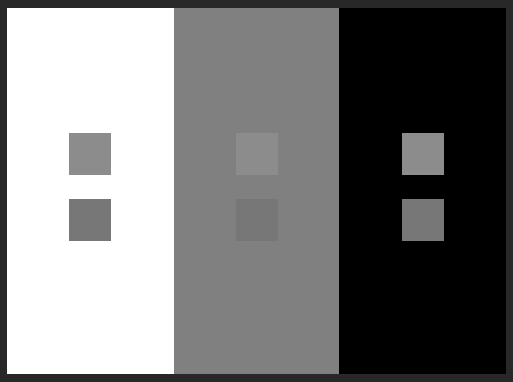
Last Time: Color

2

Crispening

Perceived difference depends on background



From Fairchild, *Color Appearance Models*

3

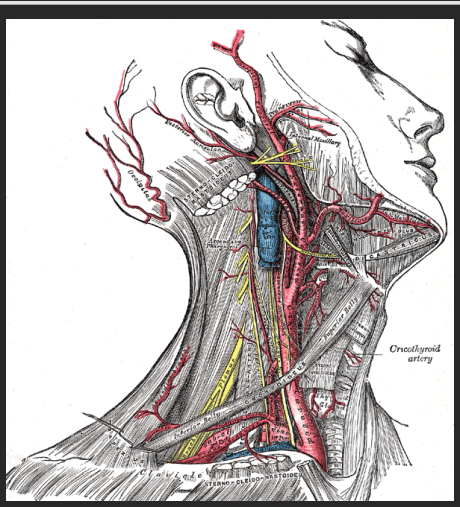
Colors according to XKCD...

4

Using Color in Visualization

5

Gray's Anatomy



Superficial dissection of the right side of the neck, showing the carotid and subclavian arteries

http://www.bartleby.com/107/illus520.html

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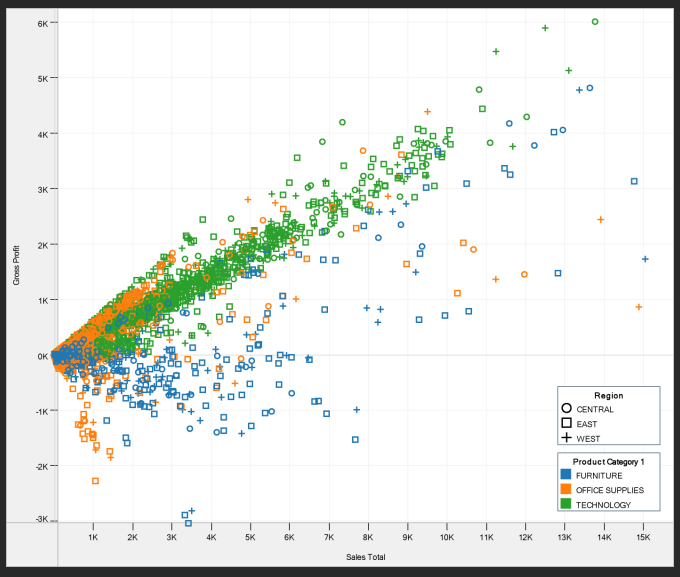
Molecular Models

Organic Chemistry Molecular Model Set
http://www.indigo.com/models/gphmodel/62003.html

8

Product Categories



Created by Tableau - Visual Analysis for Databases™

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Grouping, Highlighting

	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
red	25.37	13.70	0.05	26.27	14.13	0.04	18.41	10.16	0.05	17.43	9.30	0.00
green	22.14	51.24	0.35	20.68	49.17	0.44	21.11	46.00	0.20	16.36	37.95	0.12
blue	13.17	3.71	74.89	15.38	5.20	86.83	11.55	3.37	65.53	9.96	3.44	56.14
gray	63.46	73.30	78.05	64.66	71.99	90.08	52.96	62.49	67.99	45.54	53.65	58.14
black	0.66	0.70	0.77	0.63	0.66	1.09	0.47	0.58	0.70	0.44	0.54	0.71

	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
red	25.37	13.70	0.05	26.27	14.13	0.04	18.41	10.16	0.05	17.43	9.30	0.00
green	22.14	51.24	0.35	20.68	49.17	0.44	21.11	46.00	0.20	16.36	37.95	0.12
blue	13.17	3.71	74.89	15.38	5.20	86.83	11.55	3.37	65.53	9.96	3.44	56.14
gray	63.46	73.30	78.05	64.66	71.99	90.08	52.96	62.49	67.99	45.54	53.65	58.14
black	0.66	0.70	0.77	0.63	0.66	1.09	0.47	0.58	0.70	0.44	0.54	0.71

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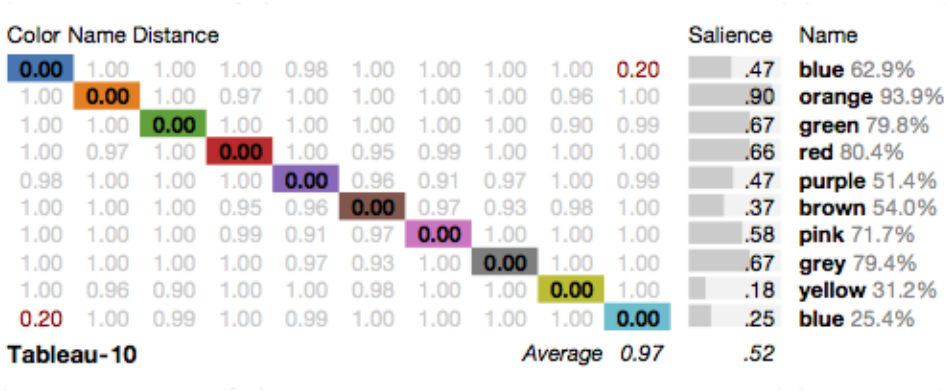
Palette Design + Color Names

Minimize overlap and ambiguity of color names



http://vis.stanford.edu/color-names

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Palette Design + Color Names

Minimize overlap and ambiguity of color names

Color Name Distance										Salience	Name
0.00	1.00	1.00	0.89	0.07	1.00	0.35	0.99	1.00	0.89	.30	**blue** 50.5%
1.00	0.00	0.99	1.00	1.00	0.92	1.00	0.84	0.98	0.99	.21	**red** 27.8%
1.00	0.99	0.00	1.00	0.98	1.00	1.00	1.00	0.17	1.00	.34	**green** 36.8%
0.89	1.00	1.00	0.00	0.98	1.00	0.71	0.93	1.00	0.32	.55	**purple** 67.3%
0.07	1.00	0.98	0.98	0.00	1.00	0.36	1.00	0.97	0.95	.20	**blue** 36.6%
1.00	0.92	1.00	1.00	1.00	0.00	1.00	0.97	0.99	1.00	.39	**orange** 51.9%
0.35	1.00	1.00	0.71	0.36	1.00	0.00	0.95	0.92	0.42	.13	**blue** 15.7%
0.99	0.84	1.00	0.93	1.00	0.97	0.95	0.00	0.98	0.85	.16	**pink** 29.4%
1.00	0.98	0.17	1.00	0.97	0.99	0.92	0.98	0.00	0.97	.12	**green** 21.7%
0.89	0.99	1.00	0.32	0.95	1.00	0.42	0.85	0.97	0.00	.30	**purple** 23.9%
Excel-10								*Average*	*0.87*	.27	

http://vis.stanford.edu/color-names

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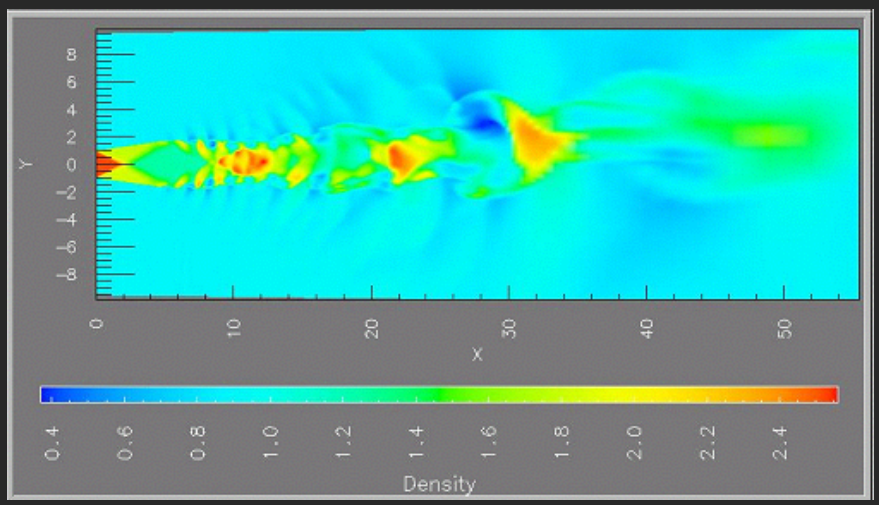
Mapping Data to Color (Rainbows)



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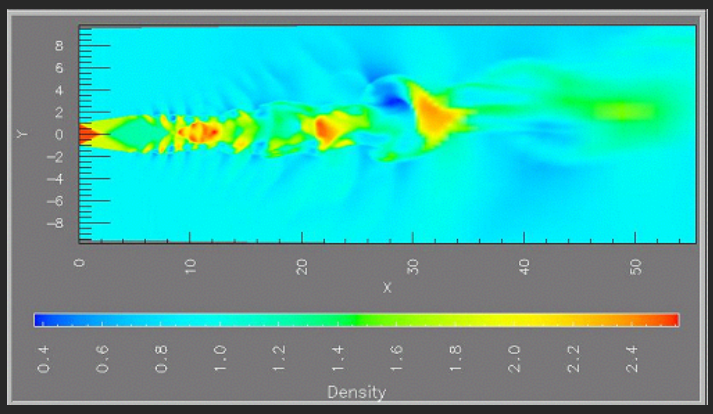
Avoid rainbow color maps!



