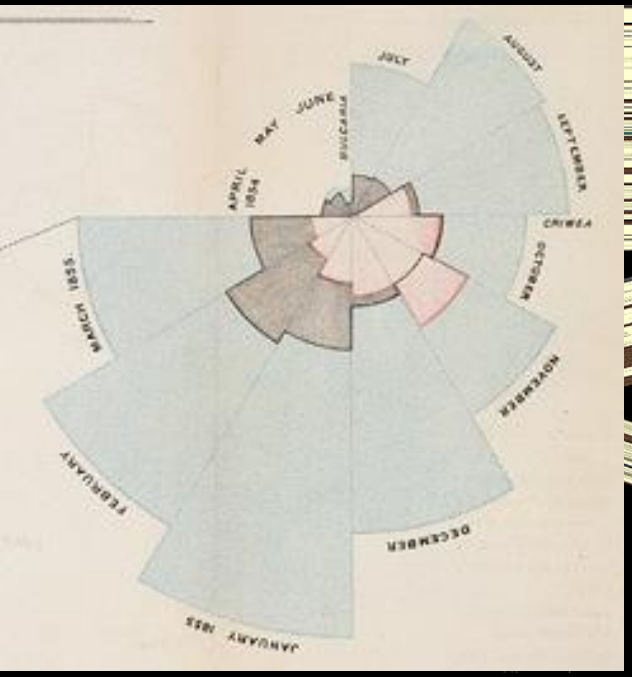
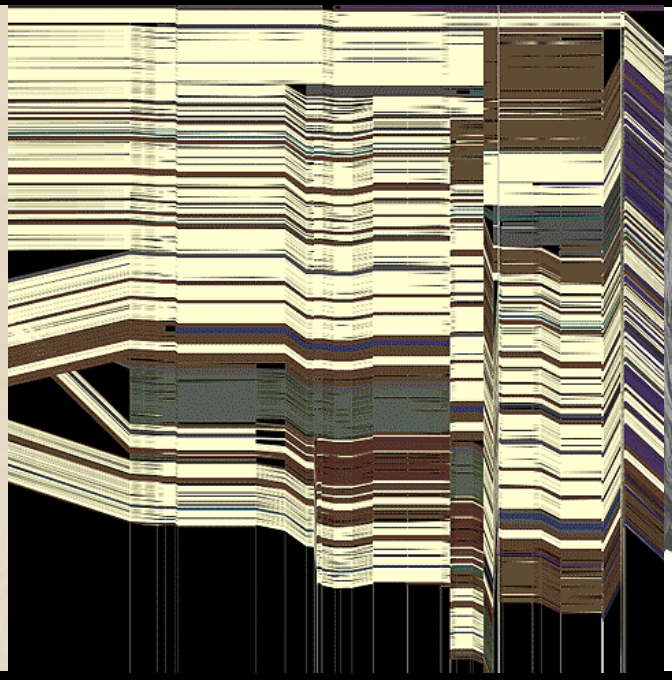
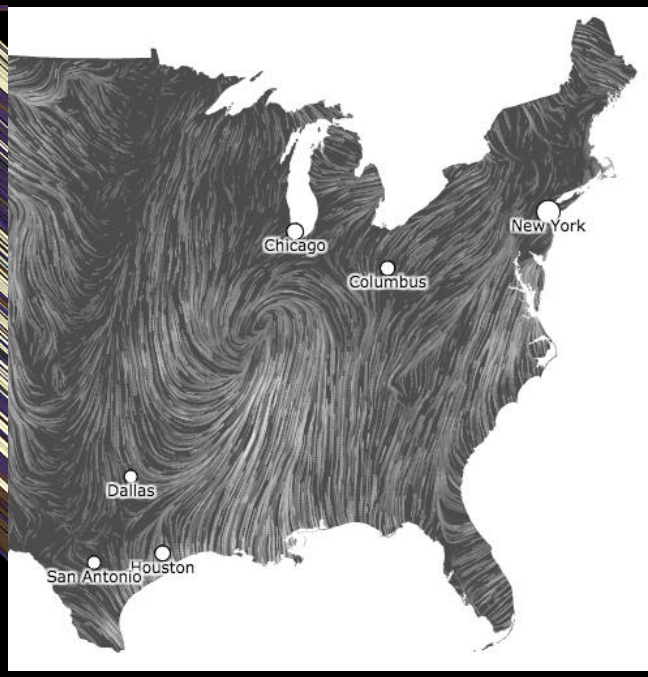
CSE 442 - Data Visualization

Animation







Leilani Battle University of Washington

Why Use Motion?

Visual variable to encode data

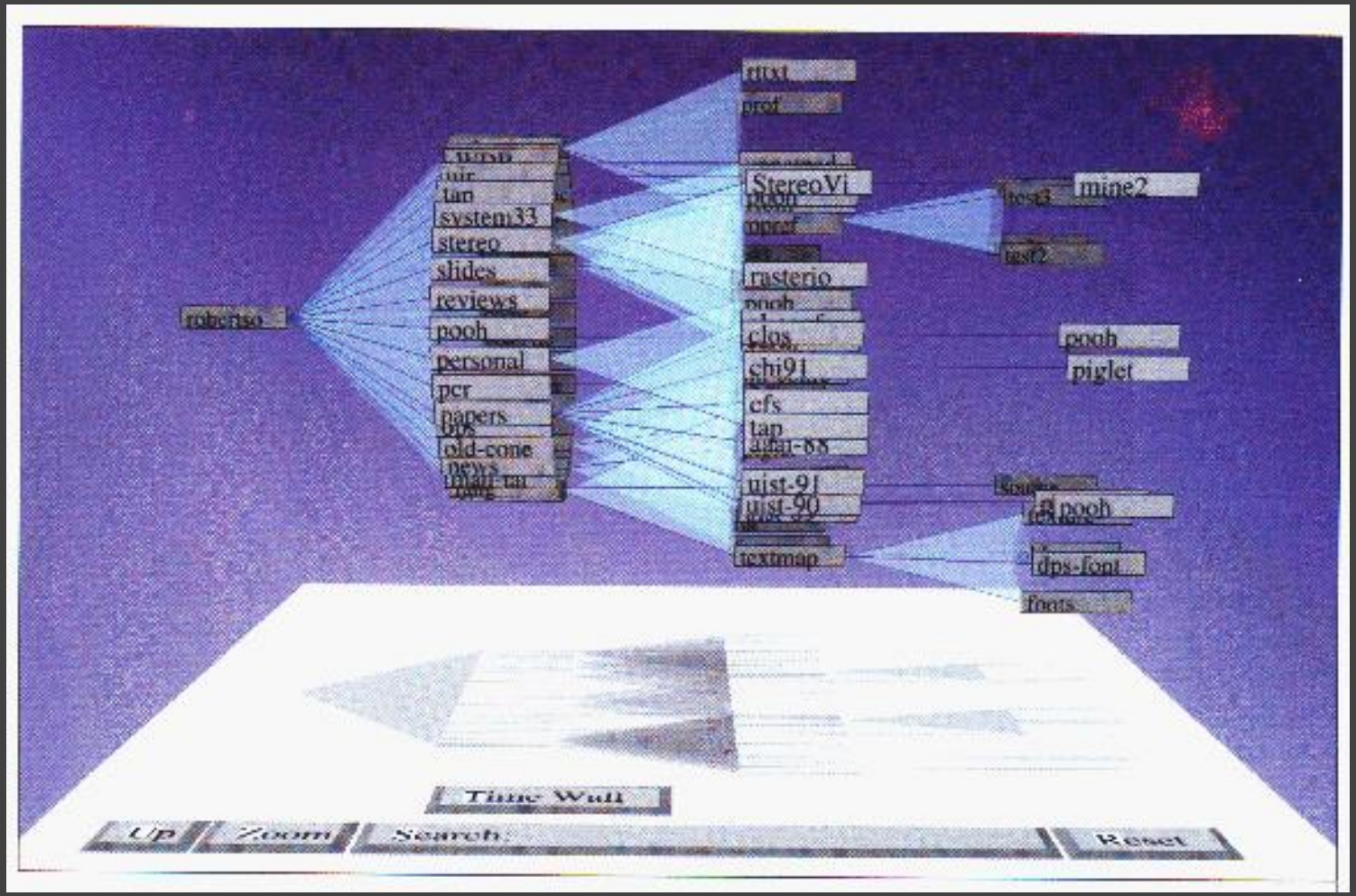
Direct attention

Understand system dynamics

Understand state transition

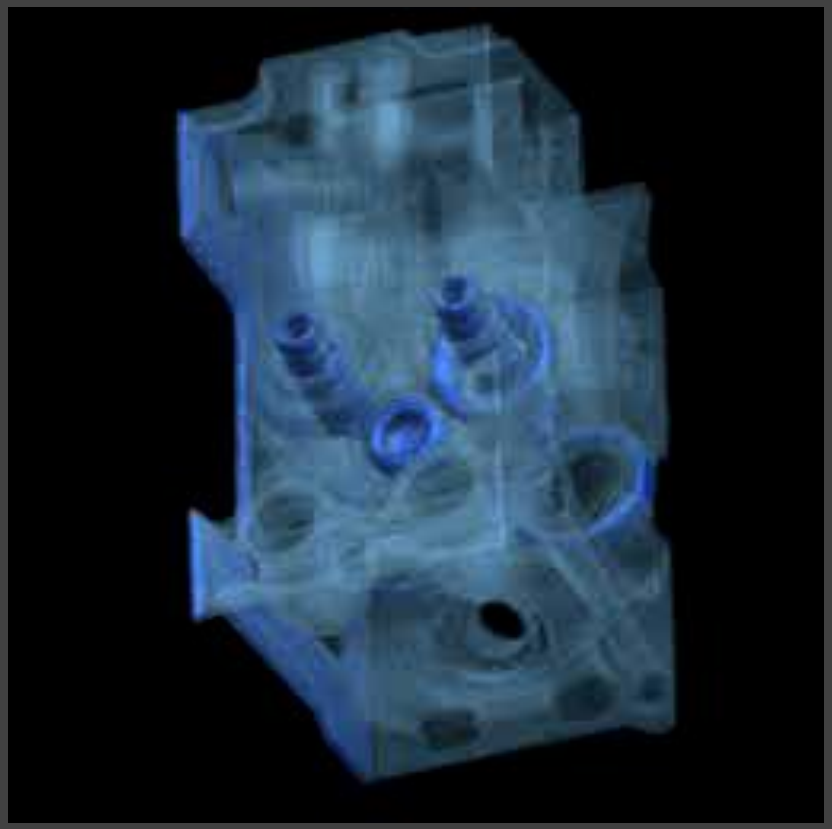
Increase engagement

Cone Trees [Robertson 91]



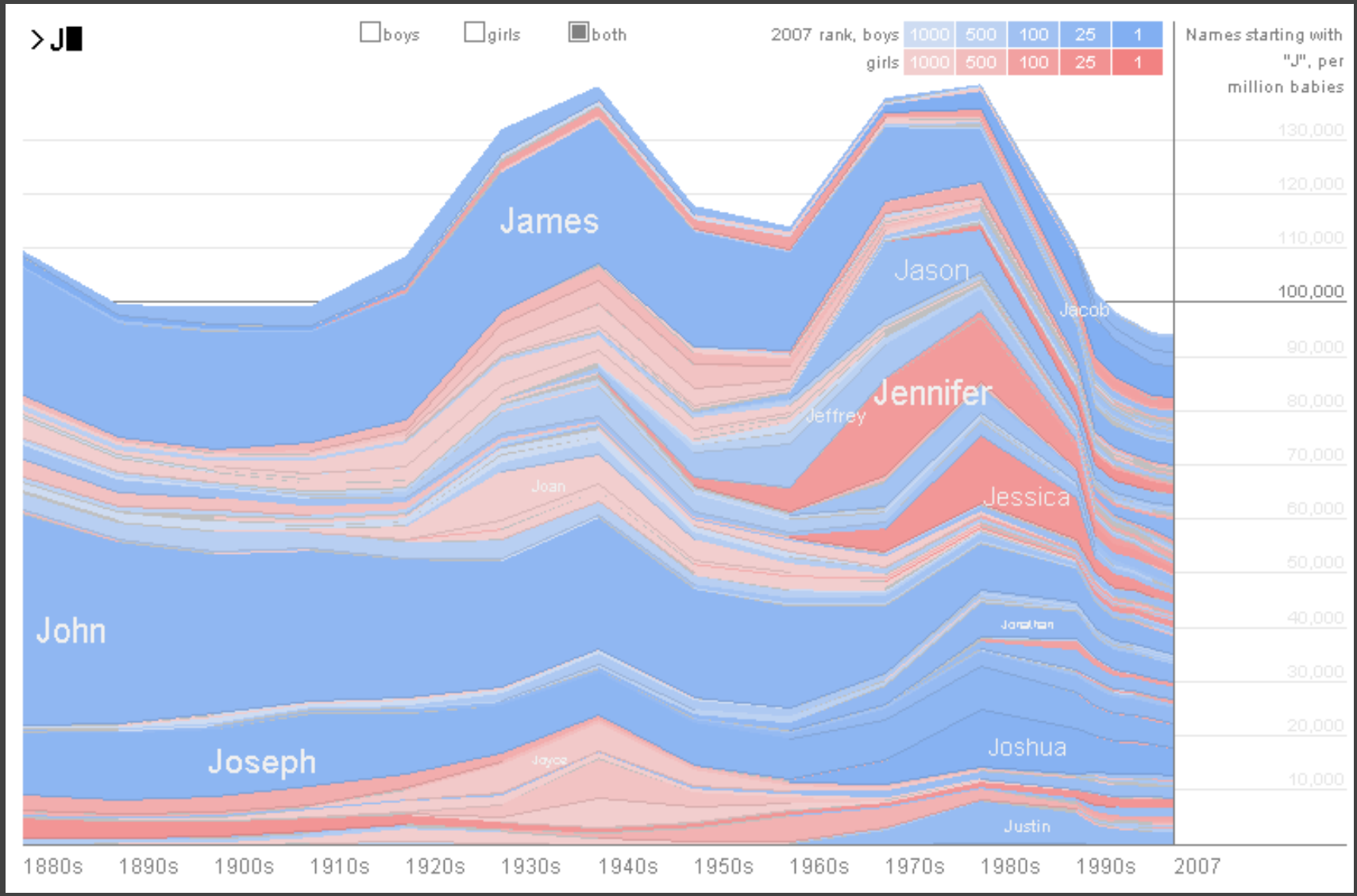
Video

Volume Rendering [Lacroute 95]

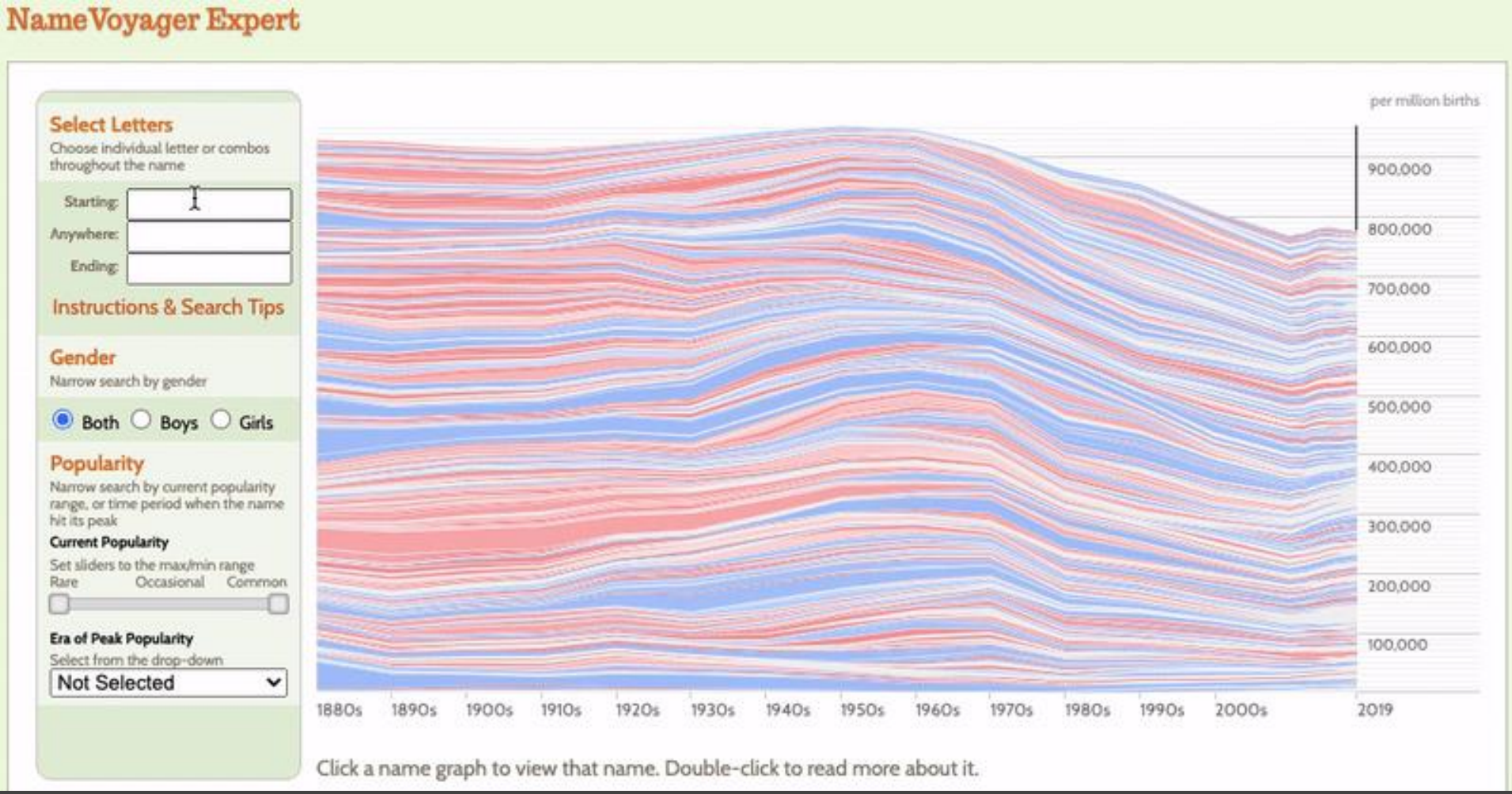


Video

NameVoyager [Wattenberg 06]



NameVoyager [Wattenberg 06]



Learning Goals

How do people perceive animations, particularly within visualizations?

How can we use animations to enhance a viewer's understanding of a visualization?

Topics

Motion perception

Animated transitions in visualizations

Implementing animations

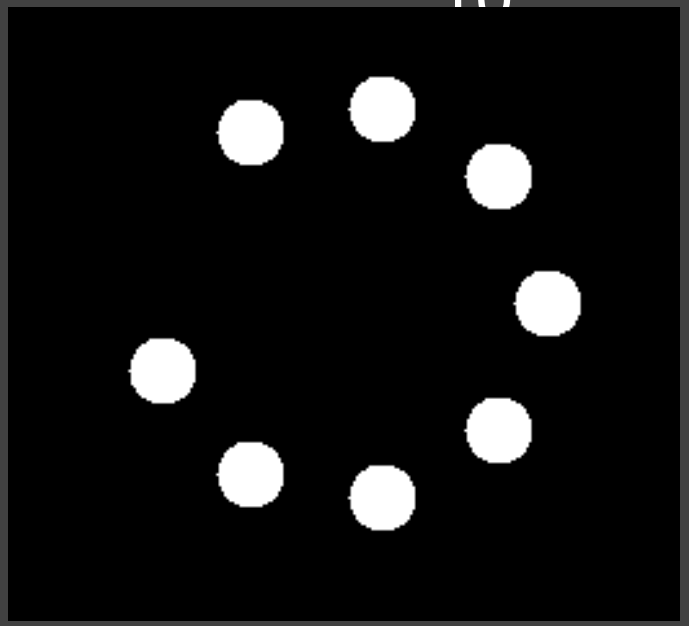
Motion Perception

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 motion! We can tell discrete yet movement.



