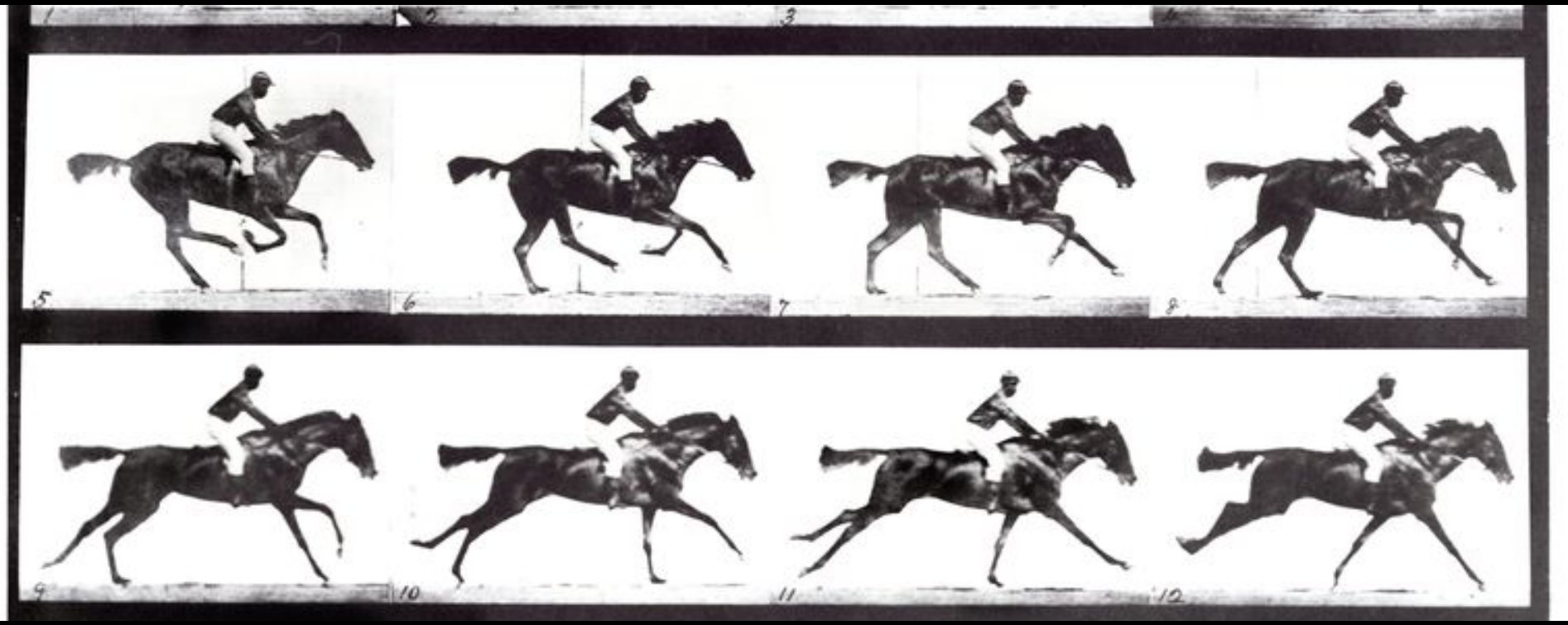
CSE 442 - Data Visualization

Animation



Matthew Conlen University of Washington

Why Use Motion?

Visual variable to encode data

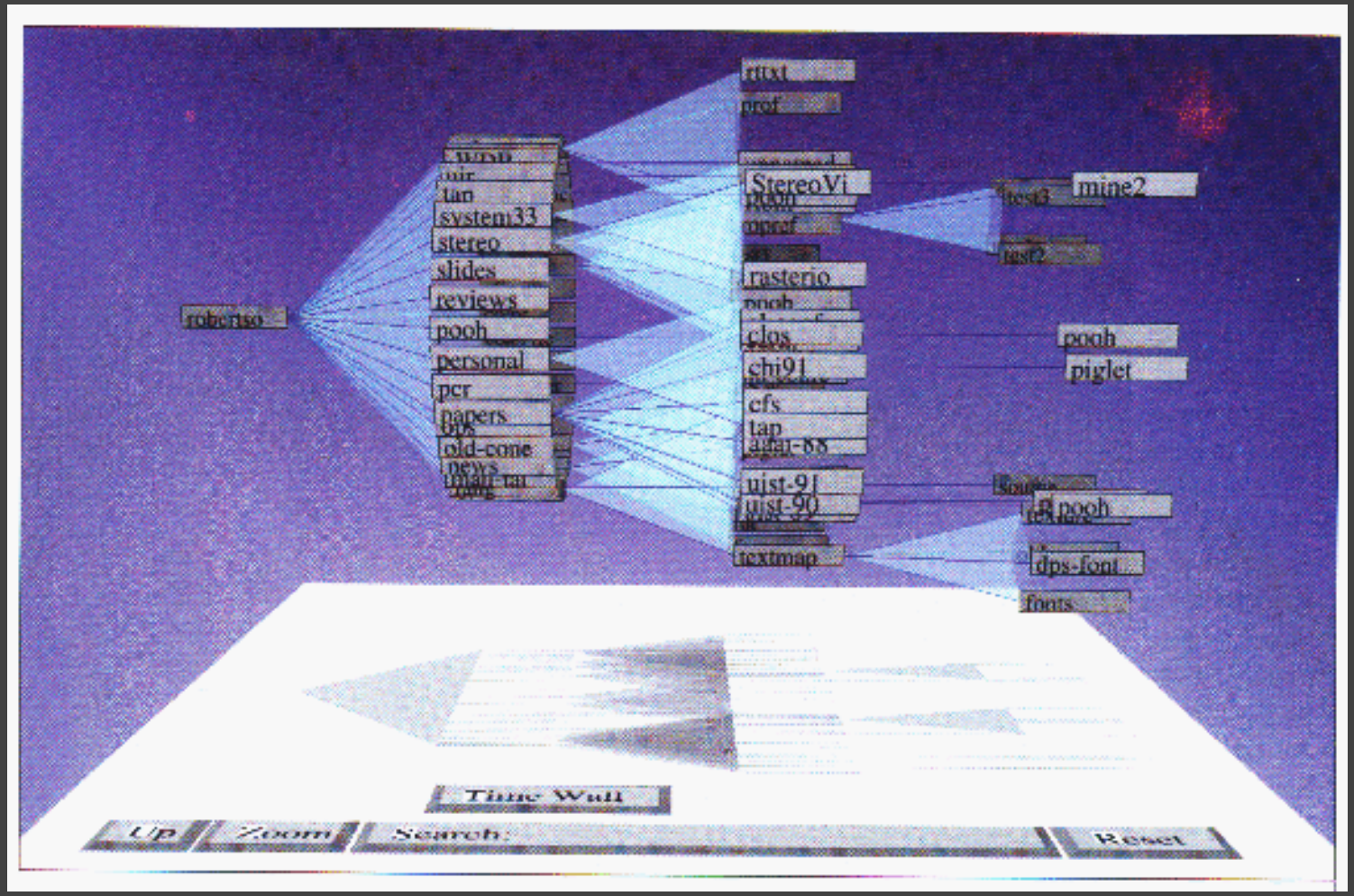
Direct attention

Understand system dynamics

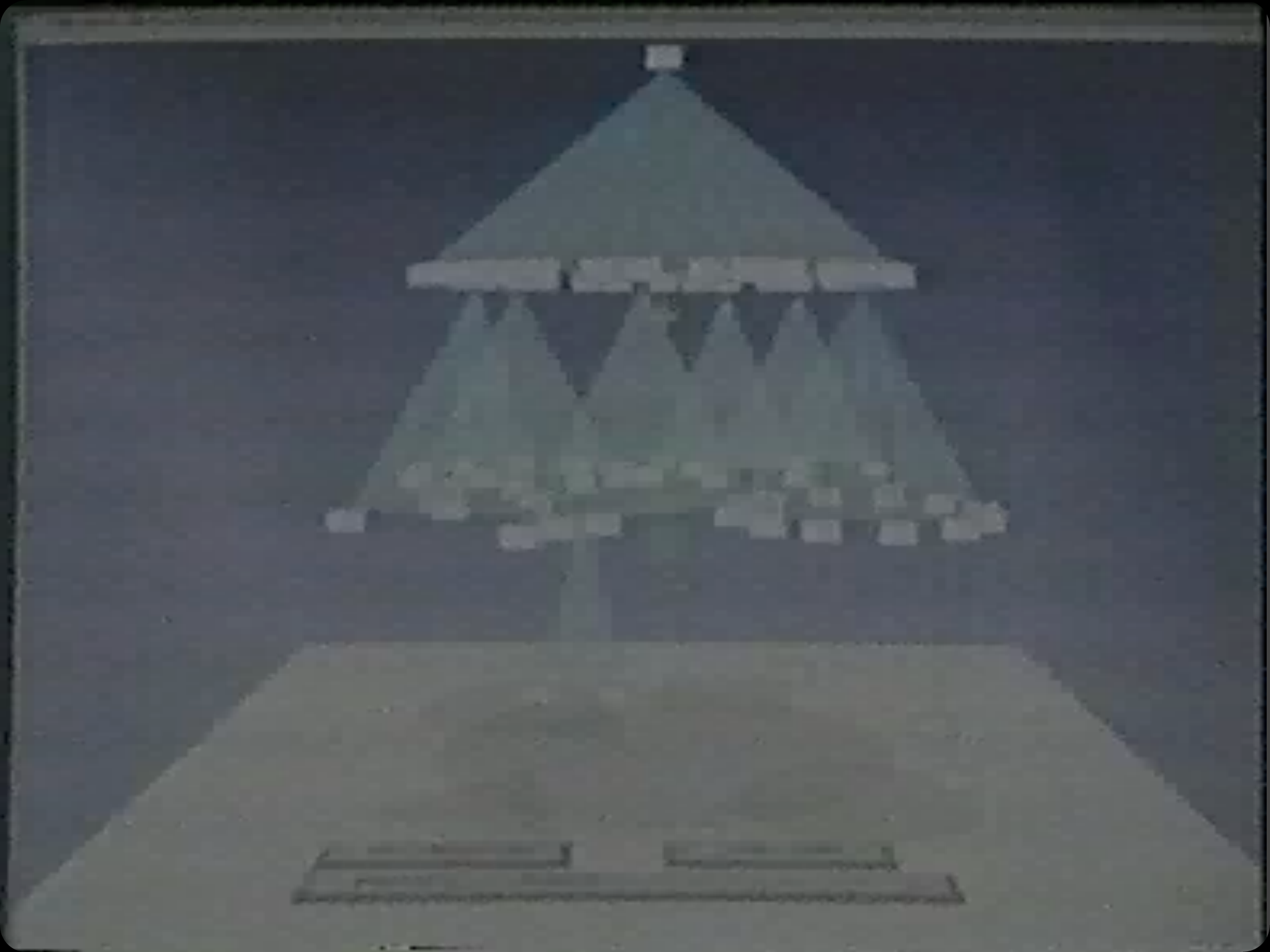
Understand state transition

Increase engagement

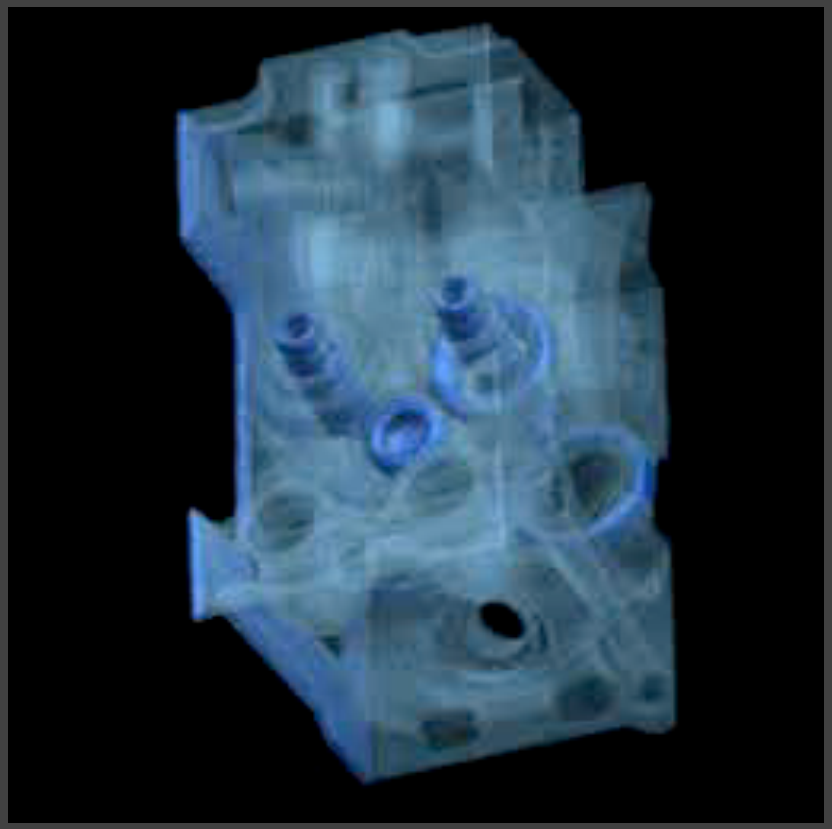
Cone Trees [Robertson 91]



Video

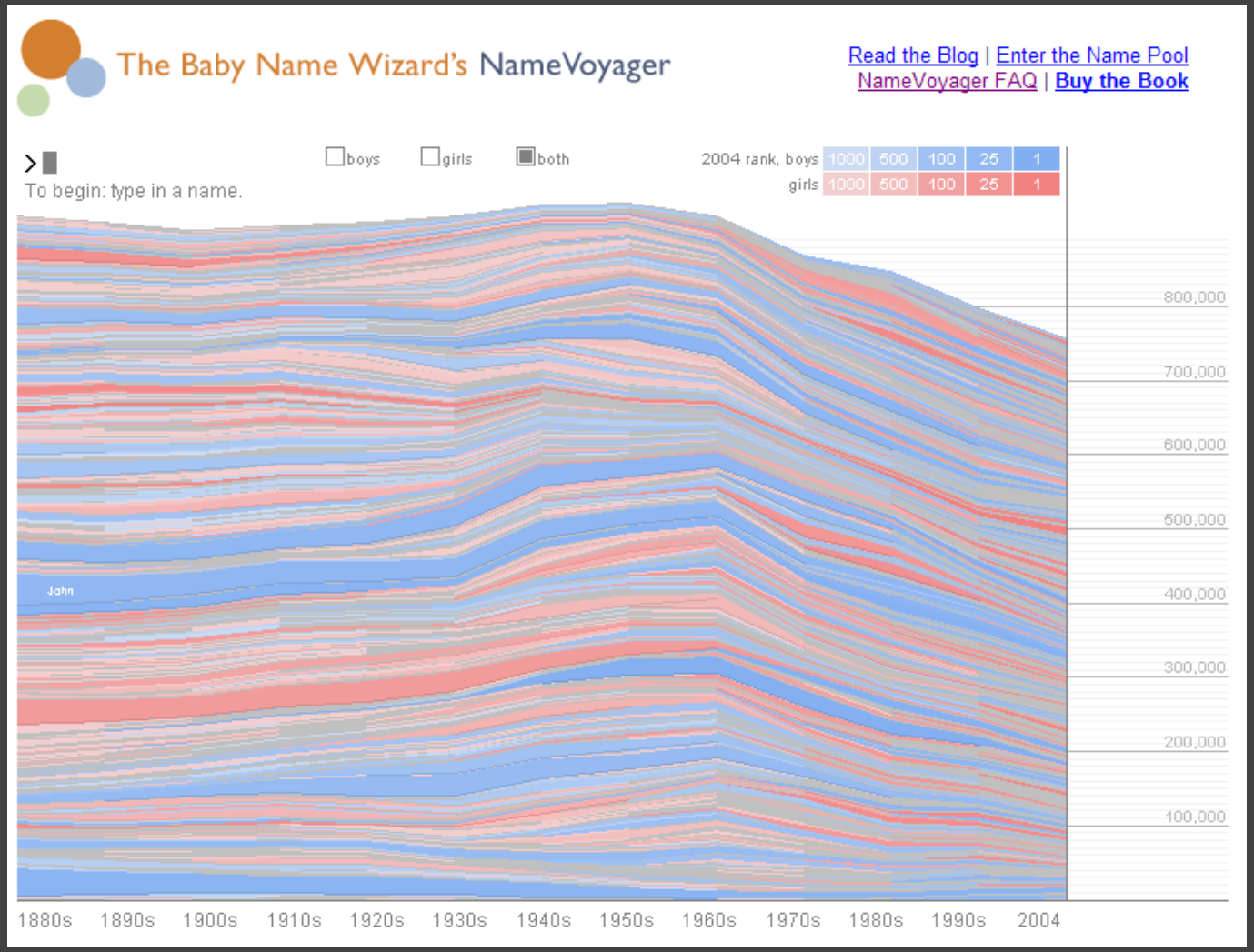


Volume Rendering [Lacroute 95]



Video

NameVoyager [Wattenberg 04]



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

Topics

Motion perception

Animated transitions in visualizations

Implementing animations

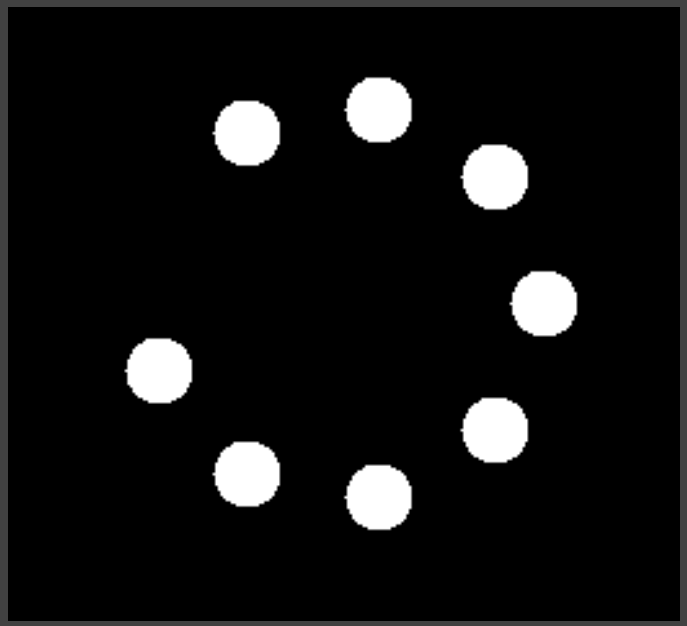
Motion Perception

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).



TV ~30fps (33ms)
Computer 60fps (16ms)
VR 90-120fps (8-11ms)

Motion as Visual Cue

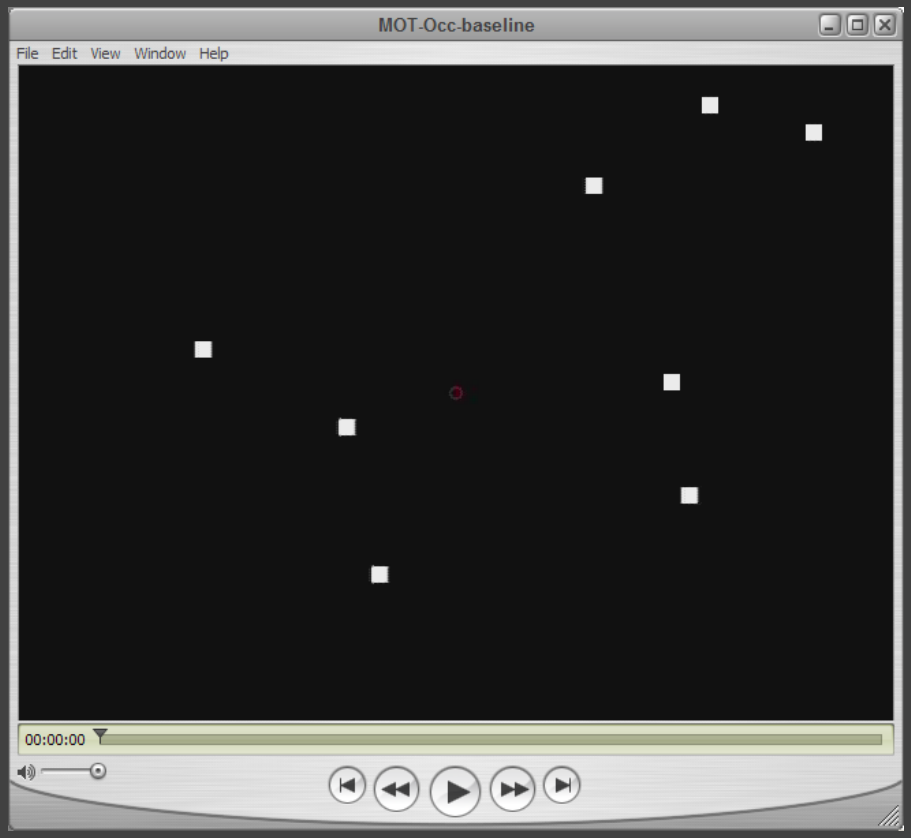
Pre-attentive, stronger than color, shape, …

