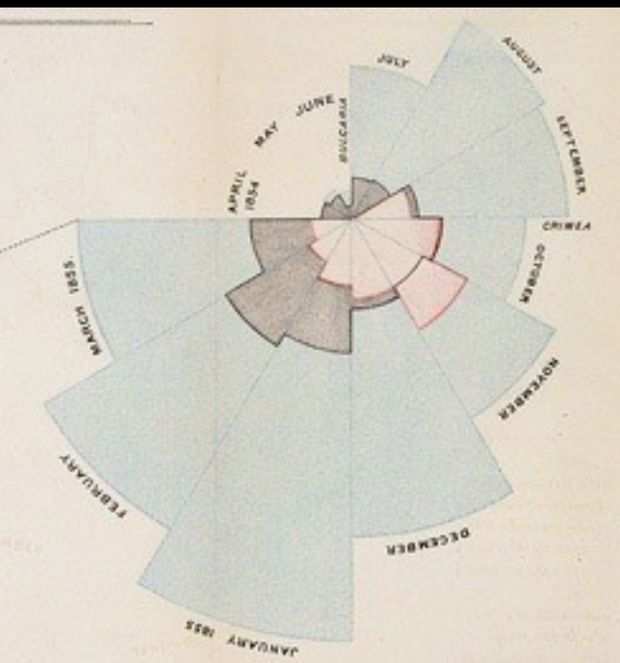
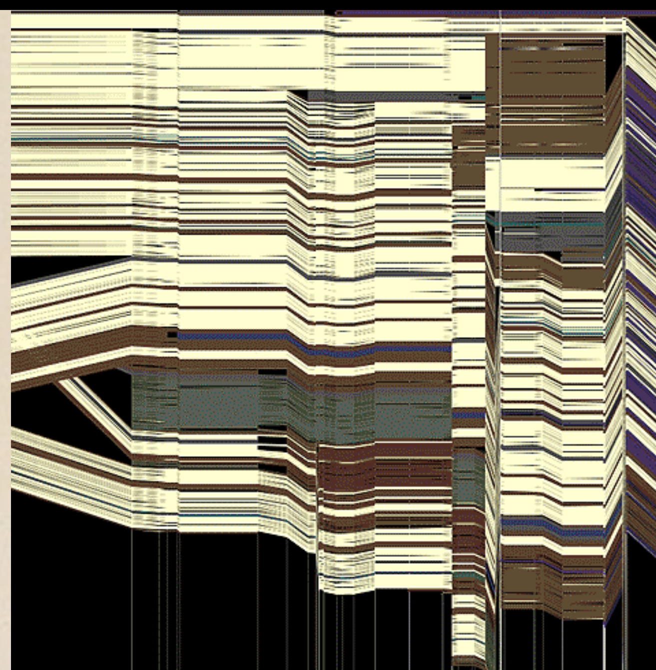
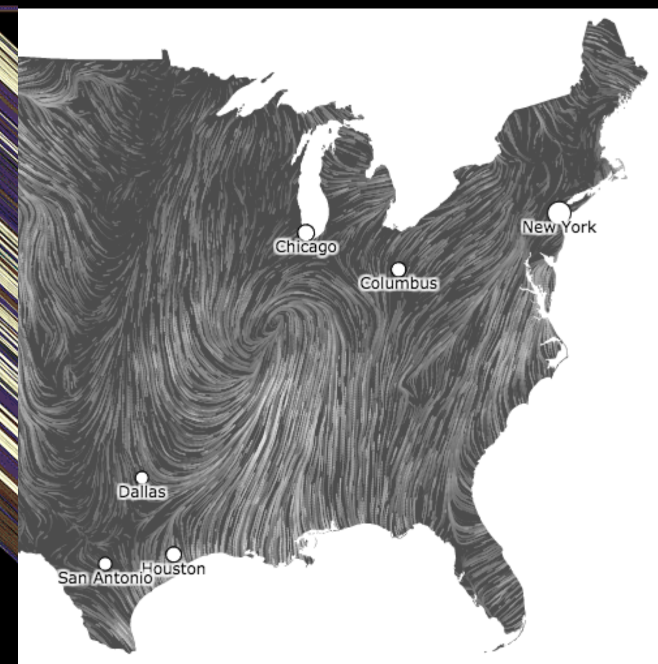
CSE 442 - Data Visualization

Animation







Jeffrey Heer University of Washington

Why Use Motion?

Why Use Motion?

Visual variable to encode data

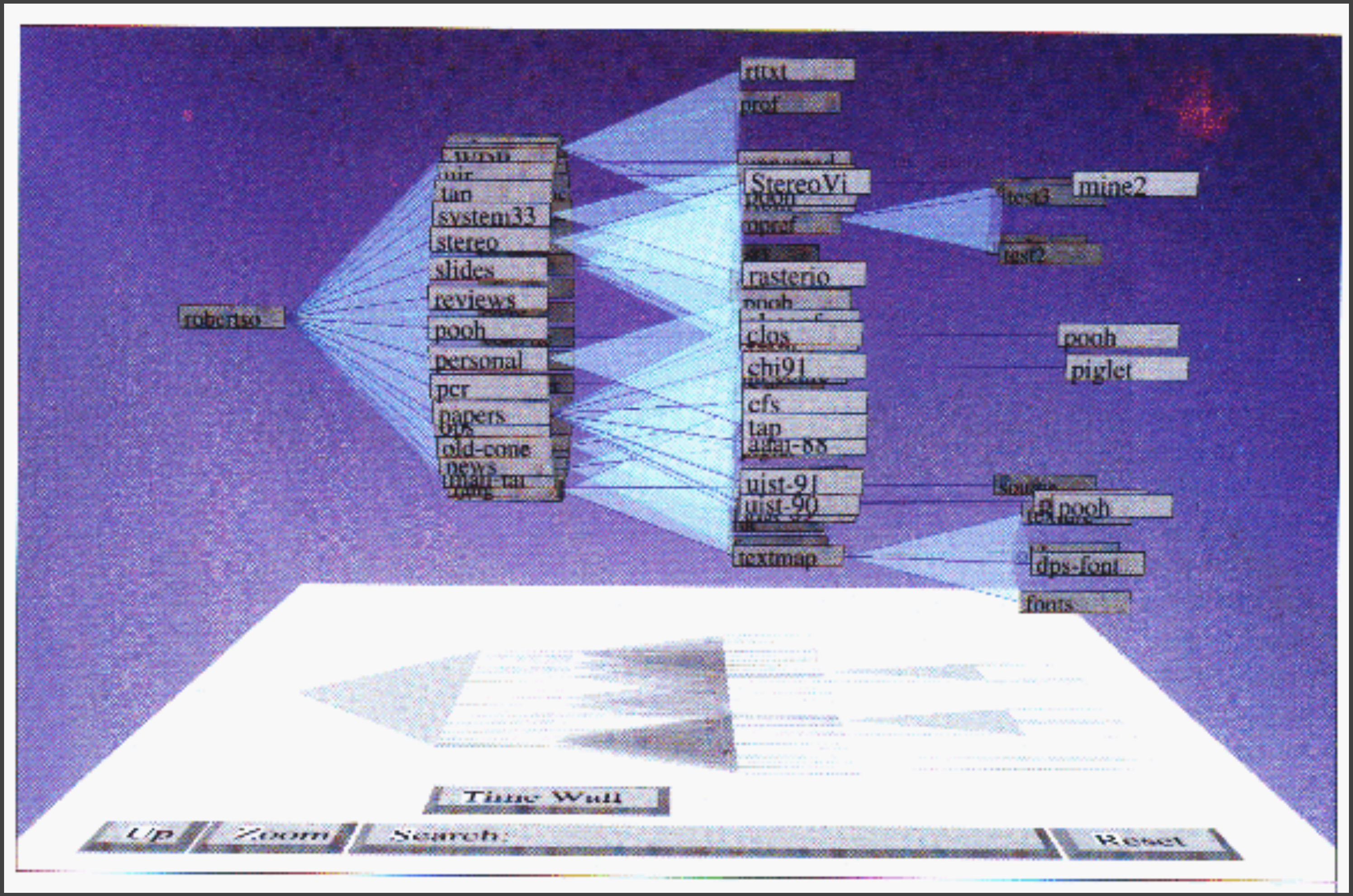
Direct attention

Understand system dynamics

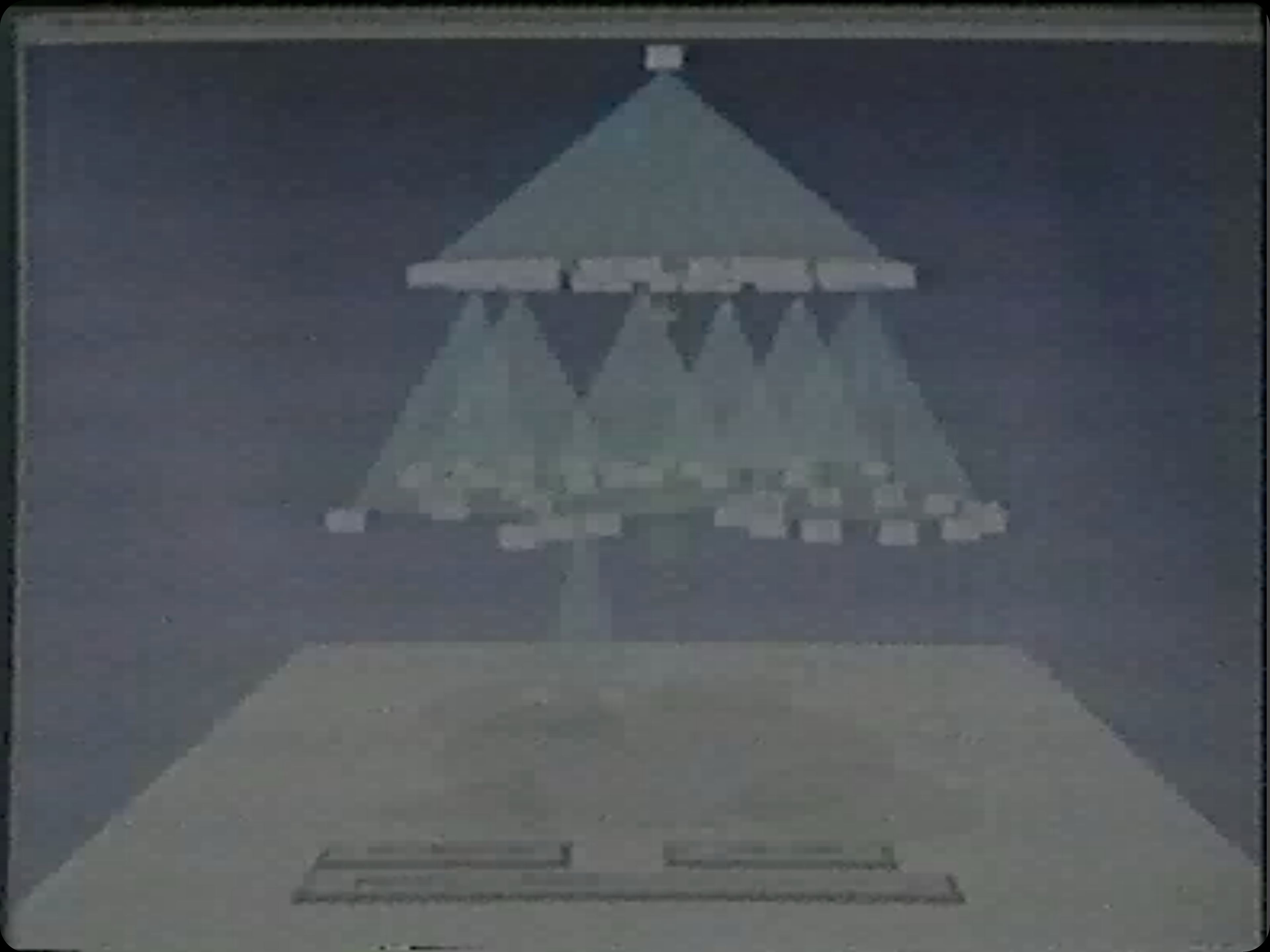
Understand state transition

Increase engagement

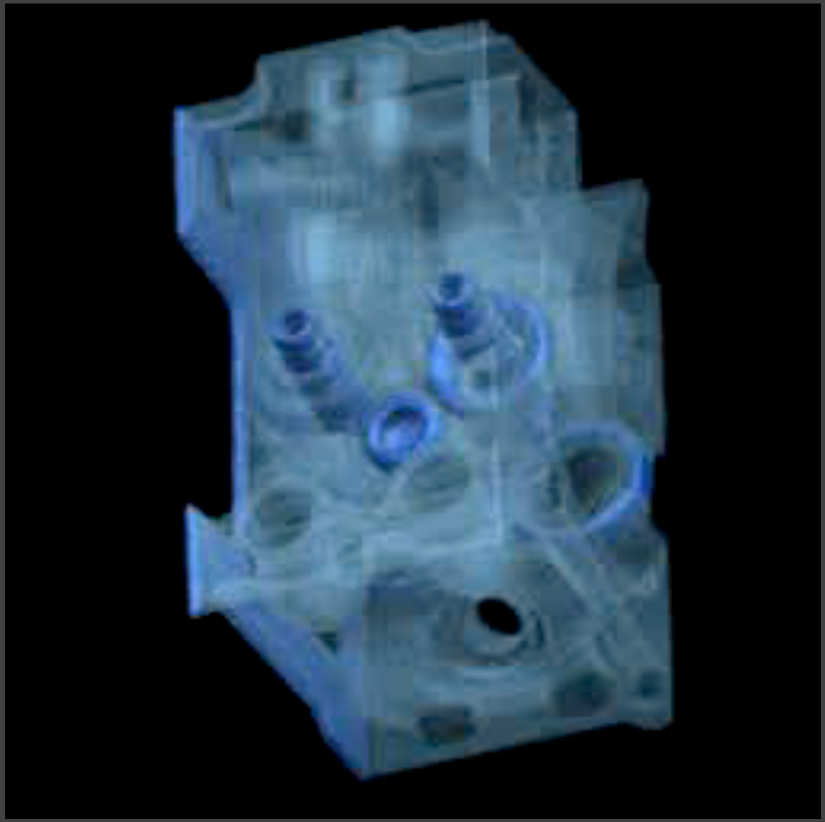
Cone Trees [Robertson 91]



Video

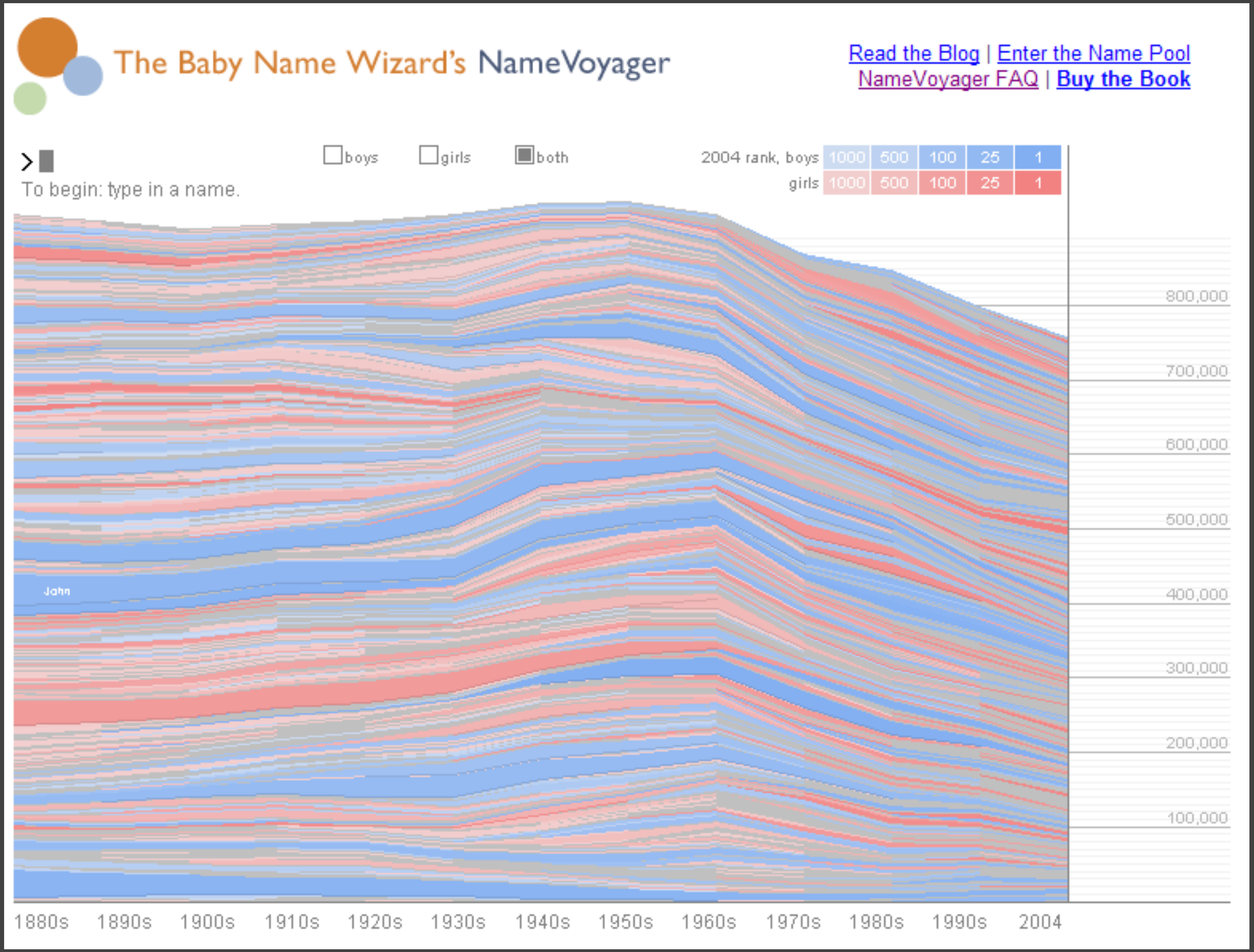


Volume Rendering [Lacroute 95]



Video

NameVoyager [Wattenberg 04]



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

Topics

Motion perception

Animated transitions in visualizations

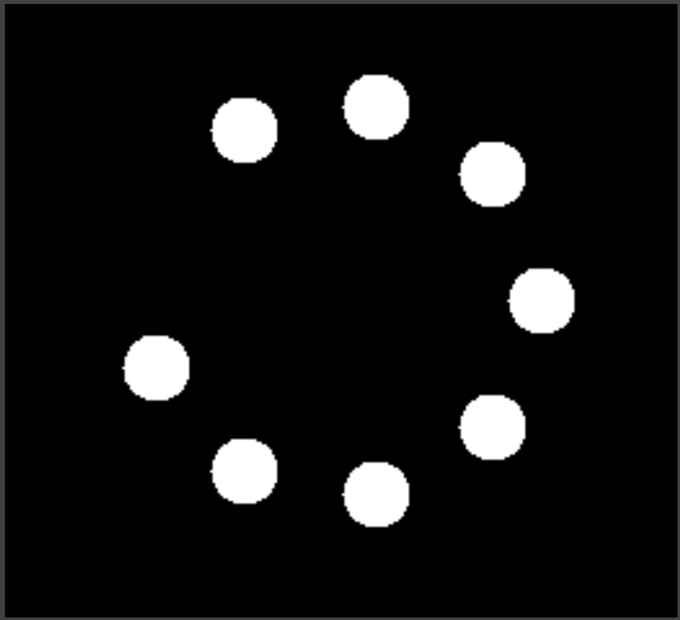
Implementing animations

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

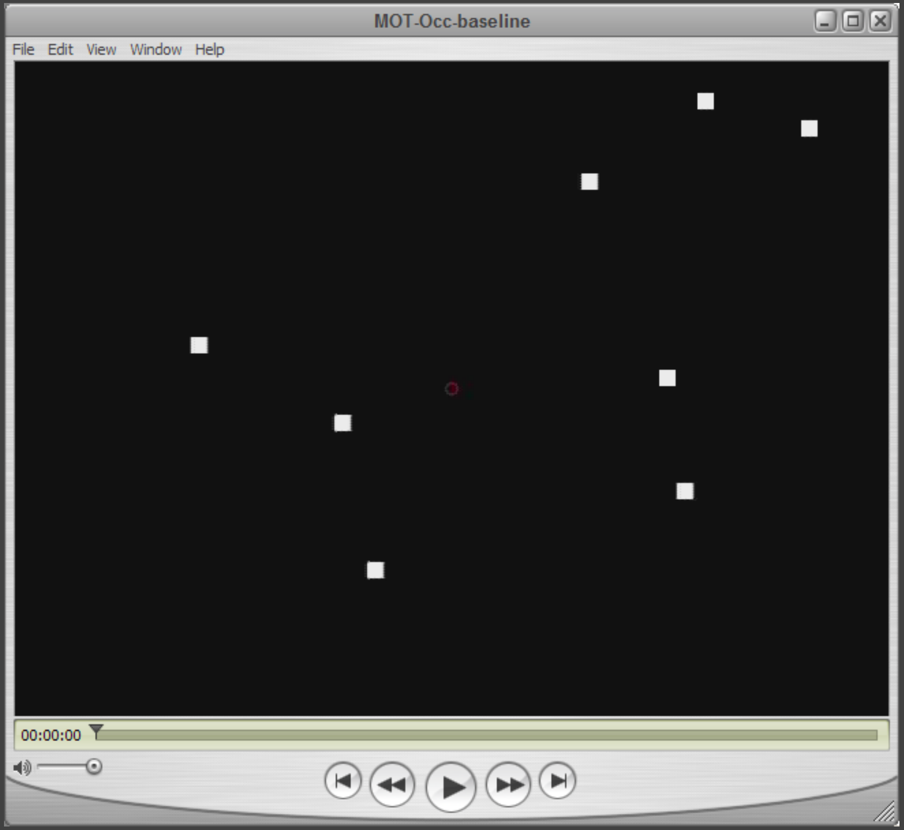
Pre-attentive, stronger than color, shape, …