Motion as Visual Cue

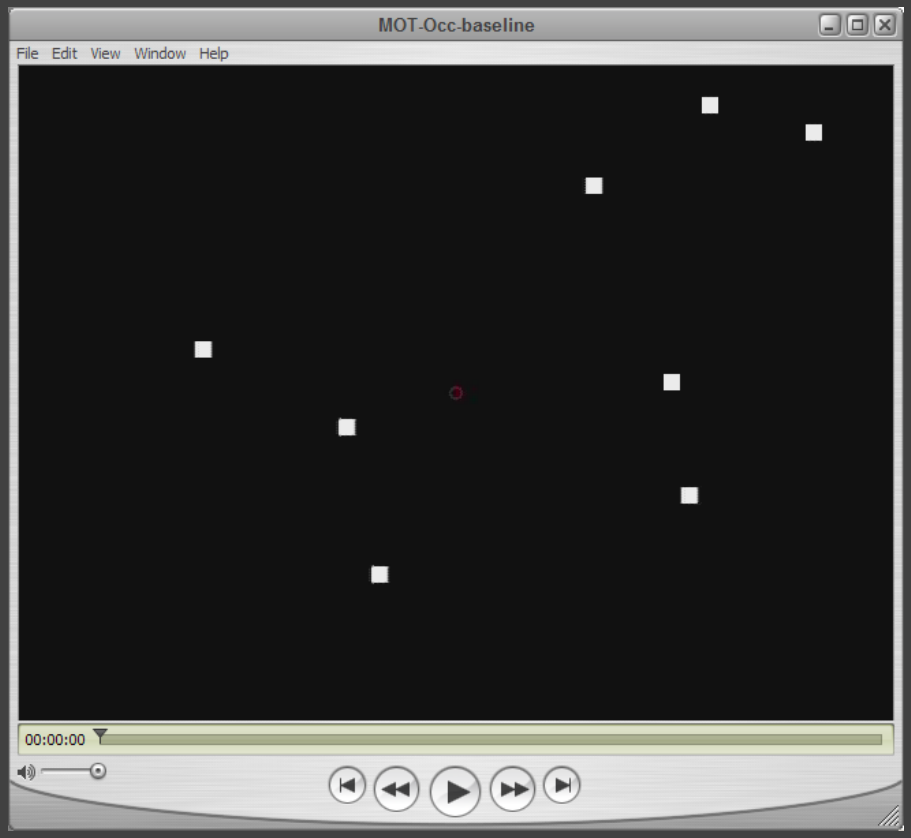
Pre-attentive, stronger than color, shape, …

More sensitive to motion at periphery

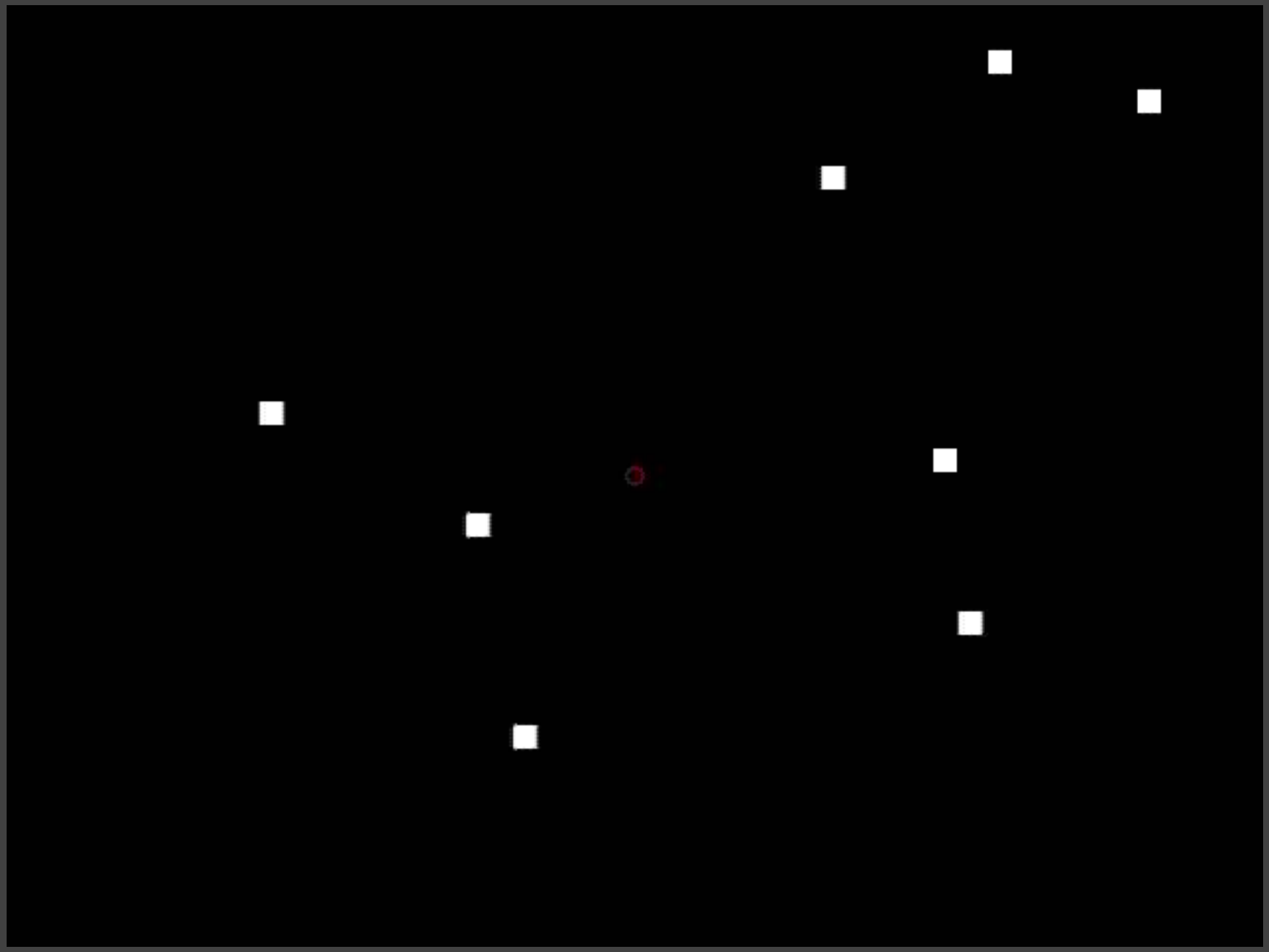
Similar motions perceived as a group

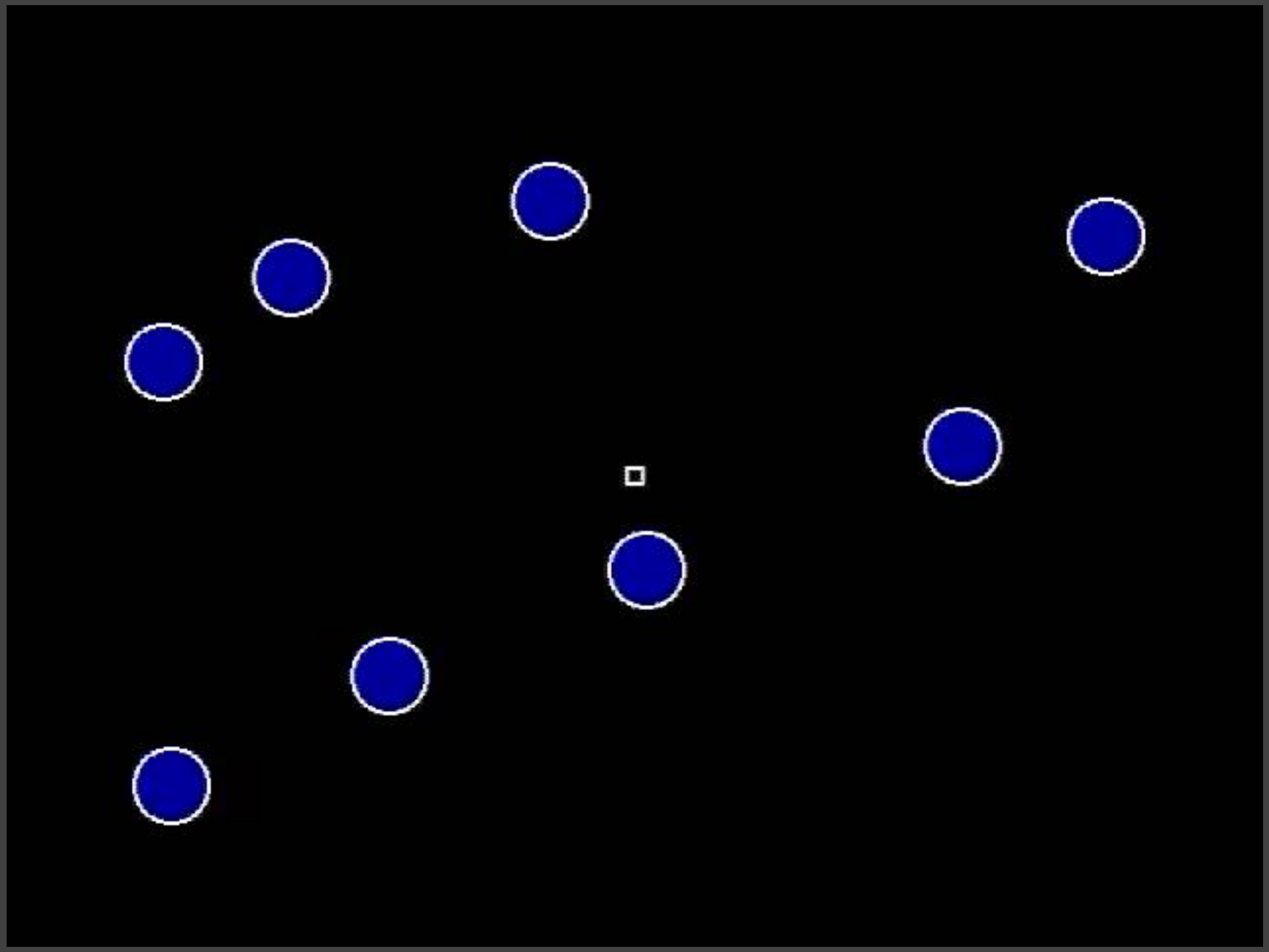
Motion parallax provide 3D cue (like stereopsis)

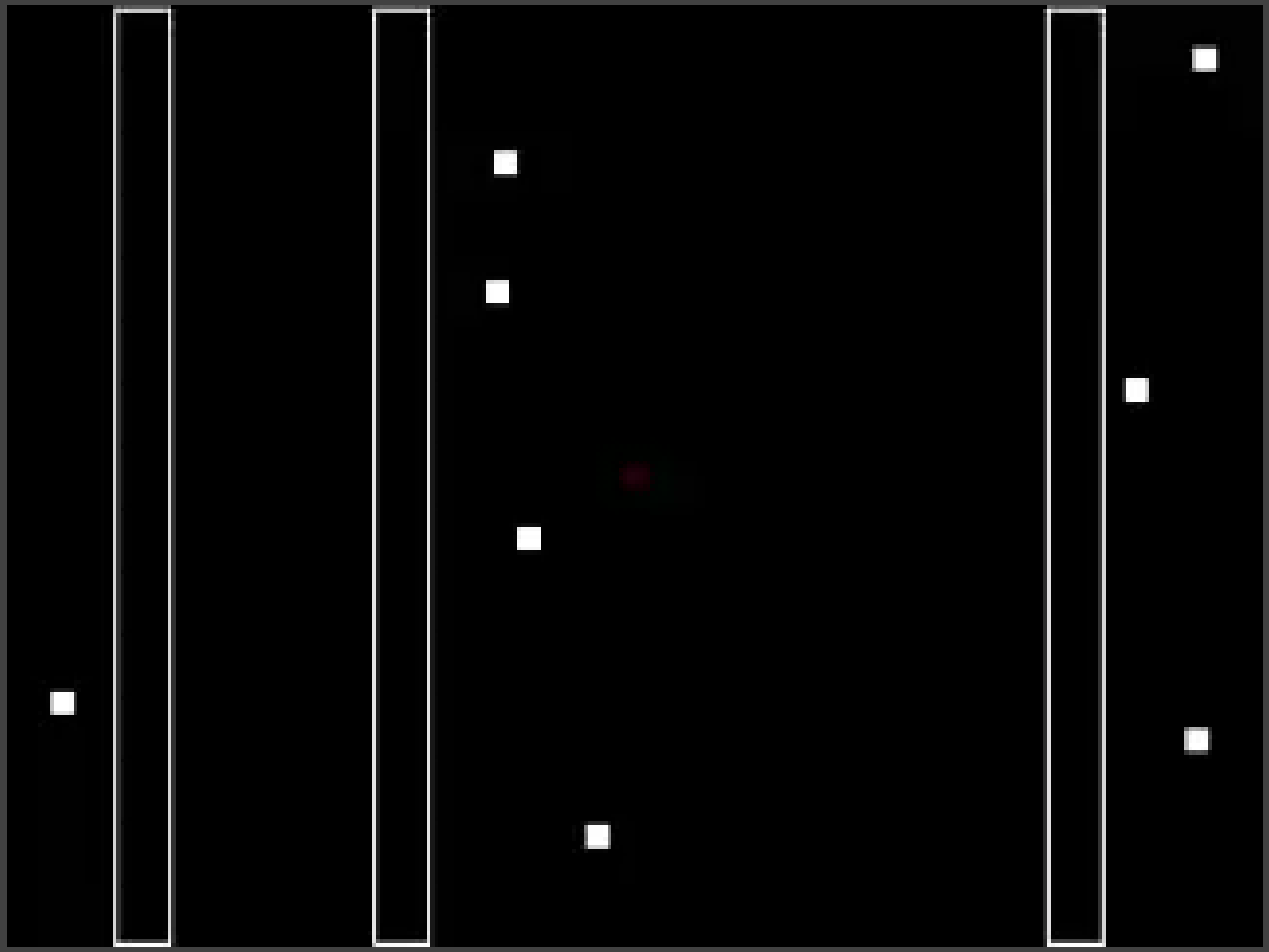
Tracking Multiple Targets

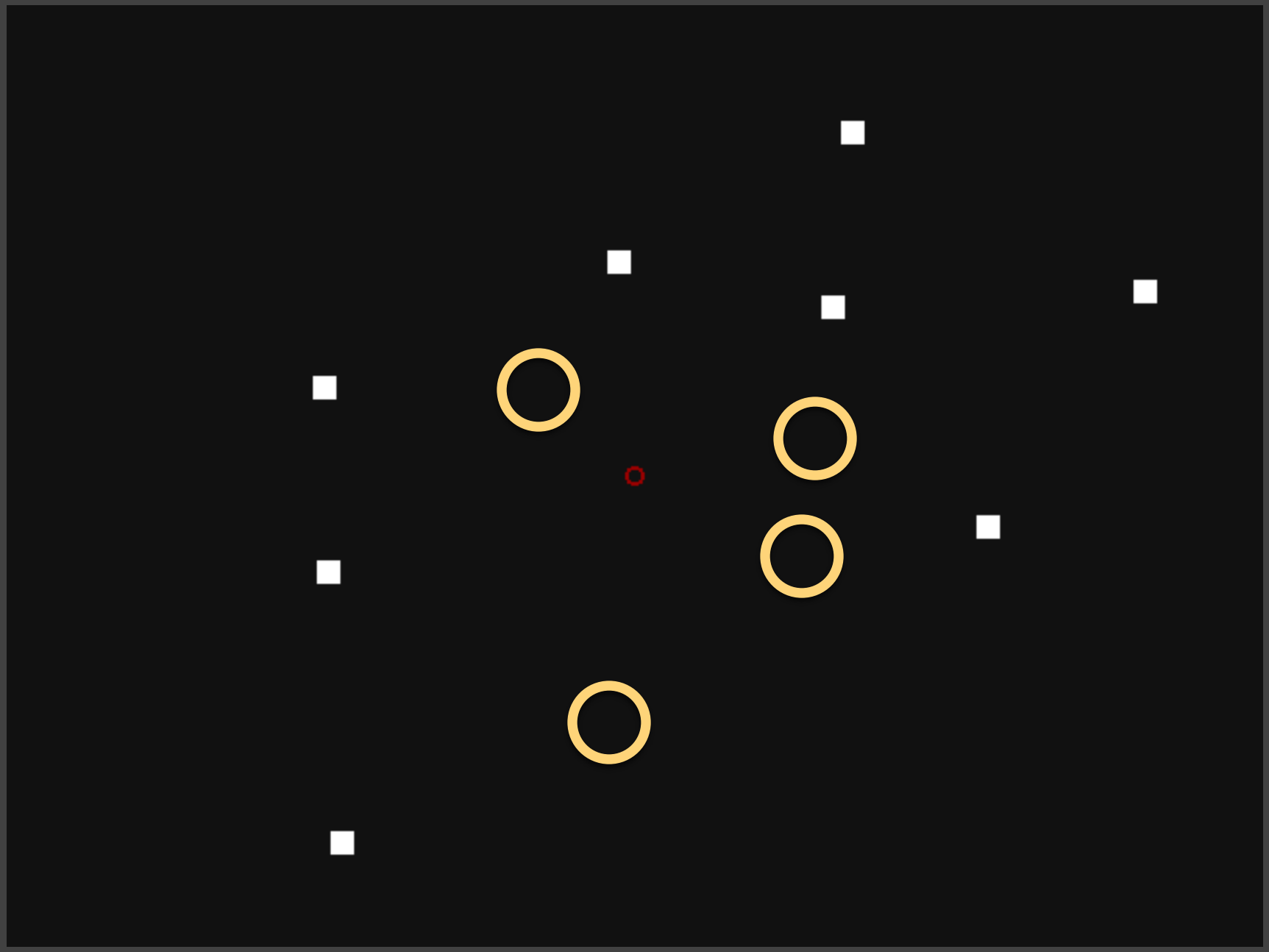


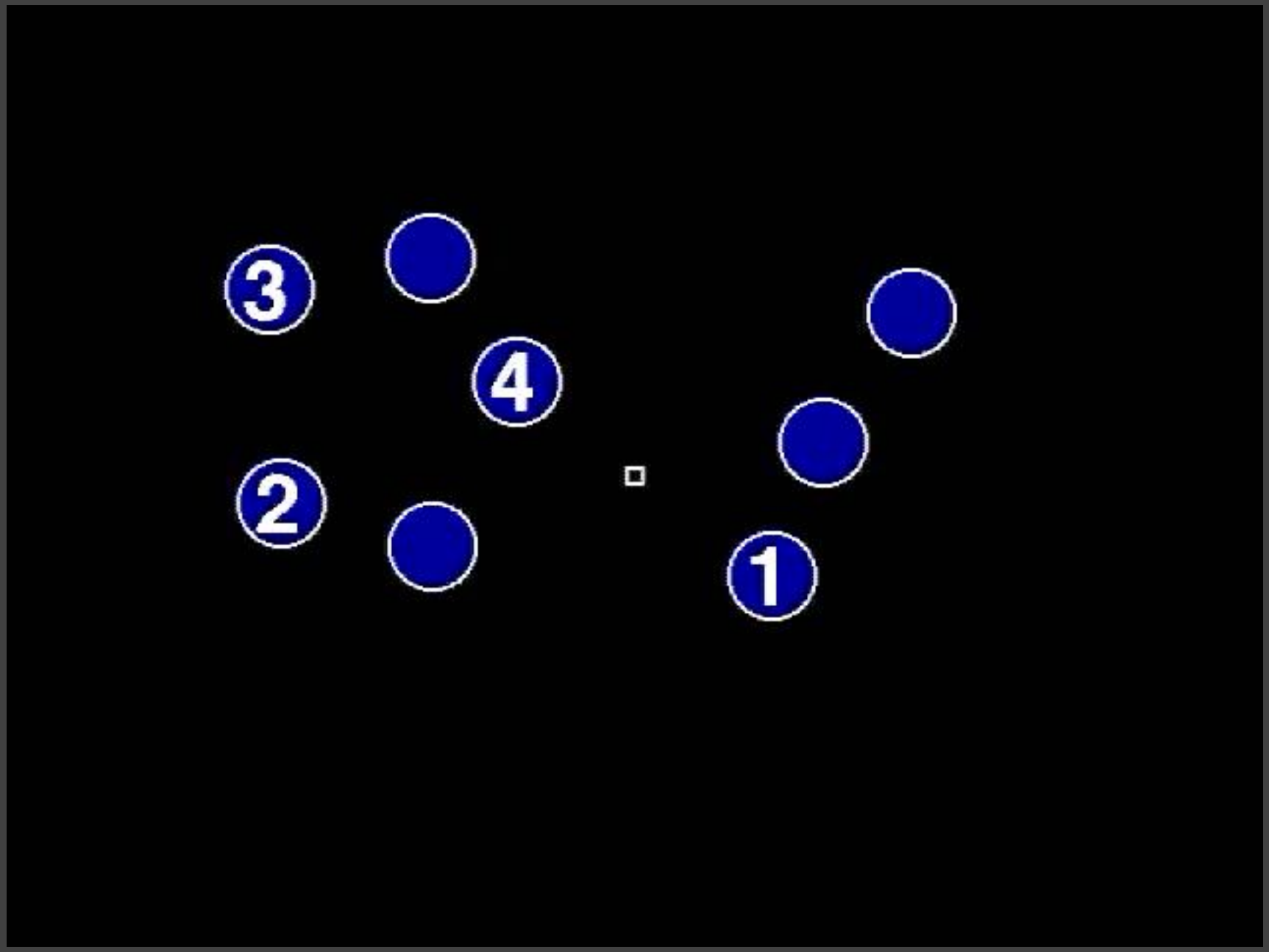
How many dots can we simultaneously track?