More sensitive to motion at periphery

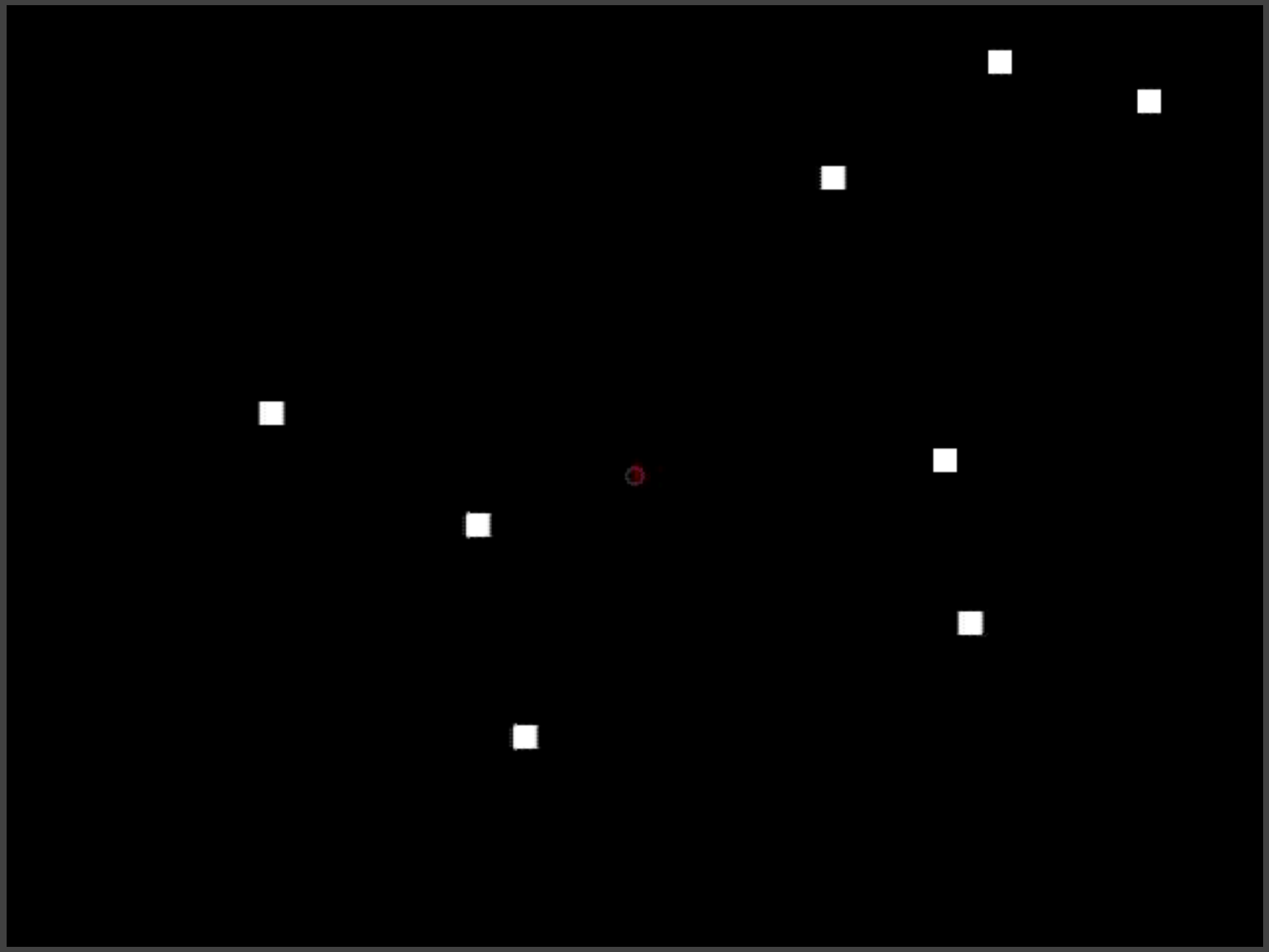
Similar motions perceived as a group

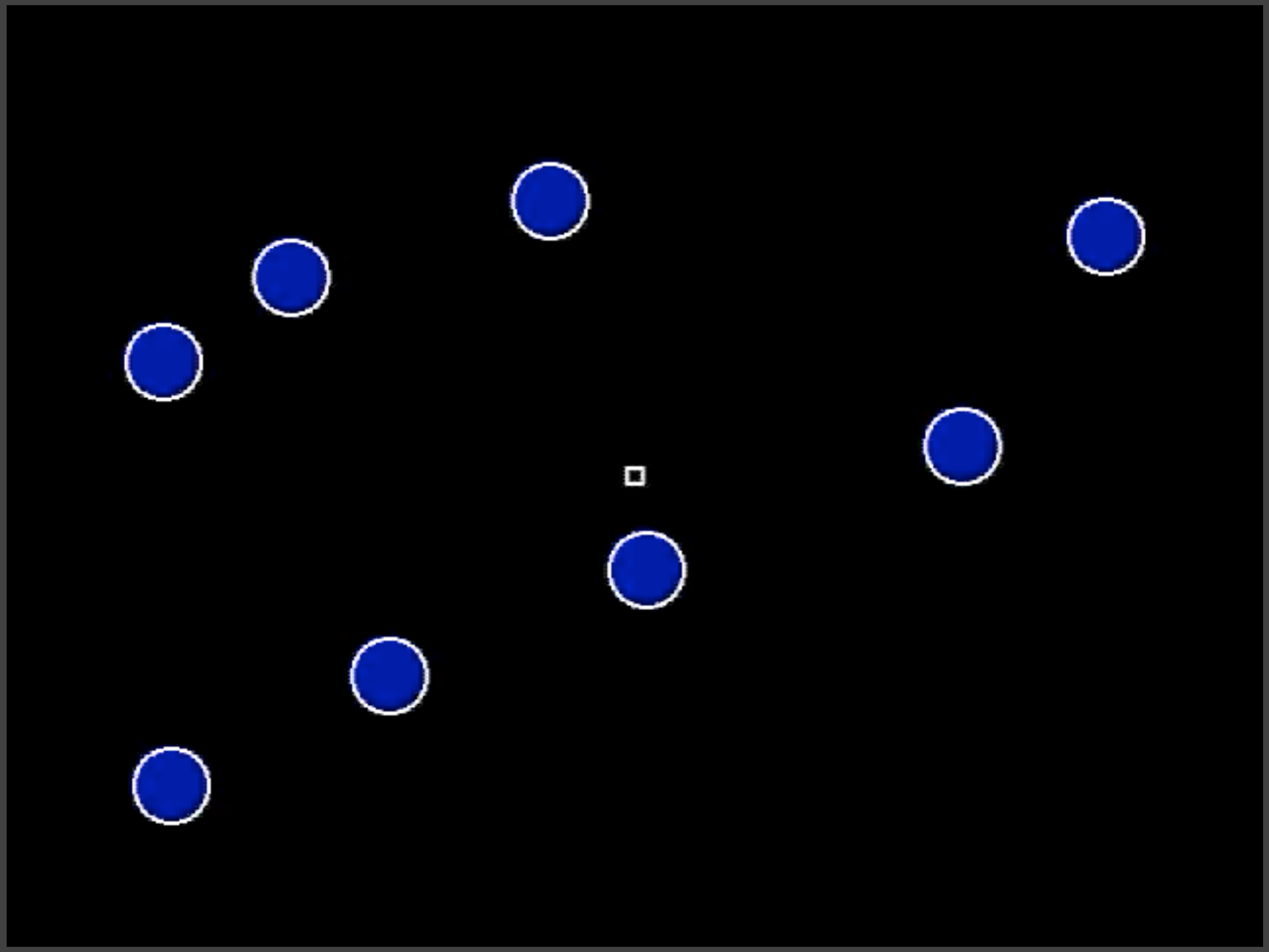
Motion parallax provide 3D cue (like stereopsis)

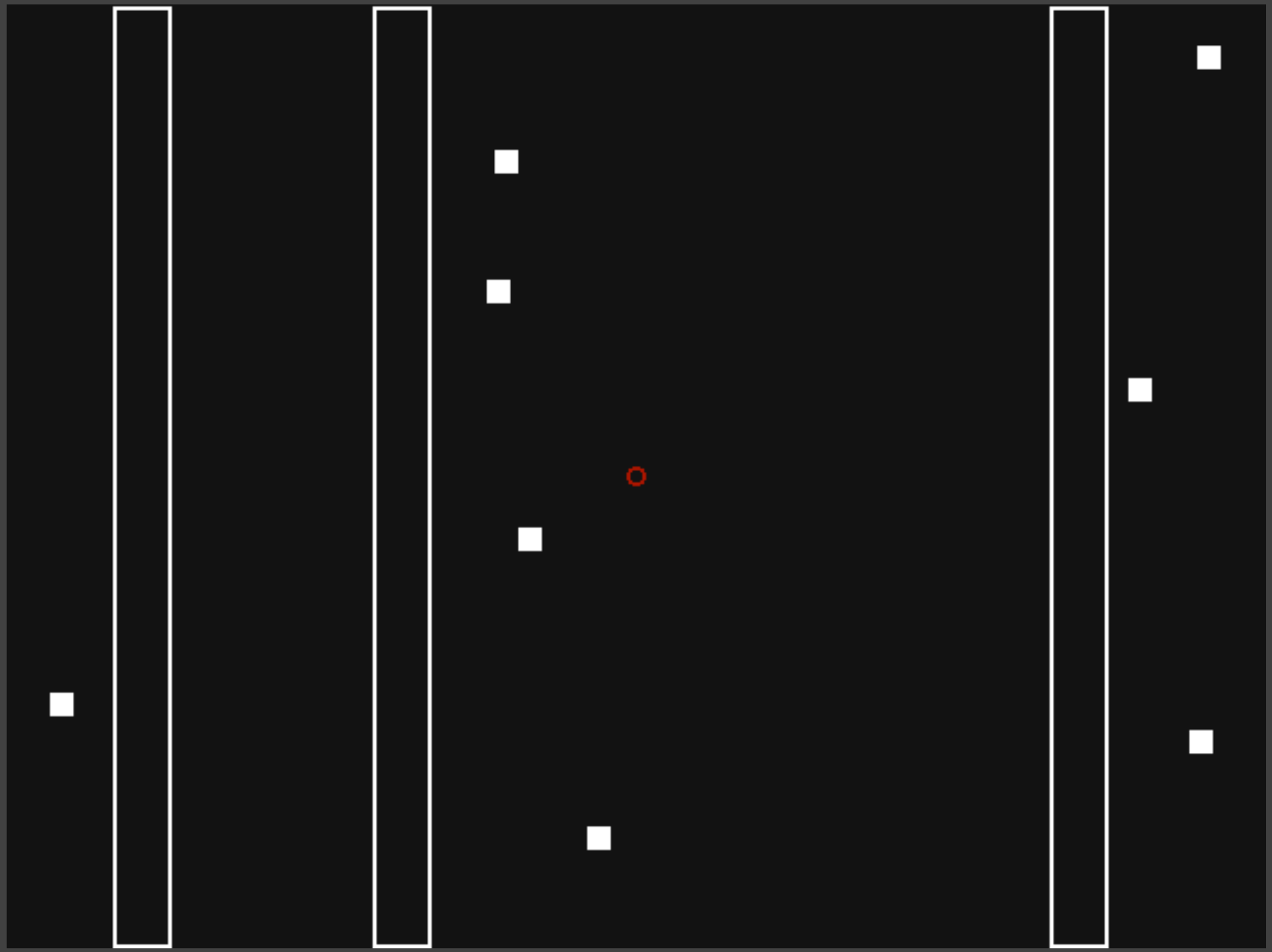
Tracking Multiple Targets

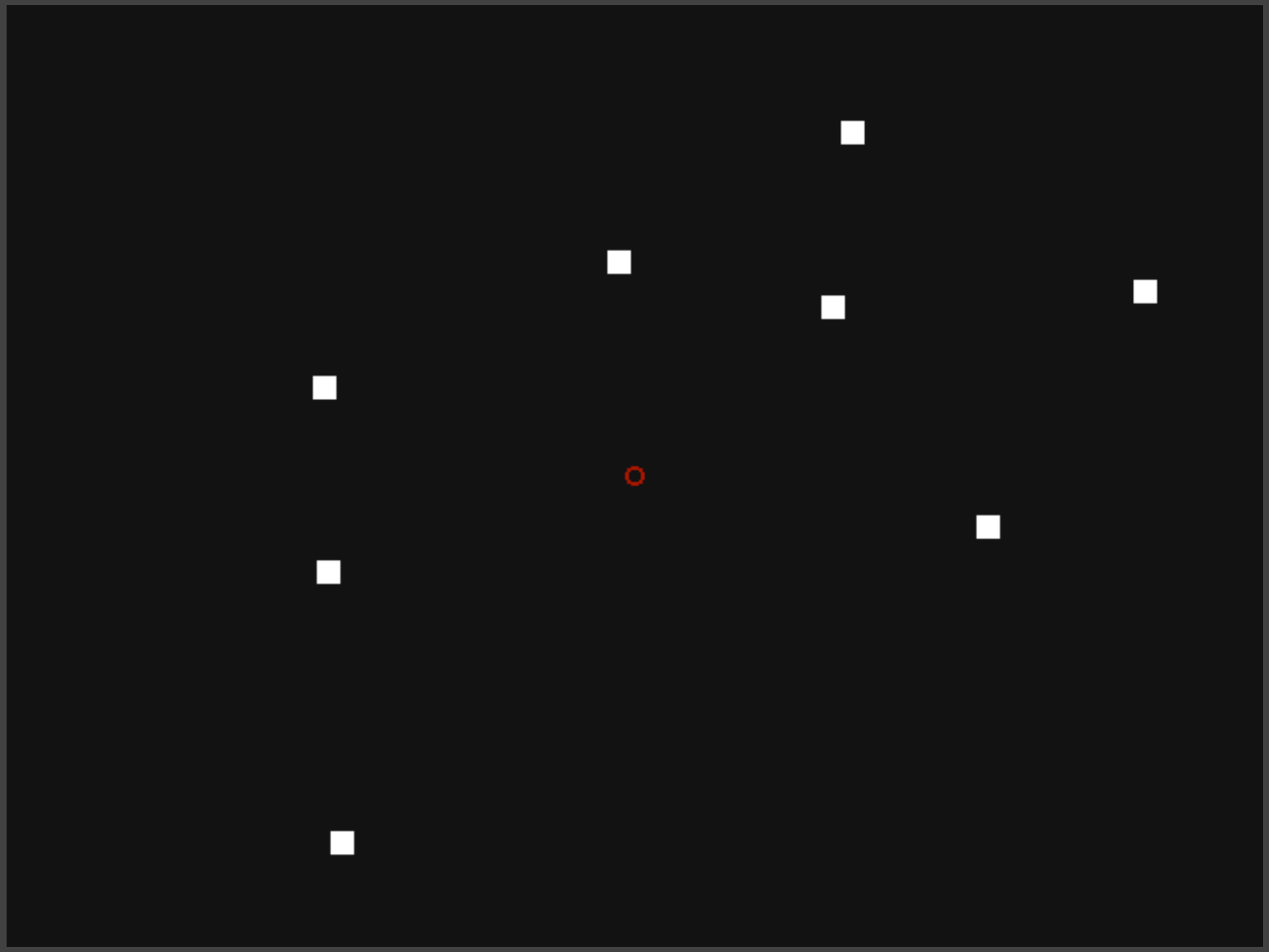


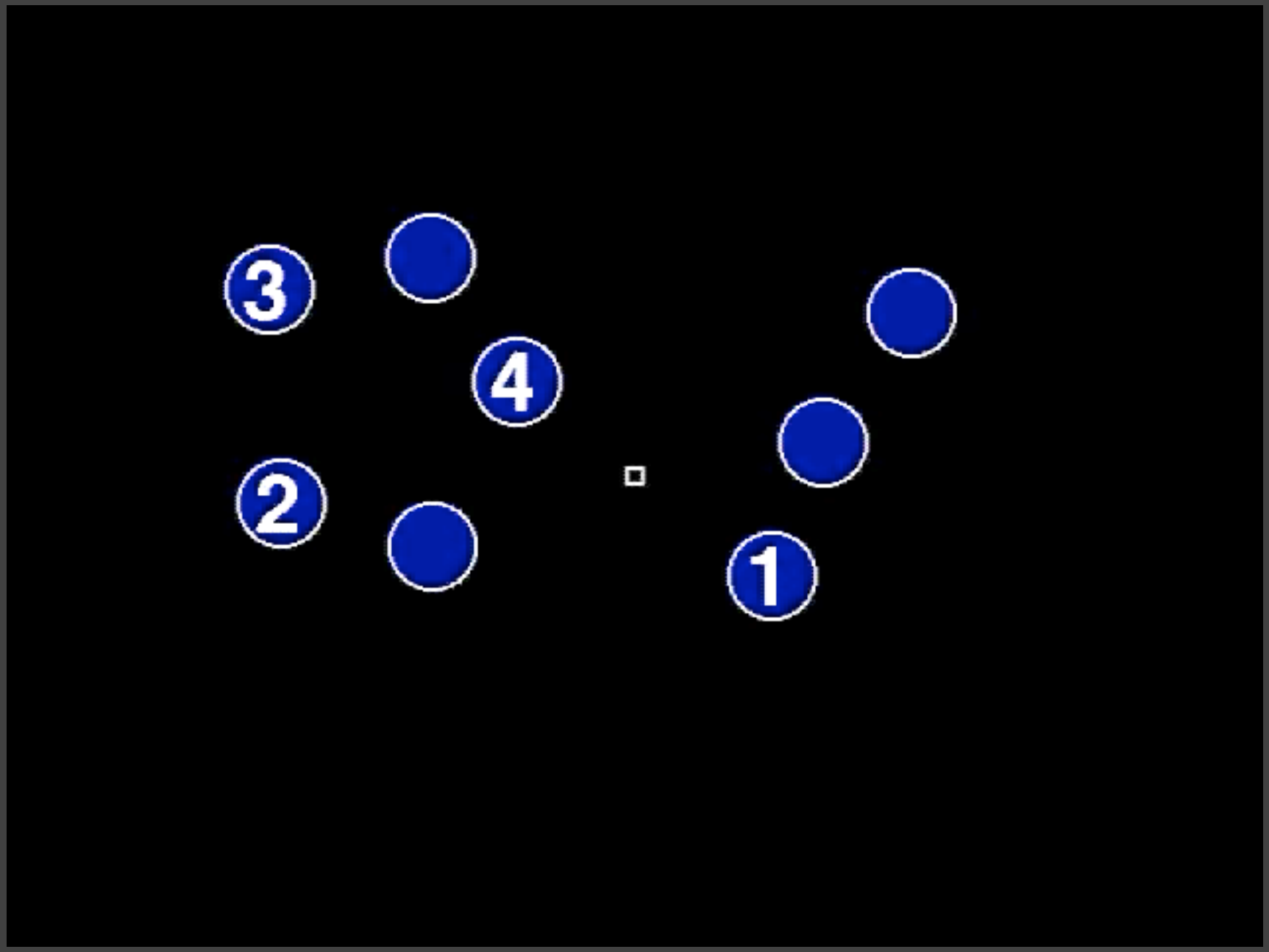
How many dots can we simultaneously track?



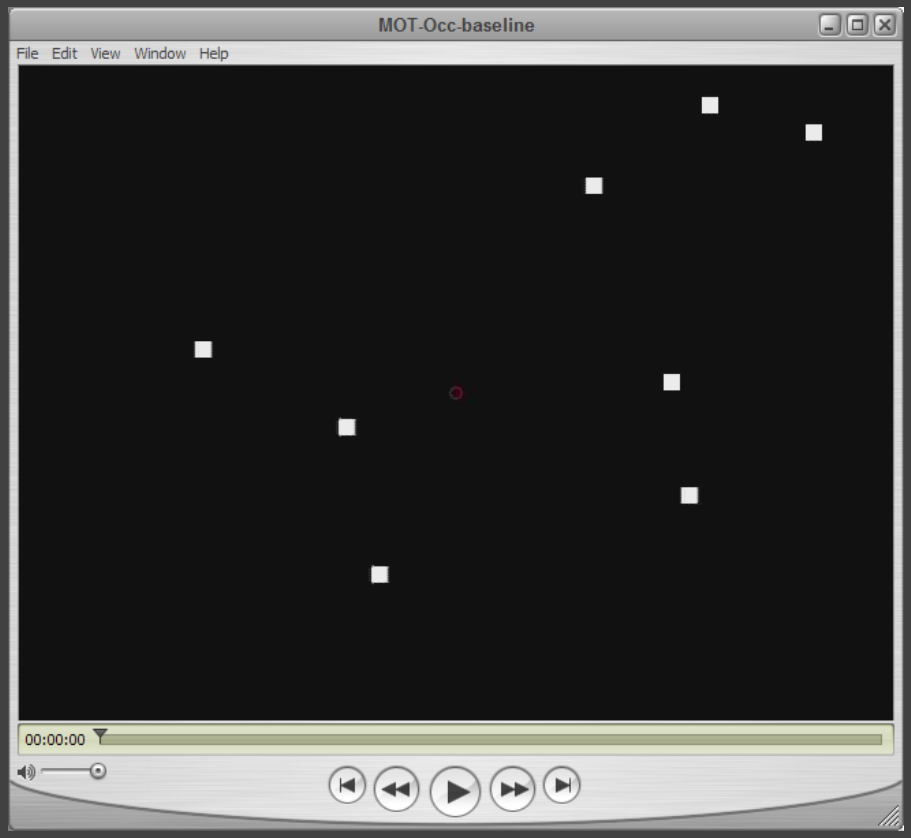







3
4
2
1

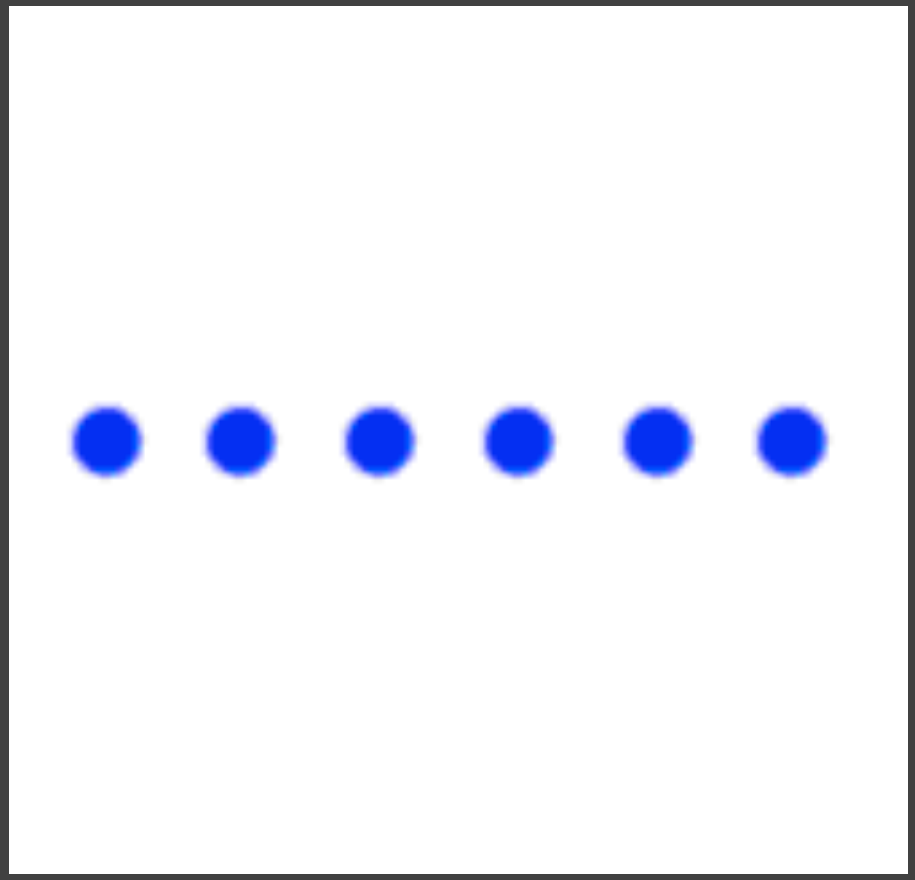
Tracking Multiple Targets



How many dots can we simultaneously track?

