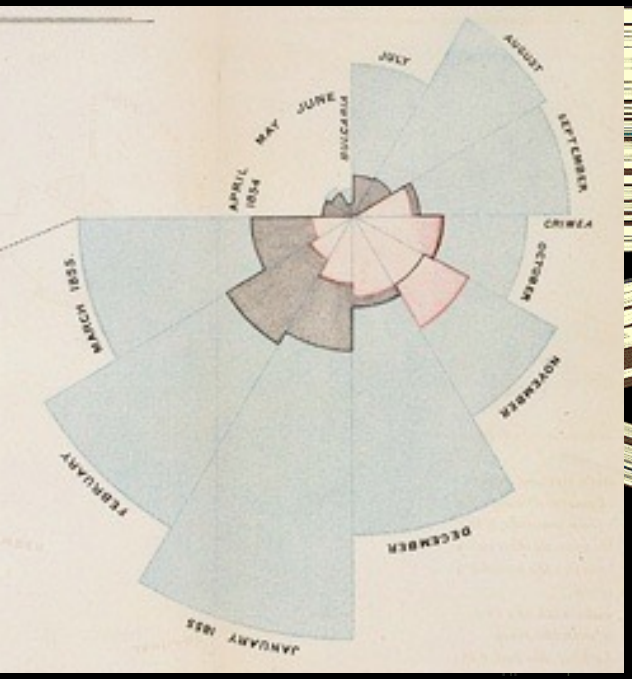
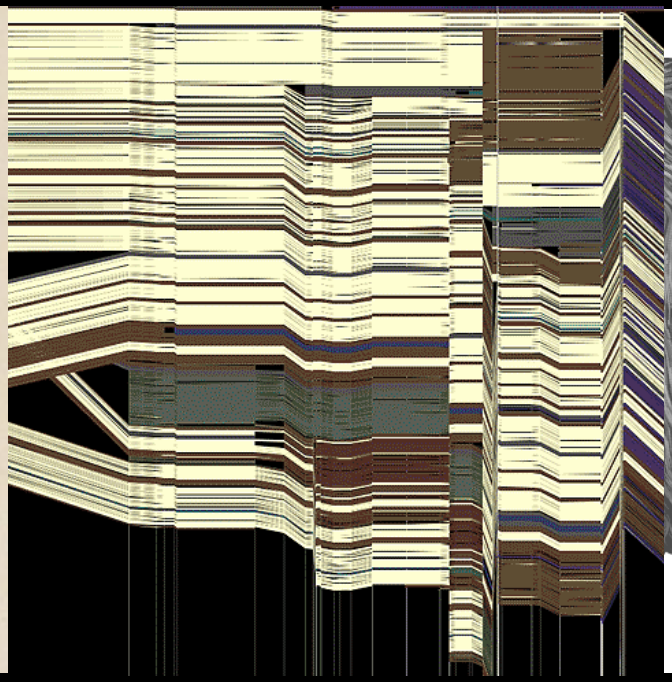
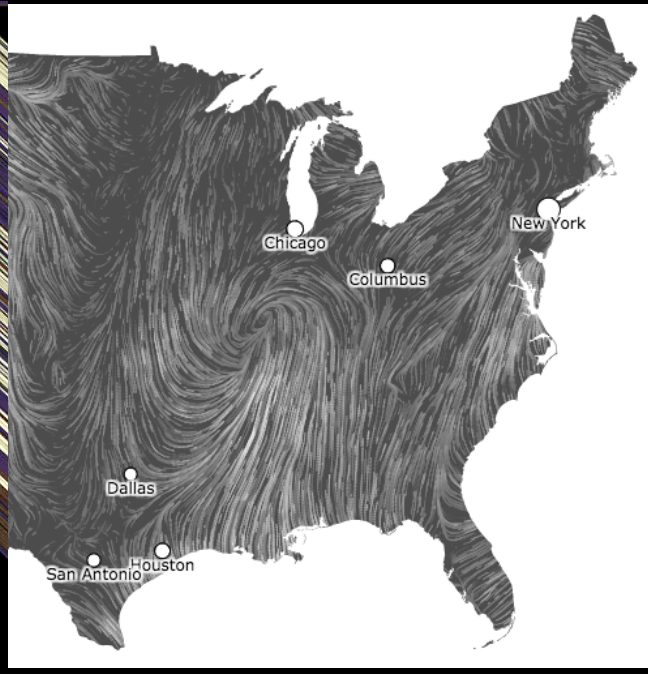
CSE 442 - Data Visualization

# Animation






Jeffrey Heer University of Washington

# Why Use Motion?

Visual variable to encode data

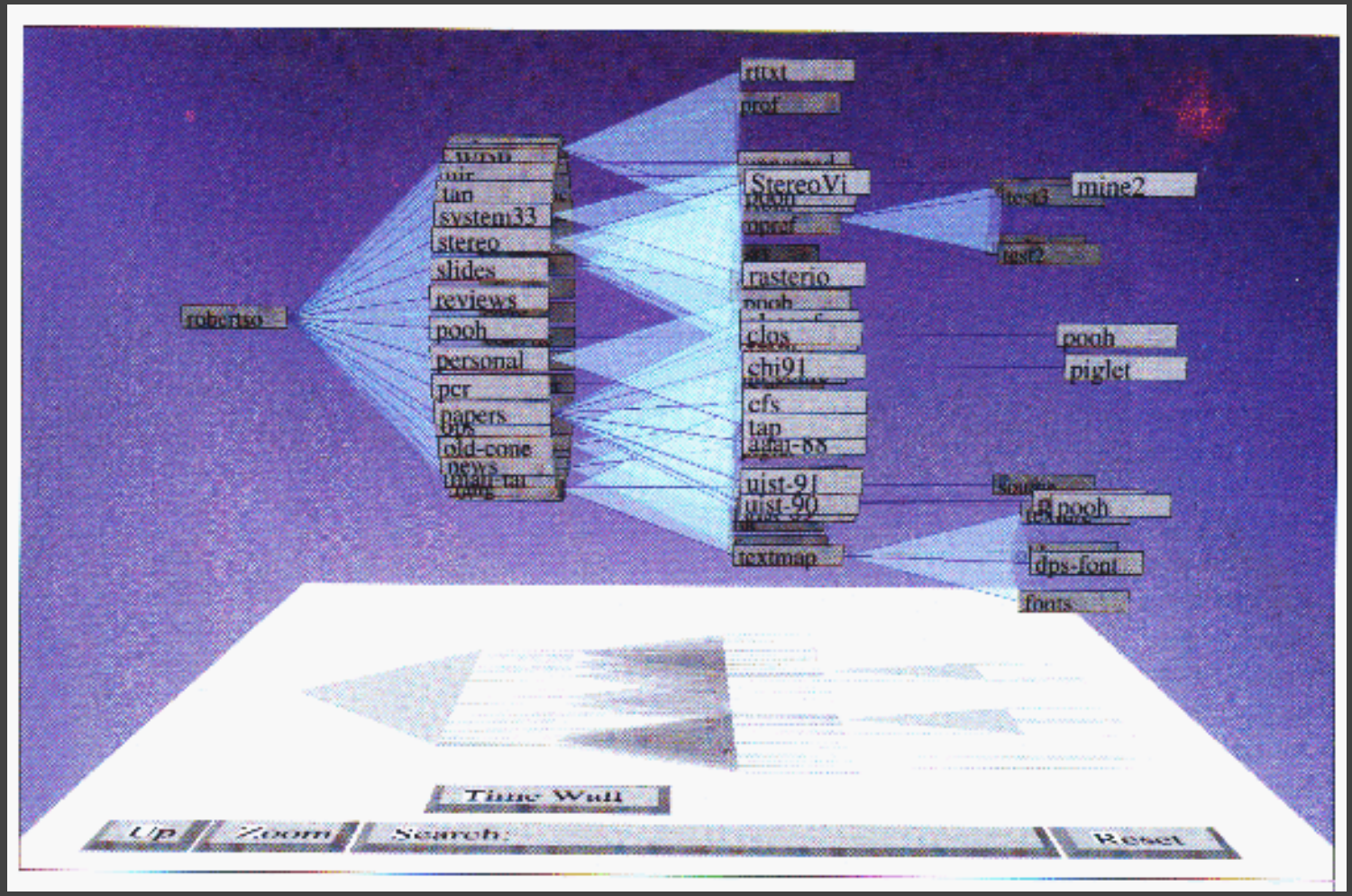
Direct attention

Understand system dynamics

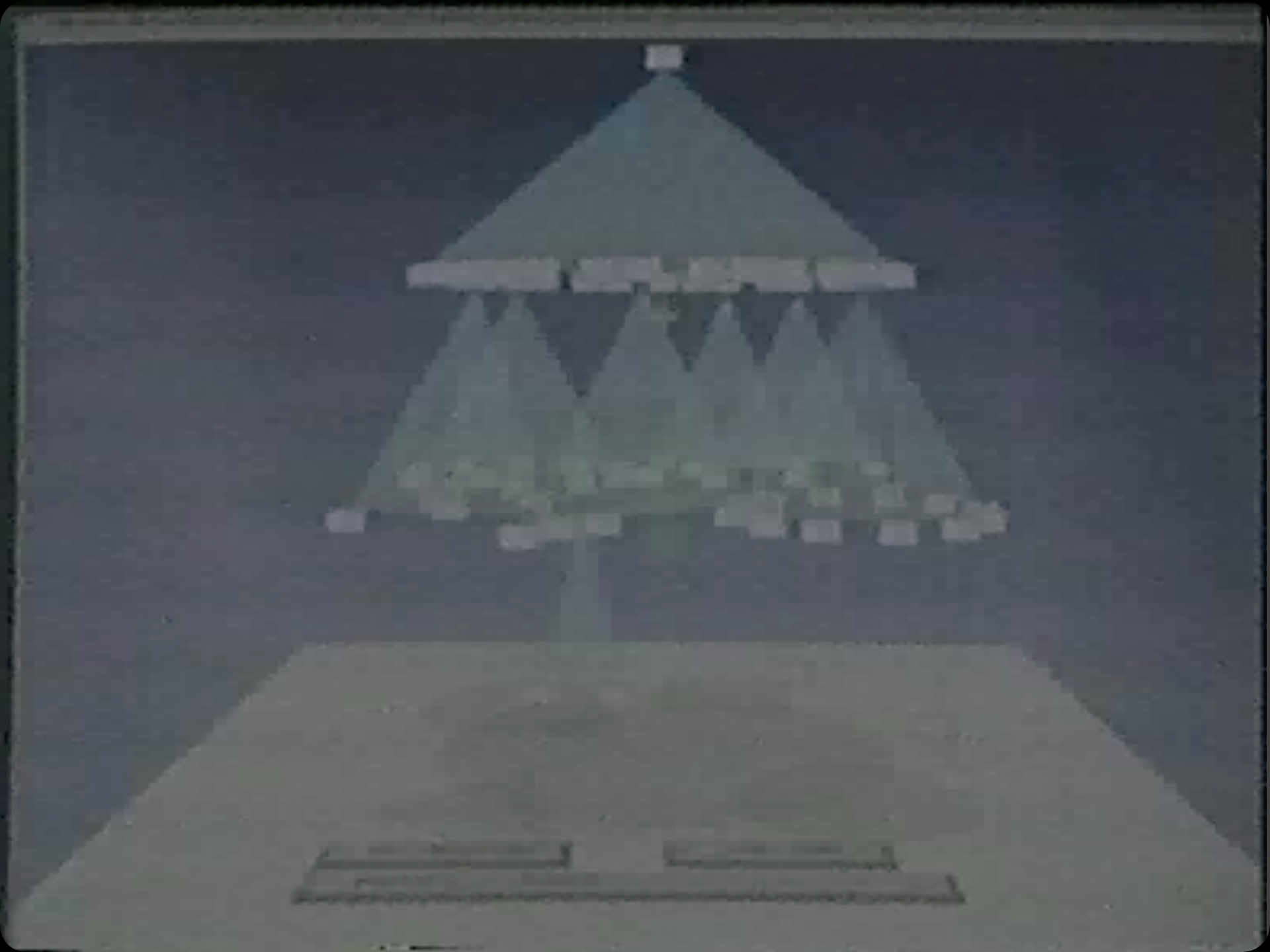
Understand state transition

Increase engagement

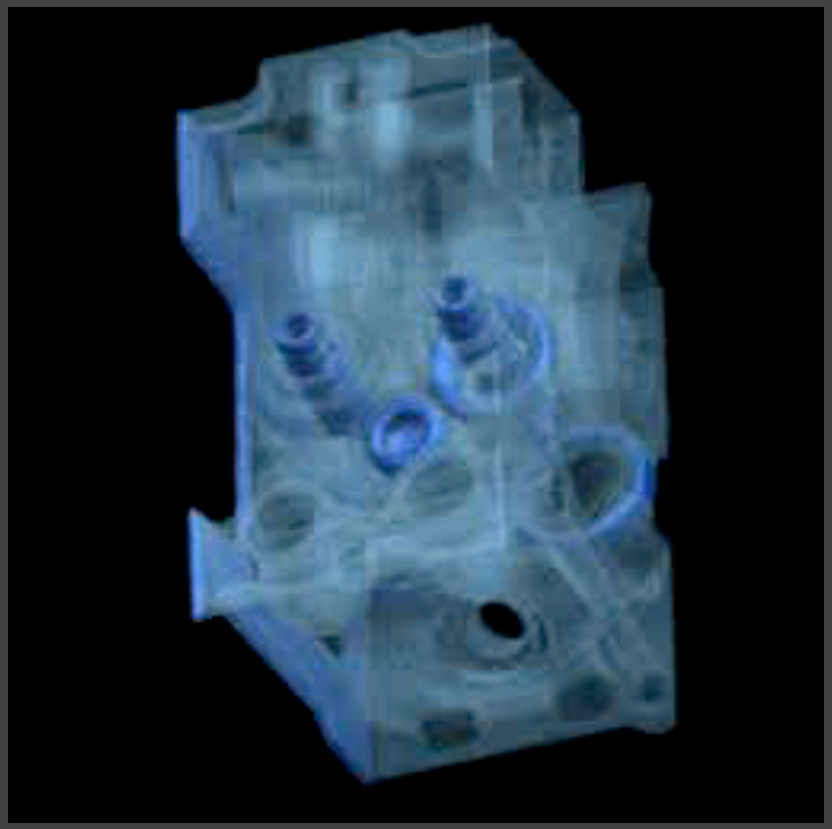
# Cone Trees [Robertson 91]




Video

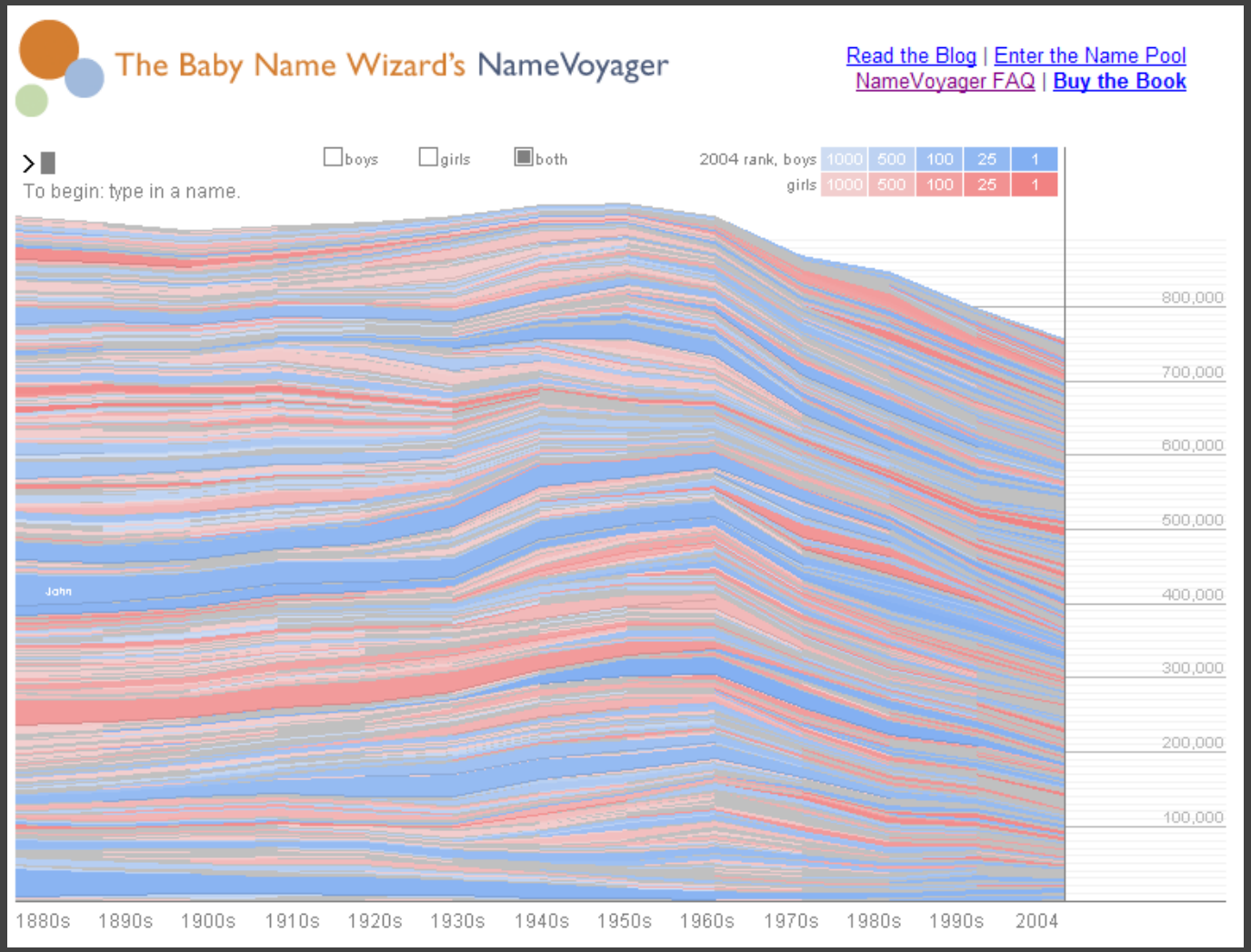


# Volume Rendering [Lacroute 95]



Video

# NameVoyager [Wattenberg 04]




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

# Topics

Motion perception

Animated transitions in visualizations

Implementing animations

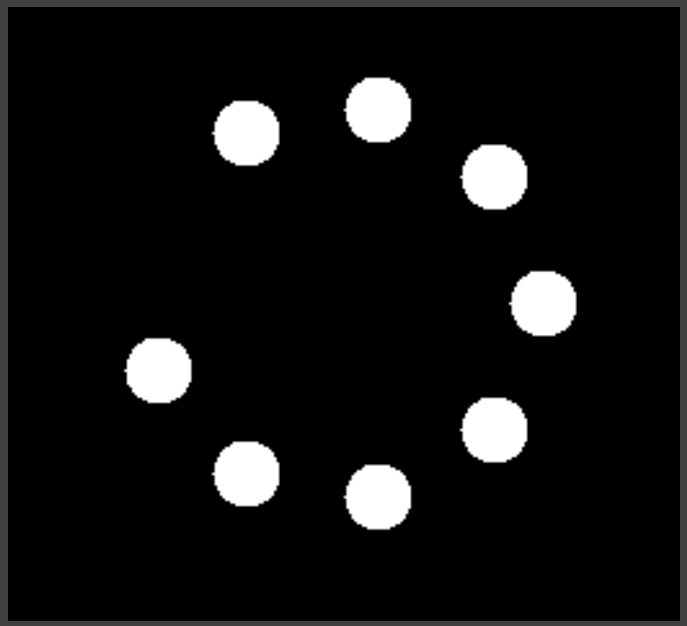
# Motion Perception

# Perceiving Animation

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

Smooth motion perceived

at ~10 frames/sec (100 ms).