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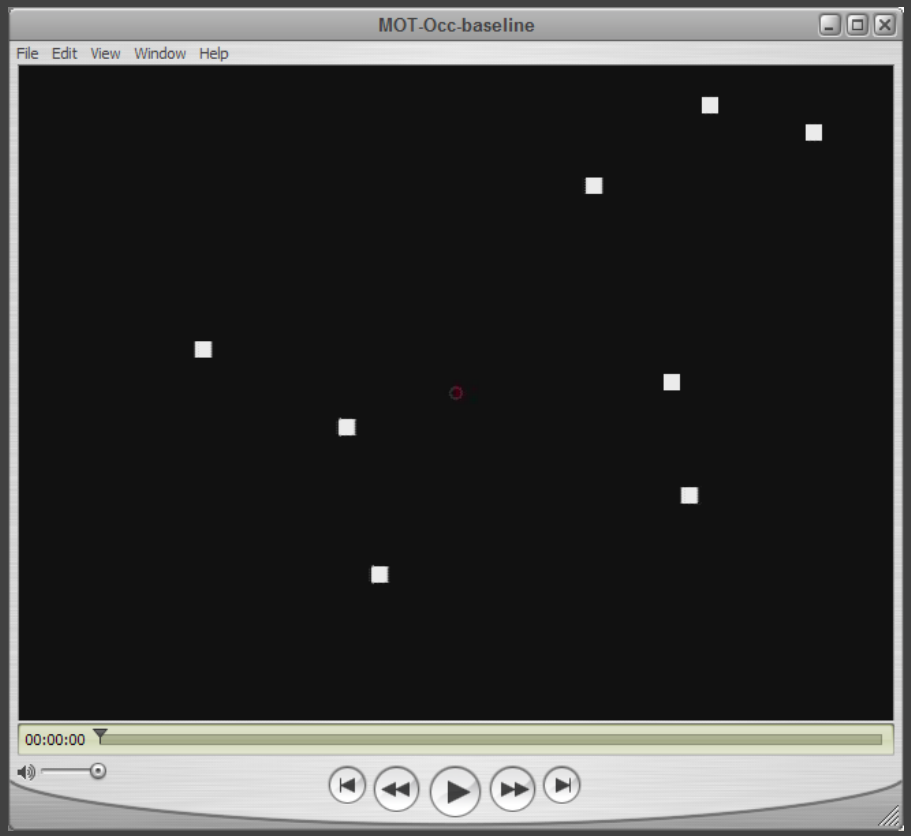
Tracking Multiple Targets

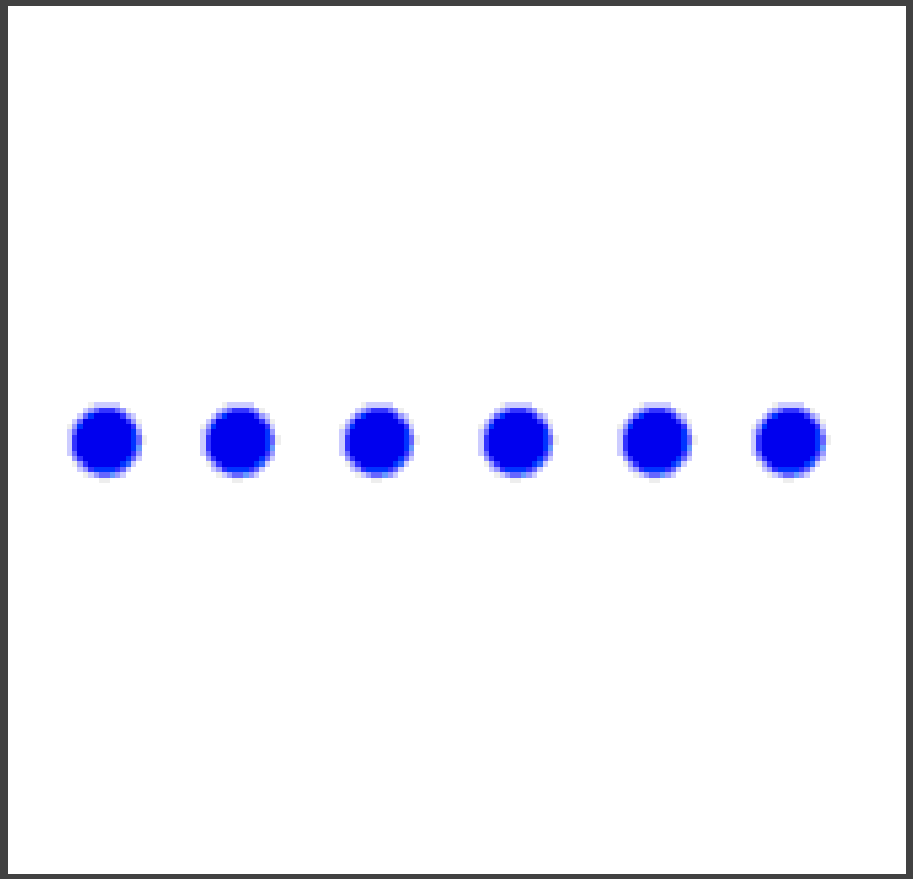


How many dots can we simultaneously track?

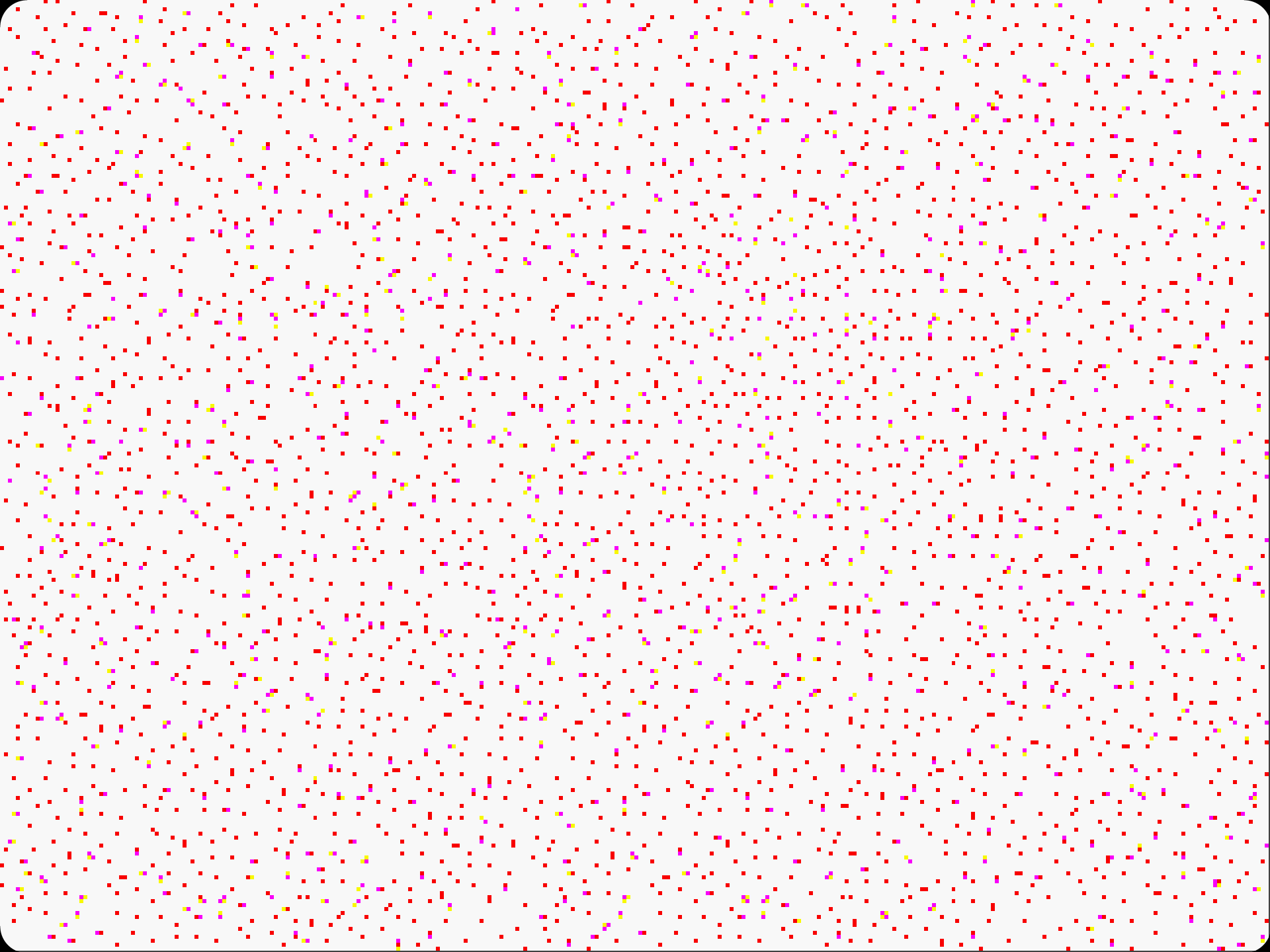
~4-6. Difficulty increases sig. at 6.

[Yantis 92, Pylyshn 88, Cavanagh 05]

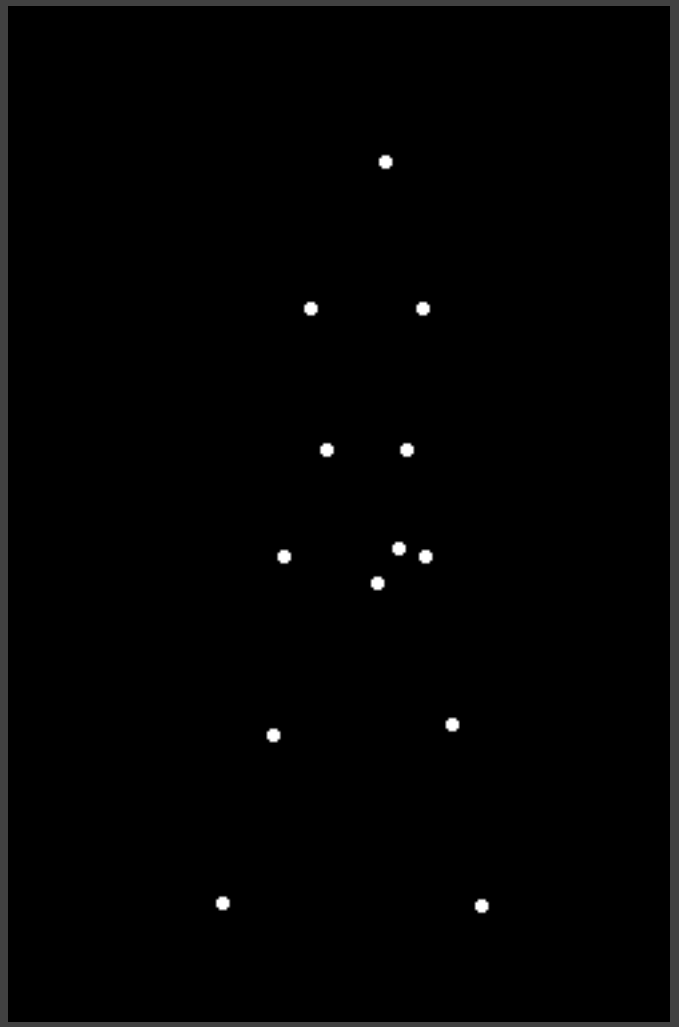
Grouped Dots Count as 1 Object



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

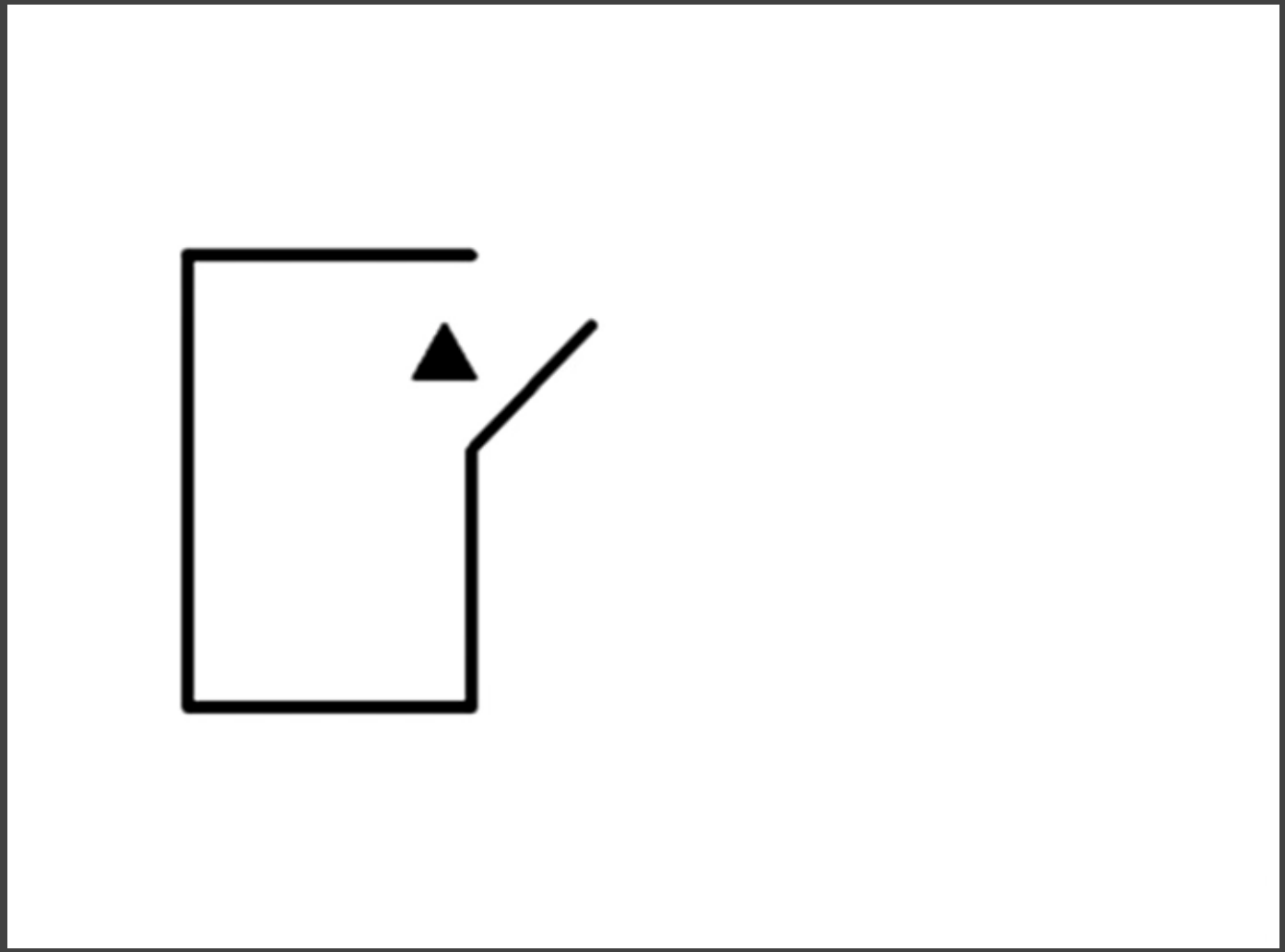
start end

Shows transition better, but

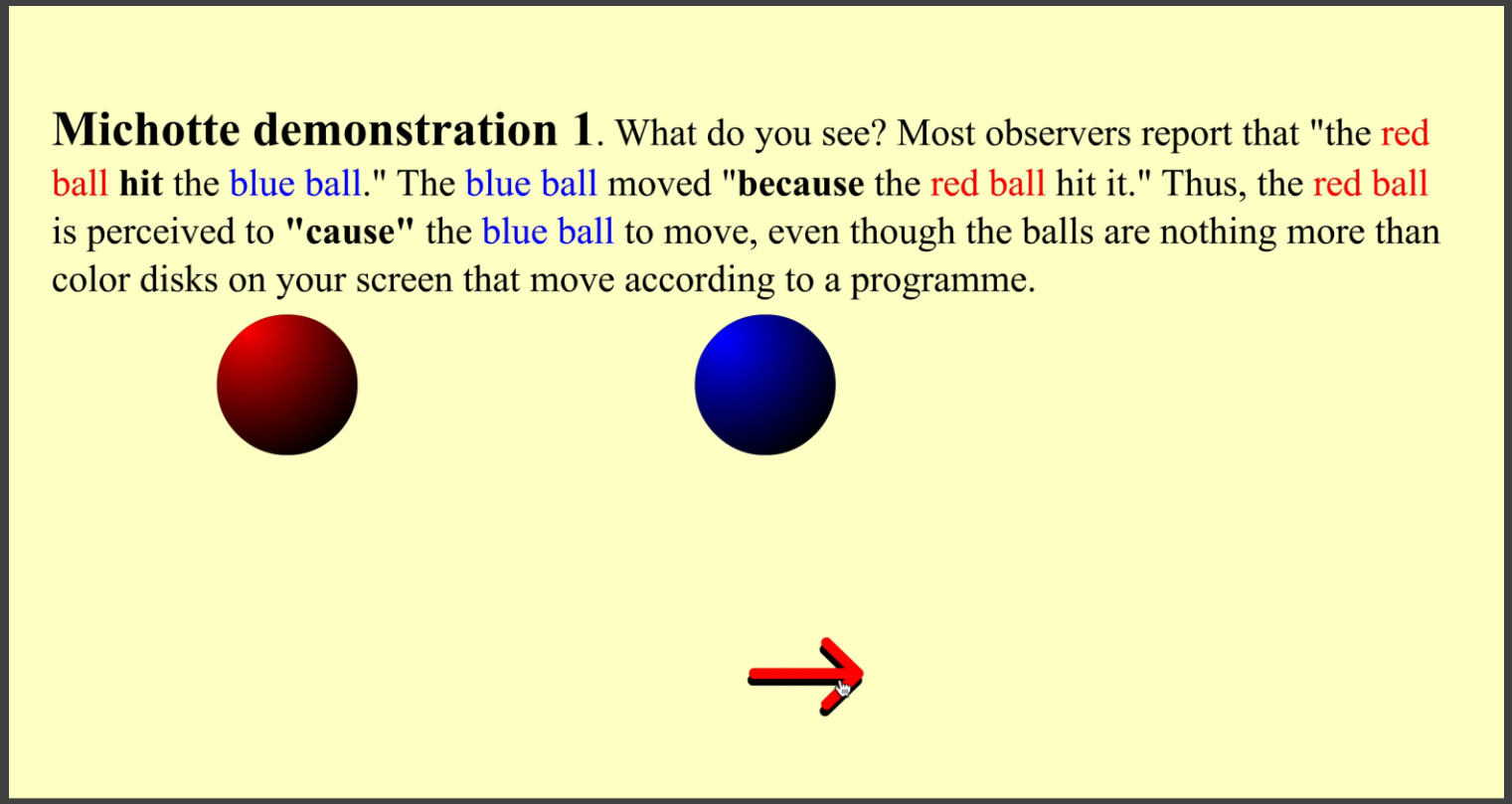
Still may be too fast, or too slow

Too many objects may move at once

Constructing Narratives [Heider 44]

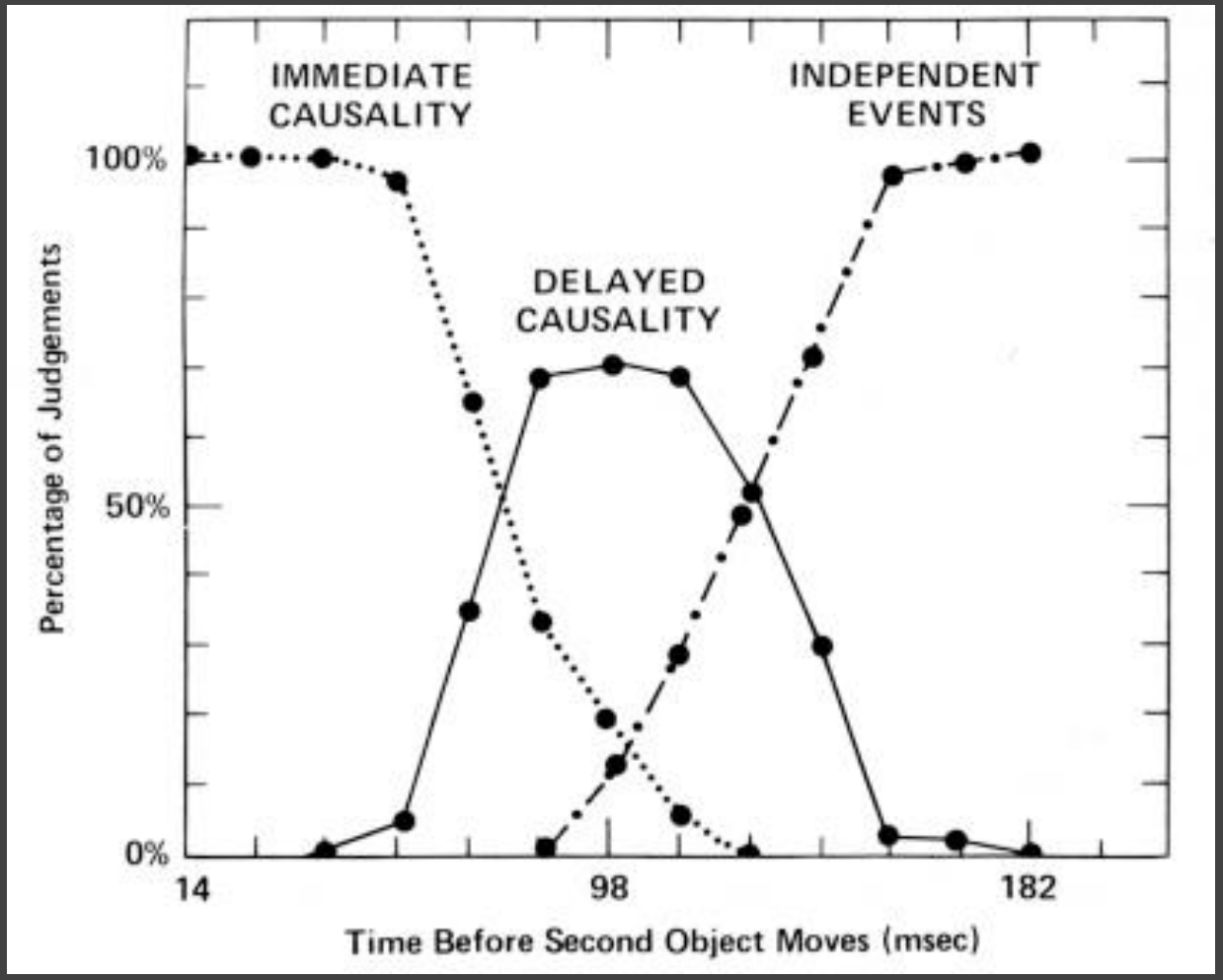


Attribution of Causality [Michotte 46]



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

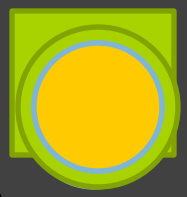
Attribution of Causality [Michotte 46]



[Reprint from Ware 04]

What are Potential Downsides to Animations?