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

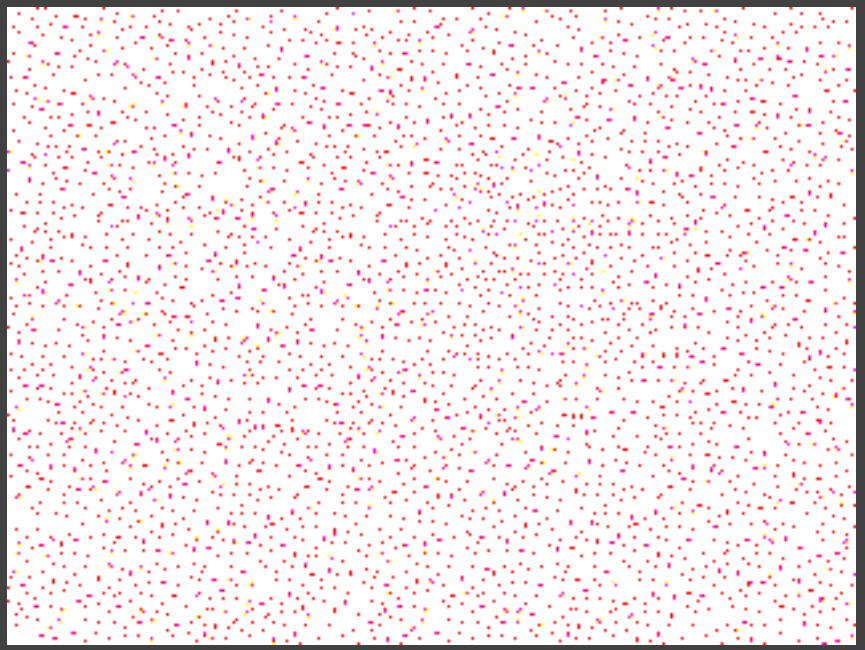
Grouped Dots Count as 1 Object



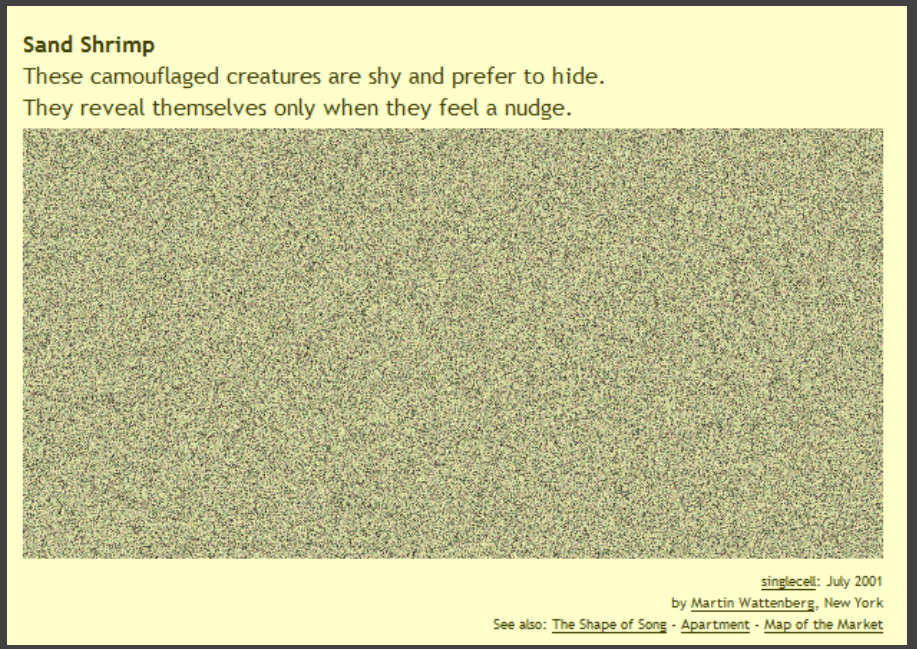
Dots moving together are grouped

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

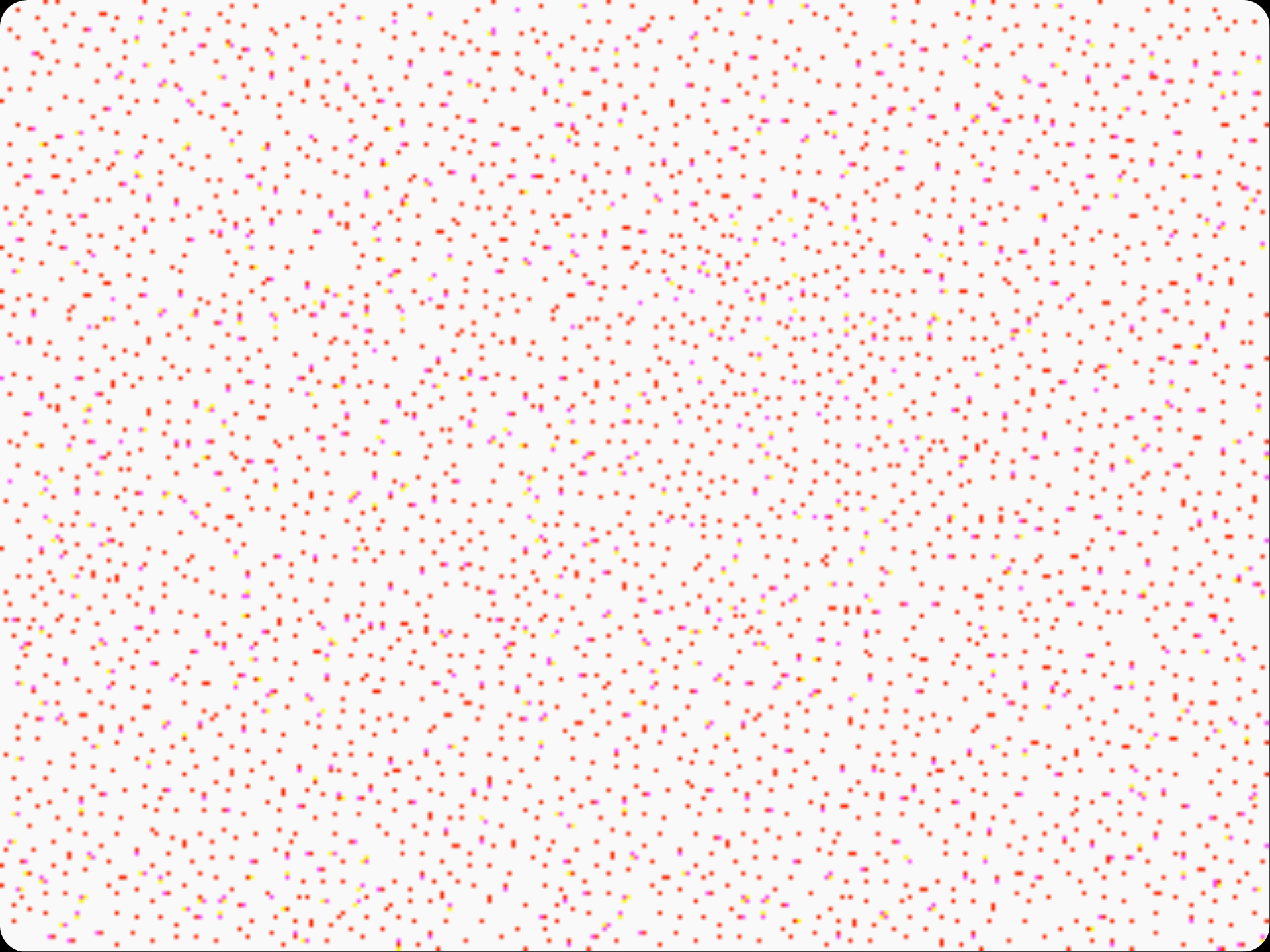
Segment by Common Fate



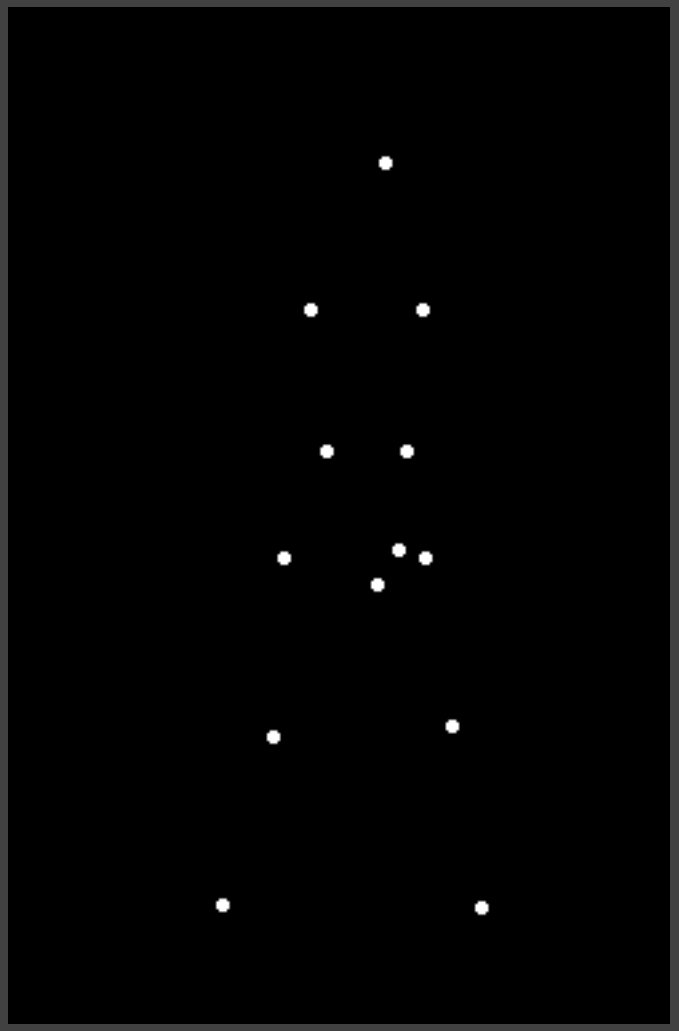
http://dragon.uml.edu/psych/commfate.html



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

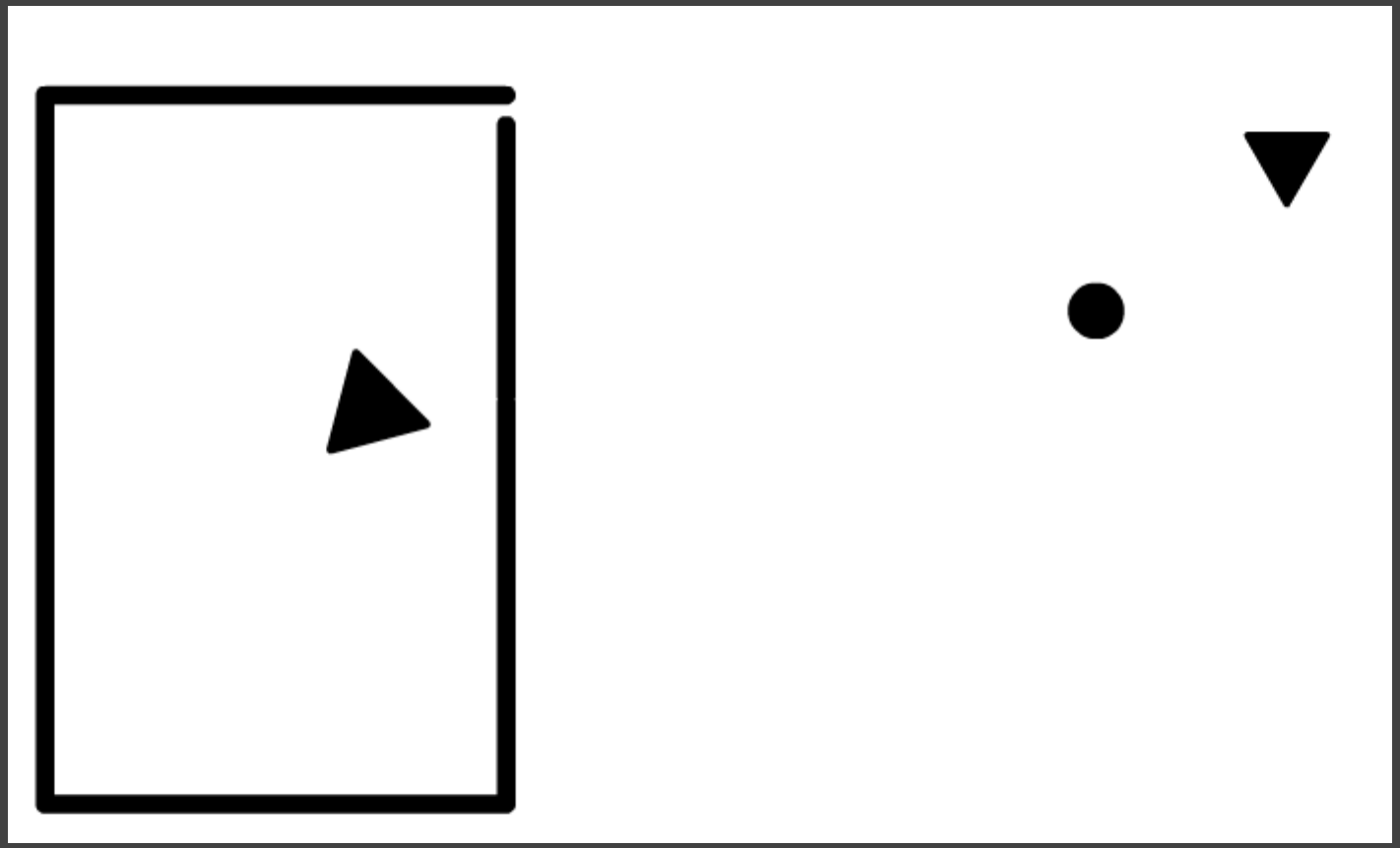
start end

Shows transition better, but

Still may be too fast, or too slow

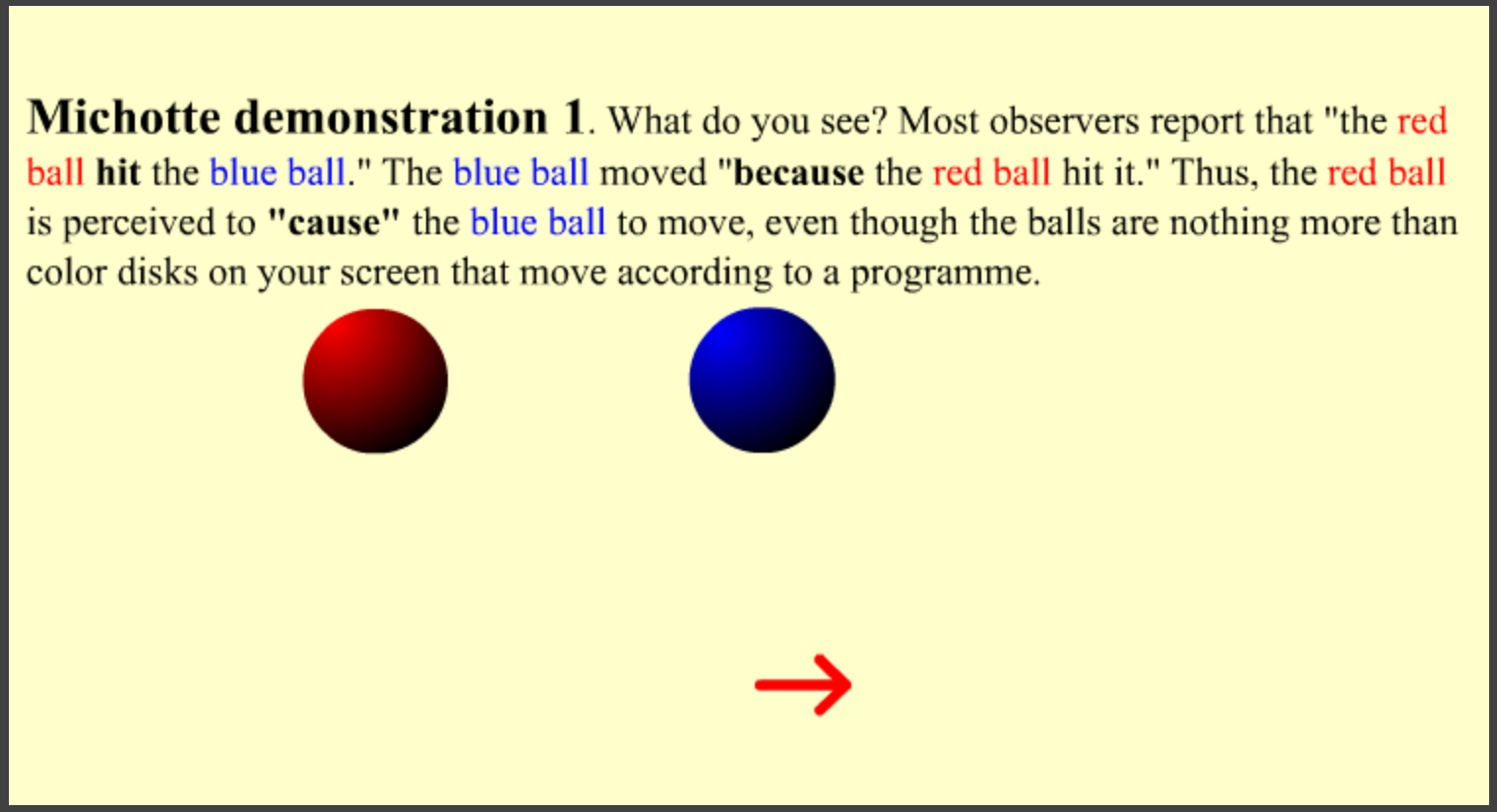
Too many objects may move at once

Constructing Narratives



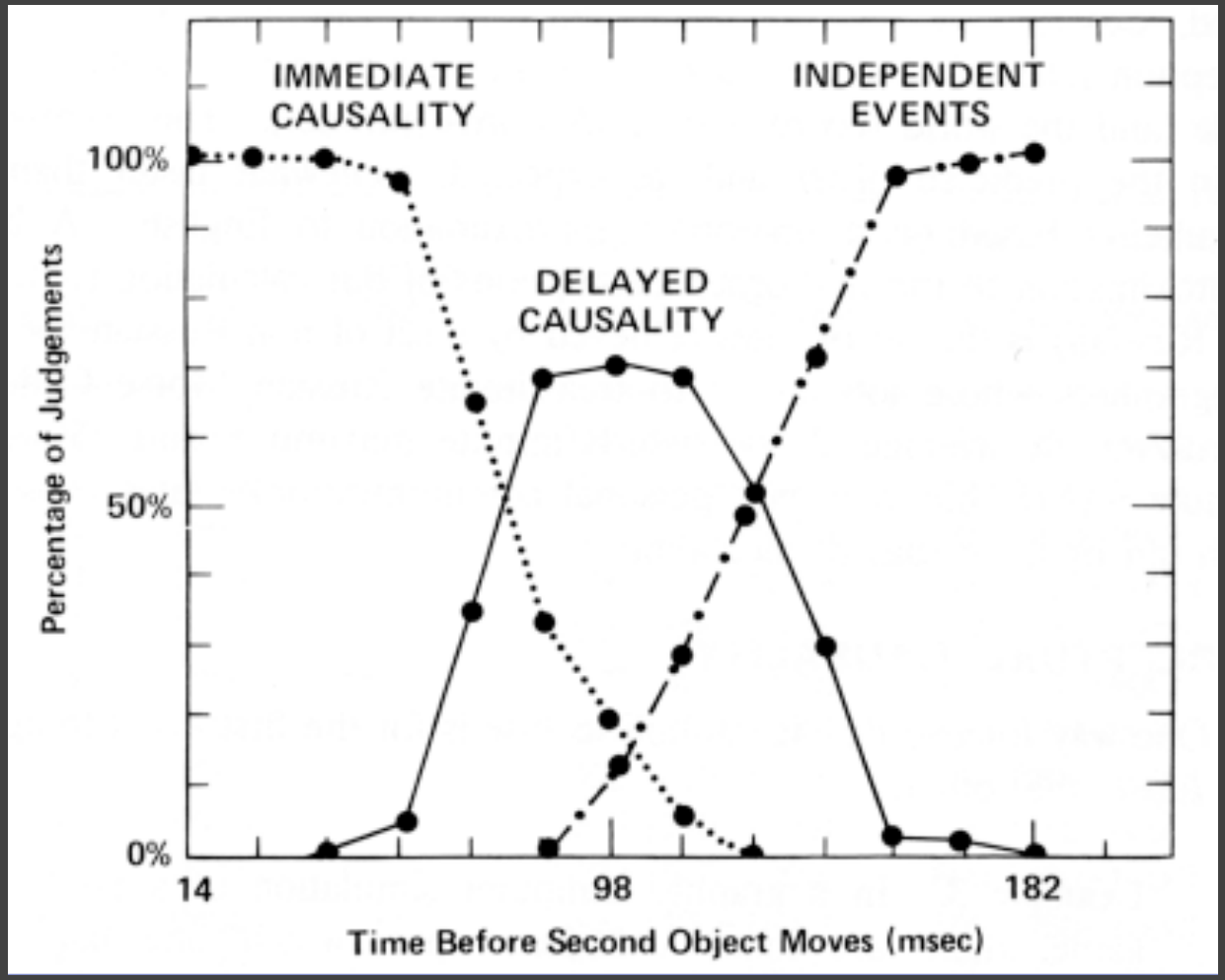
http://anthropomorphism.org/img/Heider_Flash.swf

Attribution of Causality [Michotte 46]



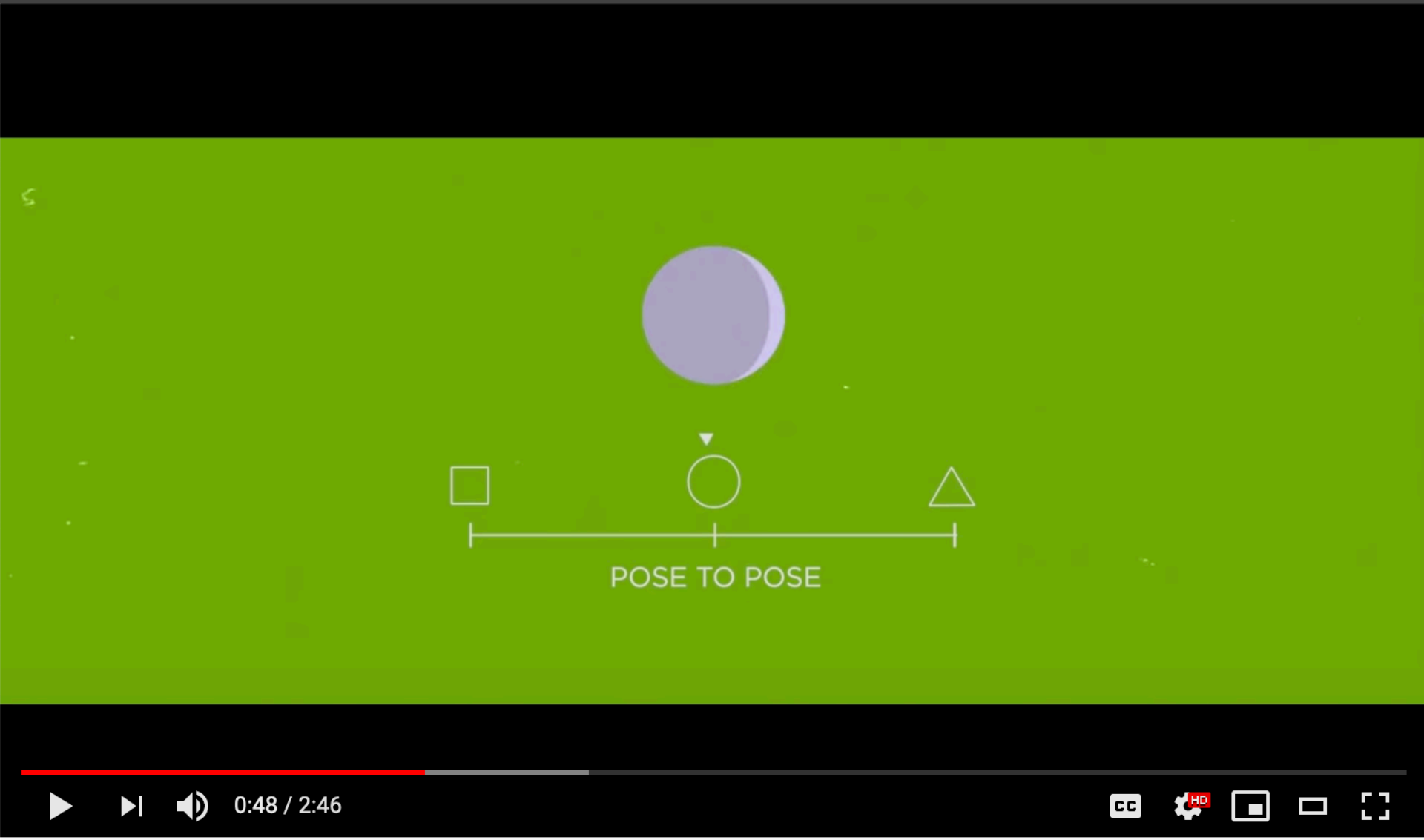
http://cogweb.ucla.edu/Discourse/Narrative/michotte-demo.swf

