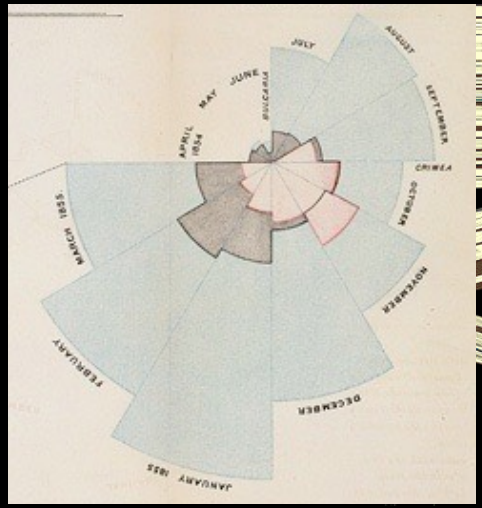
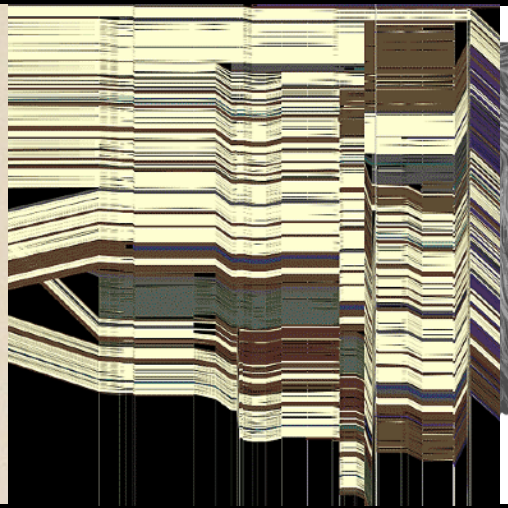
CSE 442 - Data Visualization

Animation





Jeffrey Heer University of Washington

Why Use Motion?

Visual variable to encode data

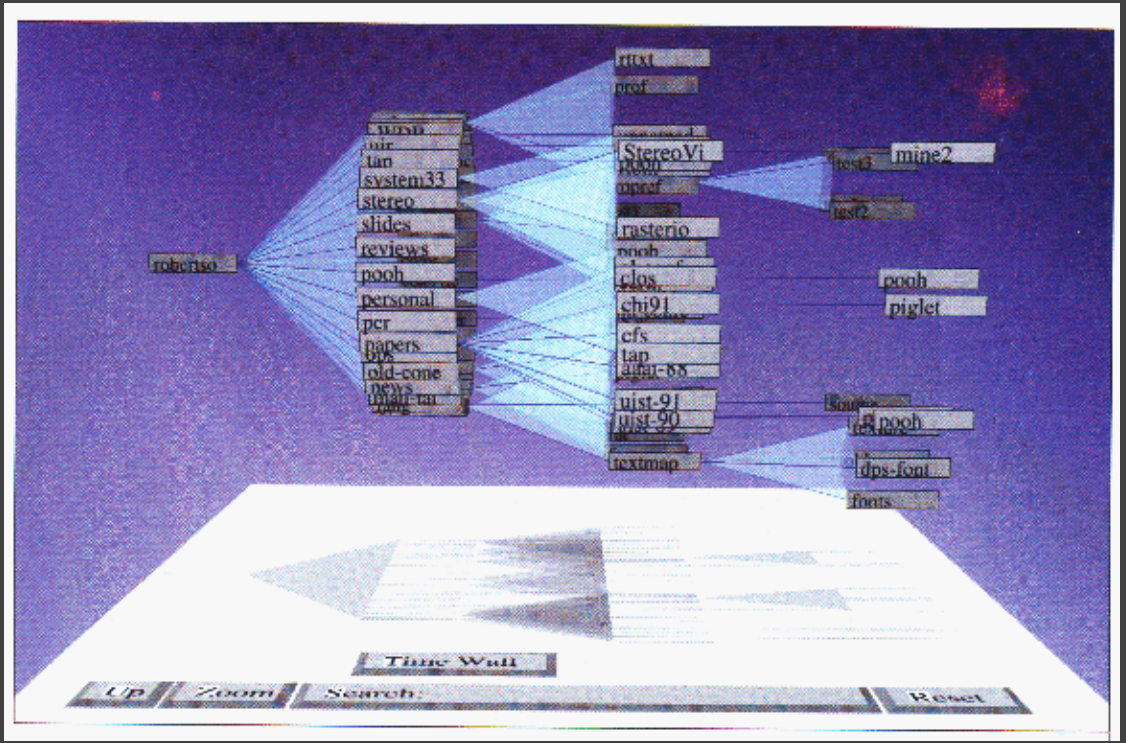
Direct attention

Understand system dynamics

Understand state transition

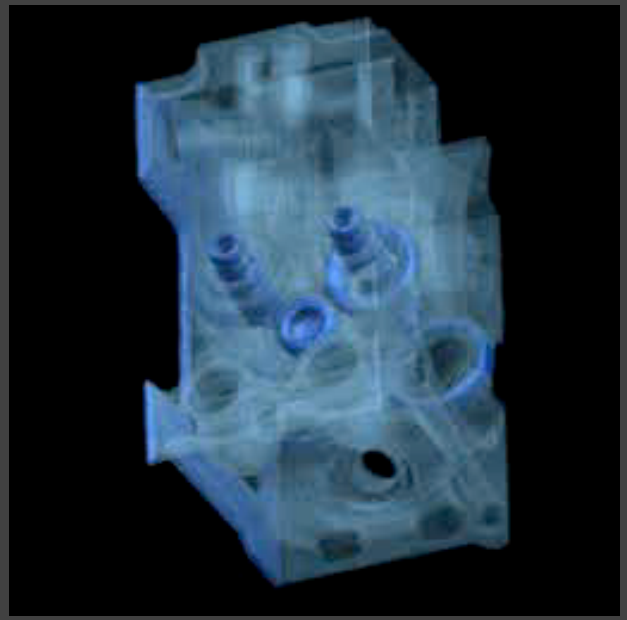
Increase engagement

Cone Trees [Robertson 91]



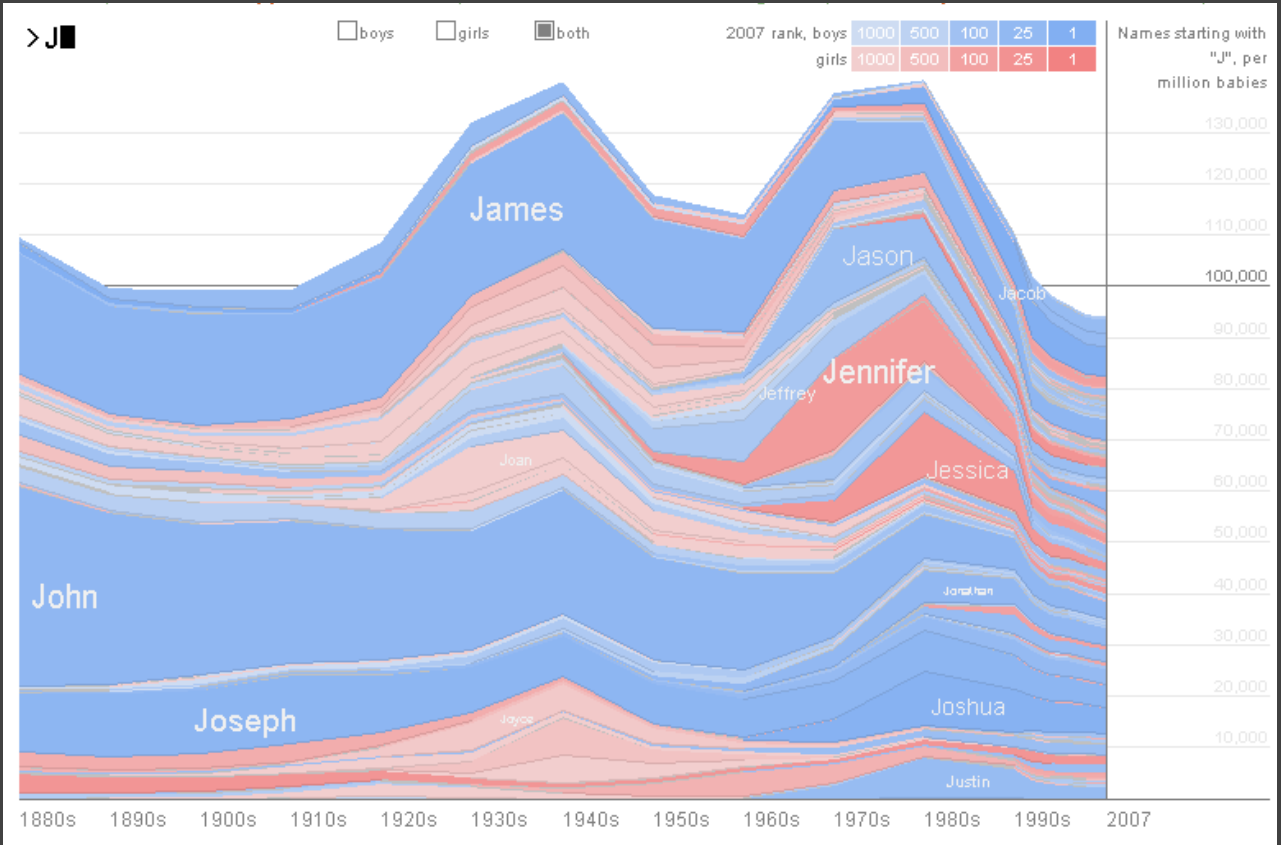
Video

Volume Rendering [Lacroute 95]



Video

NameVoyager [Wattenberg 06]



Topics

Motion perception

Animated transitions in visualizations

Implementing animations

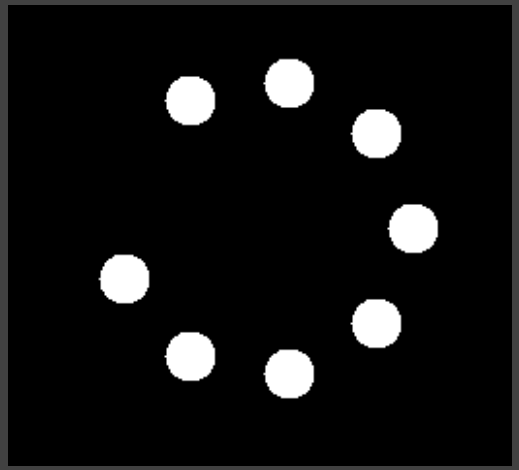
Motion Perception

Perceiving Animation

Under what conditions does a sequence of static images give rise to motion perception?

Motion is perceived at about ~10 frames/sec (100 ms).

But this does not have to be *smooth* motion! We can tell frames are discrete yet perceive movement.



Motion as Visual Cue

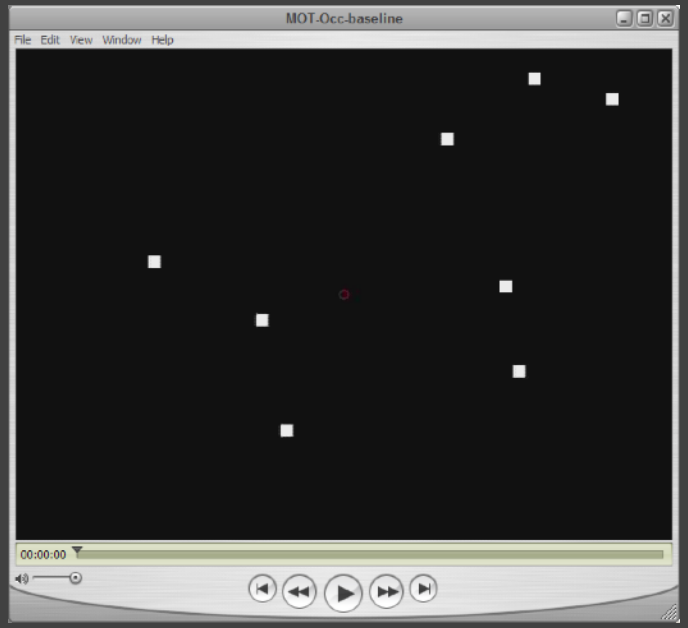
Pre-attentive, stronger than color, shape, …