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

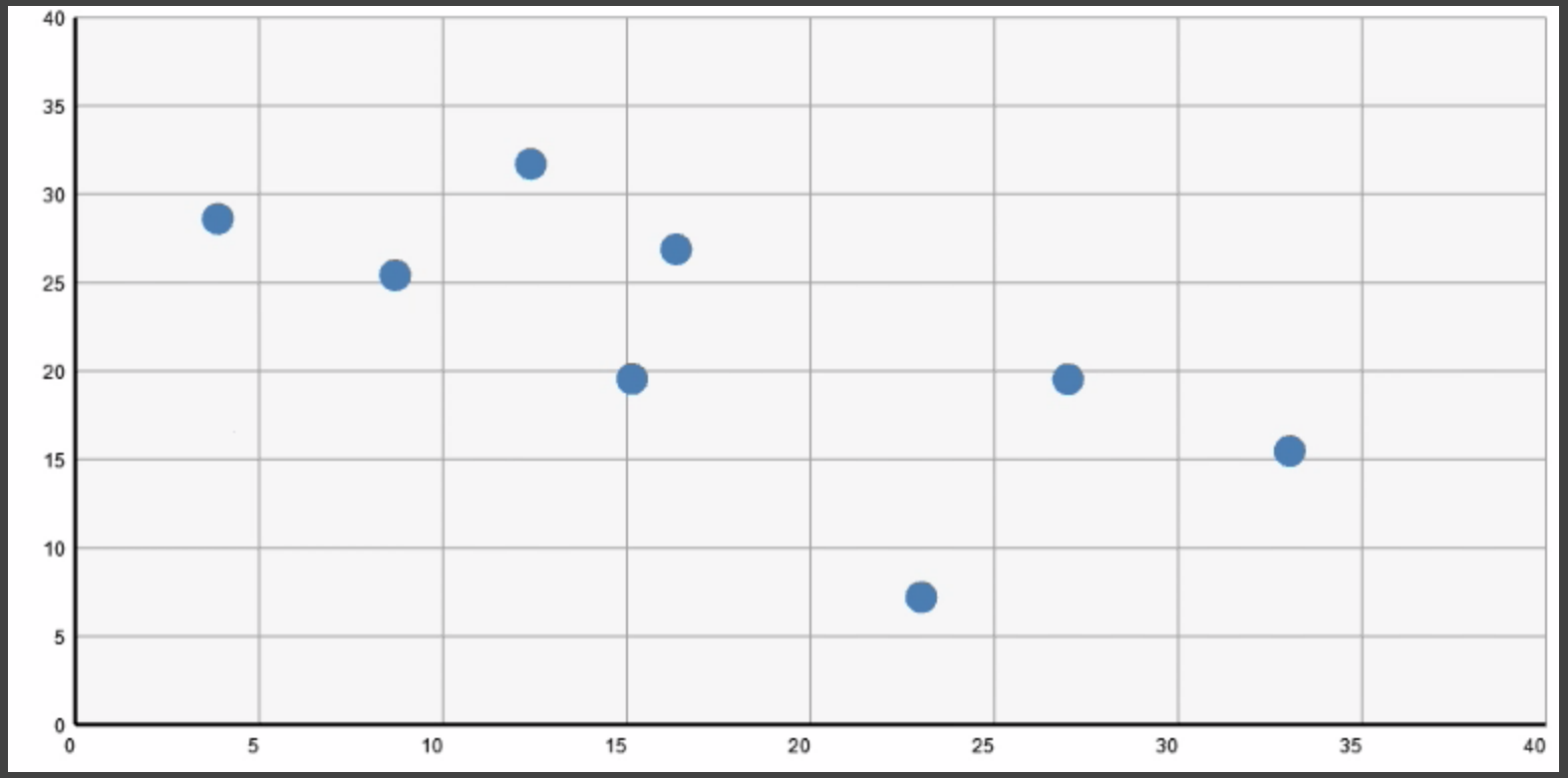
Cannot simultaneously attend to multiple motions

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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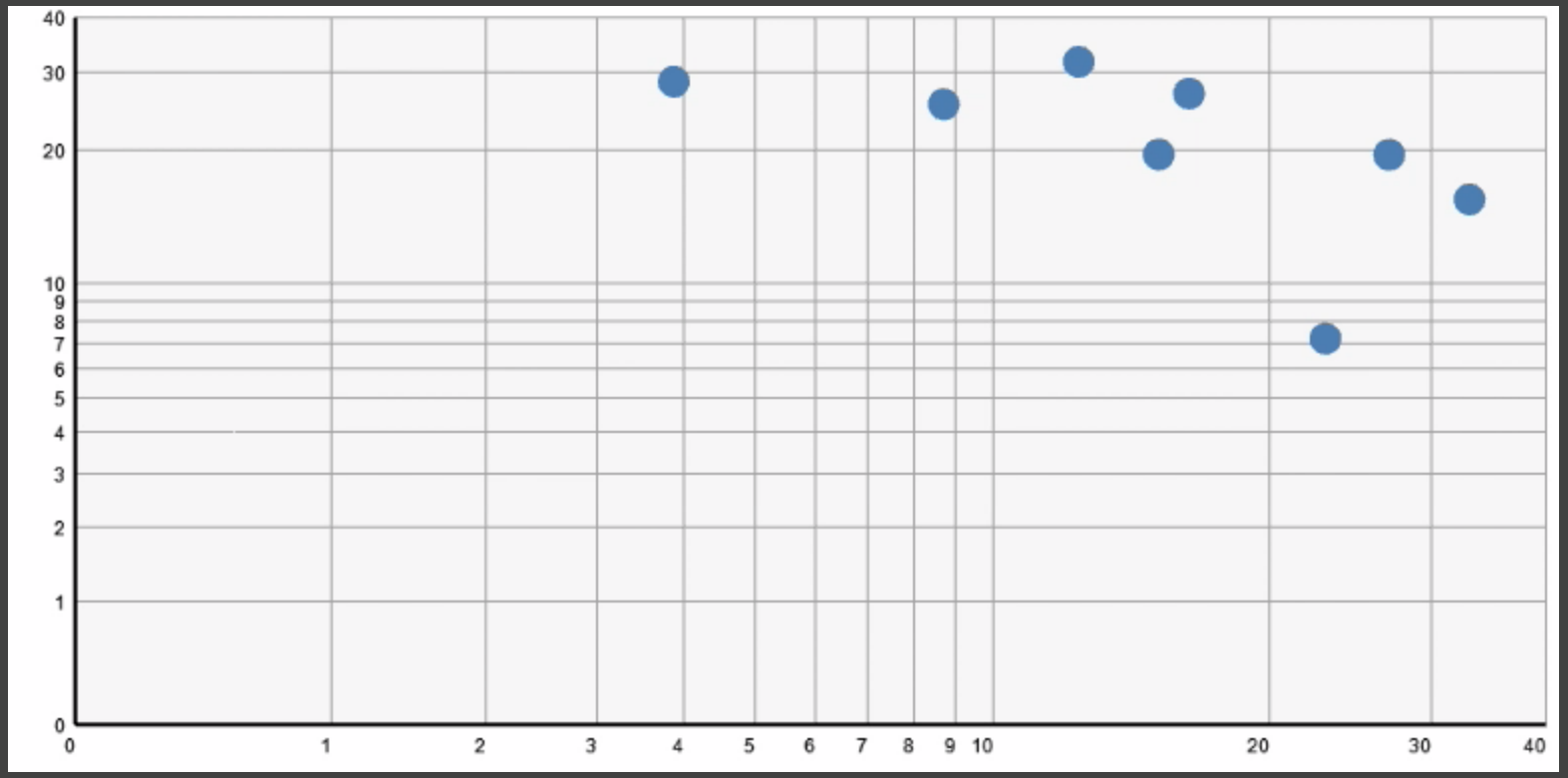
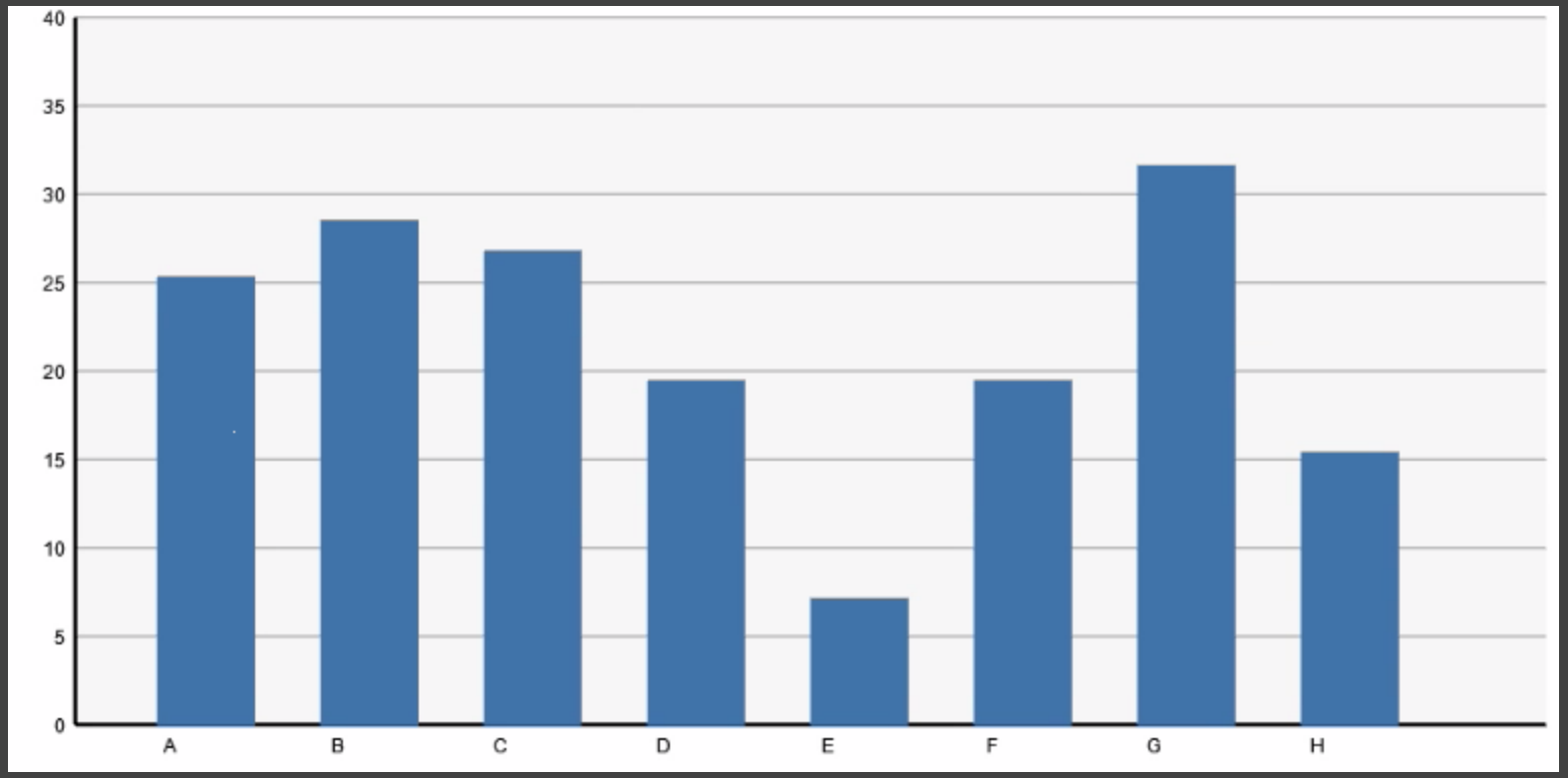
Log Transform

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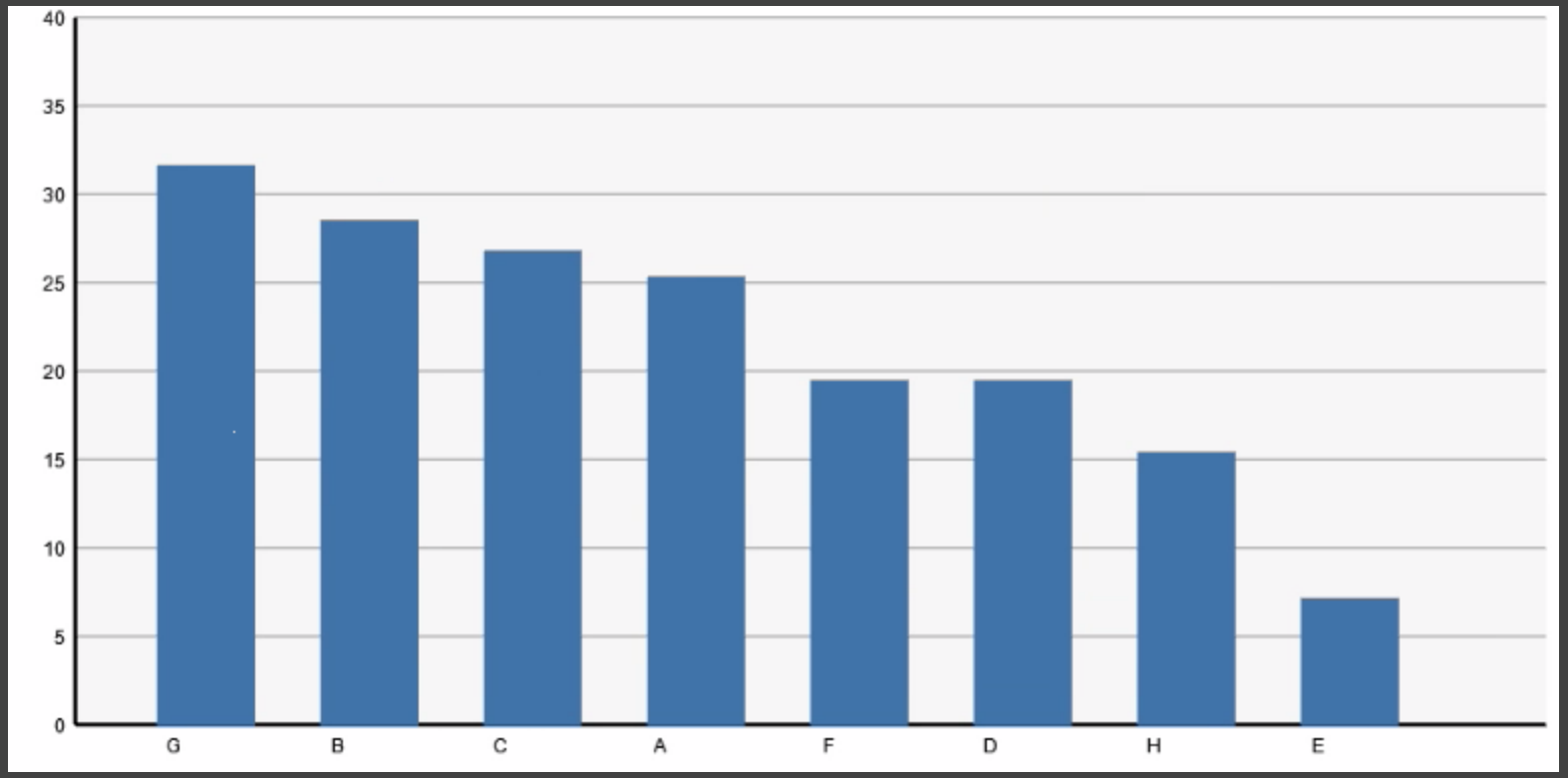

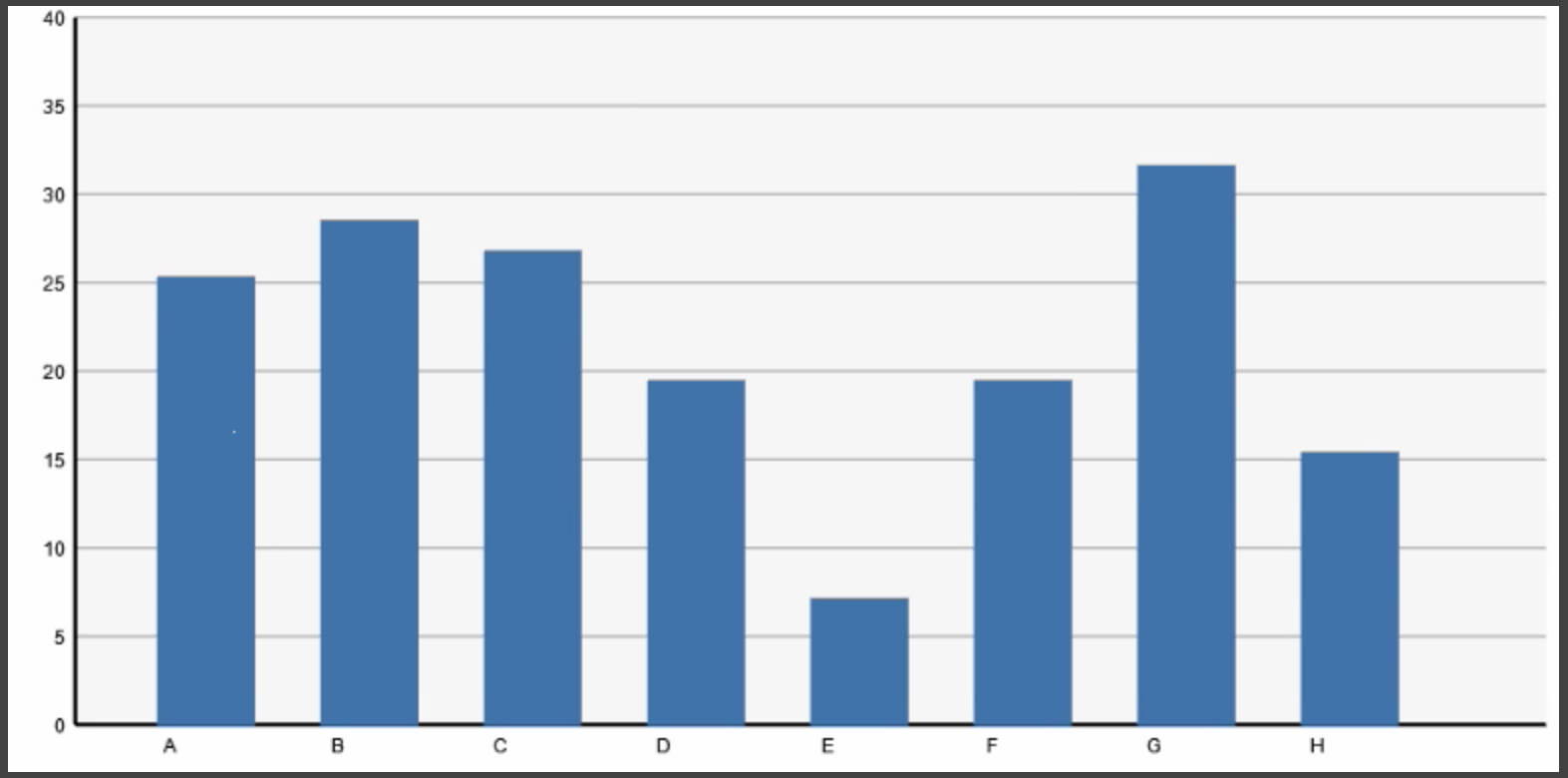
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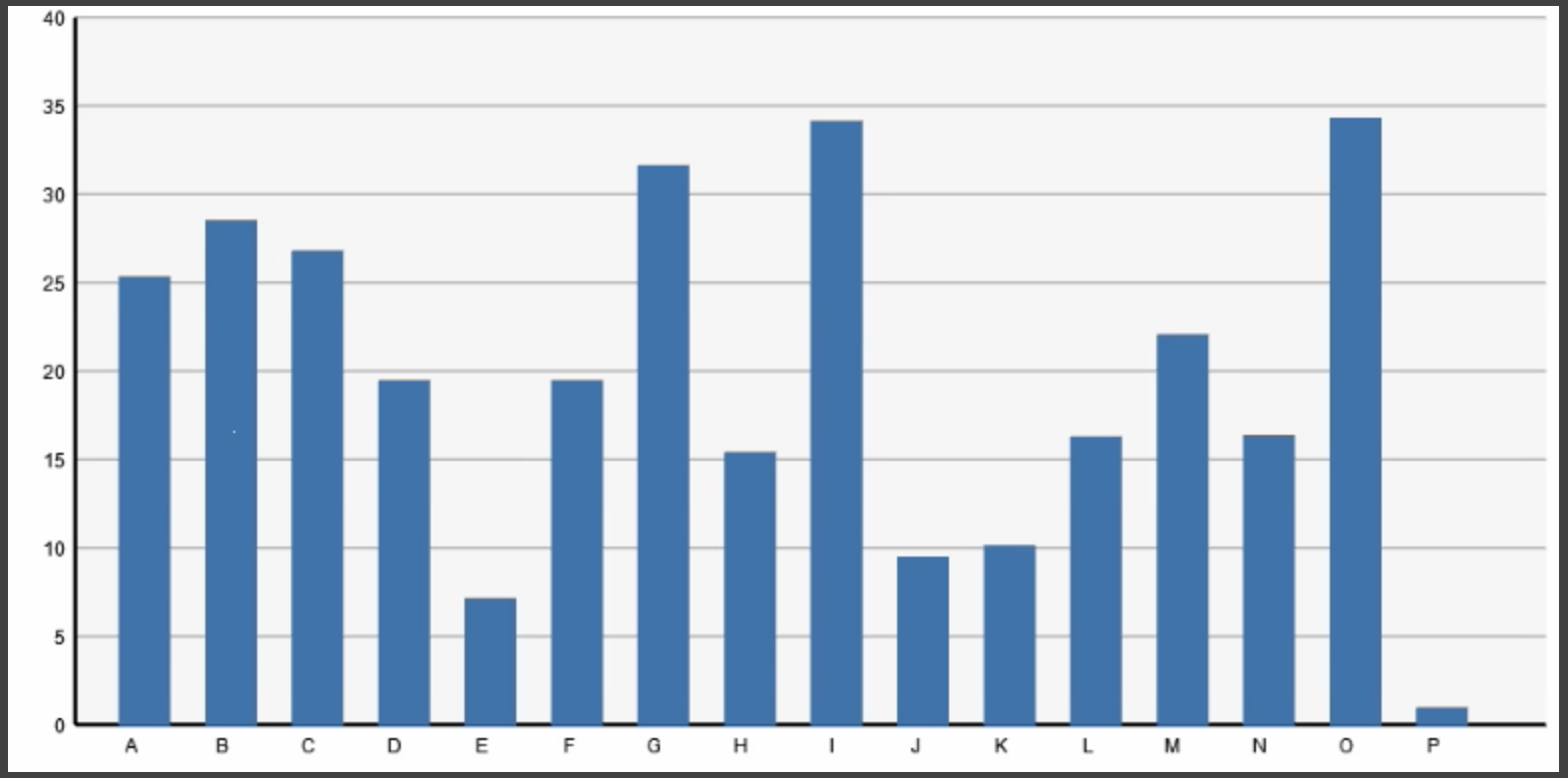
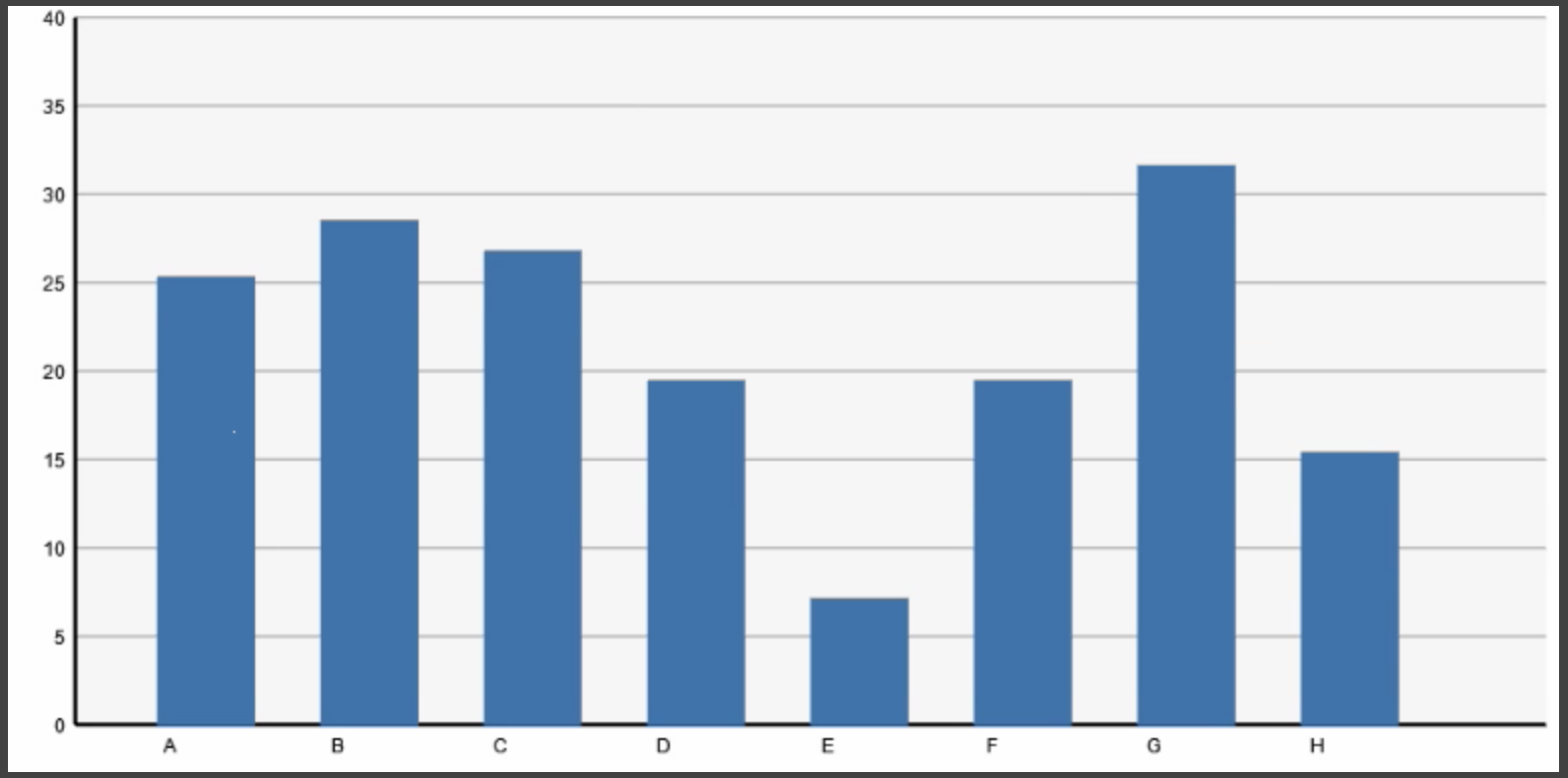
Filtering