Attribution of Causality [Michotte 46]



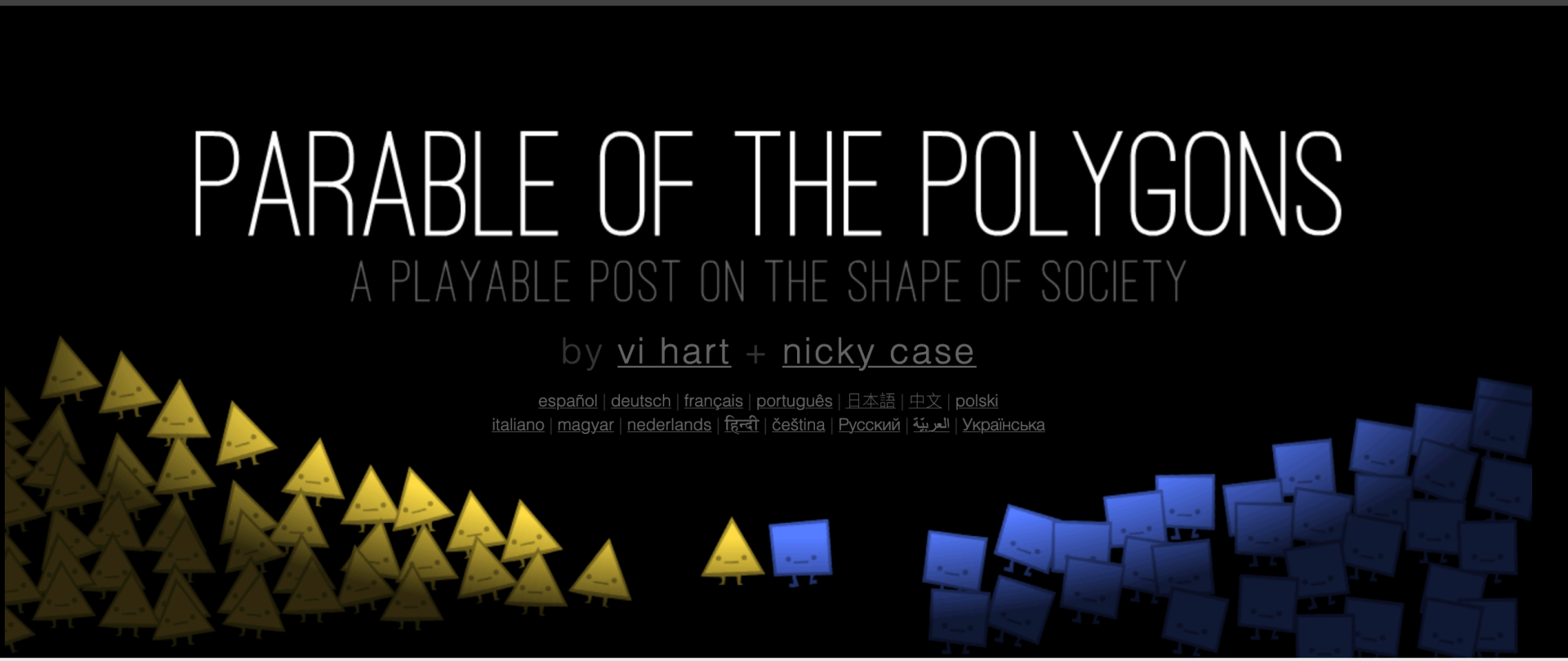
[Reprint from Ware 04]

Artists know the power of animation



The Illusion of Life | Principle of Animation | 12 Basic Principle of Animation

Case study #1- Nicky Case



This is a story of how harmless choices can make a harmful world.

These little cuties are 50% Triangles, 50% Squares, and 100% slightly shapist. But only slightly! In fact, every polygon *prefers* being in a diverse crowd:

Case study #2- NYTimes Graphics

THE NEW HEALTH CARE
Lessons That Go Beyond the Coronavirus Outbreak

The Election Year Economy Is Everything Trump Could Hope For

New Doubts From Iowa Caucuses: How 'Satellite' Votes Are Being Measured

Iowa Caucus Results Riddled With Errors and Inconsistencies

Extensive Data Shows Punishing Reach of Racism for Black Boys

By **EMILY BADGER, CLAIRE CAIN MILLER, ADAM PEARCE** and **KEVIN QUEALY** MARCH 19, 2018

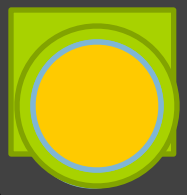
Black boys raised in America, even in the wealthiest families and living in some of the most well-to-do neighborhoods, still earn less in adulthood than white boys with similar backgrounds, according to a sweeping new study that traced the lives of millions of children.

White boys who grow up rich are likely to remain that way. Black boys raised at the top, however, are more likely to become poor than to stay wealthy in their own adult households.

Follow the lives of 3,469 boys who grew up in rich families . . .

. . .and see where they end up as adults:

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

Animation: Can It Facilitate?

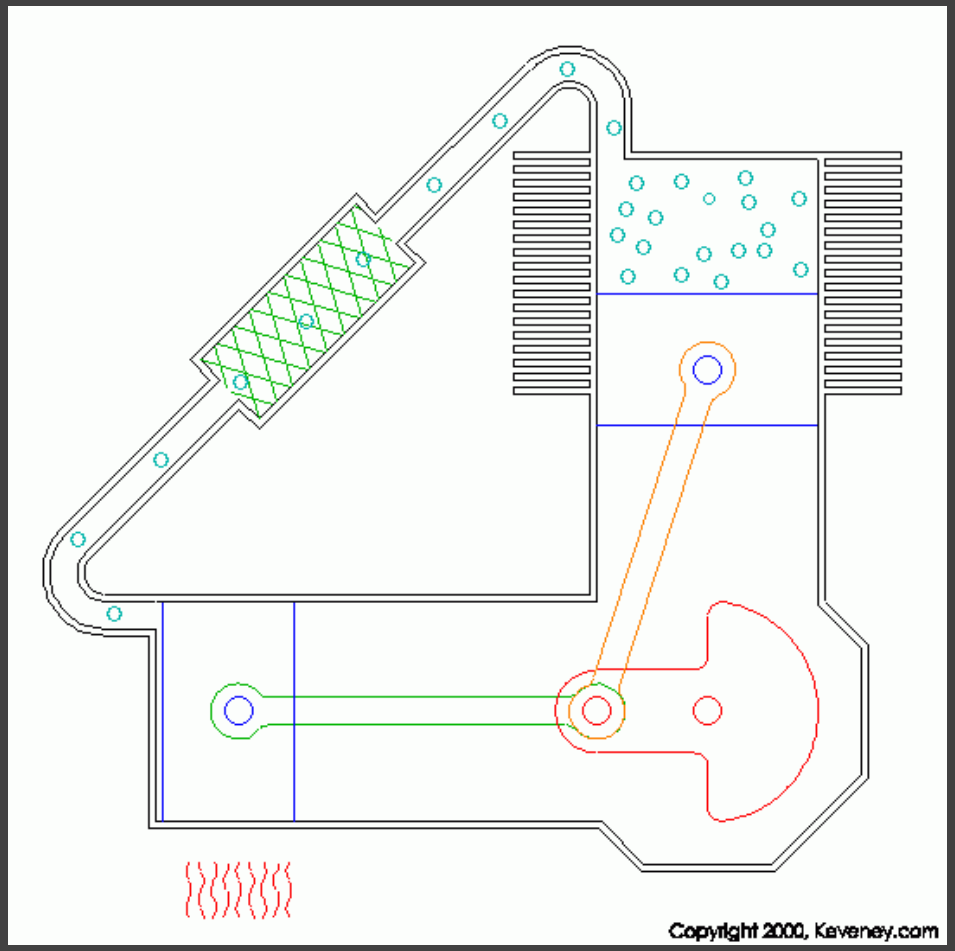
Tversky et al reviewed studies in animation for **conveying dynamic processes**.

- Where benefits were found, the comparison was often unfair: the information was not equivalent
- In other cases, no difference in learning

Implications:

- Comparisons of static and animated displays should use displays with equivalent information
- Static sequence may be as good or better

Break into Static Steps



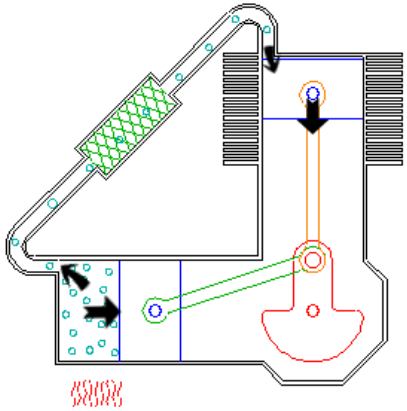
Two-cylinder Stirling engine

http://www.keveney.com/Vstirling.html

Break into Static Steps

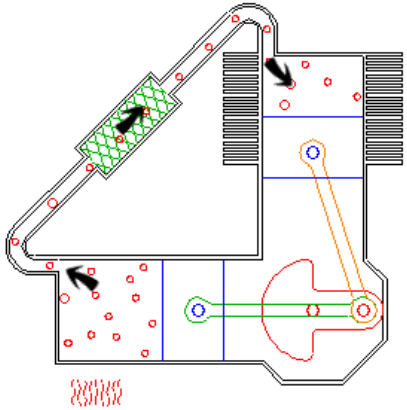
1

Expansion. At this point, most of the gas in the system has just been driven into the hot cylinder. The gas heats and expands driving both pistons inward.



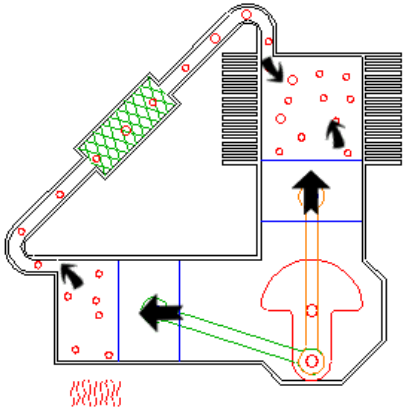
2

Transfer. At this point, the gas has expanded (about 3 times in this example). Most of the gas (about 2/3rds) is still located in the hot cylinder. Flywheel momentum carries the crankshaft the next 90 degrees, transferring the bulk of the gas to the cool cylinder.



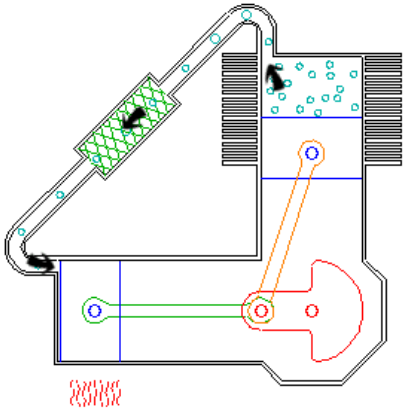
3

Contraction. Now the majority of the expanded gas has been shifted to the cool cylinder. It cools and contracts, drawing both pistons outward.



4

Transfer. The now contracted gas is still located in the cool cylinder. Flywheel momentum carries the crank another 90 degrees, transferring the gas to back to the hot cylinder to complete the cycle.



Two-cylinder Stirling engine

http://www.keveney.com/Vstirling.html

Challenges

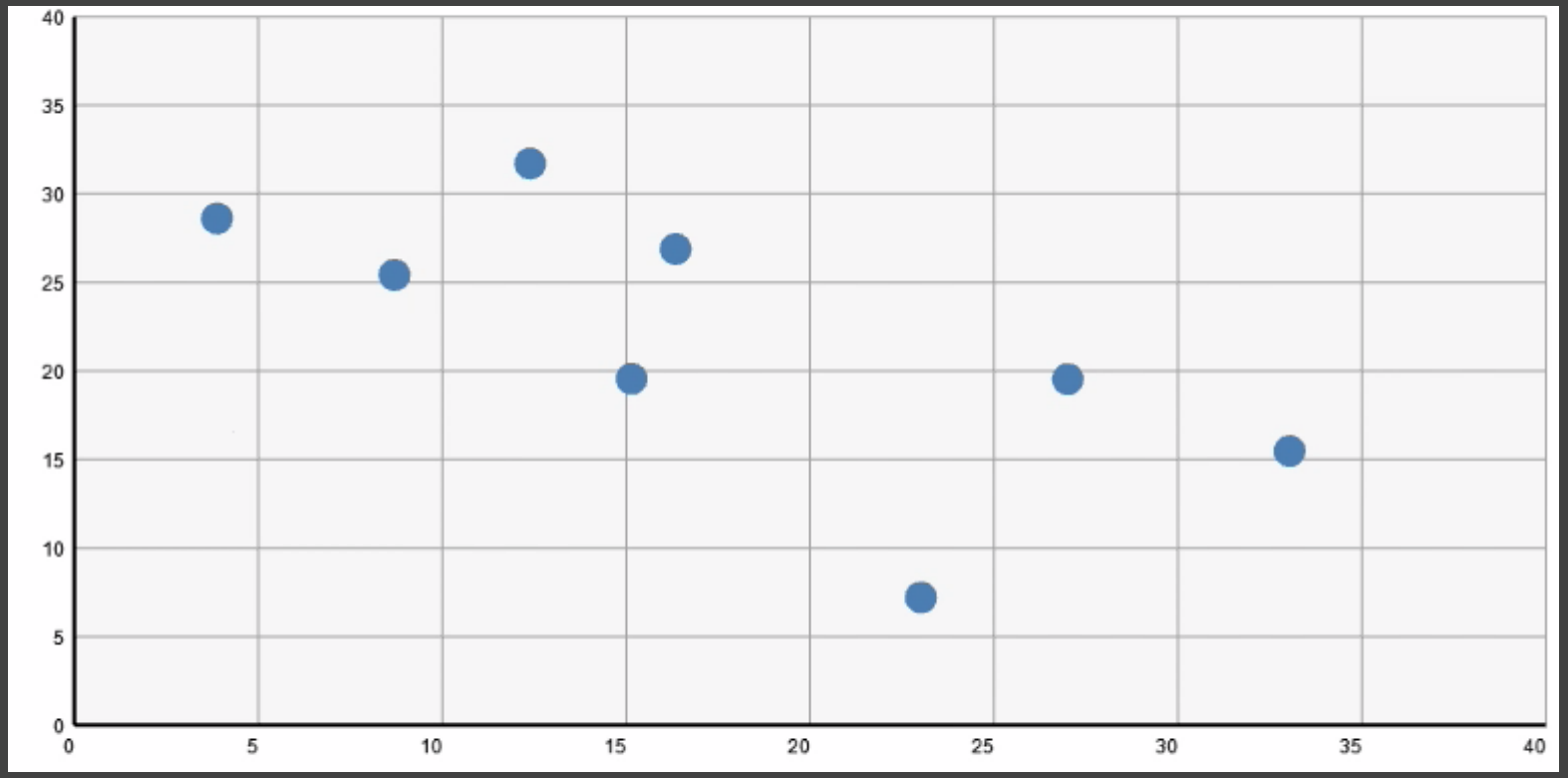
Choosing the **set of steps**:
How to segment process into steps?
Steps often shown sequentially for clarity, rather than showing everything simultaneously

Tversky suggests:
Coarse level – segment based on objects
Finer level – segment based on actions

- Static depictions often omit finer level segmentation

Resource: *Understanding Comics,* Scott McCloud

Animated Transitions in Statistical Graphics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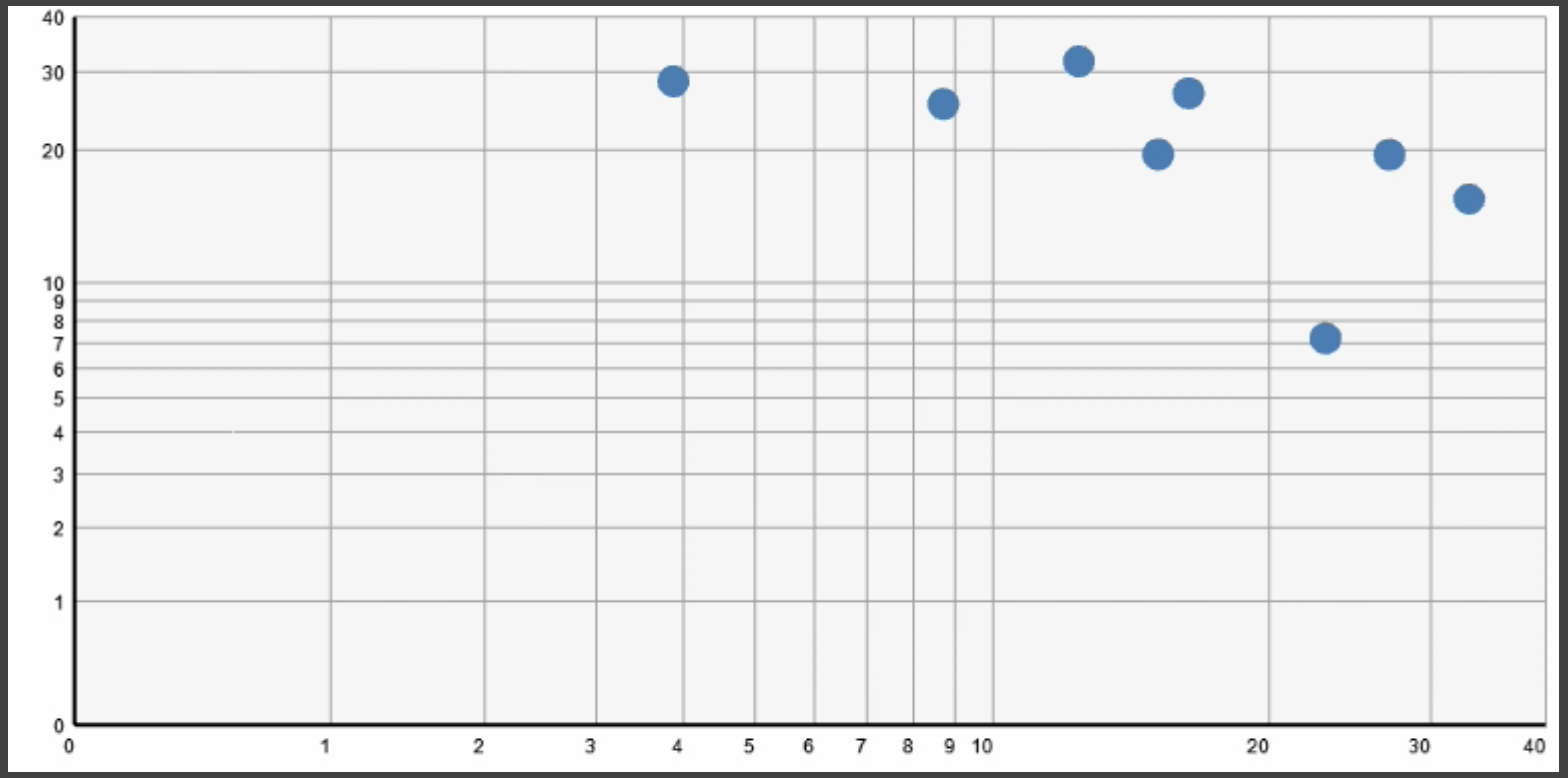
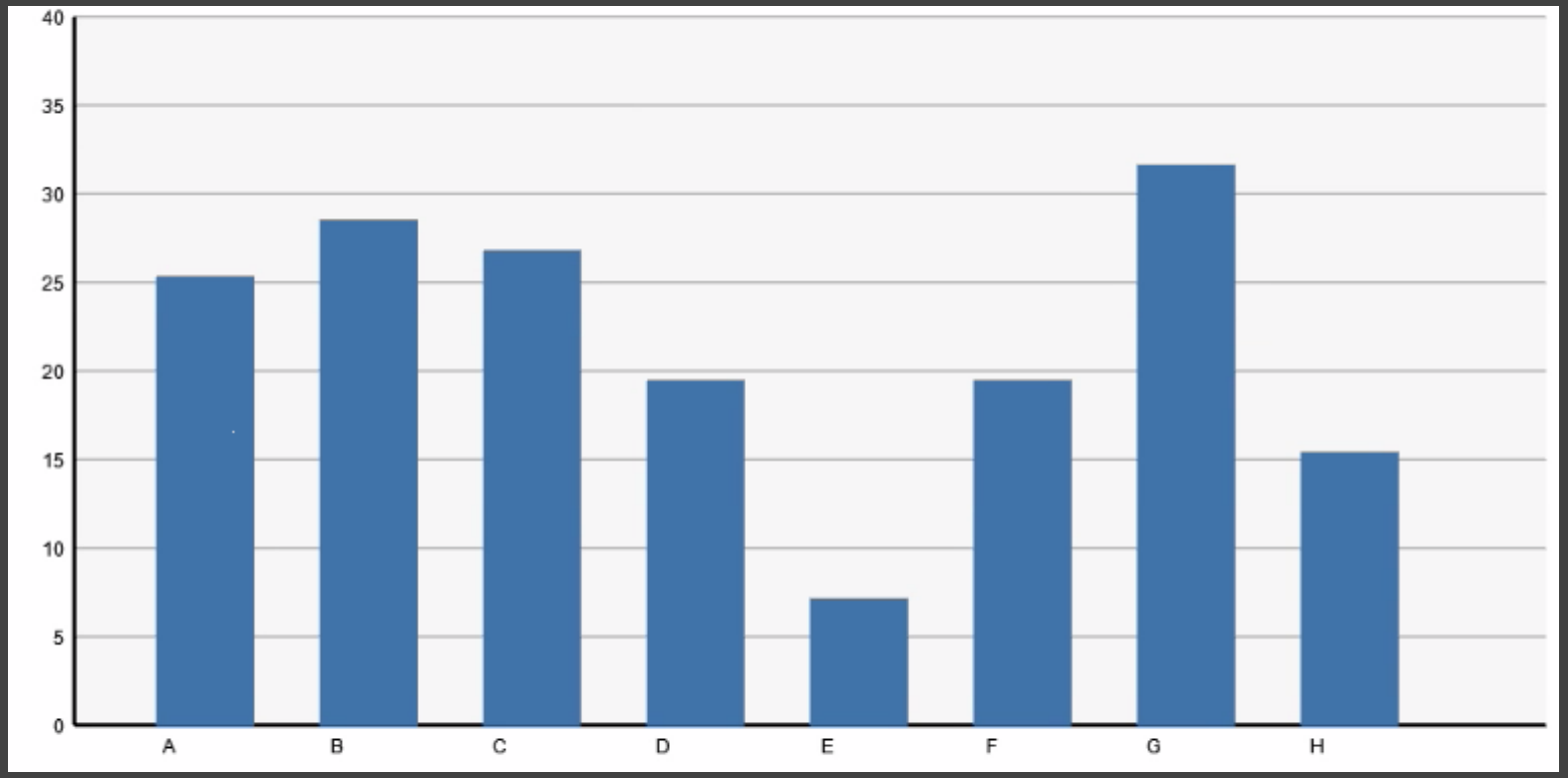
Log Transform