More sensitive to motion at periphery

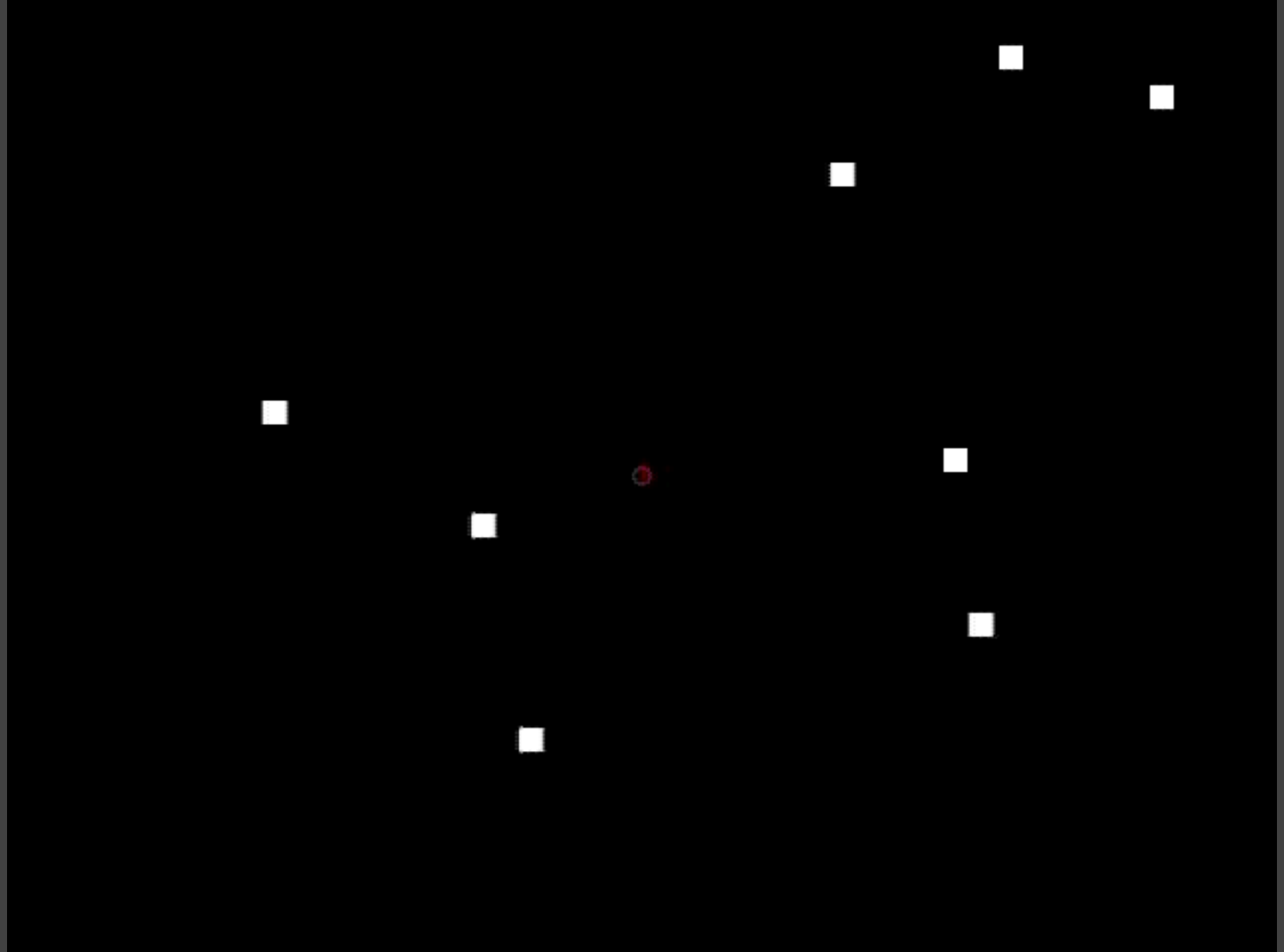
Similar motions perceived as a group

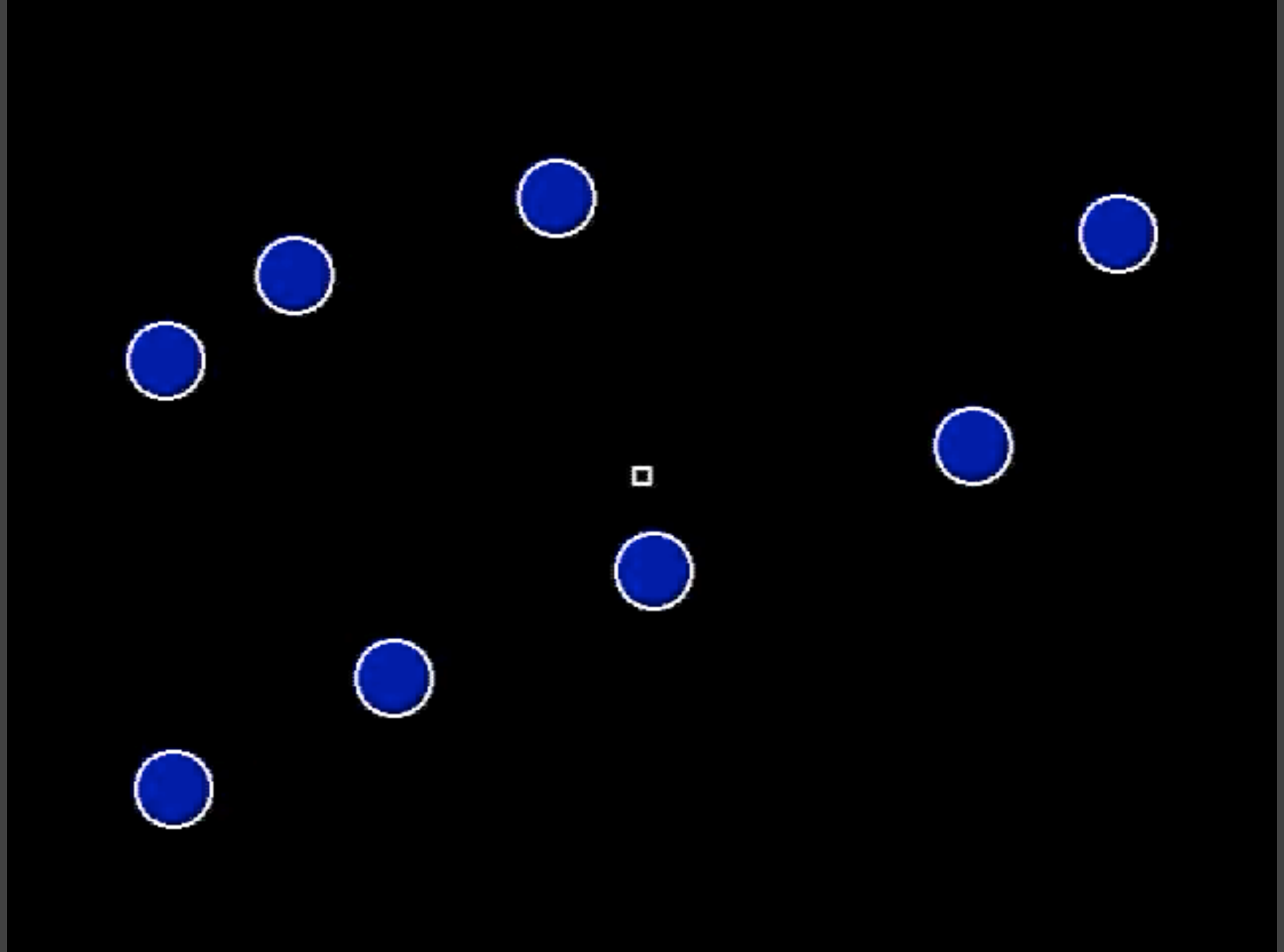
Motion parallax provide 3D cue (like stereopsis)

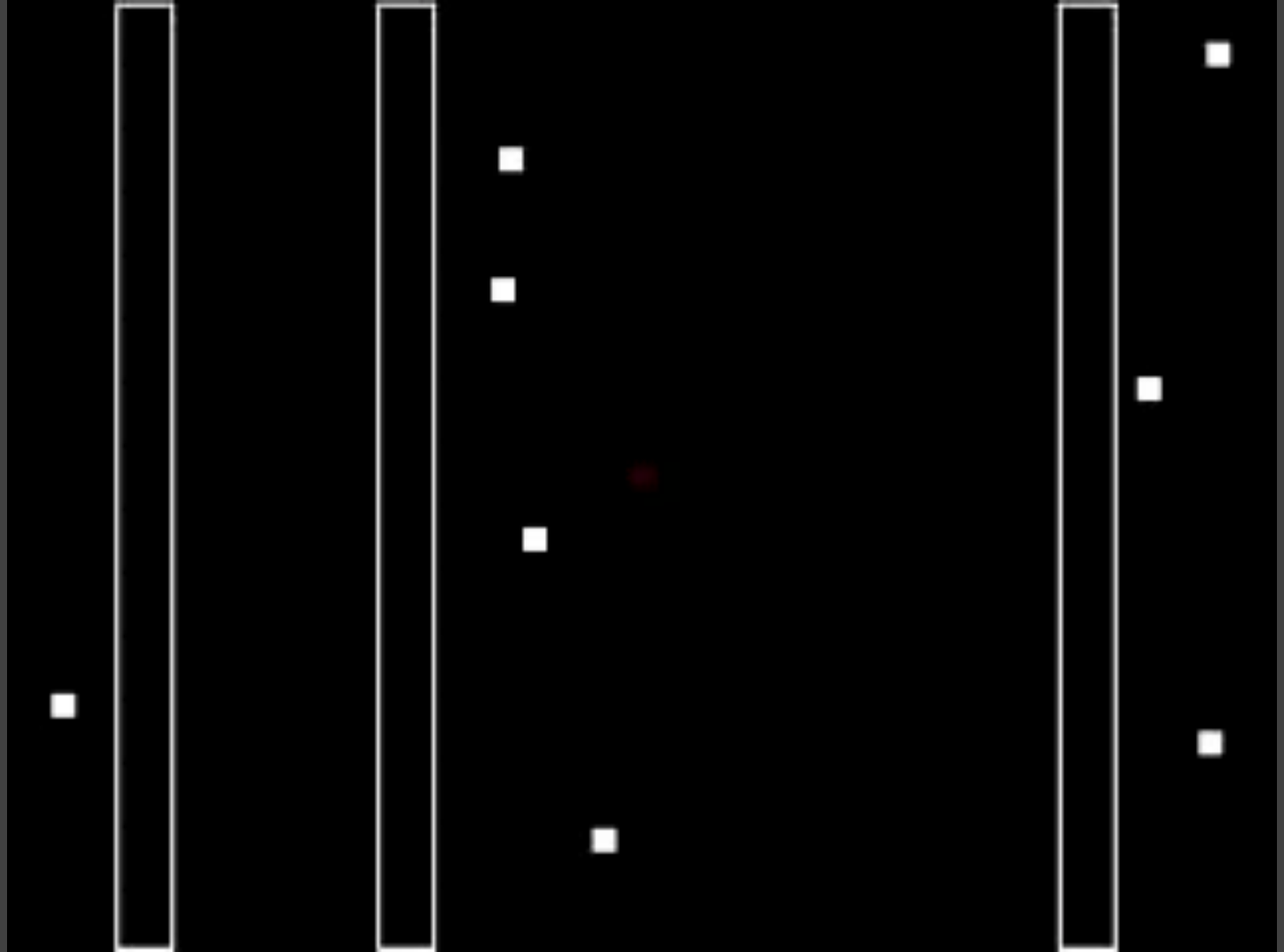
Tracking Multiple Targets

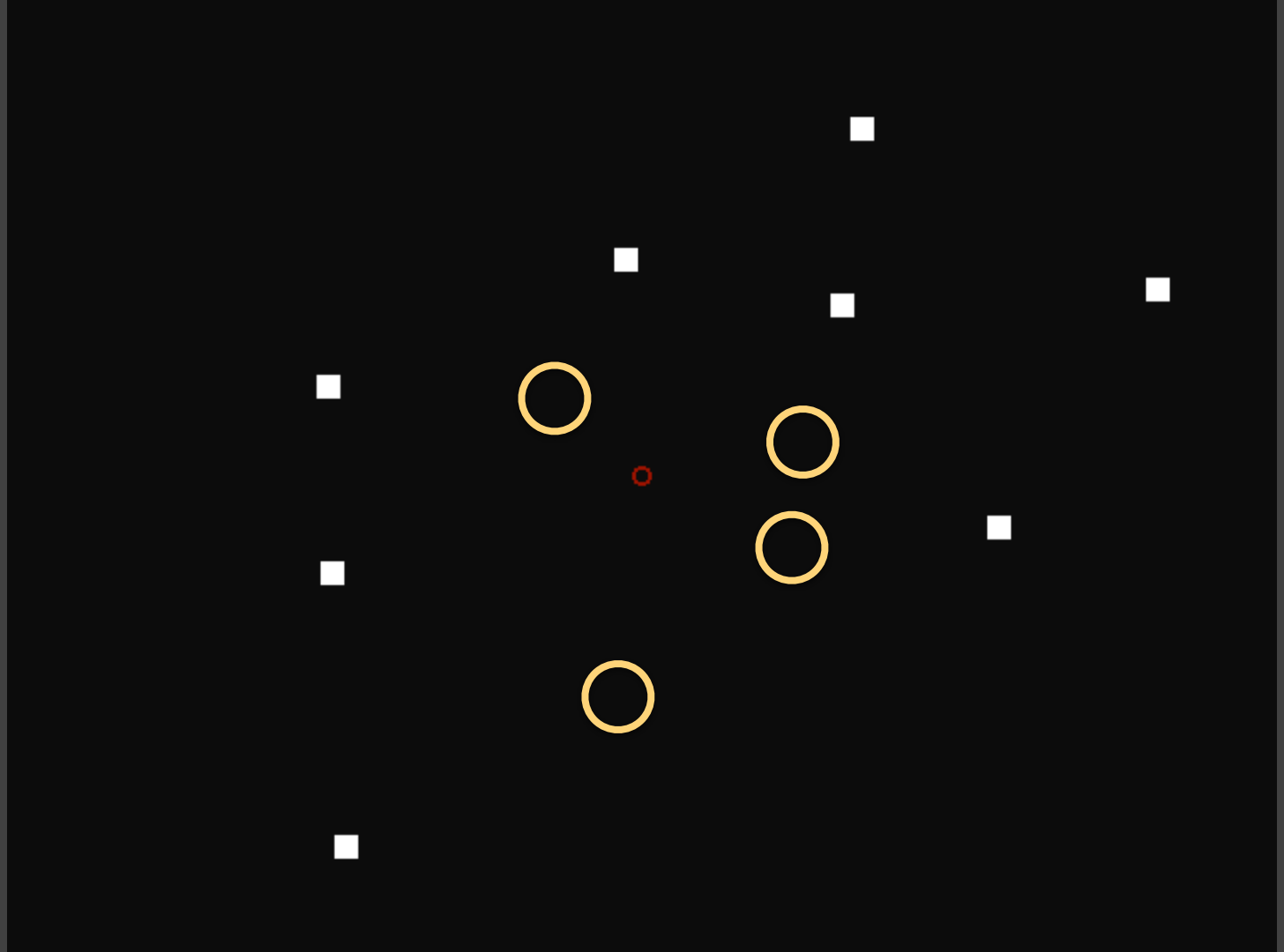


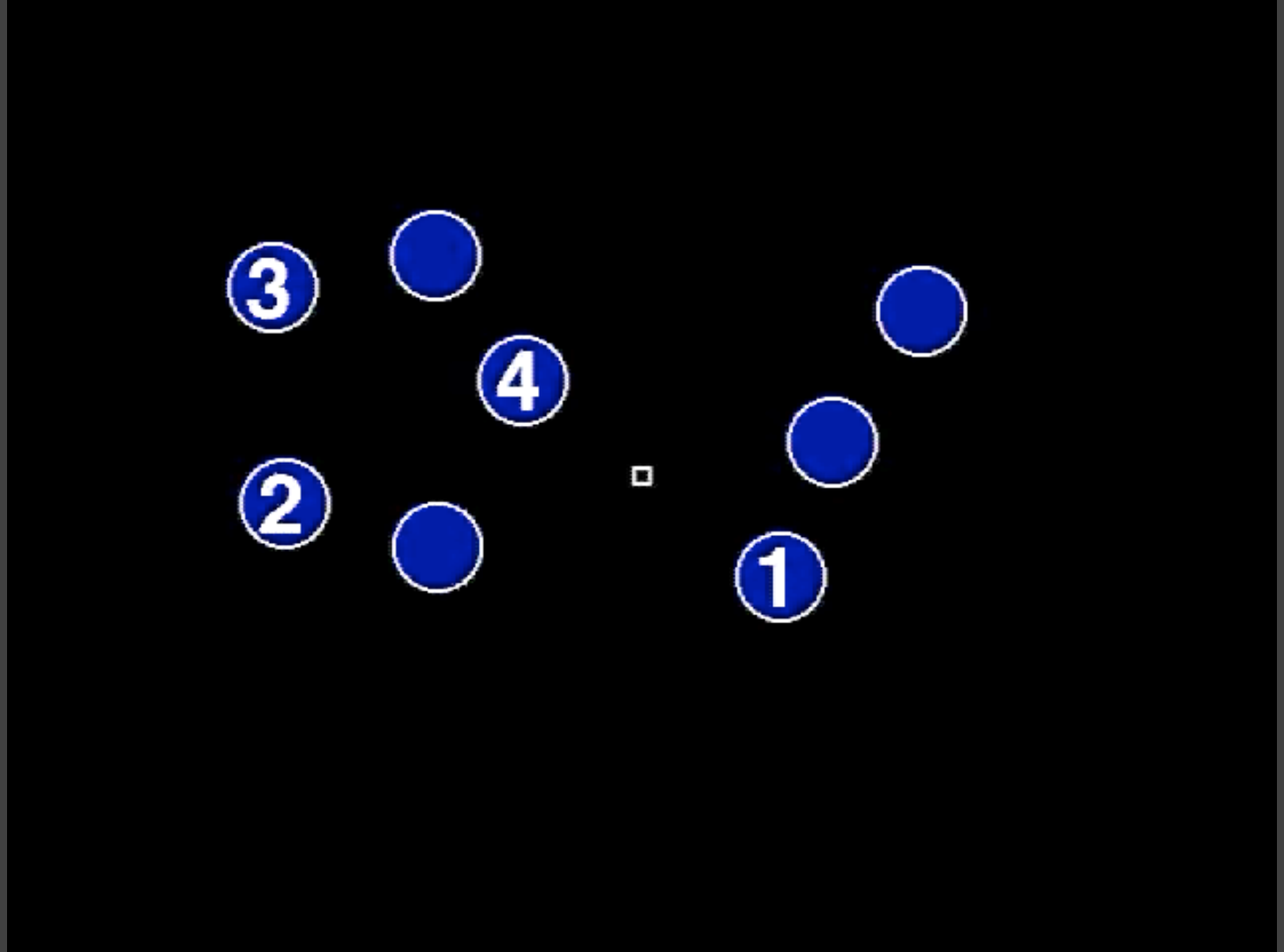
How many dots can we simultaneously track?