More sensitive to motion at periphery

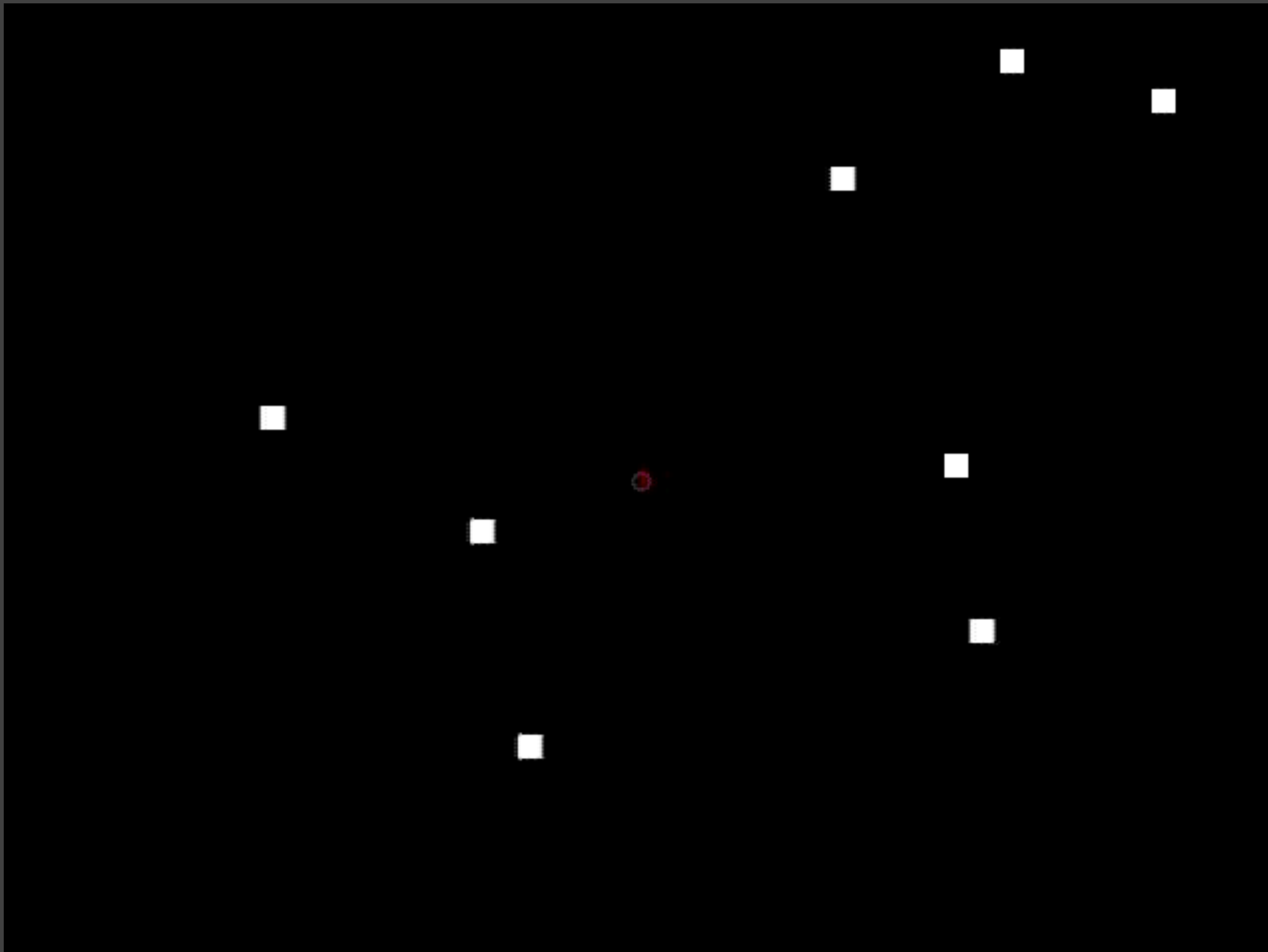
Similar motions perceived as a group

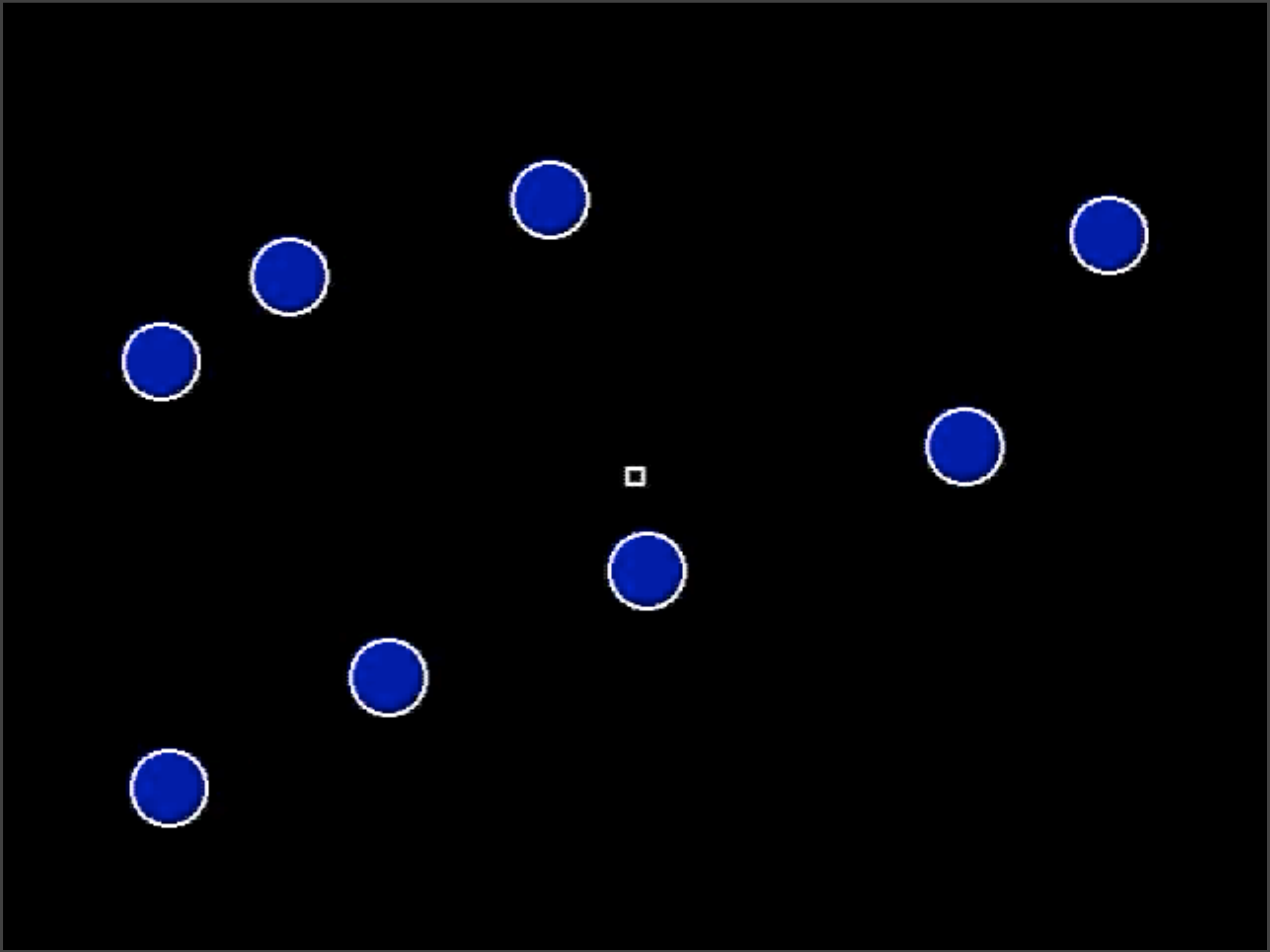
Motion parallax provide 3D cue (like stereopsis)

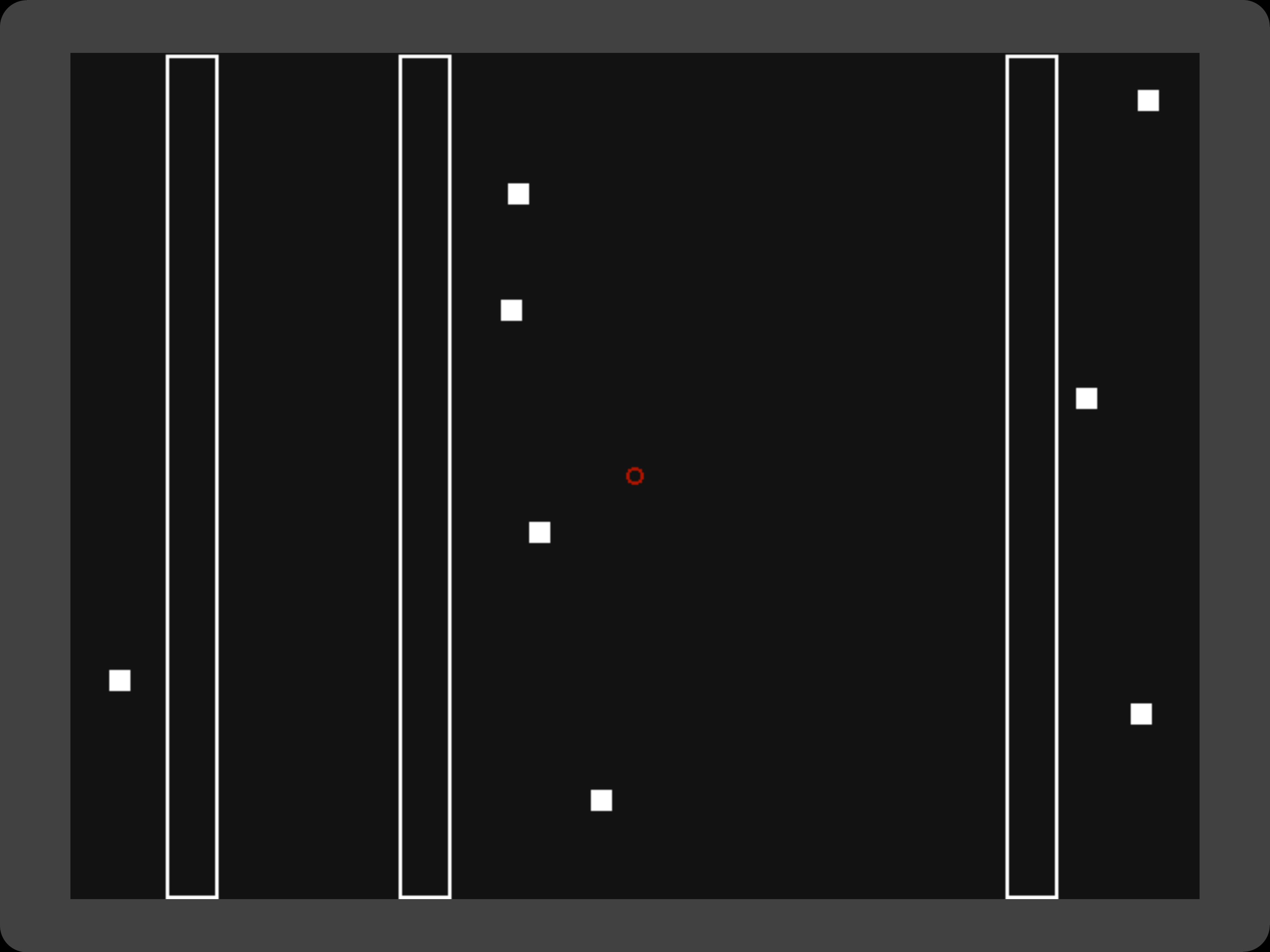
Tracking Multiple Targets

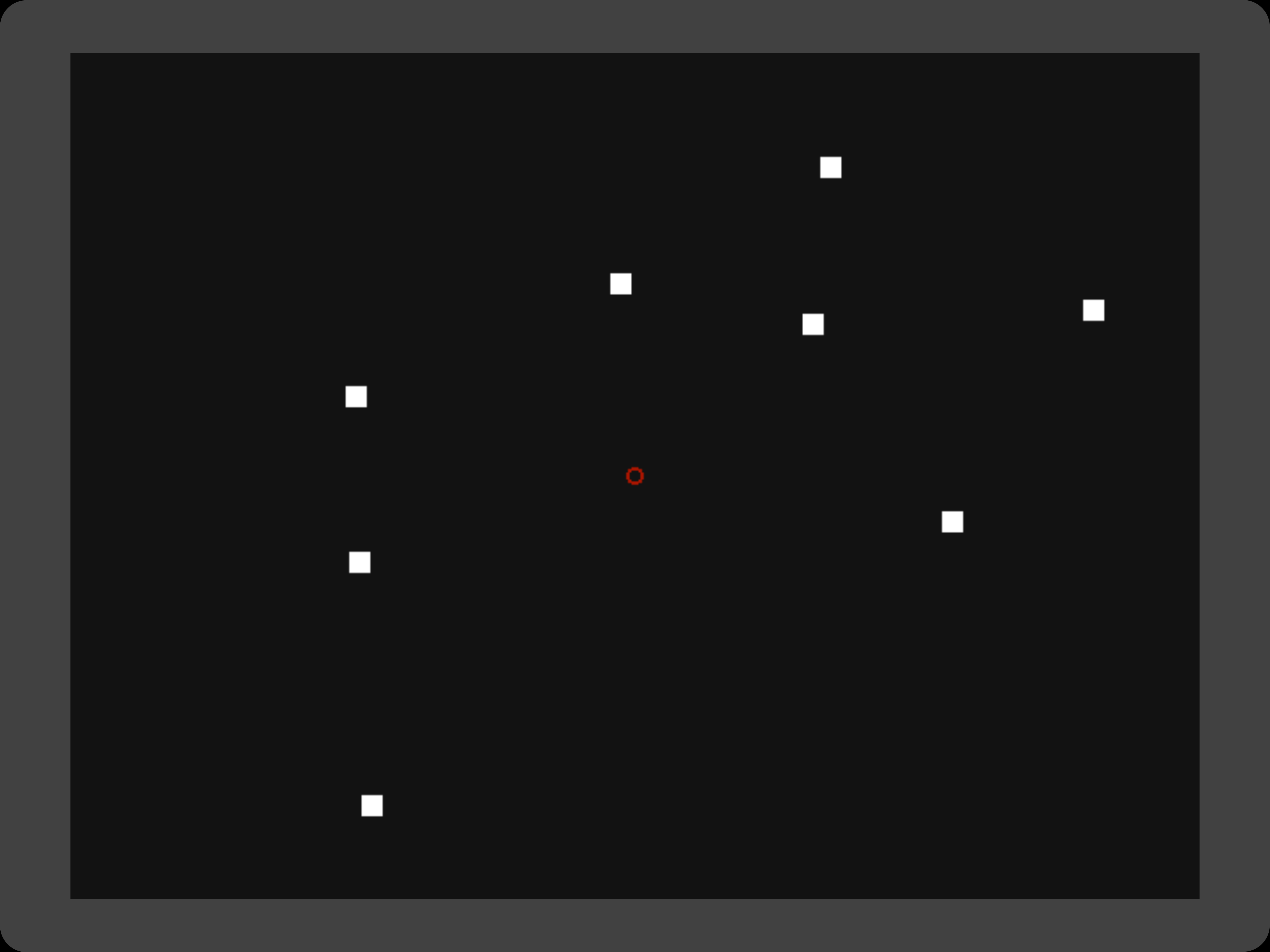


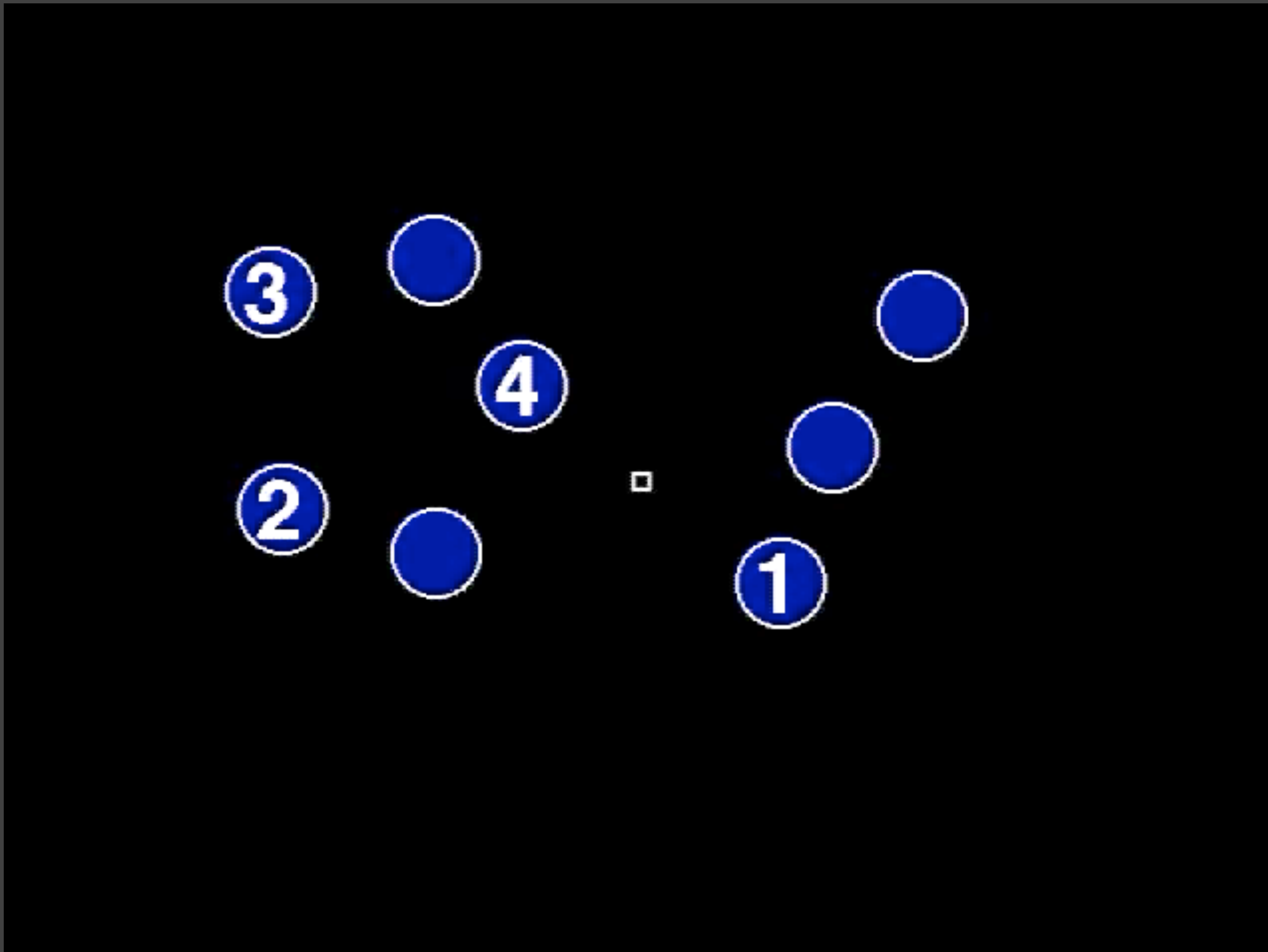
How many dots can we simultaneously track?