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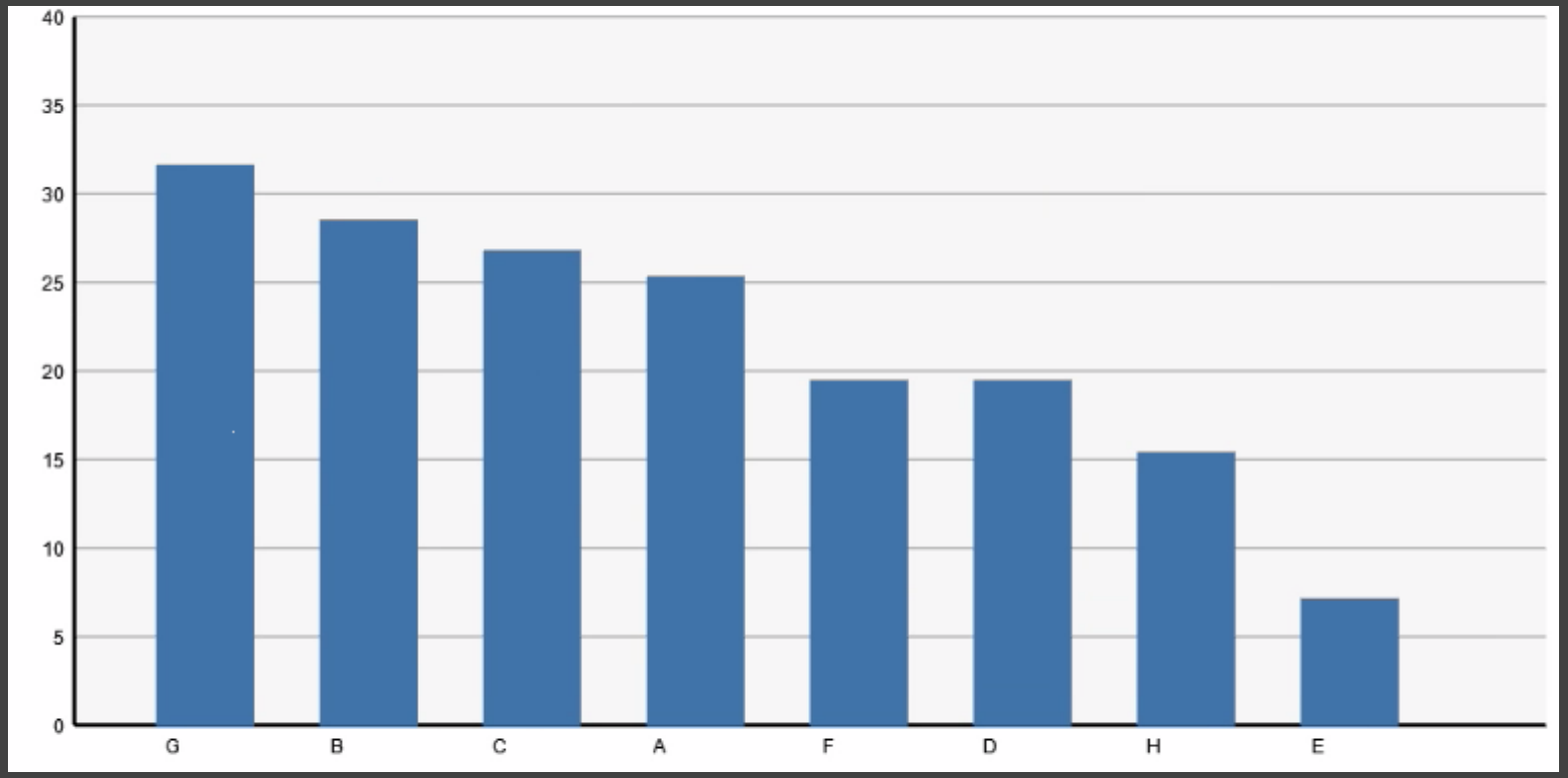
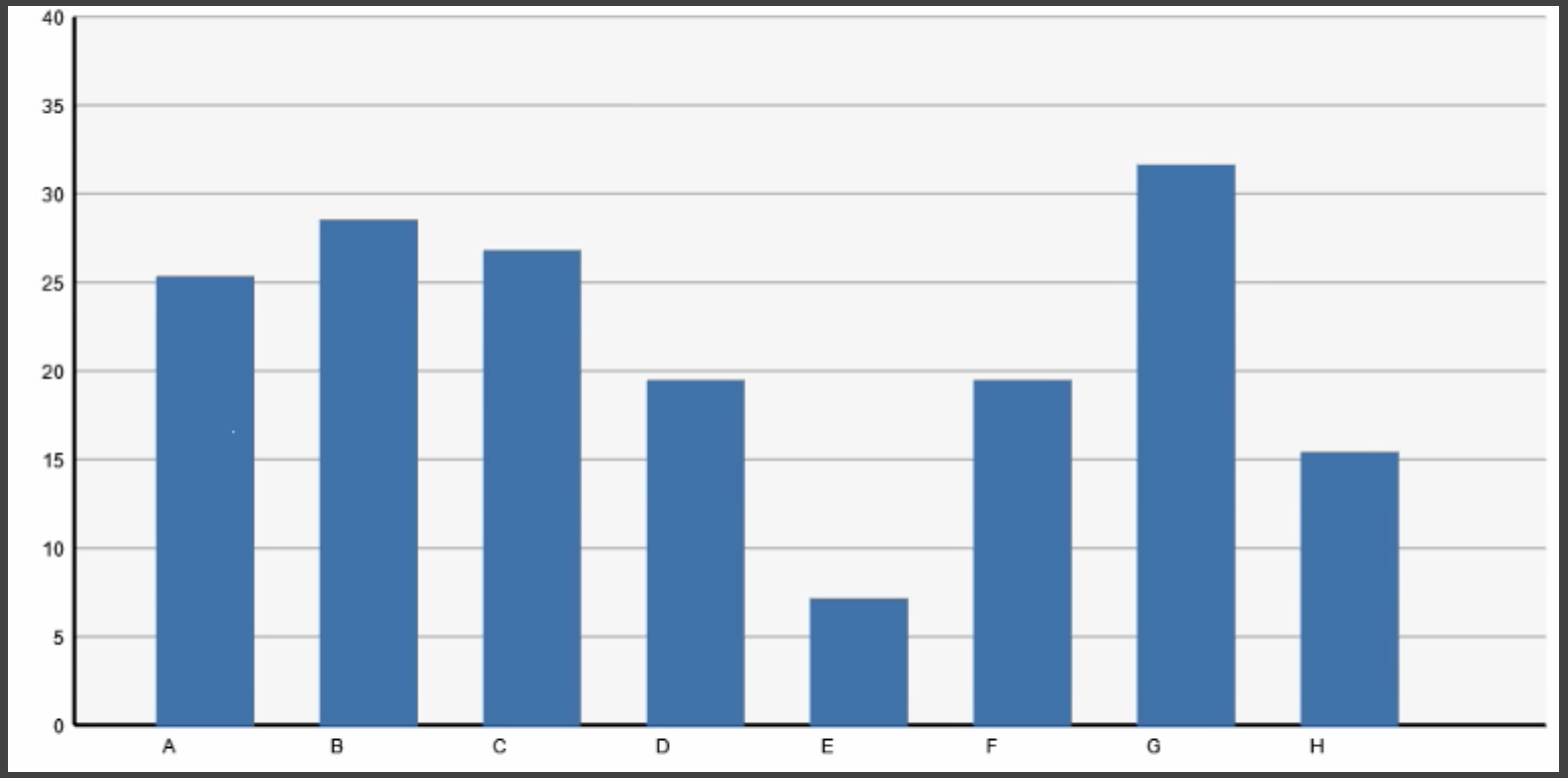
Sorting

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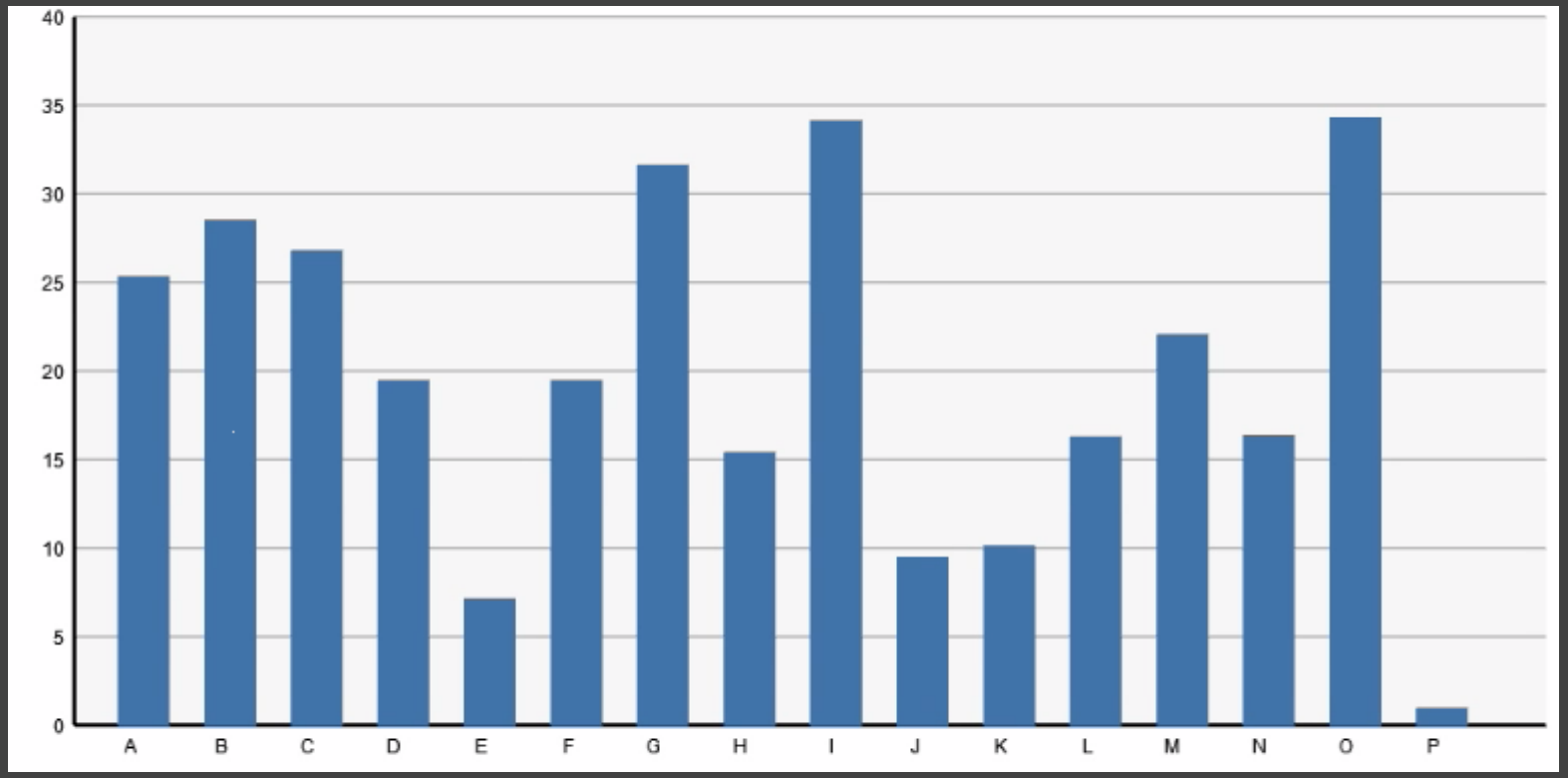
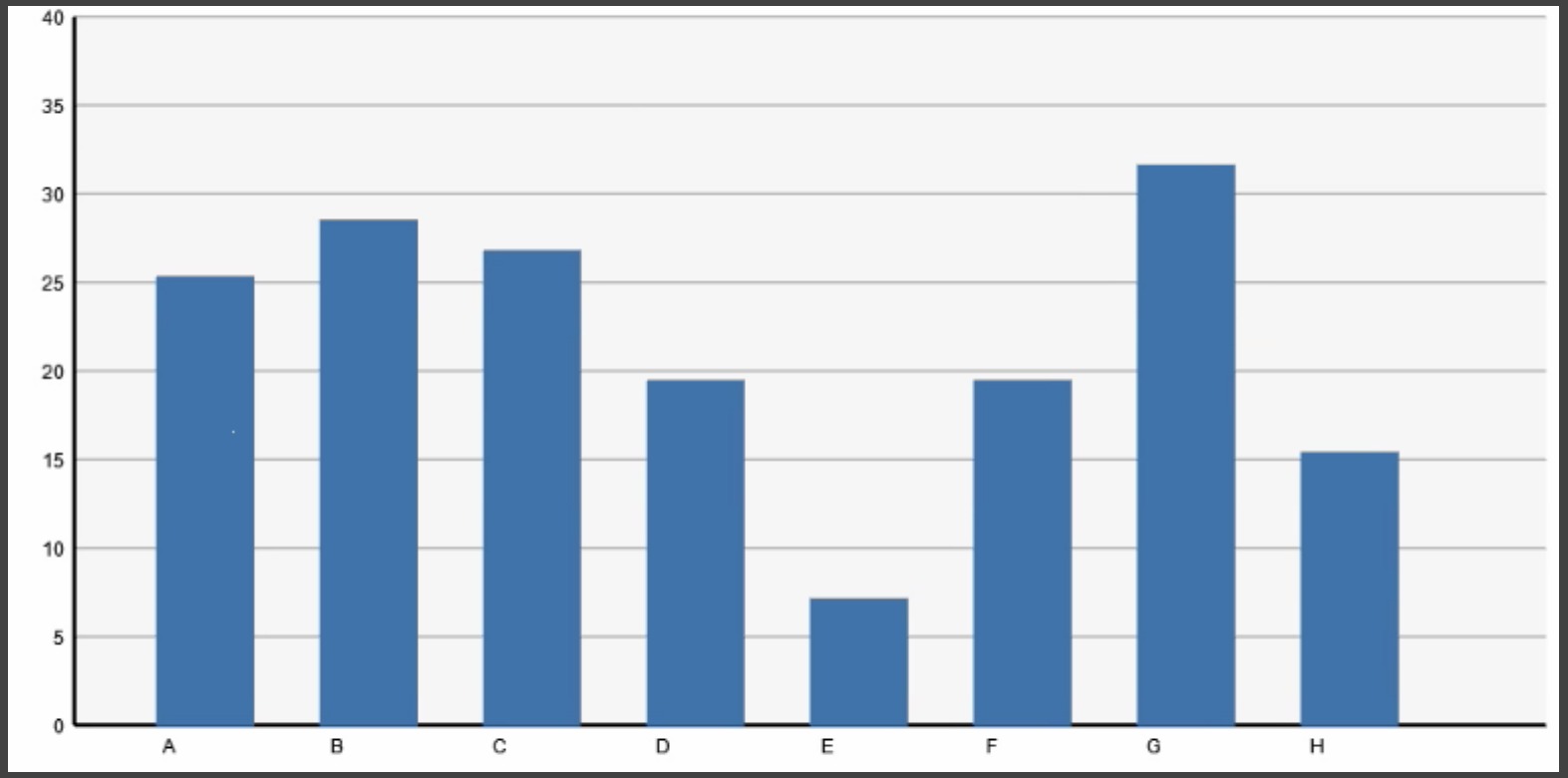
Filtering