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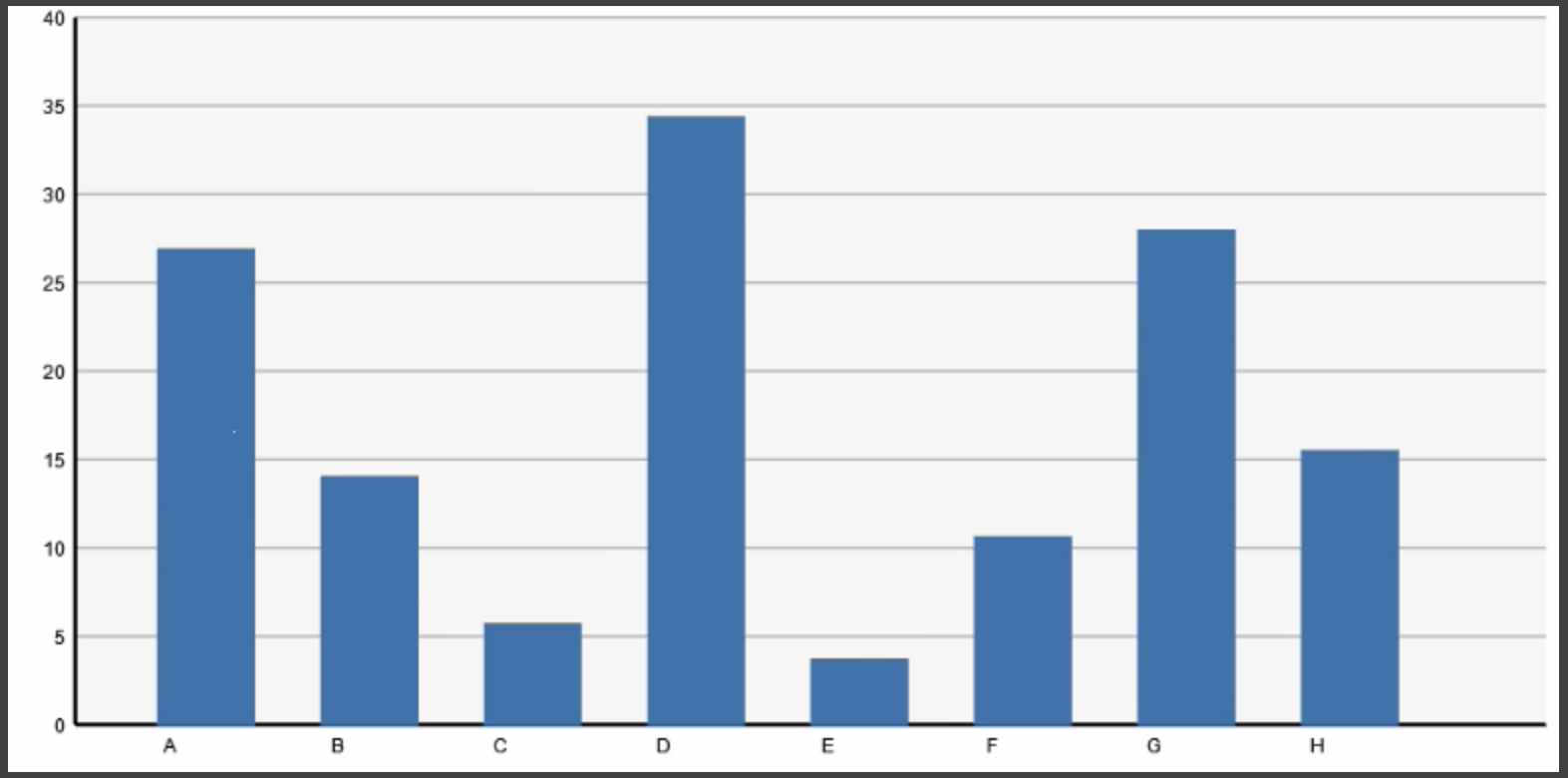
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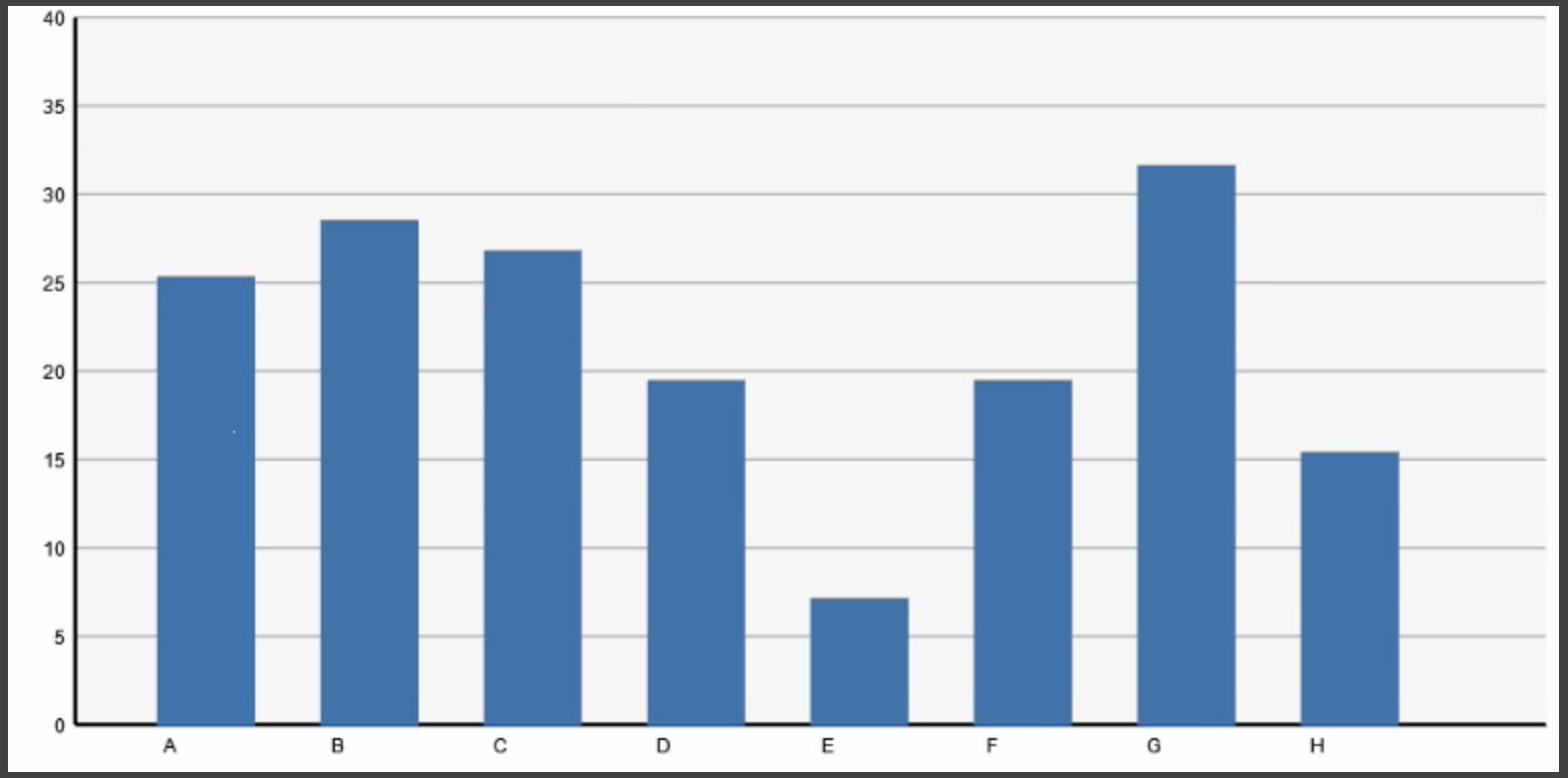
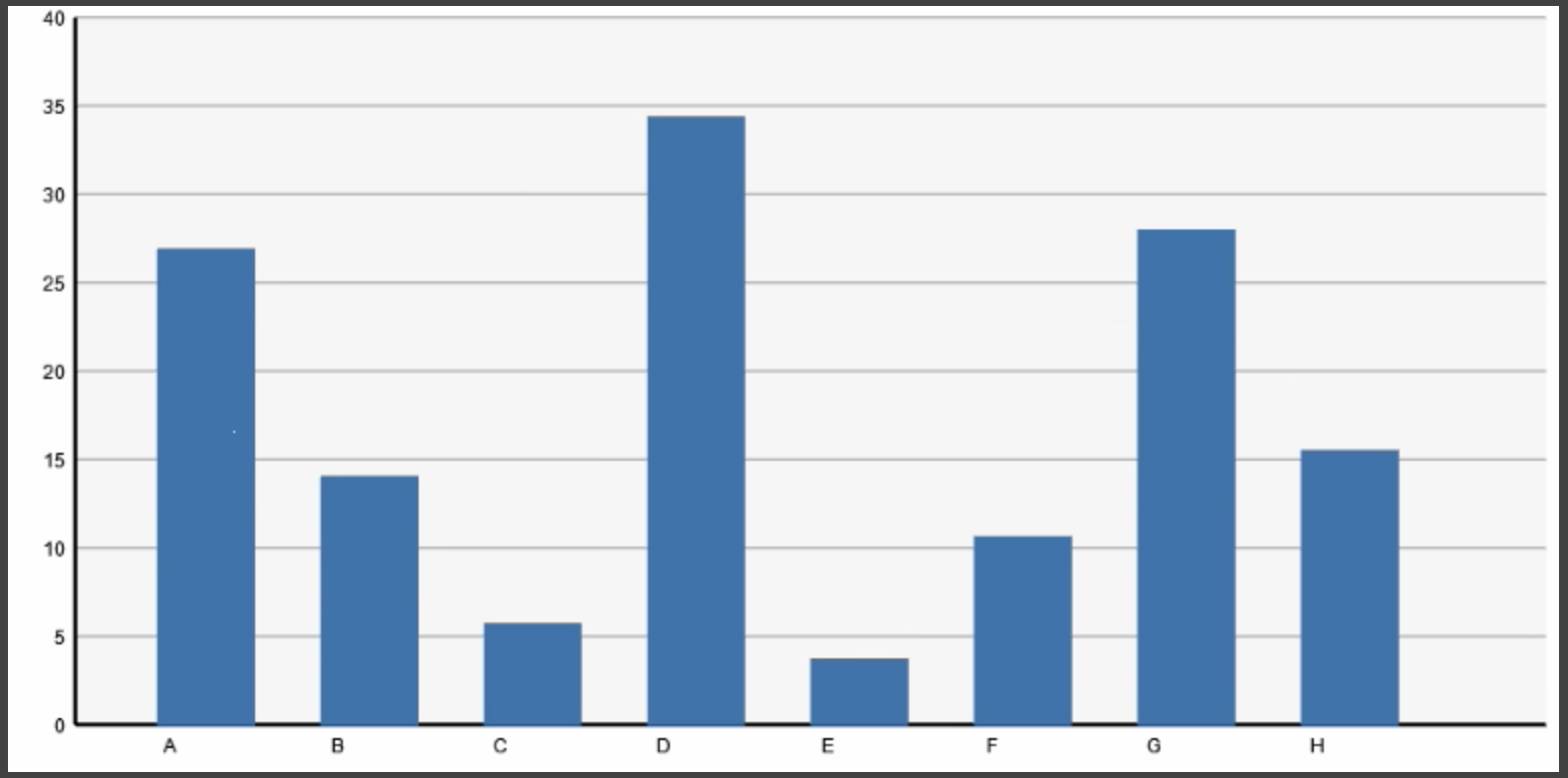
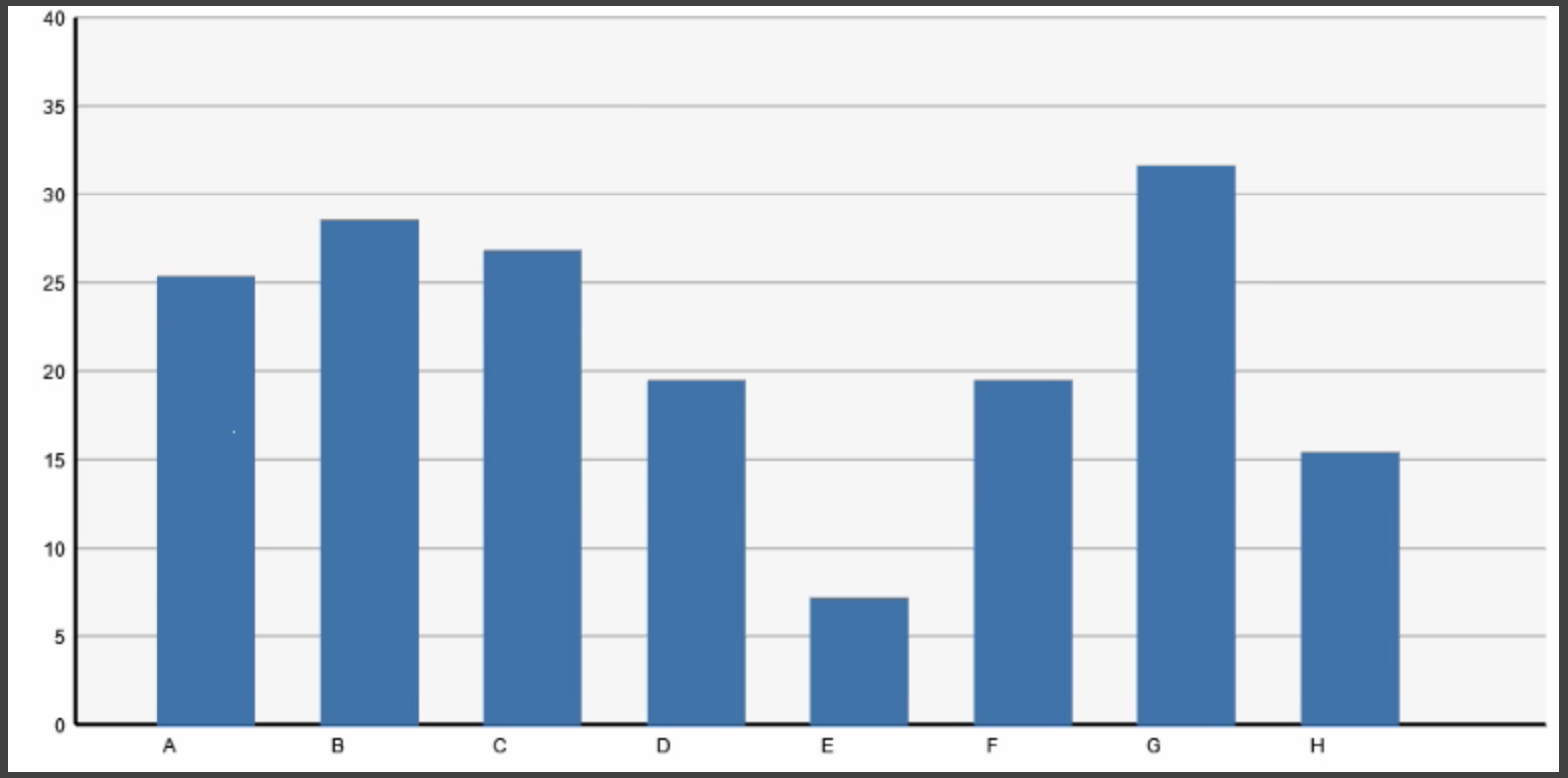