1. Hues are not naturally ordered
2. People segment colors into classes, perceptual banding
3. Naïve rainbows unfriendly to color blind viewers
4. Low luminance colors (blue) hide high frequencies

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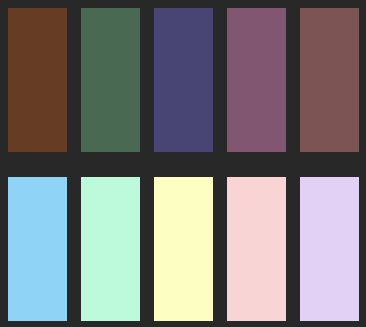
Tints and Tones

Tone or shade

- Hue + black
- Decrease saturation
- Decrease lightness

Tint

- Hue + white
- Decrease saturation
- Increase lightness



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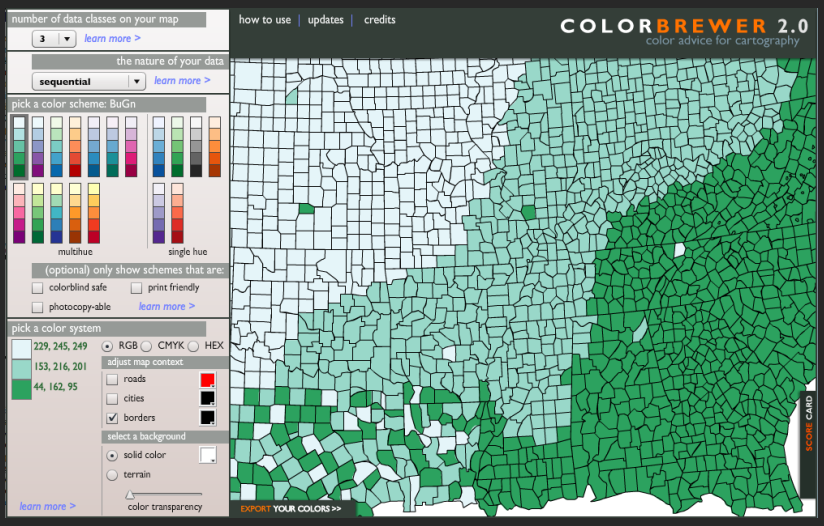
Color Brewer



www.colorbrewer.org

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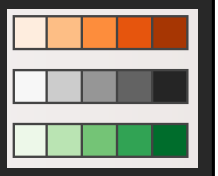
Quantitative color encoding

Sequential color scale

- Ramp in luminance, possibly also hue
- Typically higher values map to darker colors



Diverging color scale

- Useful when data has a meaningful "midpoint"
- Use neutral color (e.g., grey) for midpoint
- Use saturated colors for endpoints

Limit number of steps in color to 3-9

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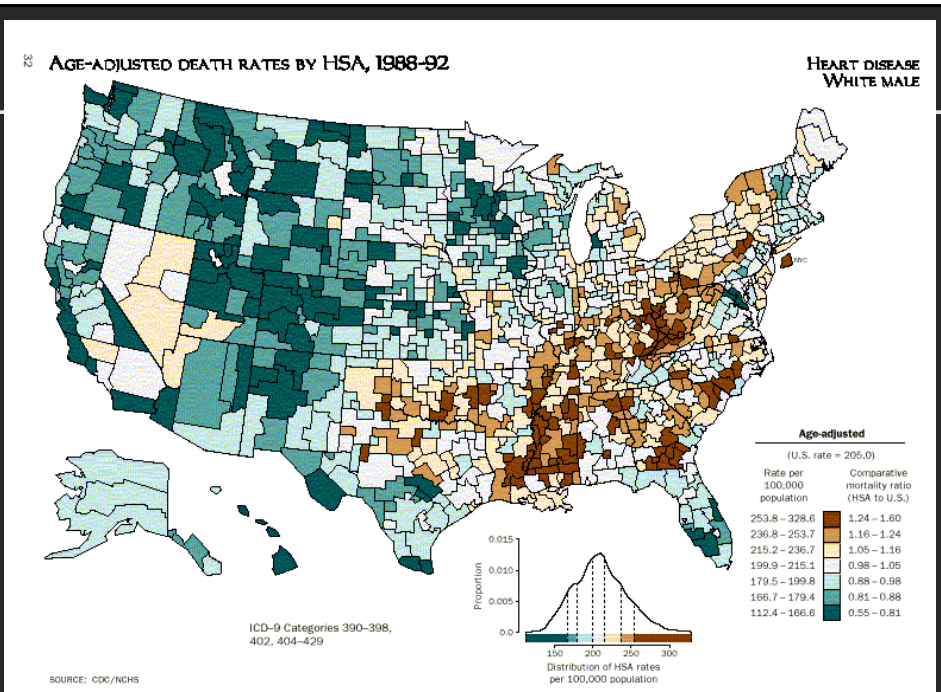

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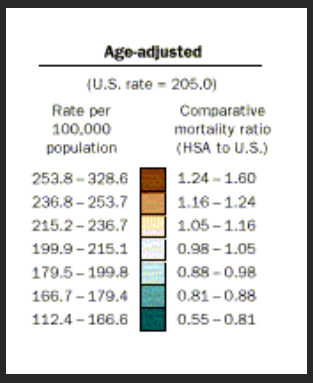
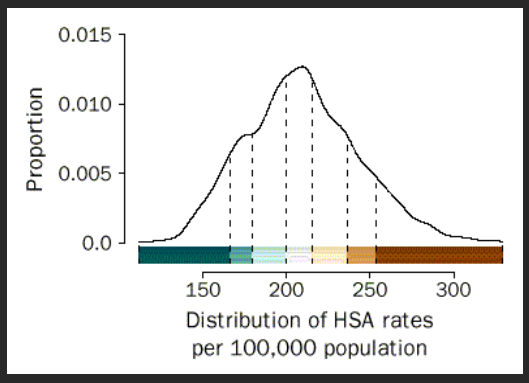
Classing quantitative data





Age-adjusted mortality rates for the United States

Common option: break into 5 or 7 quantiles

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Classing Quantitative Data

Equal interval (arithmetic progression)

Quantiles *(recommended)*

Standard deviations

Clustering (Jenks' natural breaks / 1D K-Means)

- Minimize within group variance
- Maximize between group variance

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Summary

Color perception

- Better acuity for luminance than for hue
- Beware of simultaneous contrast, crispening, spreading

Color naming

- Use colors that are easily distinguished by name

Color palettes

- Use small number of hues (about 6)
- Avoid rainbow palette except in special cases
- Steal well designed palettes (e.g. ColorBrewer)
- Consider sequential and diverging scales for Q data

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Announcements

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Final project

Data analysis/explainer or conduct research

- **Data analysis**: Analyze dataset in depth & make a visual explainer
- **Research**: Pose problem, Implement creative solution

Deliverables

- **Data analysis/explainer**: Article with multiple interactive visualizations
- **Research**: Implementation of solution and web-based demo if possible
- **Short video (2 min)** demoing and explaining the project

Schedule

- Project proposal: Thu 10/29
- Design Review and Feedback: Tue 11/17 & Thu 11/19
- Final code and video: Sat 11/21 11:59pm

Grading

- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

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Animation

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Question

The goal of visualization is to convey information

How does *animation* help convey information?