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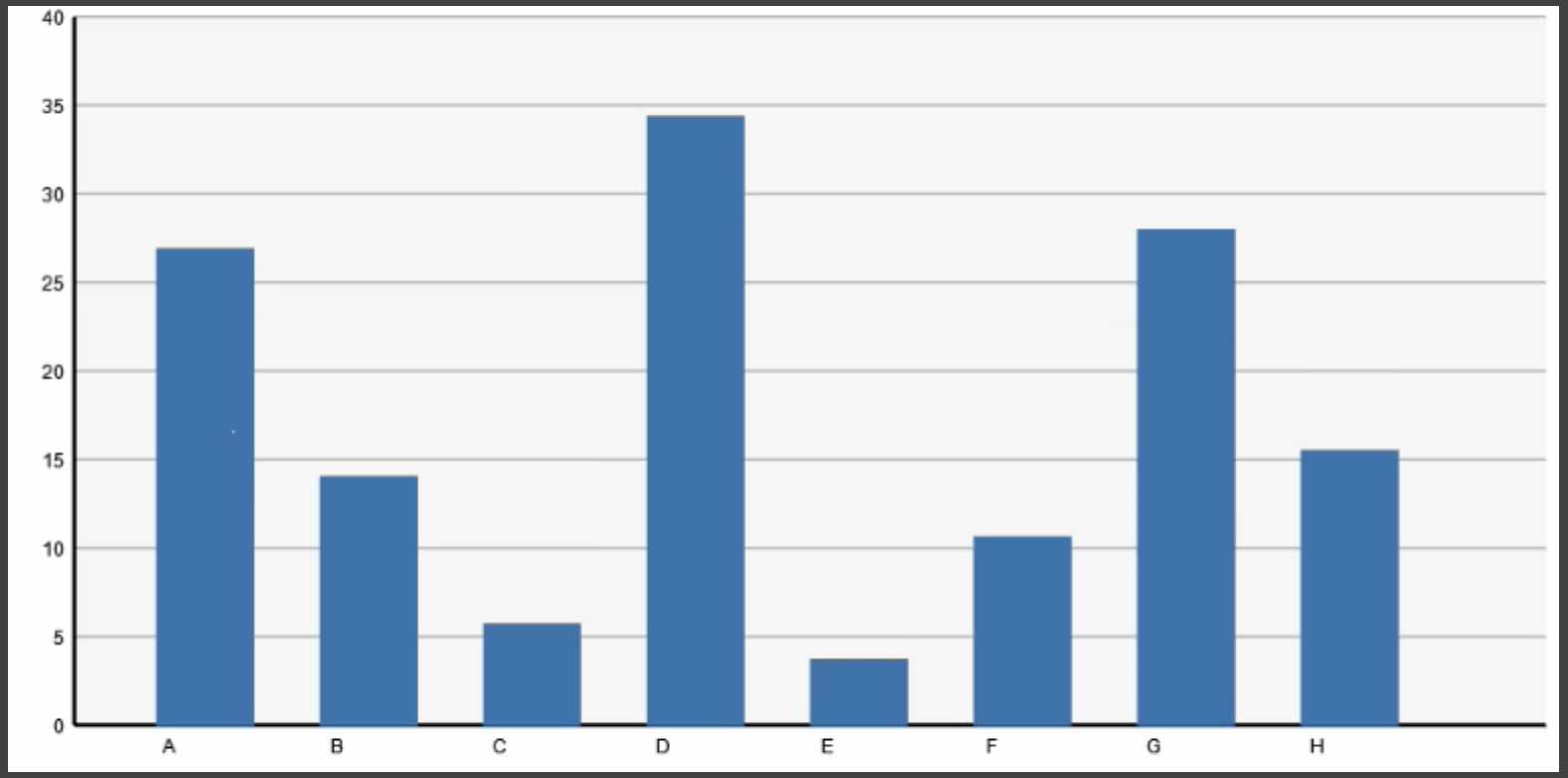
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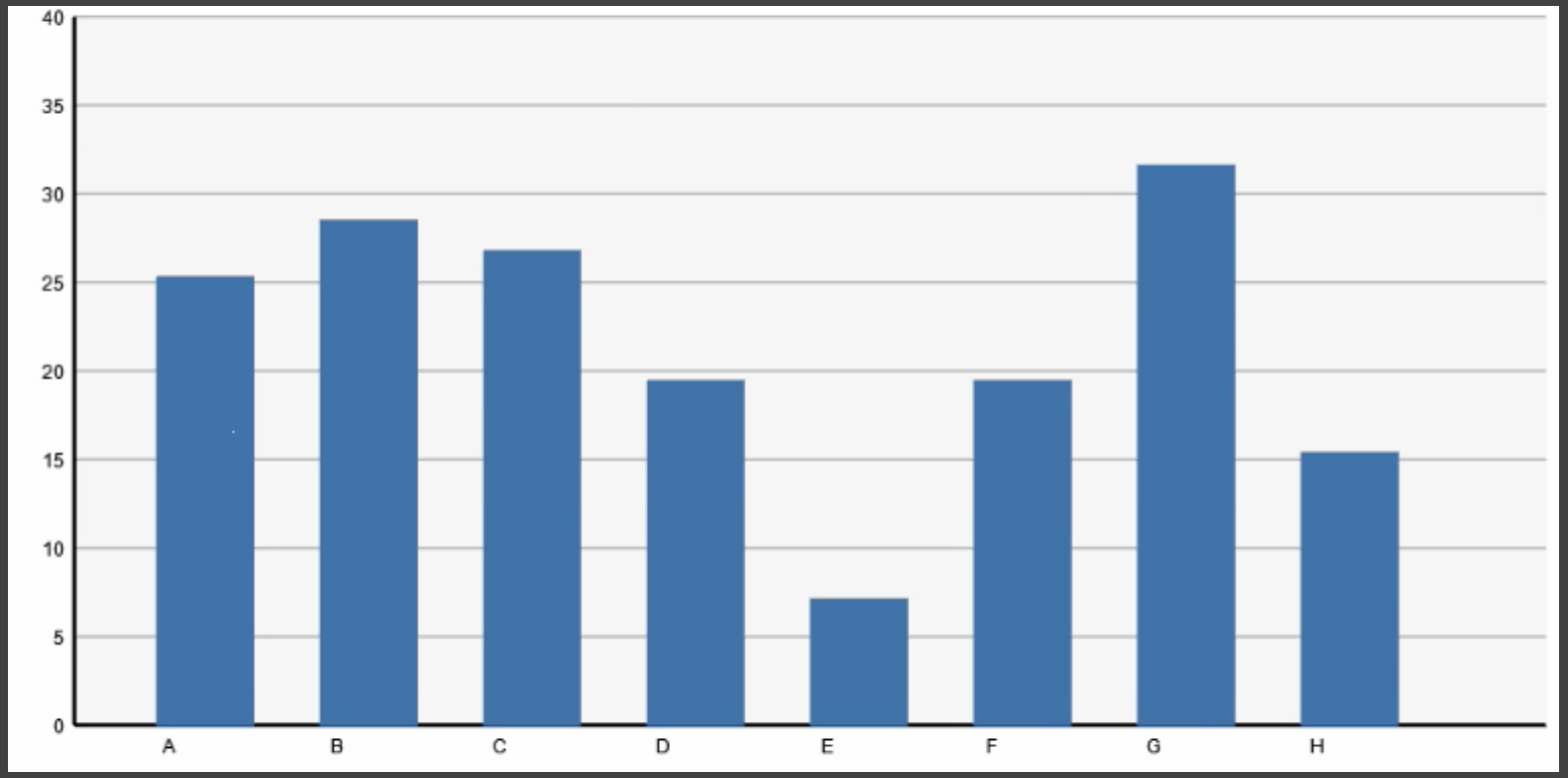
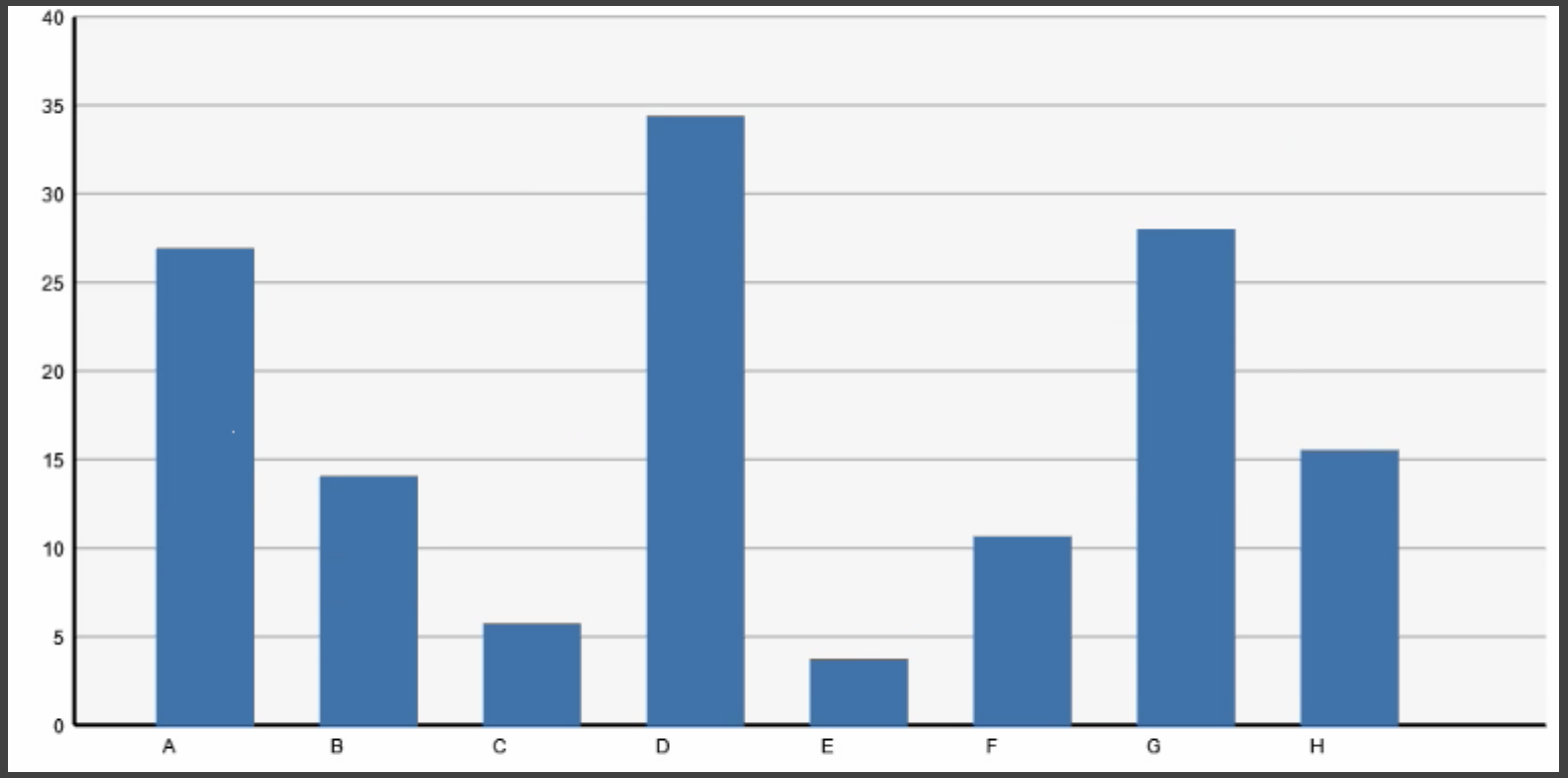
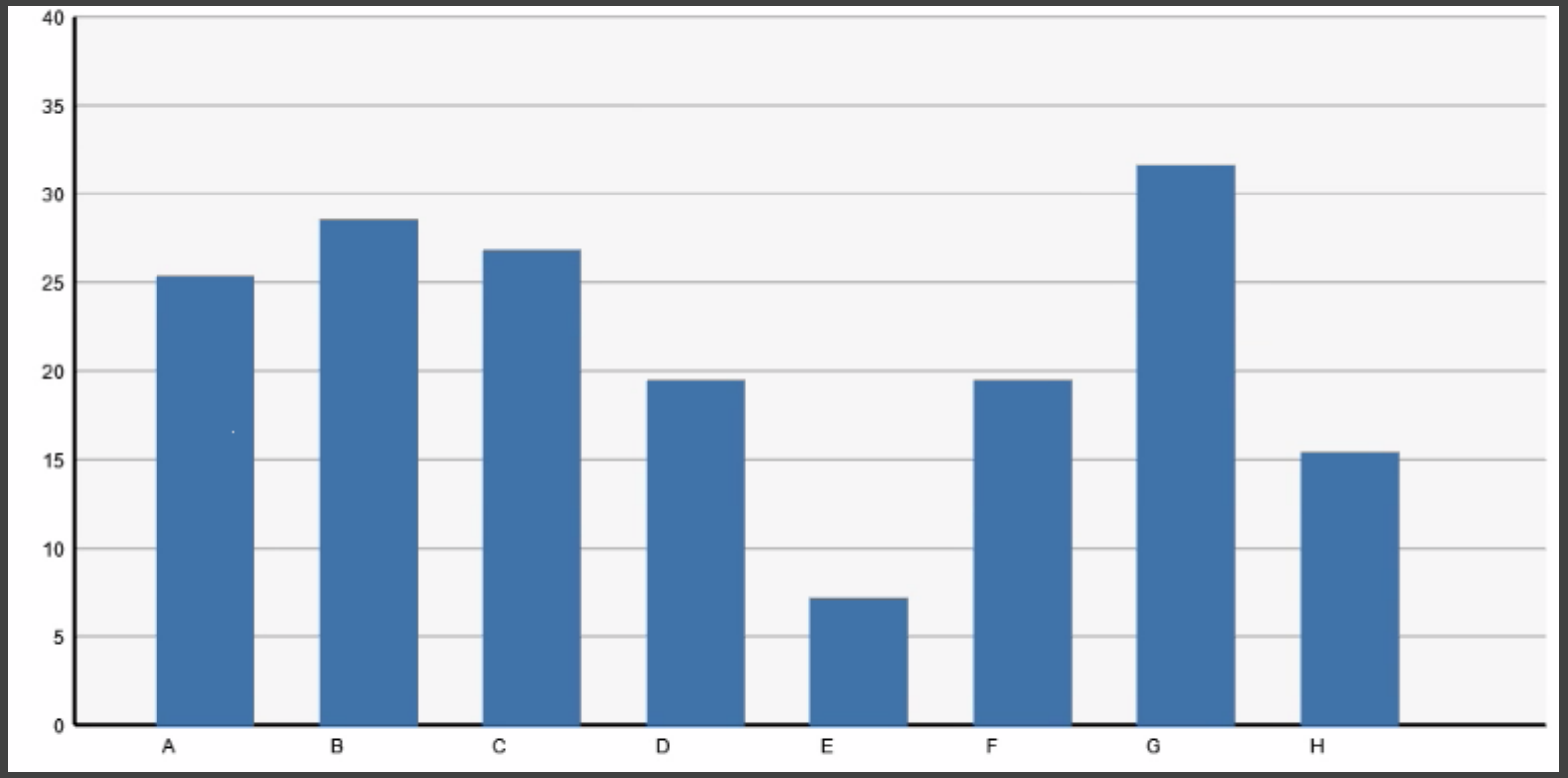


Month 1

Timestep



Month 2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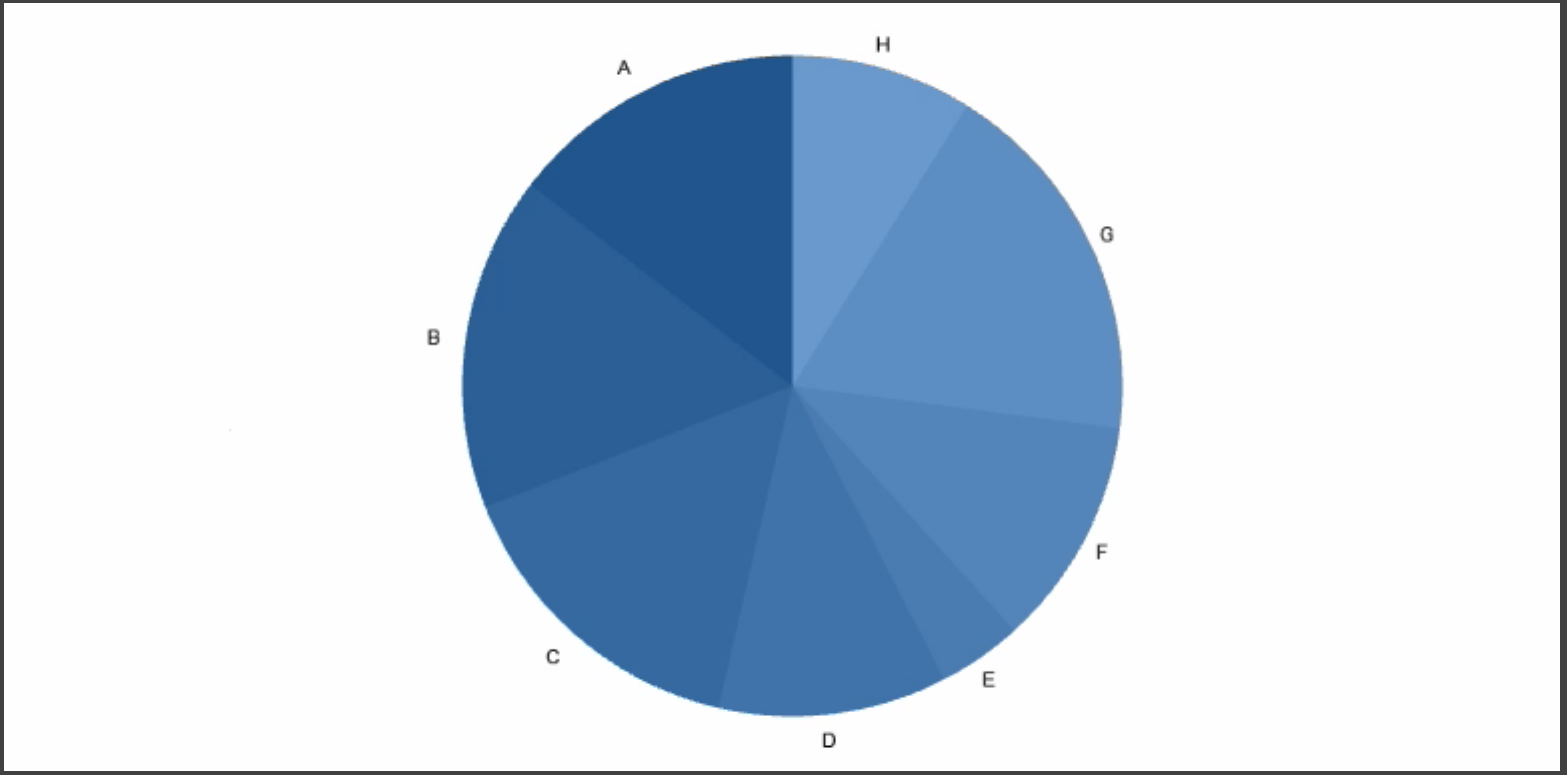
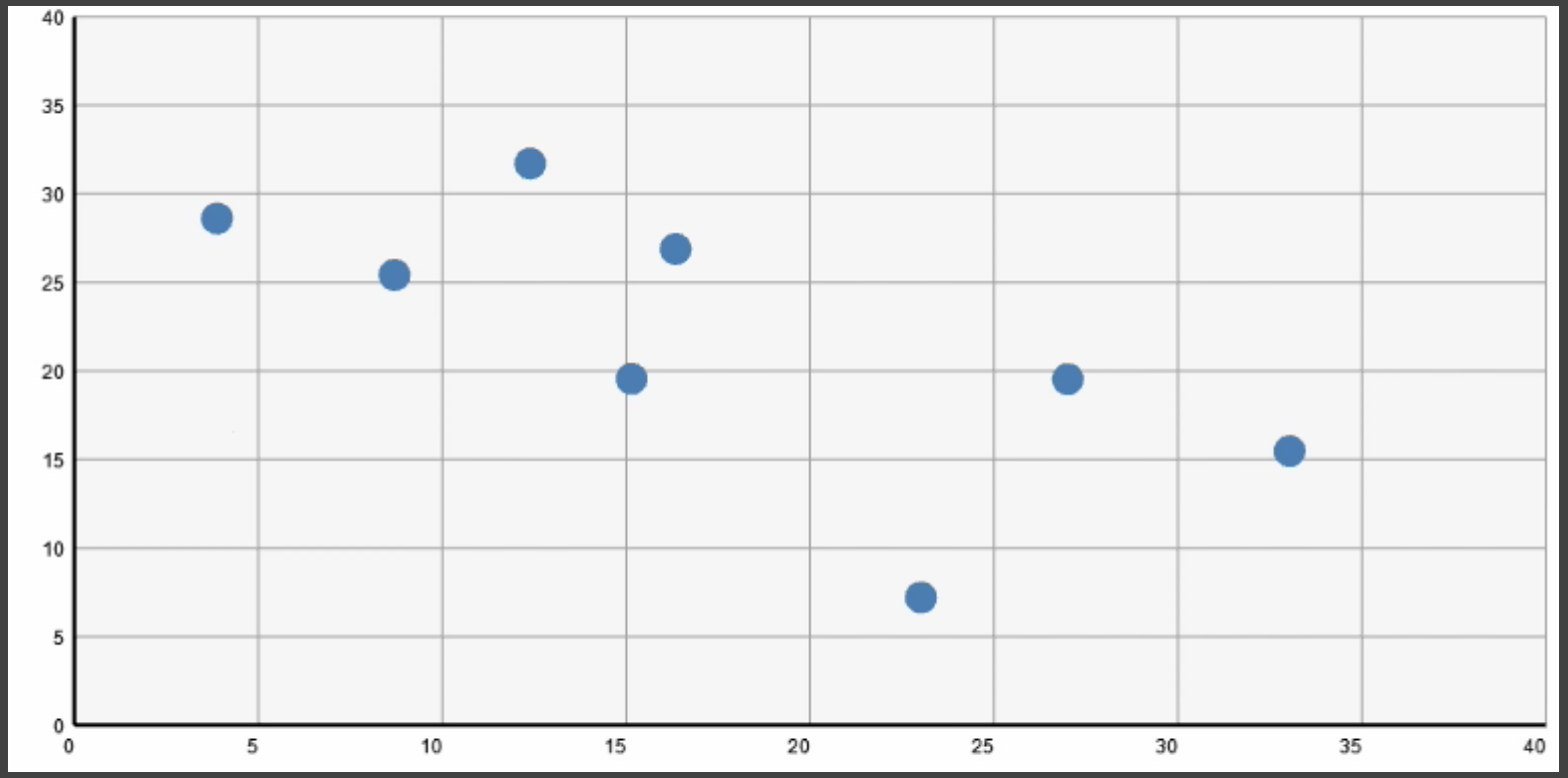
Change Encodings

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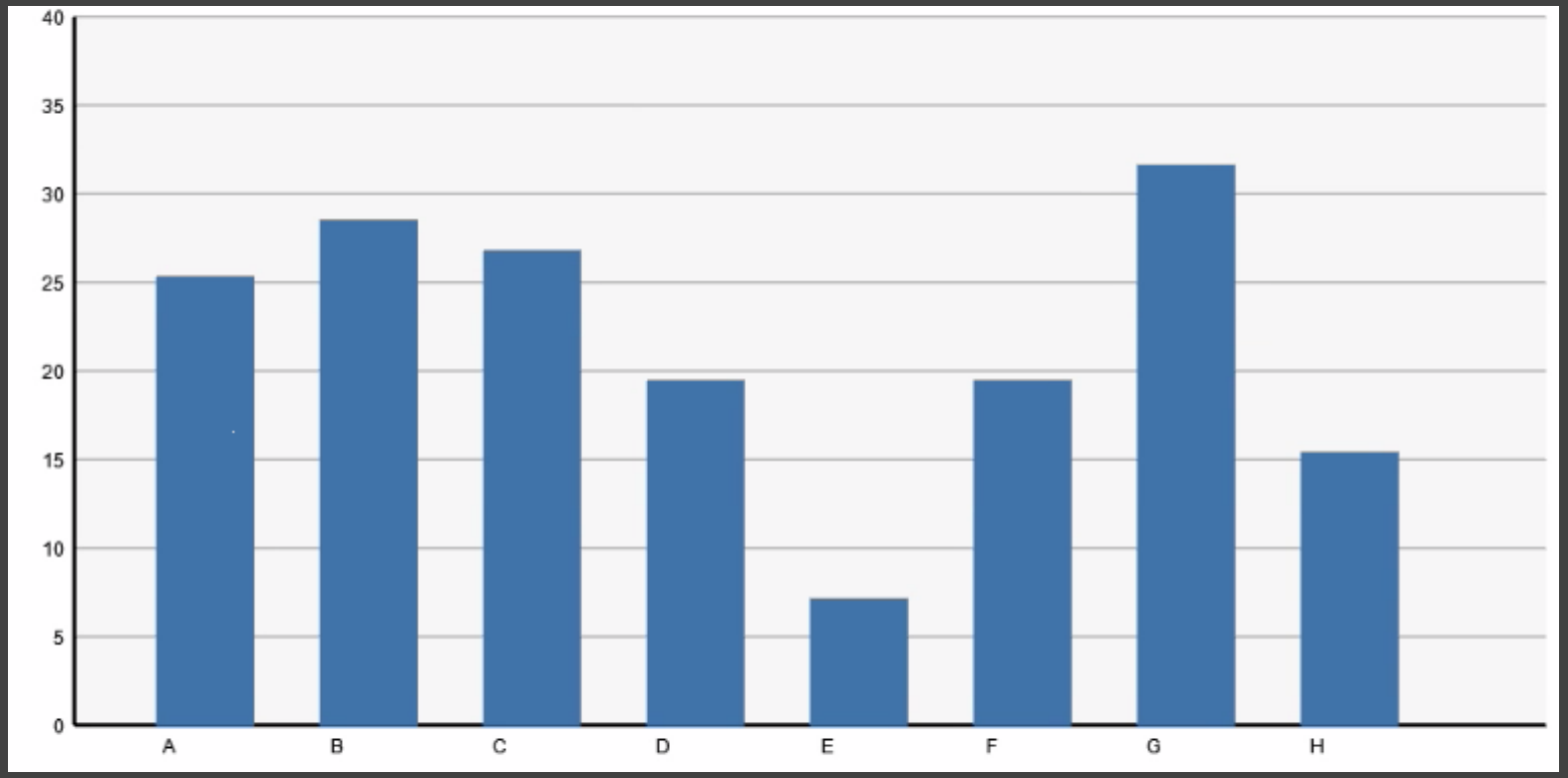
Change Data Dimensions



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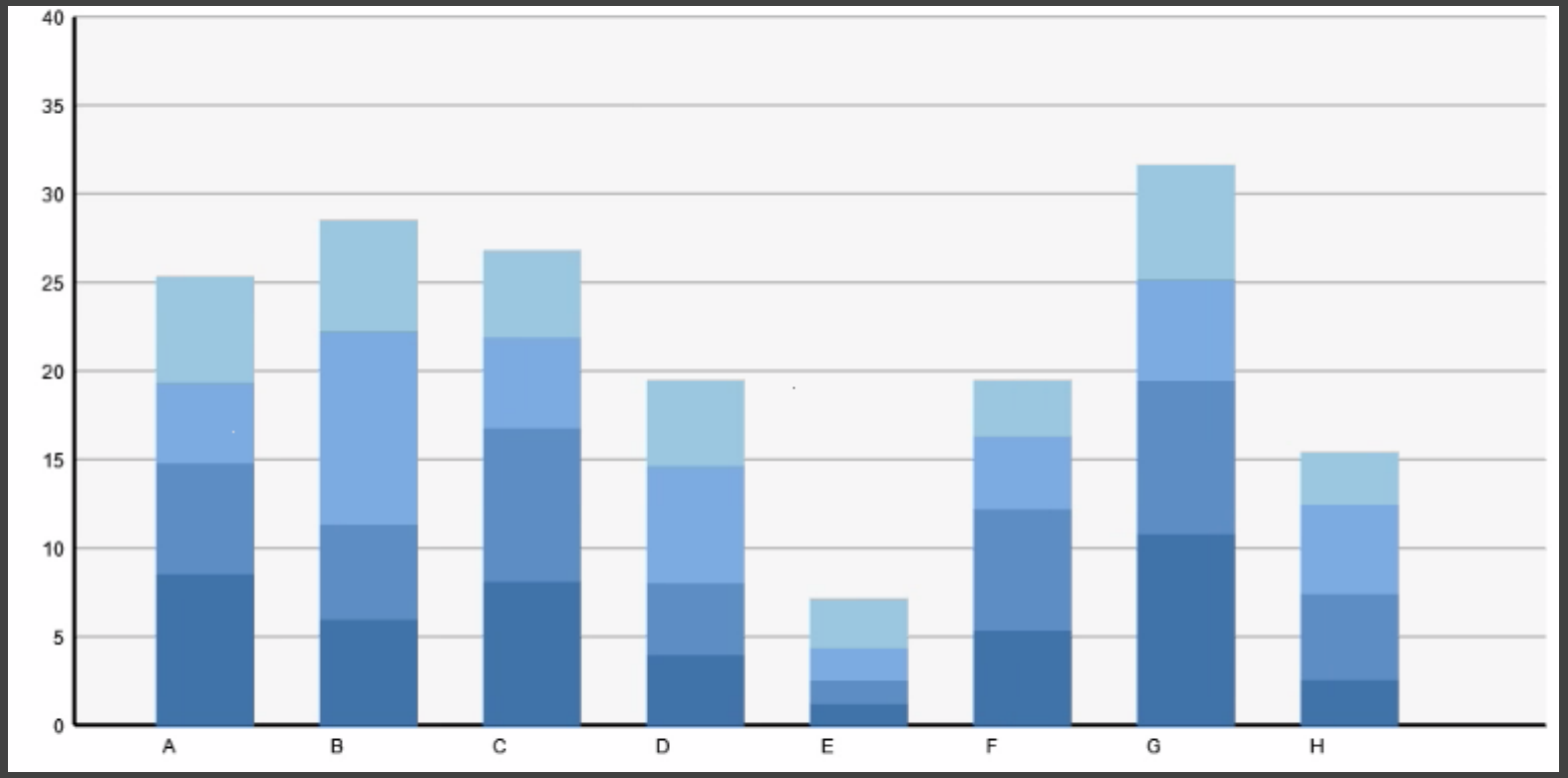
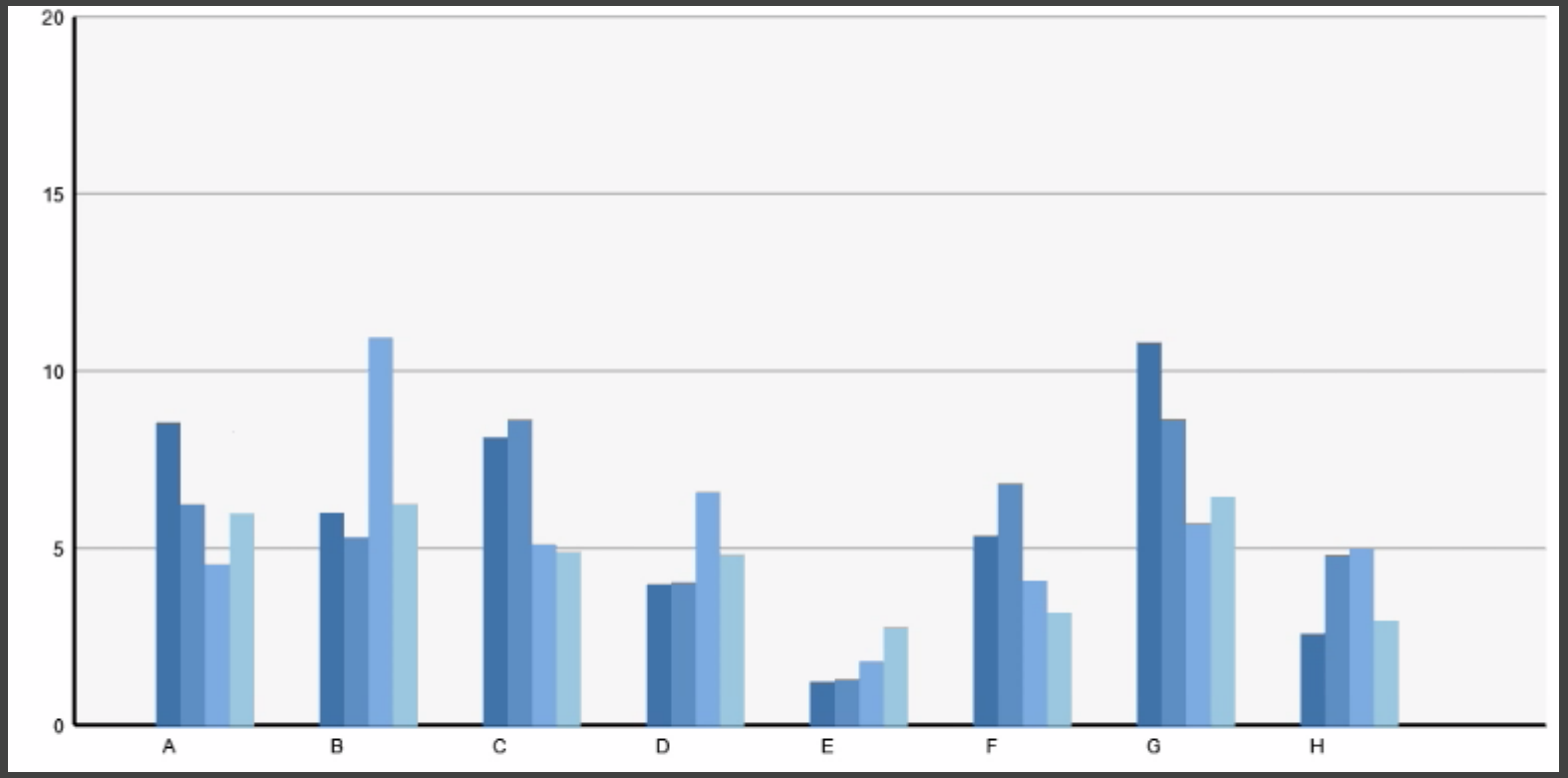