Month 1

Timestep



Month 2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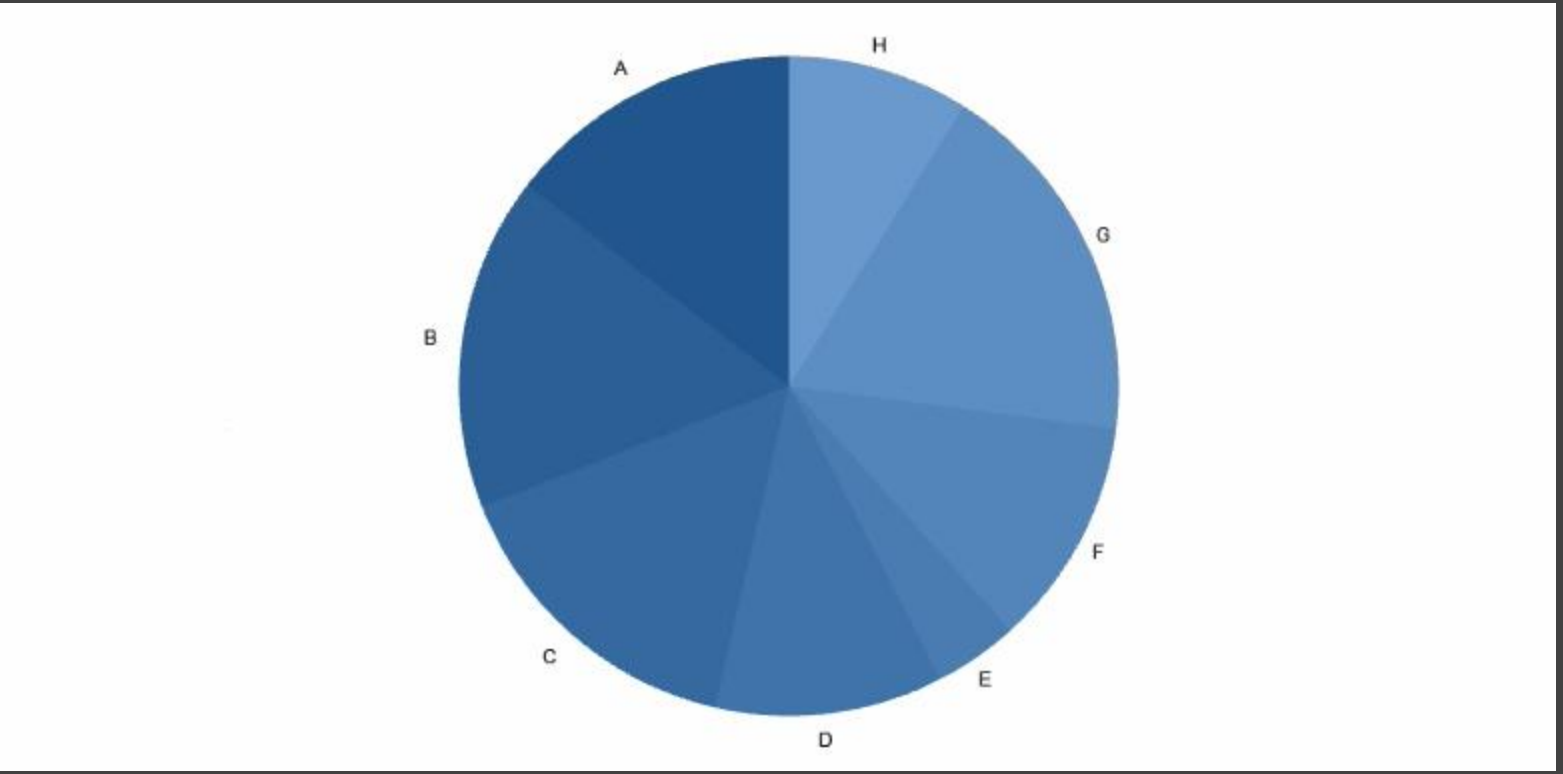
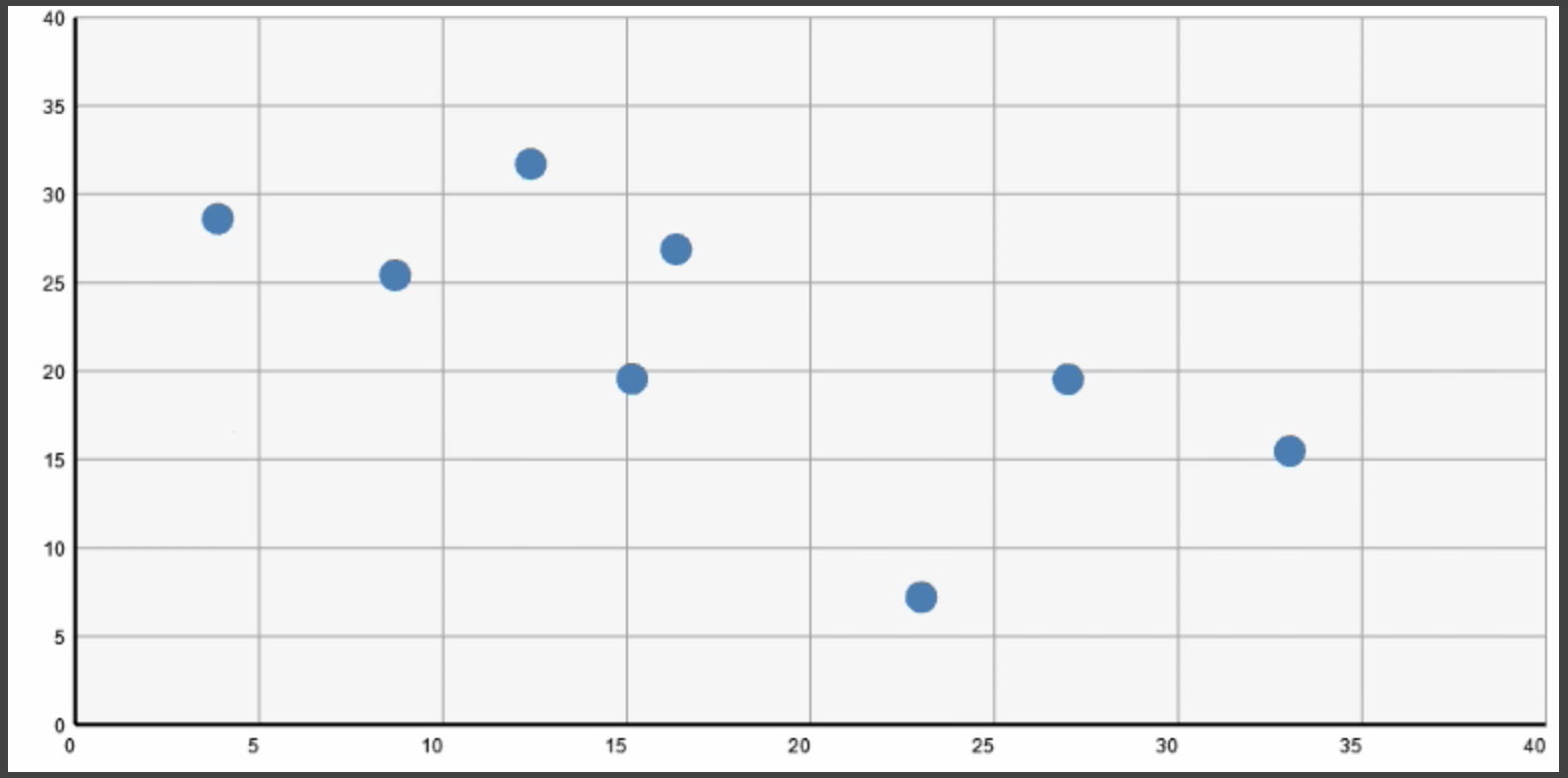
Change Encodings

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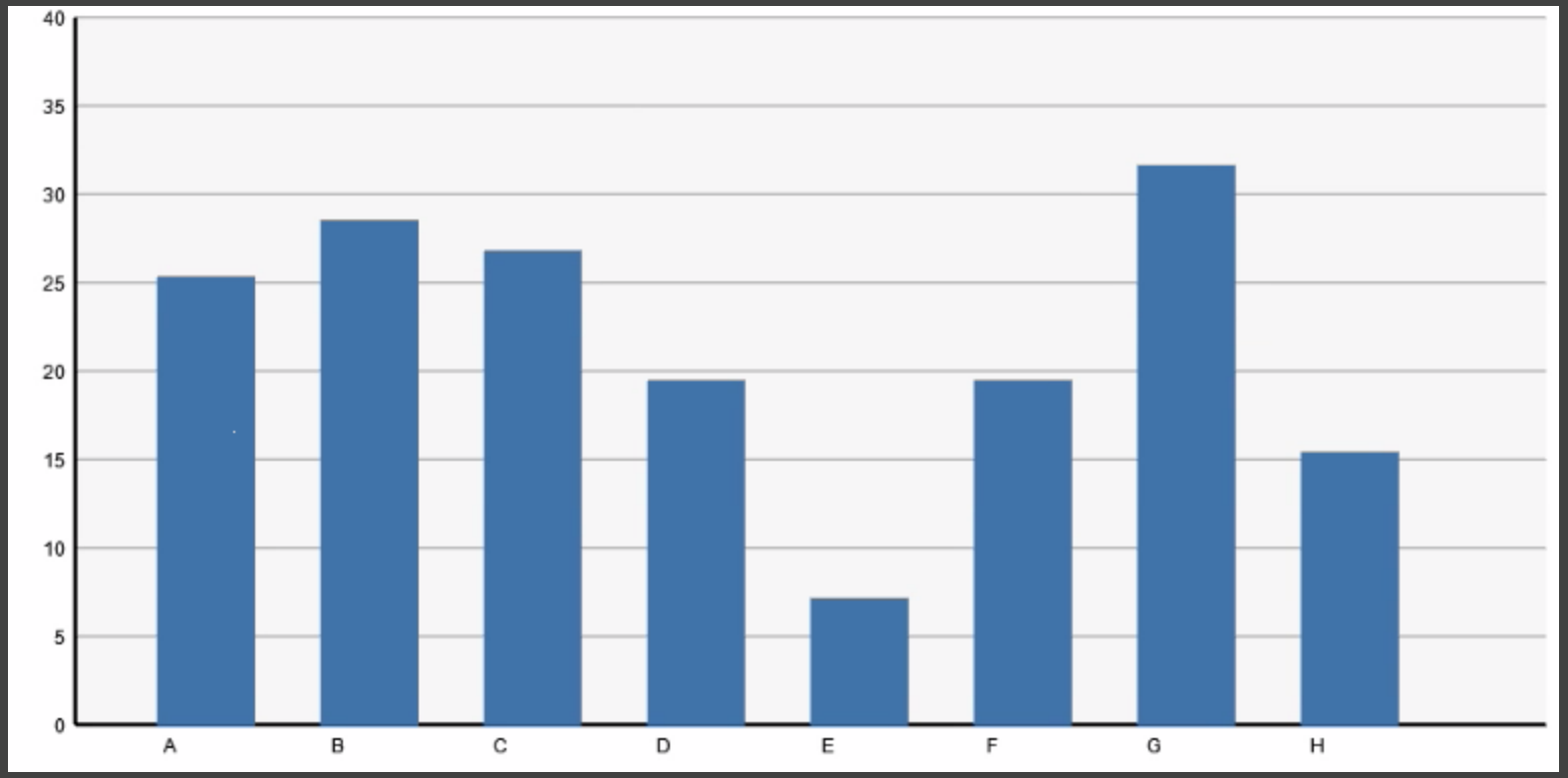
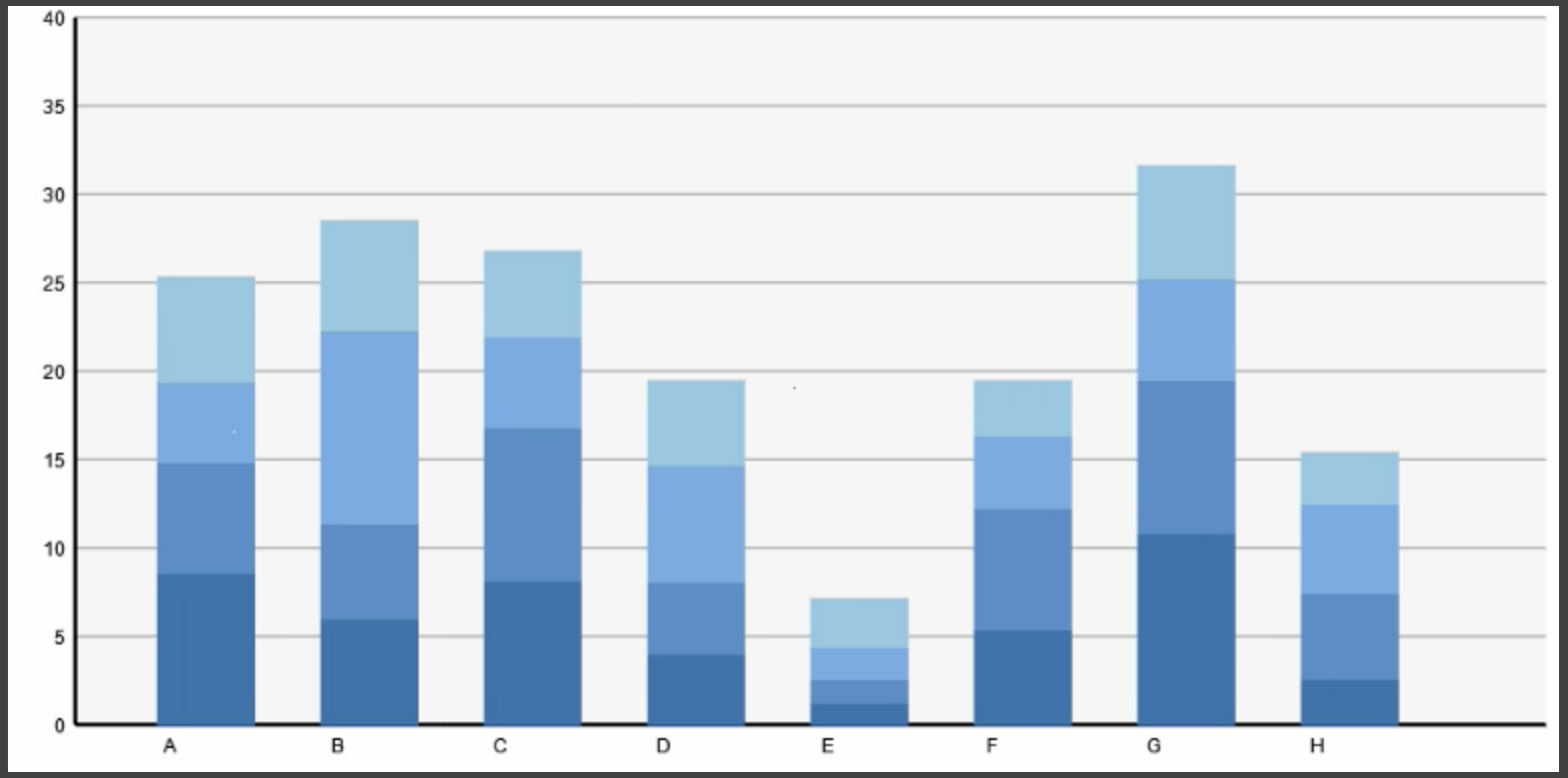
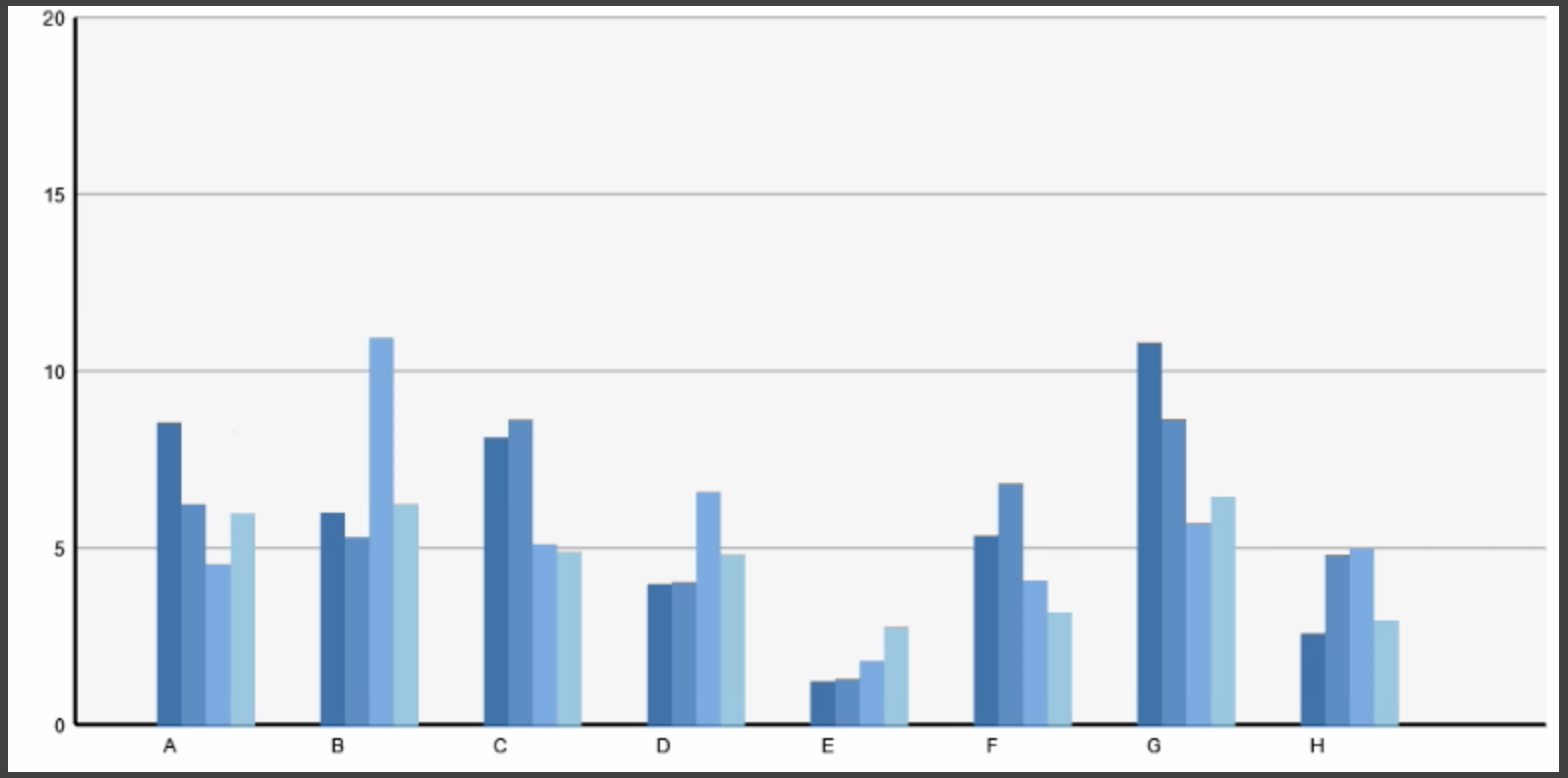
Change Data Dimensions



Change Data Dimensions



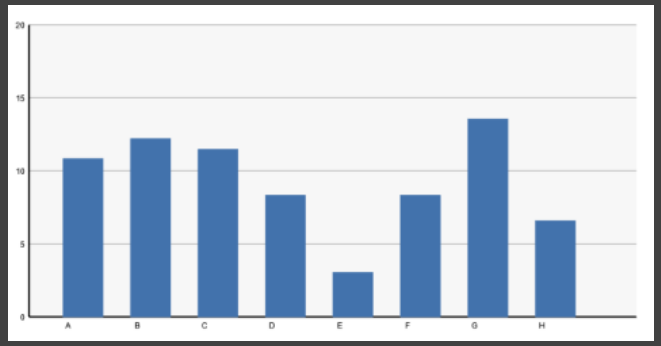
Change Encodings + Axis Scales



Data Graphics & Transitions

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

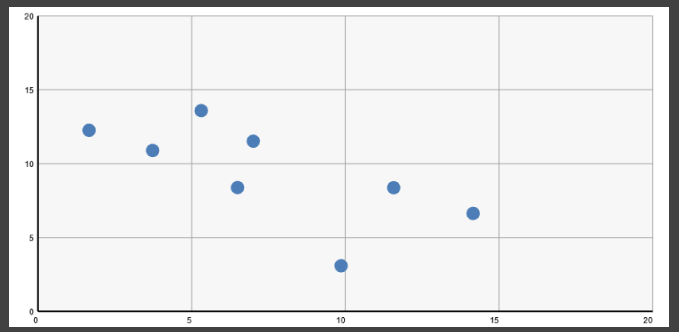
Visual Encoding



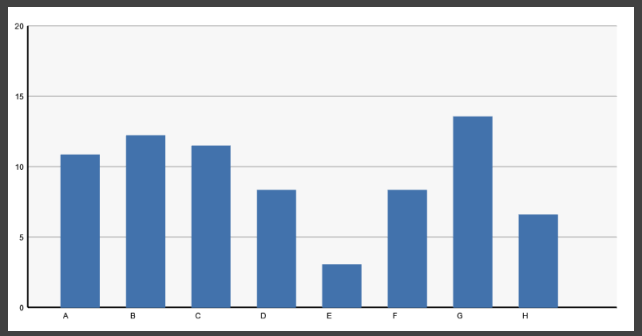
Change selected data dimensions or encodings

Animation to communicate changes?

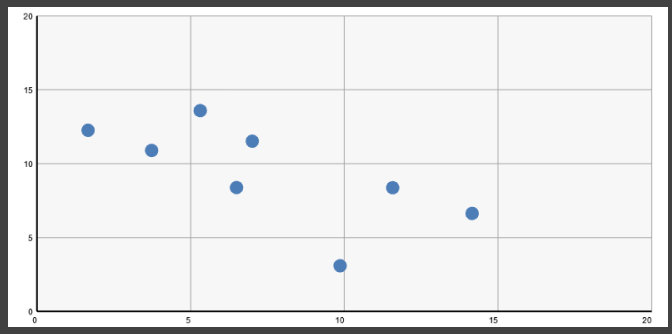
Category	Sales	Profit
A	11	7
B	13	10
C	12	6
D	8	5
E	3	1



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]

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

Visual marks should always represent the same data tuple.