# Motion as Visual Cue

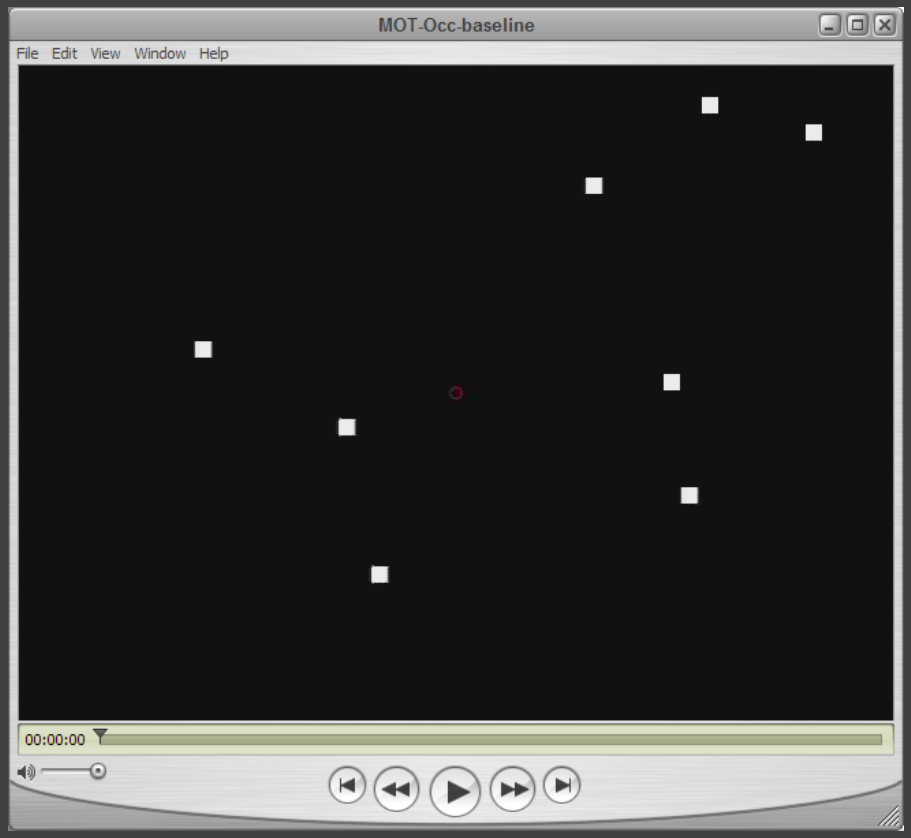
Pre-attentive, stronger than color, shape, …

More sensitive to motion at periphery

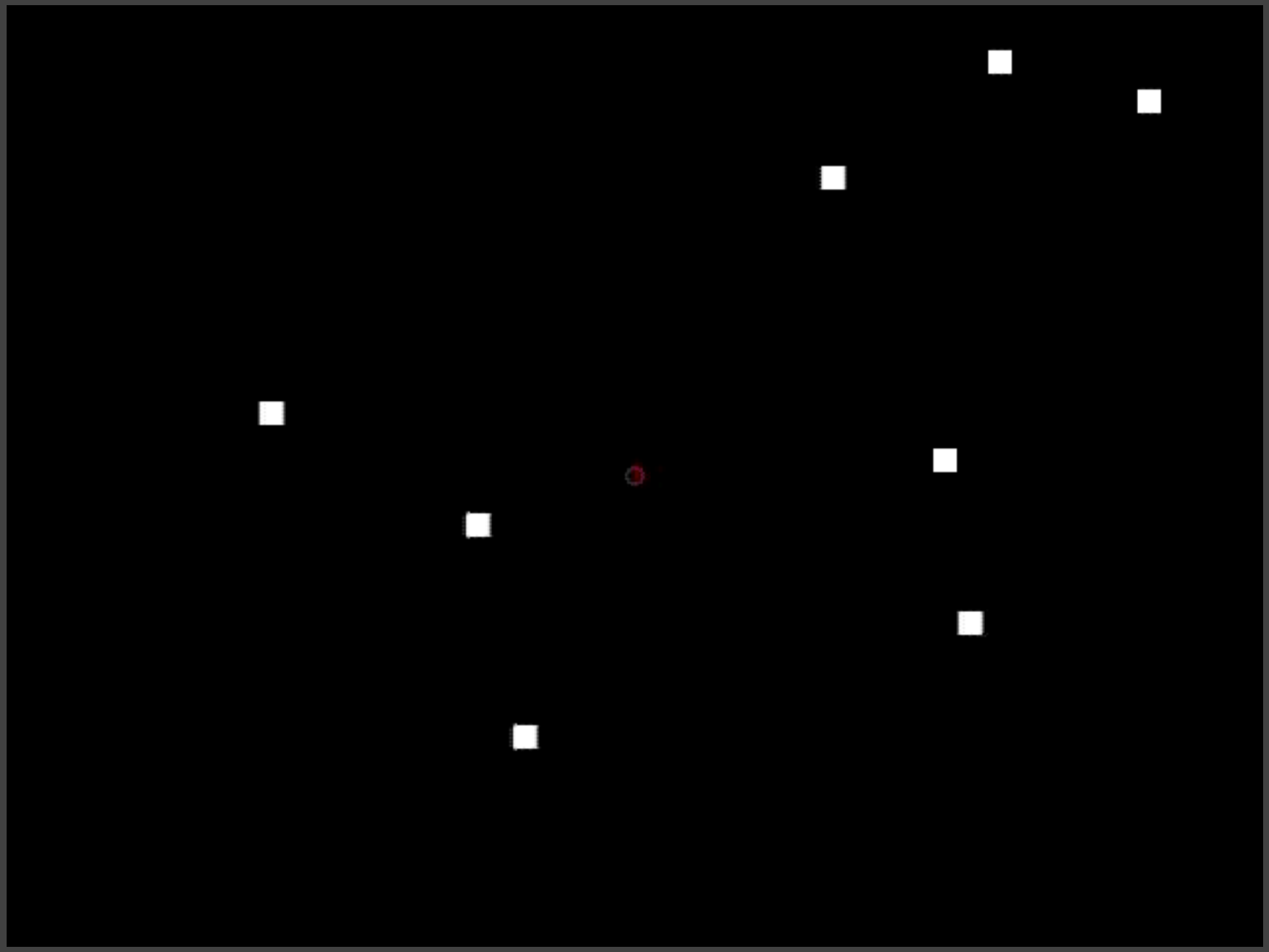
Similar motions perceived as a group

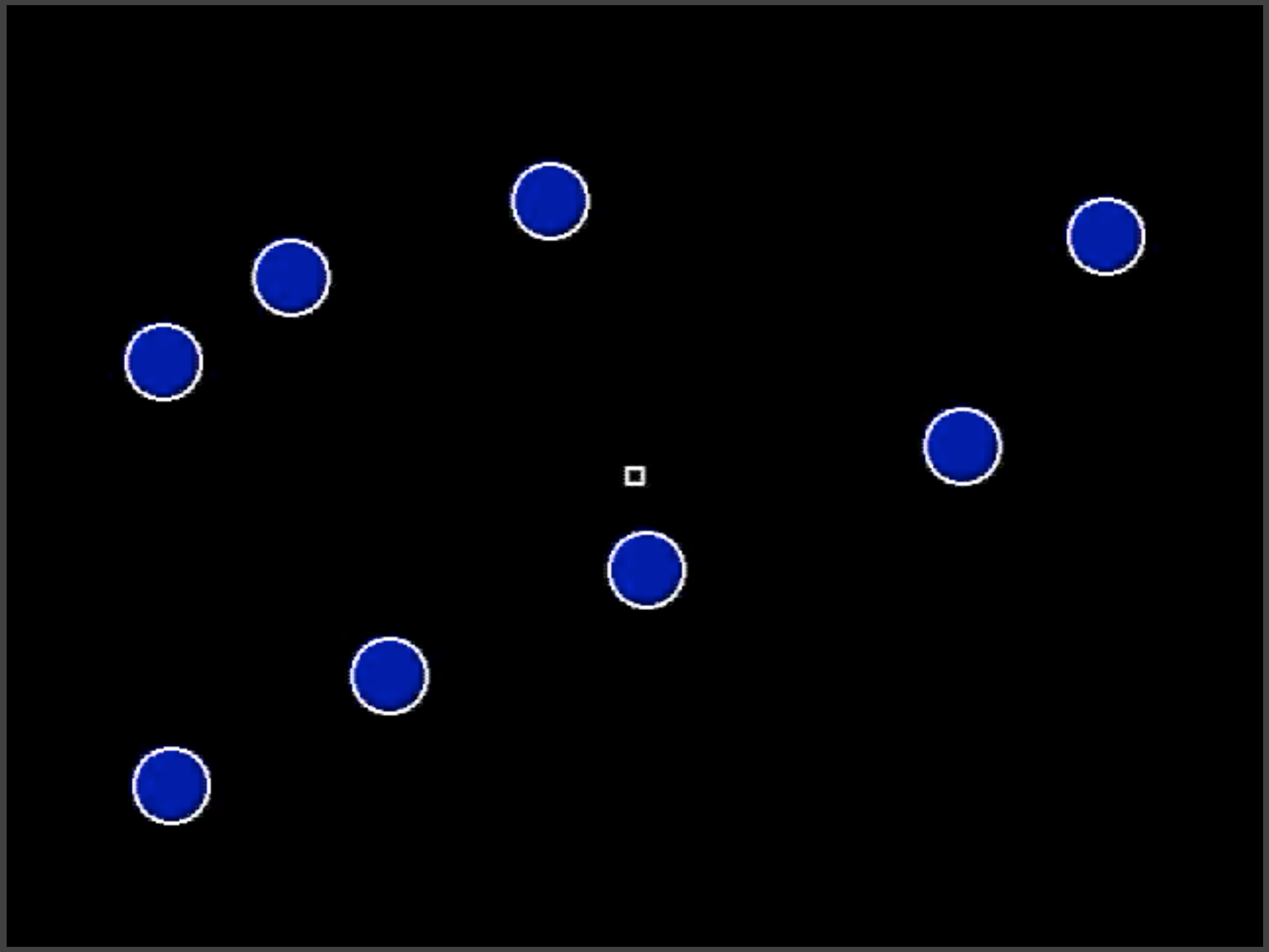
Motion parallax provide 3D cue (like stereopsis)

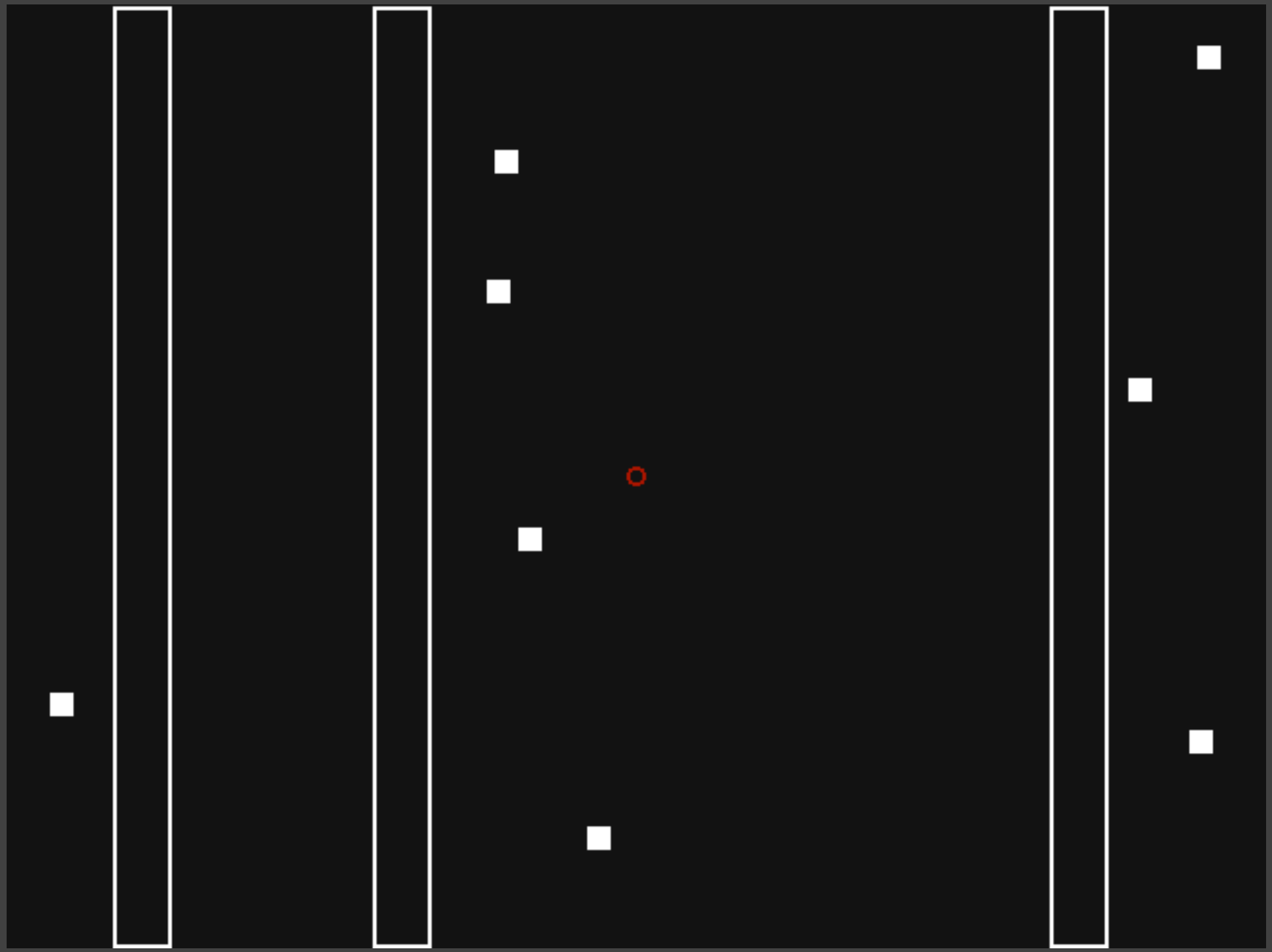
# Tracking Multiple Targets

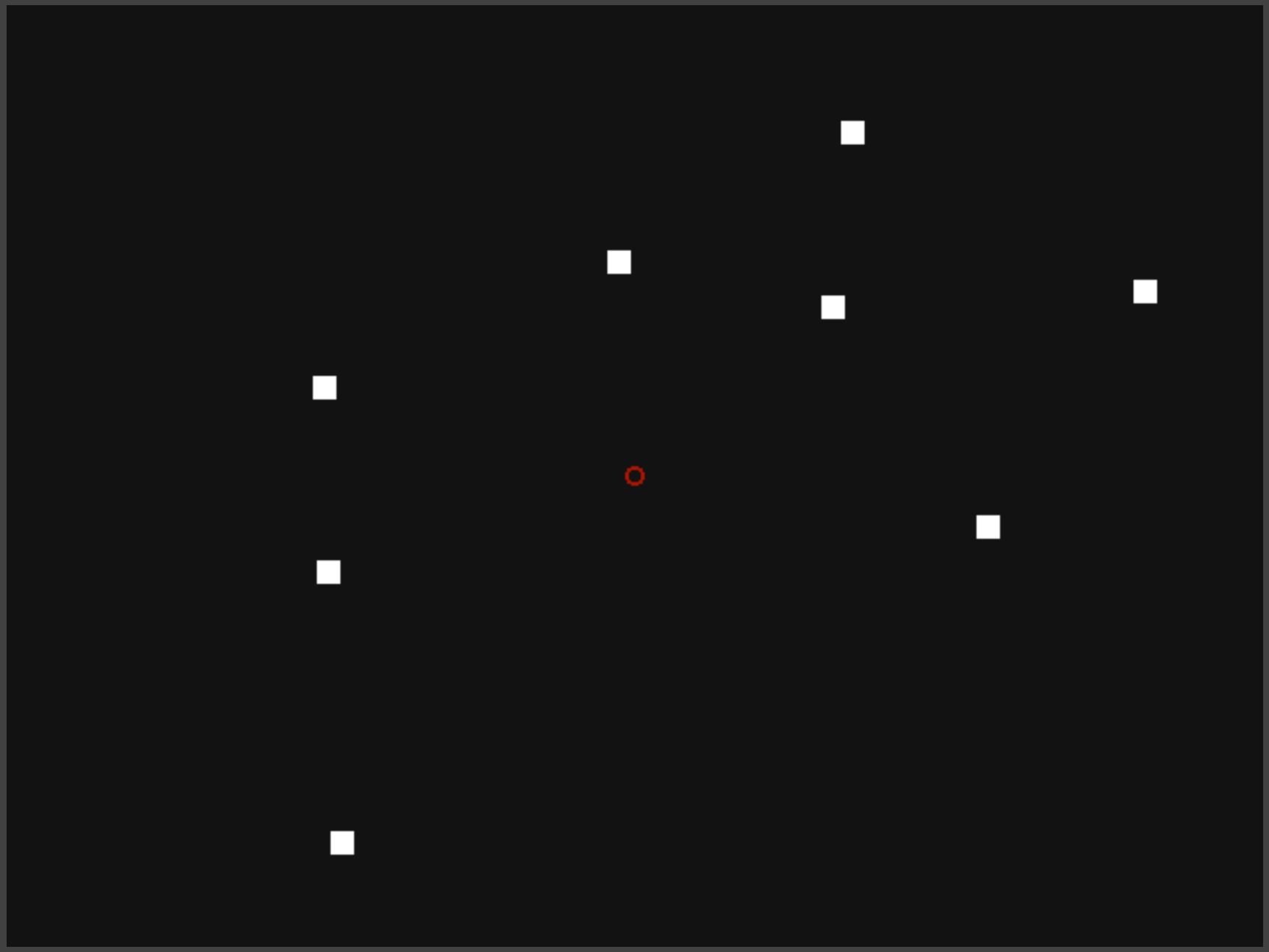


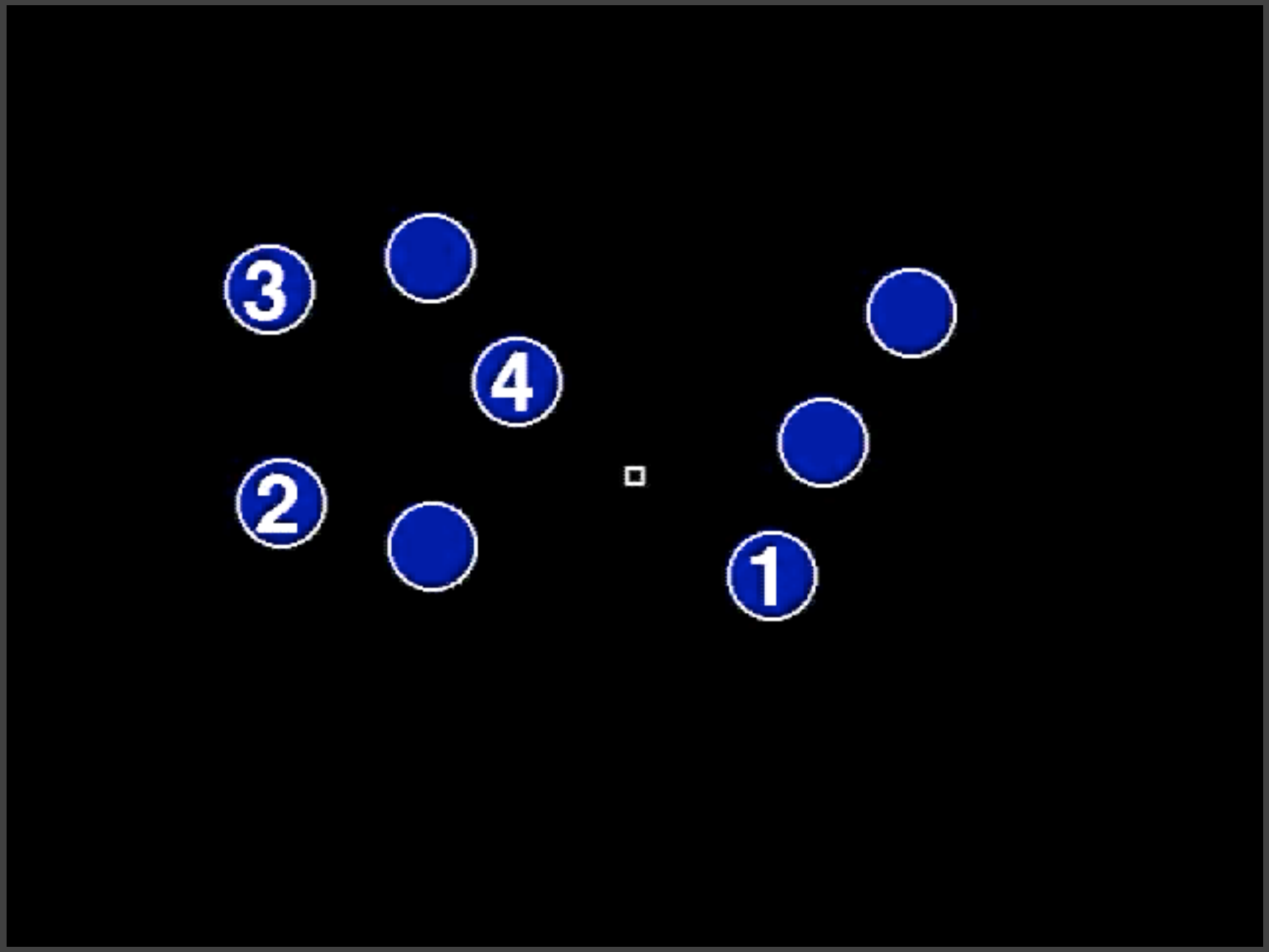

How many dots can we simultaneously track?