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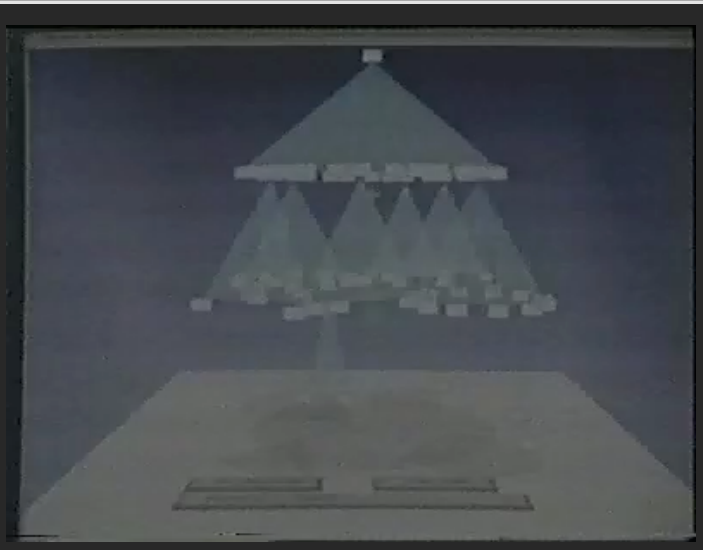
Cone Trees [Robertson 91]



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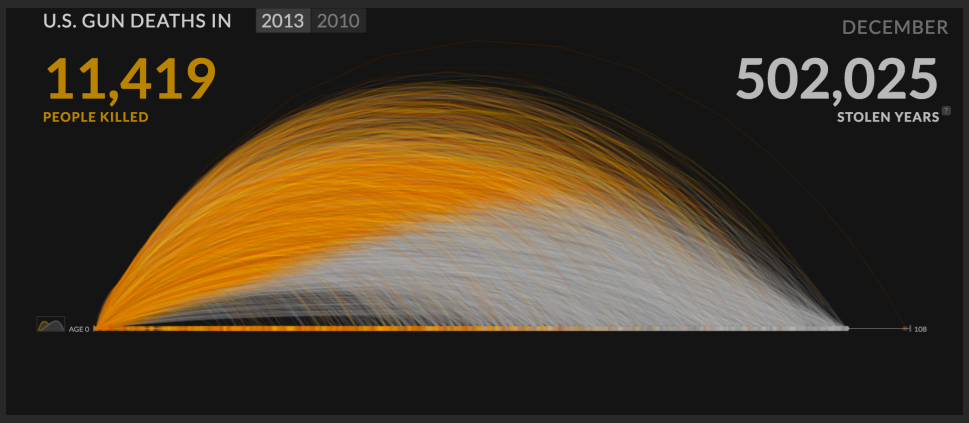
U.S. Gun Deaths [Periscopic 2013]



http://guns.periscopic.com/?year=2013

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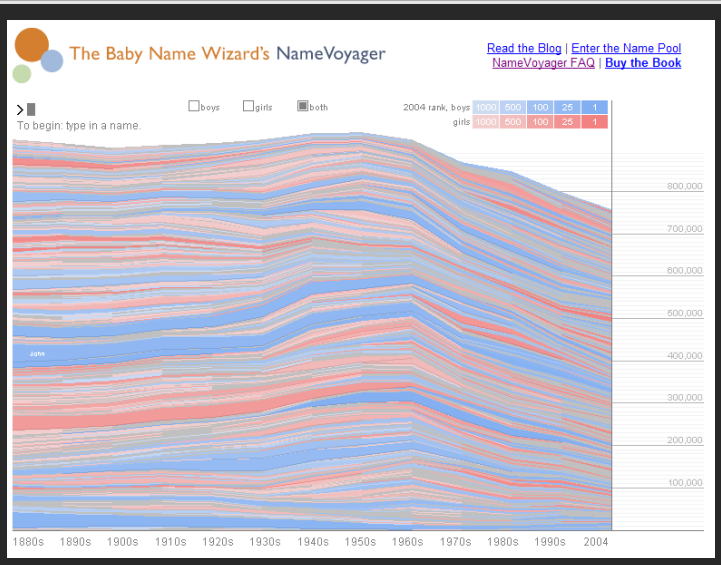
NameVoyager [Wattenberg 04]



http://www.babynamewizard.com/namevoyager/lnv0105.html

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Why Use Motion?

Visual variable to encode data

Direct attention

Understand system dynamics

Understand state transition

Increase engagement

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Topics

Understanding motion
Animated transitions in visualization
Implementing animation

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Understanding Motion

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Motion as a visual cue

Pre-attentive

- Stronger than color, shape, …

Triggers an orientation response
Motion parallax provides 3D cue
More sensitive to motion at periphery

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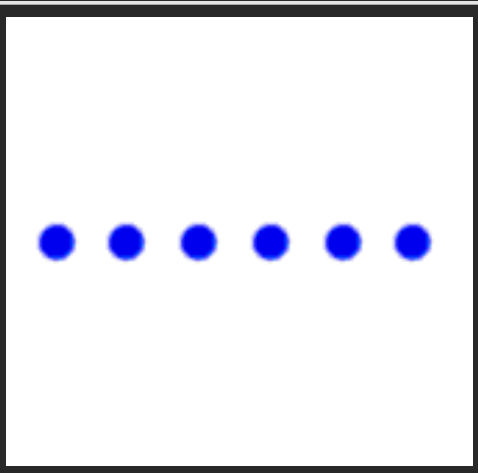
Grouped dots count as 1 object



Dots moving together are grouped

http://coe.sdsu.edu/eet/articles/visualperc1/start.htm

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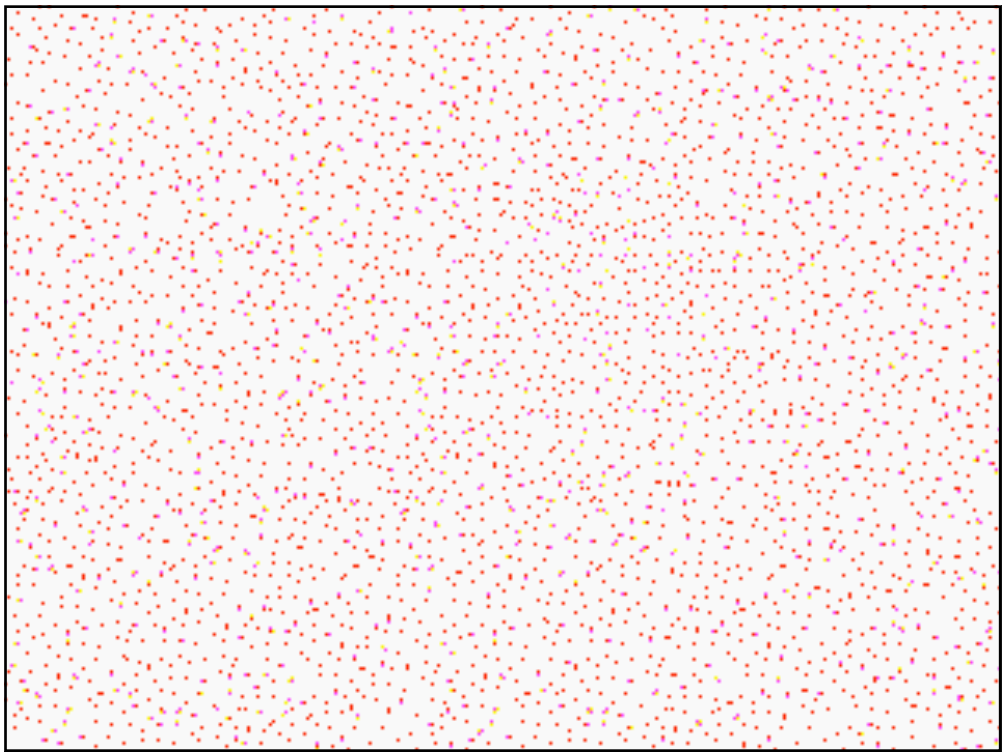

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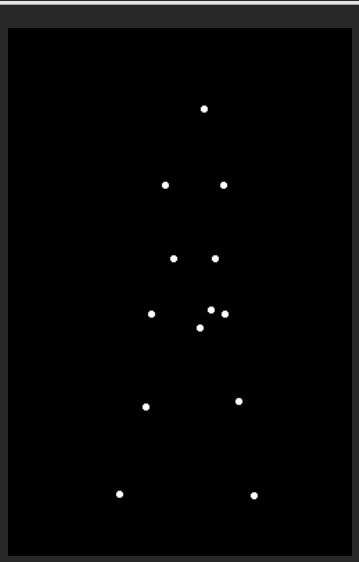
Grouping based on biological motion



[Johansson 73]

http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/

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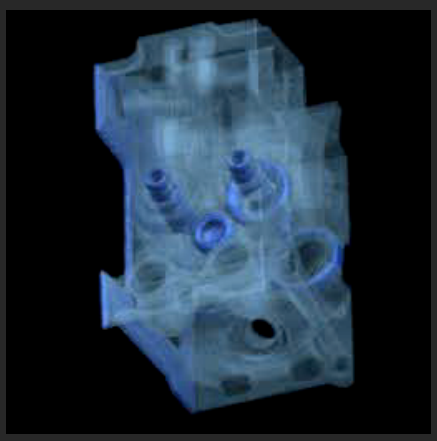
Volume rendering [Lacroute 95]



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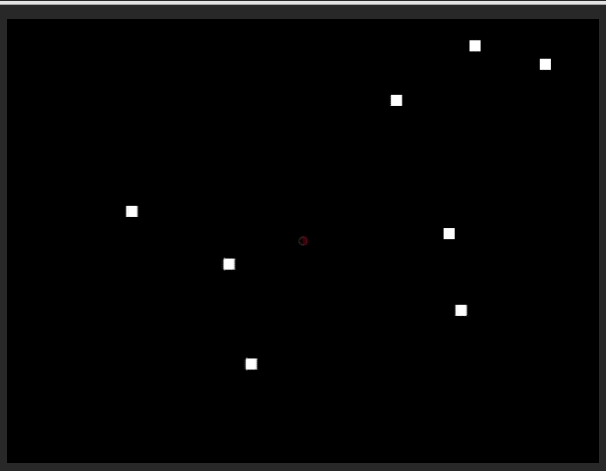
Tracking multiple targets



How many dots can we simultaneously track?