3
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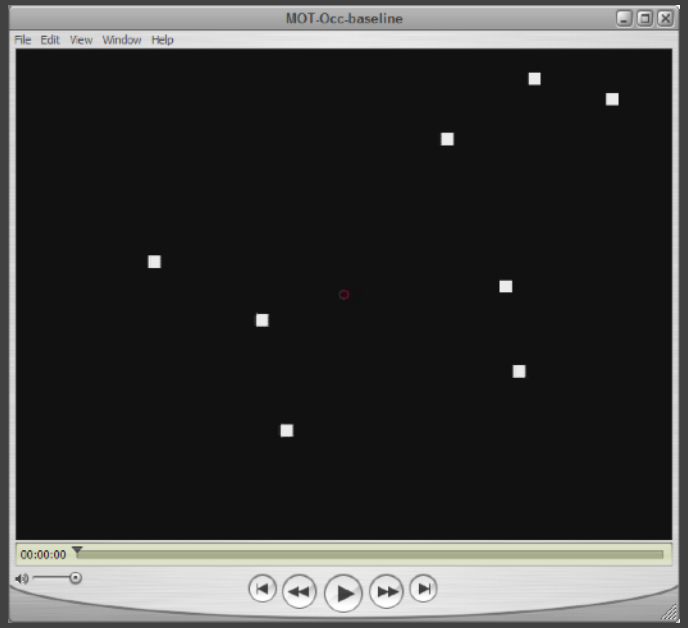
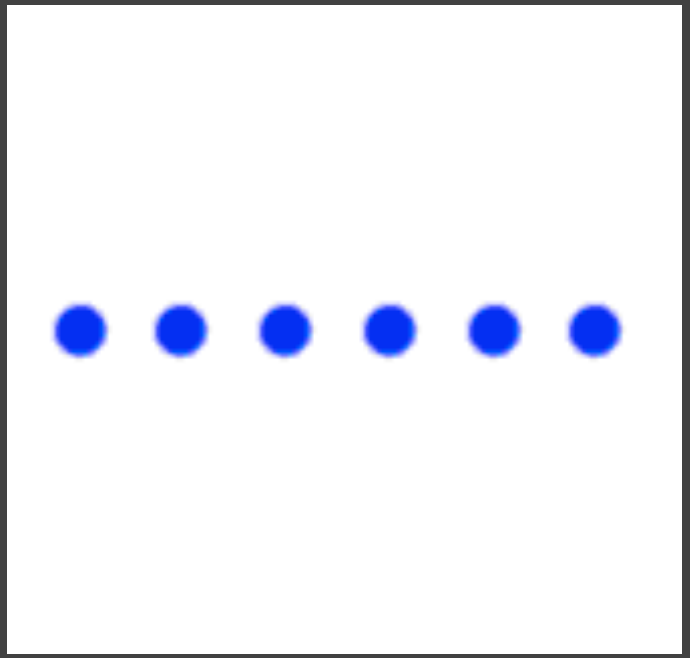
Tracking Multiple Targets



How many dots can we simultaneously track?

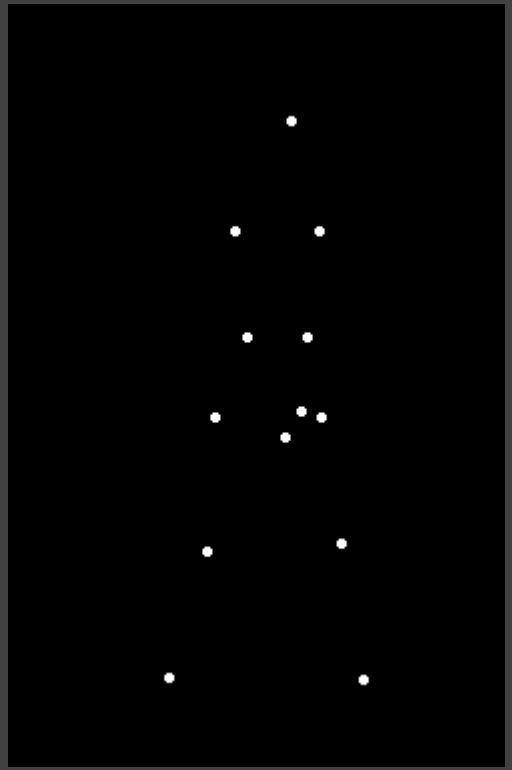
~4-6. Difficulty increases sig. at 6. [Yantis 92, Pylyshn 88, Cavanagh 05]

Grouped Dots Count as 1 Object



Dots moving together are grouped

Grouping of Biological Motion



[Johansson 73]

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

Motions Show Transitions

See change from one state to next

start

Motions Show Transitions

See change from one state to next

end

Motions Show Transitions

See change from one state to next

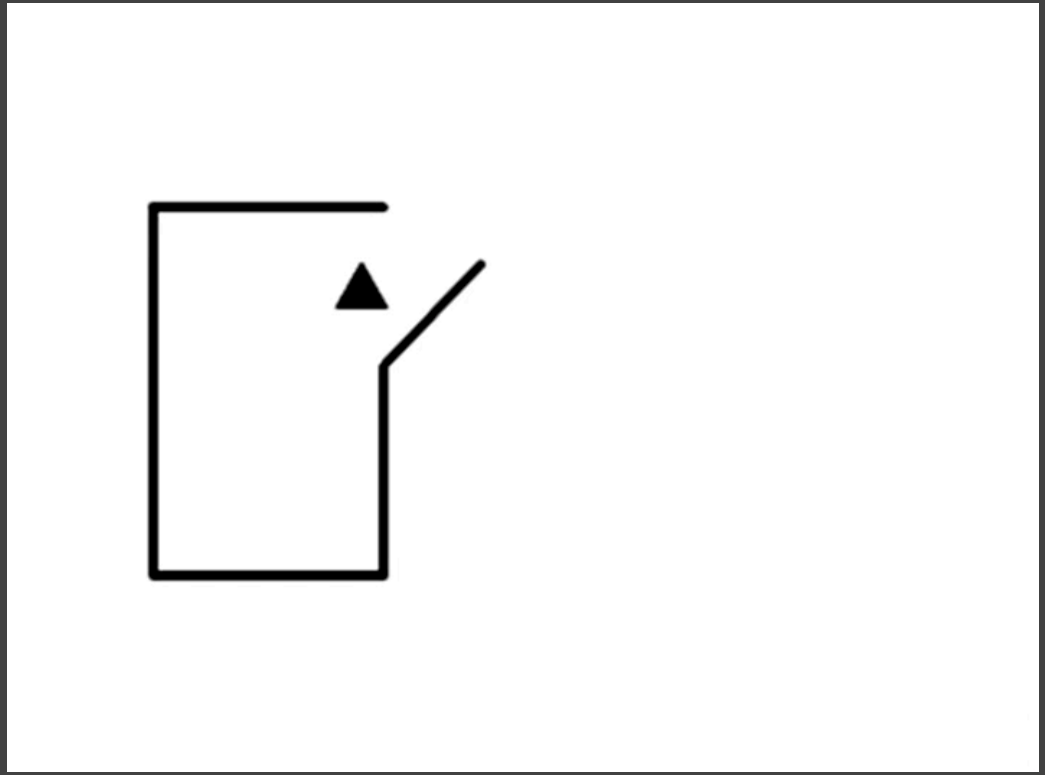
start end

Shows transition better, but

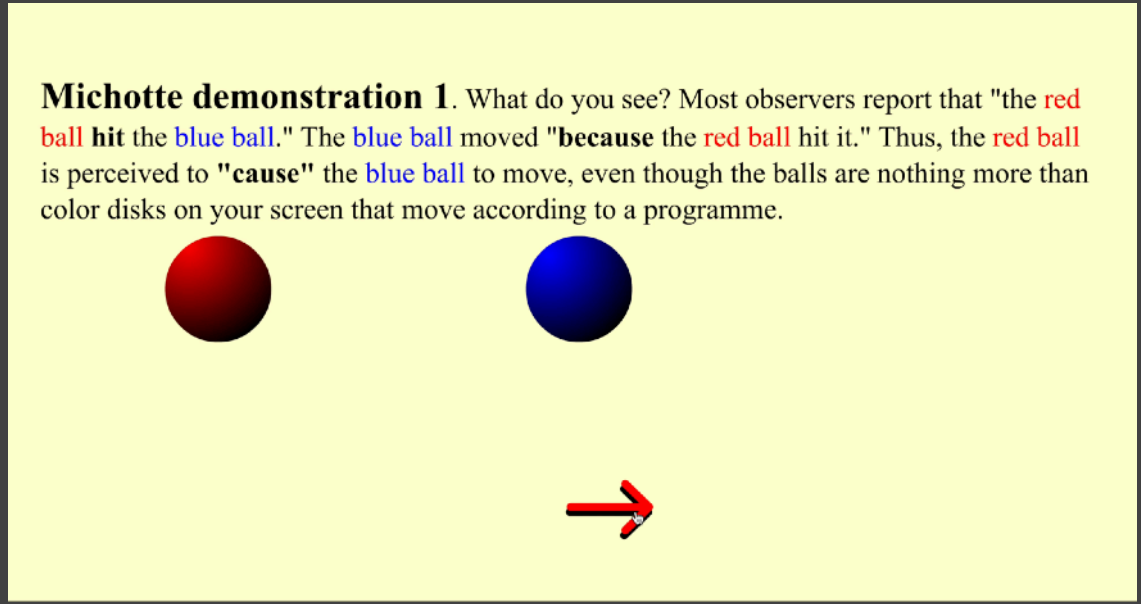
Still may be too fast, or too slow

Too many objects may move at once

Constructing Narratives [Heider 44]

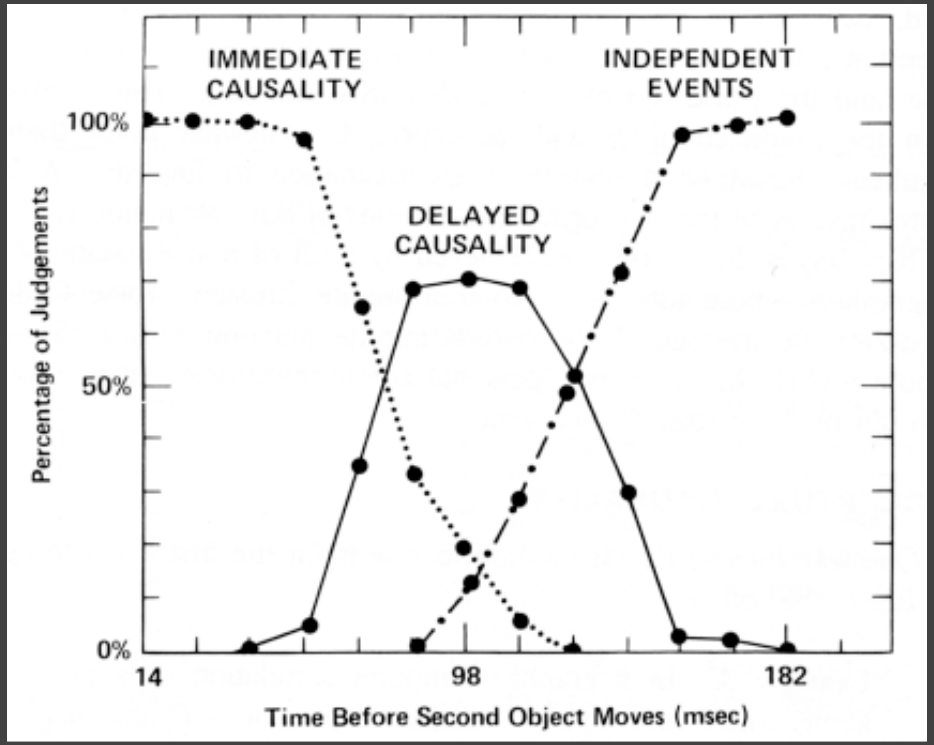


Attribution of Causality [Michotte 46]



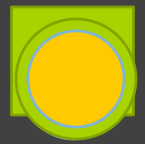
http://cogweb.ucla.edu/Discourse/Narrative/michotte-demo.swf

Attribution of Causality [Michotte 46]



[Reprint from Ware 04]

Animation	Helps?	Hurts?
Attention	direct attention	distraction
Constancy	change tracking	false relations
Causality	cause and effect	false agency
Engagement	increase interest	“chart junk”
Calibration		too slow: boring
		too fast: errors



Problems with Animation [Tversky]