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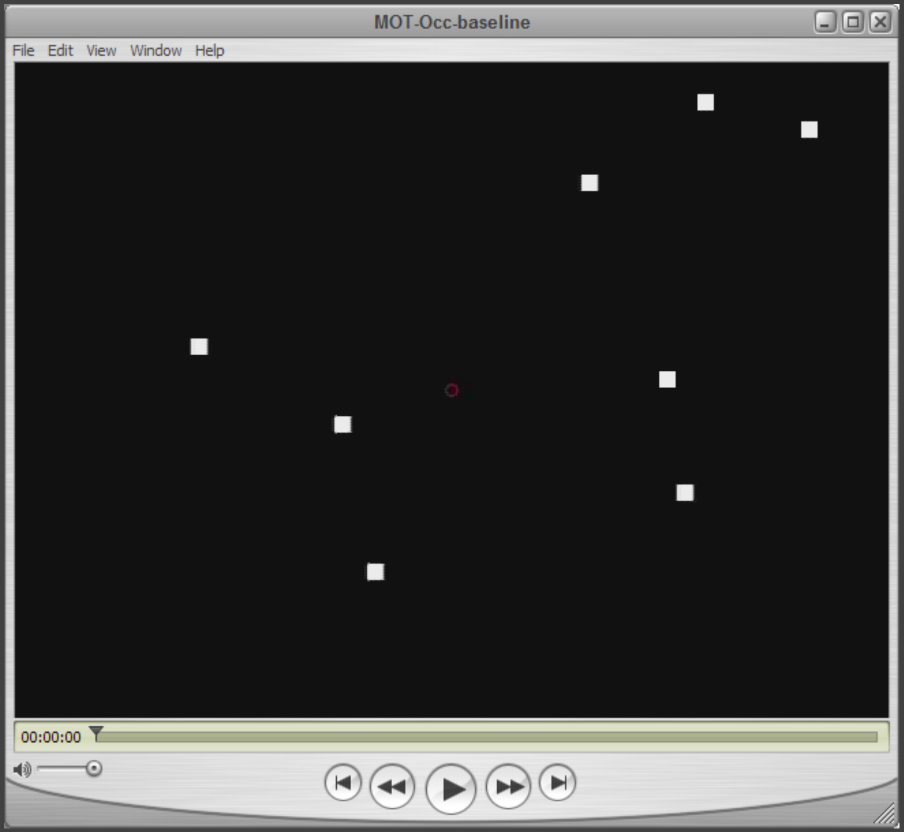
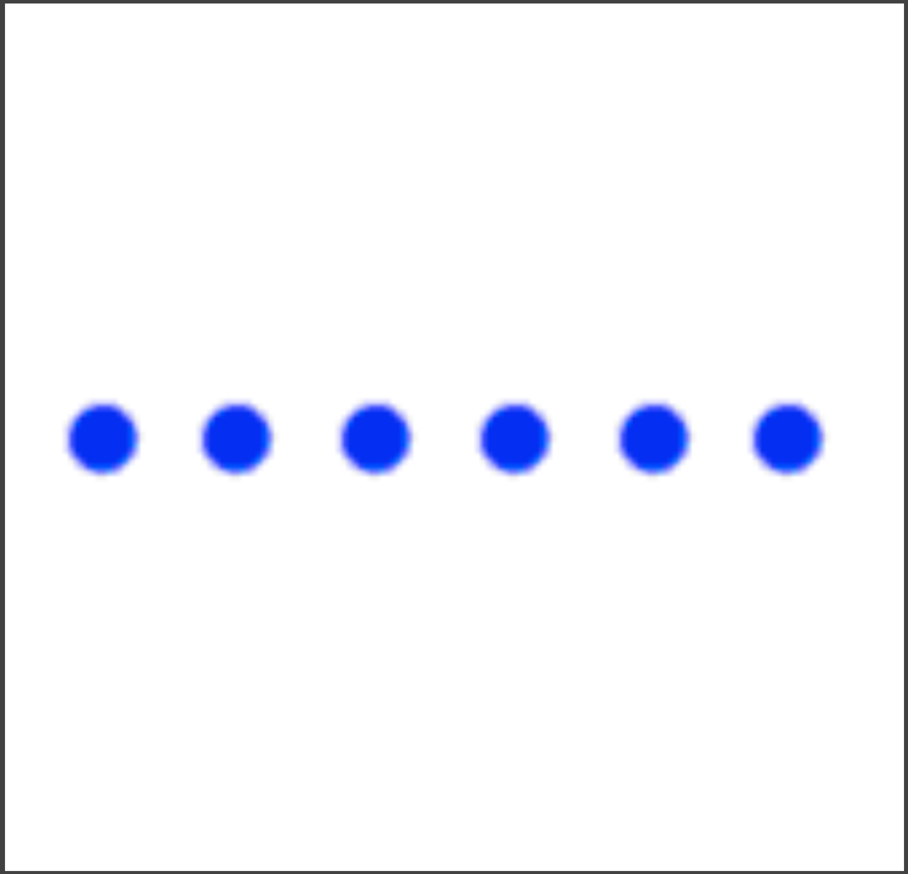
Tracking Multiple Targets



How many dots can we simultaneously track?

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

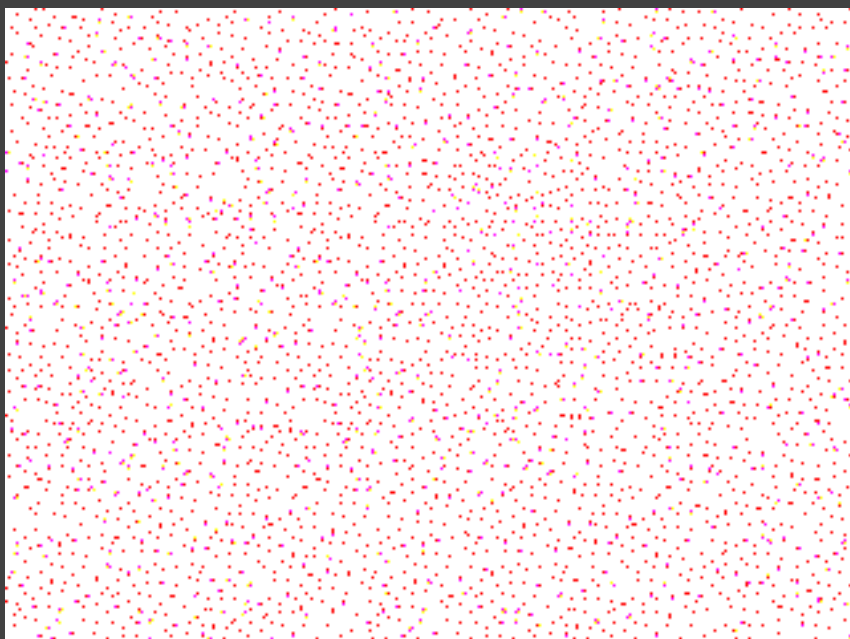
Grouped Dots Count as 1 Object



Dots moving together are grouped

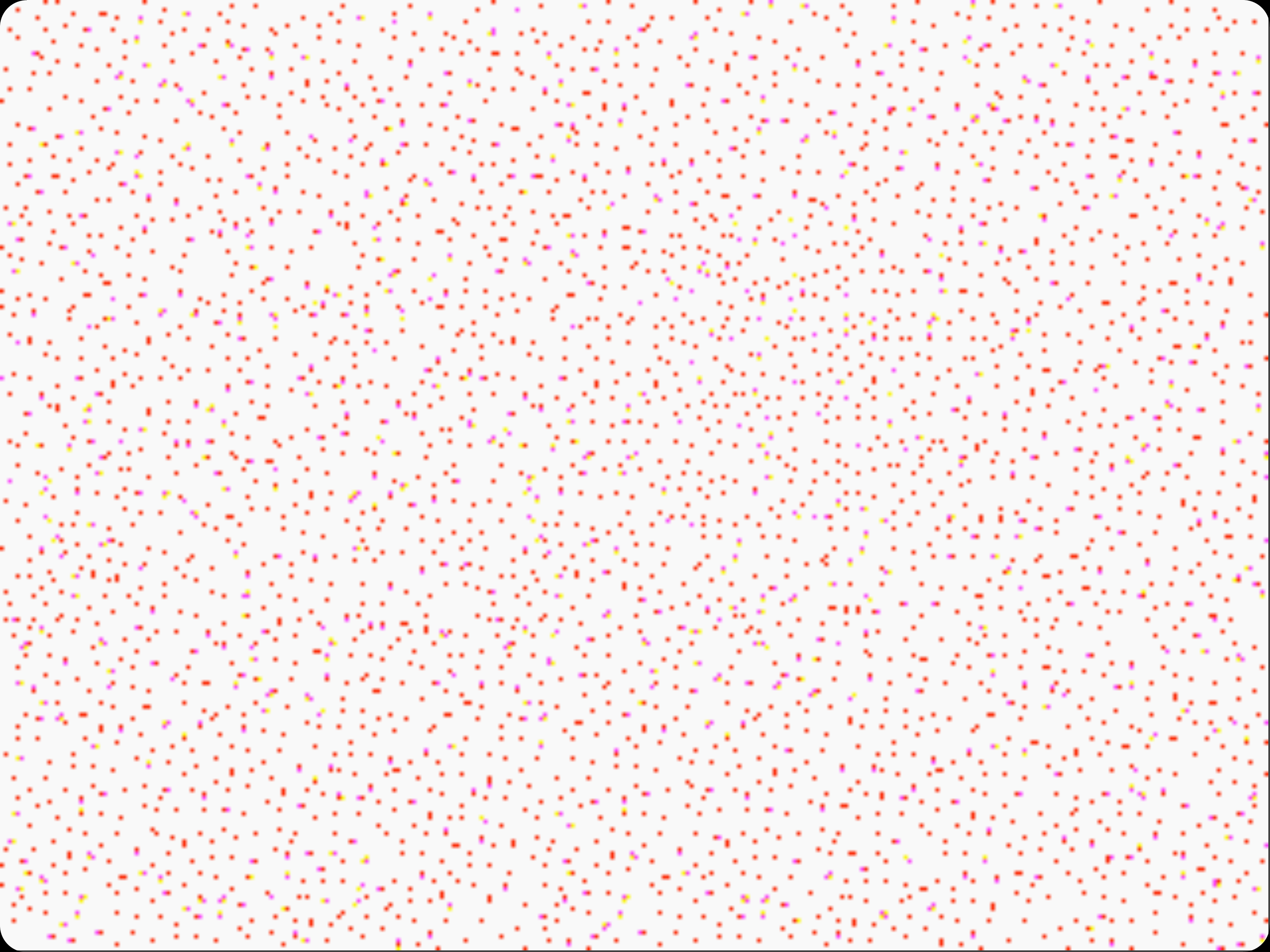
http://coe.sdsu.edu/eet/articles/visualperc1/start.htm

Segment by Common Fate

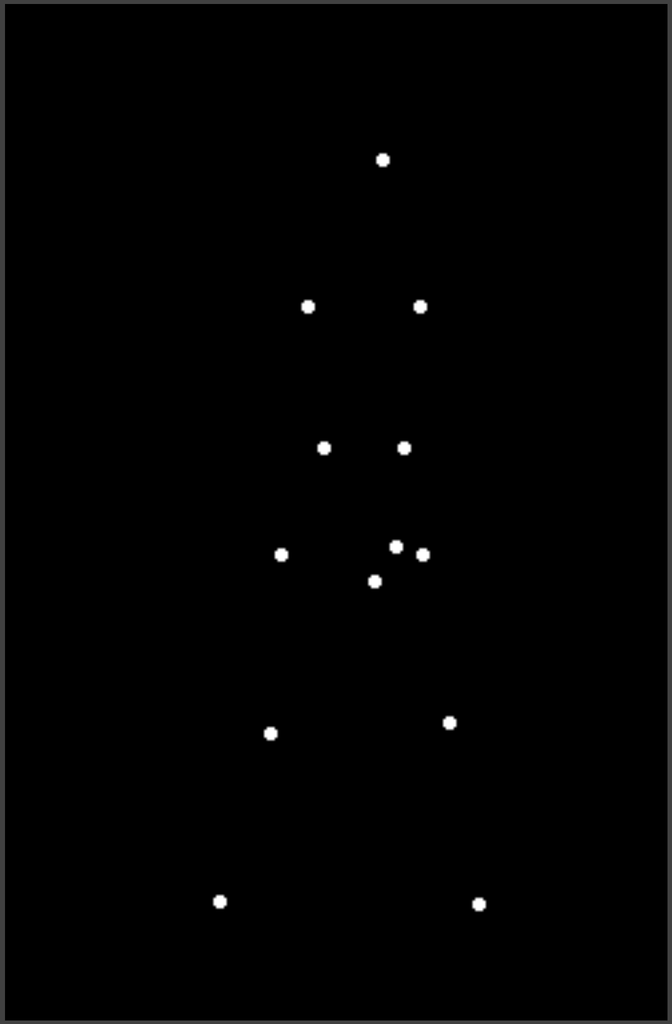


http://dragon.uml.edu/psych/commfate.html

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

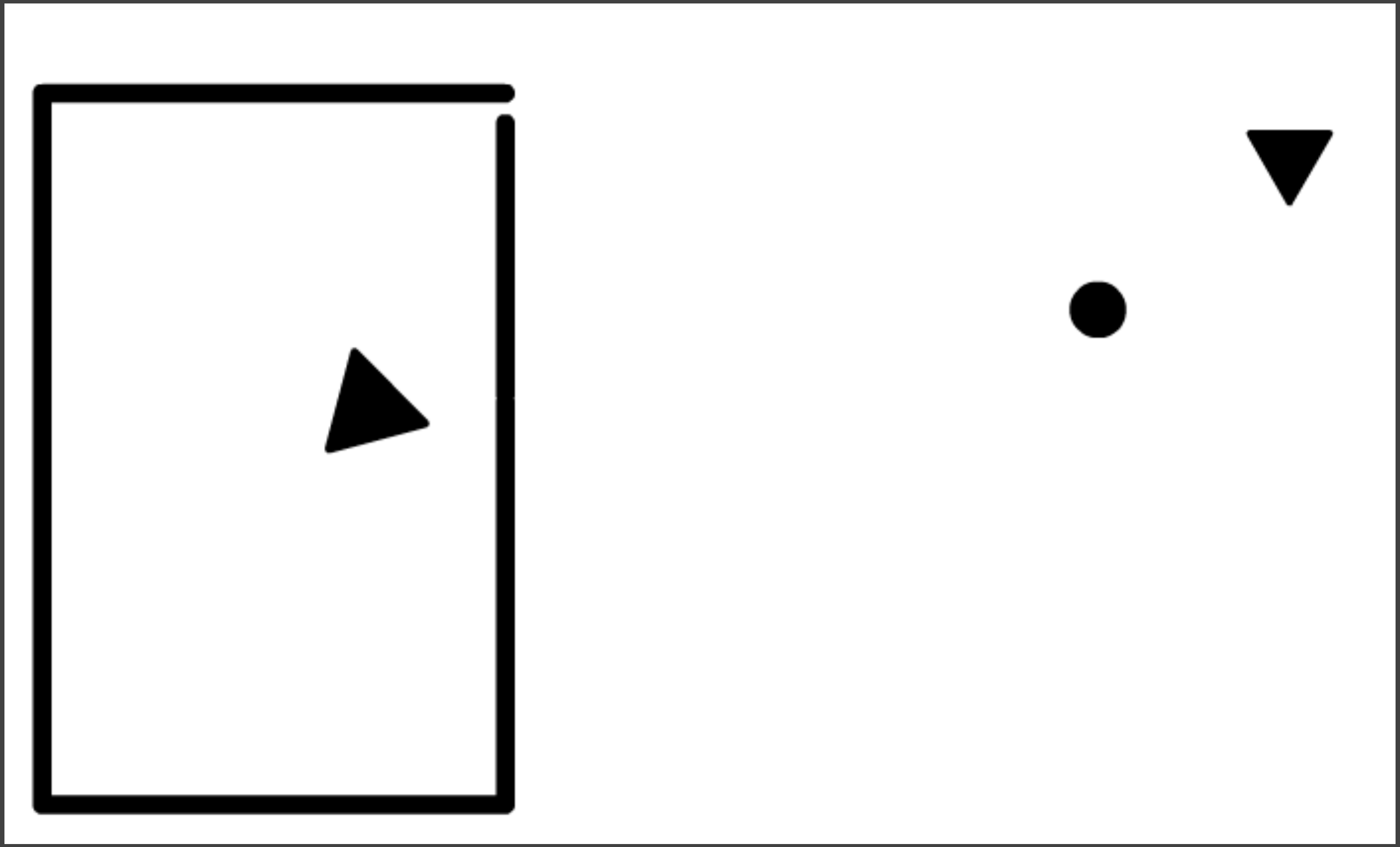
See change from one state to next

Shows transition better, but

Still may be too fast, or too slow

Too many objects may move at once

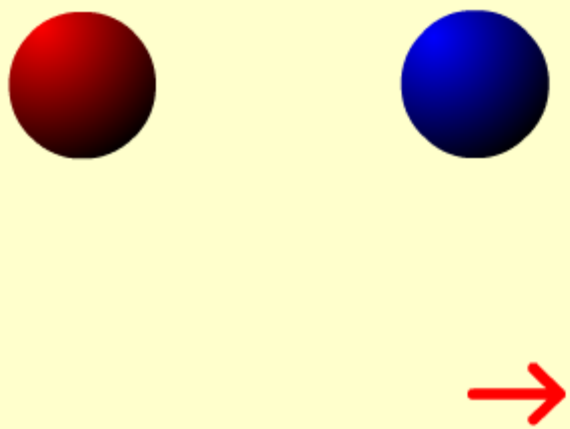
Constructing Narratives



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

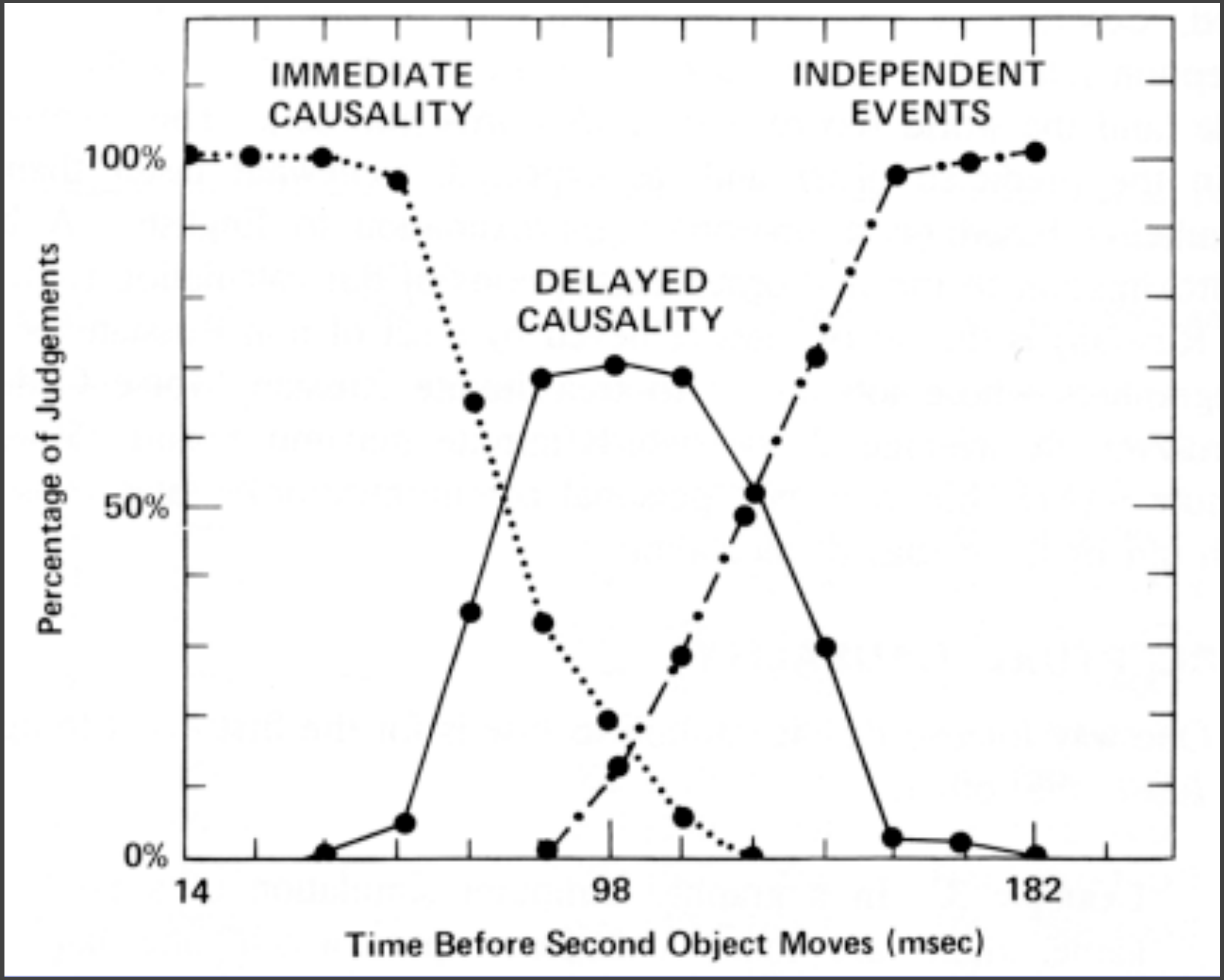
Attribution of Causality [Michotte 46]