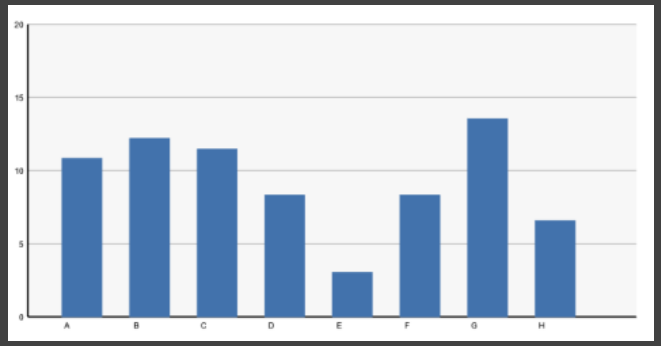
Change Encodings + Axis Scales



Data Graphics & Transitions

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

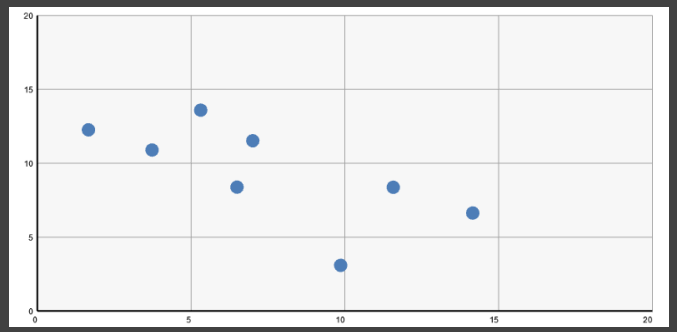
Visual Encoding



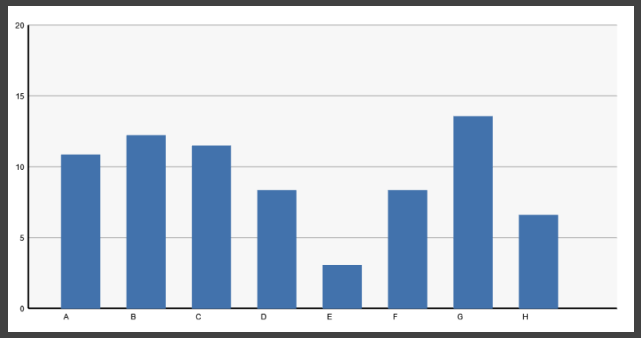
Change selected data dimensions or encodings

Animation to communicate changes?

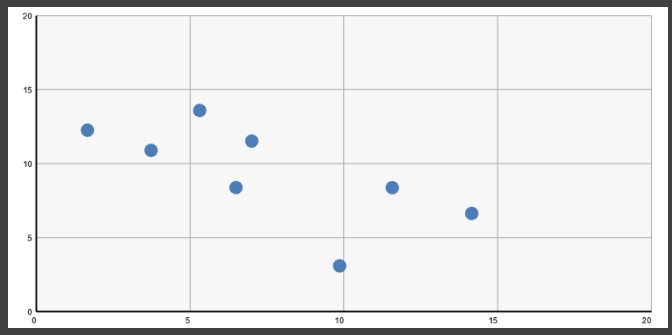
Category	Sales	Profit
A	11	7
B	13	10
C	12	6
D	8	5
E	3	1



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

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
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Minimize occlusion
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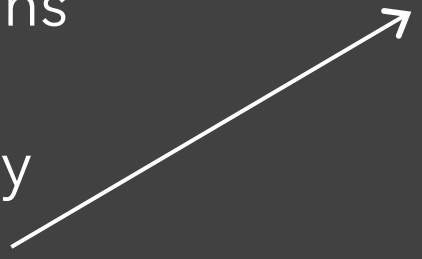


Keep animation as simple as possible. If complicated, break into simple stages.

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)

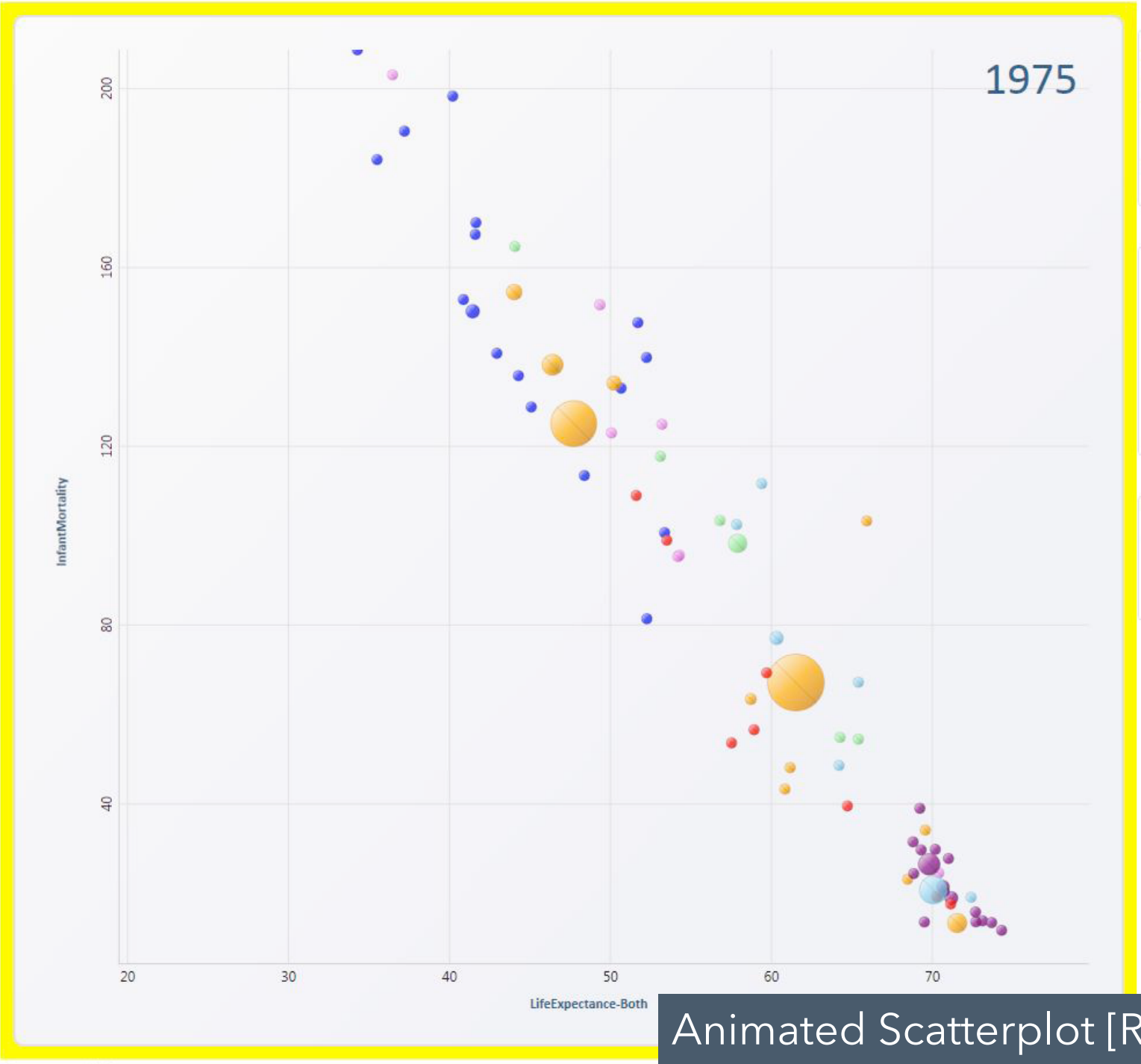
Subjects preferred animated transitions

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
(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.

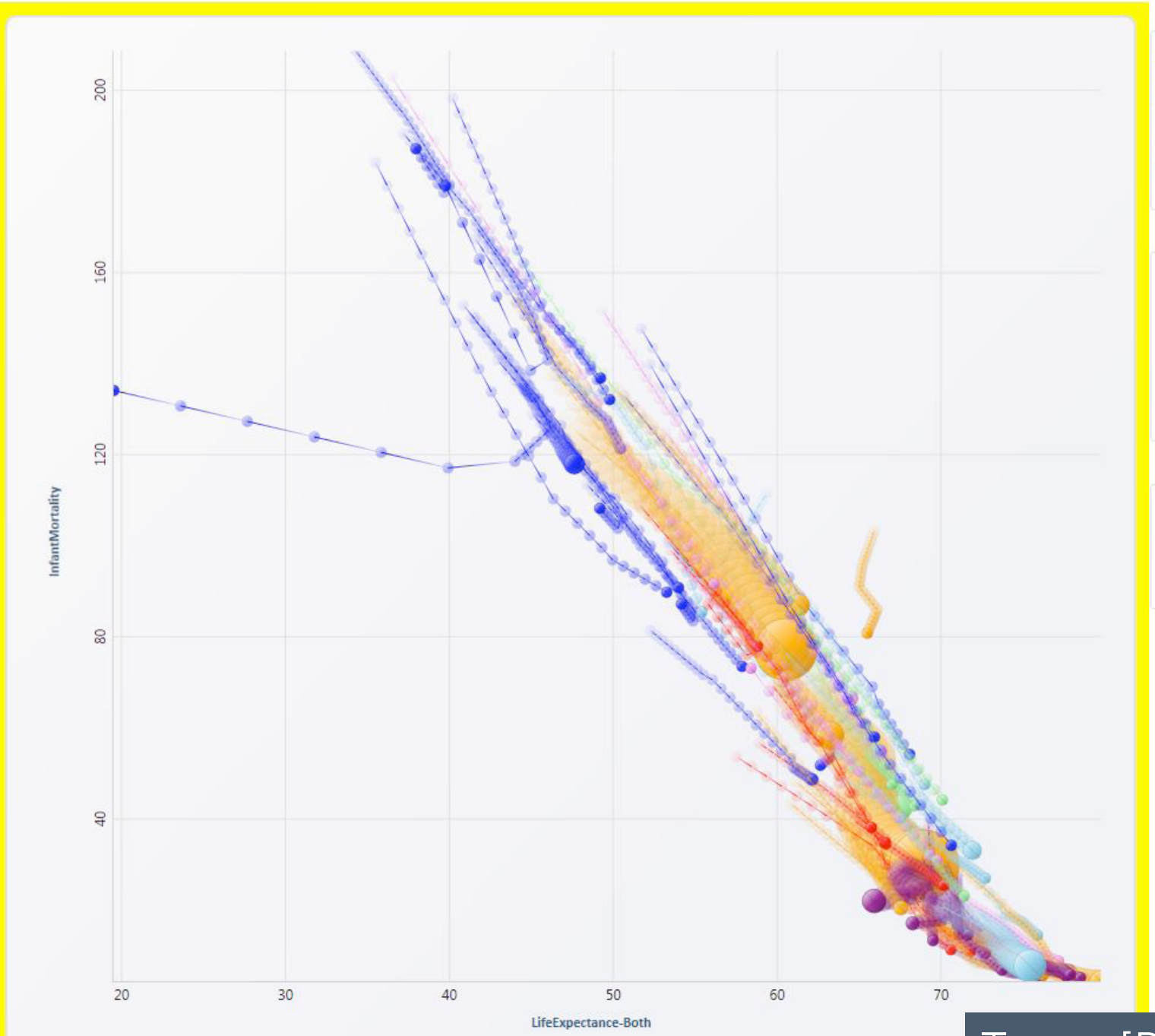
Answers set: 0/2

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
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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

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Traces [Robertson 08]

Color Legend (continent)

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Task

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

Answers set: 0/2

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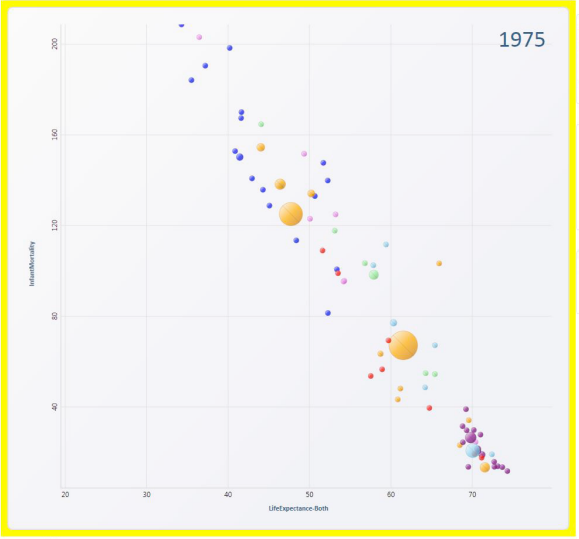
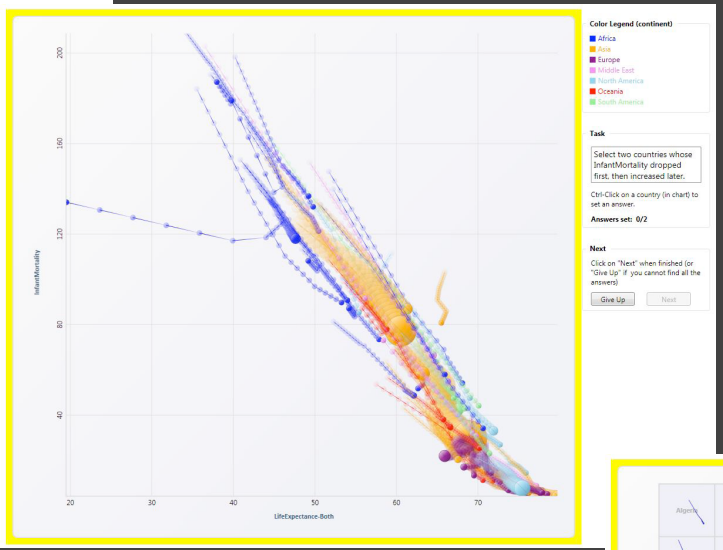
Small Multiples [Robertson 08]





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 Due on Thursday

In class review. We'll also discuss criteria for peer review.

~4 minutes per project.
Very informal, I'll drive us on a tour through the projects.

Implementing Animation

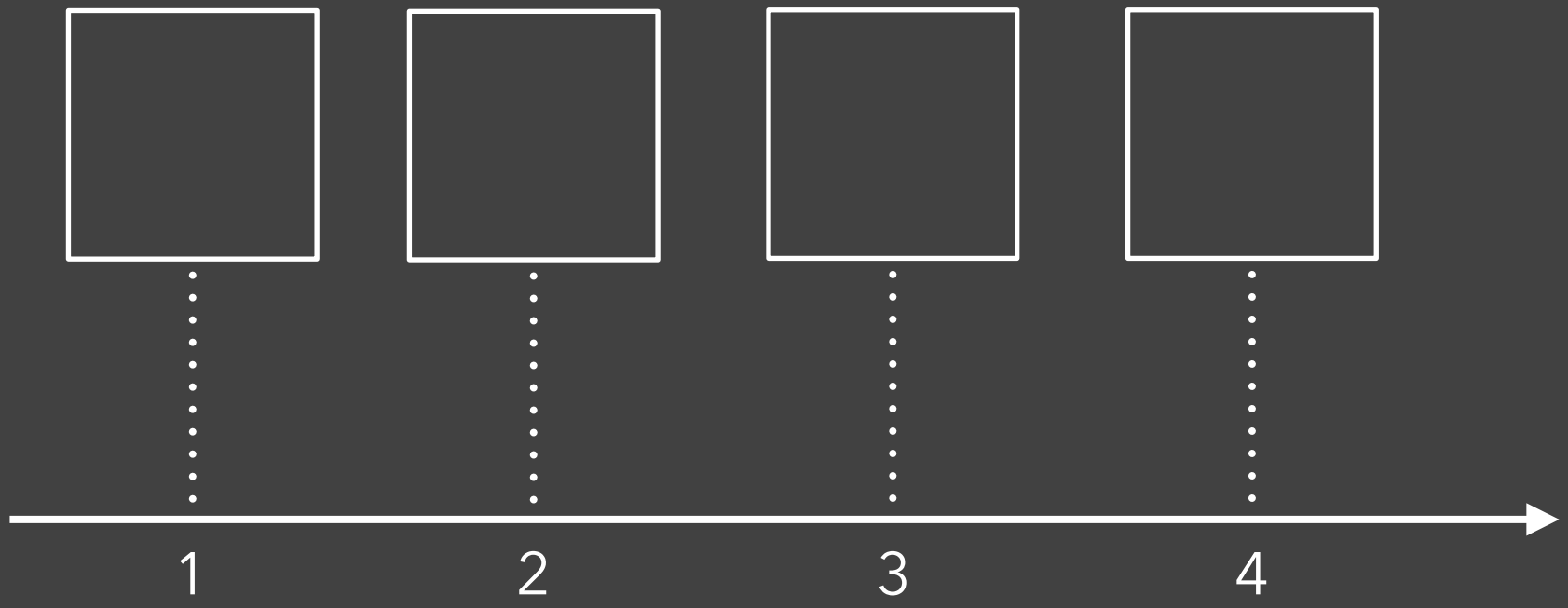
Animation Approaches

Frame-Based Animation

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

Developer defines the redraw function

Frame-Based Animation



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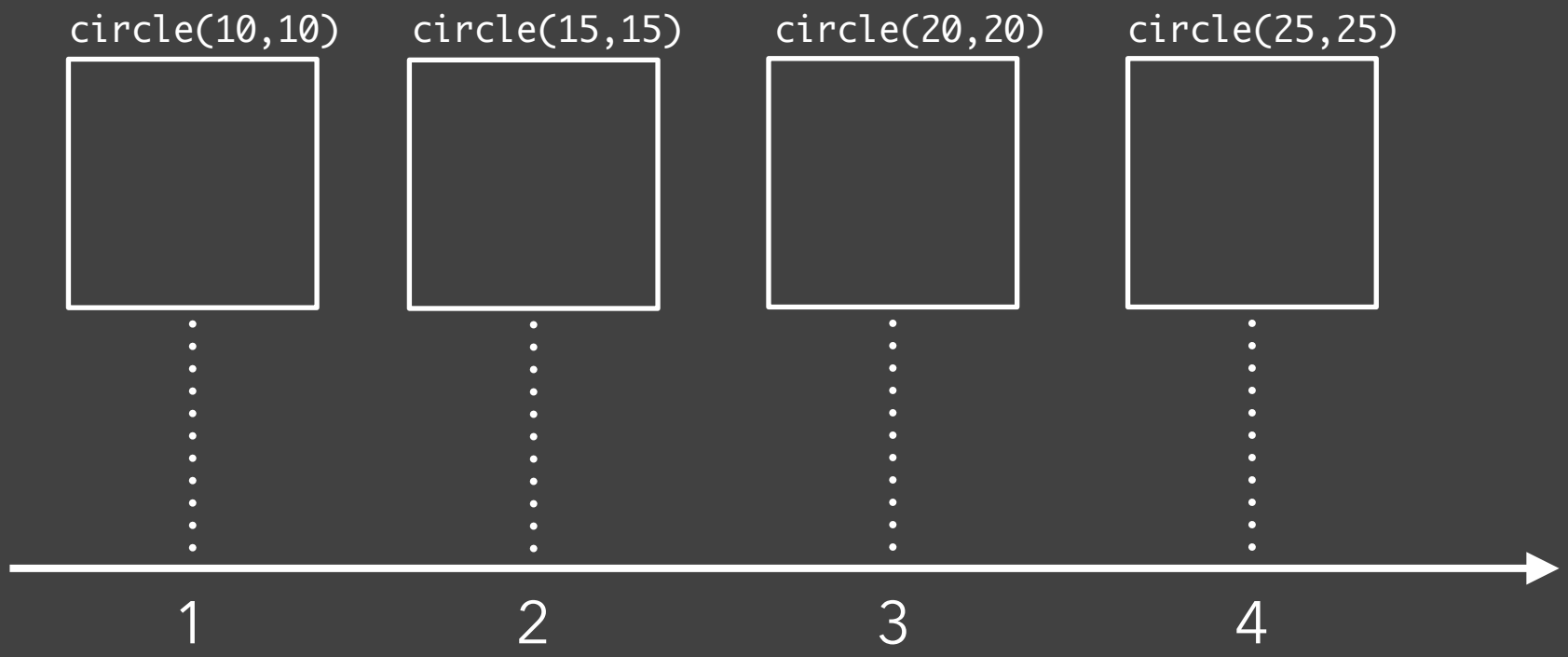