Difficult to estimate paths and trajectories

Motion is fleeting and transient

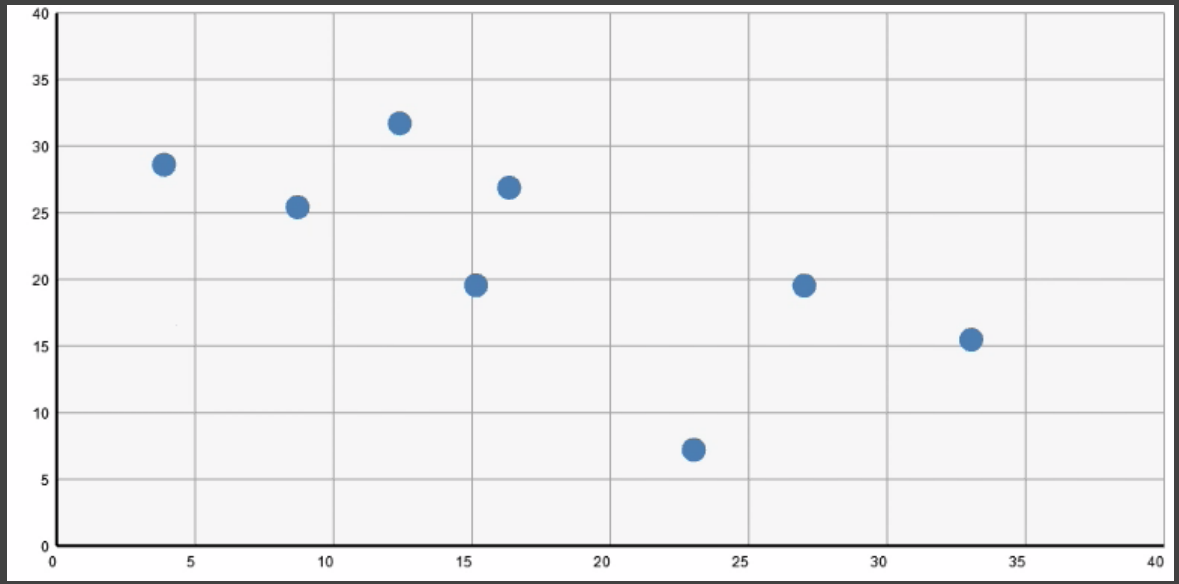
Cannot simultaneously attend to multiple motions

Parse motion into events, actions and behaviors

Misunderstanding and wrongly inferring causality

Anthropomorphizing physical motion may cause confusion or lead to incorrect conclusions

Animated Transitions in Statistical Graphics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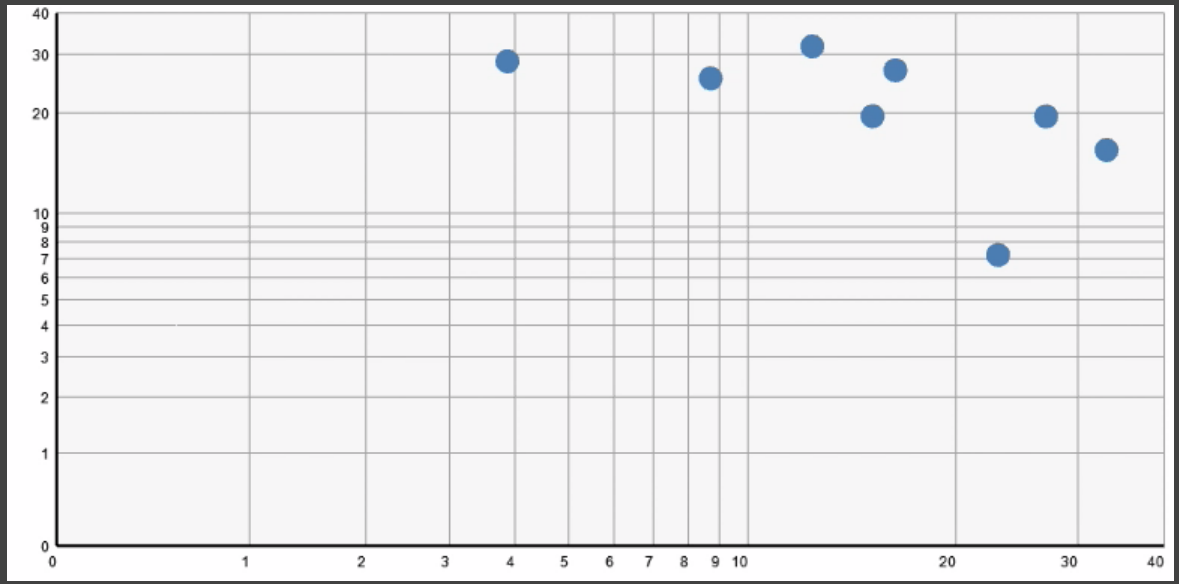
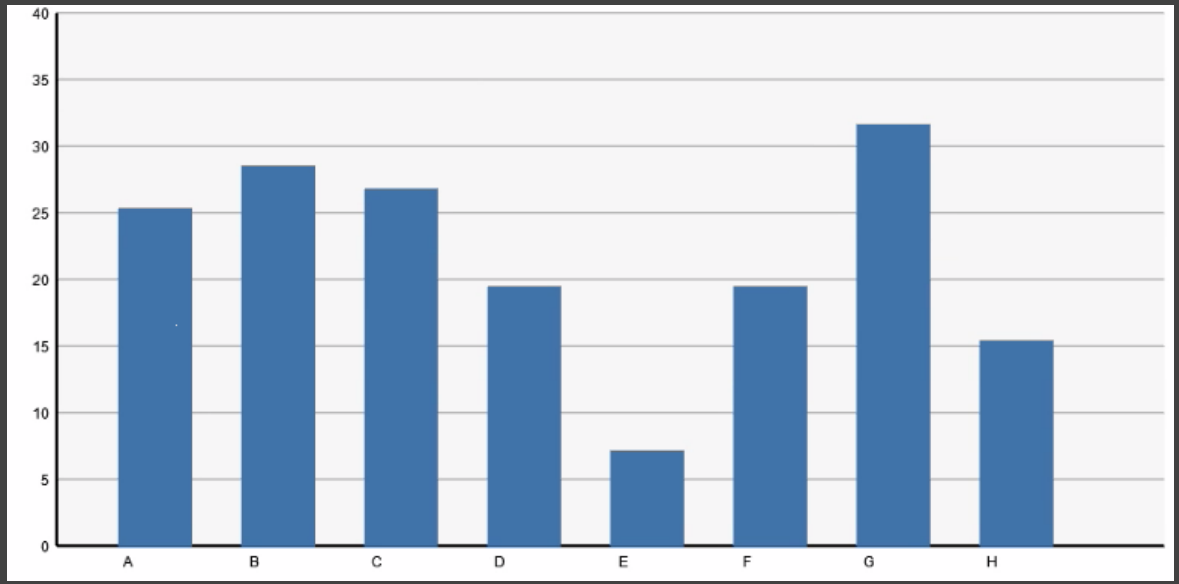
Log Transform

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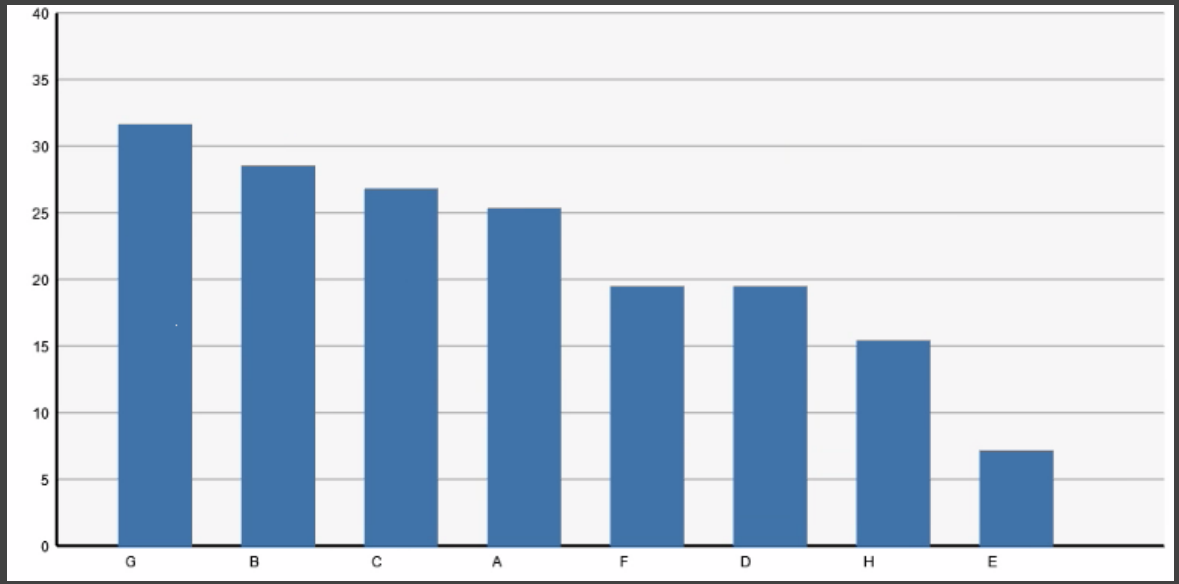
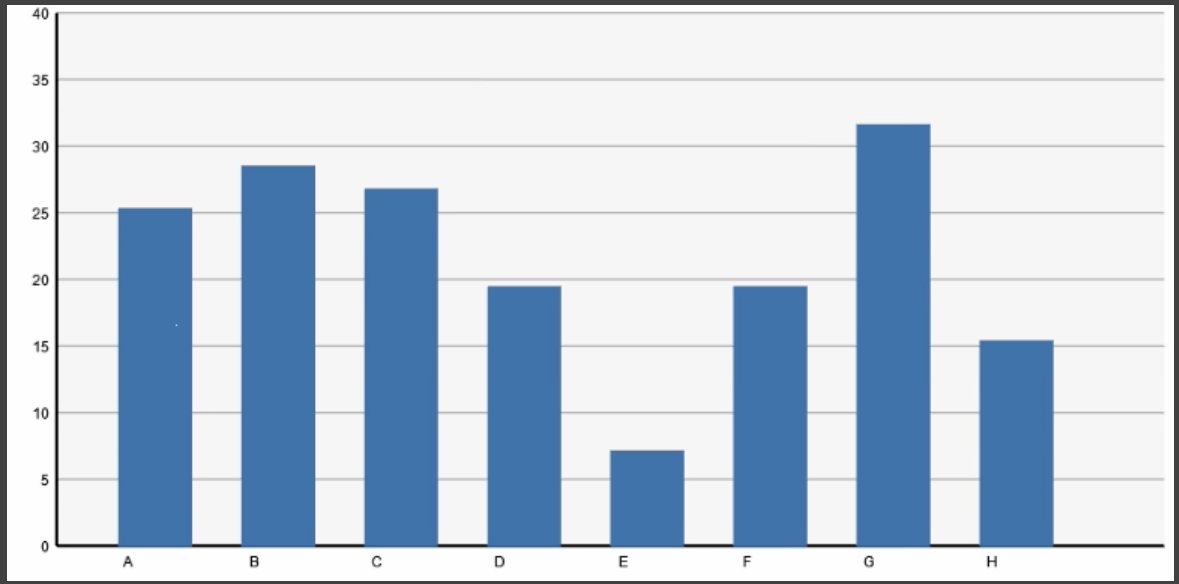
Sorting

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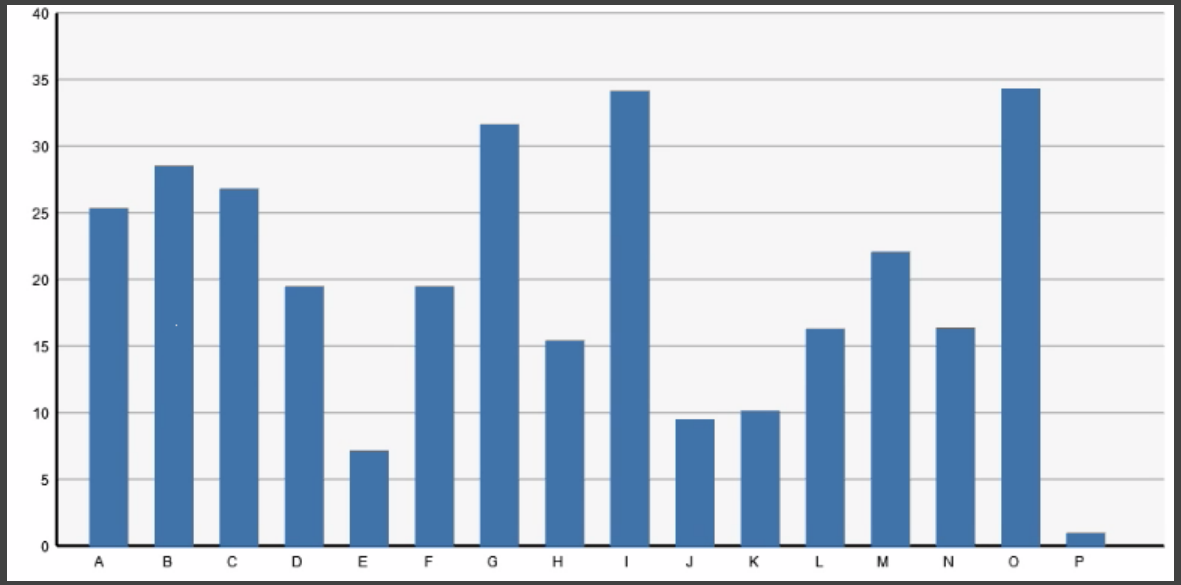
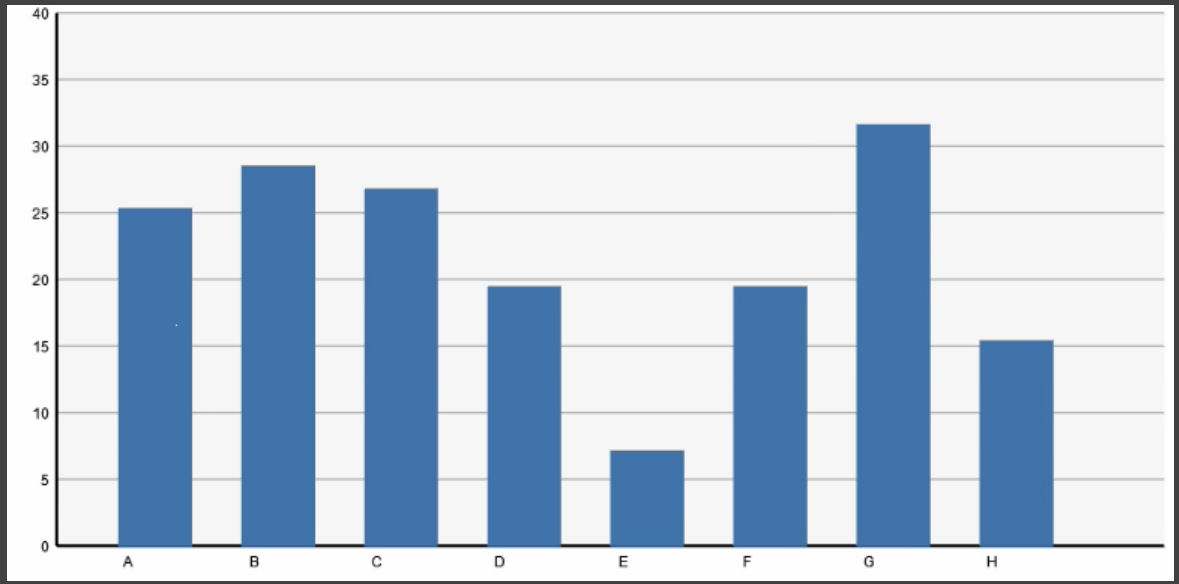
Filtering