3
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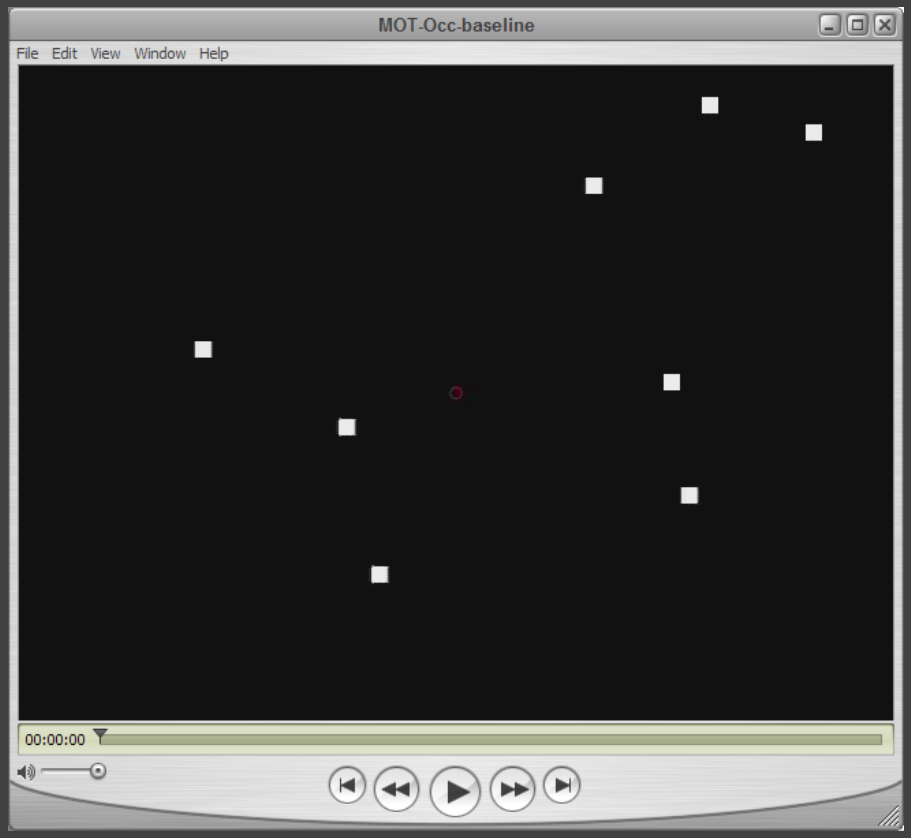
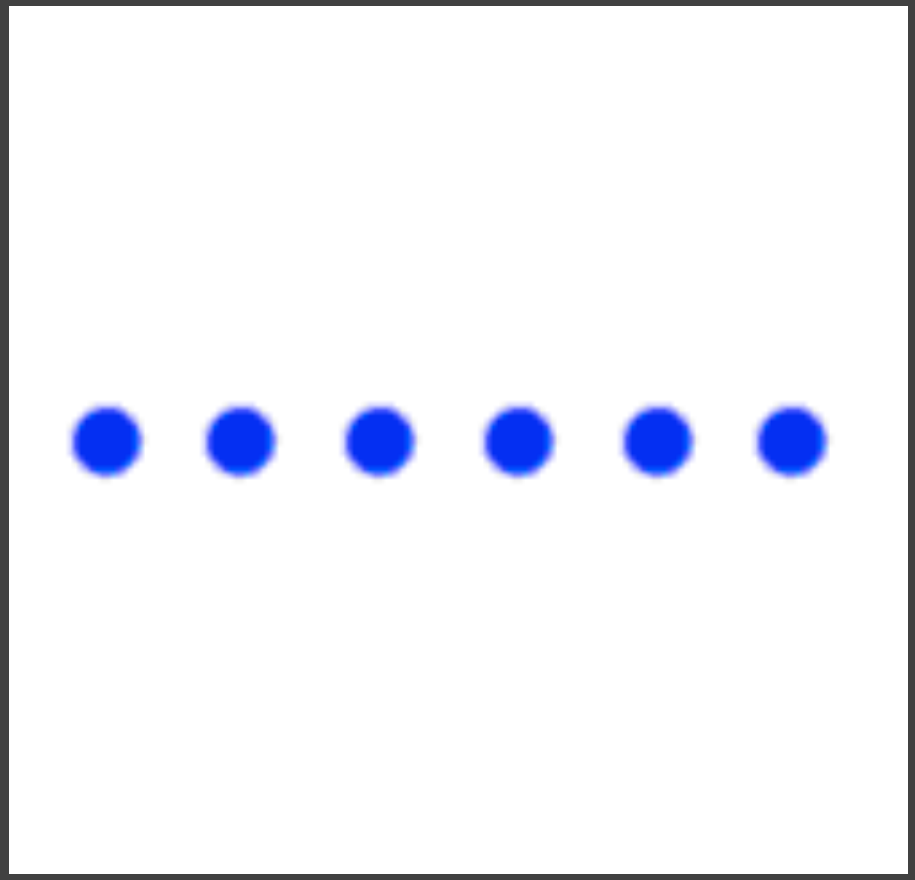
# Tracking Multiple Targets




How many dots can we simultaneously track?

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

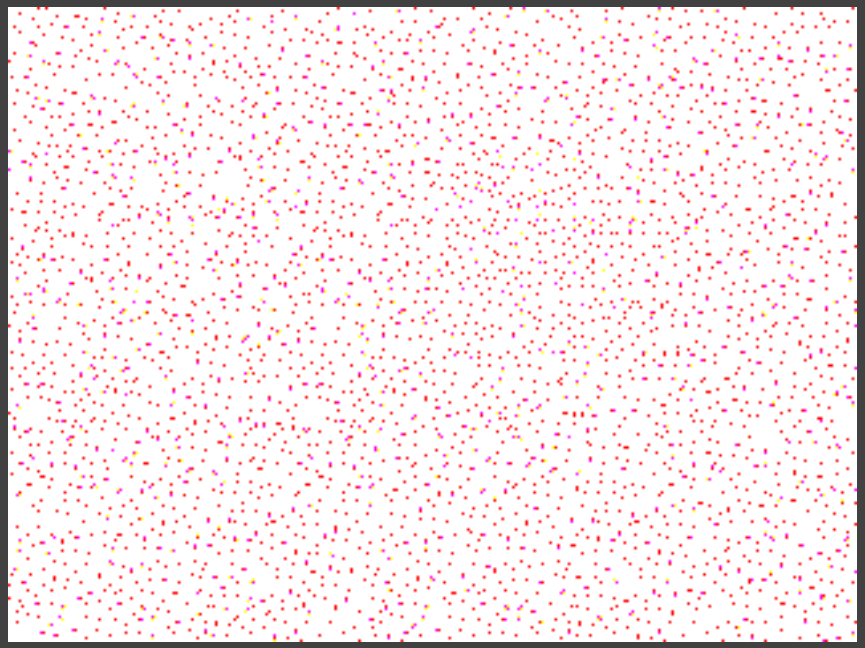
# Grouped Dots Count as 1 Object



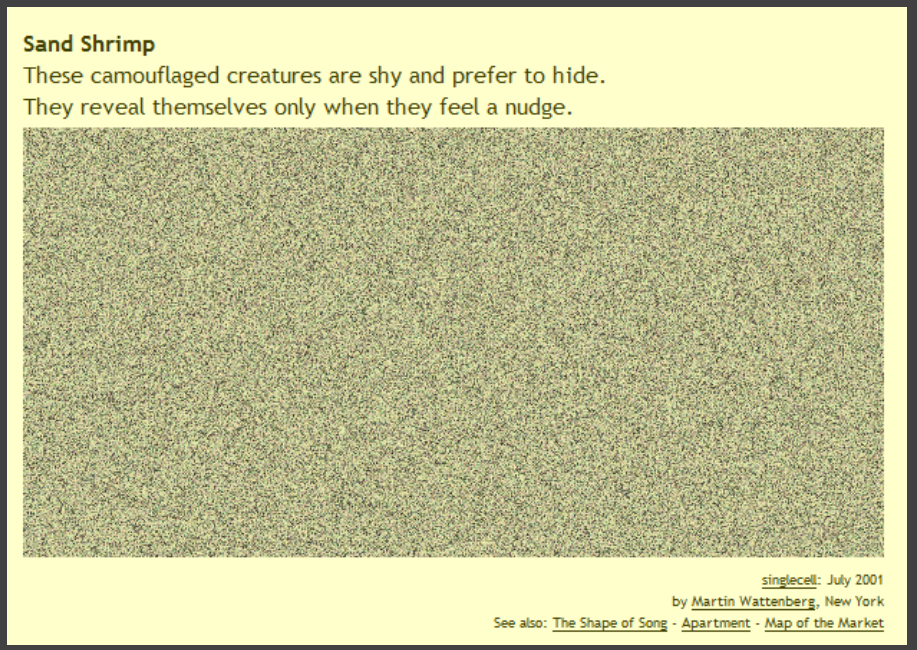
Dots moving together are grouped

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

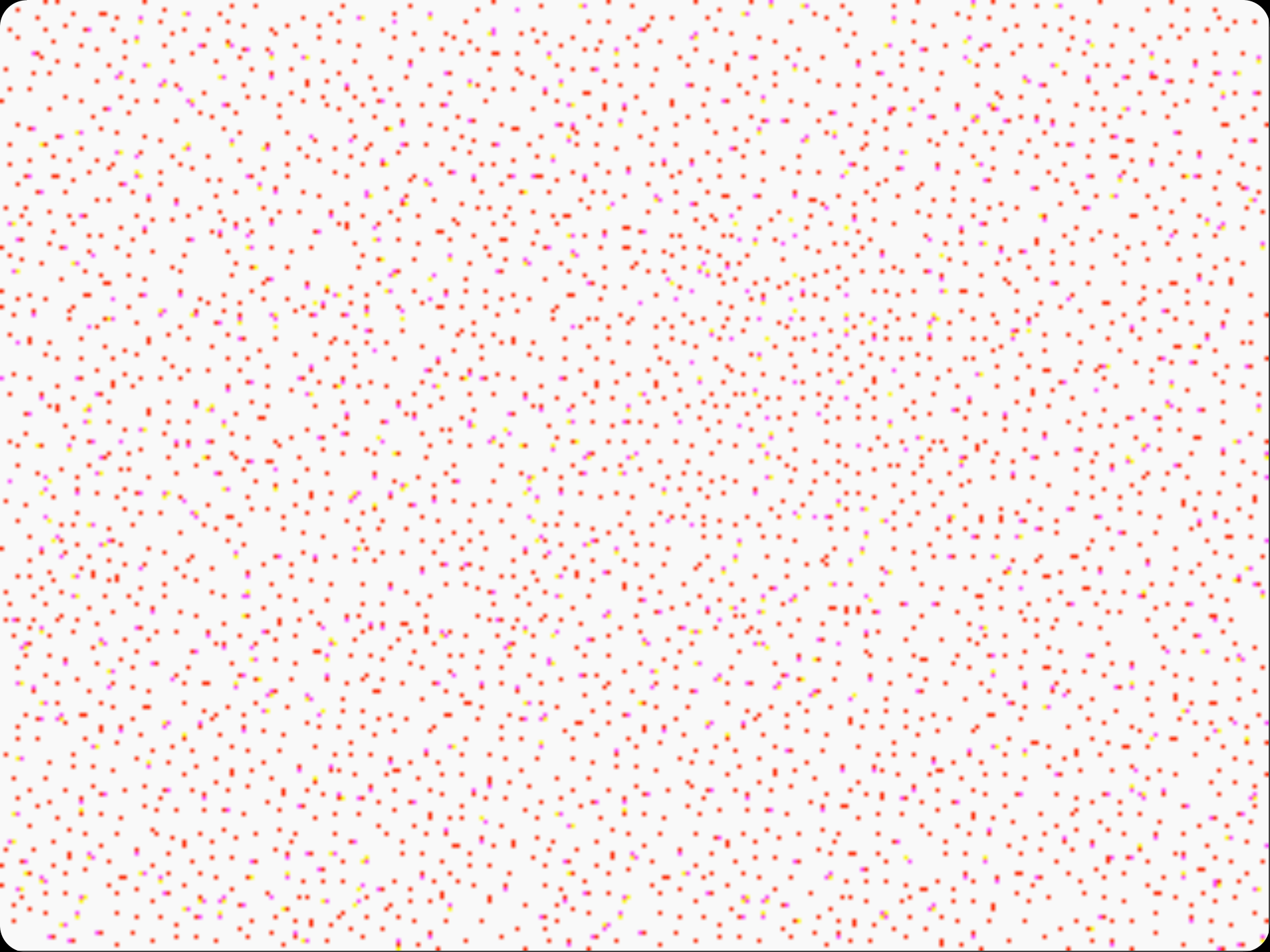
# Segment by Common Fate



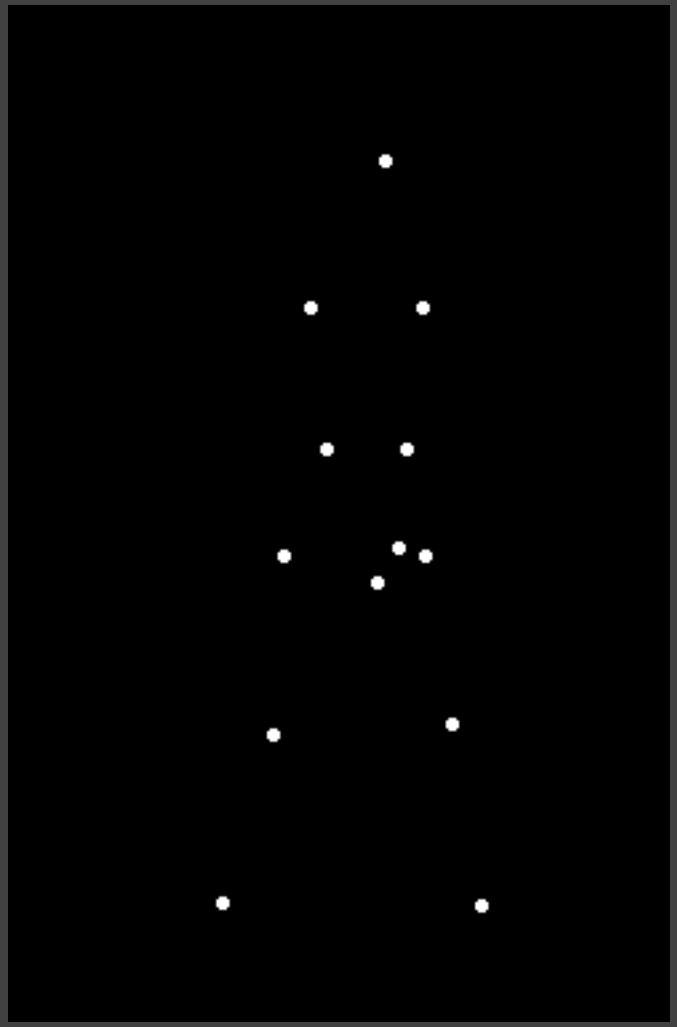
http://dragon.uml.edu/psych/commfate.html




http://www.singlecell.org/july/index.html



# 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

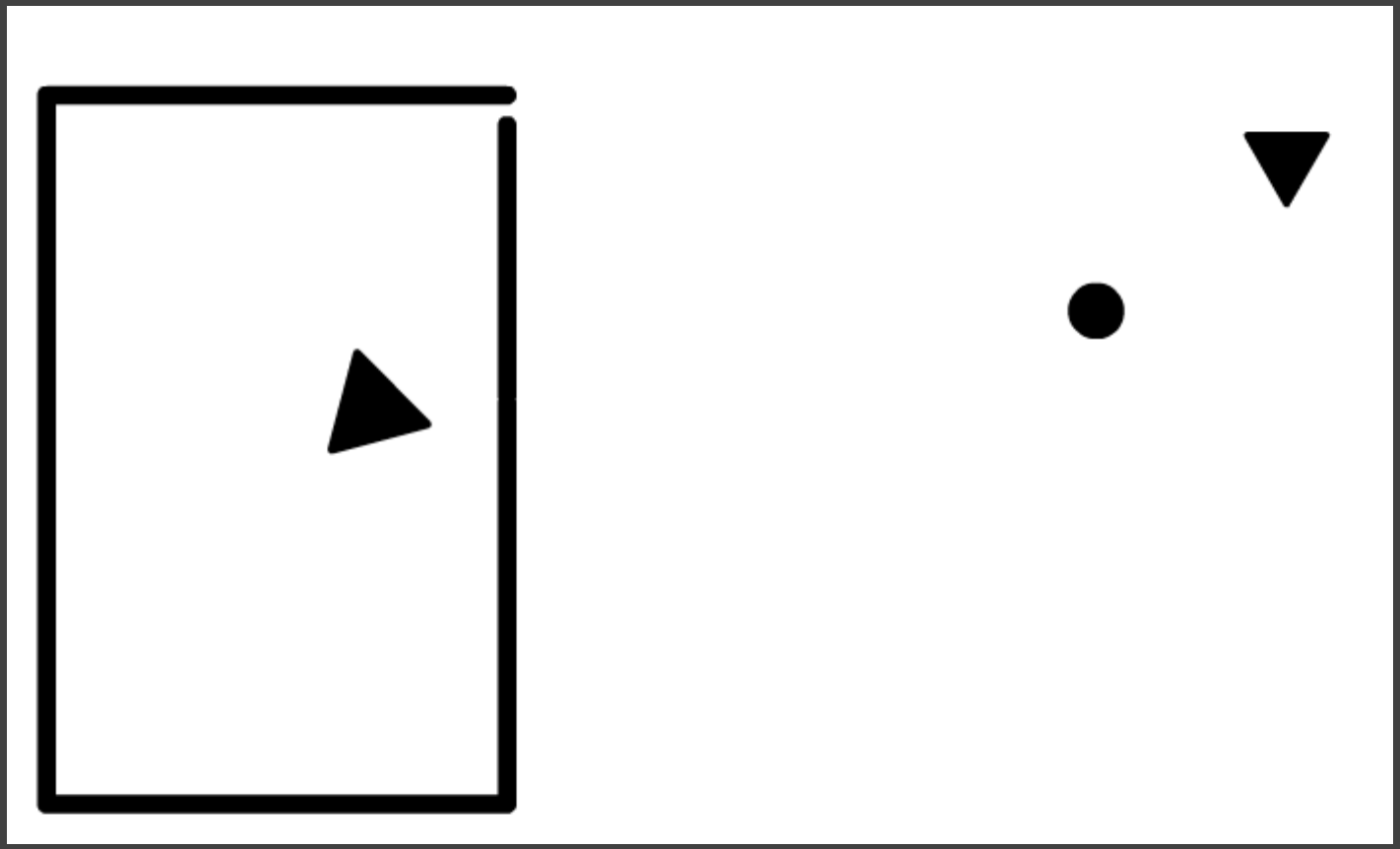
start end

**Shows transition better, but**

Still may be too fast, or too slow

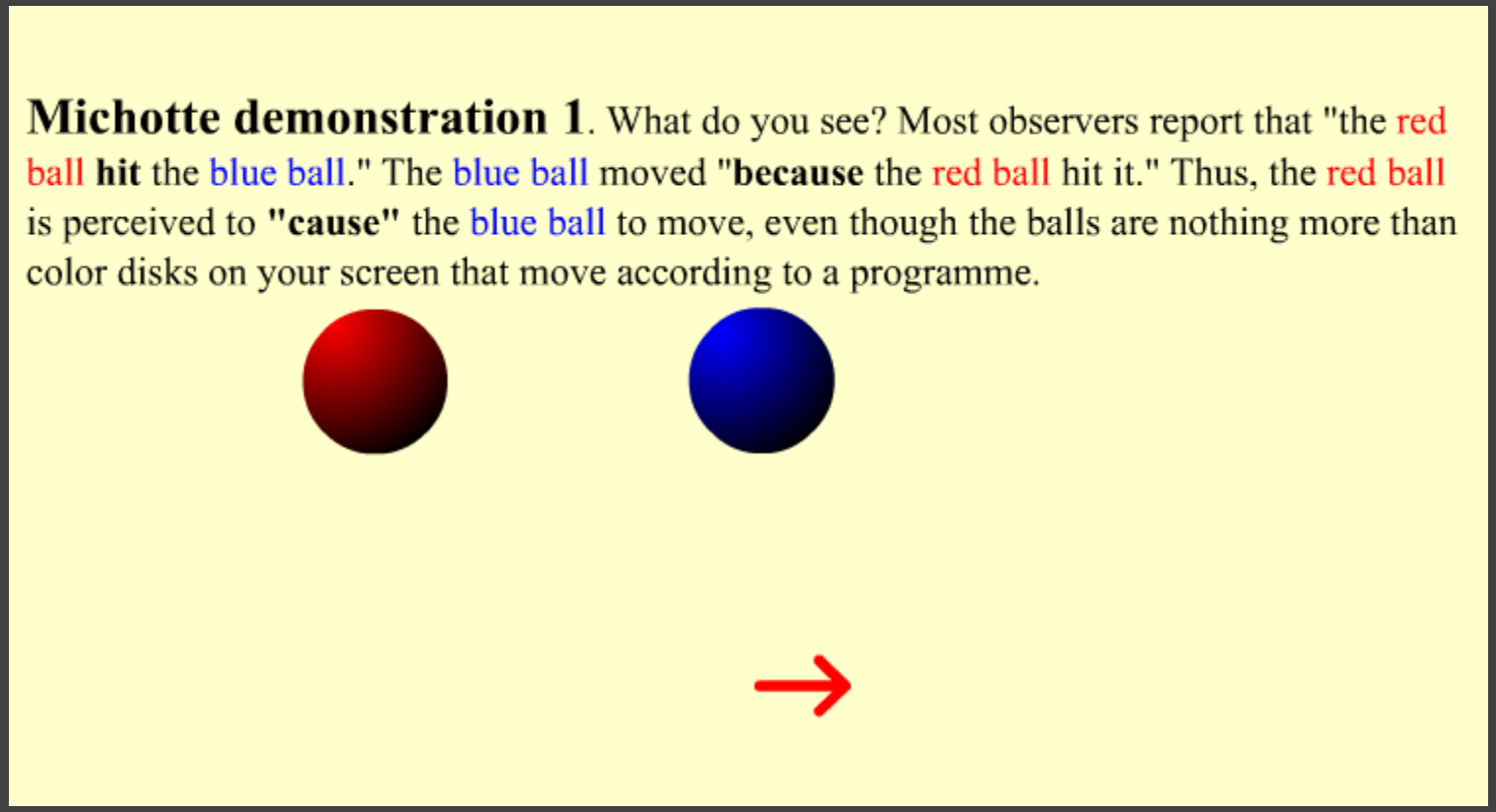
Too many objects may move at once

# Constructing Narratives



http://anthropomorphism.org/img/Heider_Flash.swf

# Attribution of Causality [Michotte 46]




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

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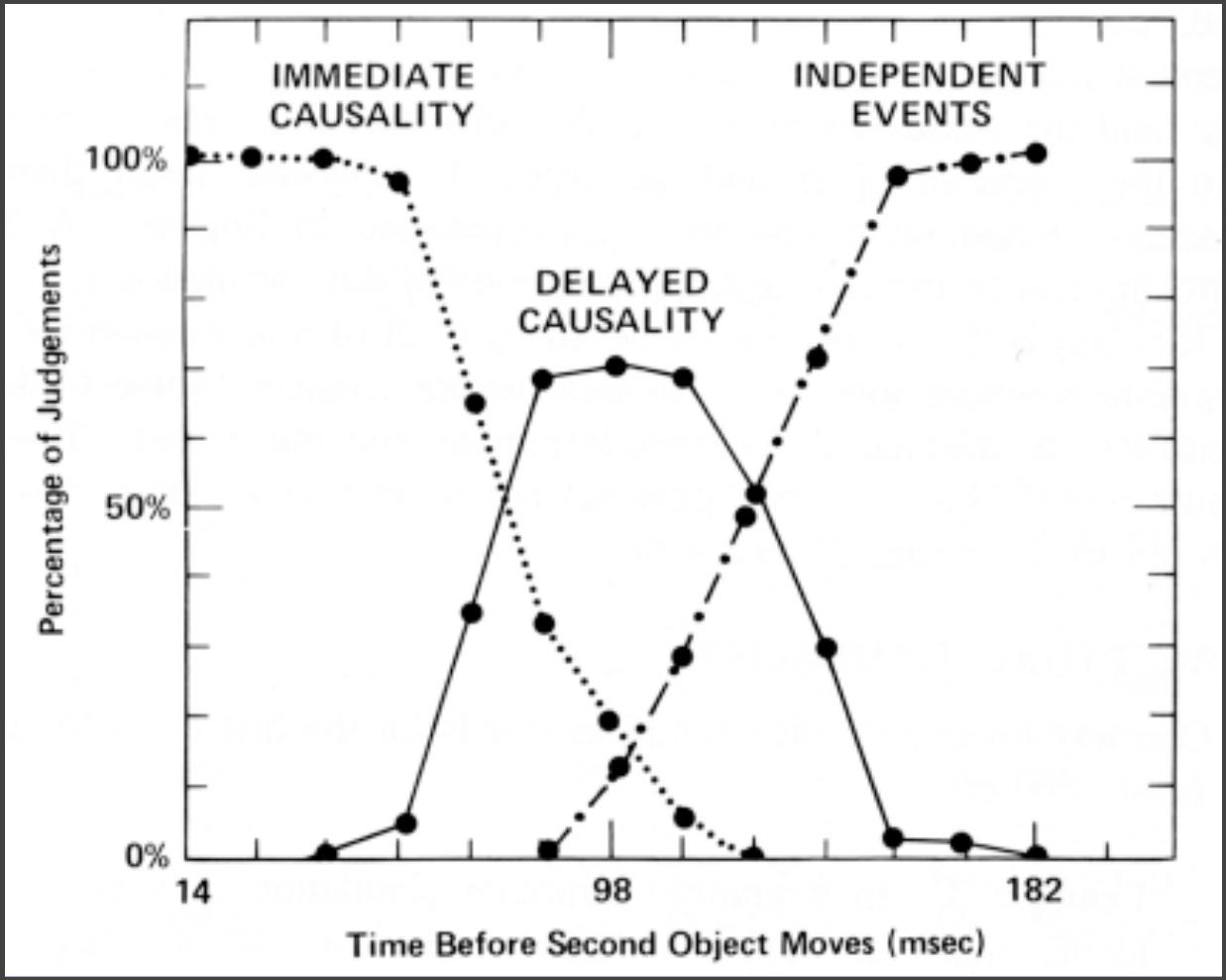
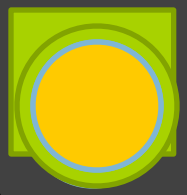