Principles for Animation [Heer]

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Maintain valid data graphics during transitions
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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

Different operators should have distinct animations.

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 → Objects are harder to track when occluded.
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

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.

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

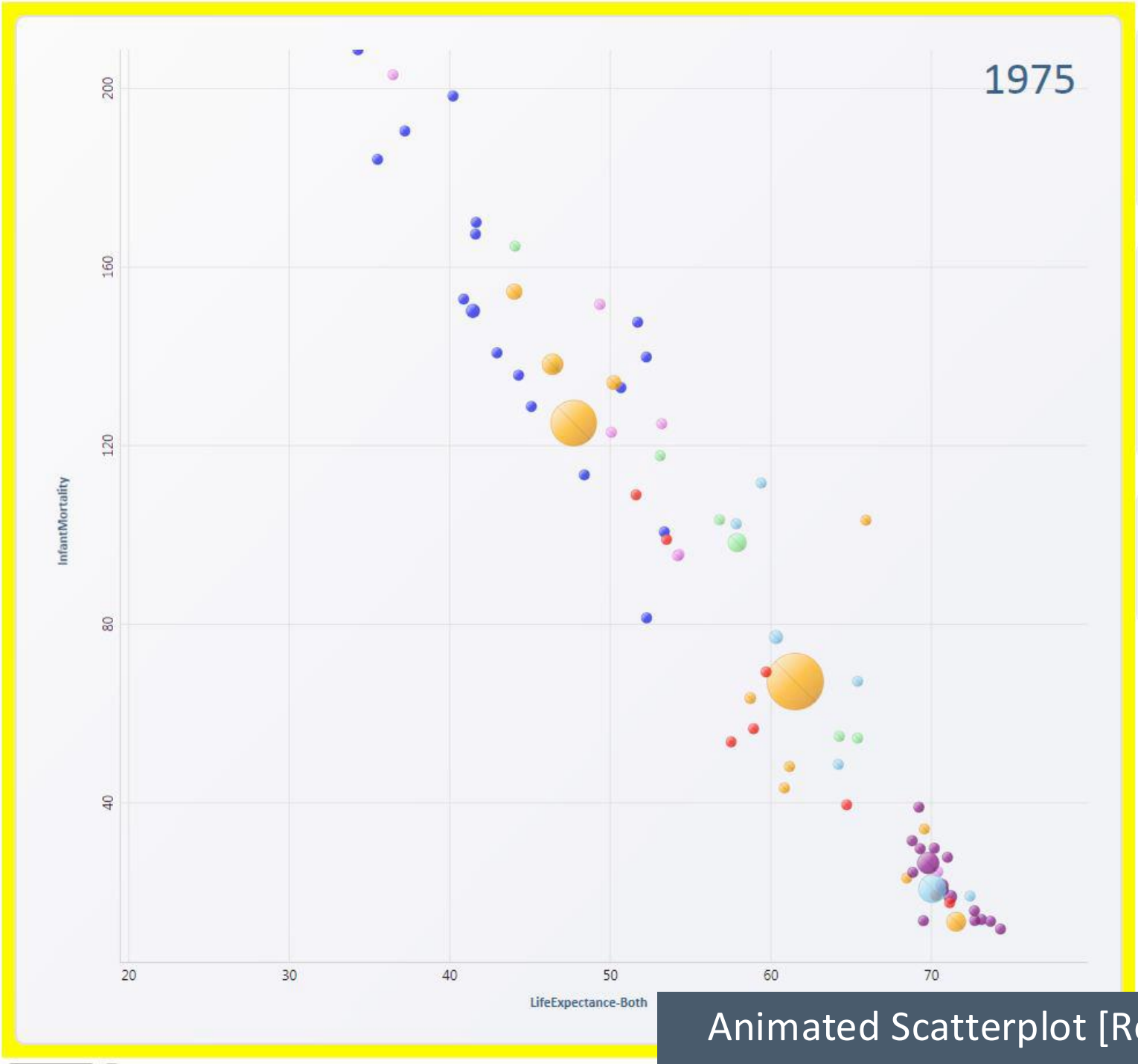
Animation in Trend Visualization

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!)



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.

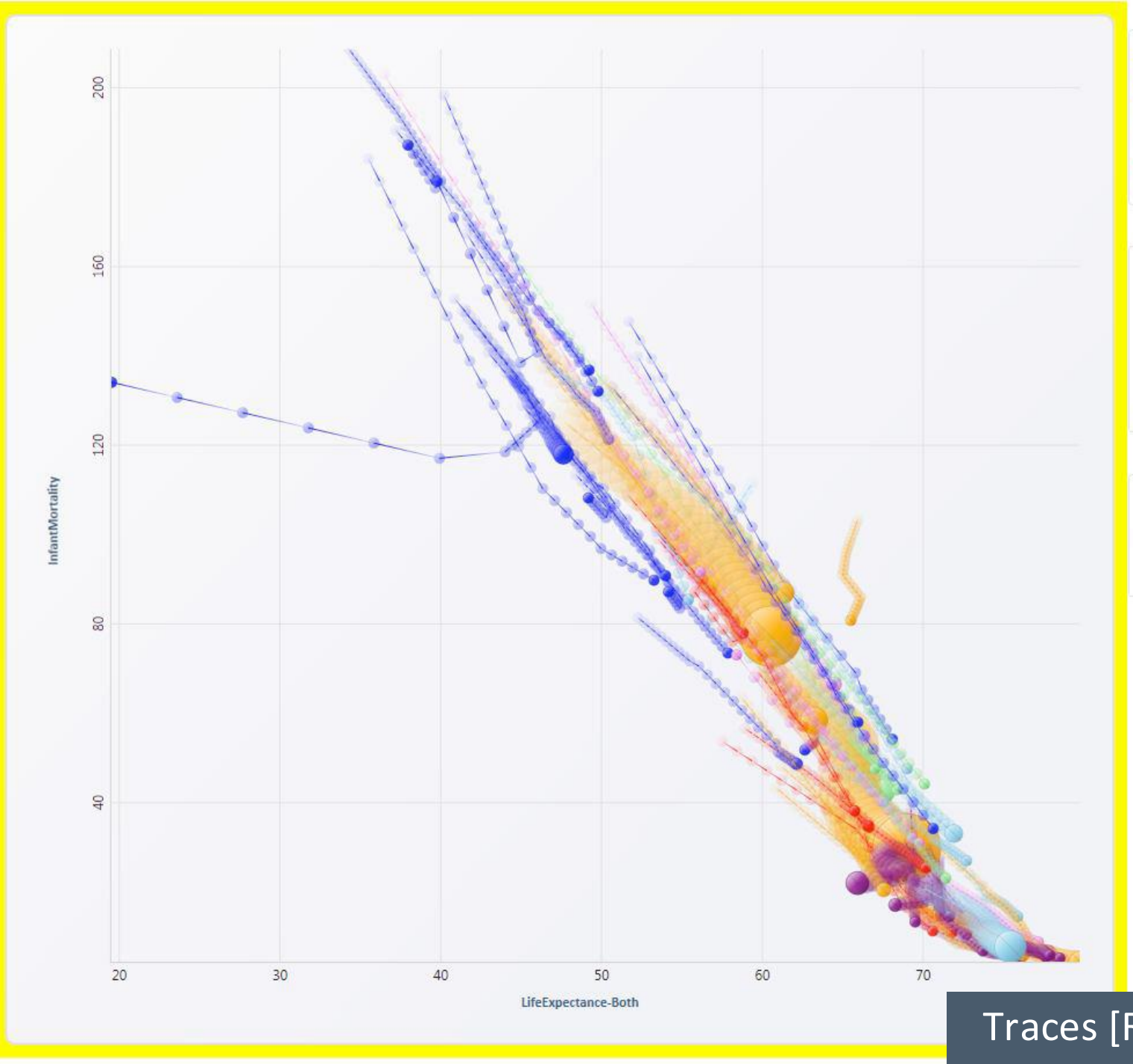
Answers set: 0/2

Next

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

Give Up | Next

Animated Scatterplot [Robertson 08]



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

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.

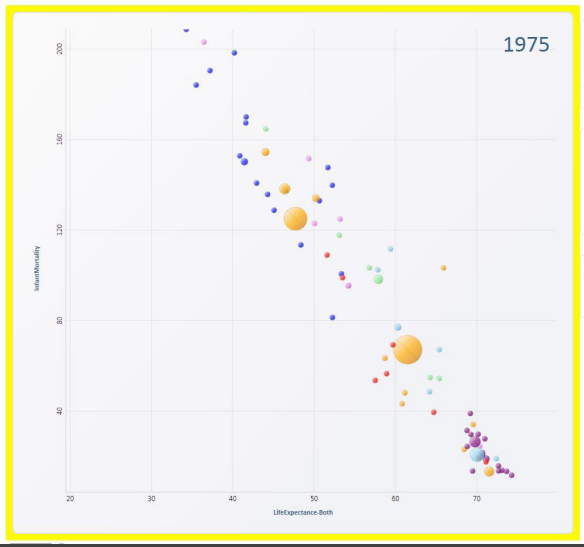
Answers set: 0/2

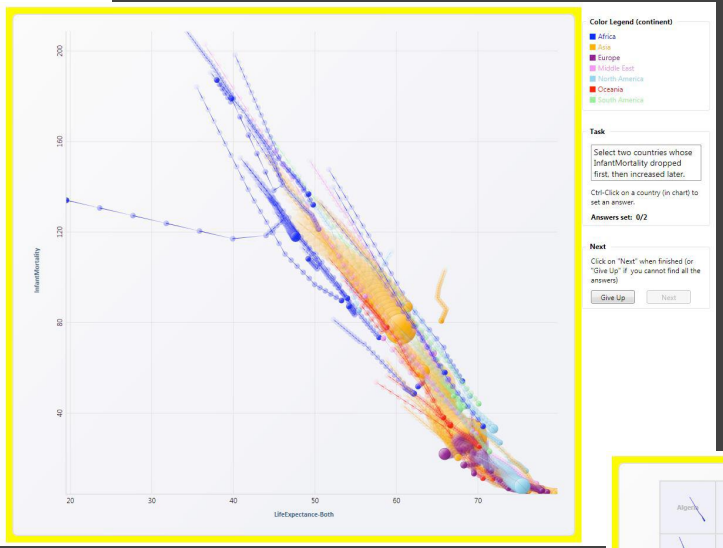
Next

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

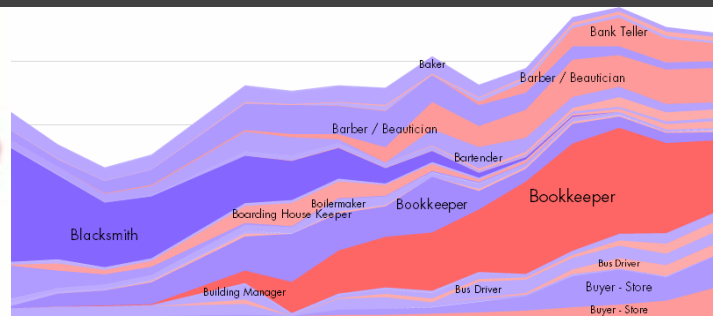
Presentation: Anim. 60% *faster* than multiples *Analysis*: Animation 82% *slower* than multiples
User preferences favor animation (even though less accurate and slower for analysis!)

Administrivia

A3: Interactive Prototype

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

Due by *11:59pm* on **Friday, Feb 18**.
Work in project teams of 3-4 people.
Team registration Due by 11:59pm on Friday, Feb 7!



Form A3 + Final Project Team

Form a **team of 3-4** for A3 and the Final Project.

(Start thinking about your Final Project, too!)

A3 is open-ended. You can use it to start exploring your FP topic if you like, or expand on A2.

Submit signup form by **Fri 2/7, 11:59pm**.

If you do not have team mates, you should:

- Post on Ed about your interests/project ideas

Final Project Schedule

Proposal	***Wed Feb 19***
Prototype	*Tues Mar 4*
Demo Video	Tue Mar 11
Video Showcase	Thu Mar 13 (in class)
Deliverables	Tue Mar 18

Logistics

Final project description posted online

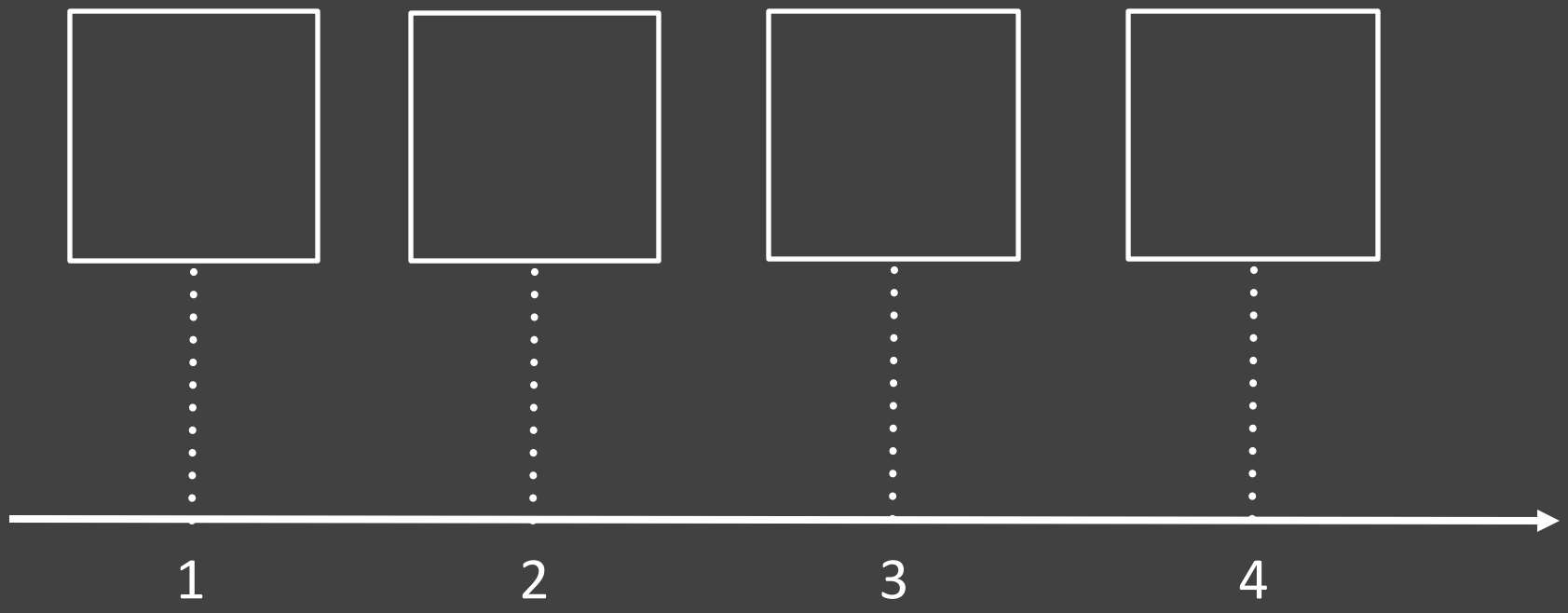
Work in groups of up to 4 people

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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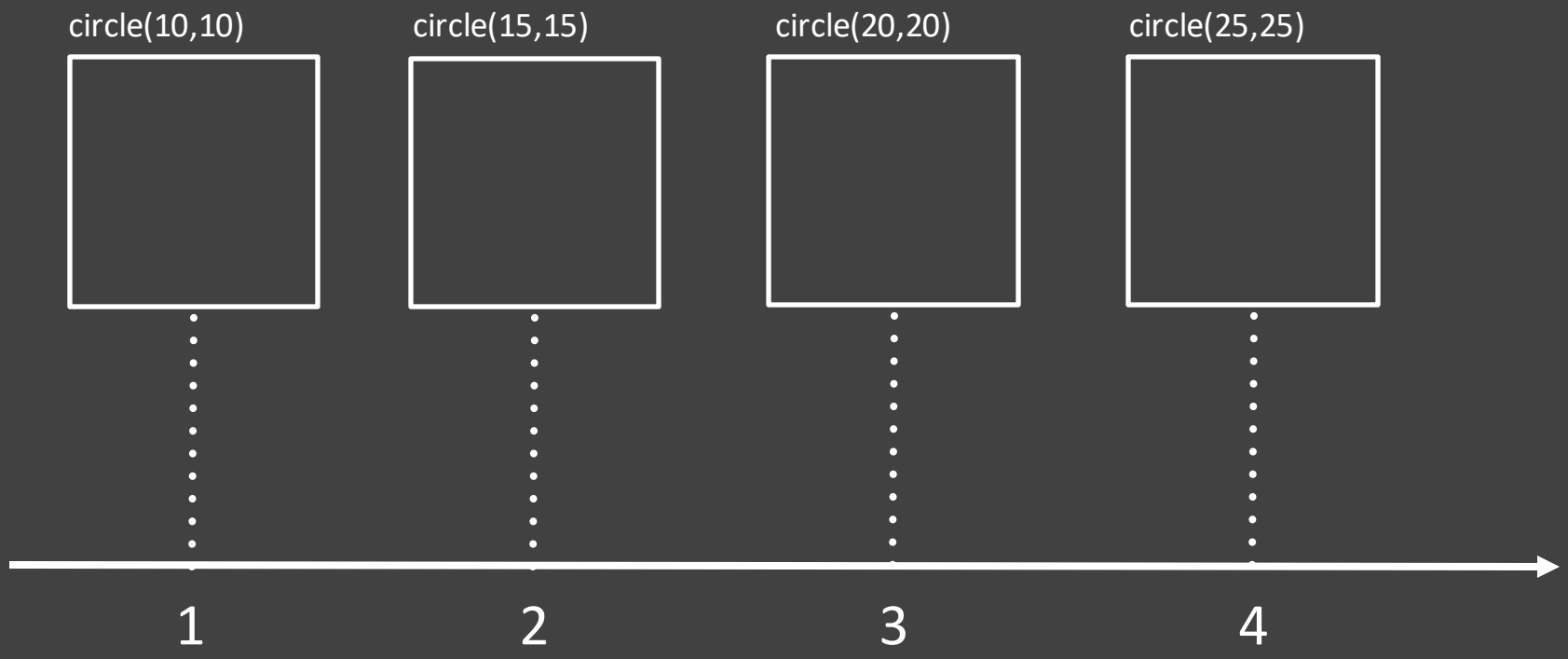

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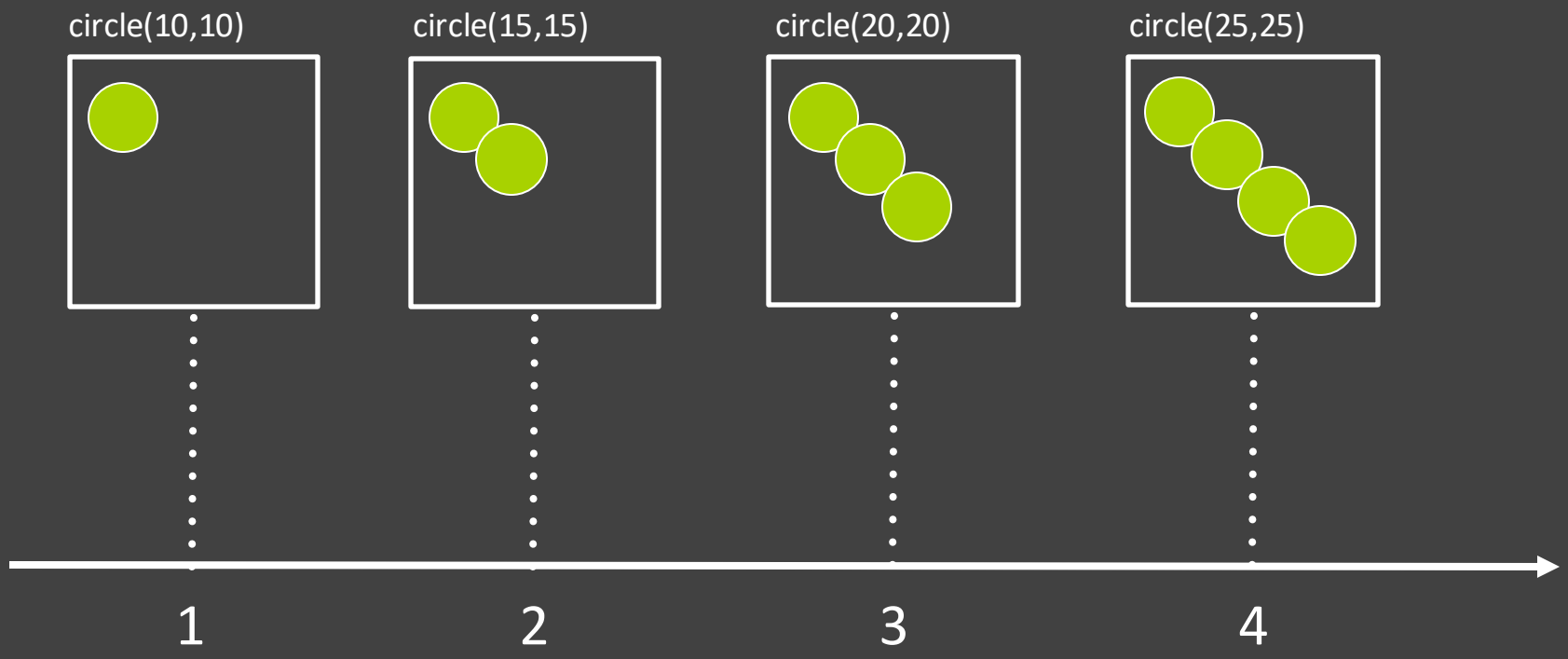