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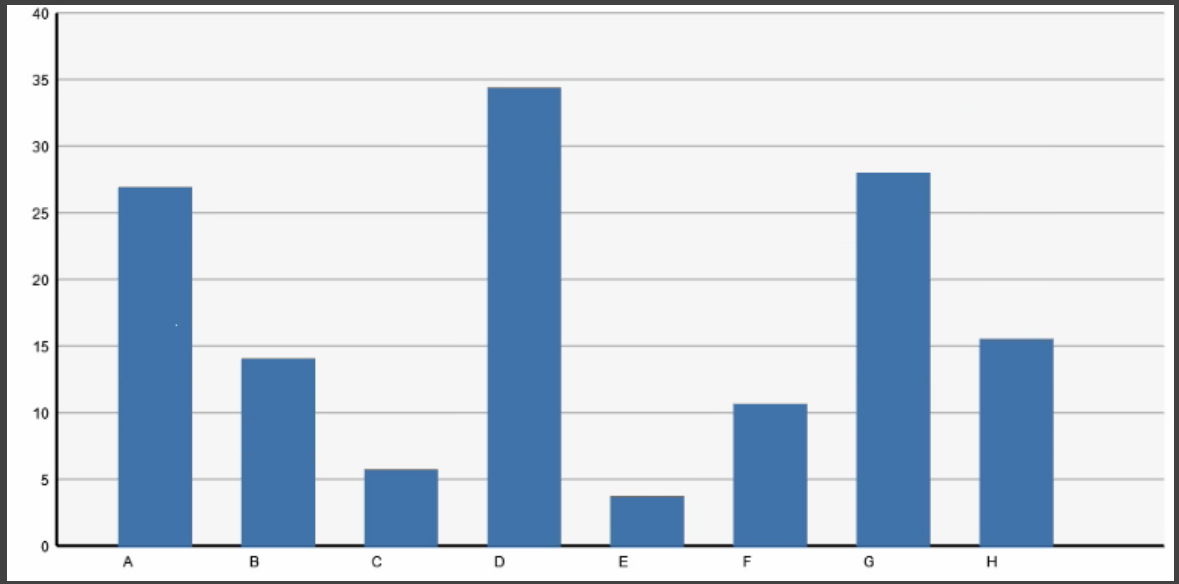
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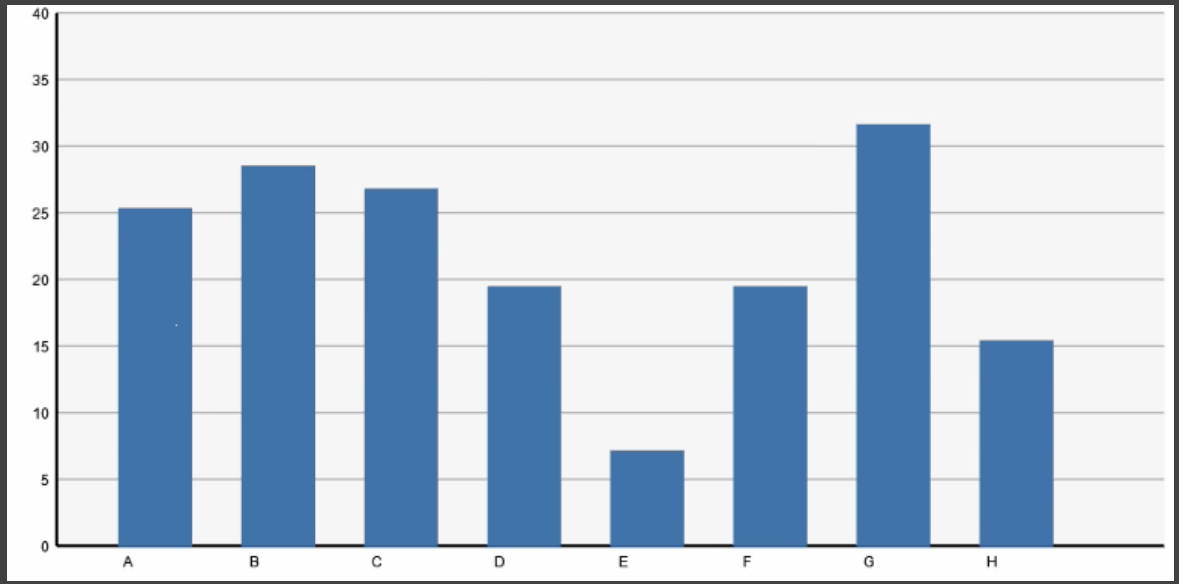
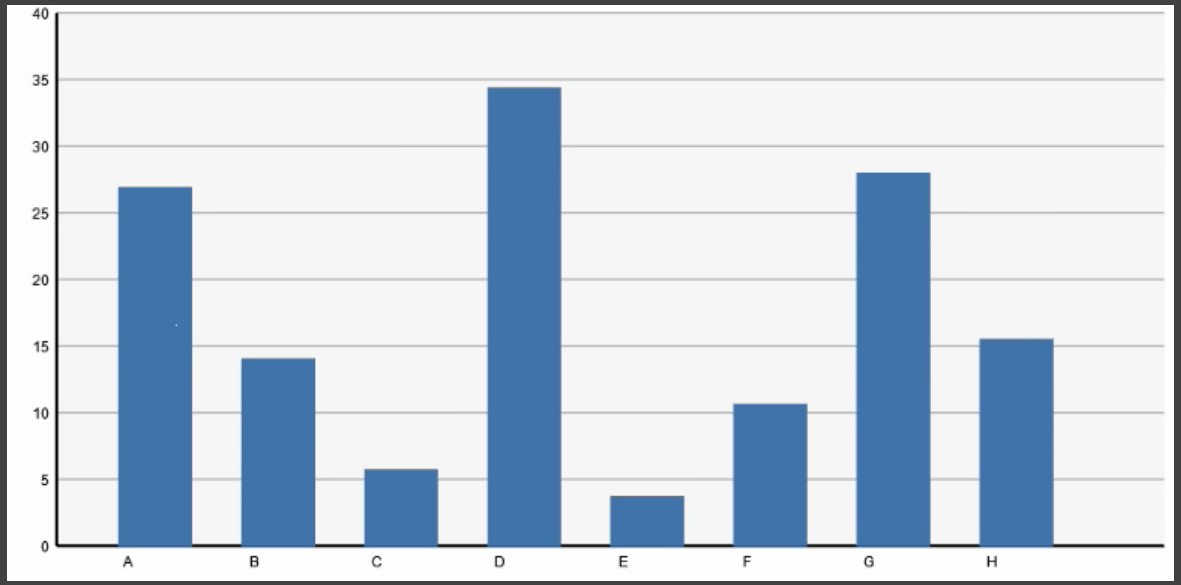
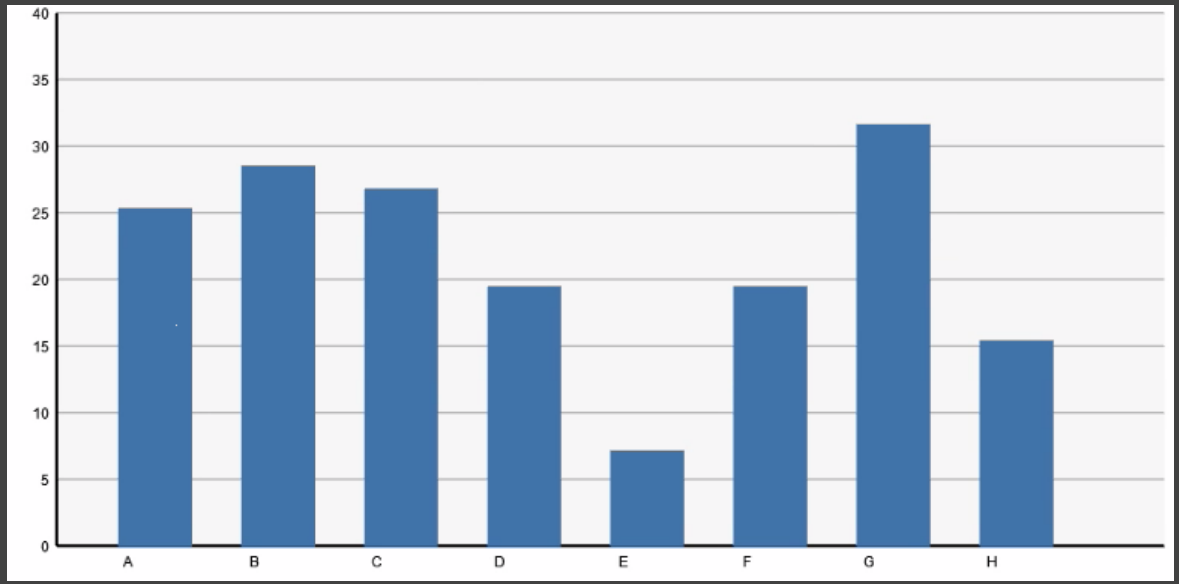


Month 1

Timestep



Month 2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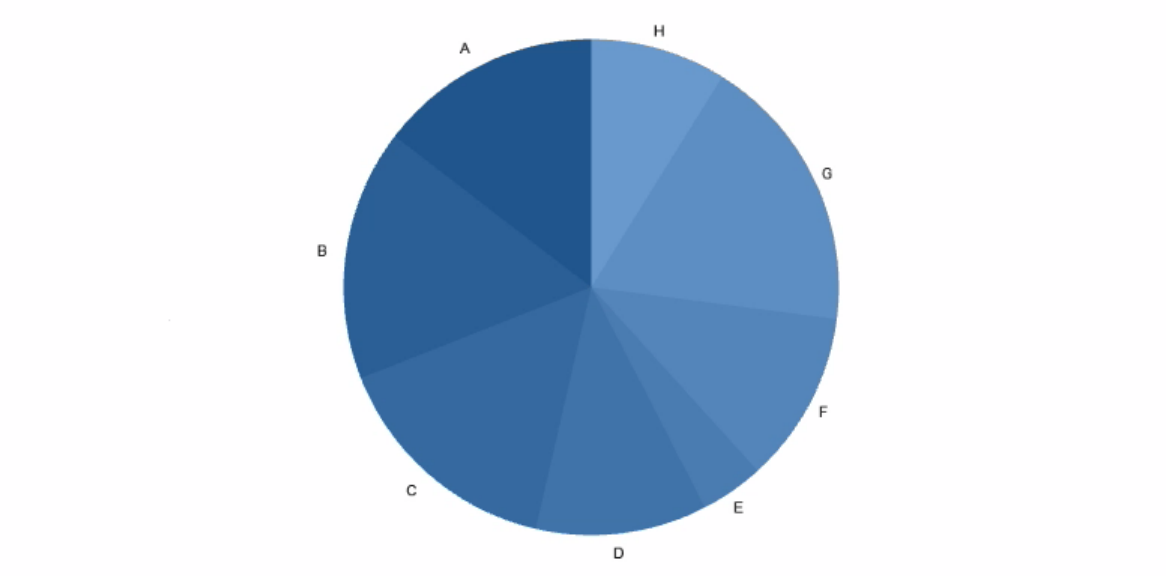
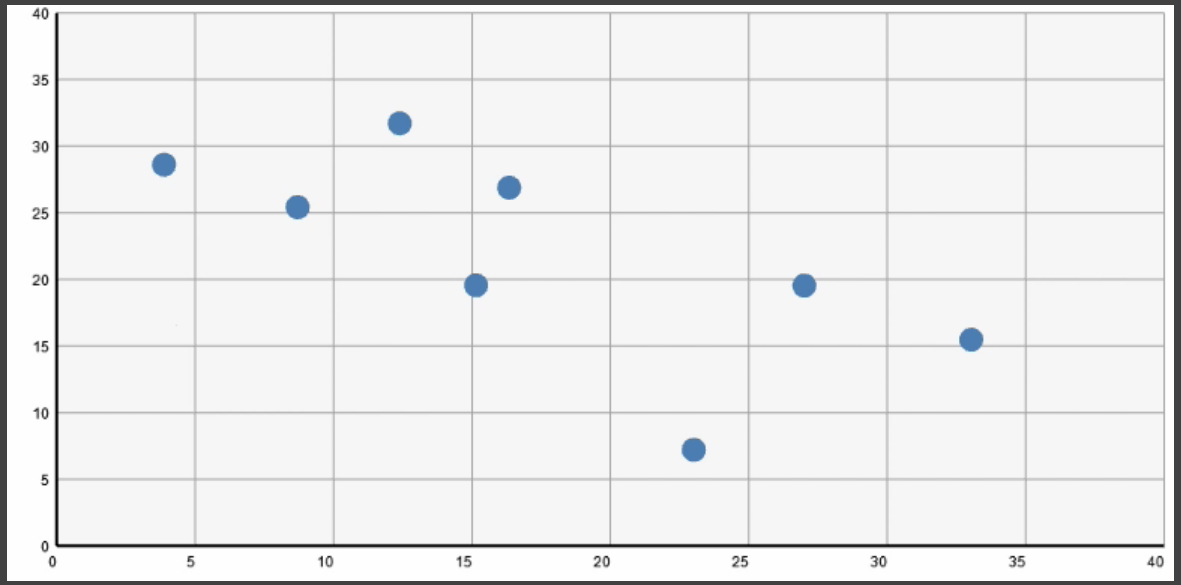
Change Encodings