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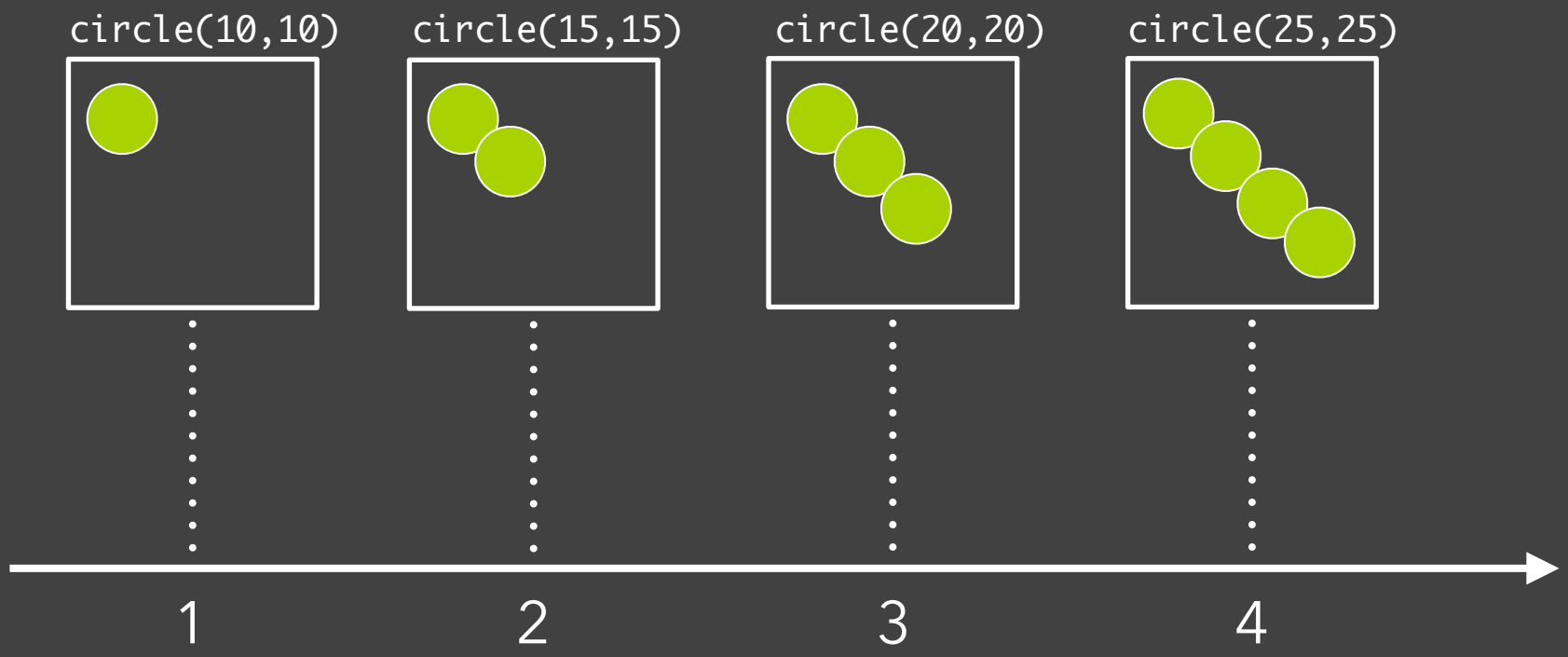

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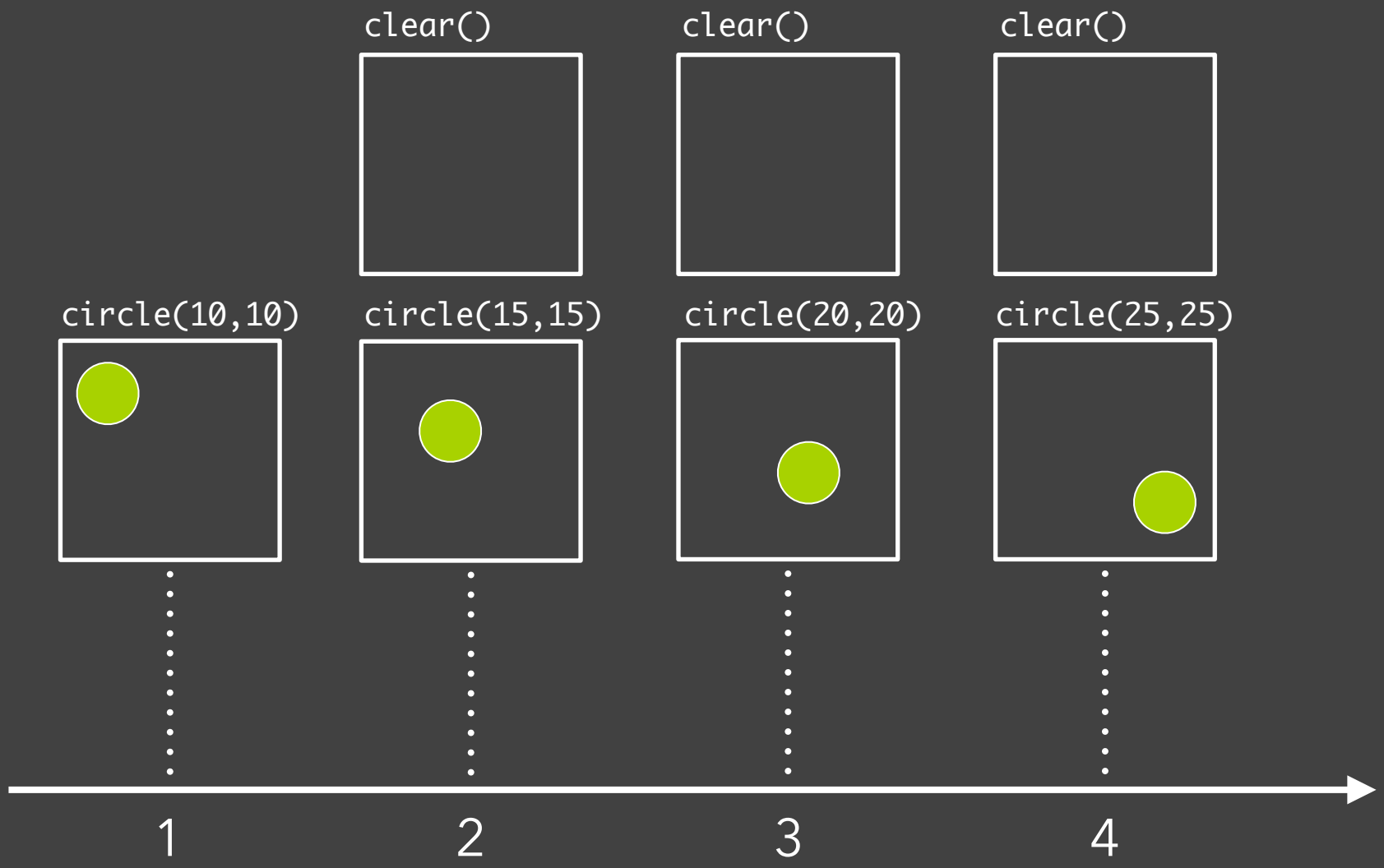

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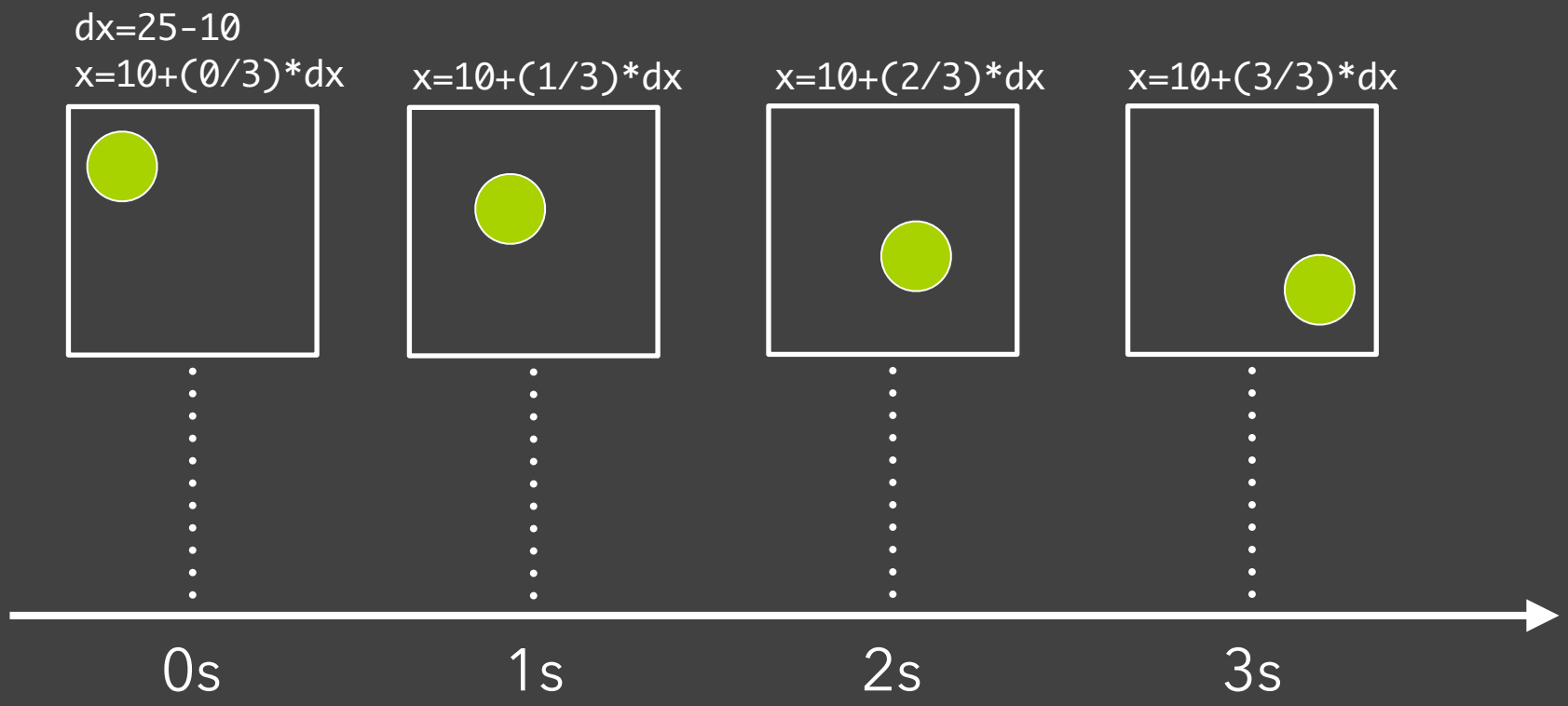
Transition-Based Animation (Hudson & Stasko '93)
Specify property value, duration & easing
Also called **tweening** (for "in-betweens")
Typically computed via **interpolation**

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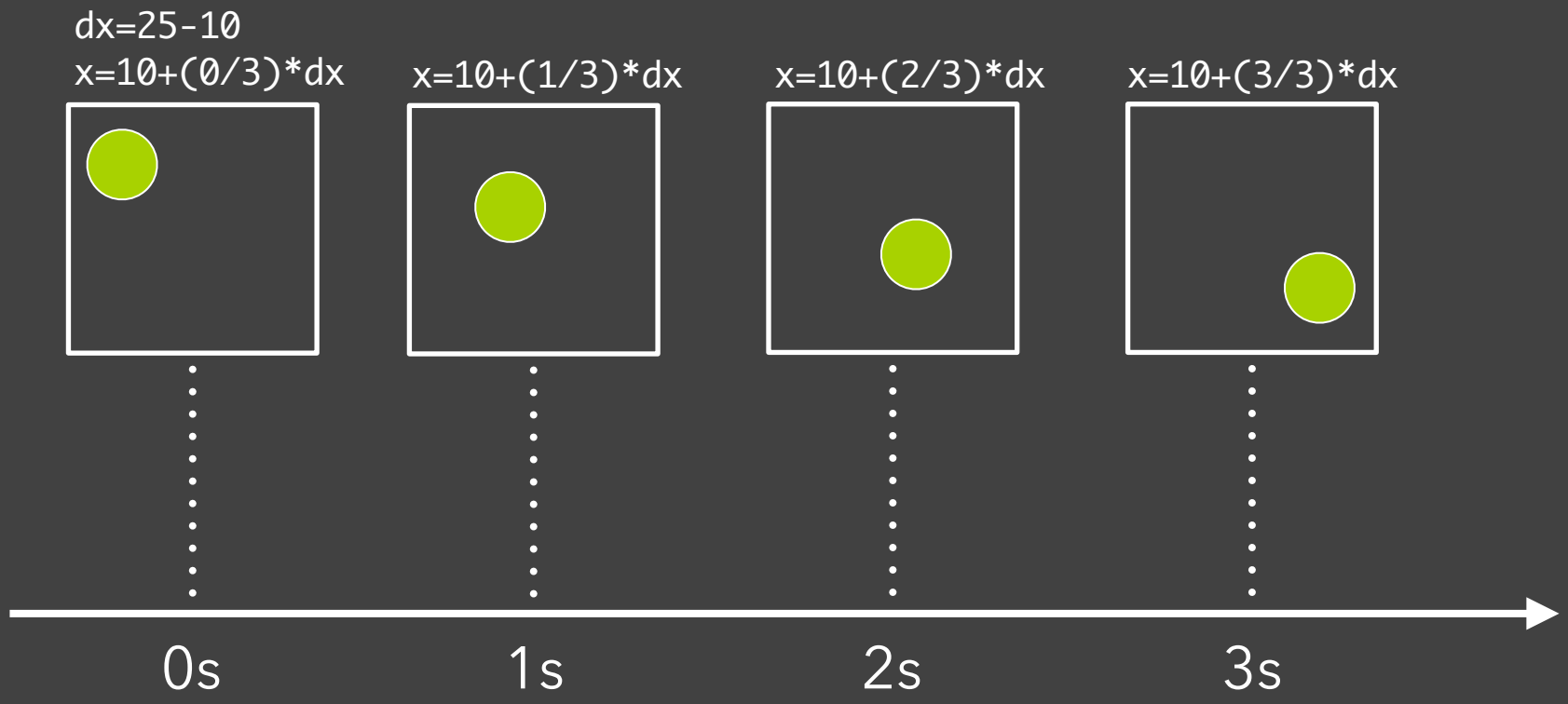
from: (10,10) **to:** (25,25) **duration:** 3sec

Toolkit handles frame-by-frame updates!



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

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// Select SVG rectangles and bind them to data values.
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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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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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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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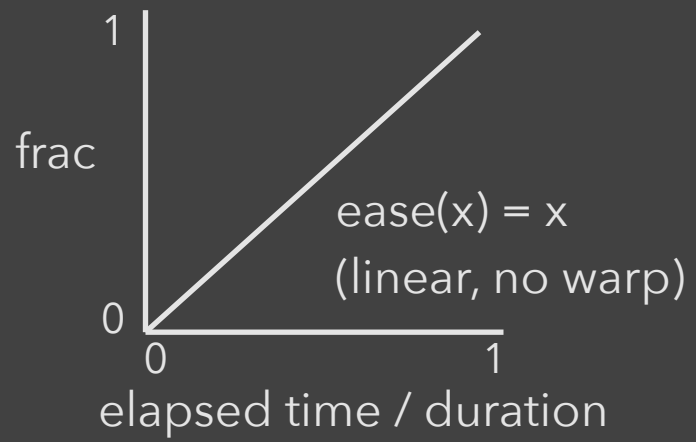

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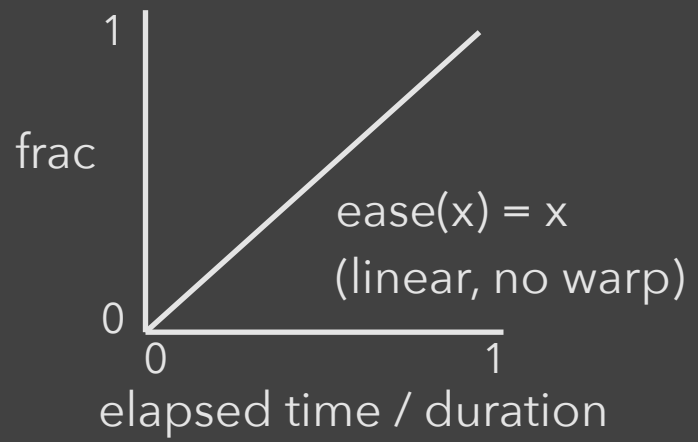

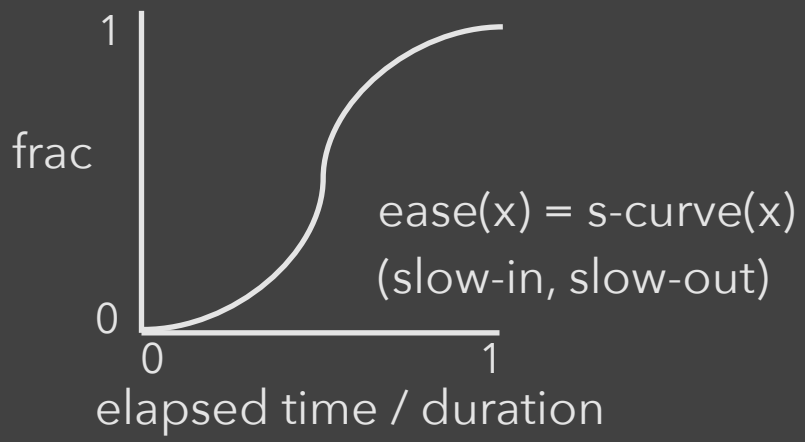

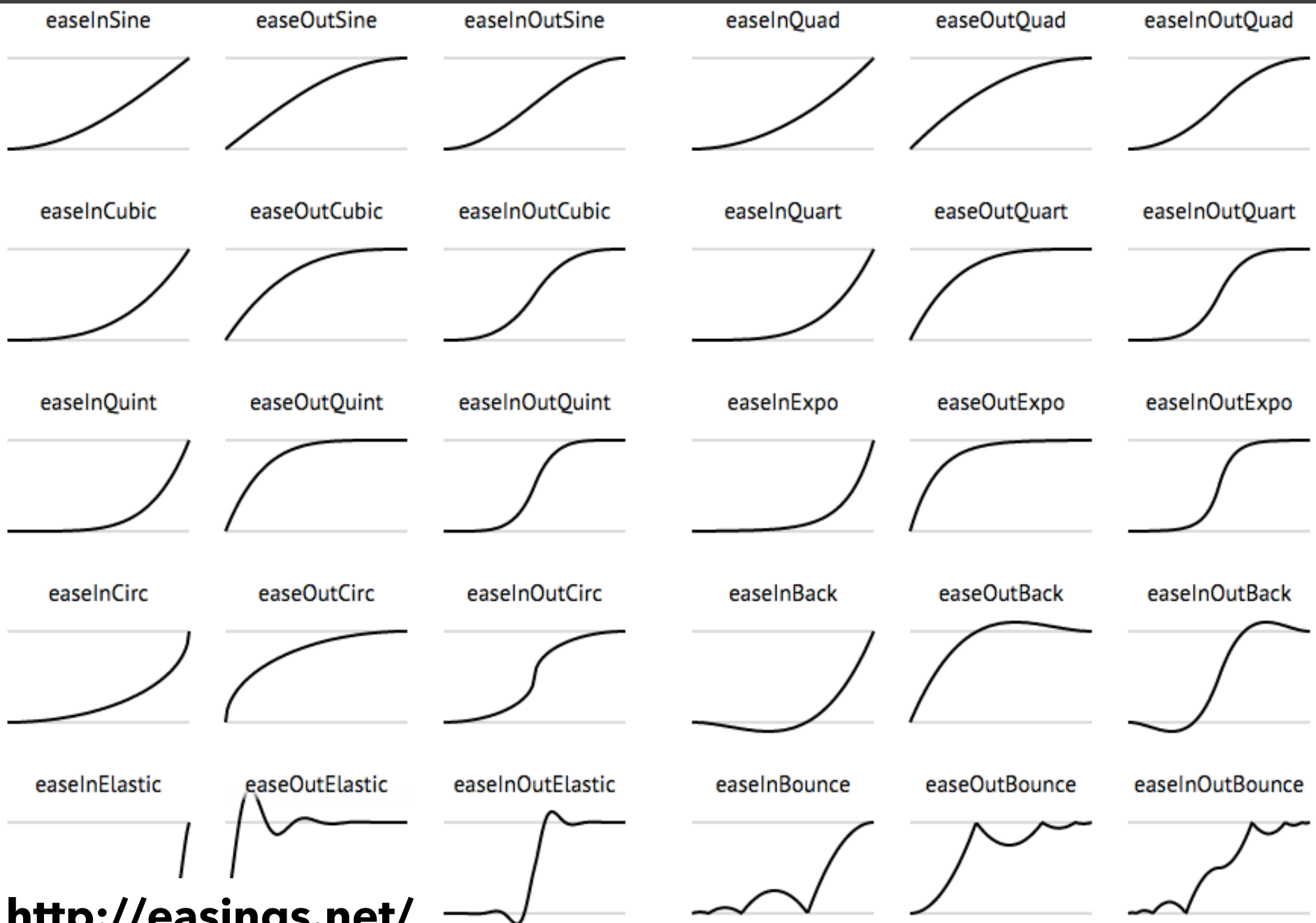

http://easings.net/

CSS Transitions

Extends CSS with Animated Transitions

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

a:hover {
  color: red;
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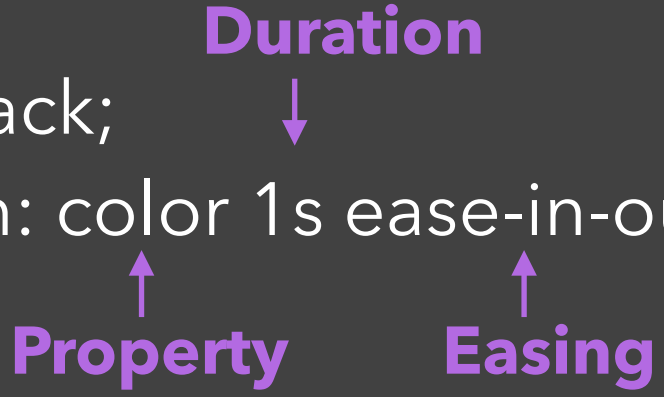

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Duration

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**