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



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

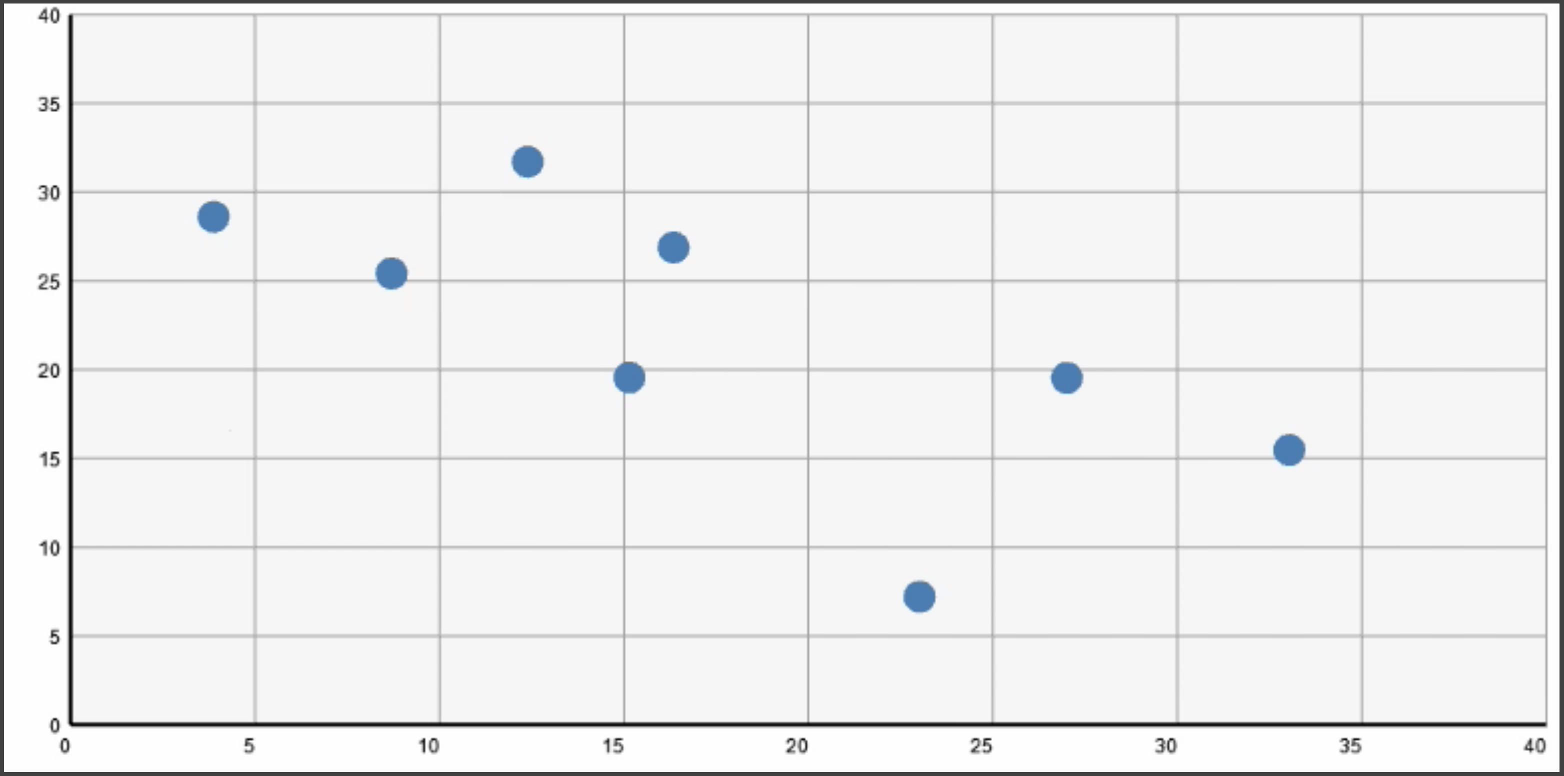
Cannot simultaneously attend to multiple motions

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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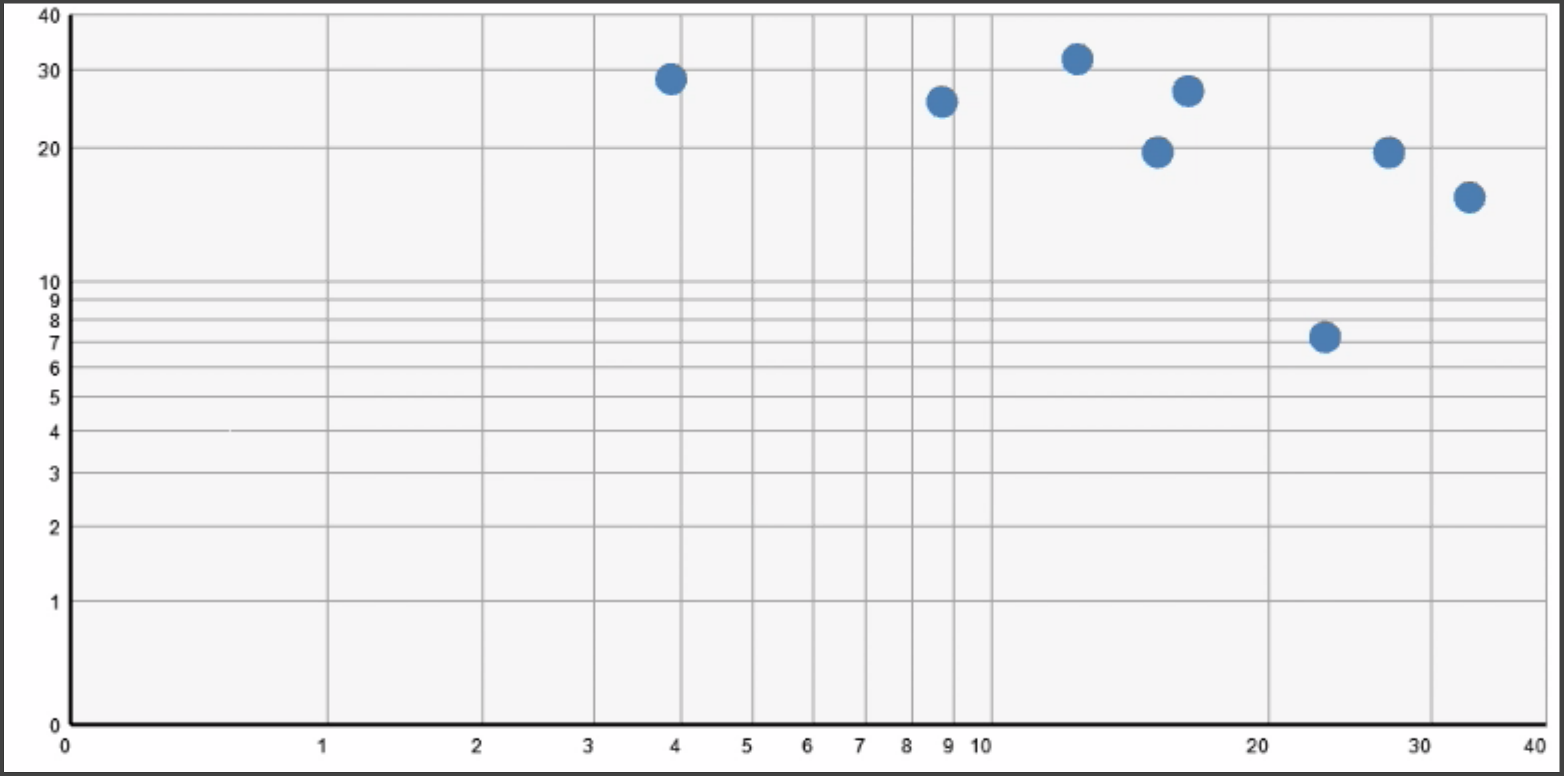
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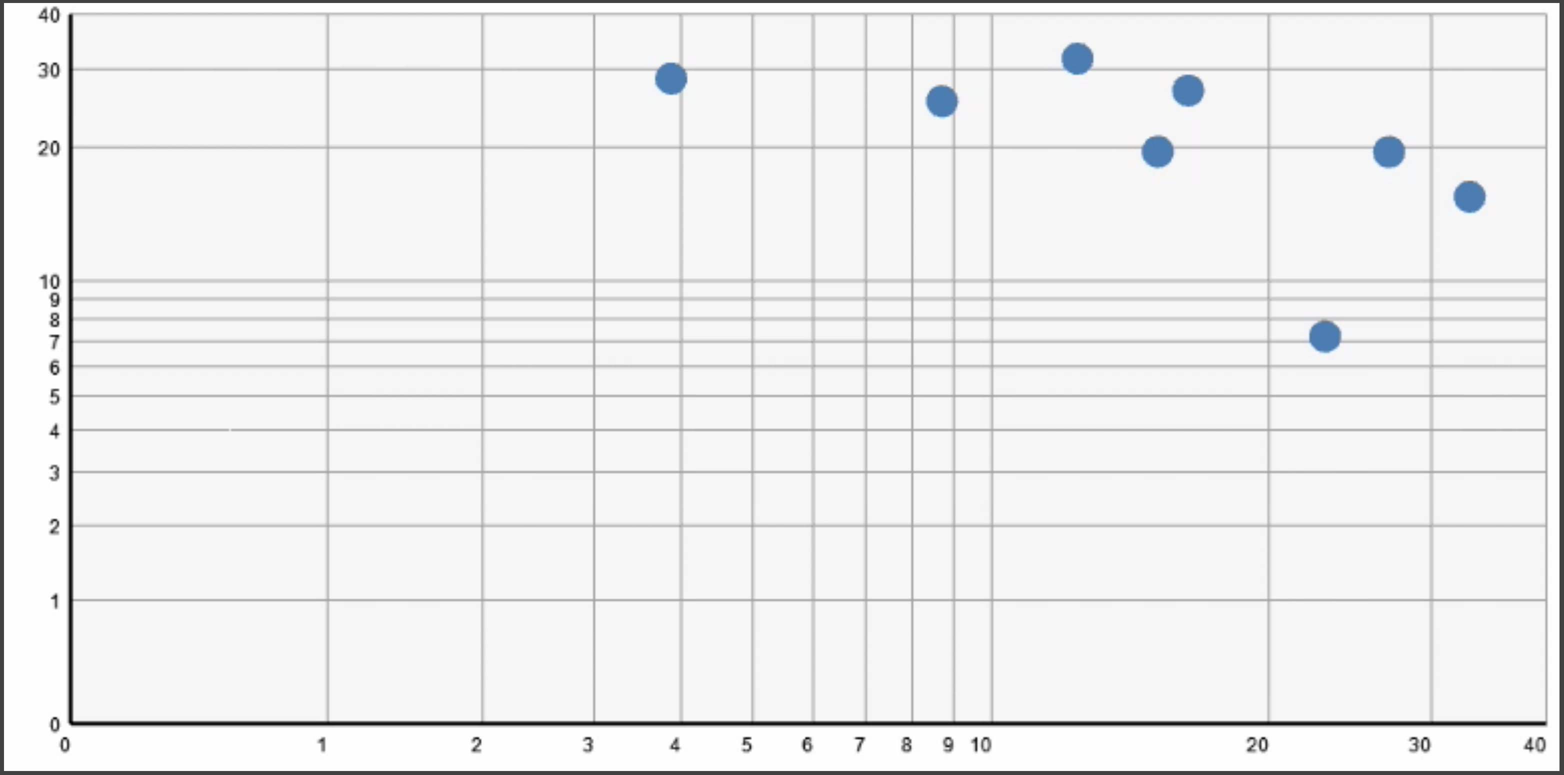
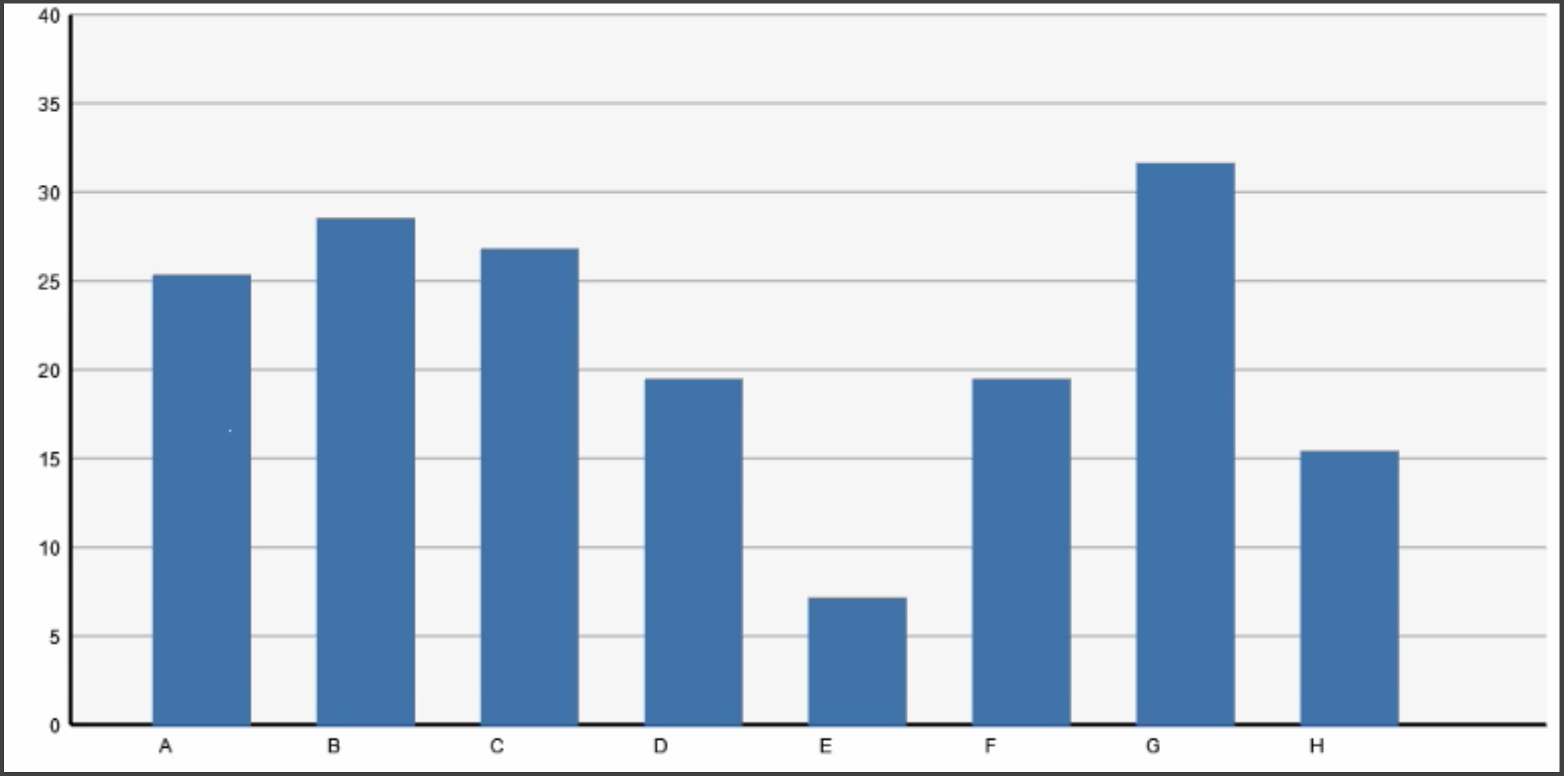
Log Transform

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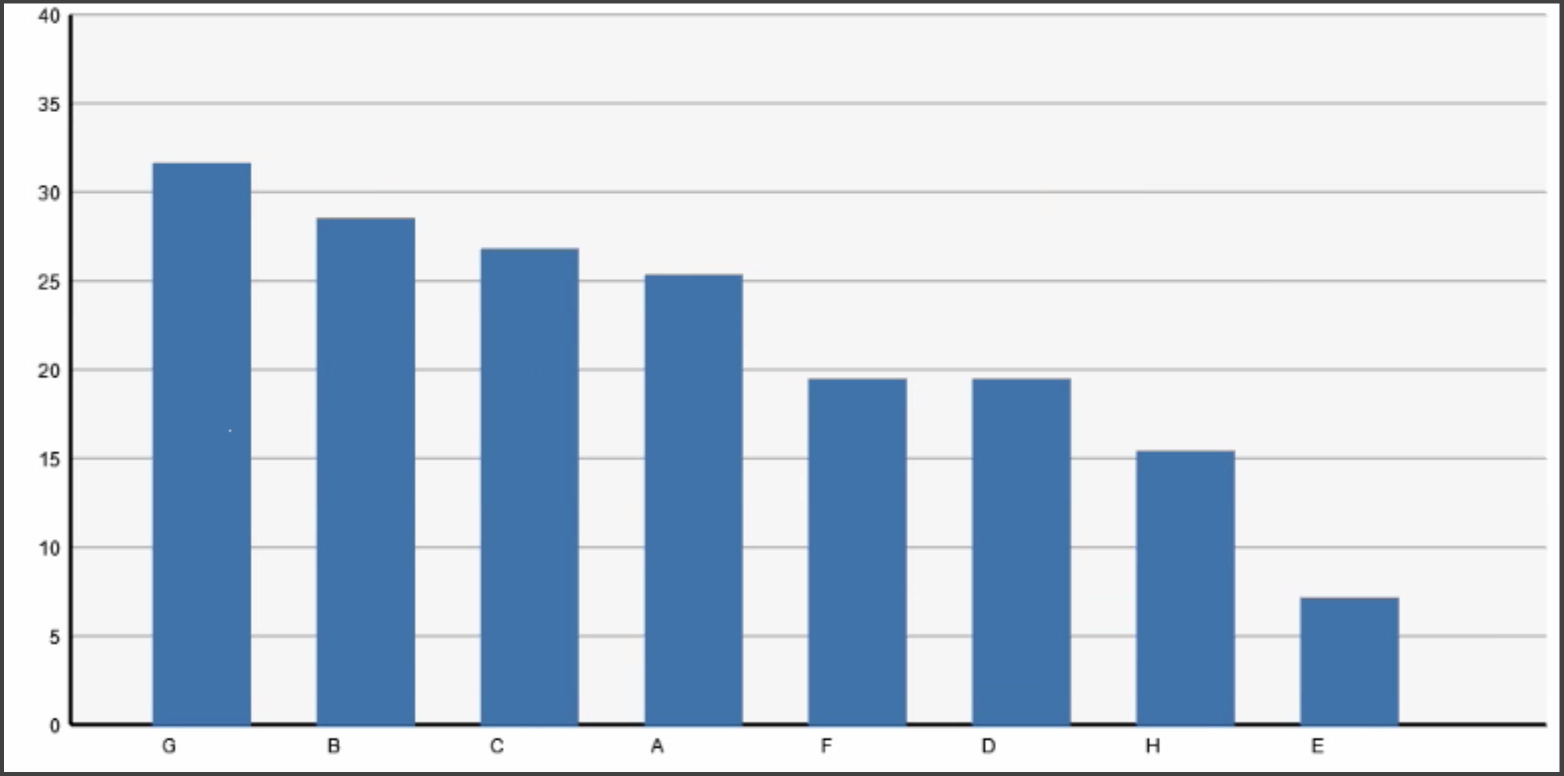