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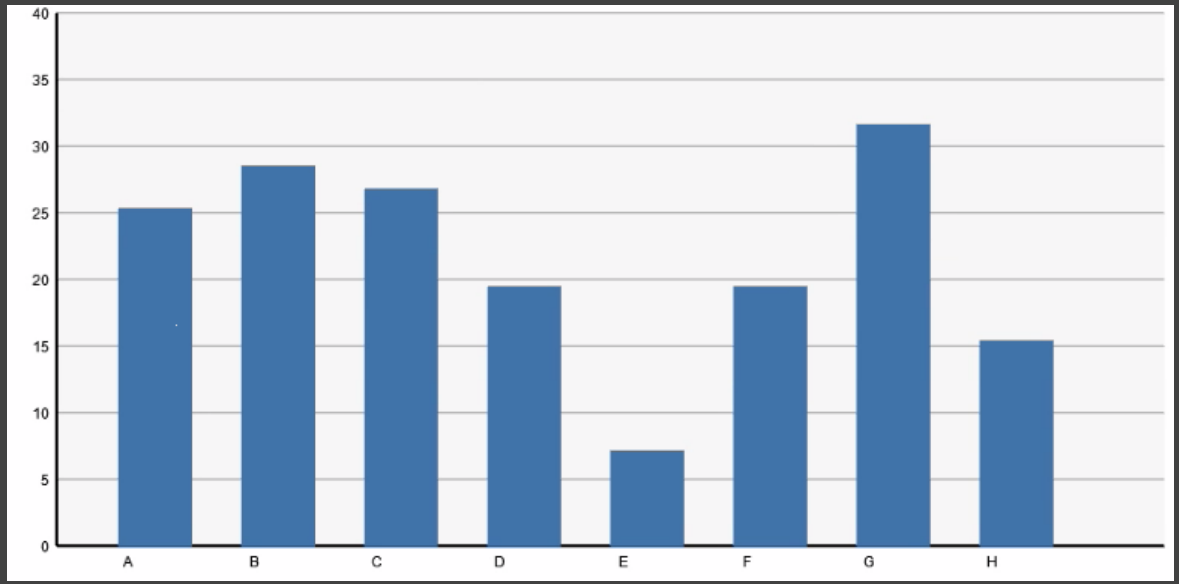
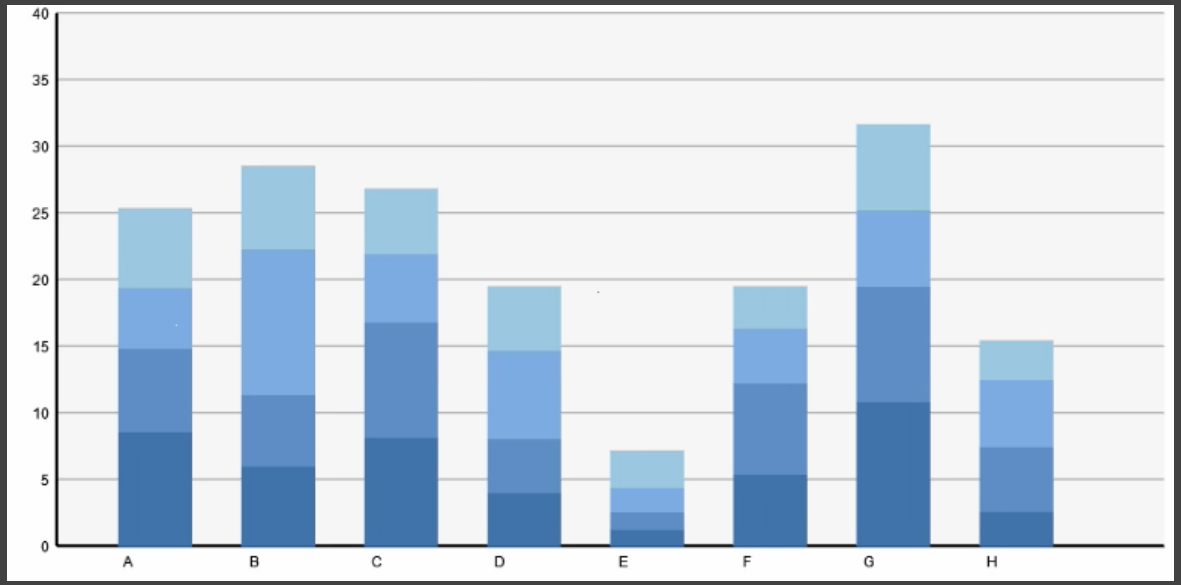
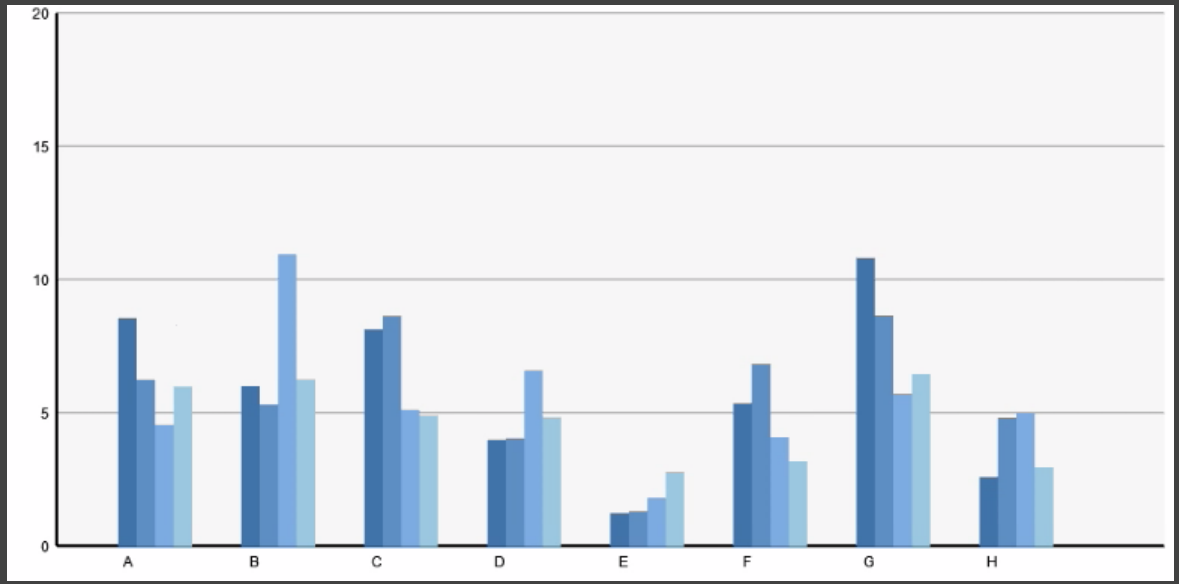
Change Data Dimensions



Change Data Dimensions



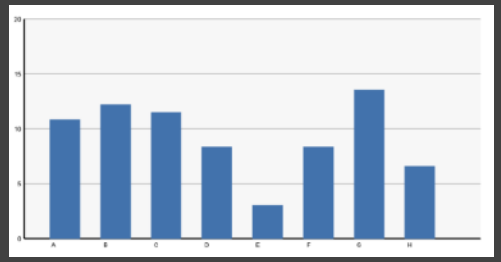
Change Encodings + Axis Scales



Data Graphics & Transitions

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

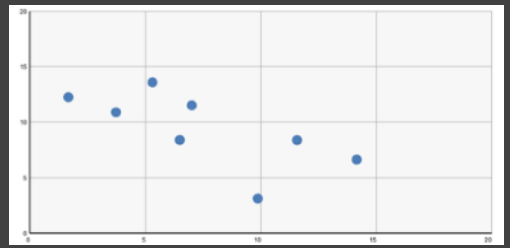
Visual Encoding



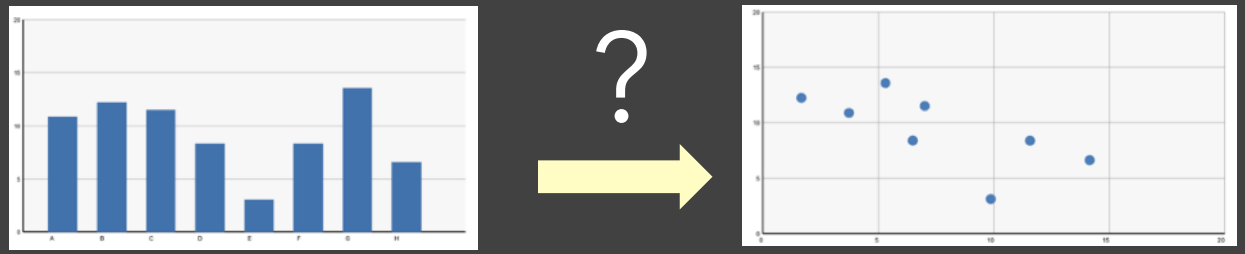
Change selected data dimensions or encodings

Animation to communicate changes?

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



Transitions between Data Graphics



During analysis and presentation it is common to transition between *related* data graphics.

Can animation help?
How does this impact perception?

Principles for Animation

Congruence *Expressiveness?*

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

Apprehension *Effectiveness?*

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

[from Tversky 02]

Principles for Animation [Heer]

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

Principles for Animation [Heer]

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

Principles for Animation [Heer]

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

Principles for Animation [Heer]

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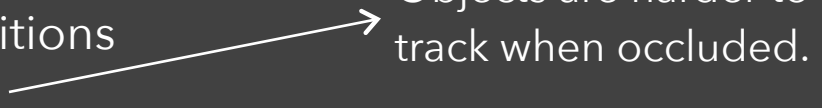

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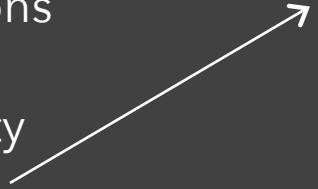


Keep animation as simple as possible. If complicated, break into simple stages.

Animated Transitions in Statistical Data Graphics

Jeffrey Heer
George G. Robertson

Microsoft Research

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 lines)

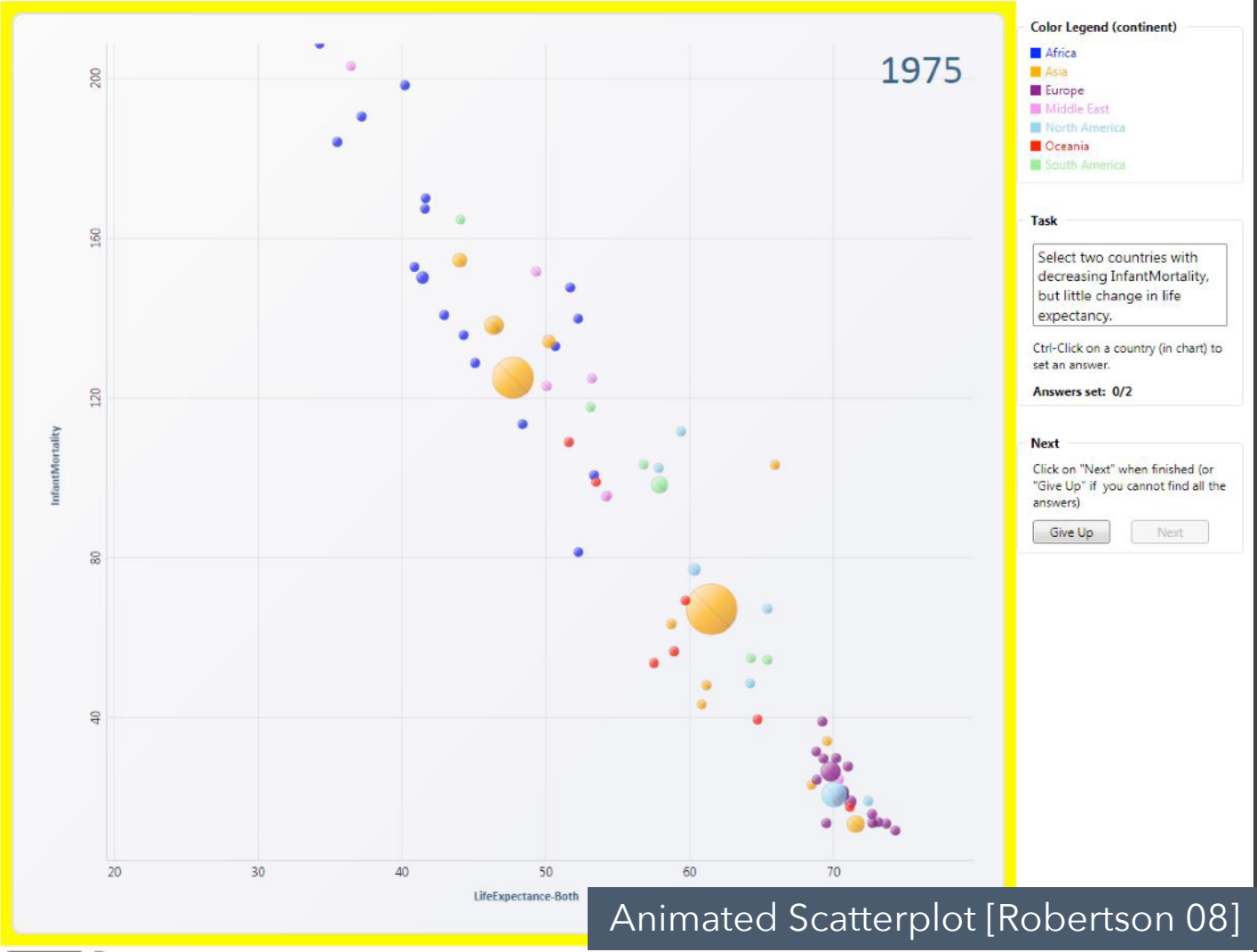
Subjects preferred animated transitions

Animation in Trend Visualization

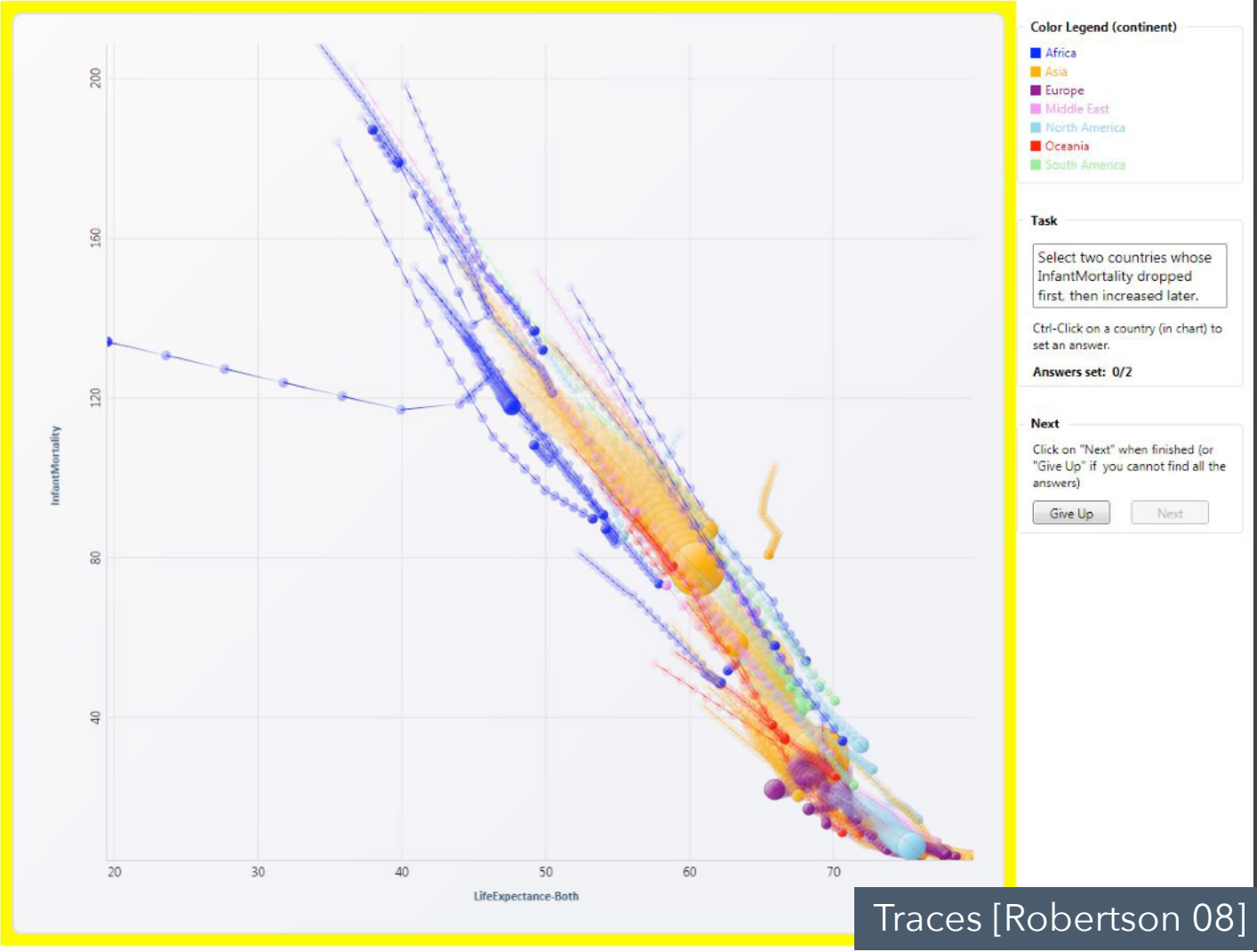
Heer & Robertson study found that animated transitions are better than static transitions for estimating changing values.