[Yantis 92, Pylyshn 88, Cavanagh 05]

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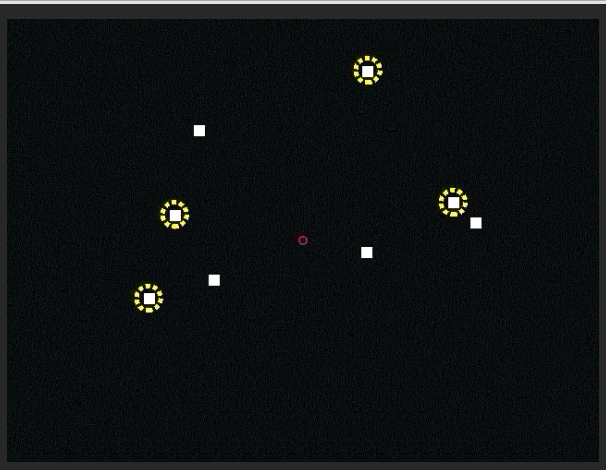
Tracking multiple targets



How many dots can we simultaneously track?

[Yantis 92, Pylyshn 88, Cavanagh 05]

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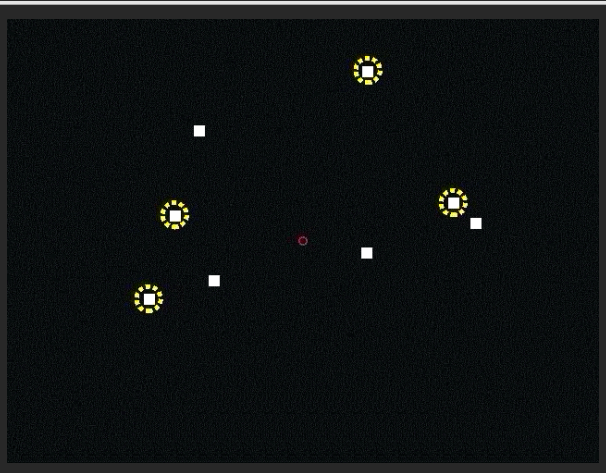
Tracking multiple targets



How many dots can we simultaneously track?

- **4 to 6 - difficulty increases significantly at 6**

[Yantis 92, Pylyshn 88, Cavanagh 05]

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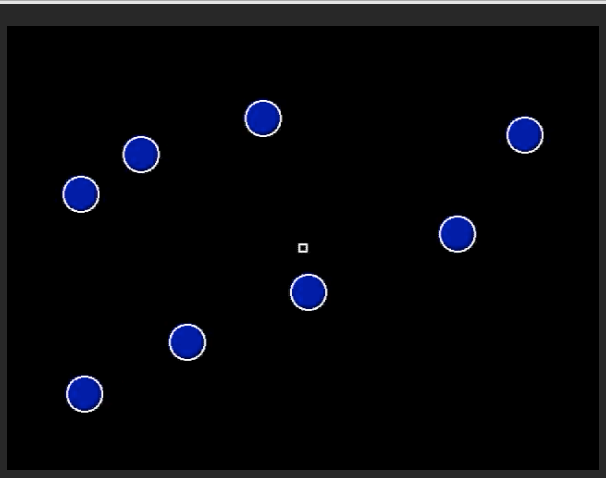
Tracking multiple targets



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[Yantis 92, Pylyshn 88, Cavanagh 05]

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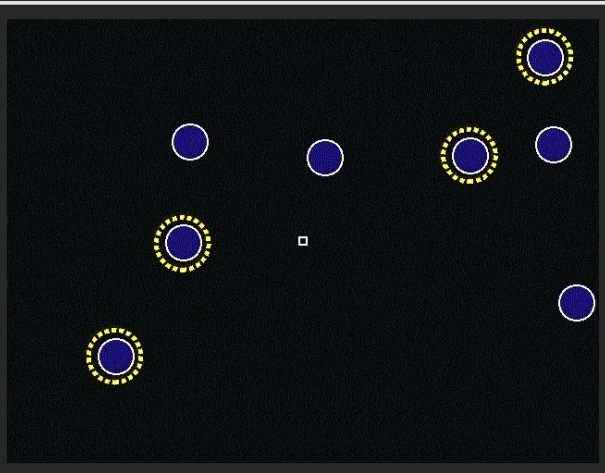
Tracking multiple targets



How many dots can we simultaneously track?

- **4 to 6 - difficulty increases significantly at 6**

[Yantis 92, Pylyshn 88, Cavanagh 05]

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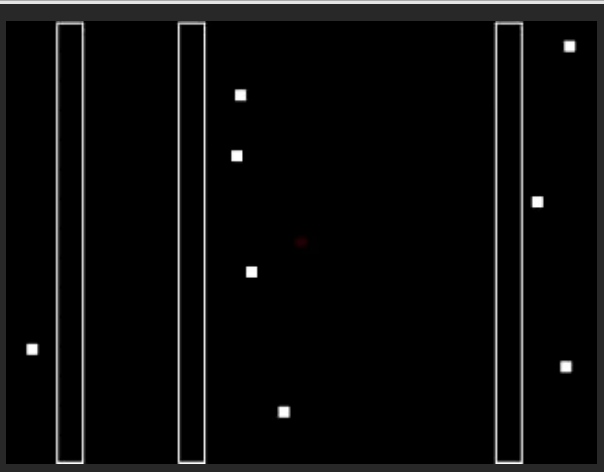
Tracking multiple targets



How many dots can we simultaneously track?

- **4 to 6 - difficulty increases significantly at 6**

[Yantis 92, Pylyshn 88, Cavanagh 05]

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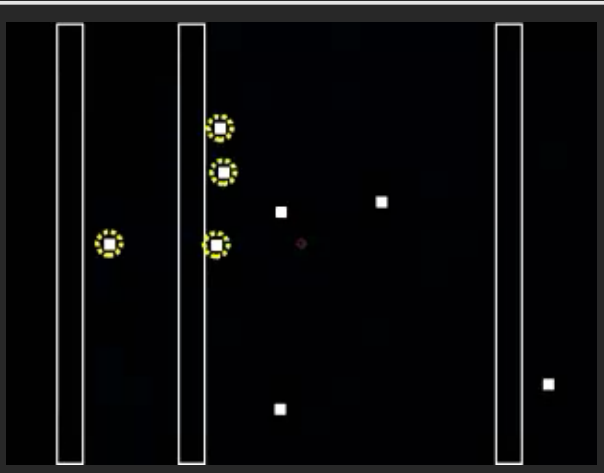
Tracking multiple targets



How many dots can we simultaneously track?

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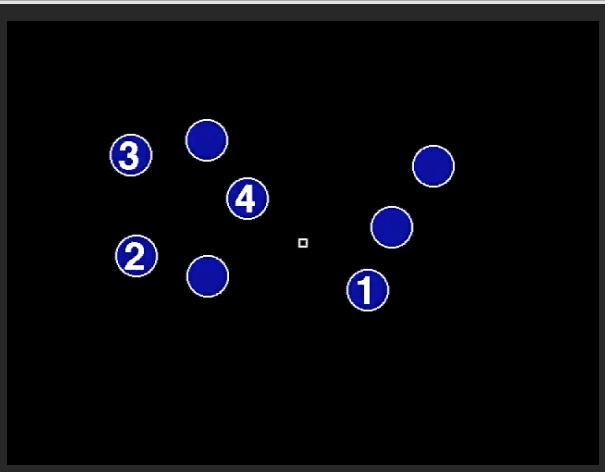
[Yantis 92, Pylyshn 88, Cavanagh 05]

83

Tracking multiple targets



How many dots can we simultaneously track?