[Reprint from Ware 04]

| **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

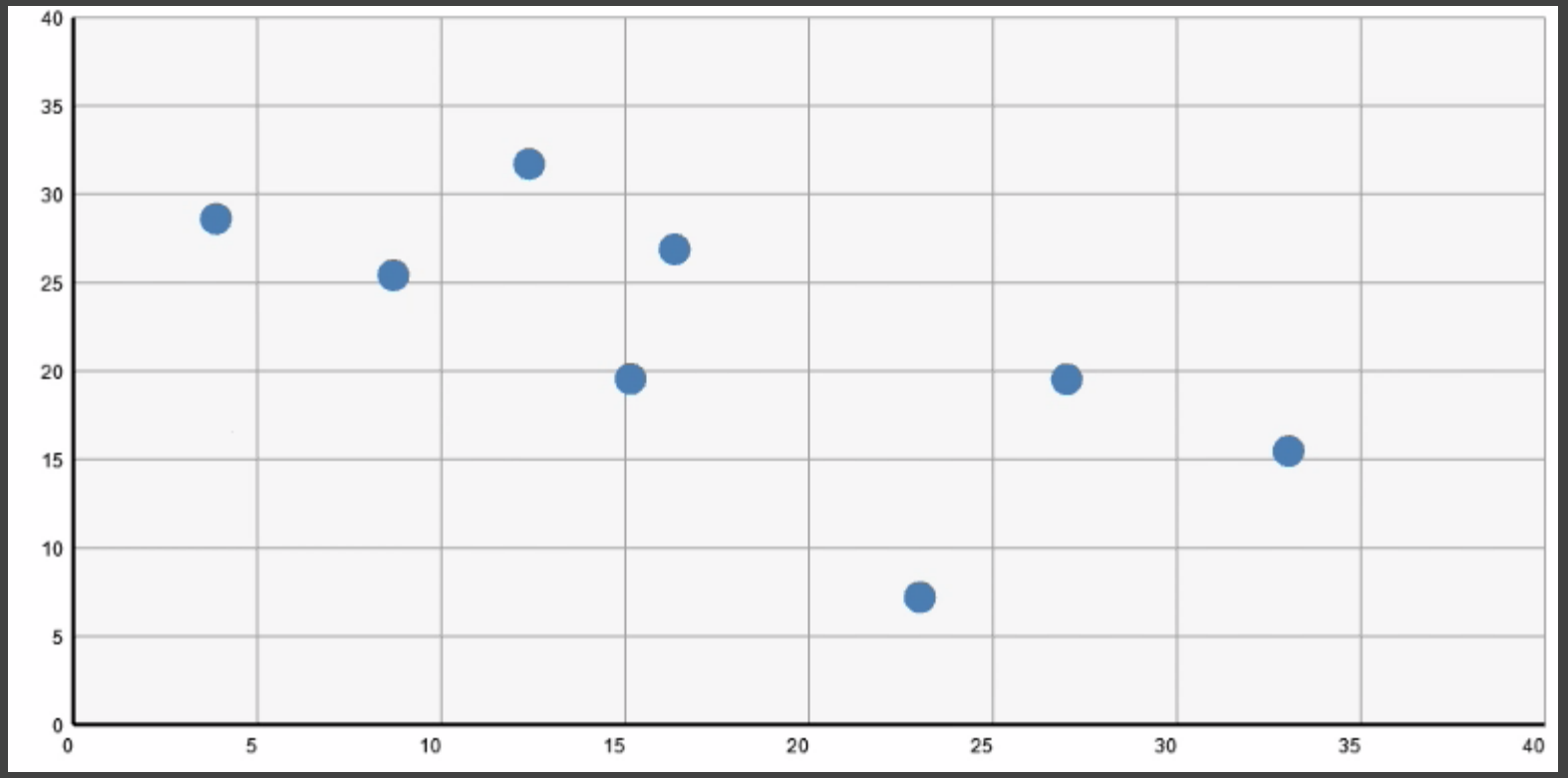
Cannot simultaneously attend to multiple motions

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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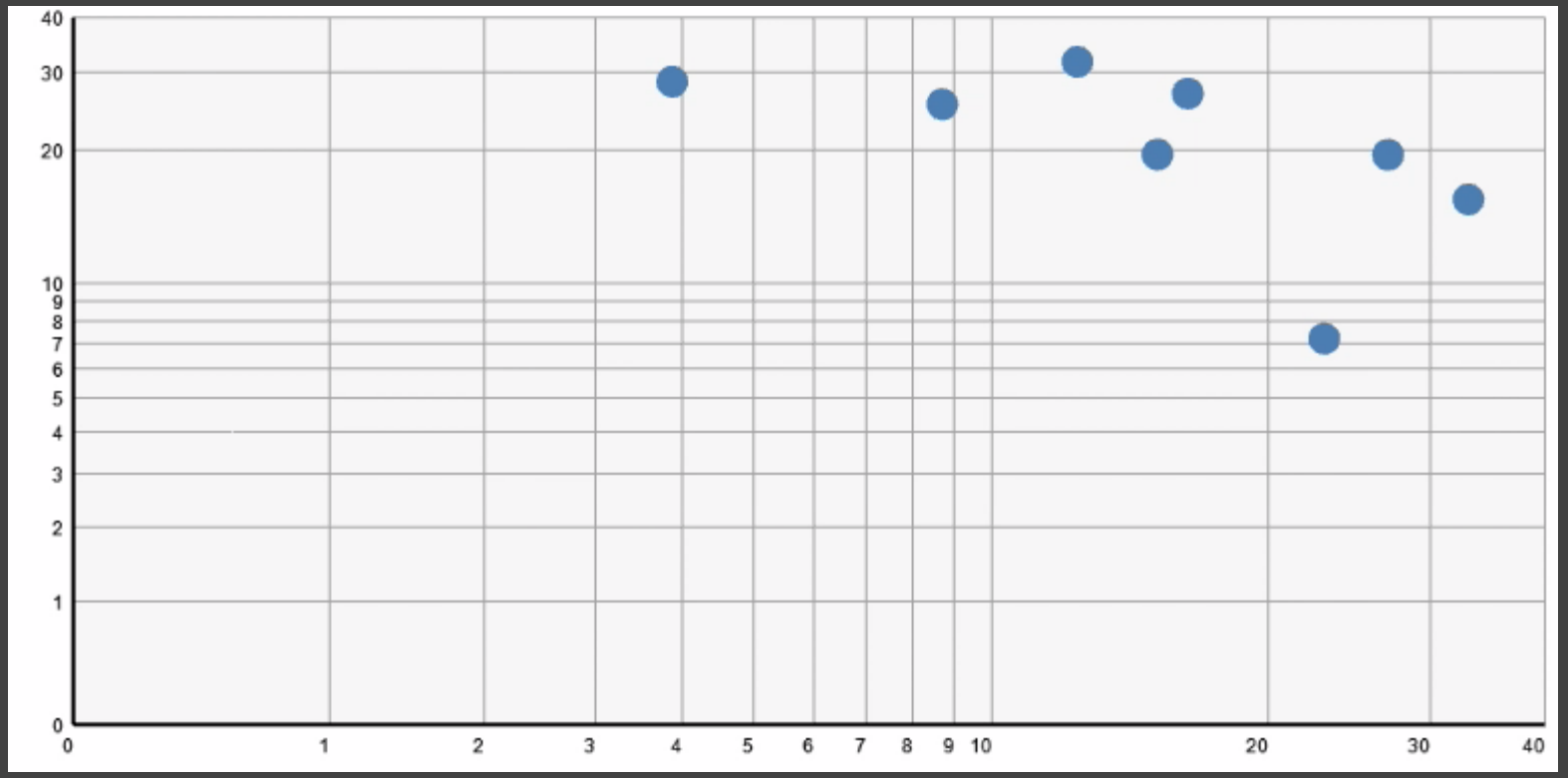
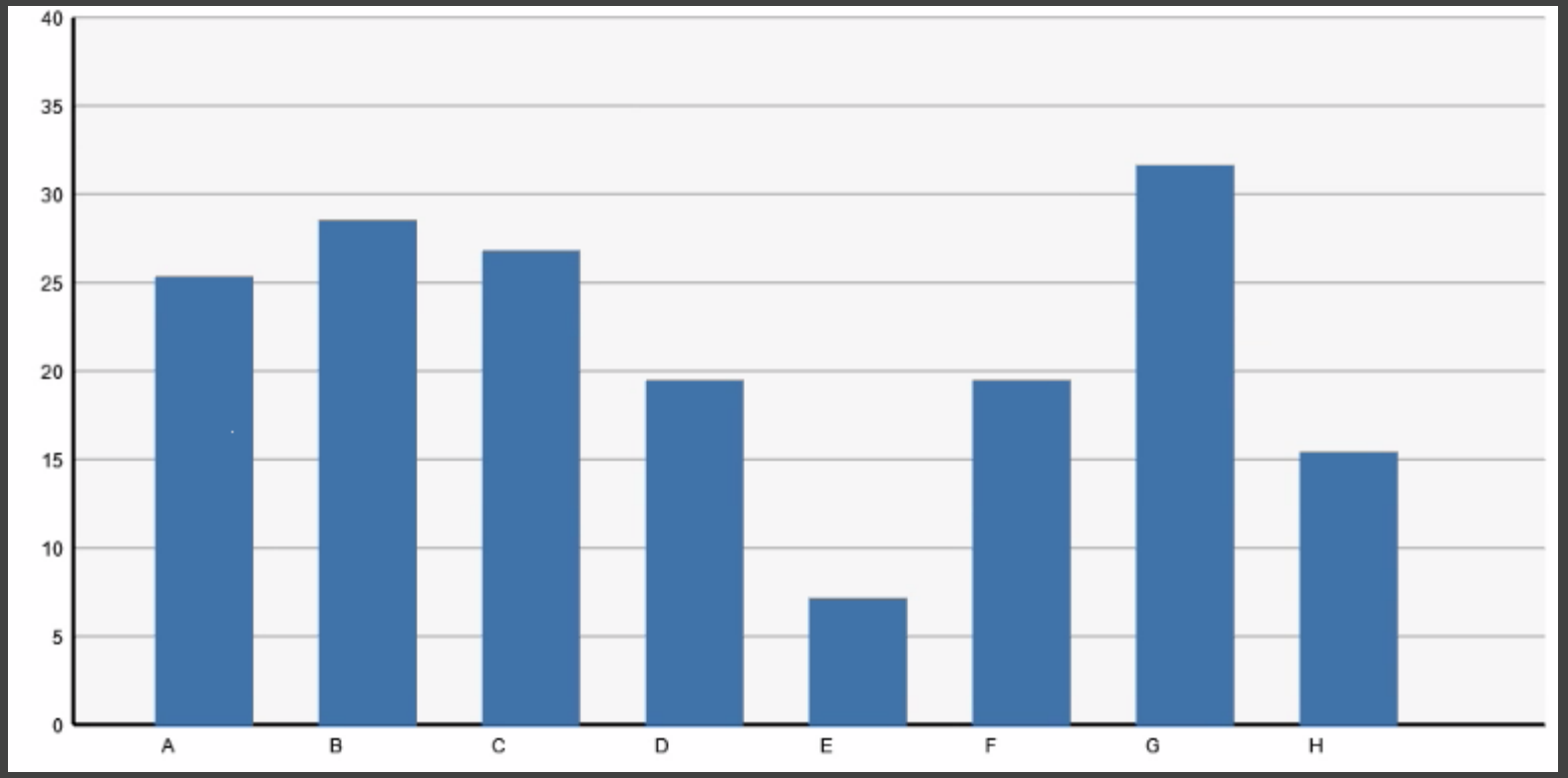
# Log Transform

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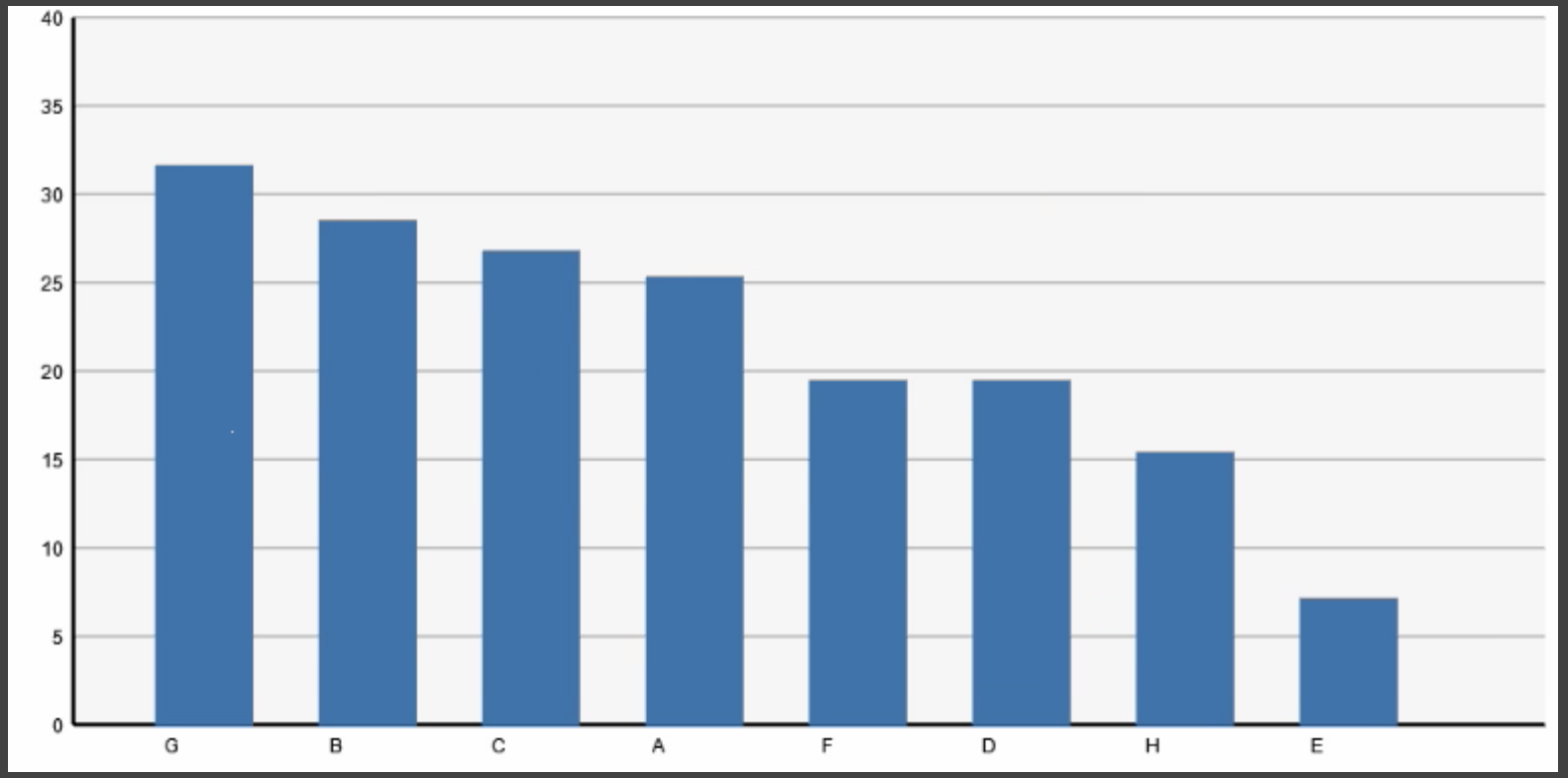
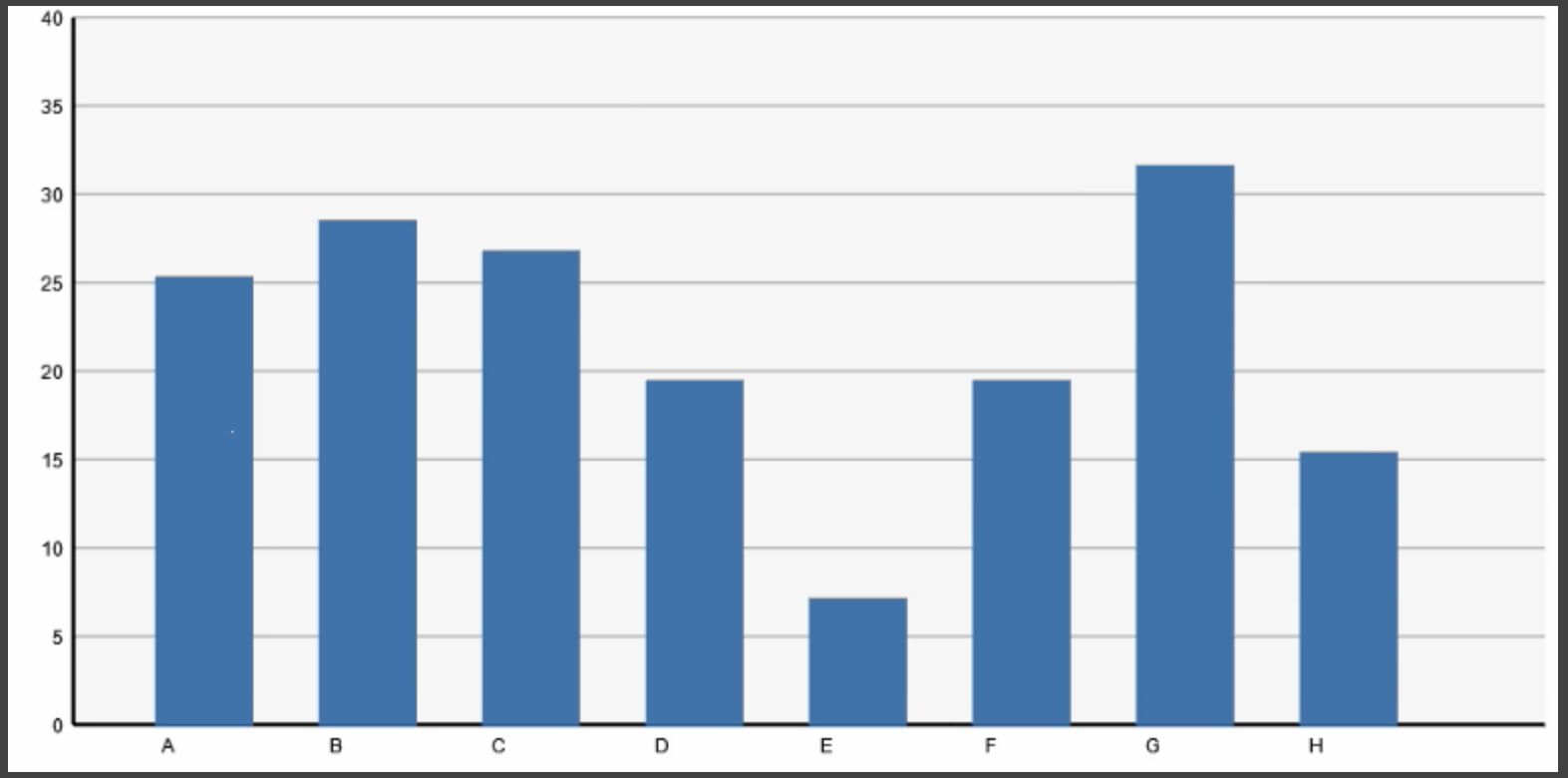
# Sorting