How does animation fare vs. static time-series depictions (as opposed to static transitions)?

Experiments by Robertson et al, InfoVis 2008
(10 Year Test-of-Time Award at InfoVis 2018!)



Animated Scatterplot [Robertson 08]



Traces [Robertson 08]

Color Legend (continent)

- Africa
- Asia
- Europe
- Middle East
- North America
- Oceania
- South America

Task

Select two countries whose InfantMortality dropped first, then increased later.

Ctrl-Click on a country (in chart) to set an answer.

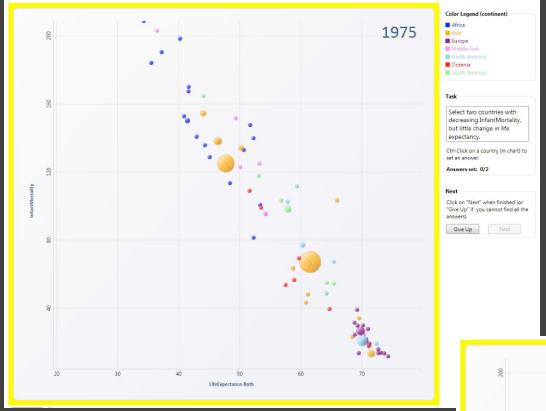
Answers set: 0/2

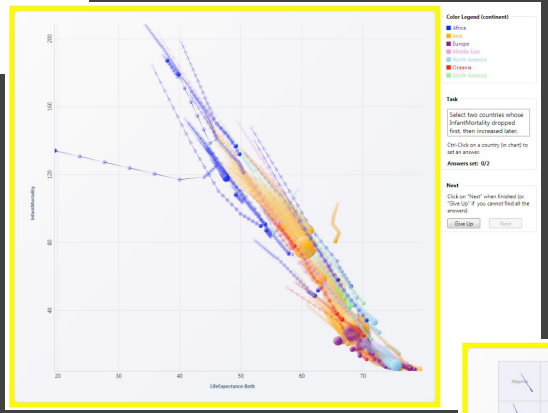
Next

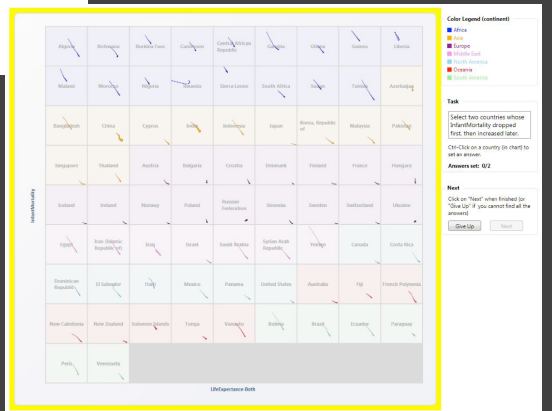
Click on "Next" when finished (or "Give Up" if you cannot find all the answers)

Give Up | Next

Small Multiples [Robertson 08]







Which to prefer for analysis?
For presentation?

Study: Analysis & Presentation

Subjects asked comprehension questions.
Presentation condition included narration.

Multiples 10% *more accurate* than animation

Presentation: Anim. 60% *faster* than multiples
Analysis: Animation 82% *slower* than multiples

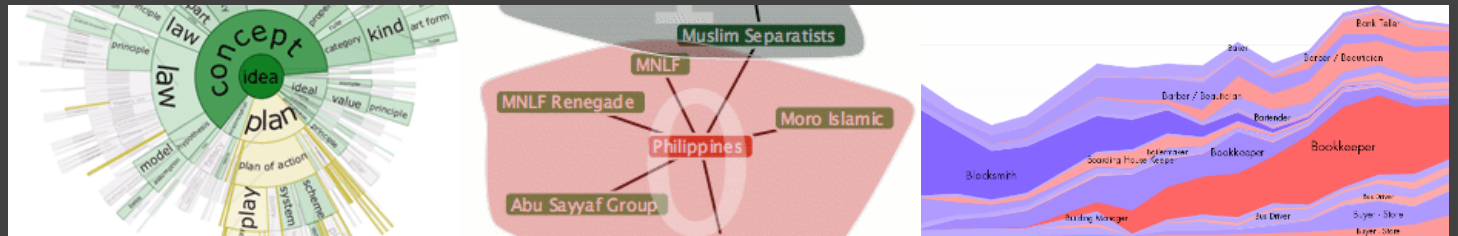
User preferences favor animation (even though less accurate and slower for analysis!)

Administrivia

A3: Interactive Visualization

Create an interactive visualization in a team of 1-3 people. Choose a dataset and a driving question, develop a visualization + interaction techniques, then deploy your visualization on the web.

1. Form team, topic & data and start prototyping.
2. Complete implementation and submit to Gradescope by **EOD Tuesday, February 17**.



Implementing Animation

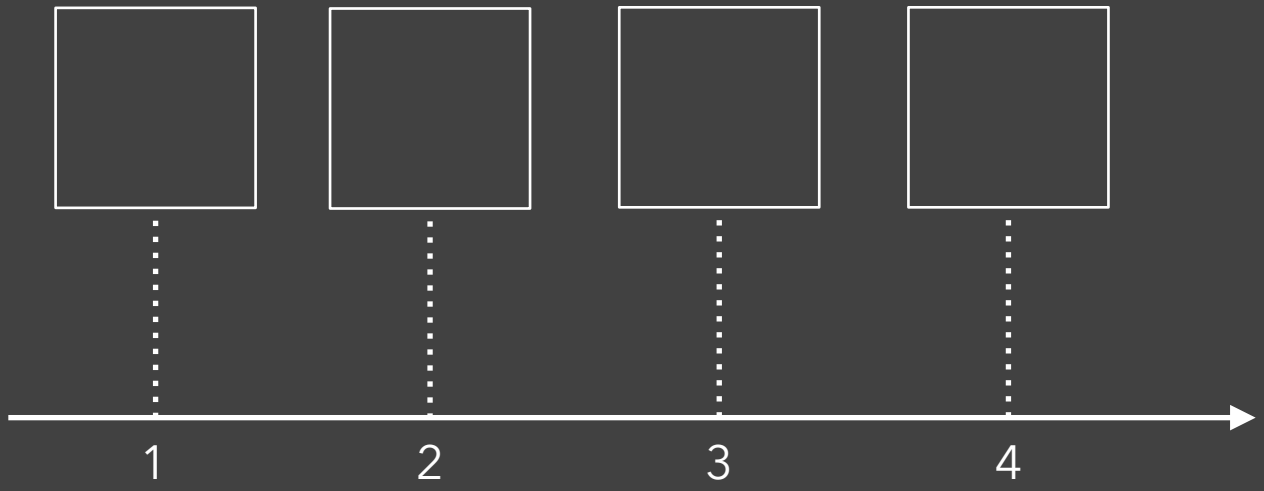
Animation Approaches

Frame-Based Animation

Redraw scene at regular interval (e.g., 16ms)

Developer defines the redraw function

Frame-Based Animation



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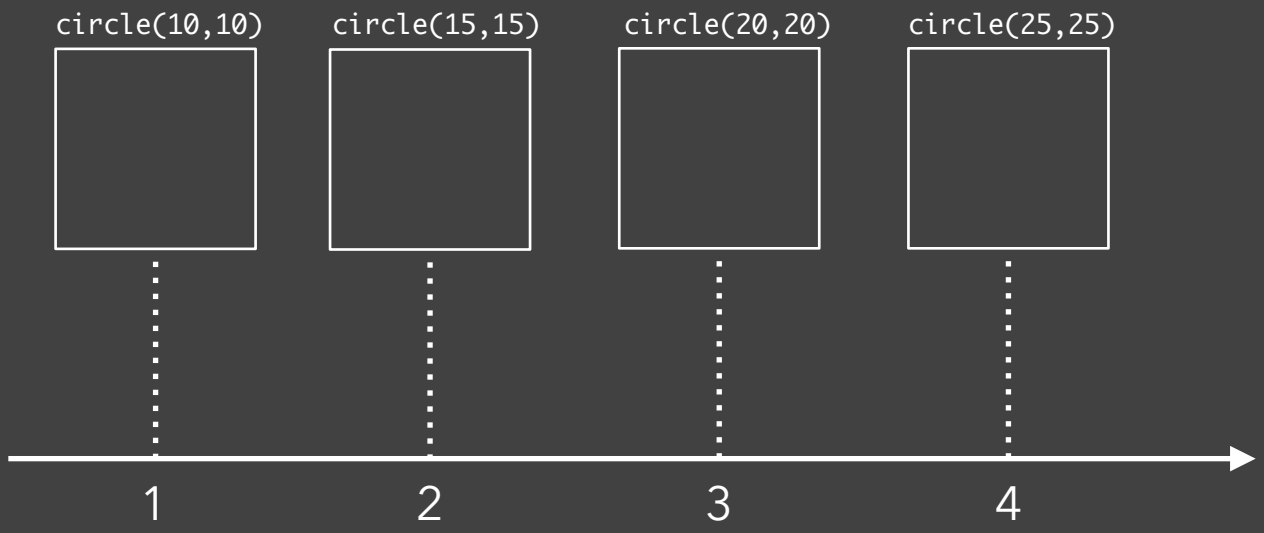

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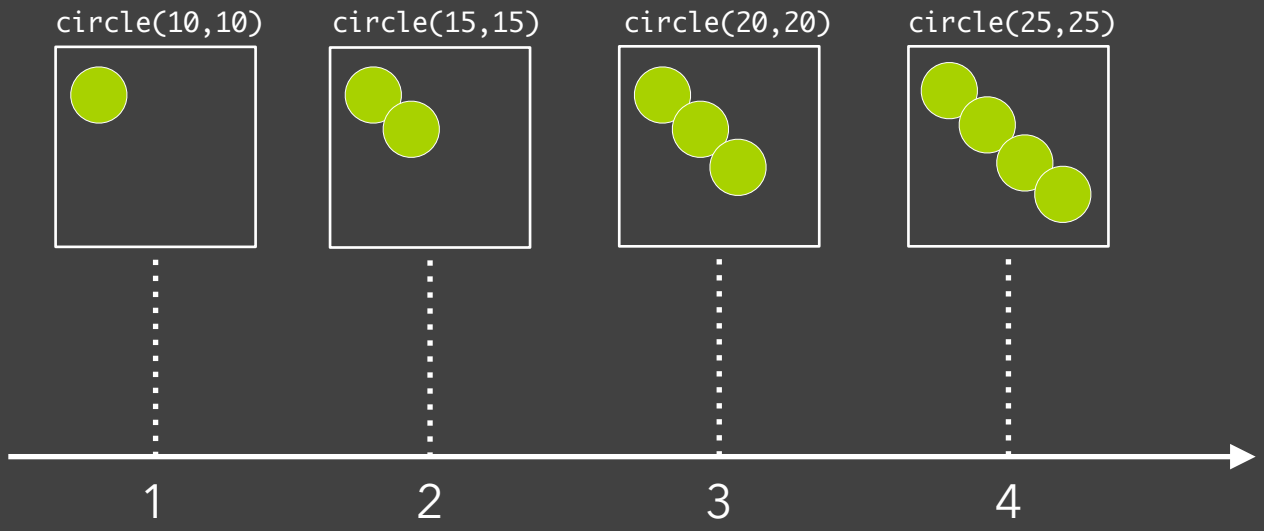

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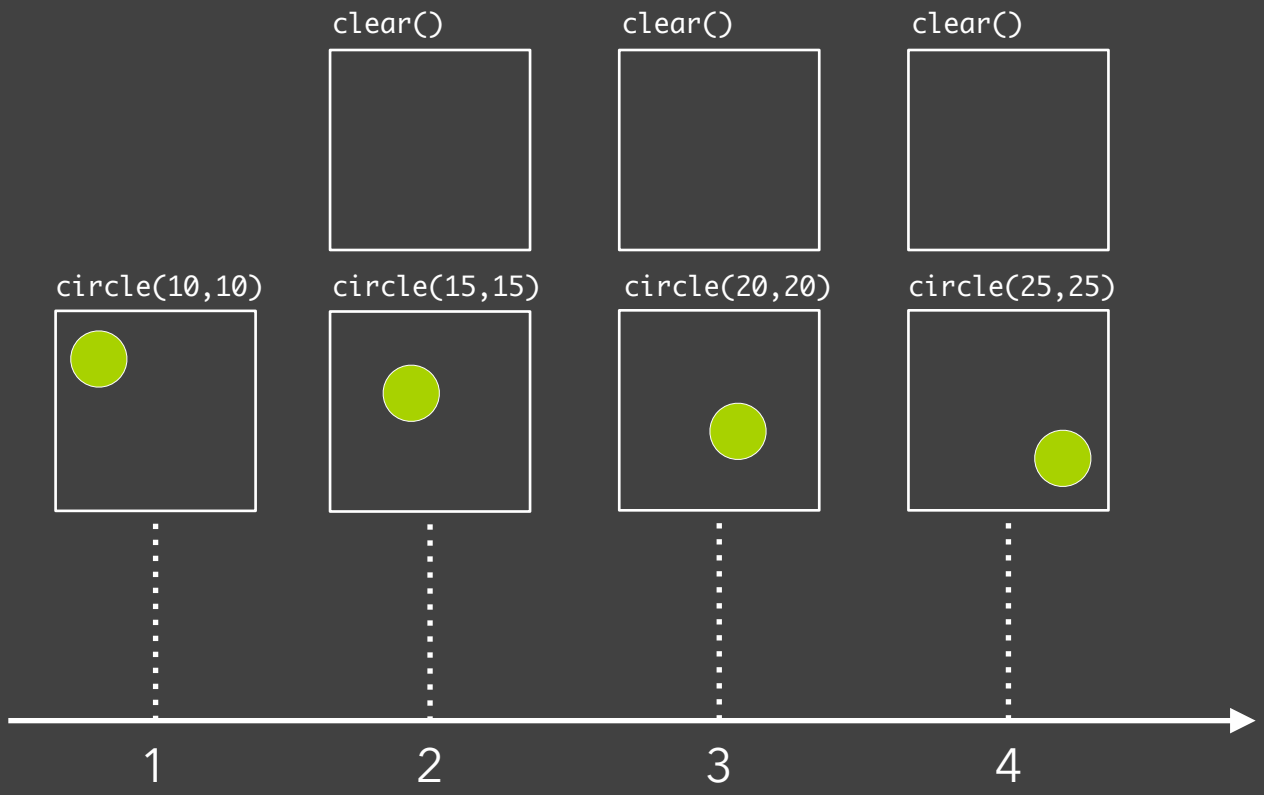