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[Yantis 92, Pylyshn 88, Cavanagh 05]

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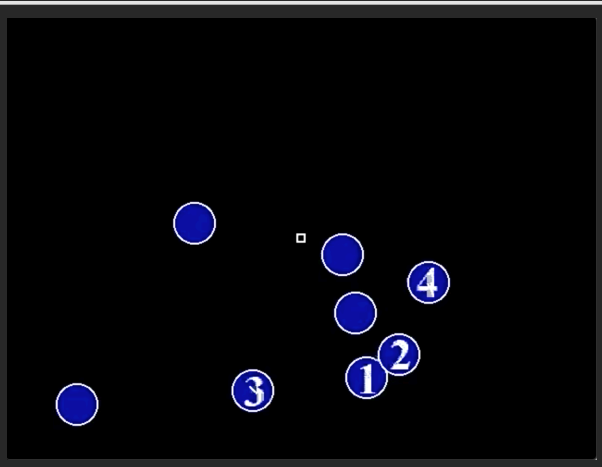
Tracking multiple targets



How many dots can we simultaneously track?

- **4 to 6 - difficulty increases significantly at 6**

[Yantis 92, Pylyshn 88, Cavanagh 05]

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Motions directly show transitions

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (mostly translations)

start

86

Motions directly show transitions

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (mostly translations)

end

87

Motions directly show transitions

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (translation, rotation, scale)

start **end**

Shows transition better, but

- Still may be too fast, or too slow
- Too many objects may move at once

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Constructing narratives

Animation from:
Heider, F. & Simmel, M. (1944).
An experimental study of apparent behavior.
American Journal of Psychology, 57, 243-259.

Courtesy of:
Department of Psychology,
University of Kansas, Lawrence

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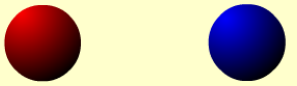
Attribution of causality [Michotte 46]

Michotte demonstration 1. What do you see? Most observers report that "the red ball **hit** the blue ball." The blue ball moved "**because** the red ball hit it." Thus, the red ball is perceived to **"cause"** the blue ball to move, even though the balls are nothing more than color disks on your screen that move according to a programme.



http://cogweb.ucla.edu/Discourse/Narrative/Heider_45.html

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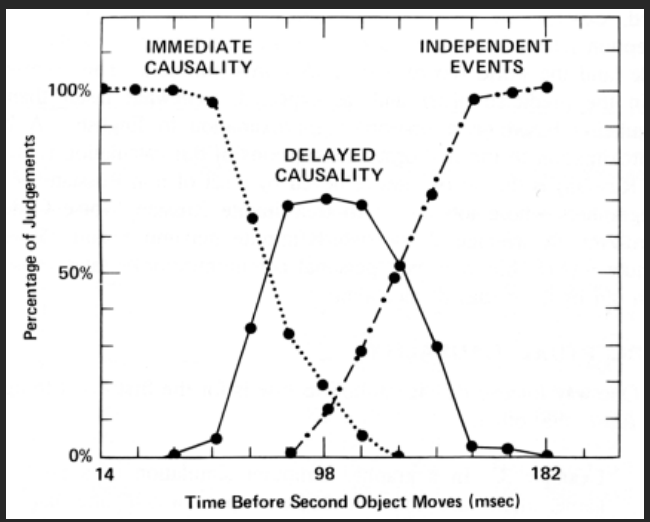
Attribution of causality [Michotte 46]



[Reprint from Ware 04]

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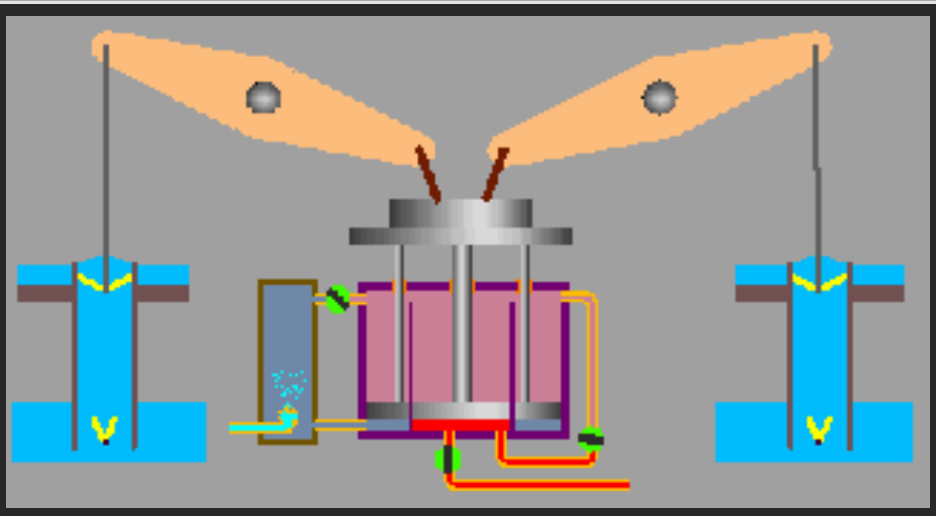
How does it work?



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Problems [Tversky 02]

Difficulties in understanding animation

- Difficult to estimate paths and trajectories
- Motion is fleeting and transient
- Cannot simultaneously attend to multiple motions
- Trying to parse motion into events, actions and behaviors
- Misunderstanding and wrongly inferring causality
- Anthropomorphizing physical motion may cause confusion or lead to incorrect conclusions

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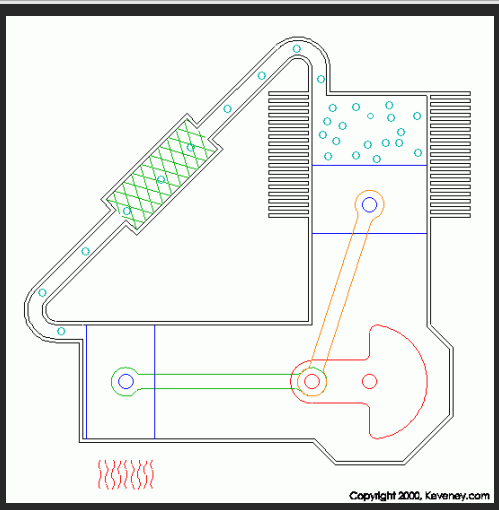
Solution I: Break into static steps



Two-cylinder Stirling engine
http://www.keveney.com/Vstirling.html

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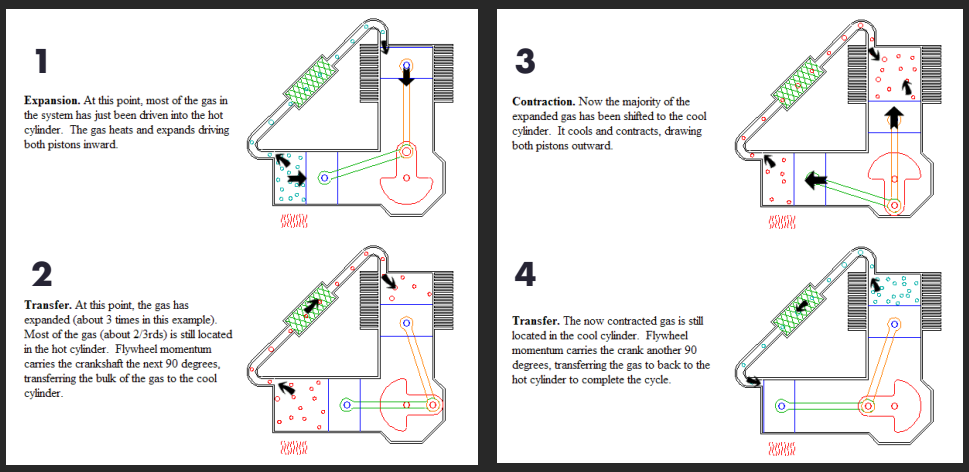
Solution I: Break into static steps



Two-cylinder Stirling engine
http://www.keveney.com/Vstirling.html

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Challenges

Choosing the set of steps

- How to segment process into steps?
- Note: Steps often shown sequentially for clarity, rather than showing everything simultaneously

Tversky suggests

- Coarse level – segment based on objects
- Finer level – segment based on actions
  - Static depictions often do not show finer level segmentation

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Animated Transitions in Statistical Graphics