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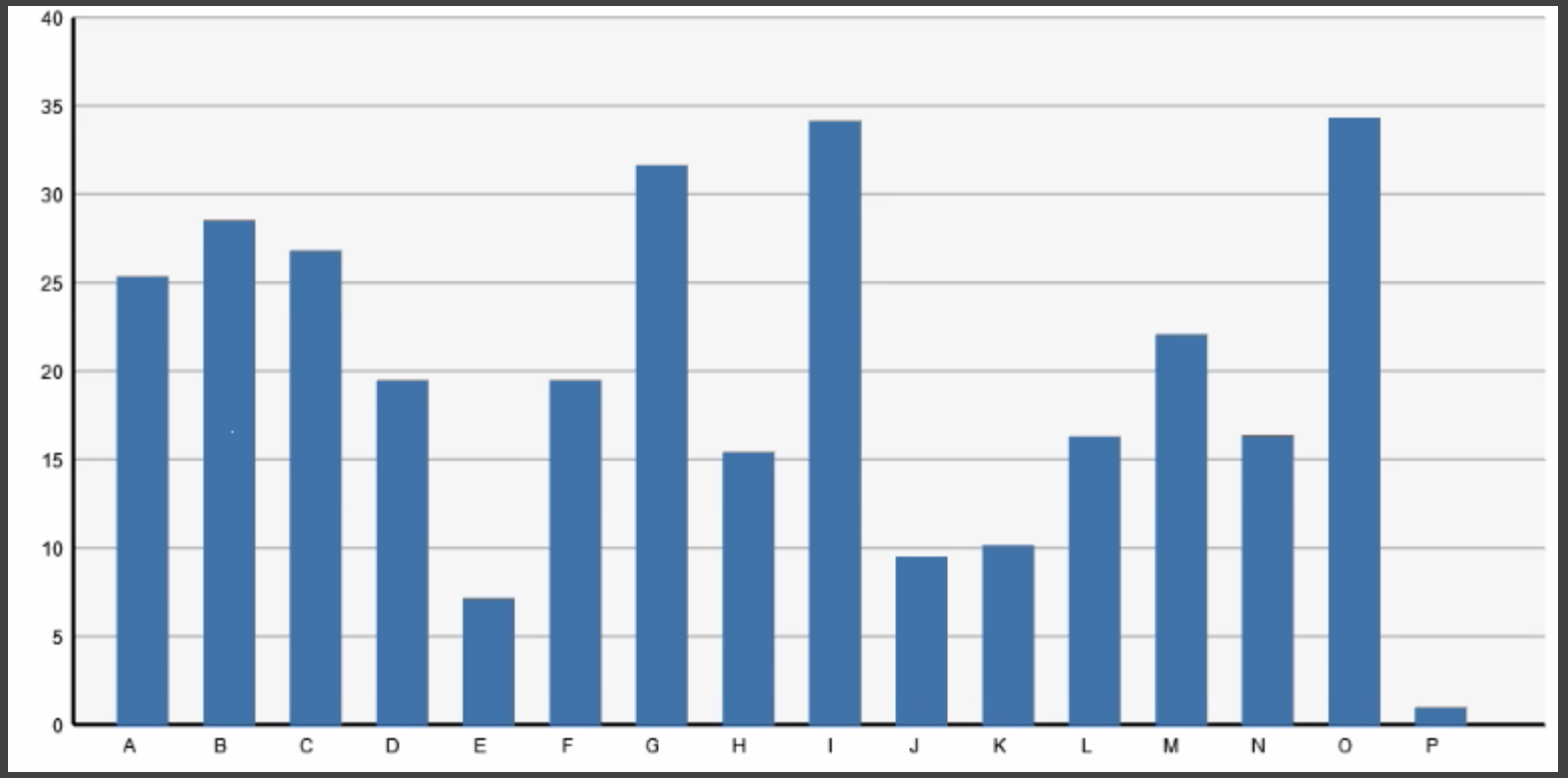
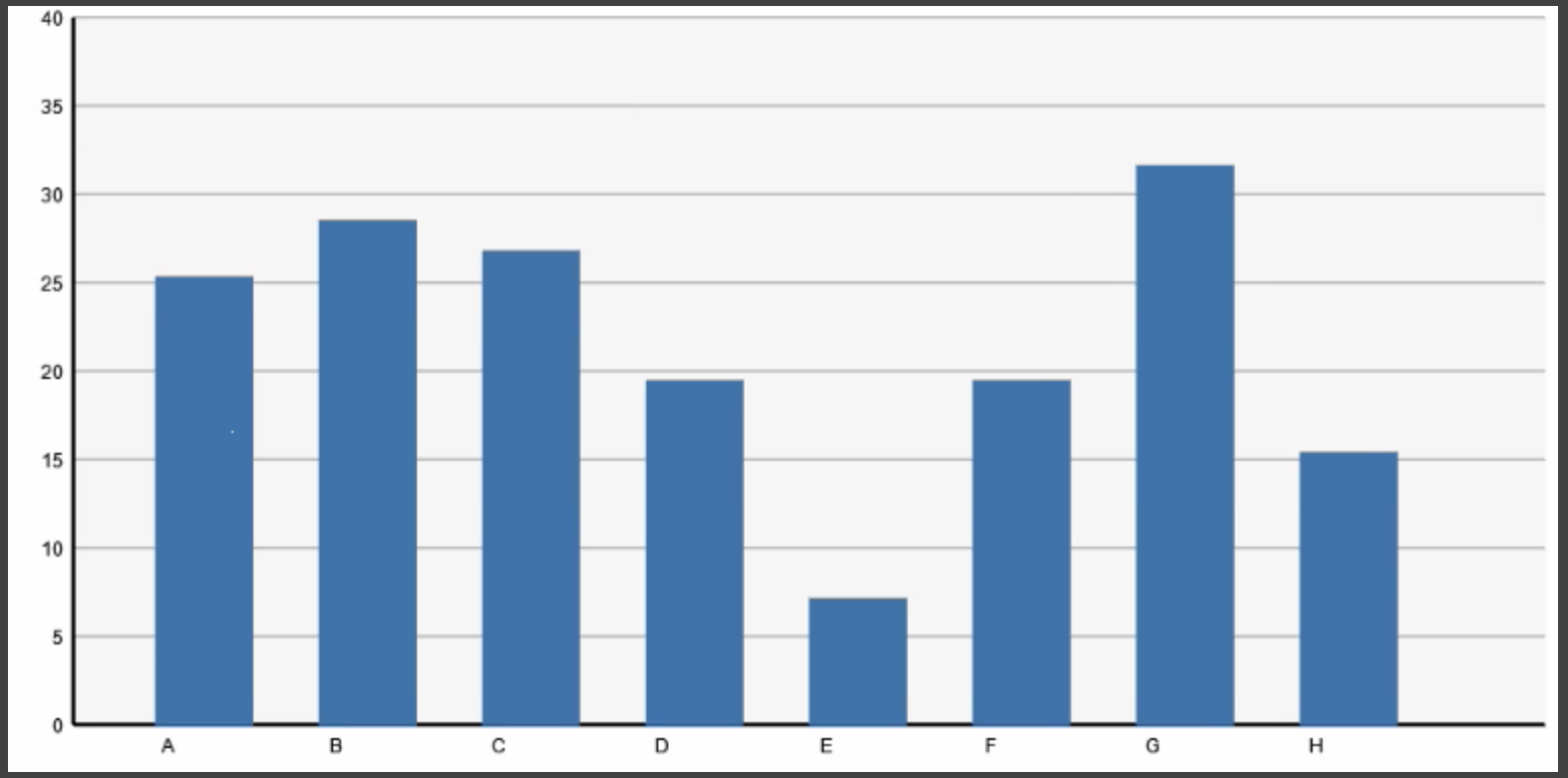
# Filtering

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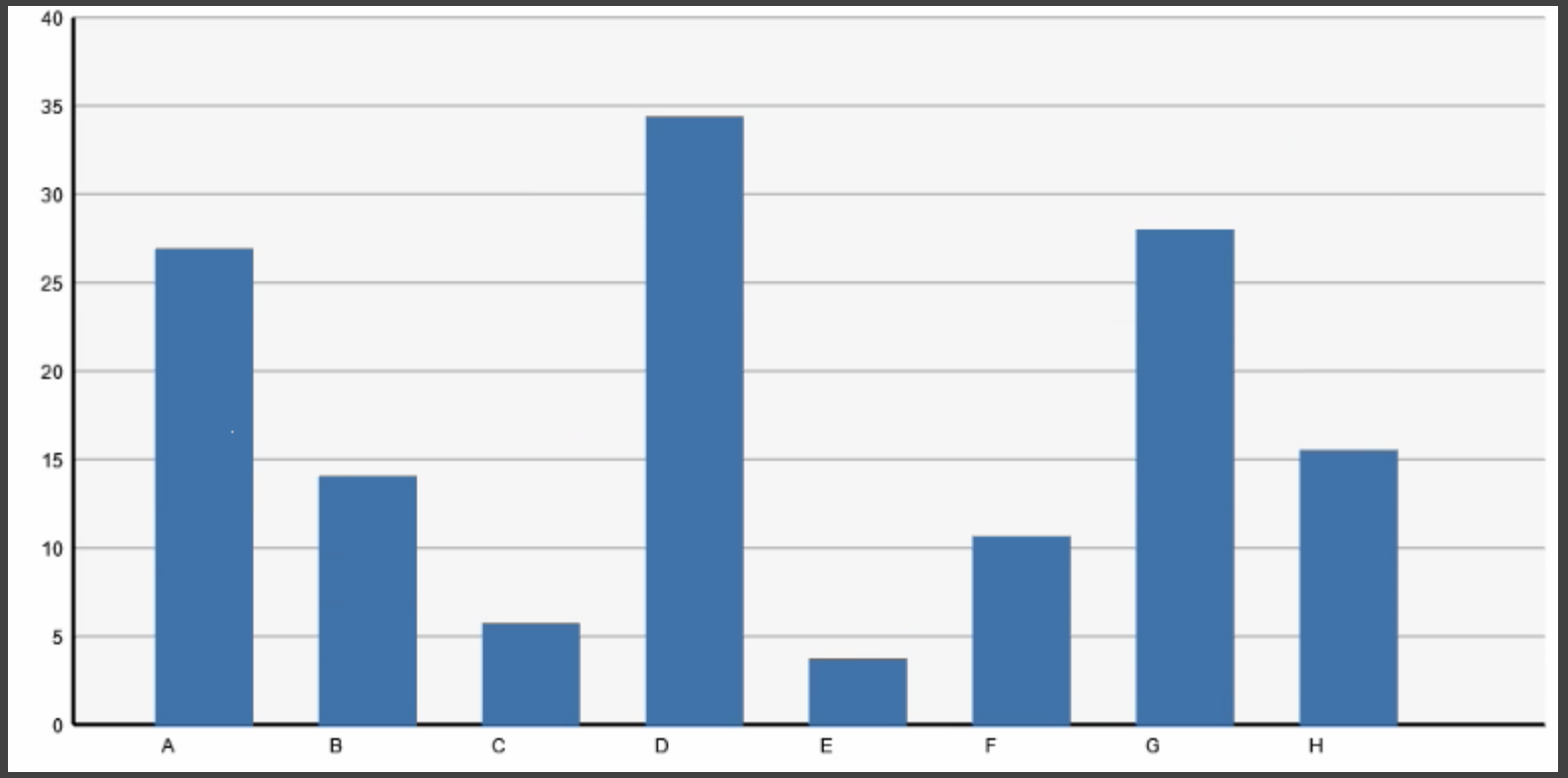
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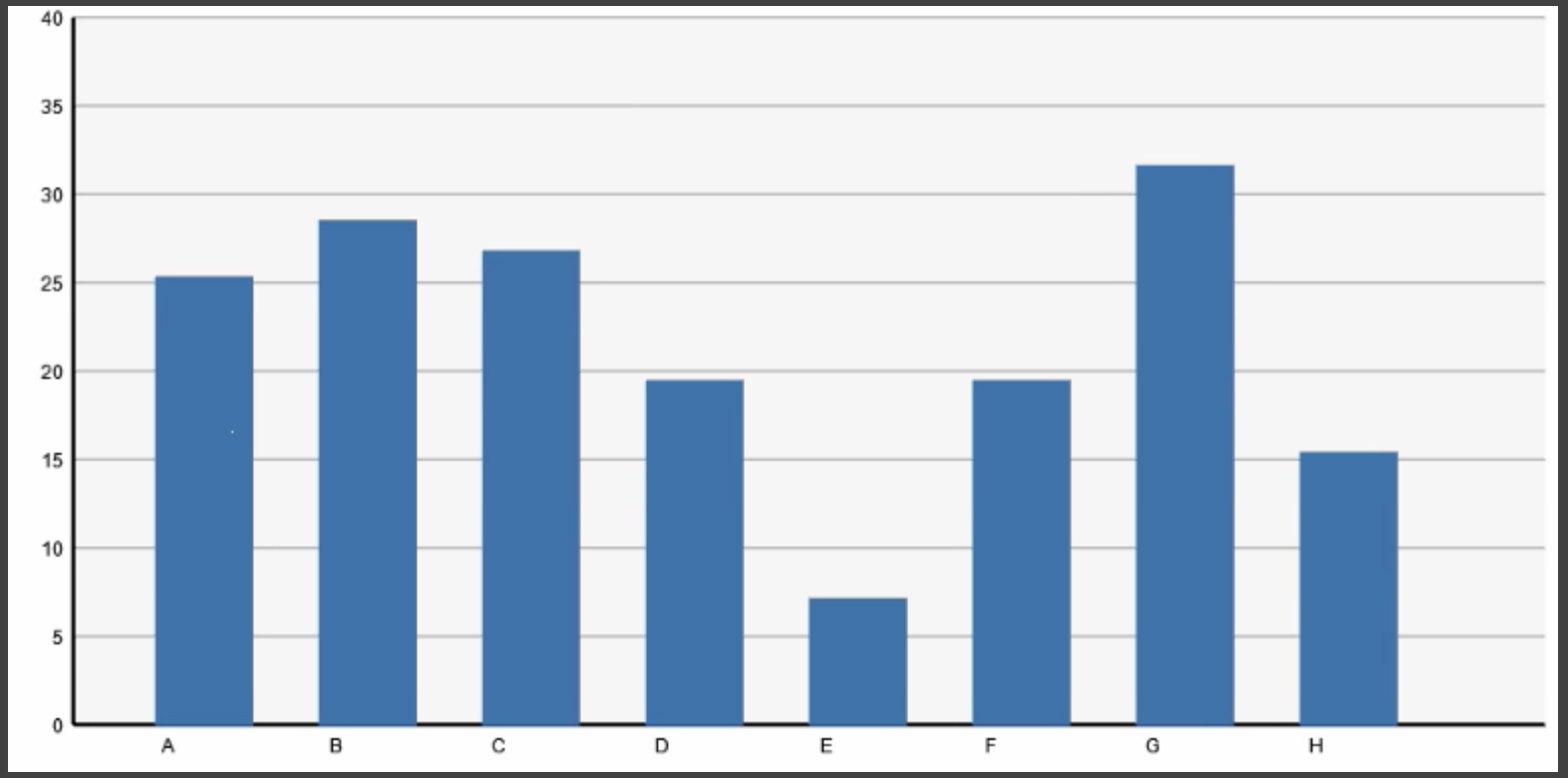
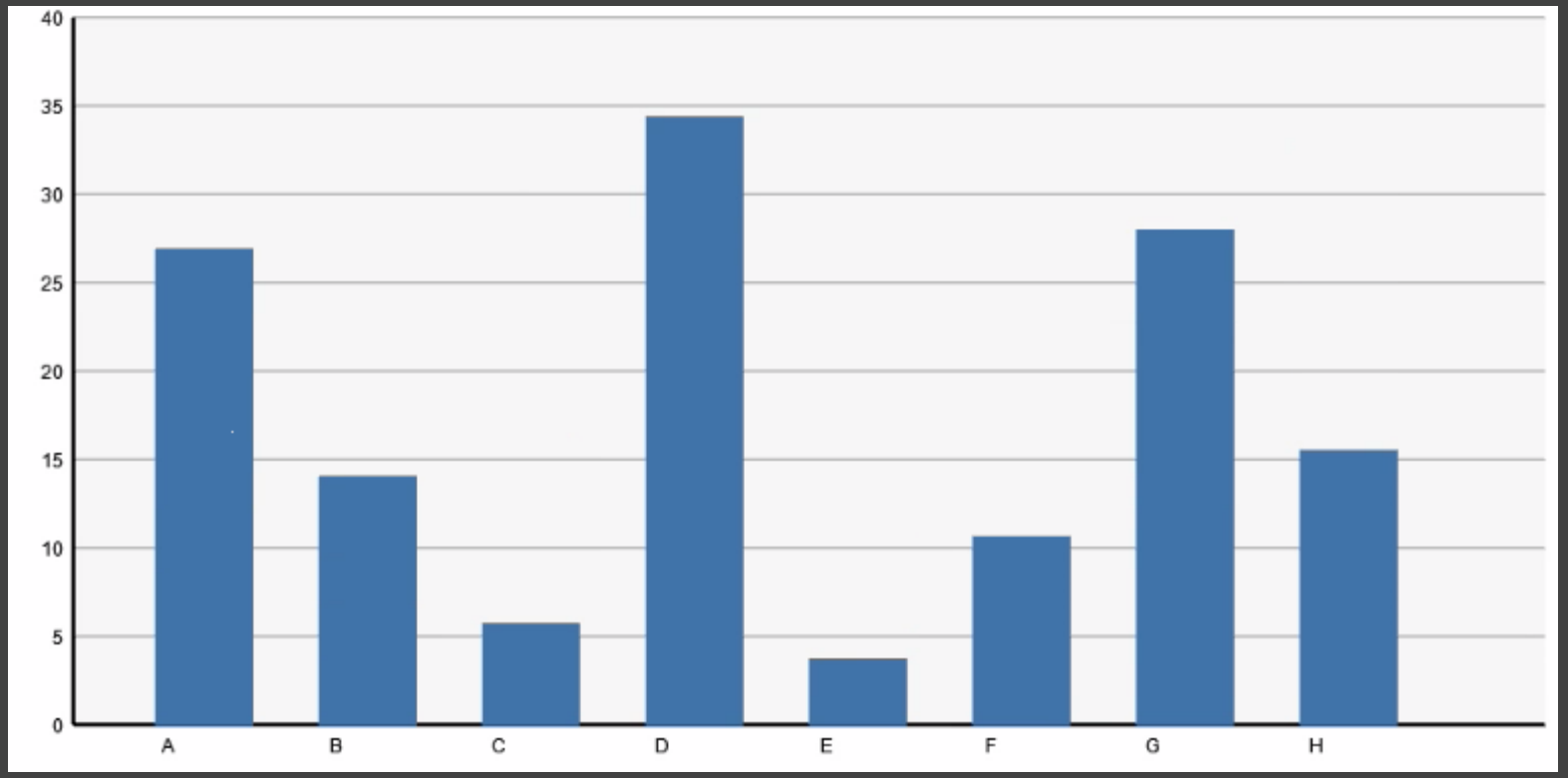
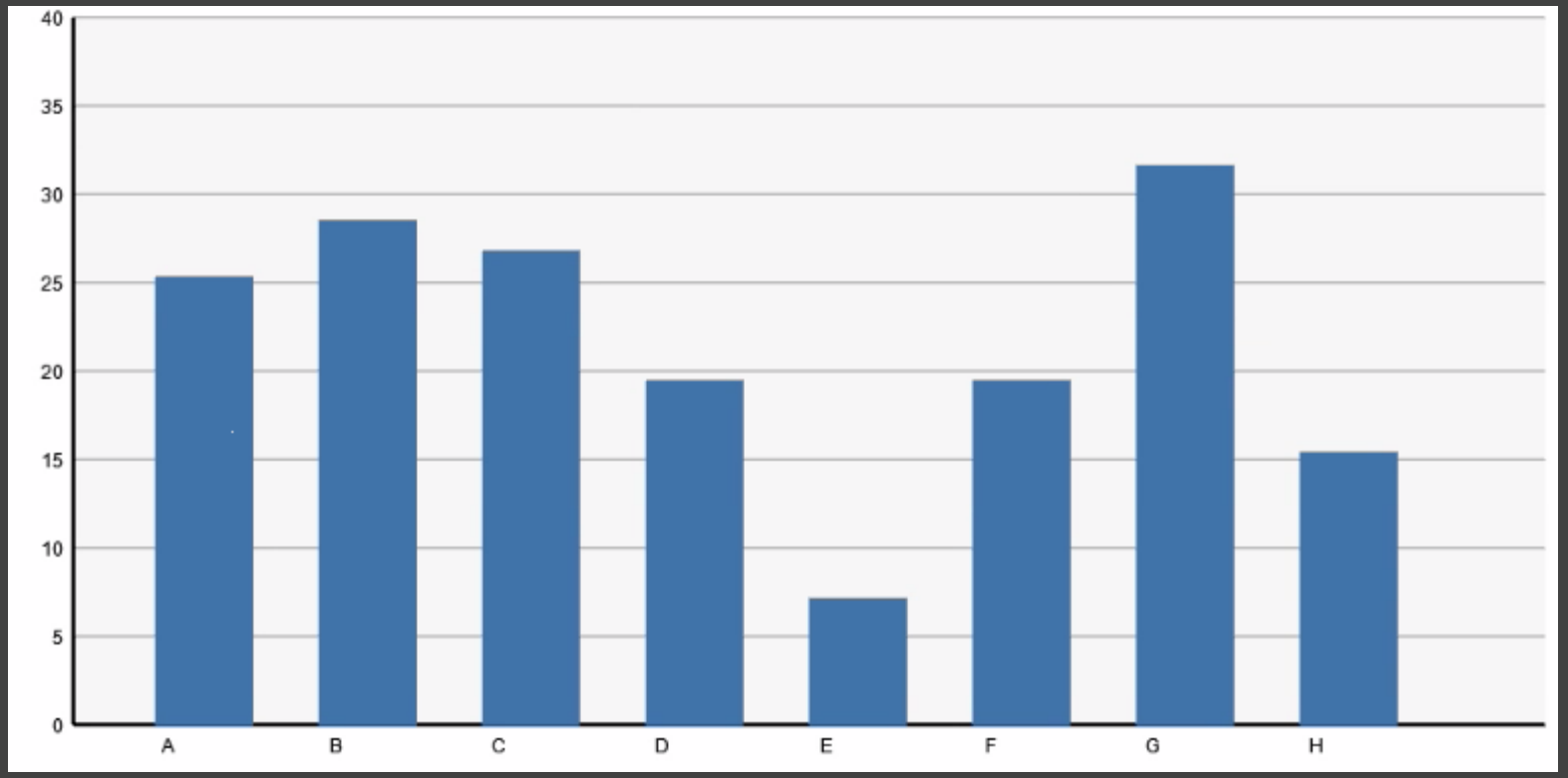