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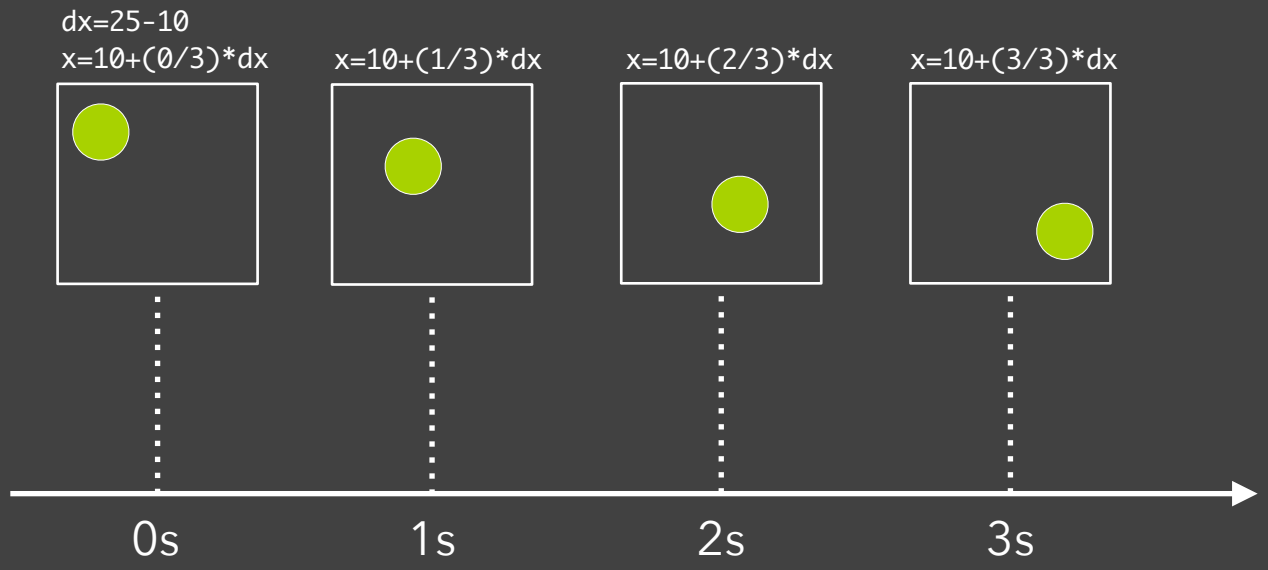
Transition-Based Animation (Hudson & Stasko '93)
Specify property value, duration & easing
Also called **tweening** (for "in-betweens")
Typically computed via **interpolation**

step(*fraction*) { $x_{now} = x_{start} + fraction * (x_{end} - x_{start})$; }

Timing & redraw managed by UI toolkit

Transition-Based Animation

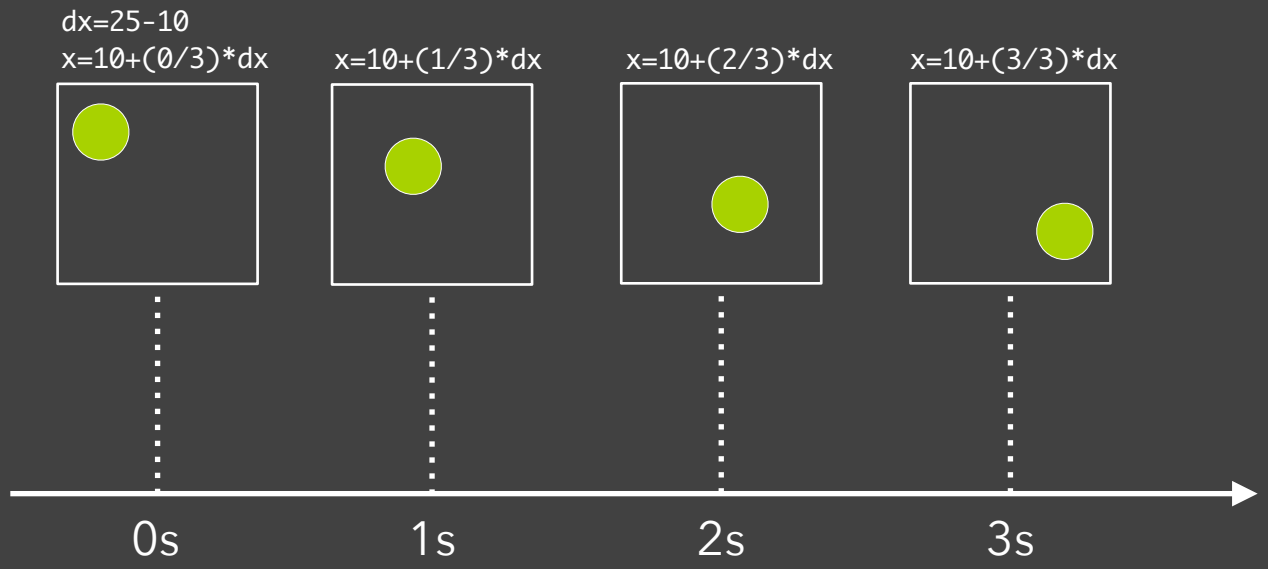
from: (10,10) **to:** (25,25) **duration:** 3sec



Transition-Based Animation

from: (10,10) **to:** (25,25) **duration:** 3sec

Toolkit handles frame-by-frame updates!



D3 Transitions

Any d3 ***selection*** can be used to drive animation.

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// Select SVG rectangles and bind them to data values.
var bars = svg.selectAll(“rect.bars”).data(values);

// Static transition: update position and color of bars.
bars
    .attr(“x”, d => xScale(d.foo))
    .attr(“y”, d => yScale(d.bar))
    .style(“fill”, d => colorScale(d.baz));
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// Select SVG rectangles and bind them to data values.
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// Animated transition: interpolate to target values using default timing
bars.transition()
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    // Animation is implicitly queued to run!
```

D3 Transitions, Continued

```
bars.transition()
    .duration(500)          // animation duration in milliseconds
    .delay(0)               // onset delay in milliseconds
    .ease(d3.easeBounce)    // set easing (or "pacing") style
    .attr("x", (d) => xScale(d.foo))
    …
```

D3 Transitions, Continued

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    .duration(500)                // animation duration in milliseconds
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    .ease(d3.easeBounce)          // set easing (or "pacing") style
    .attr("x", (d) => xScale(d.foo))
    …

bars.exit().transition()          // animate elements leaving the display
   .style("opacity", 0)           // fade out to fully transparent
   .remove();                     // remove from DOM upon completion
```

Easing (or “Pacing”) Functions

Goals: stylize animation, improve perception.

Basic idea is to warp time: as *duration* goes from start (0%) to end (100%), dynamically adjust the *interpolation fraction* using an **easing function**.

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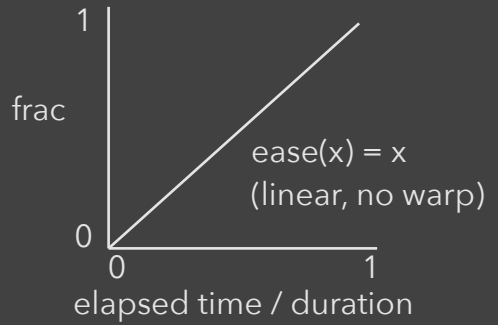

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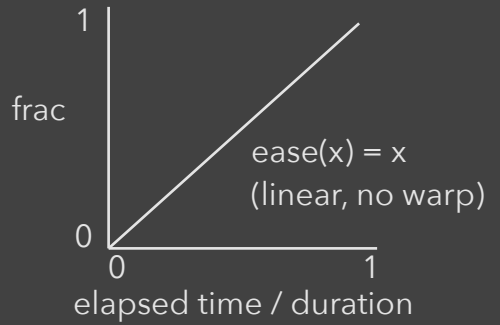

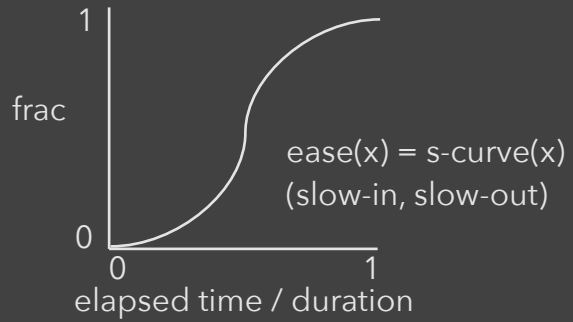

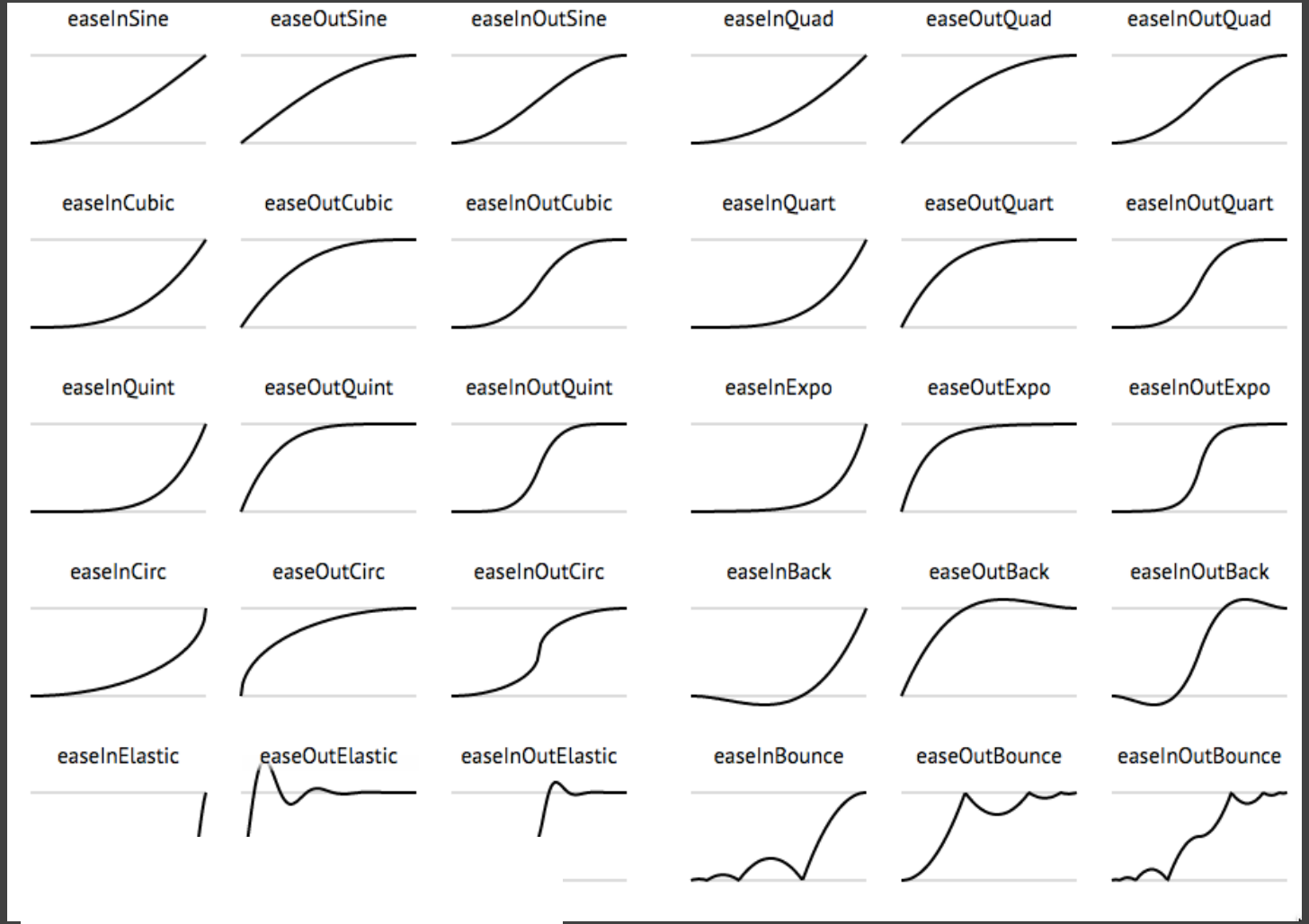
easeInSine
easeOutSine
easeInOutSine
easeInQuad
easeOutQuad
easeInOutQuad
easeInCubic
easeOutCubic
easeInOutCubic
easeInQuart
easeOutQuart
easeInOutQuart
easeInQuint
easeOutQuint
easeInOutQuint
easeInExpo
easeOutExpo
easeInOutExpo
easeInCirc
easeOutCirc
easeInOutCirc
easeInBack
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CSS Transitions

Extends CSS with Animated Transitions

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a {
  color: black;
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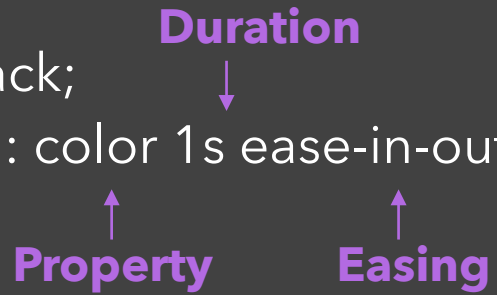

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Duration

Property

Easing

Animate color transition upon mouse in / out.

Summary

Animation is a salient visual phenomenon
Attention, object constancy, causality, timing
Design with care: congruence & apprehension

For transitions, animation has demonstrated benefits, but **consider task and timing**