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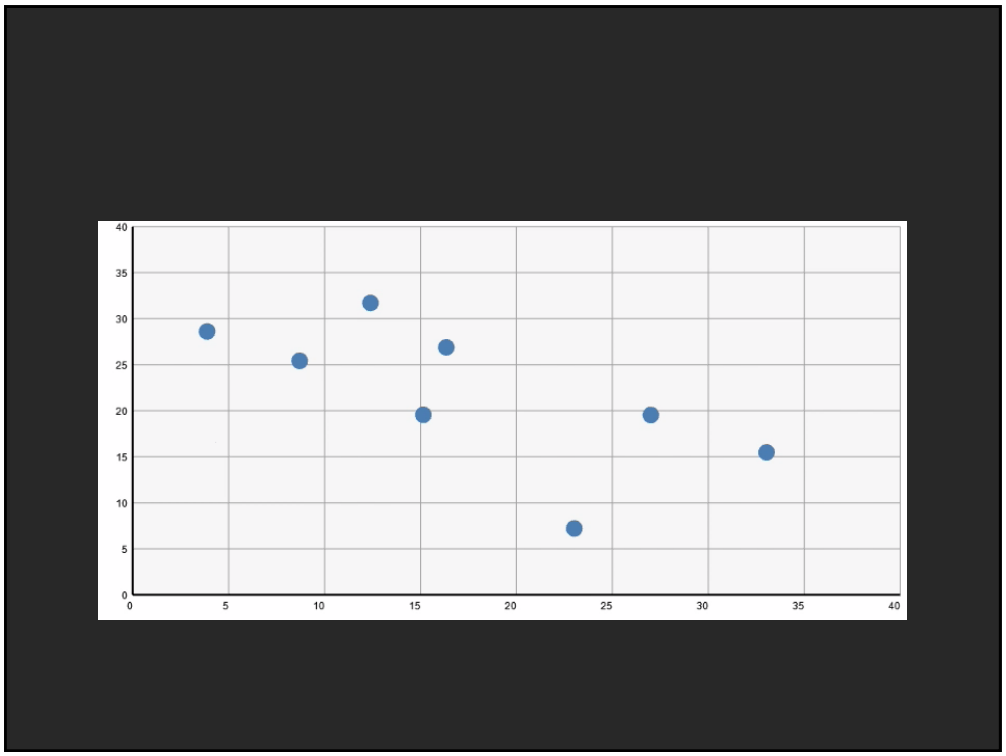

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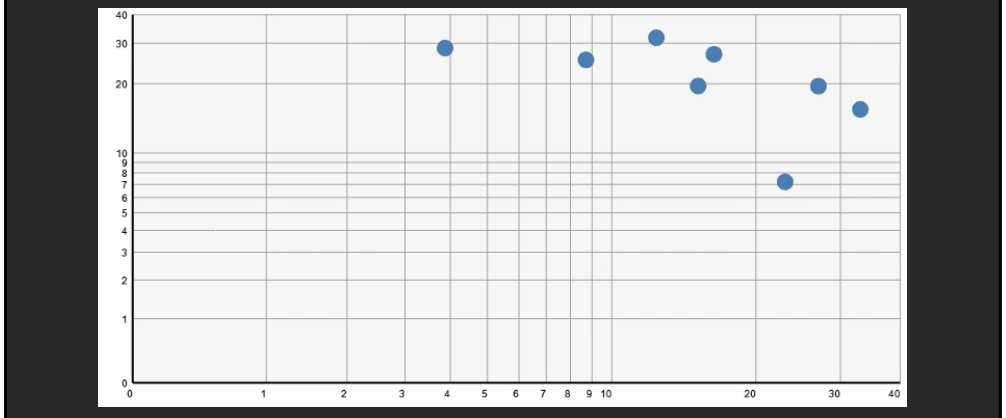
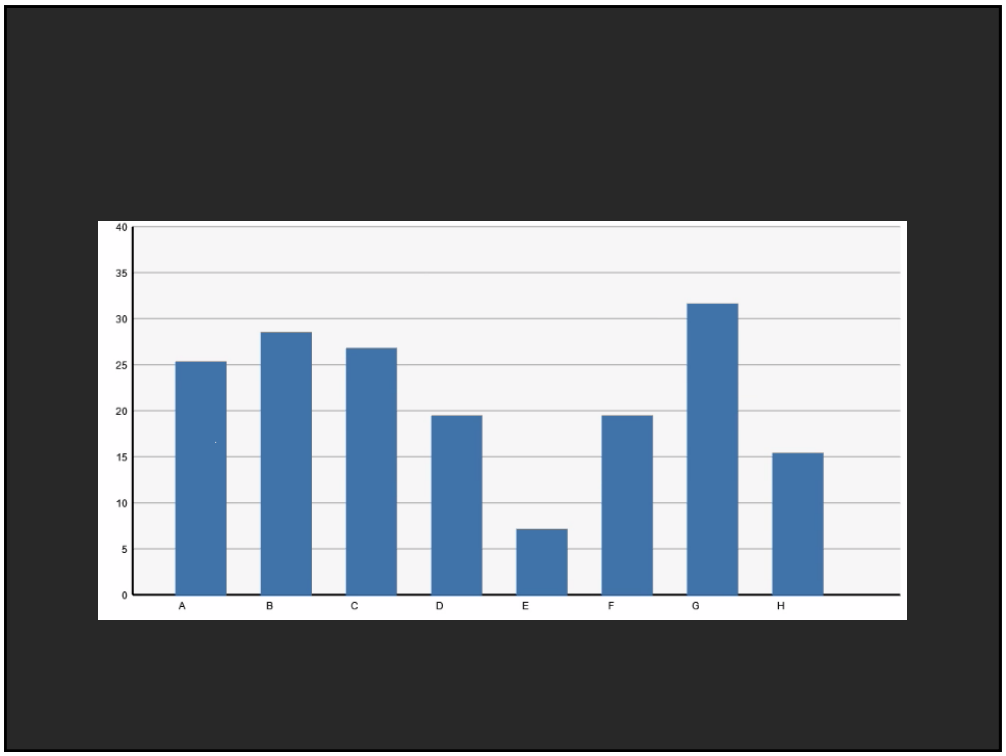
Log Transform



111



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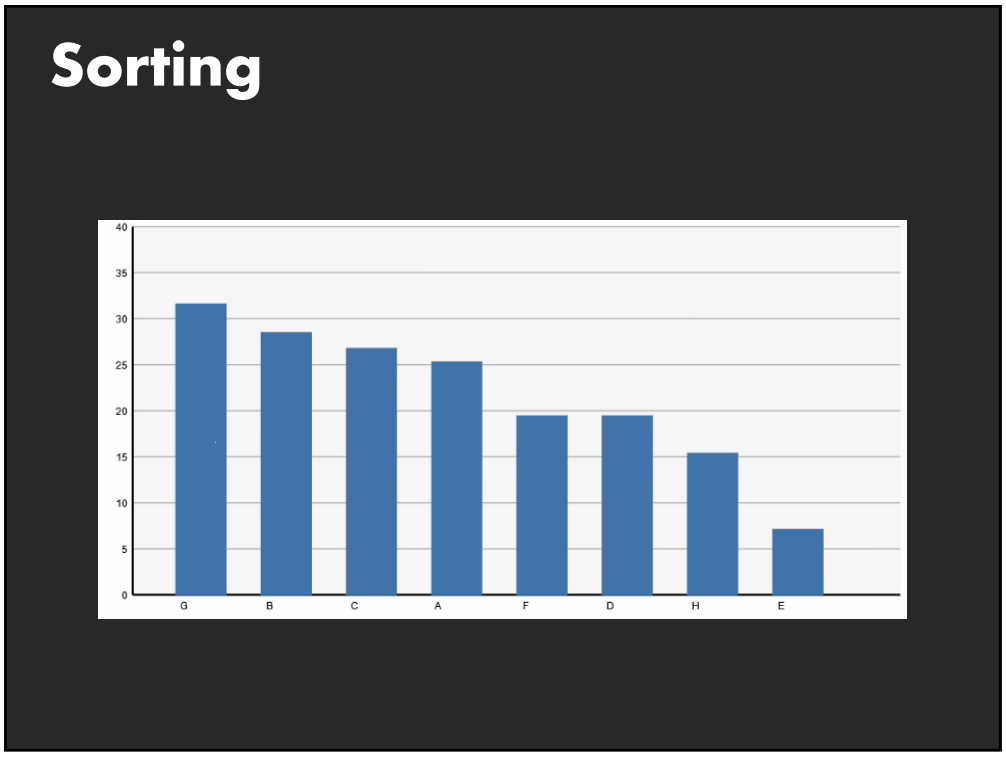
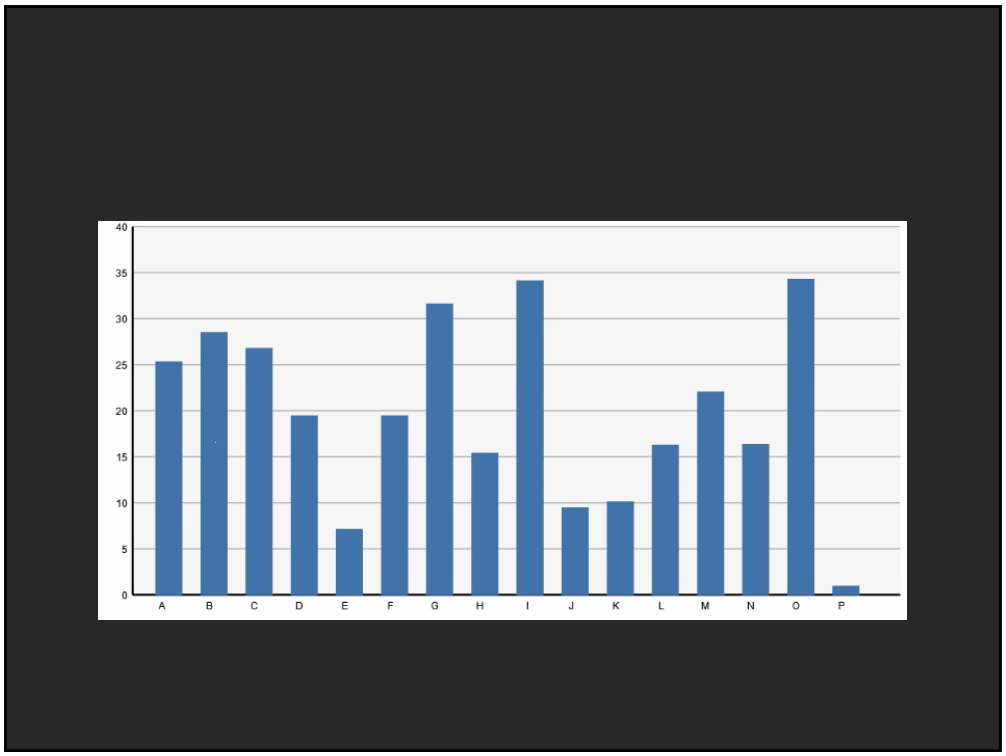
Sorting