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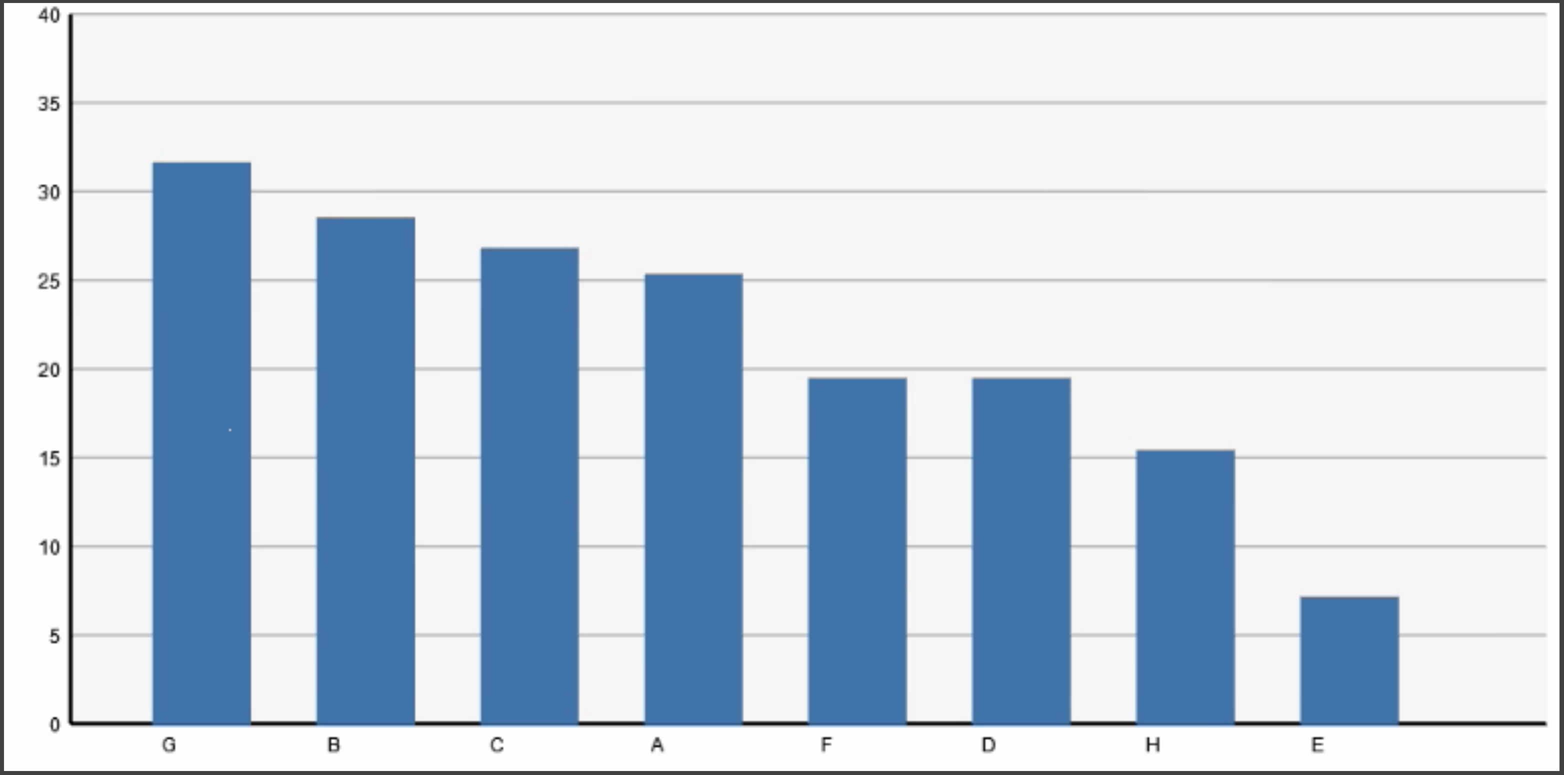
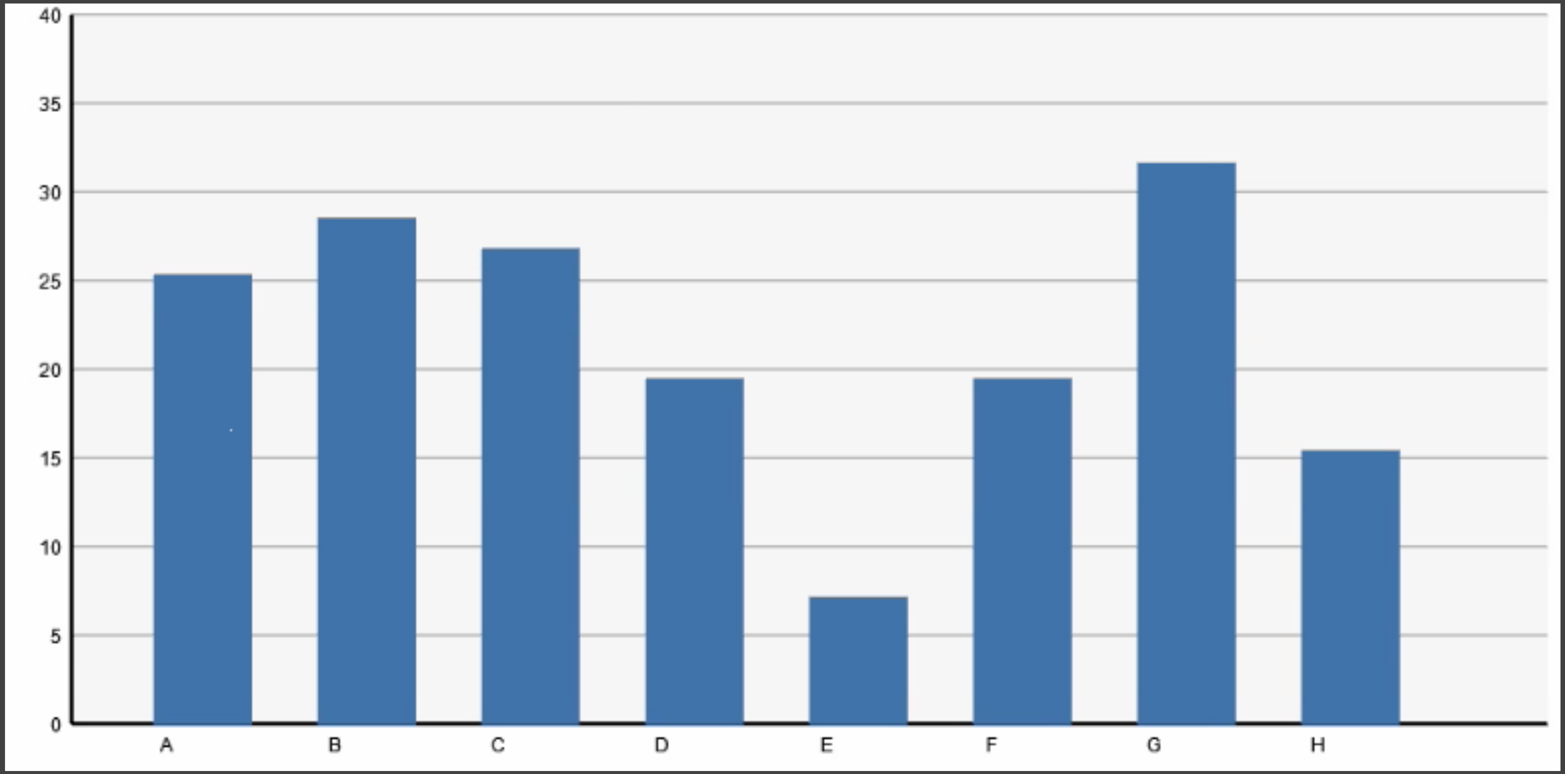
Sorting

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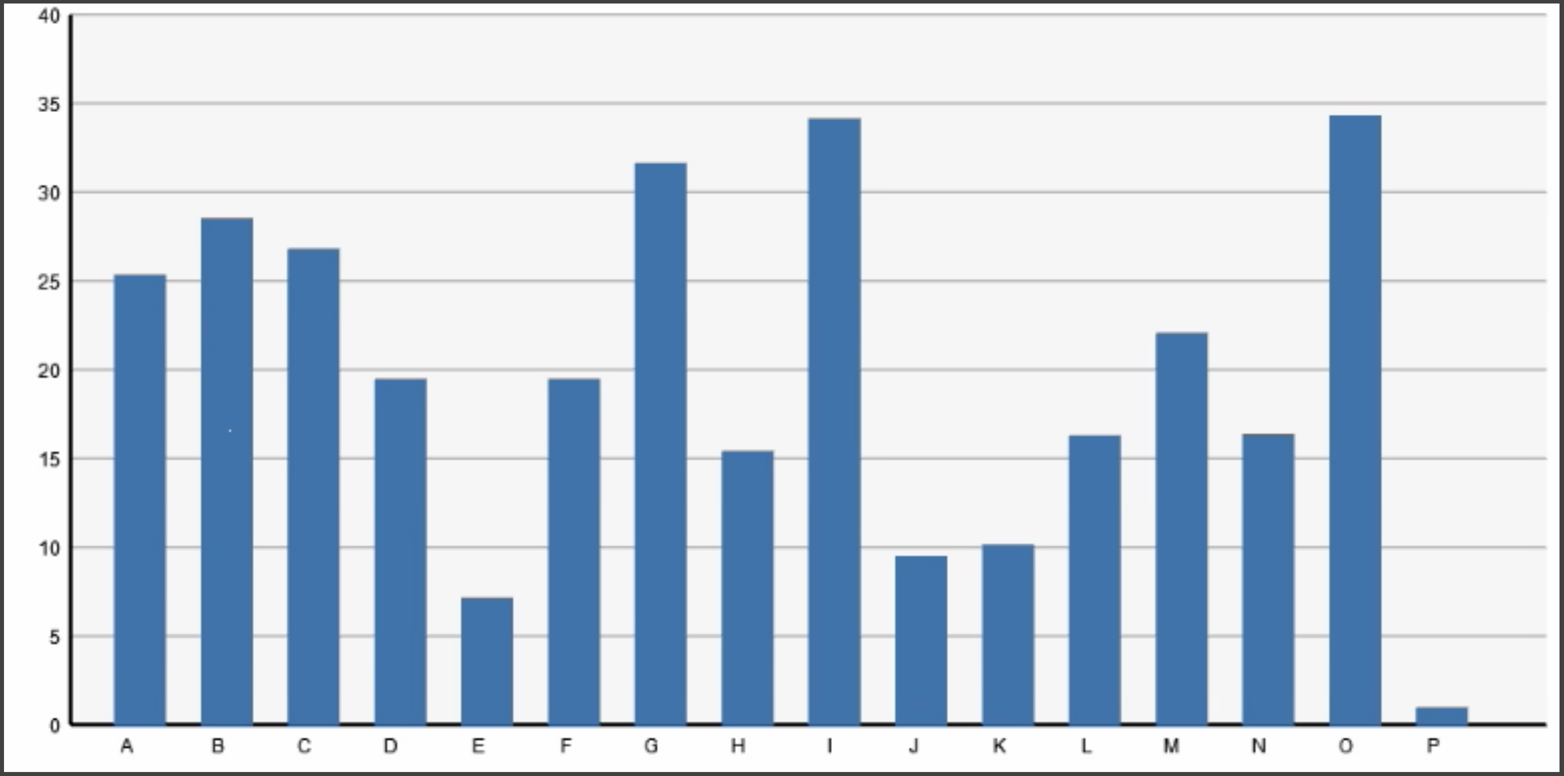
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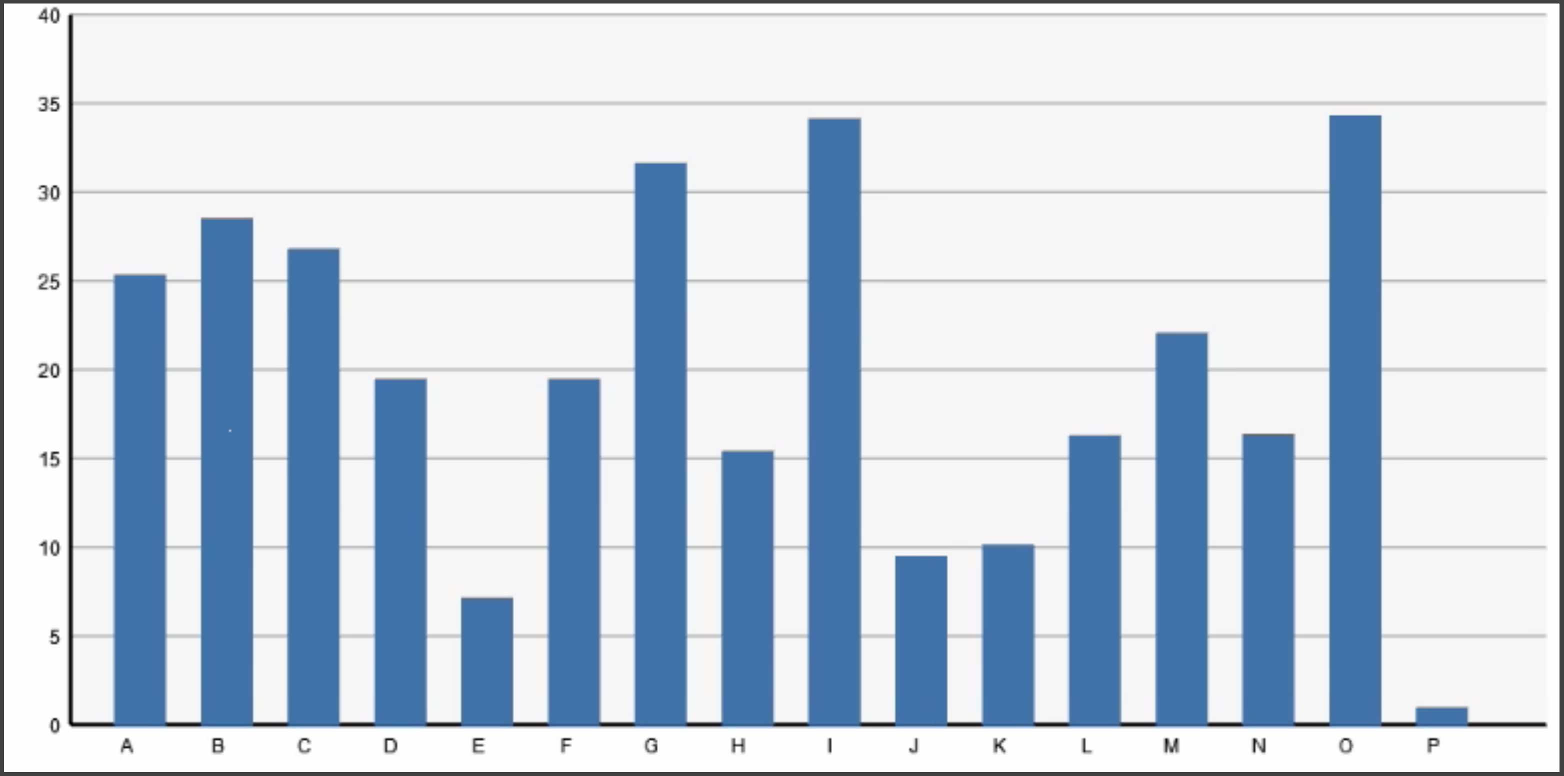
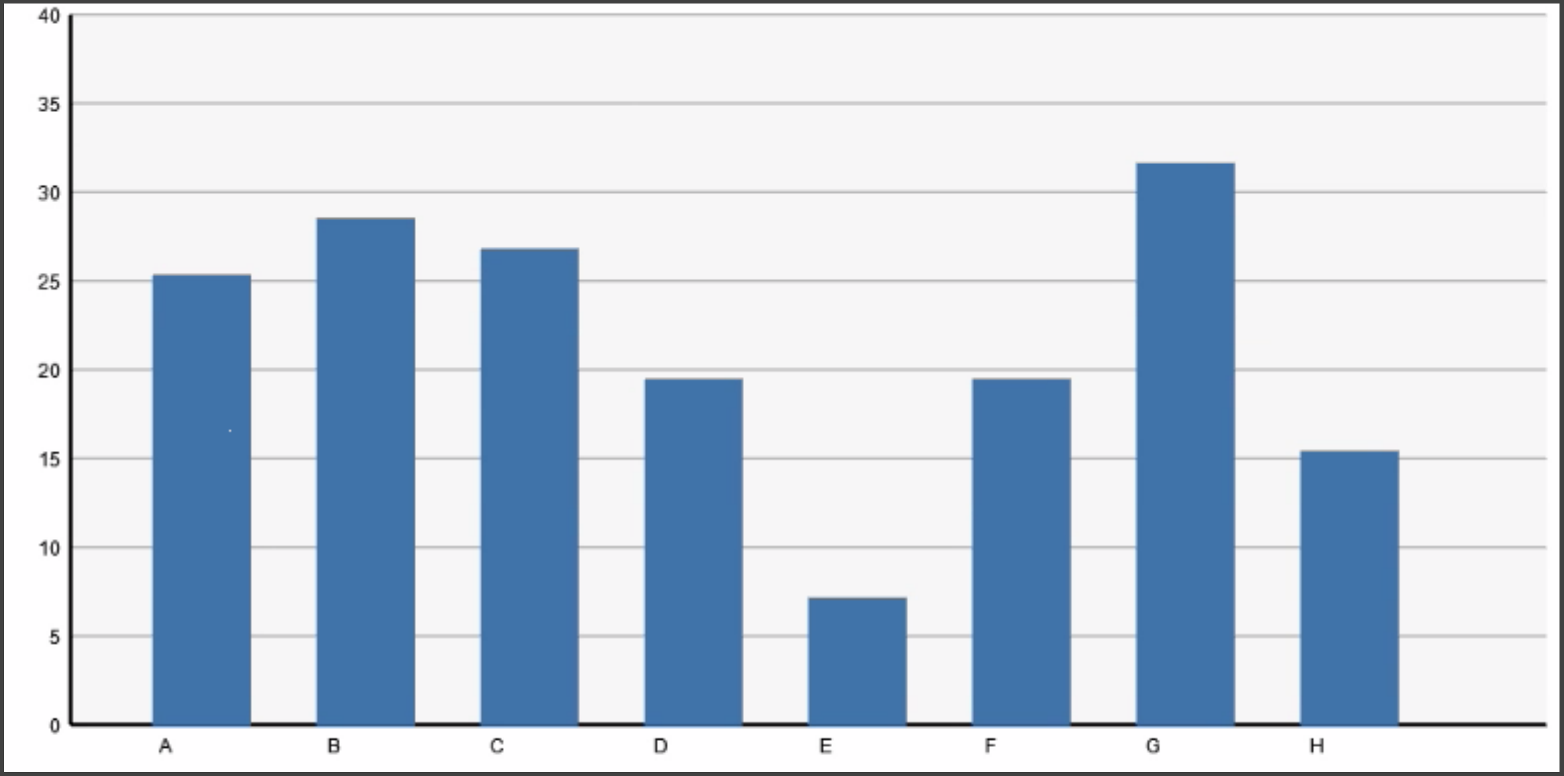
Filtering