Month 1

# Timestep




Month 2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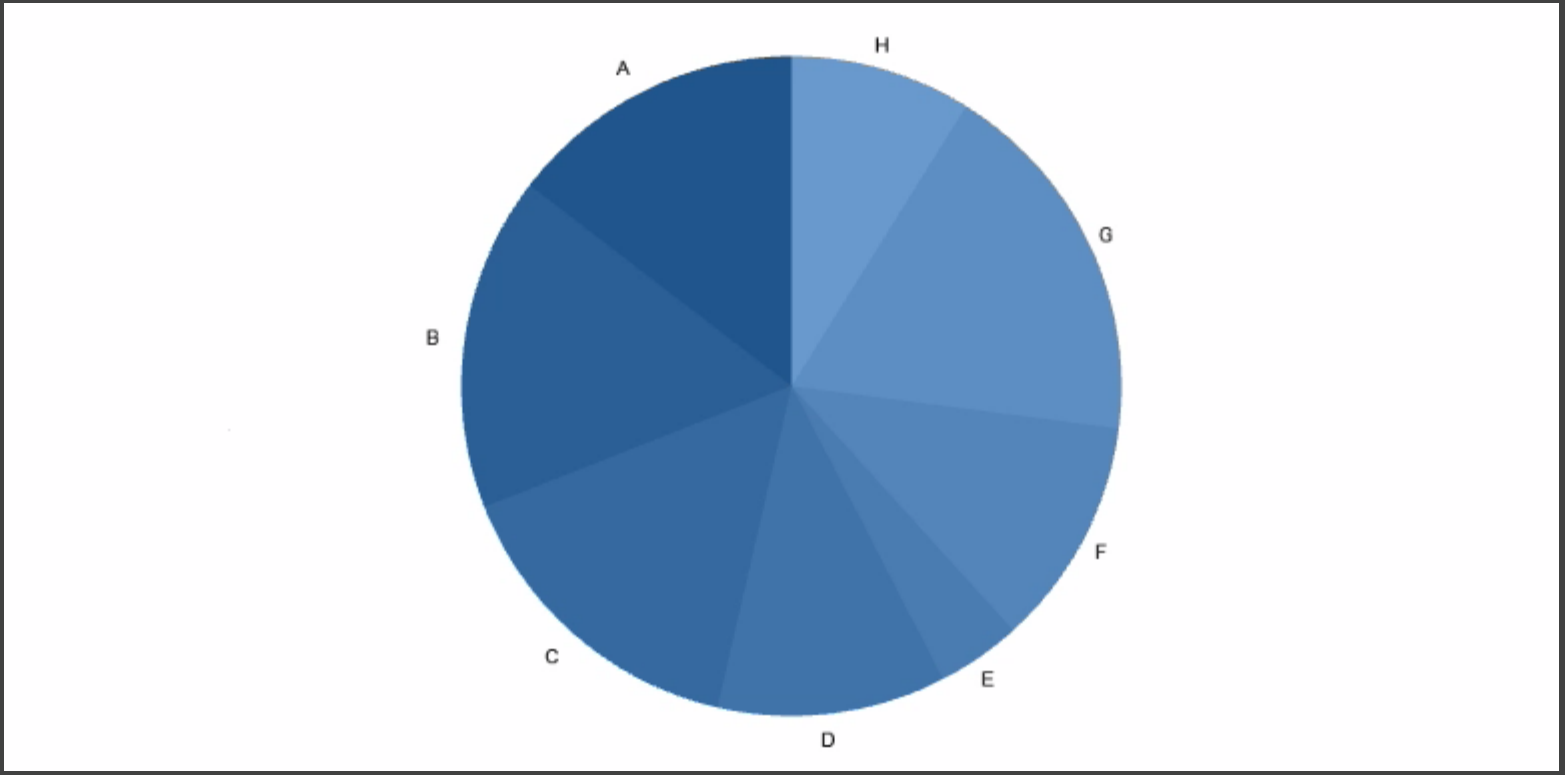
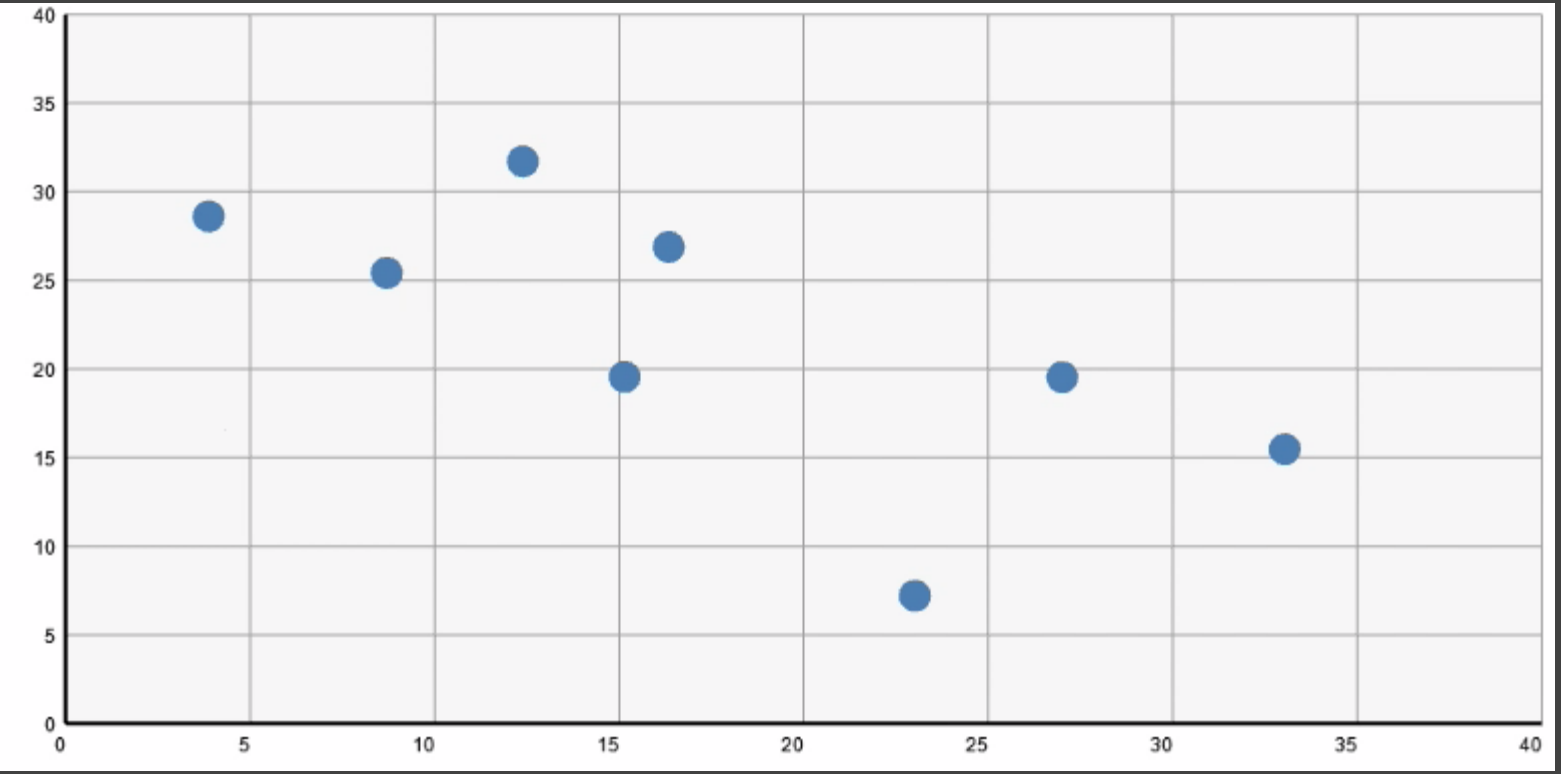
# Change Encodings

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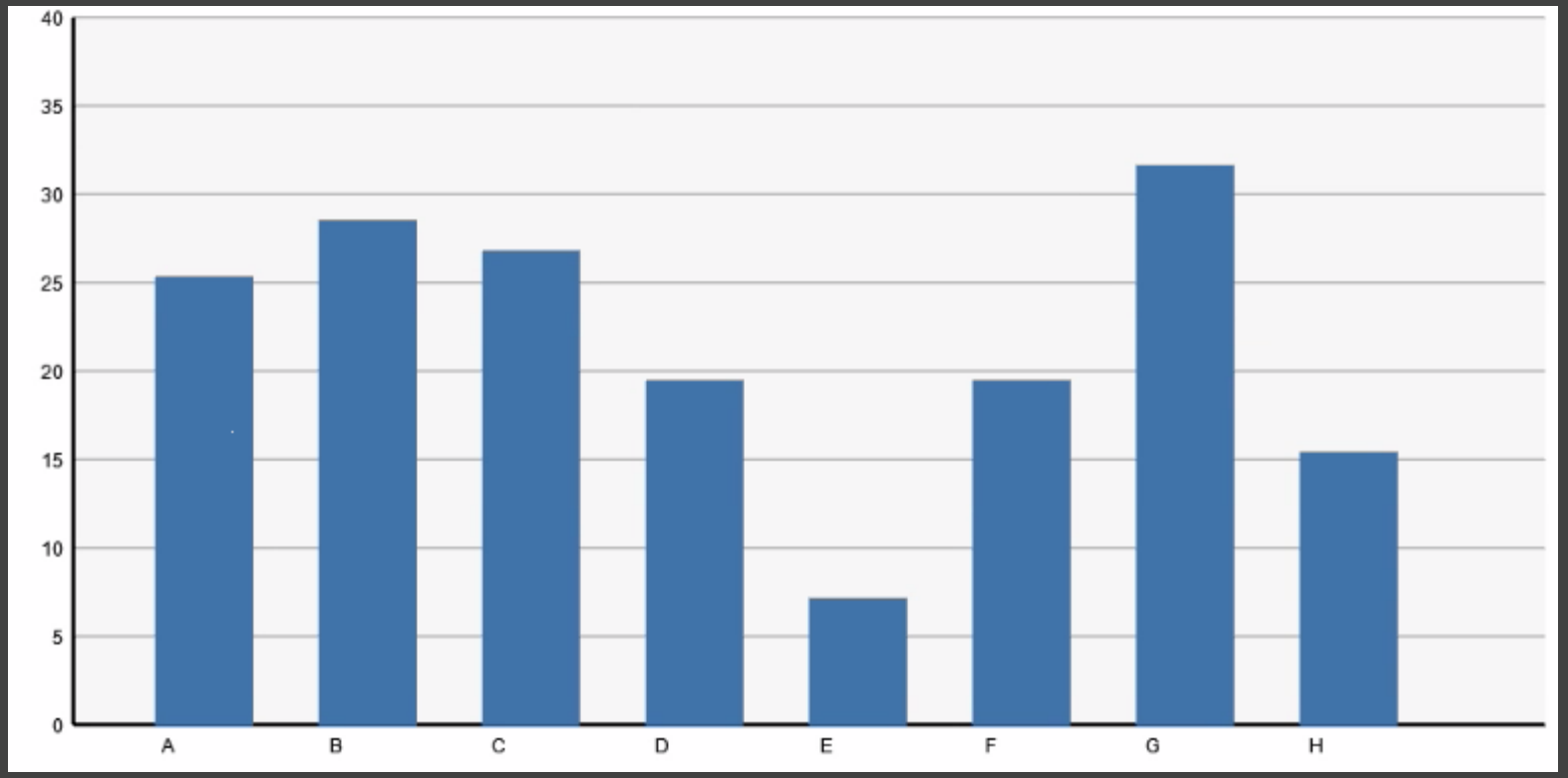
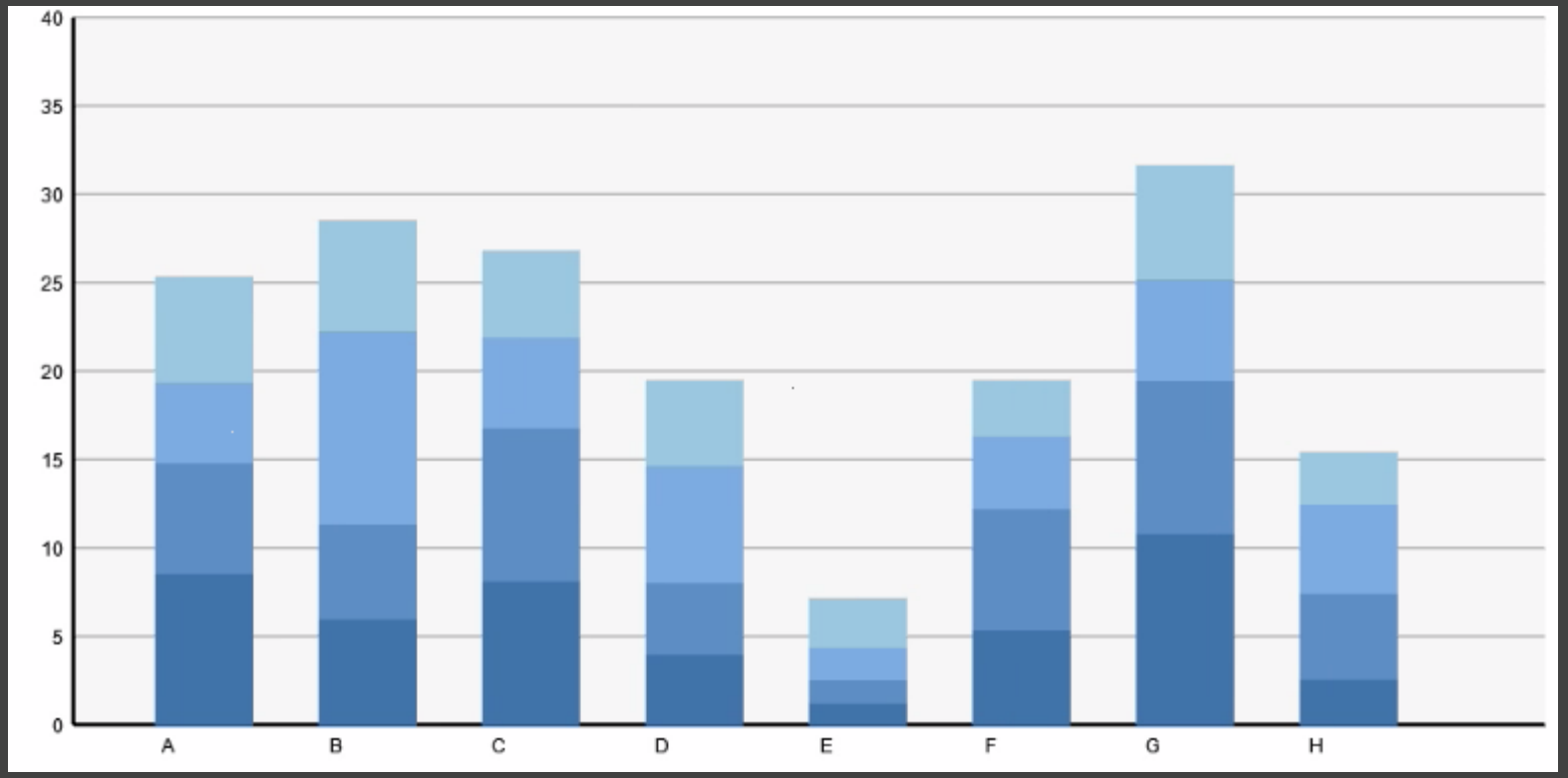
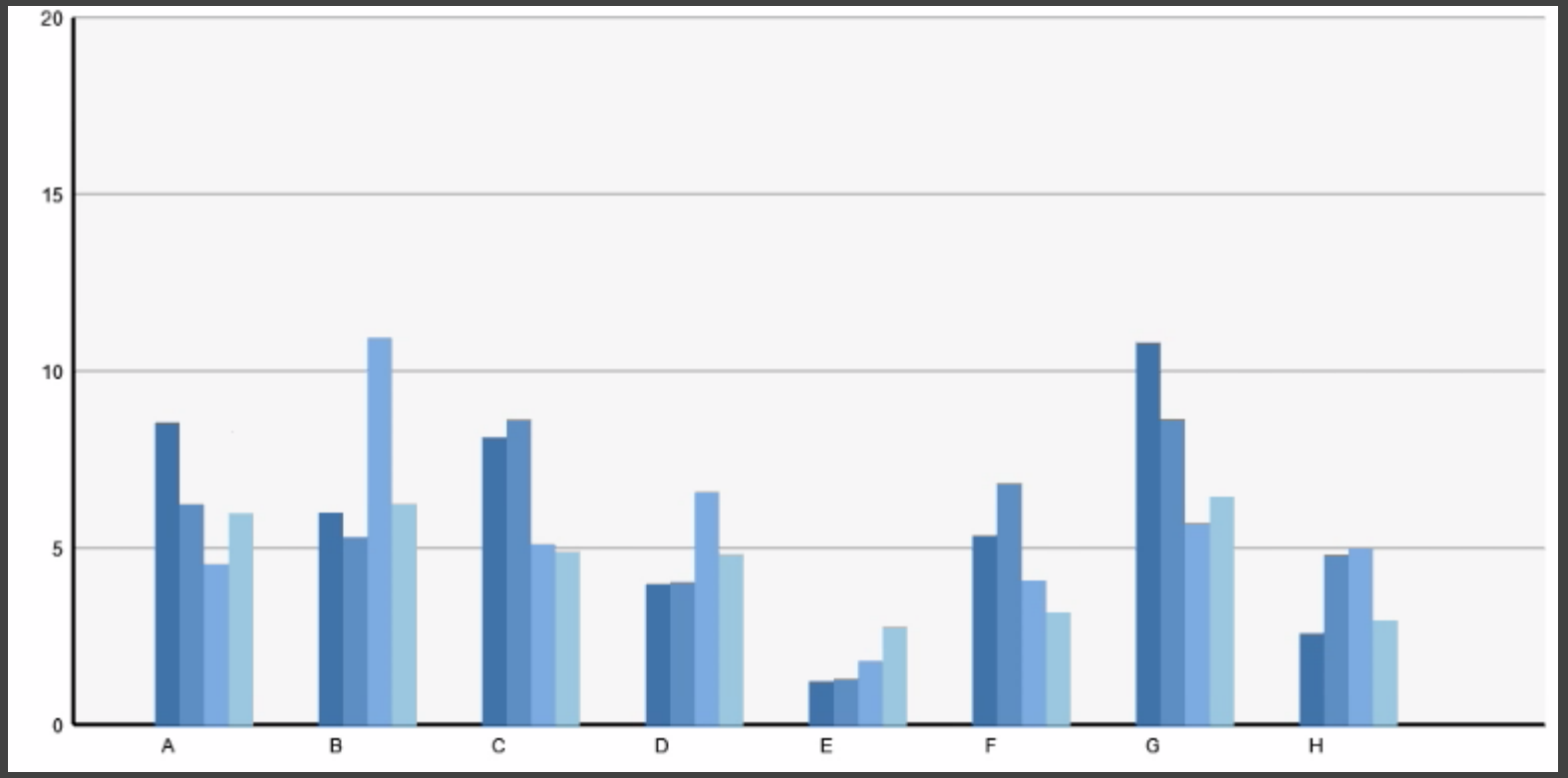


# Change Data Dimensions



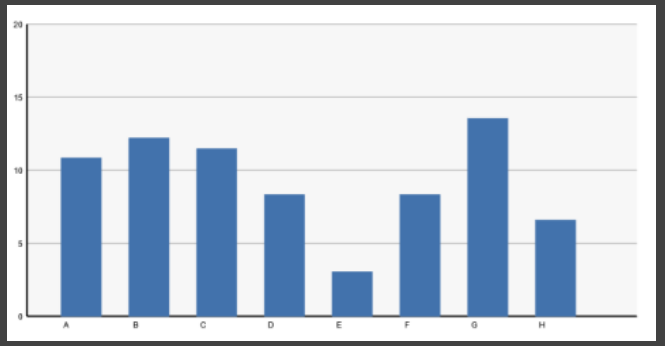
# Change Encodings + Axis Scales



# 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?

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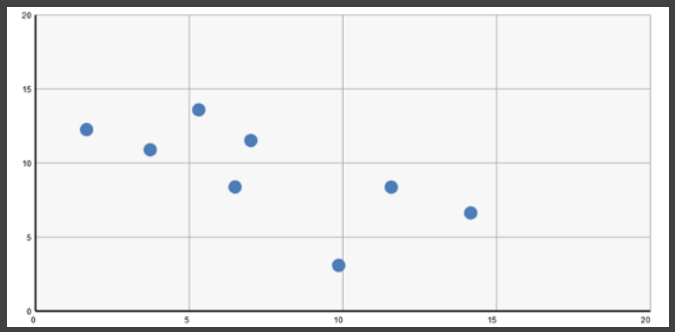
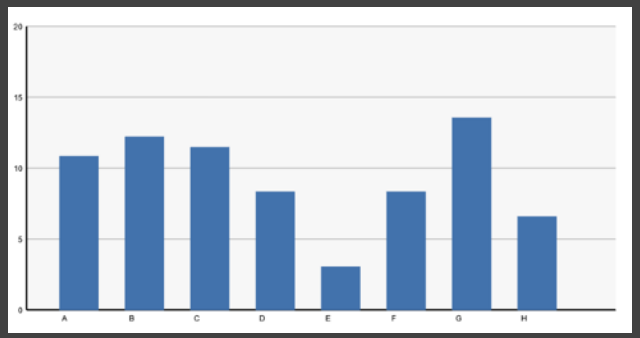


# Transitions between Data Graphics

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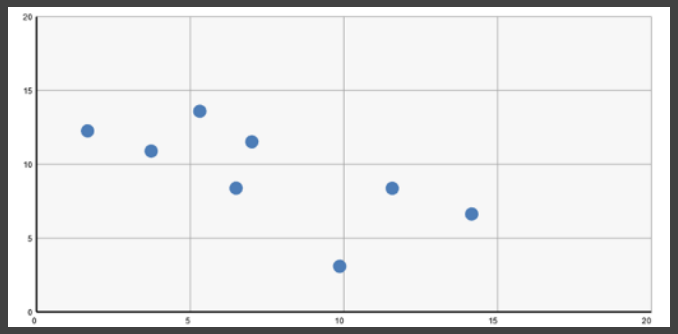


During analysis and presentation it is common to transition between *related* data graphics.