113



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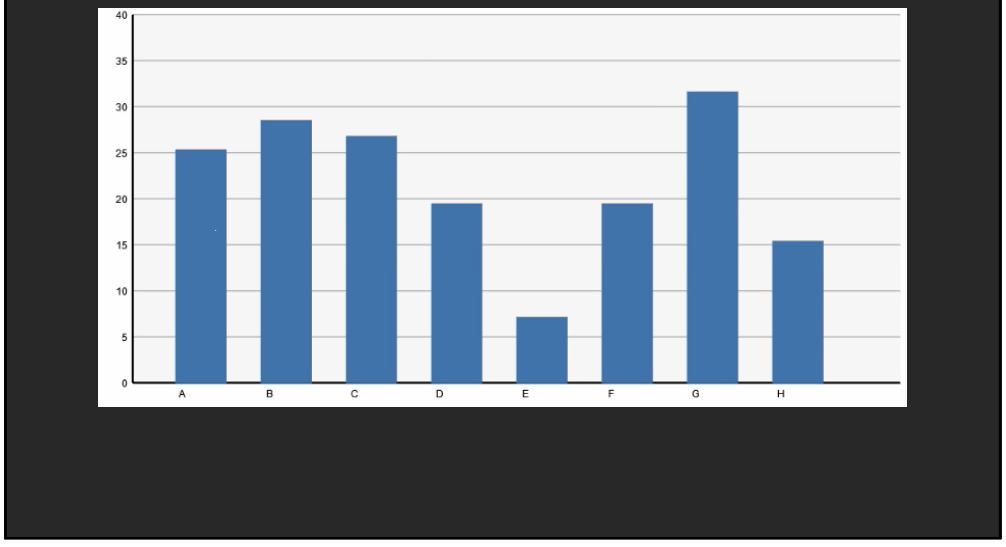
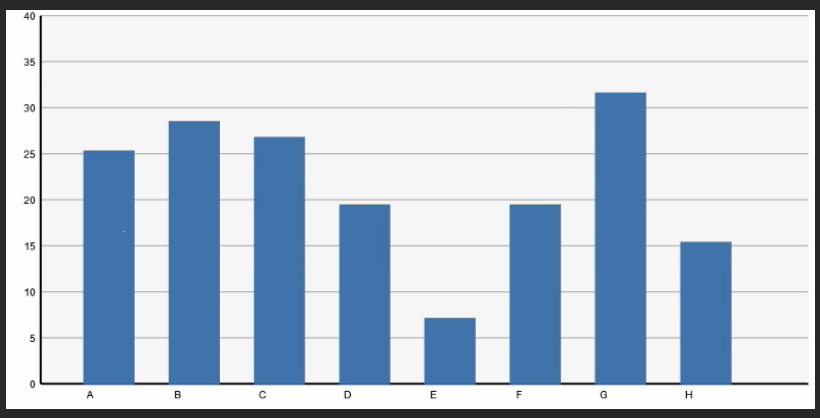
Filtering



115



Month 1

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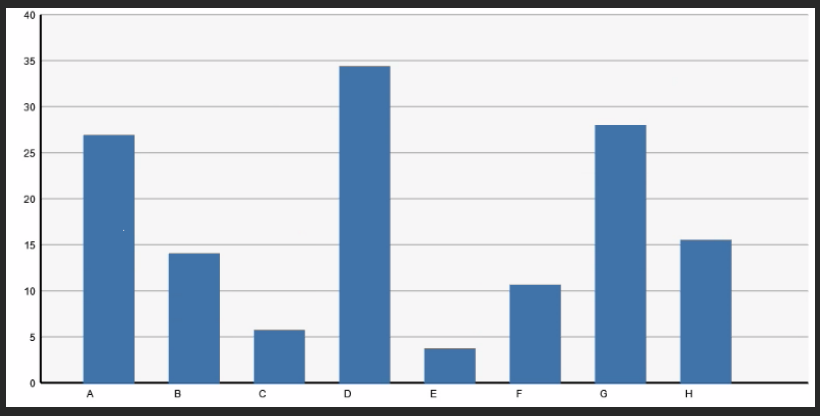
Timestep



Month 2

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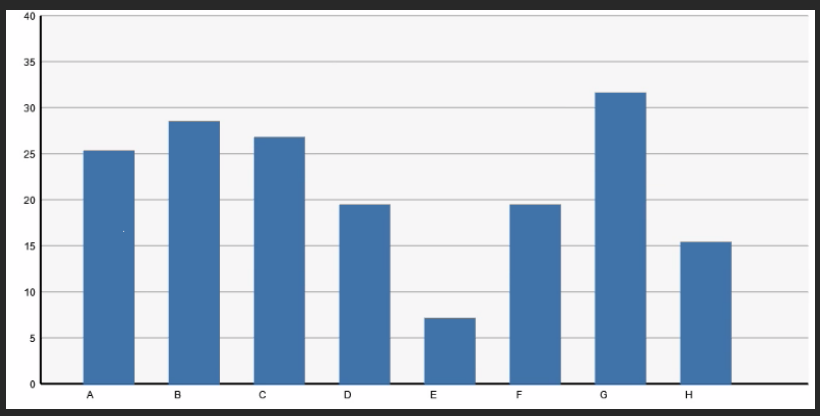

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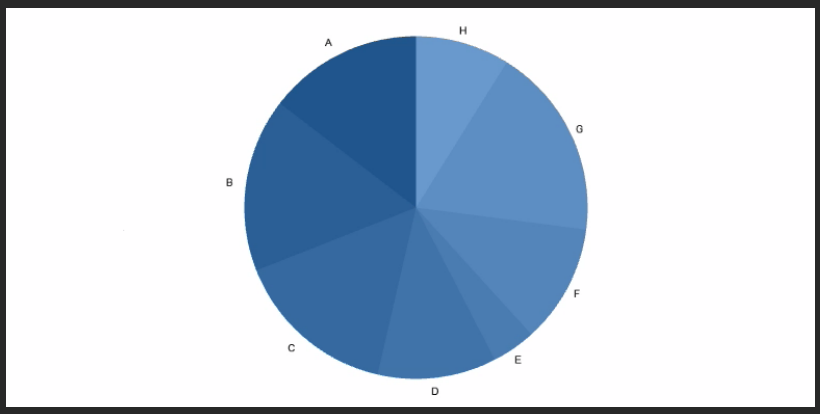
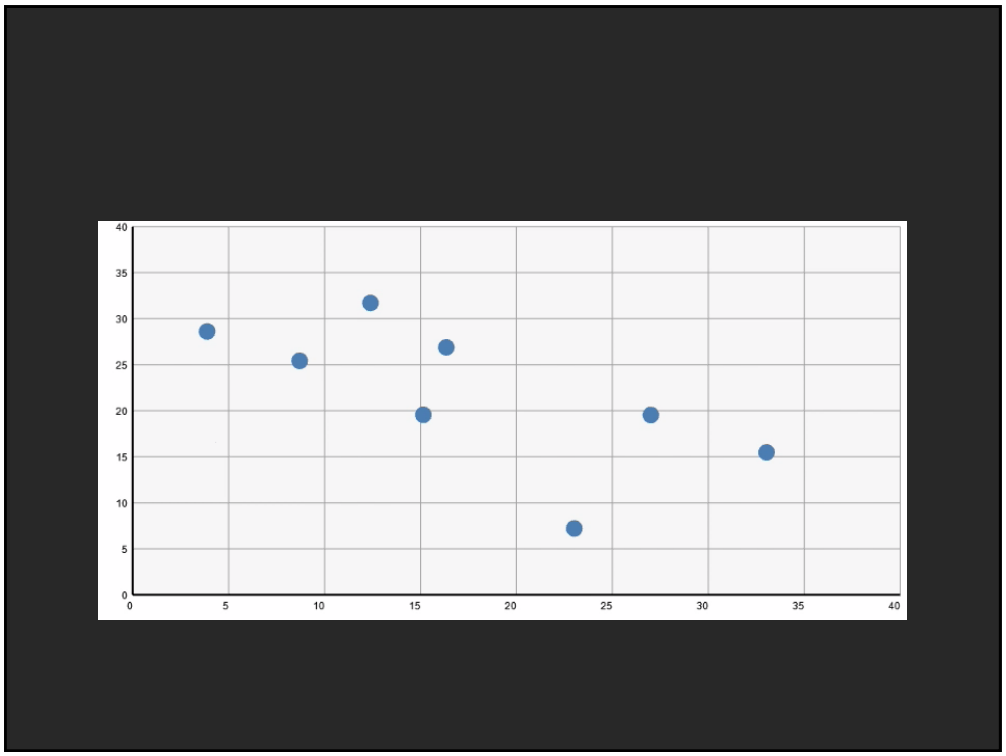
Change Encodings