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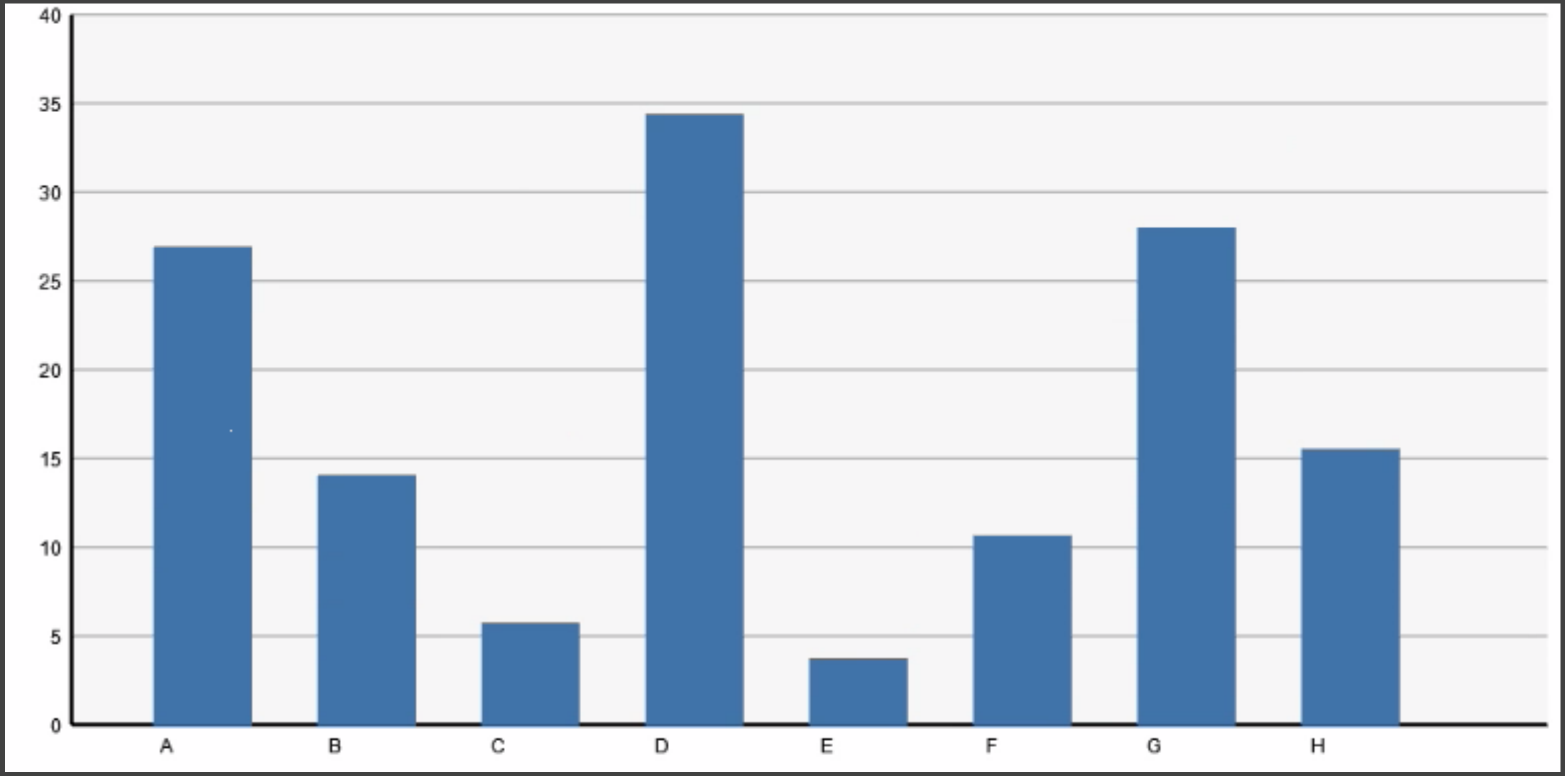
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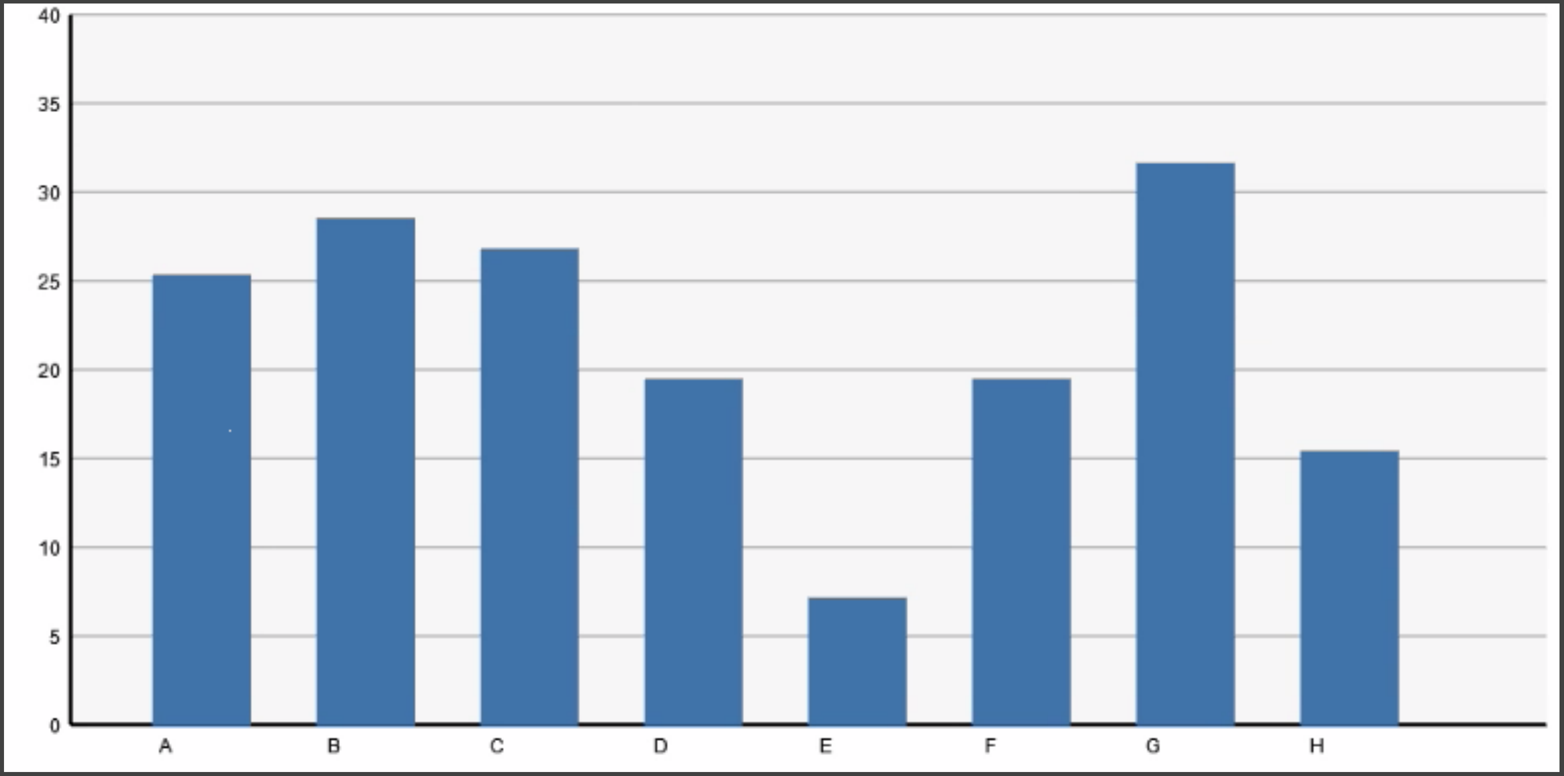
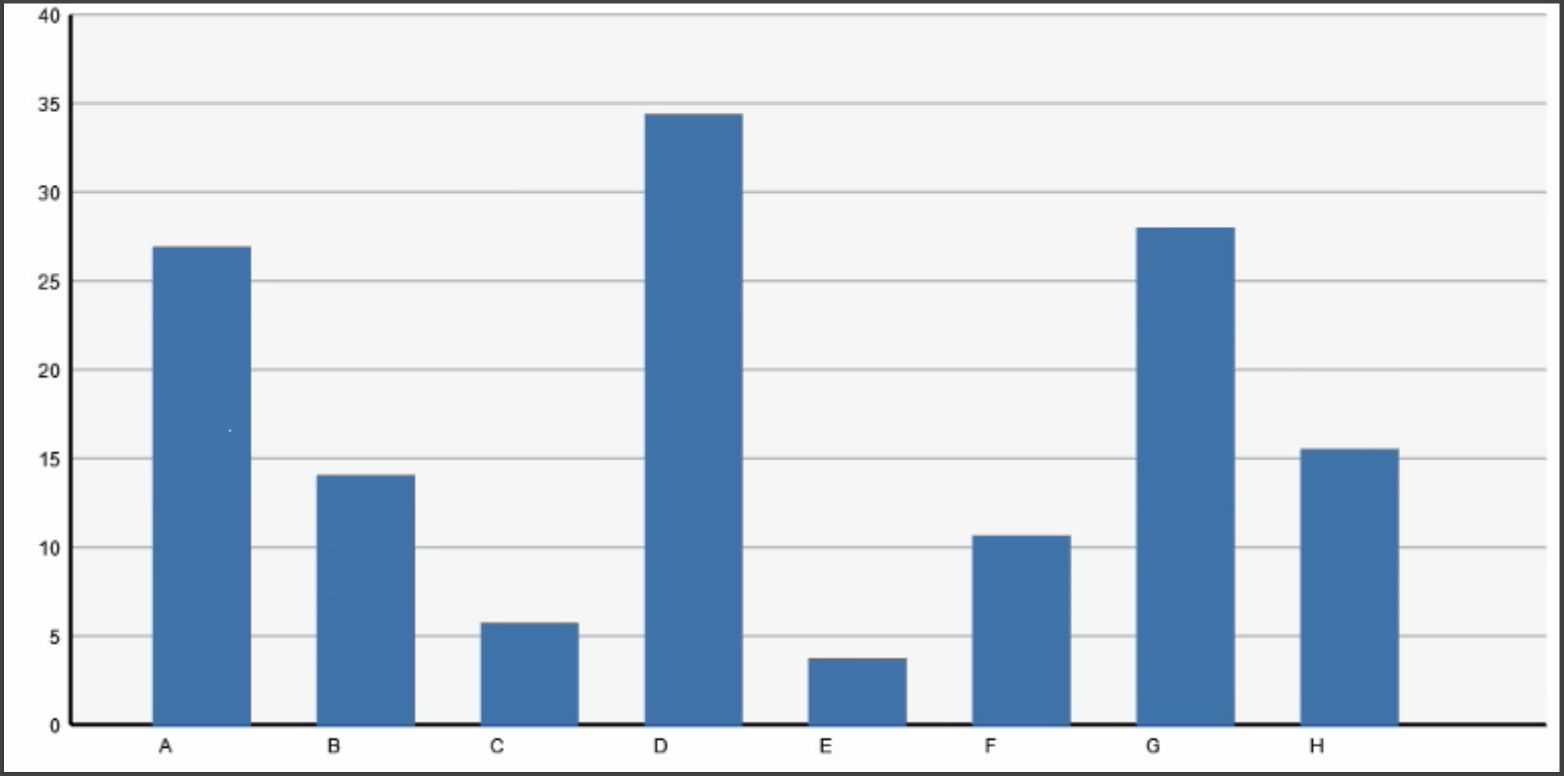
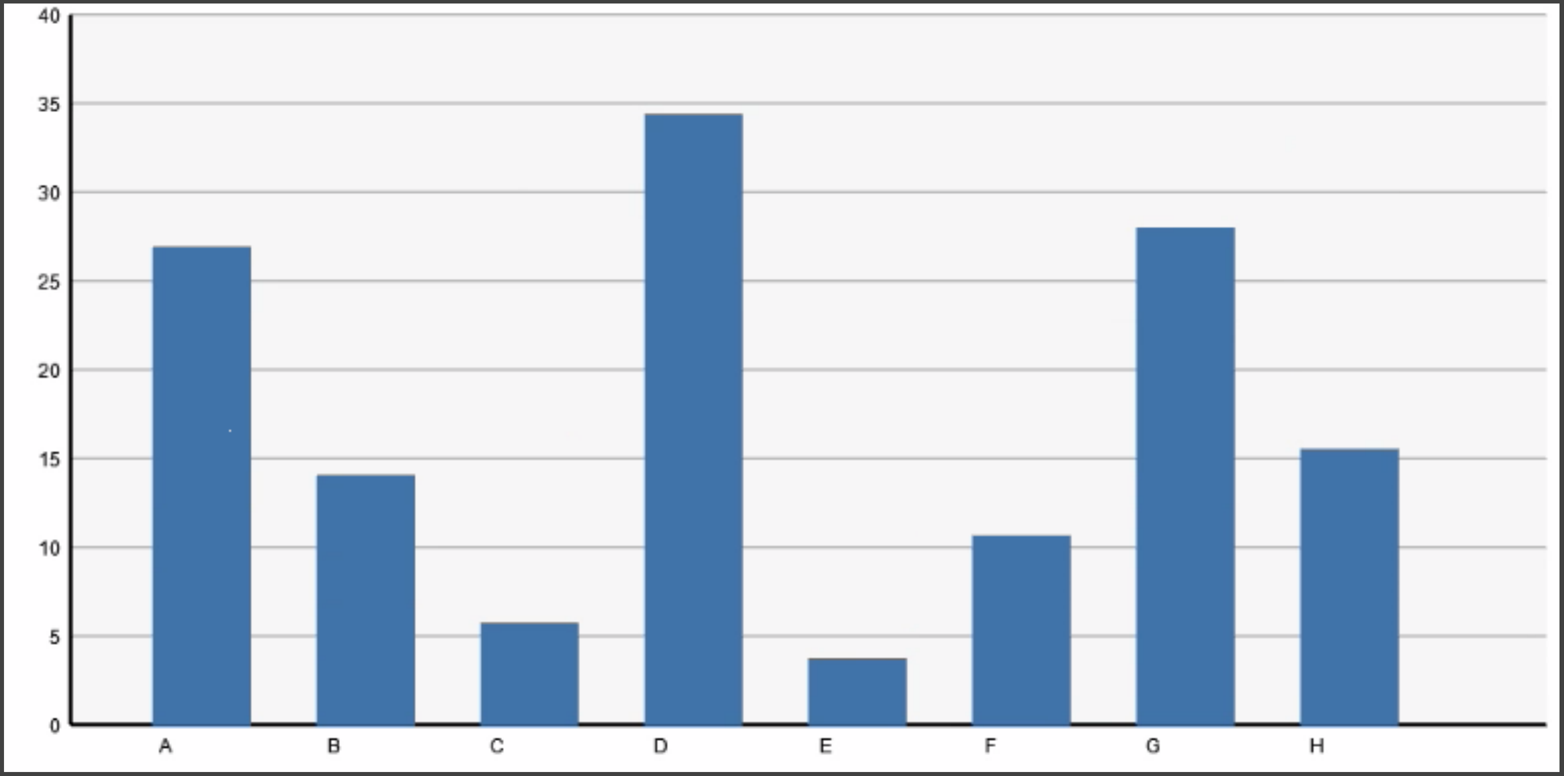


Month 1

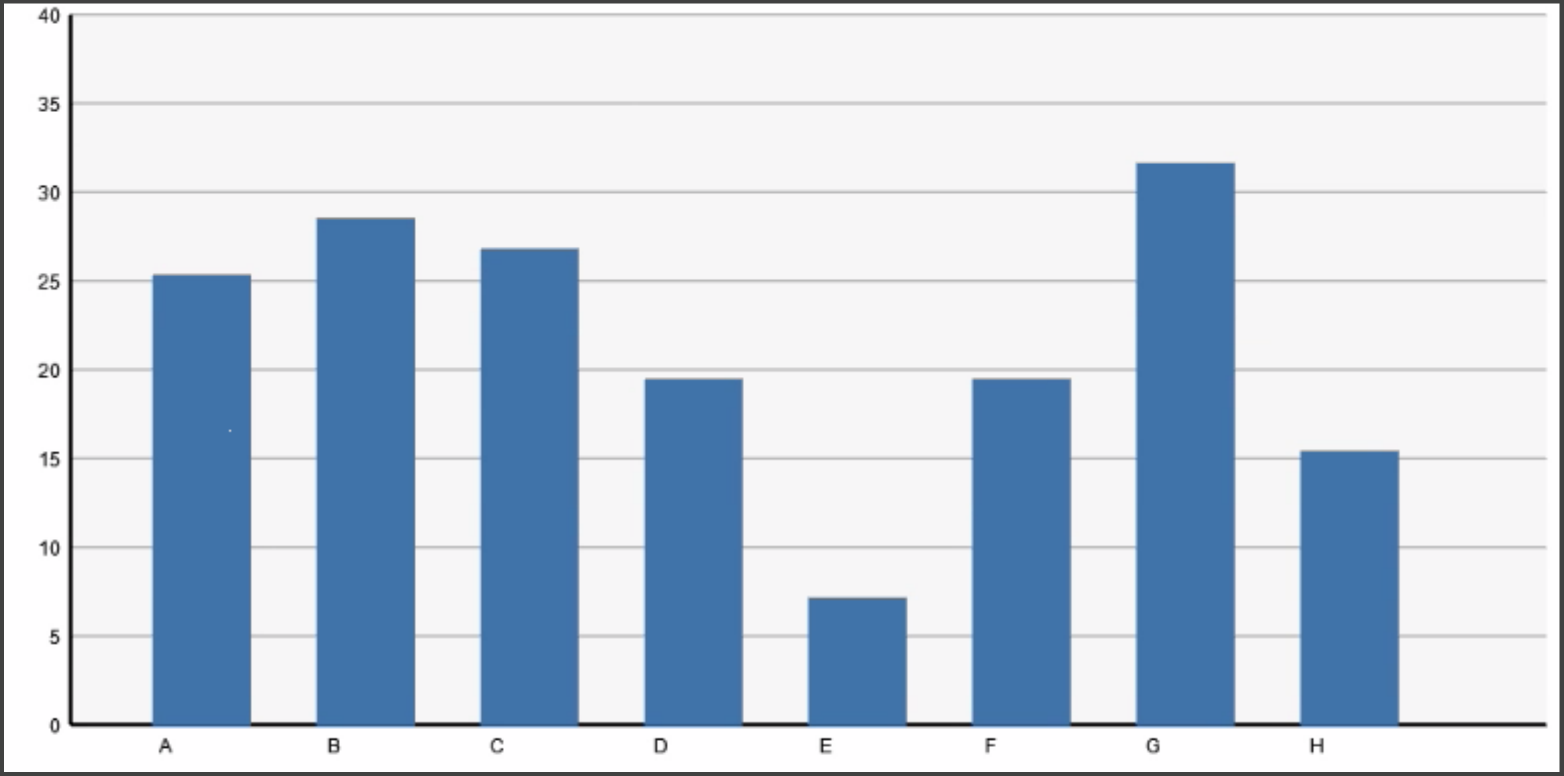


Month 2

Timestep



Month 2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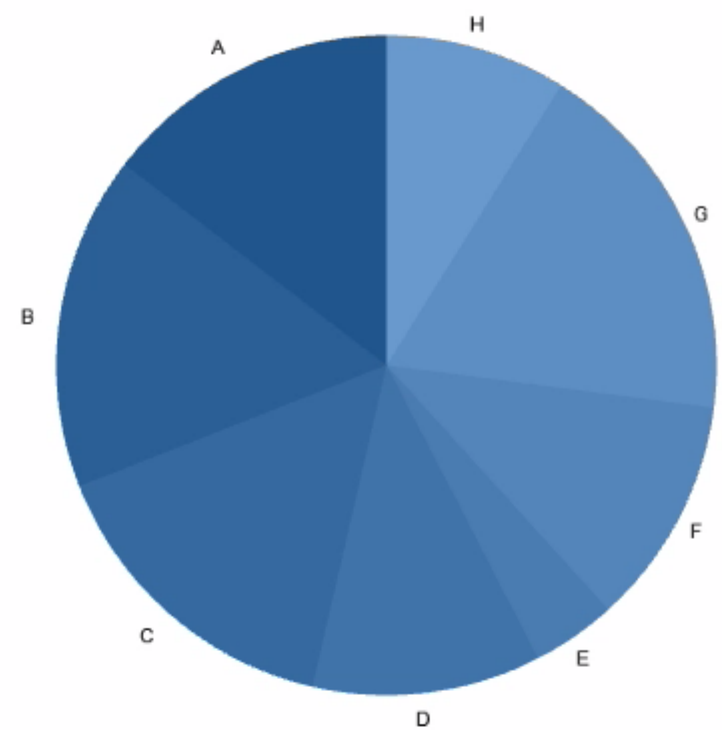

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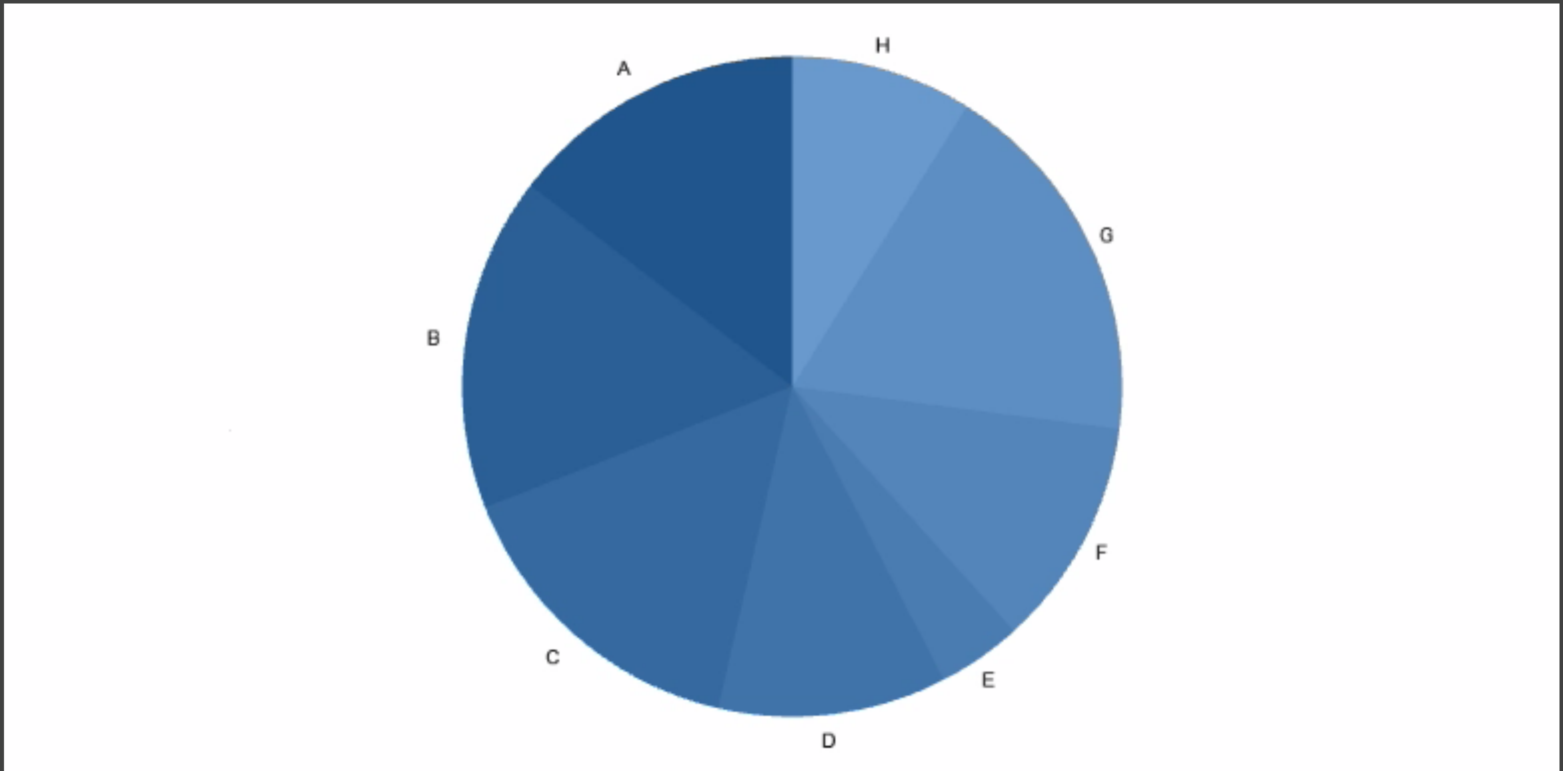
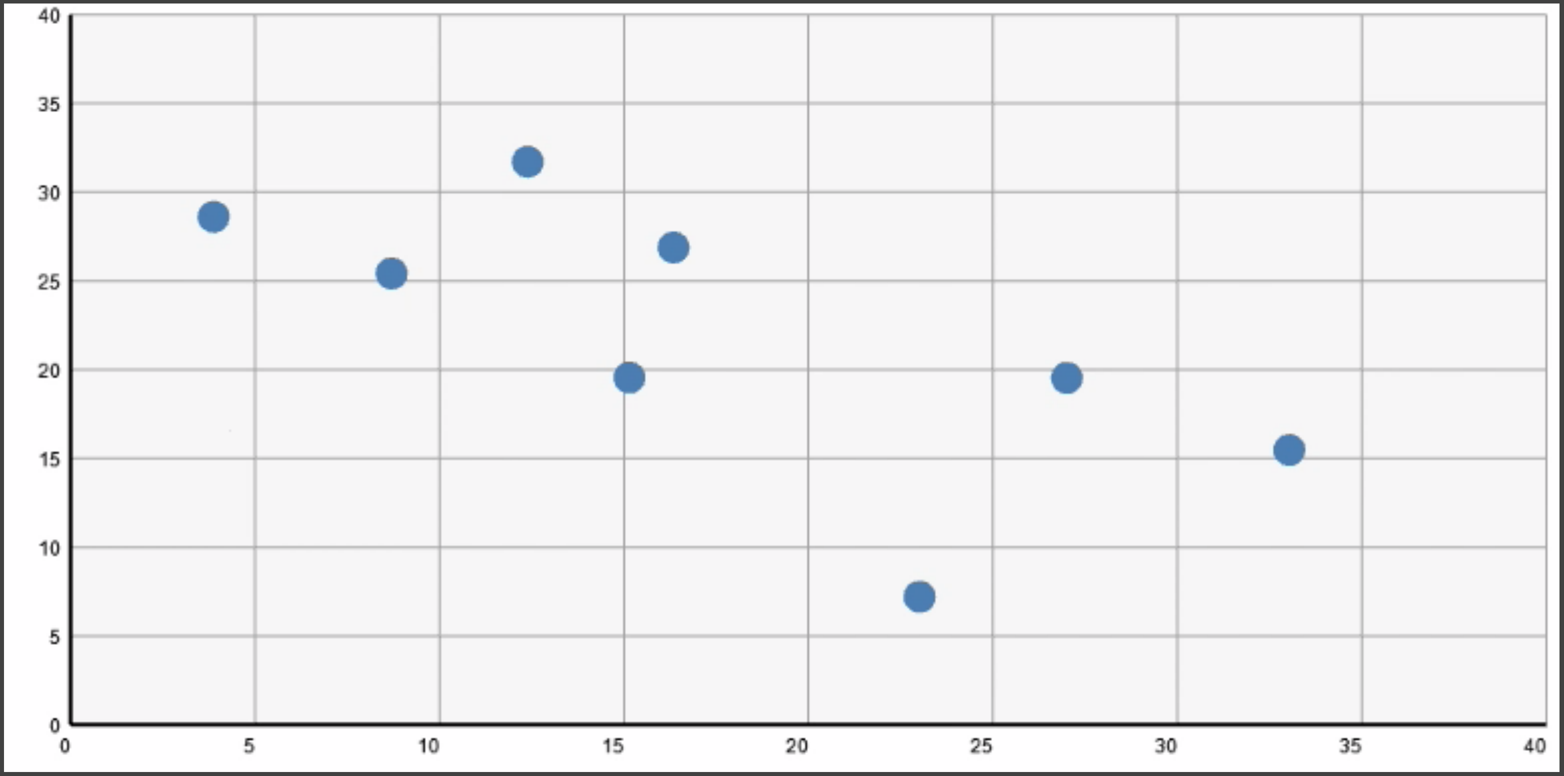
Change Encodings