**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

**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

**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

**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
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Make transitions as long as needed, but no longer

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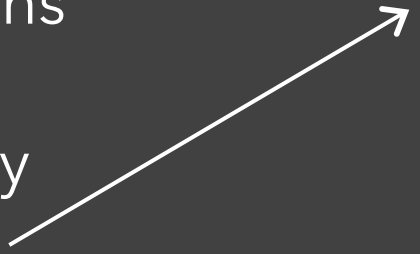
Minimize occlusion
Maximize predictability
Use simple transitions
Use staging for complex transitions
Make transitions as long as needed, but no longer



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

# 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)

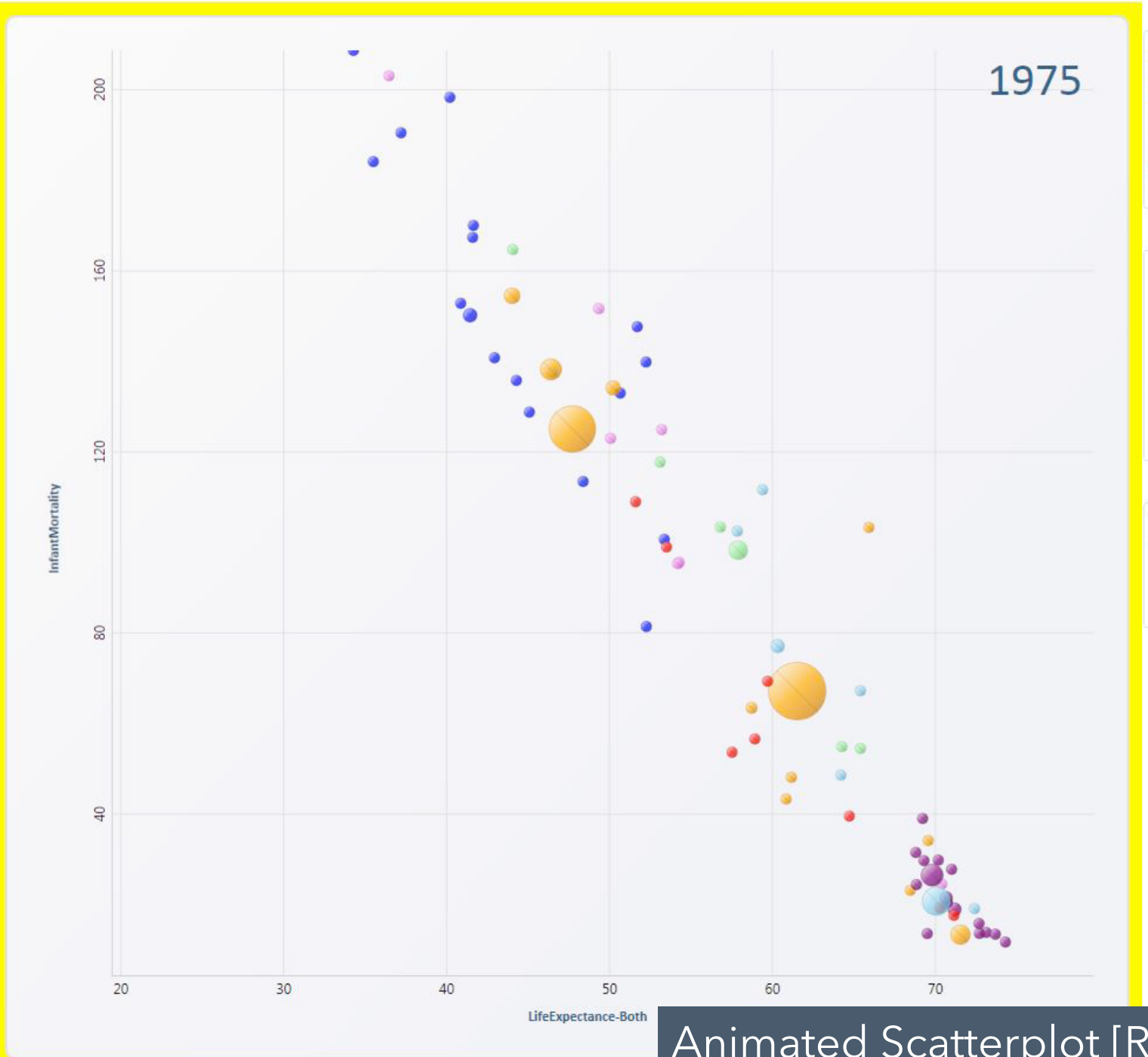
**Subjects preferred animated transitions**

# 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




**Color Legend (continent)**

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

**Task**

Select two countries with decreasing InfantMortality, but little change in life expectancy.

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

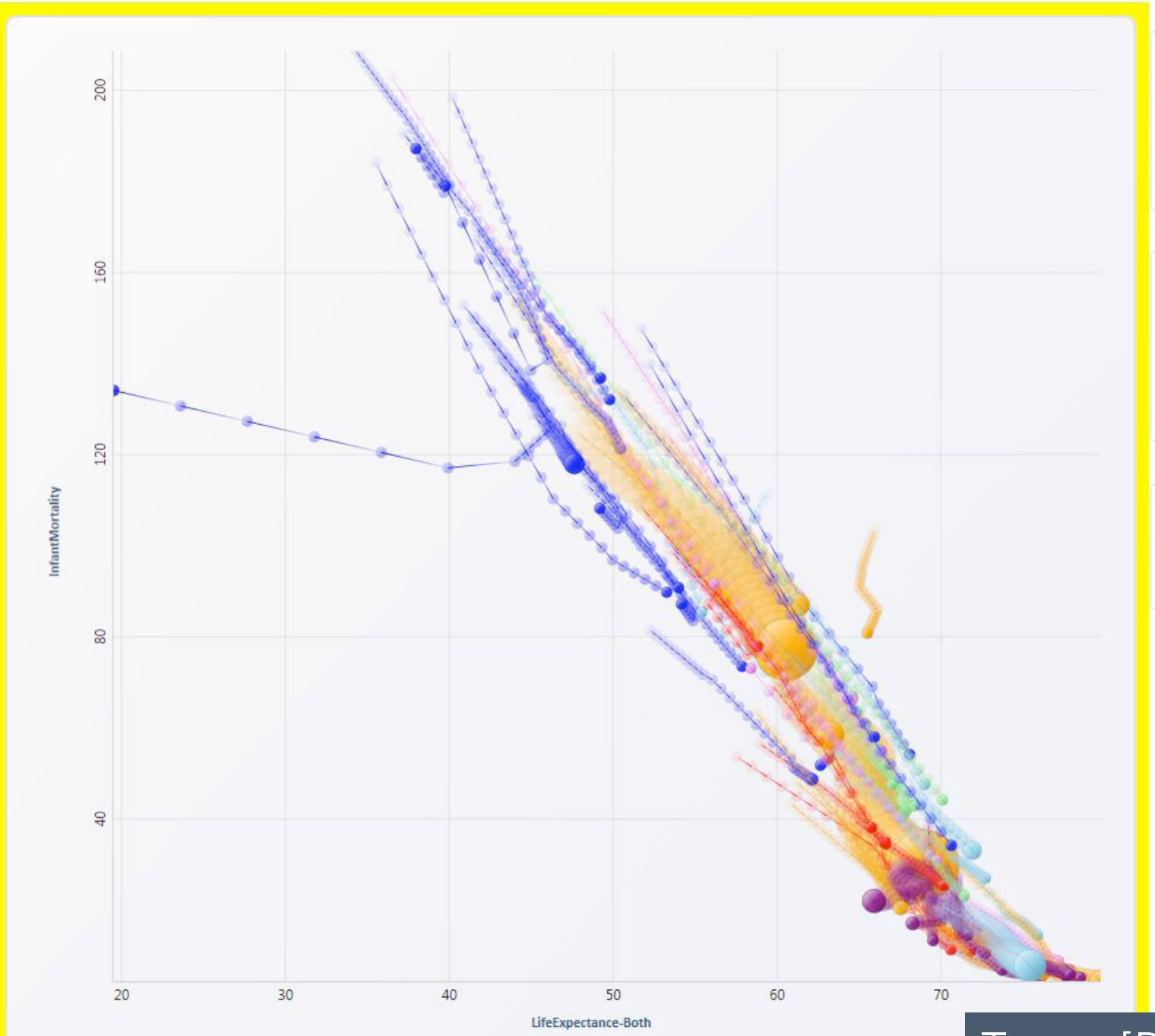
**Answers set: 0/2**

**Next**

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

Give Up | Next

# Animated Scatterplot [Robertson 08]

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- Africa
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**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**

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Give Up | Next

Traces [Robertson 08]

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

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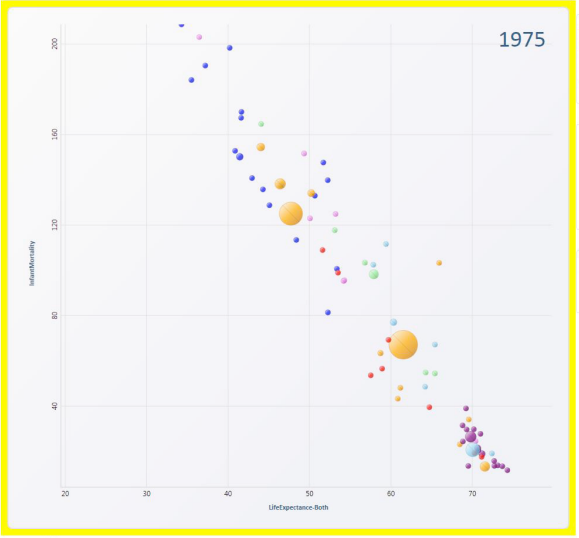
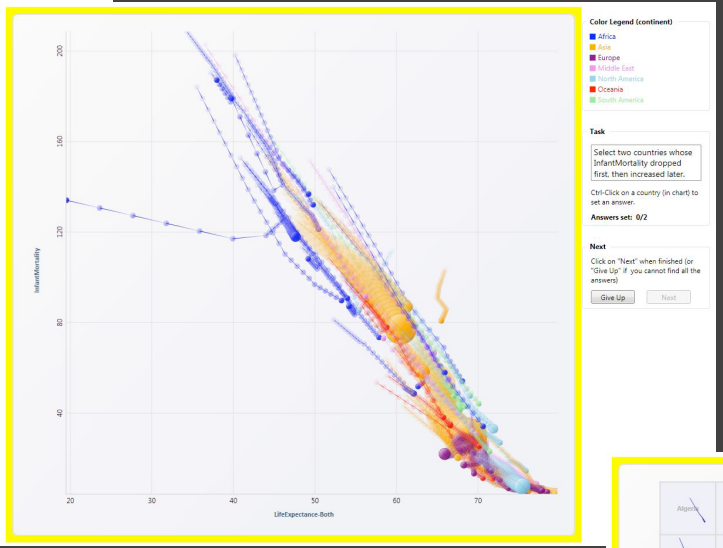
Give Up | Next

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

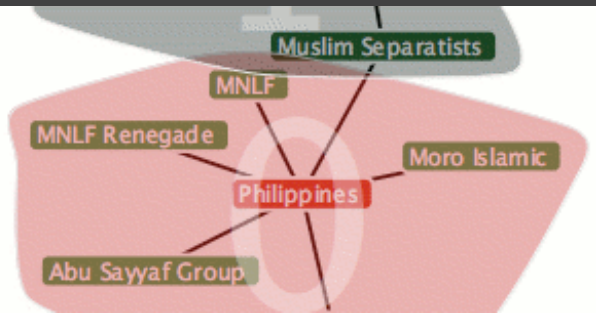
User preferences favor animation (even though less accurate and slower for analysis!)

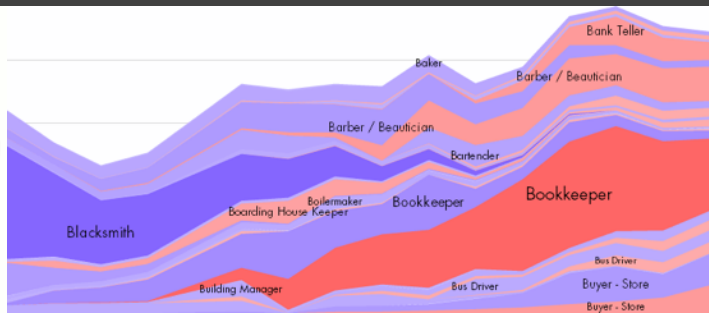
# Administrivia

# FP: Interactive Prototype

Create an interactive visualization. Choose a driving question in your topic area and develop an appropriate visualization + interaction techniques, then deploy your visualization on the web.

Due by *11:59pm* on **Wednesday, May 3**.



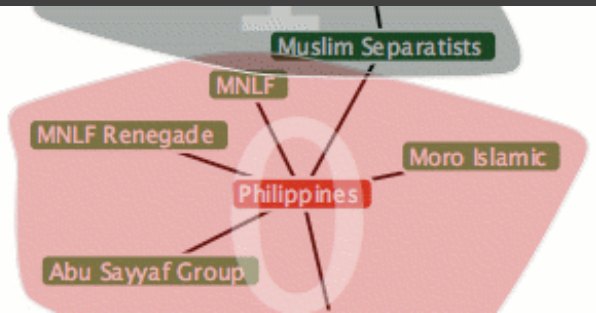
# FP: Peer Evaluations / Next Week

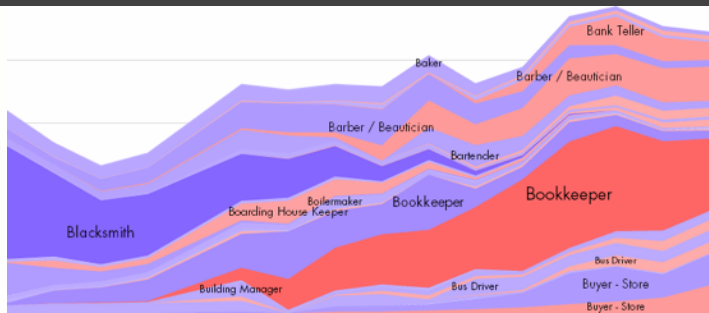
On **Thursday May 4** we will view prototype demos!

Your next milestone is to complete three peer evaluations of classmates' submissions.

We'll discuss *critique methods* next lecture.

There will be **no lecture on Tuesday May 9**, due to ACM CHI. Work on your peer evaluations!



# Implementing Animation

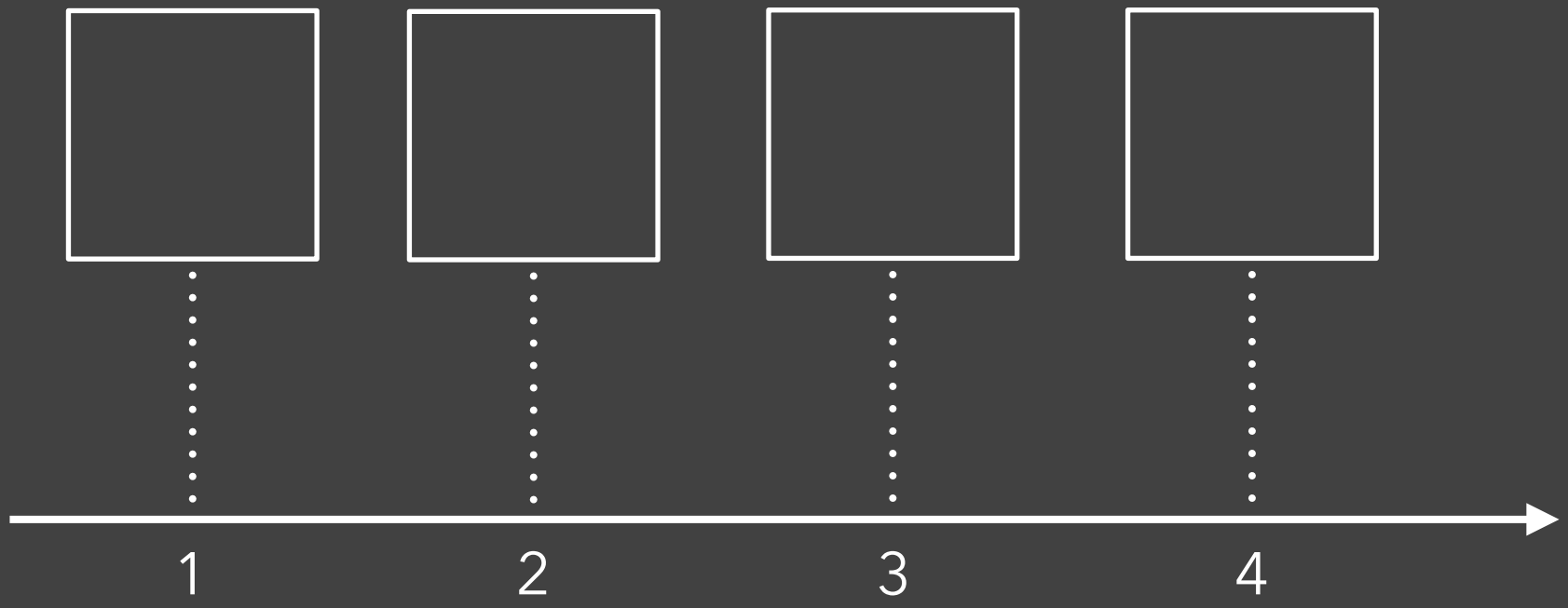
# Animation Approaches

**Frame-Based Animation**

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

Developer defines the redraw function

# Frame-Based Animation



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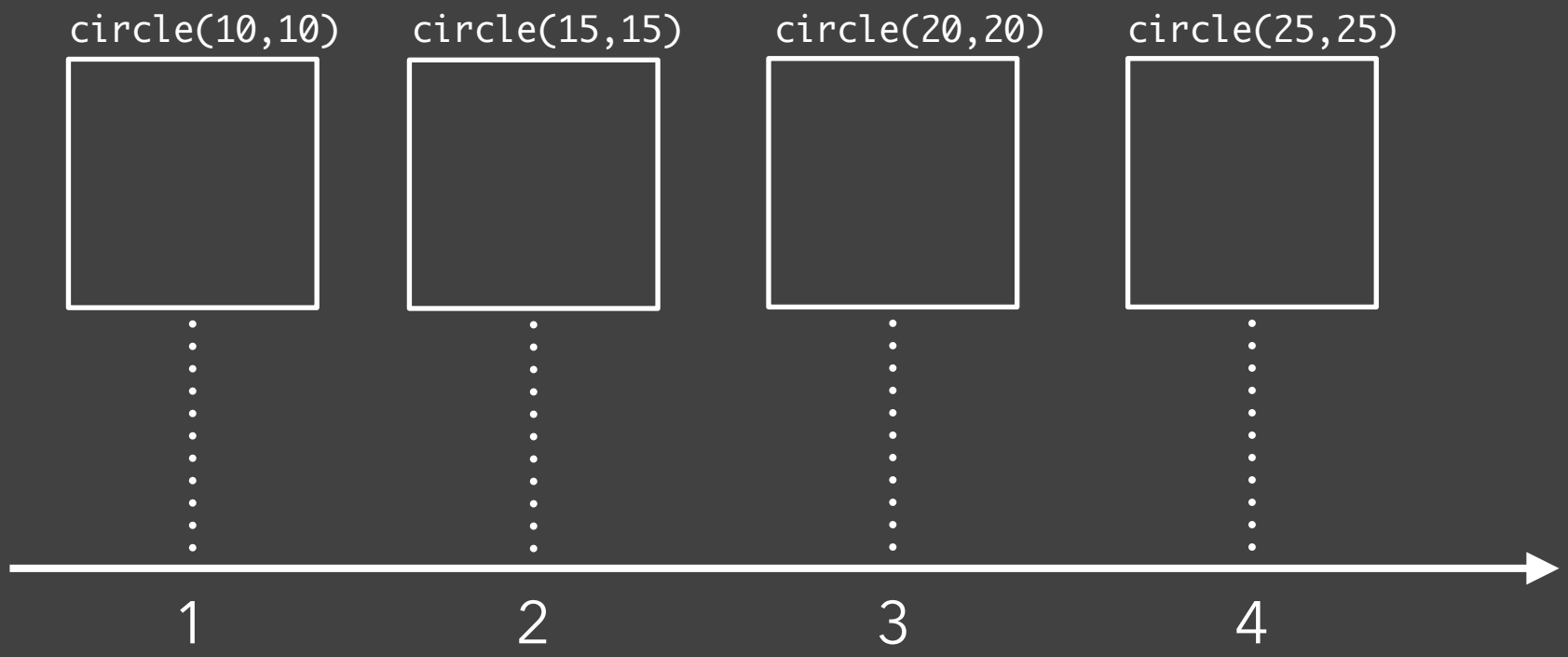