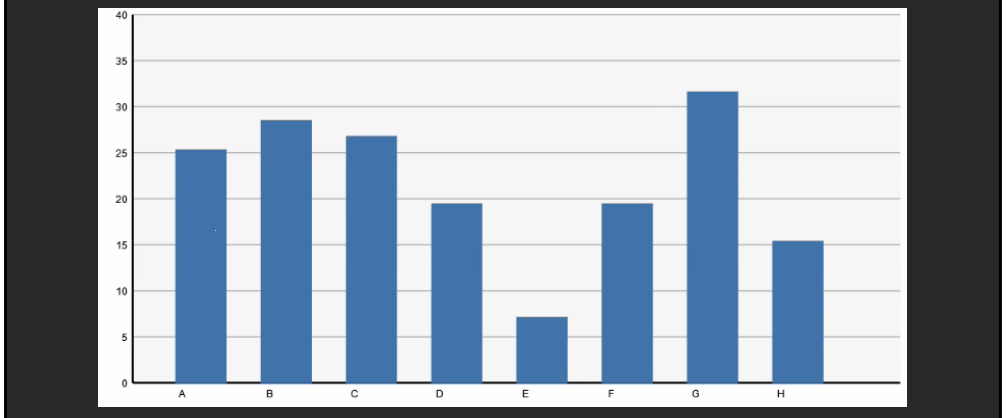


119



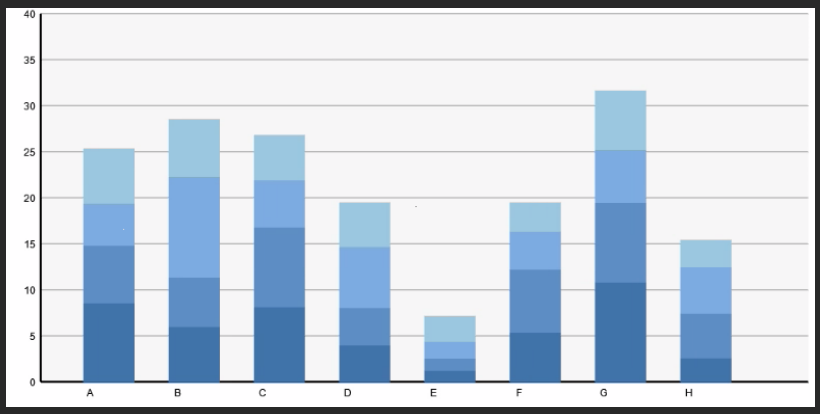
120

Change Data Dimensions



121

Change Data Dimensions



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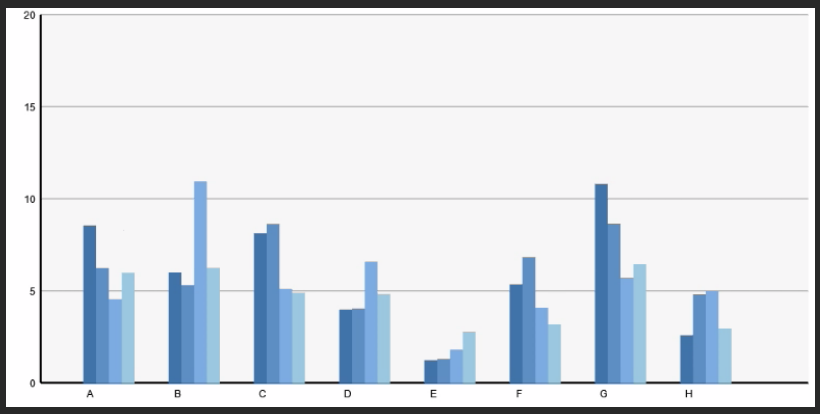
Change Encodings + Axis Scales



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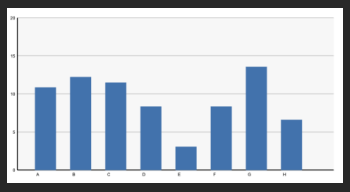
Data Graphics & Transitions

Category	Sales	Profit
A	11	7
B	13	10
C	12	6
D	8	5
E	3	1

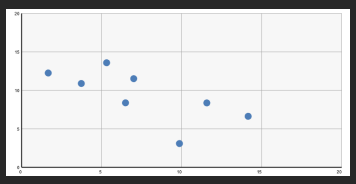
Visual Encoding



Change selected data dimensions or encodings

Animation to communicate changes?

Category	Sales	Profit
A	11	7
B	13	10
C	12	6
D	8	5
E	3	1



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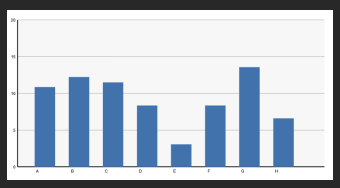
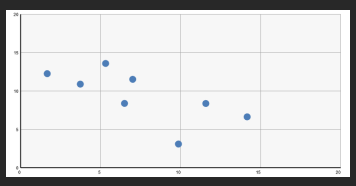
Transitions between charts





It is common to transition between *related* charts
Can animation help?
How does this impact perception?

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Principles for conveying information

Congruence:

The structure and content of the external representation should correspond to the desired structure and content of the internal representation.

Apprehension:

The structure and content of the external representation should be readily and accurately perceived and comprehended.

[from Tversky 02]

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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
- Use consistent syntactic/semantic mappings
- Respect semantic correspondence
- Avoid ambiguity

Apprehension

- Group similar transitions
- Minimize occlusion
- Maximize predictability
- Use simple transitions
- Use staging for complex transitions
- Make transitions as long as needed, but no longer

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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
- Use consistent syntactic/semantic mappings
- Respect semantic correspondence
- Avoid ambiguity

Visual marks should always represent the same data tuple.

Apprehension

- Group similar transitions
- Minimize occlusion
- Maximize predictability
- Use simple transitions
- Use staging for complex transitions
- Make transitions as long as needed, but no longer

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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
- Use consistent syntactic/semantic mappings
- Respect semantic correspondence
- Avoid ambiguity

Different operators should have distinct animations.

Apprehension

- Group similar transitions
- Minimize occlusion
- Maximize predictability
- Use simple transitions
- Use staging for complex transitions
- Make transitions as long as needed, but no longer

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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
- Use consistent syntactic/semantic mappings
- Respect semantic correspondence
- Avoid ambiguity

Apprehension

- Group similar transitions
- Minimize occlusion
- Maximize predictability
- Use simple transitions
- Use staging for complex transitions
- Make transitions as long as needed, but no longer

Objects are harder to track when occluded.

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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
- Use consistent syntactic/semantic mappings
- Respect semantic correspondence
- Avoid ambiguity

Apprehension

- Group similar transitions
- Minimize occlusion
- Maximize predictability
- Use simple transitions
- Use staging for complex transitions
- Make transitions as long as needed, but no longer

Keep animation as simple as possible. If complicated, break into simple stages.

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Animated Transitions in Statistical Data Graphics

Jeffrey Heer
George G. Robertson

Microsoft Research

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Study Conclusions

Appropriate animation improves graphical perception

Simple transitions beat "*do one thing at a time*"

Simple staging was preferred and showed benefits
but timing important and in need of study

Axis re-scaling hampers perception
Avoid if possible (use common scale)

Maintain landmarks better (delay fade out of gridlines)

Subjects preferred animated transitions

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Implementing Animation

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