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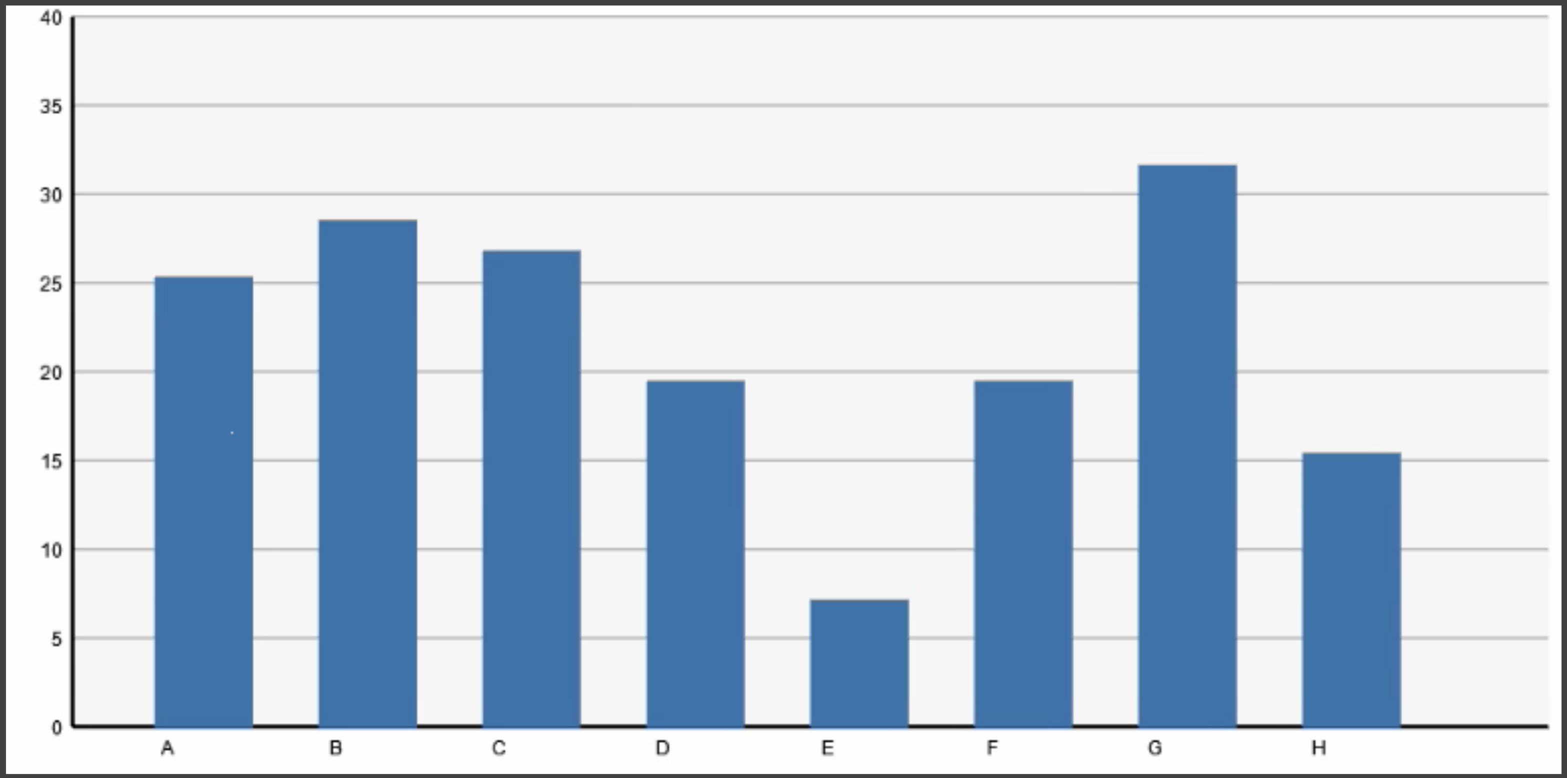

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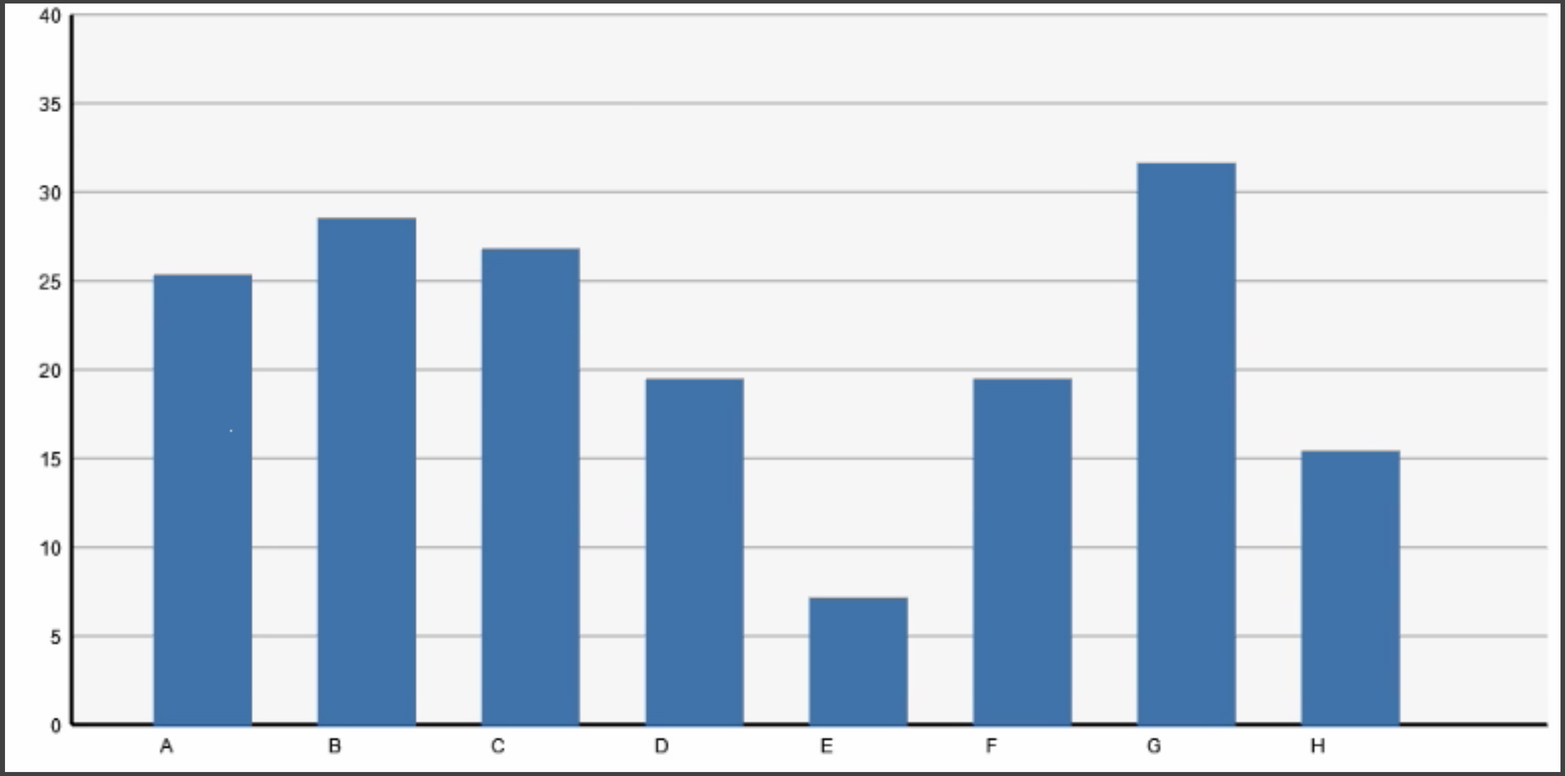
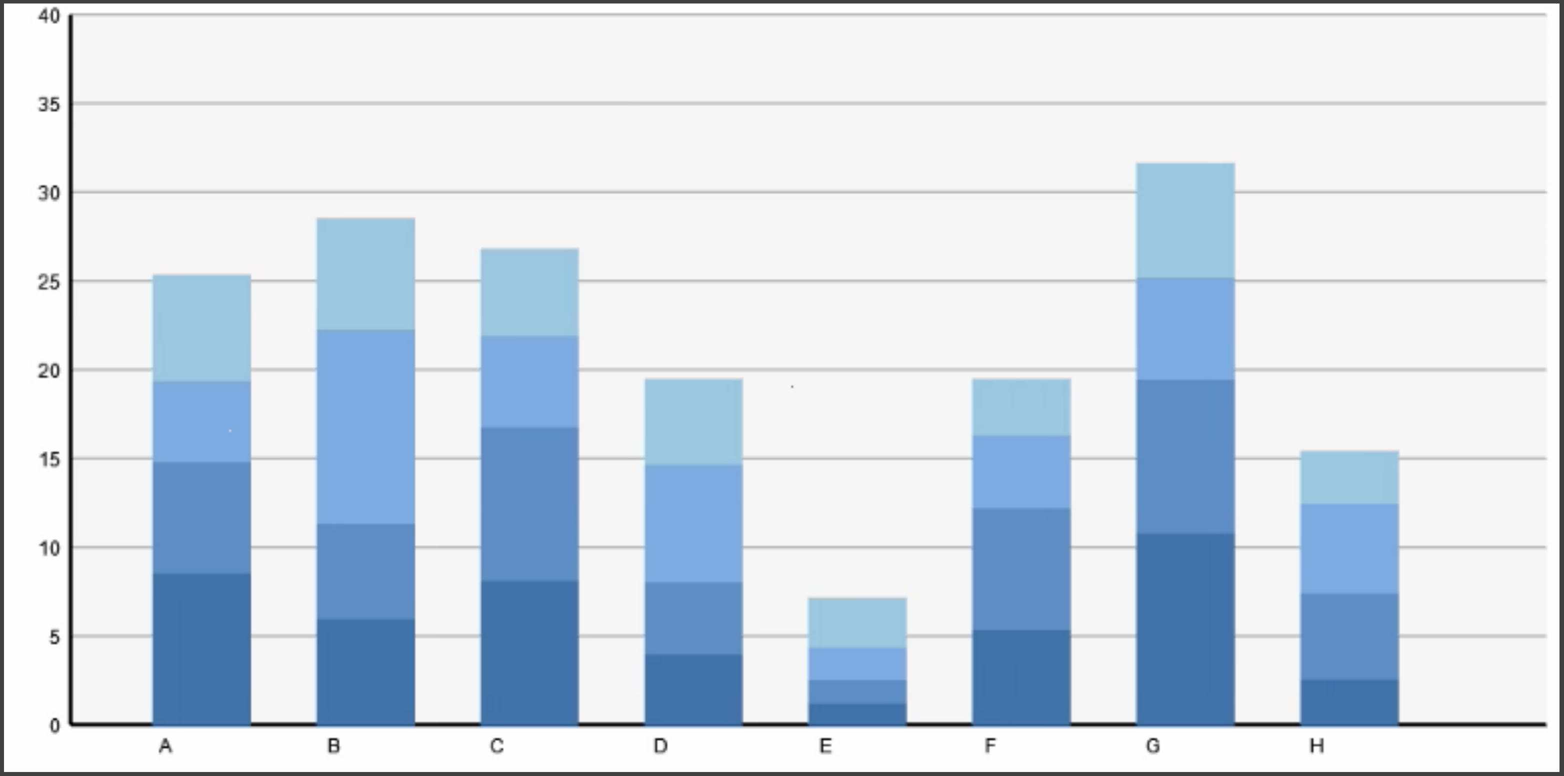
Change Data Dimensions





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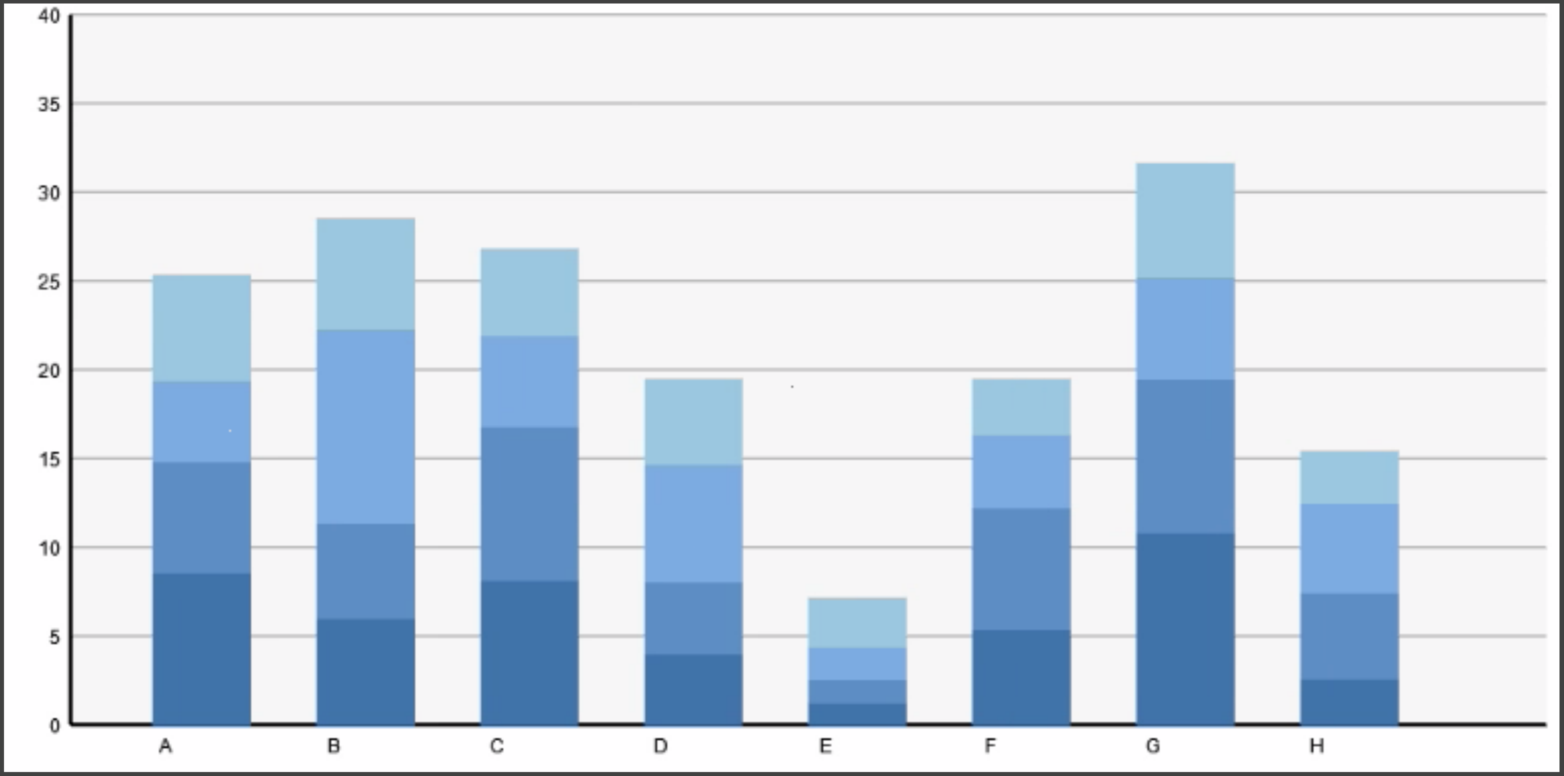