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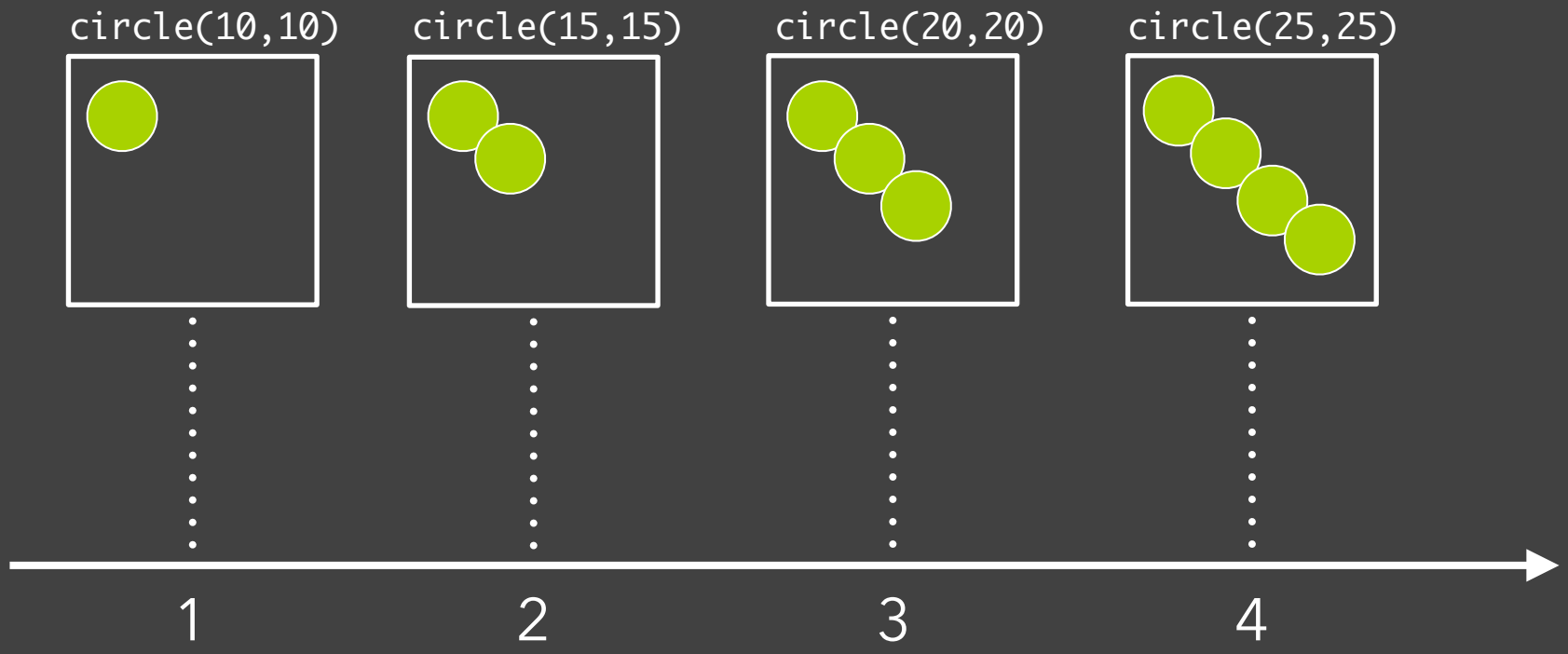

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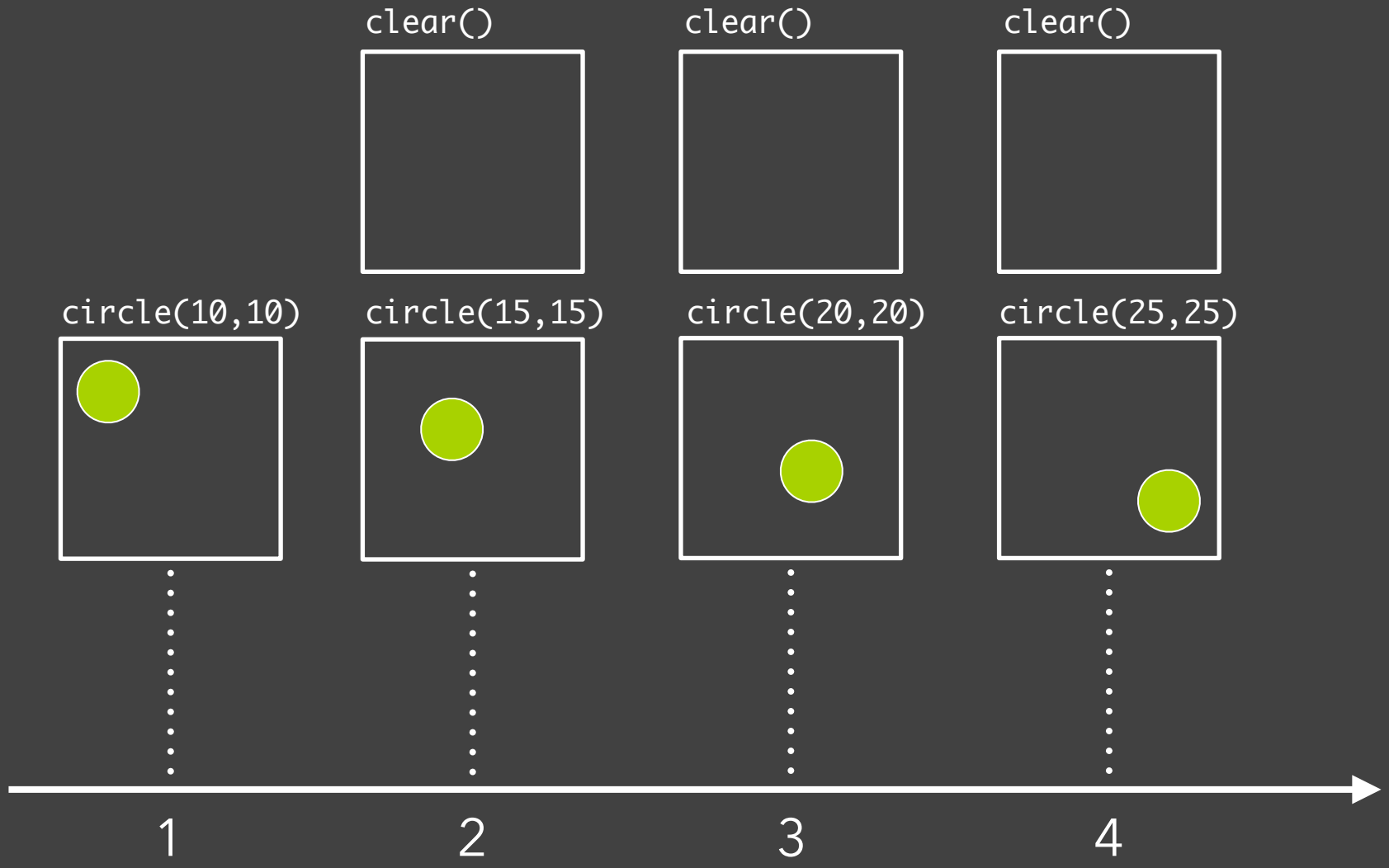

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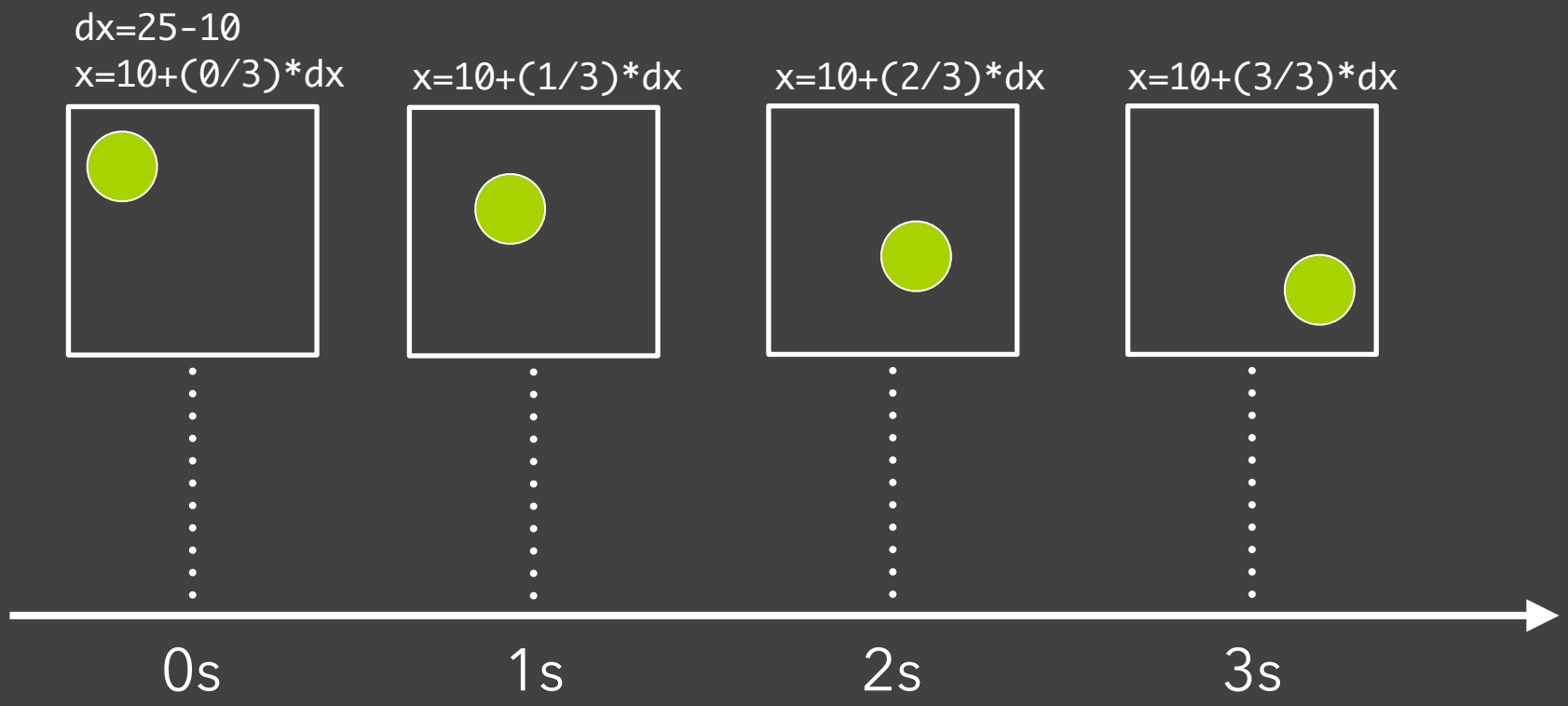
**Transition-Based Animation** (Hudson & Stasko '93)
Specify property value, duration & easing
Also called **tweening** (for "in-betweens")
Typically computed via **interpolation**

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



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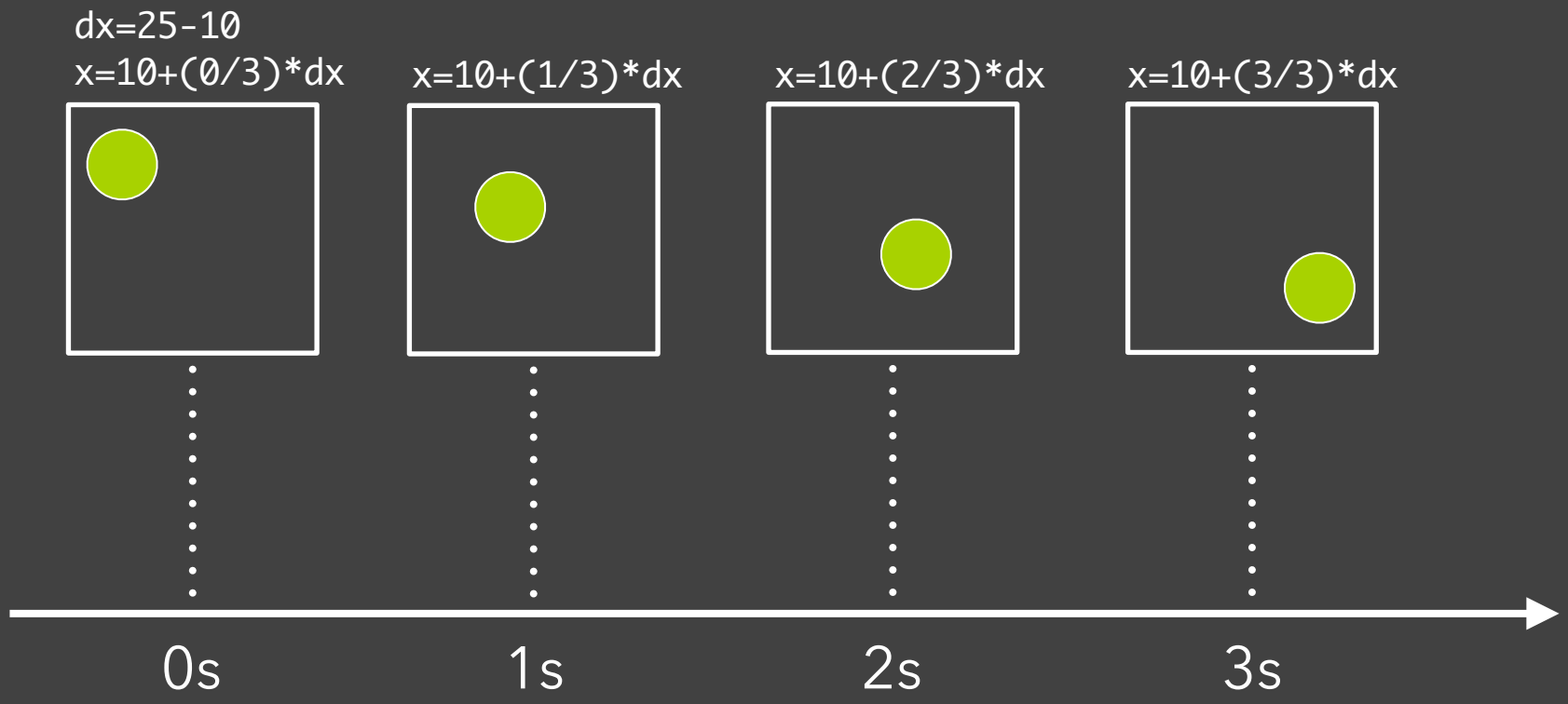
**from:** (10,10) **to:** (25,25) **duration:** 3sec

*Toolkit handles frame-by-frame updates!*



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// 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.
var bars = svg.selectAll(“rect.bars”).data(values);

// 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

```
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))
    …

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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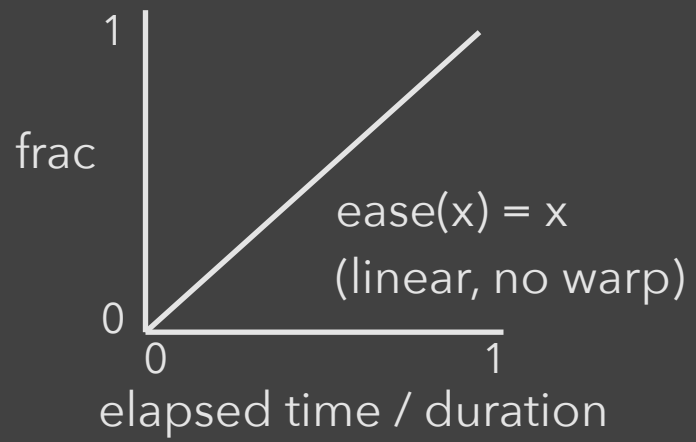

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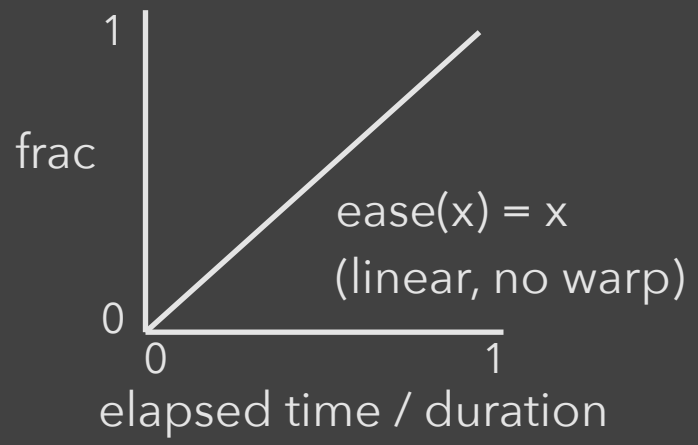


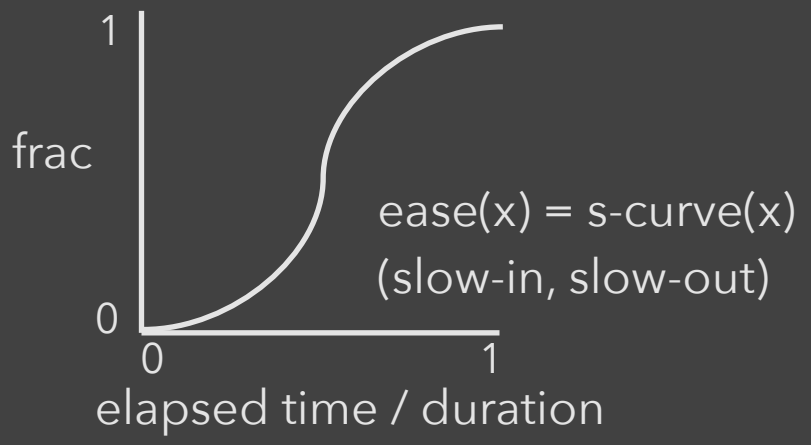

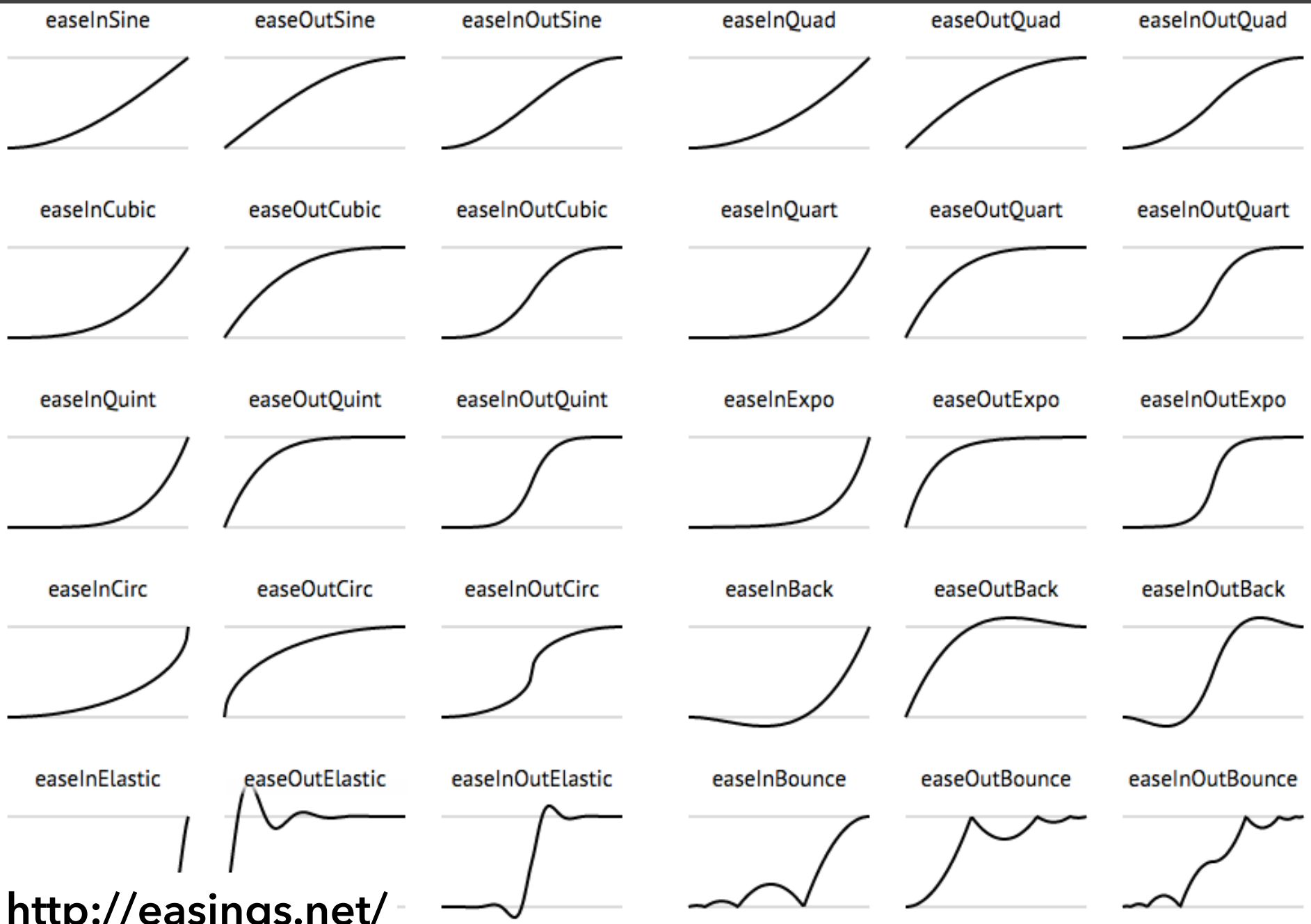


http://easings.net/

# CSS Transitions

**Extends CSS with Animated Transitions**

```
a {
  color: black;
  transition: color 1s ease-in-out;
}

a:hover {
  color: red;
}
```

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Duration

Property

Easing

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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 processes, **static images** may be preferable

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