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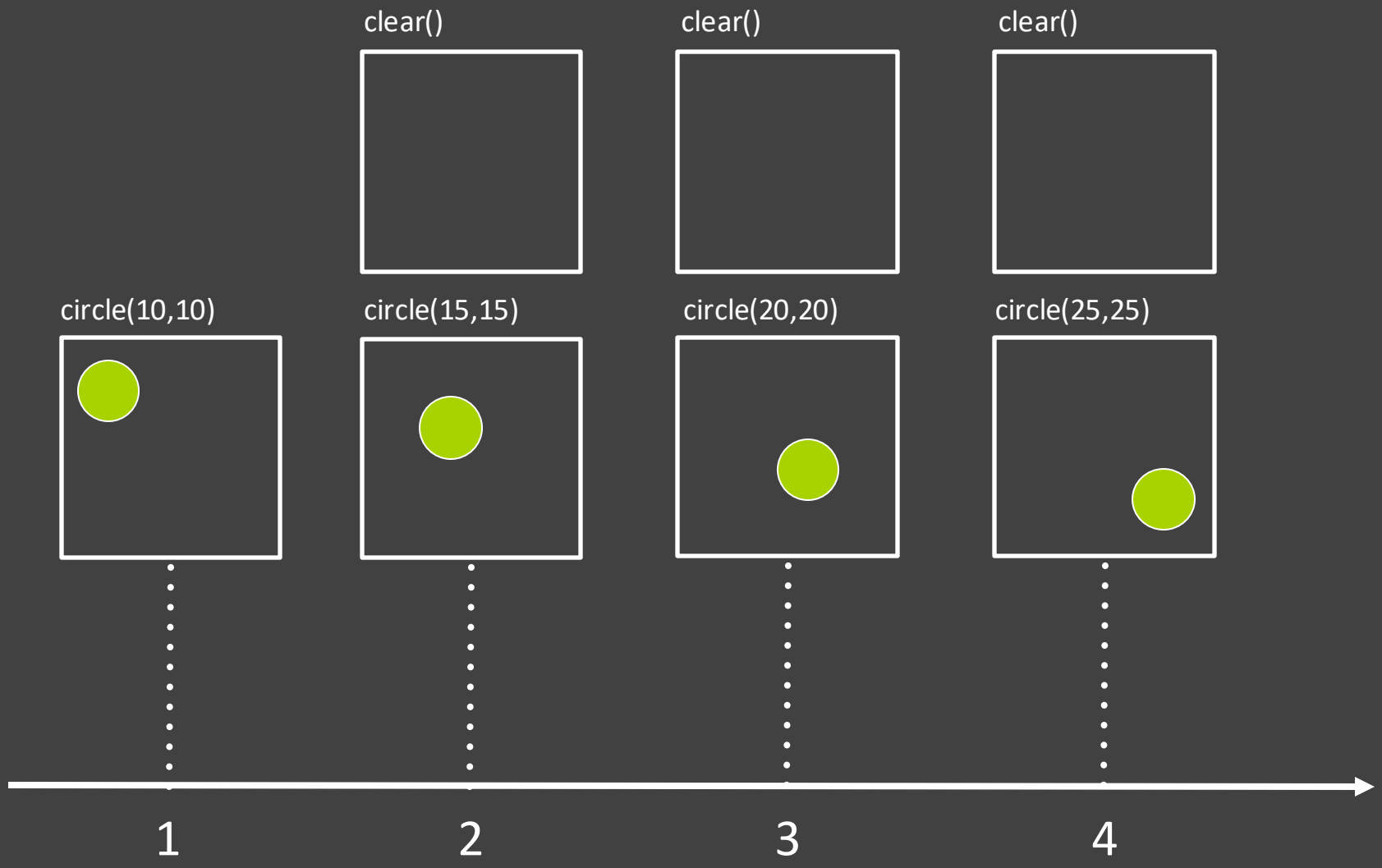

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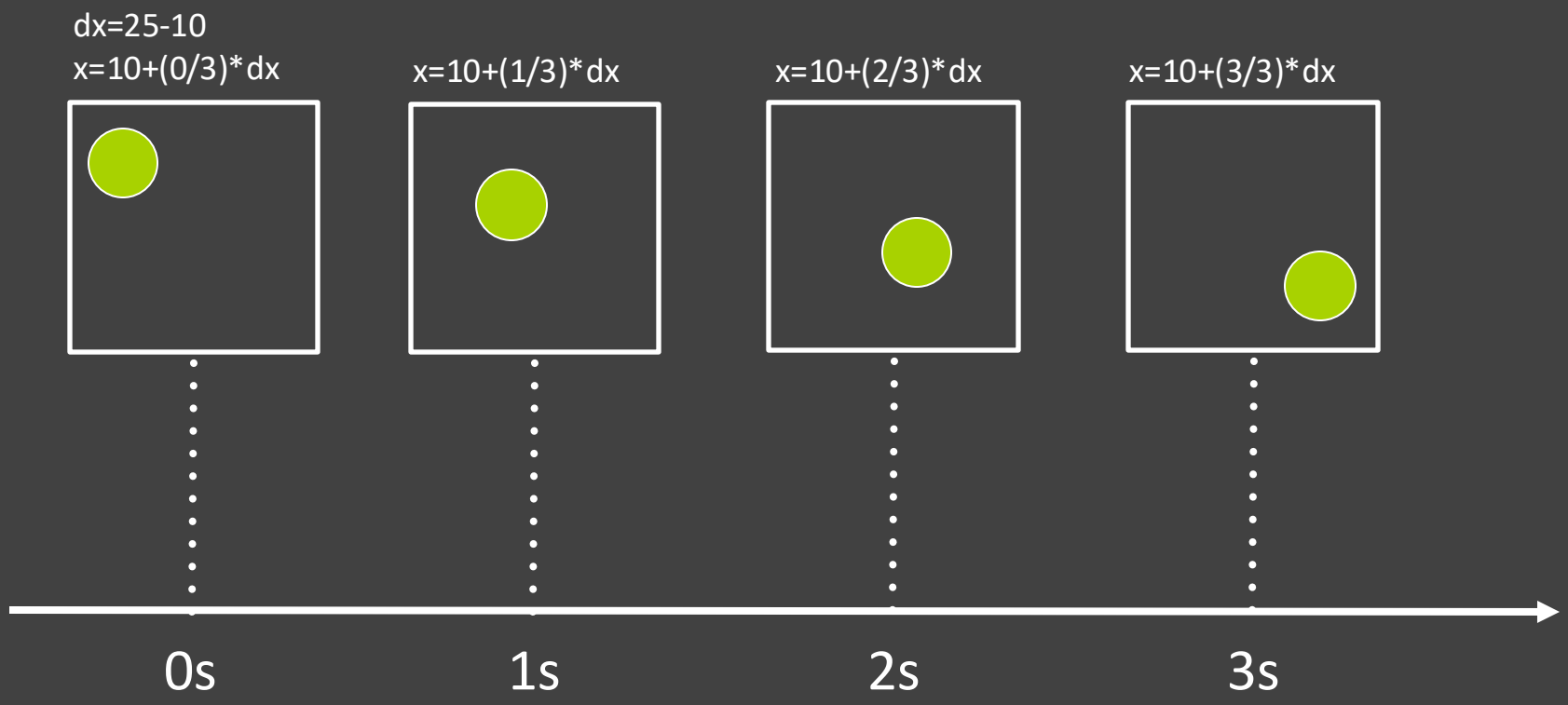
Transition-Based Animation (Hudson & Stasko '93)
Specify property value, duration & easing
Also called tweening (for "in-betweens")
Typically computed via interpolation

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

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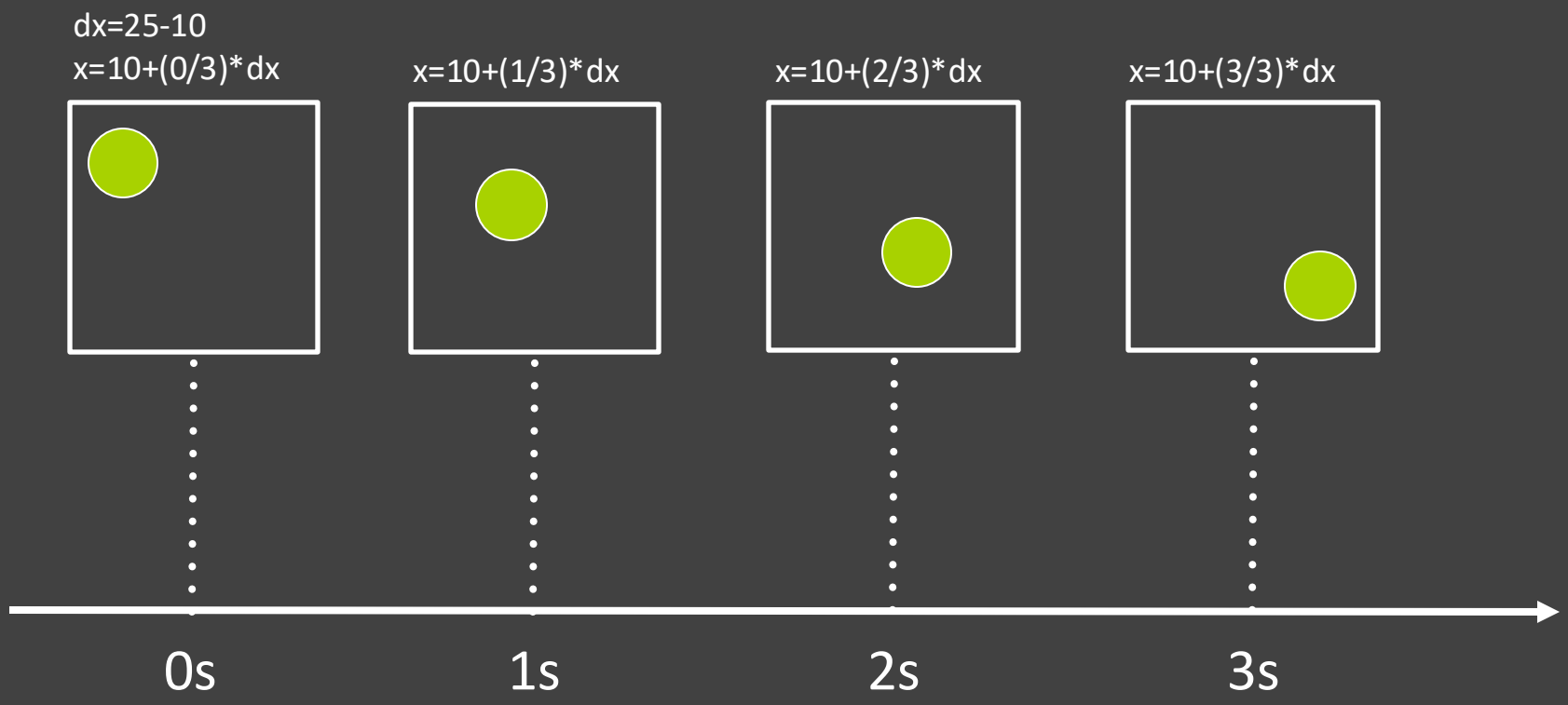
Toolkit handles frame-by-frame updates!



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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D3 Transitions

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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

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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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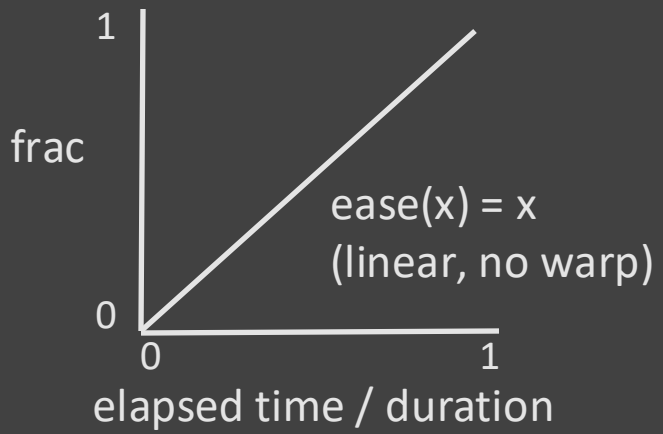

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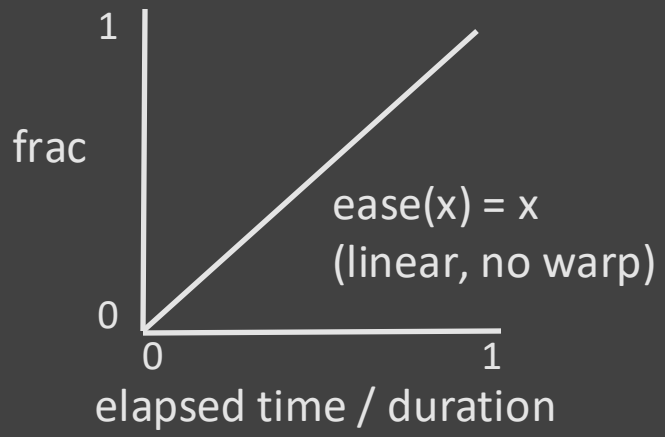

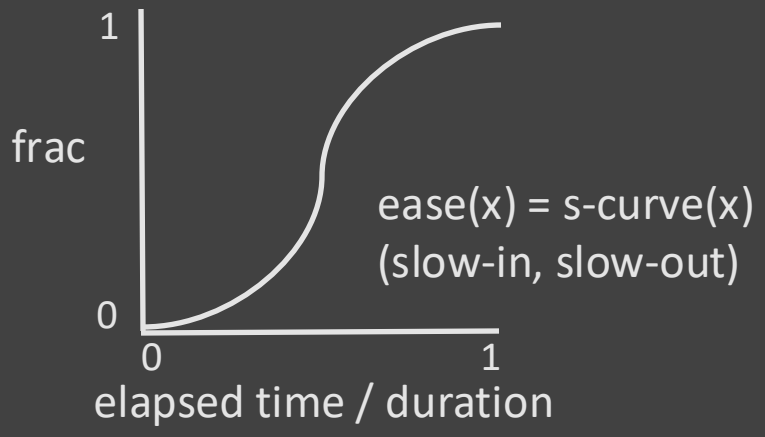

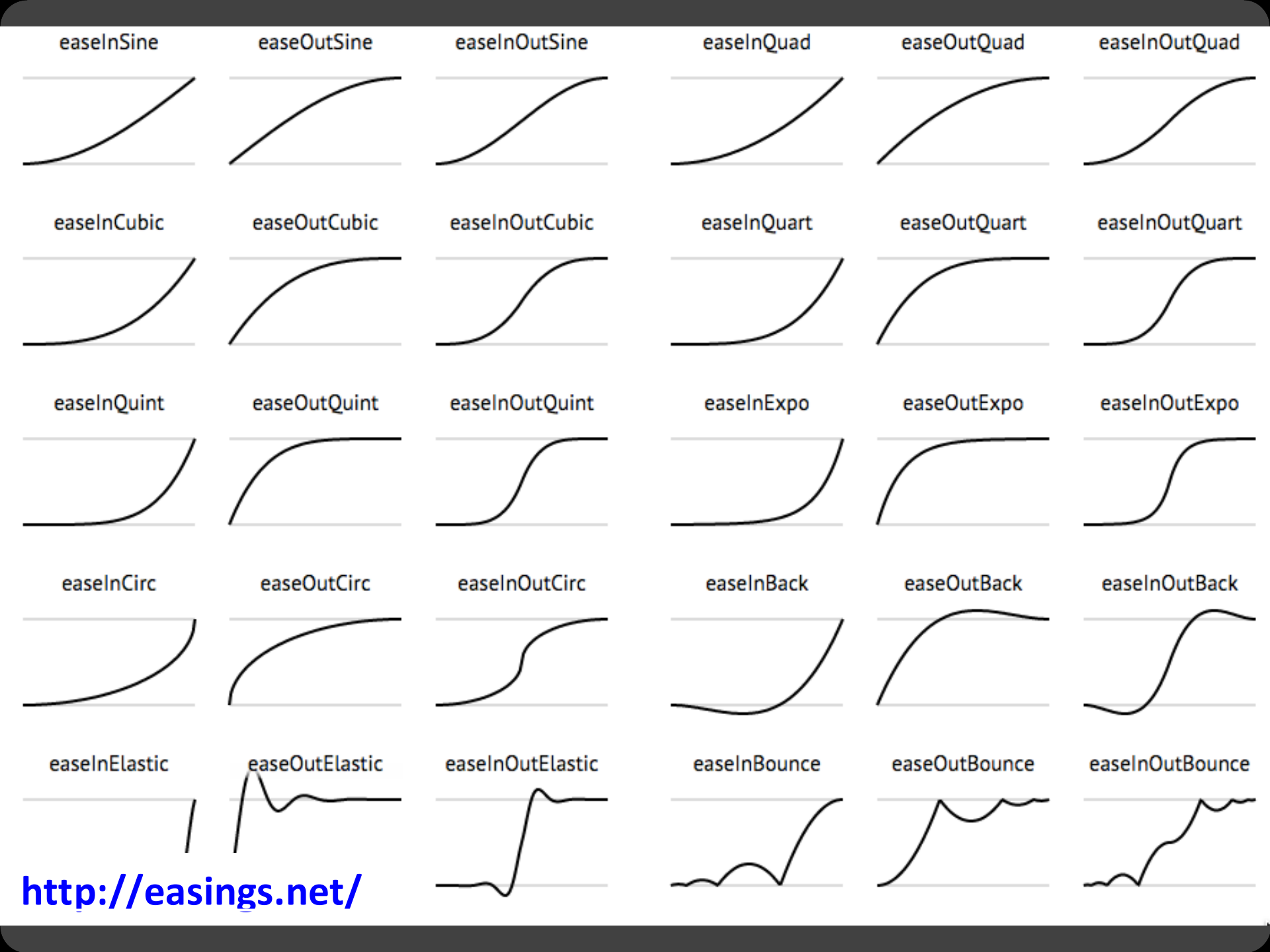
easeInSine
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easeInQuart
easeOutQuart
easeInOutQuart
easeInQuint
easeOutQuint
easeInOutQuint
easeInExpo
easeOutExpo
easeInOutExpo
easeInCirc
easeOutCirc
easeInOutCirc
easeInBack
easeOutBack
easeInOutBack
easeInElastic
easeOutElastic
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http://easings.net/

CSS Transitions

Extends CSS with Animated Transitions

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a {
  color: black;
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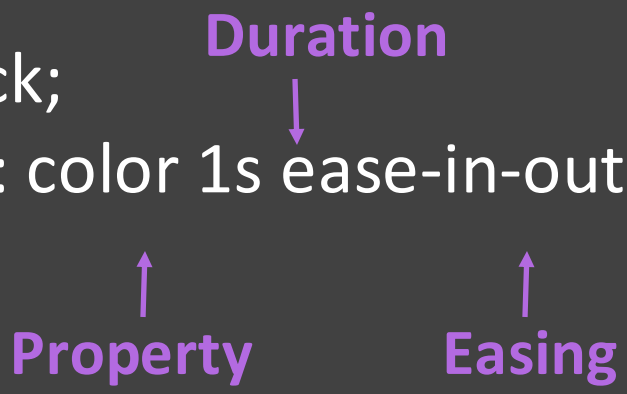

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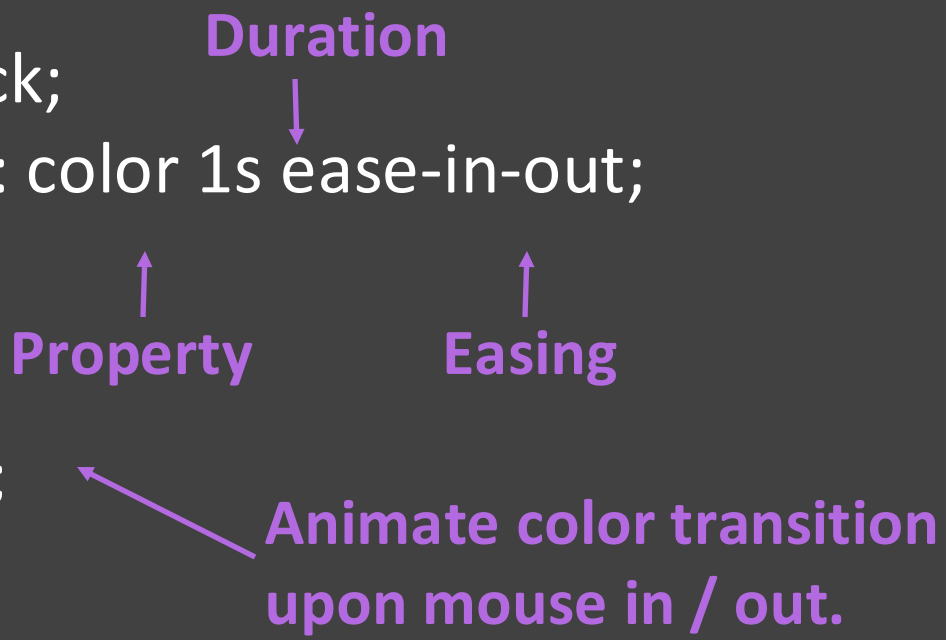

Summary

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**