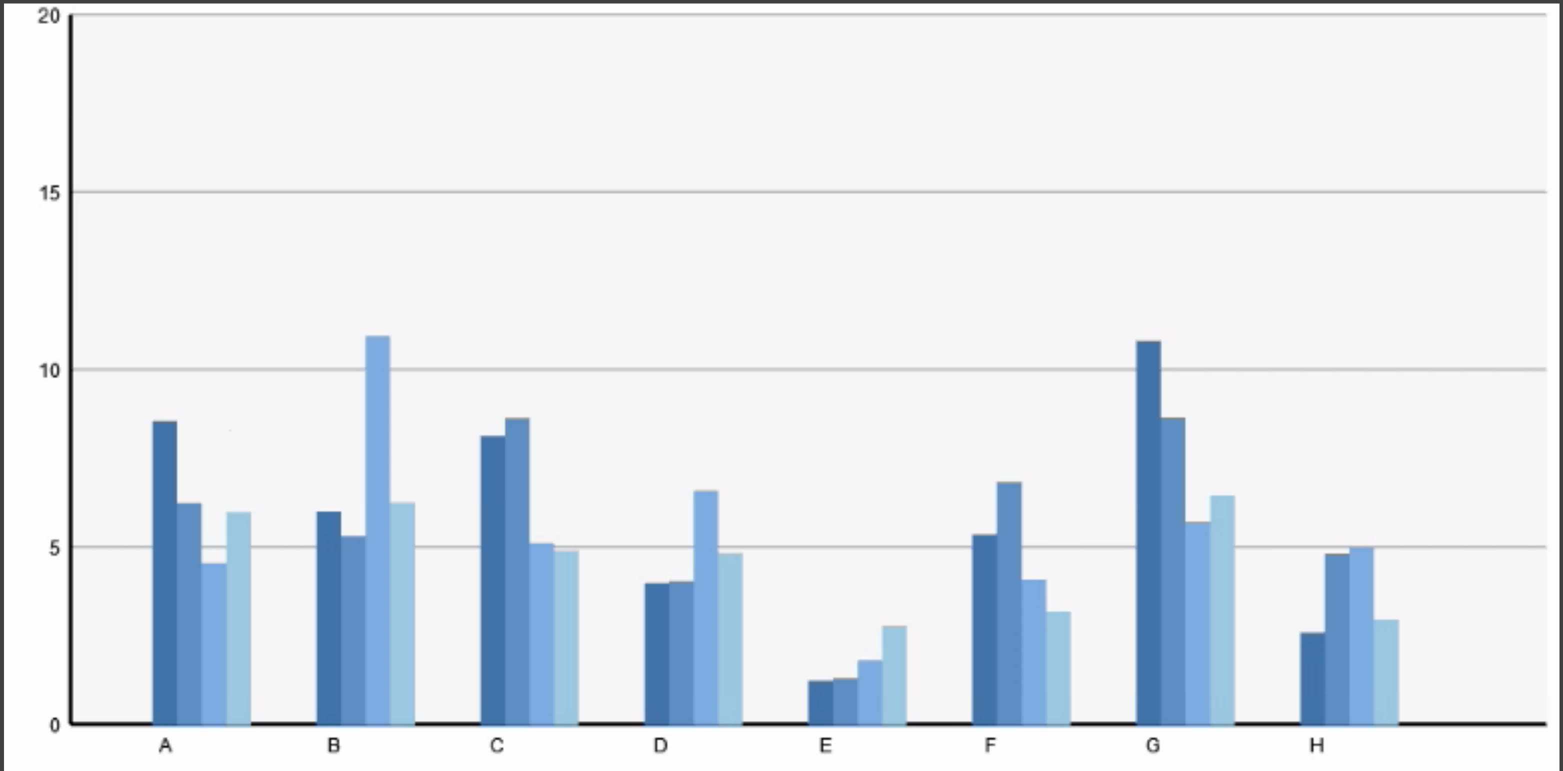

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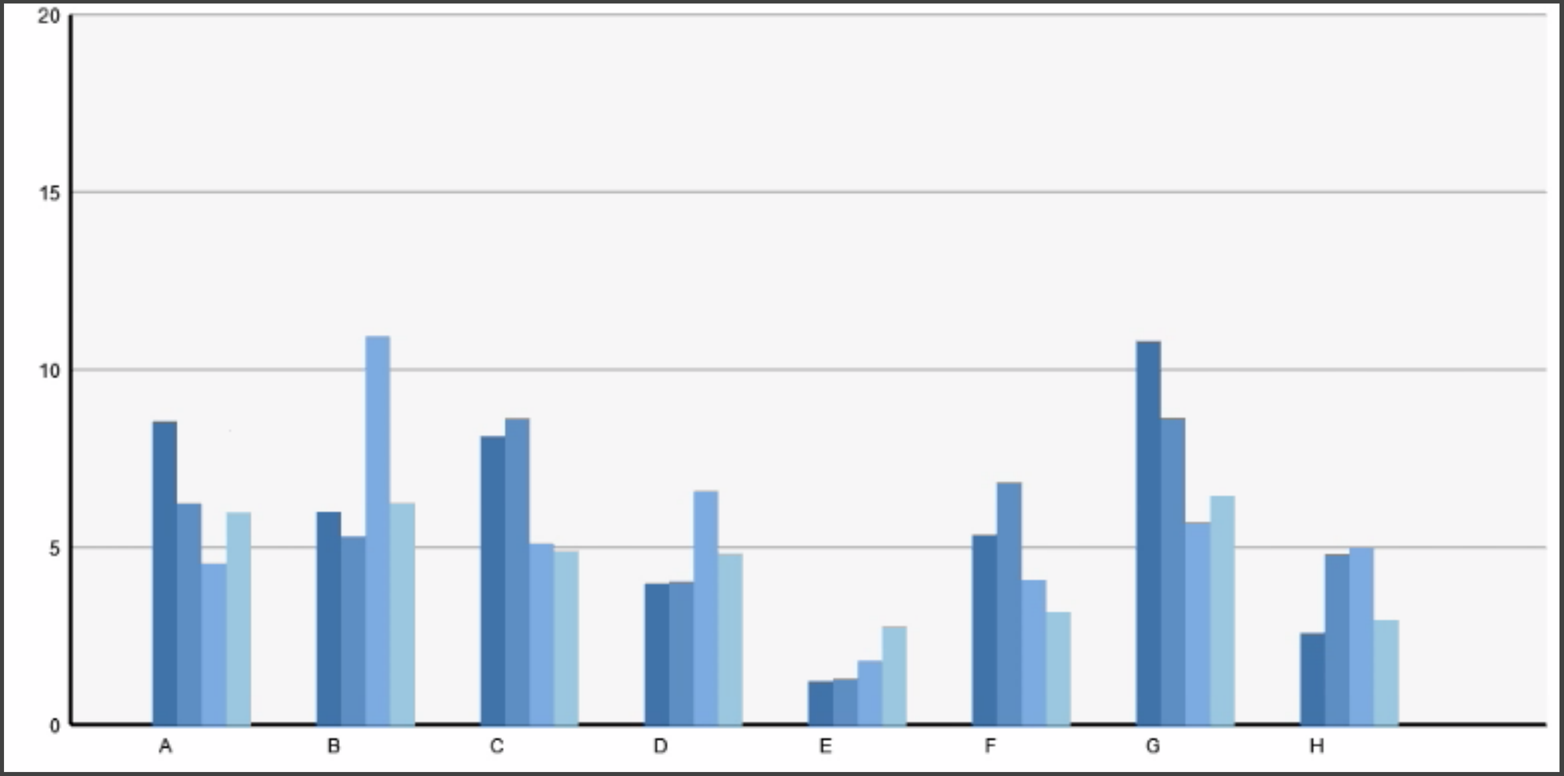
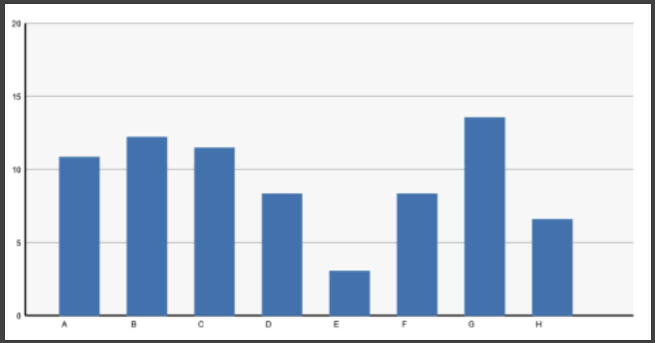
Change Encodings + Axis Scales



Data Graphics & Transitions

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

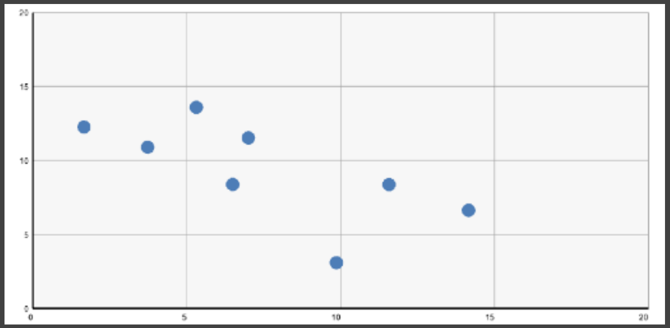
Visual Encoding



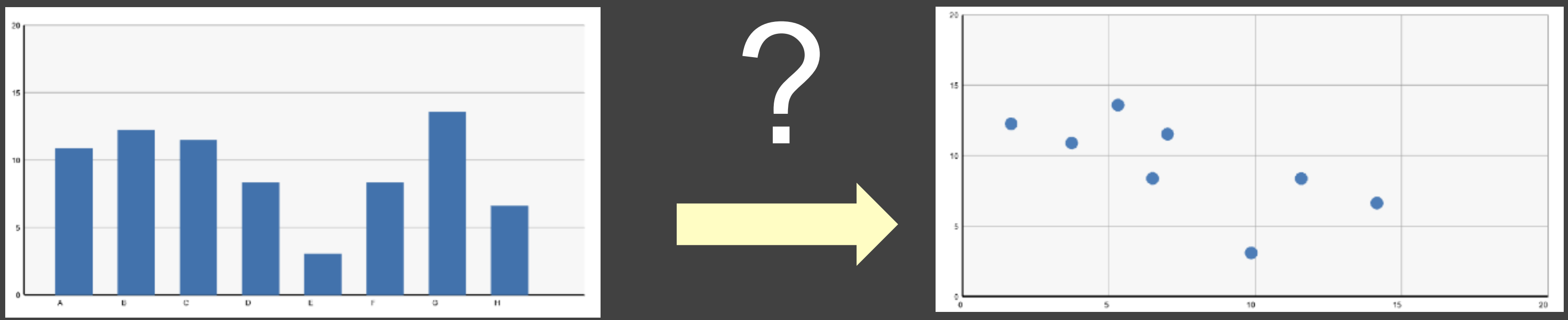
Change selected data dimensions or encodings

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

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

[from Tversky 02]

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

Principles for Animation

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Make transitions as long as needed, but no longer

Objects are harder to track when occluded.

Principles for Animation

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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.

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)

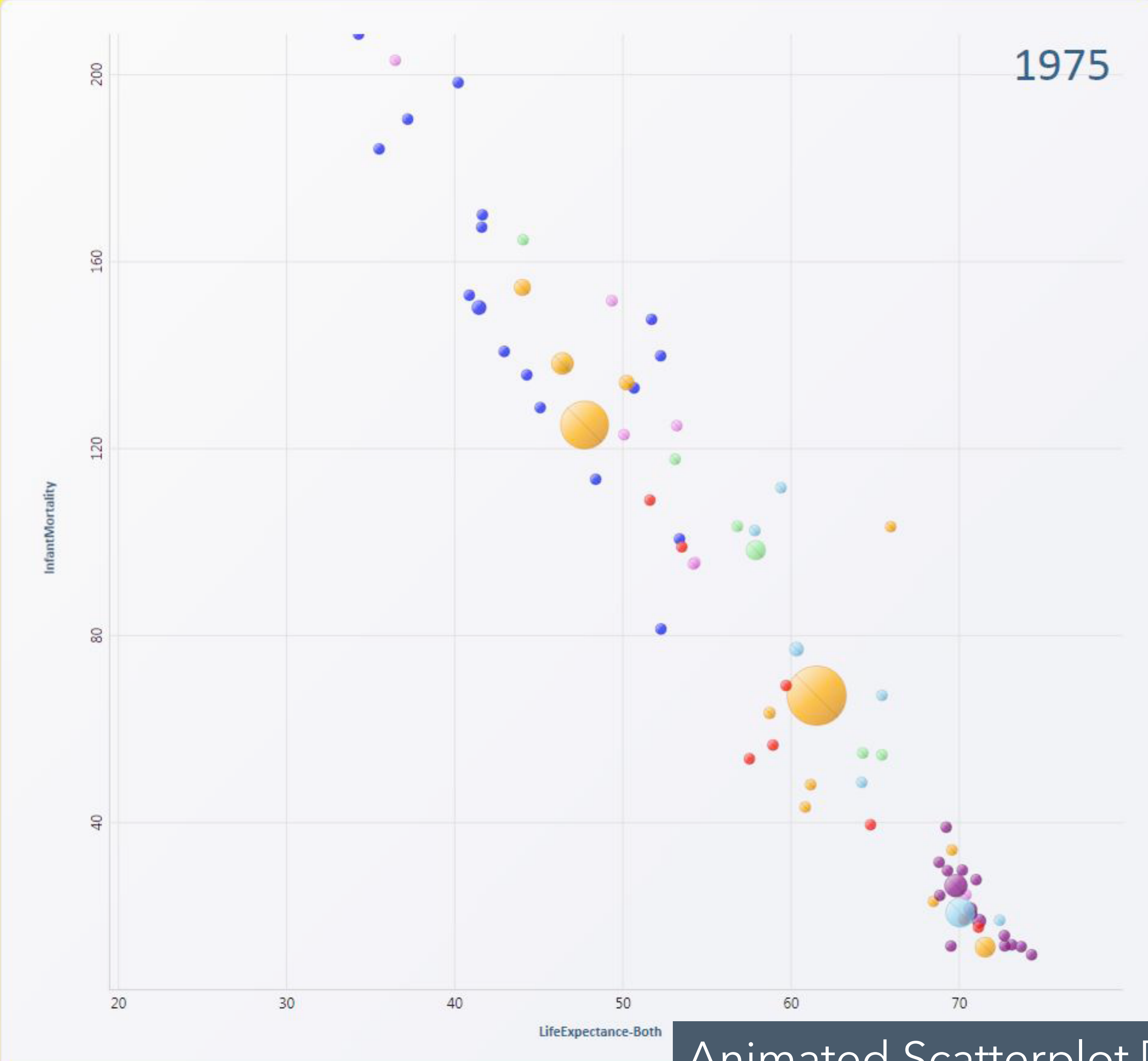
Subjects preferred animated transitions

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.

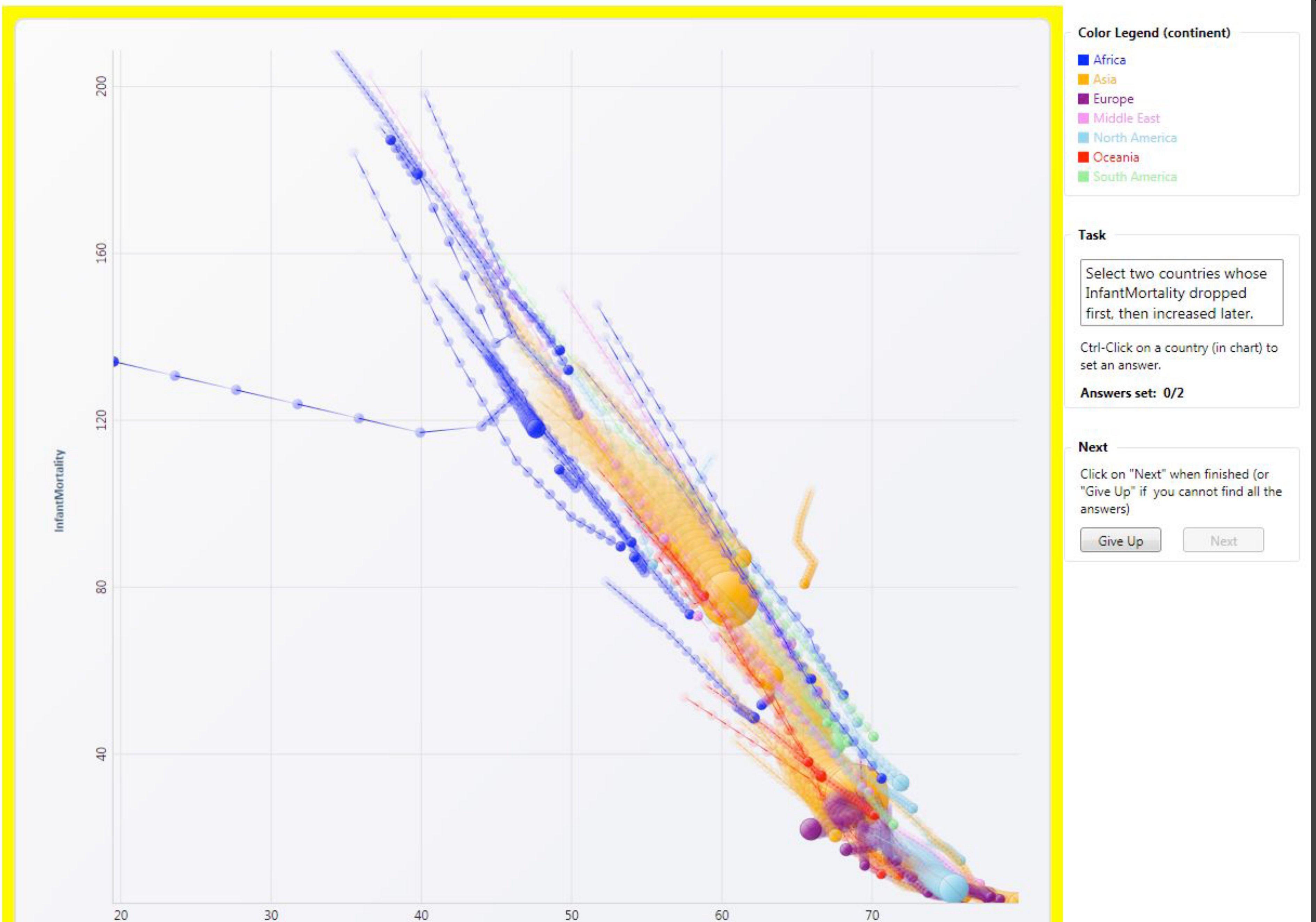
Answers set: 0/2

Next

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

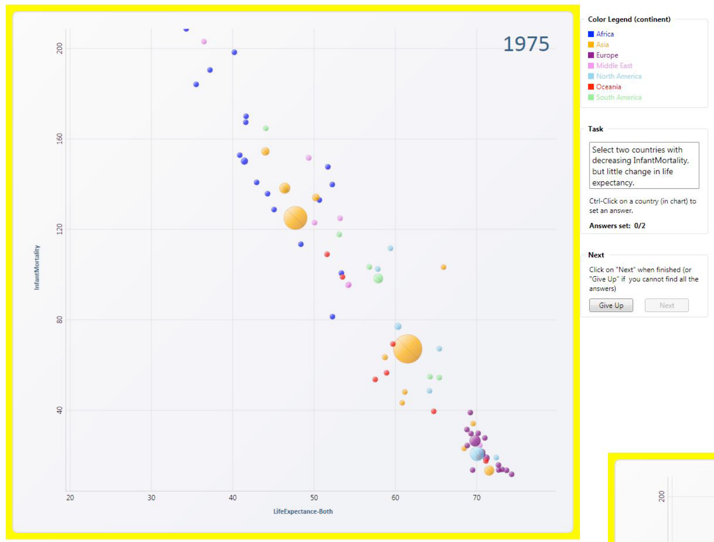
Give Up Next

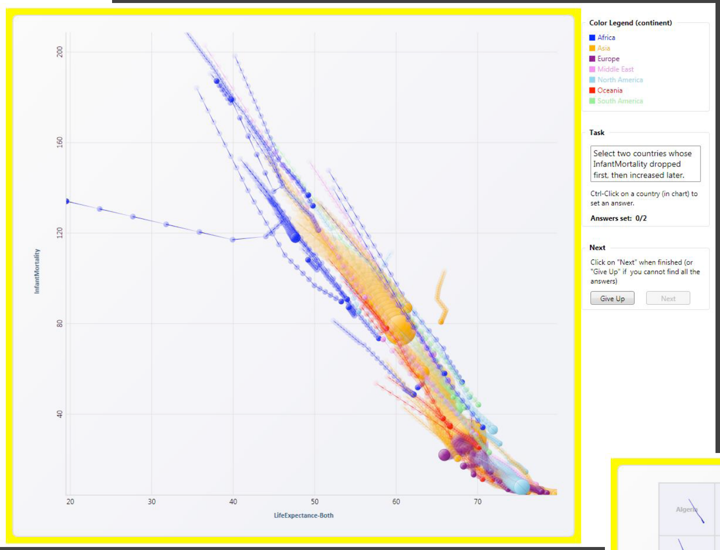
Animated Scatterplot [Robertson 08]

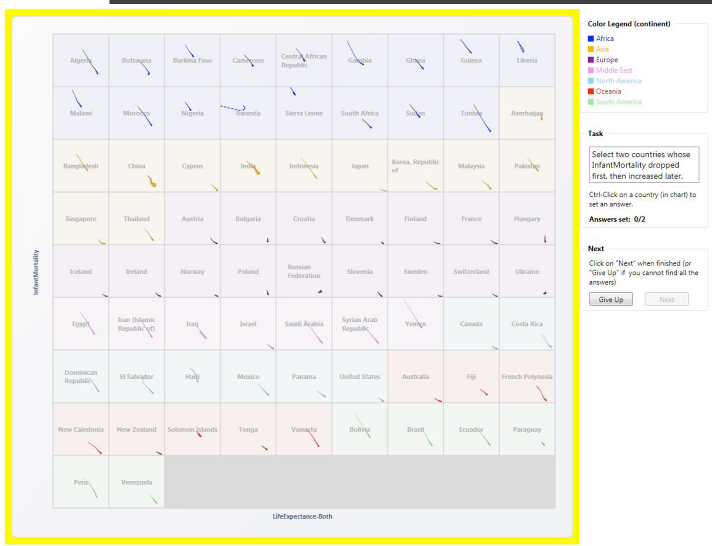


Traces [Robertson 08]

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

Final Project Schedule

Proposal	Fri Nov 9
Milestone	Tue Nov 27
Reviews	Wed Nov 28, Fri Nov 30
Deliverables	Thu Dec 6
Video Showcase	Fri Dec 7 (in class)

Logistics

Final project description posted online

Work in groups of up to 5 people

Start determining your project topic!

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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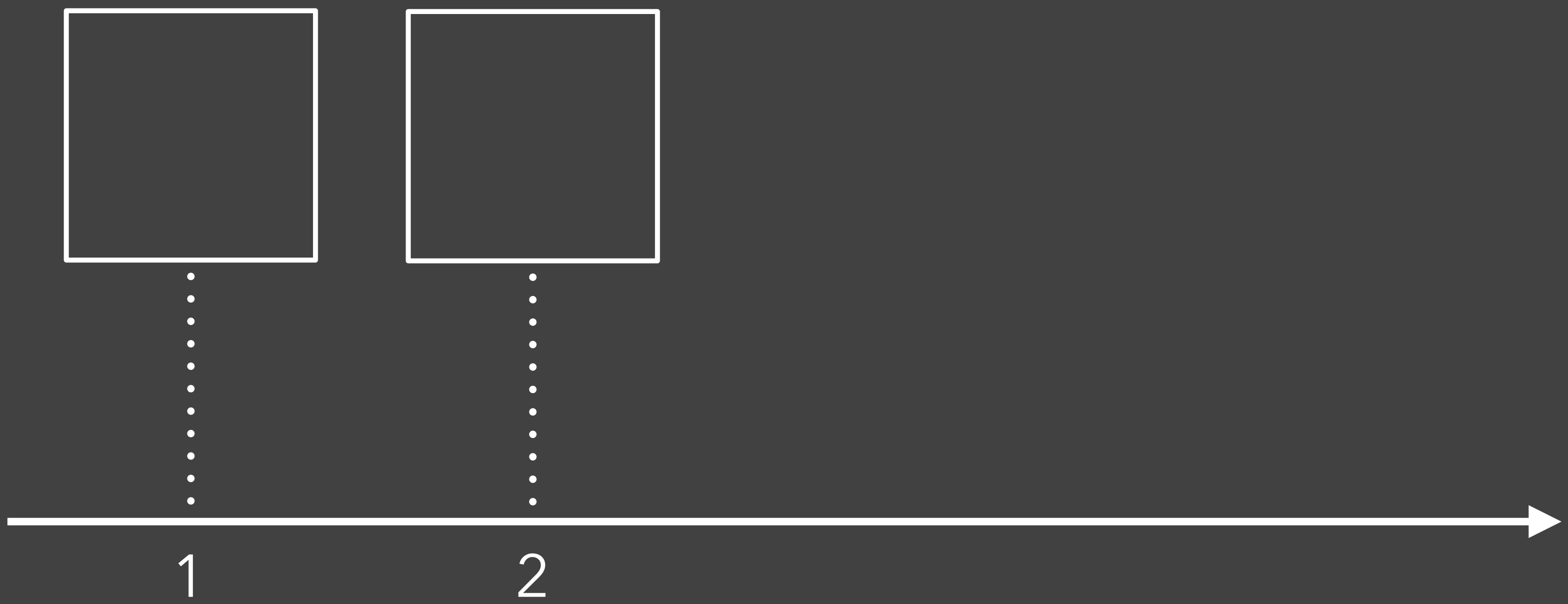

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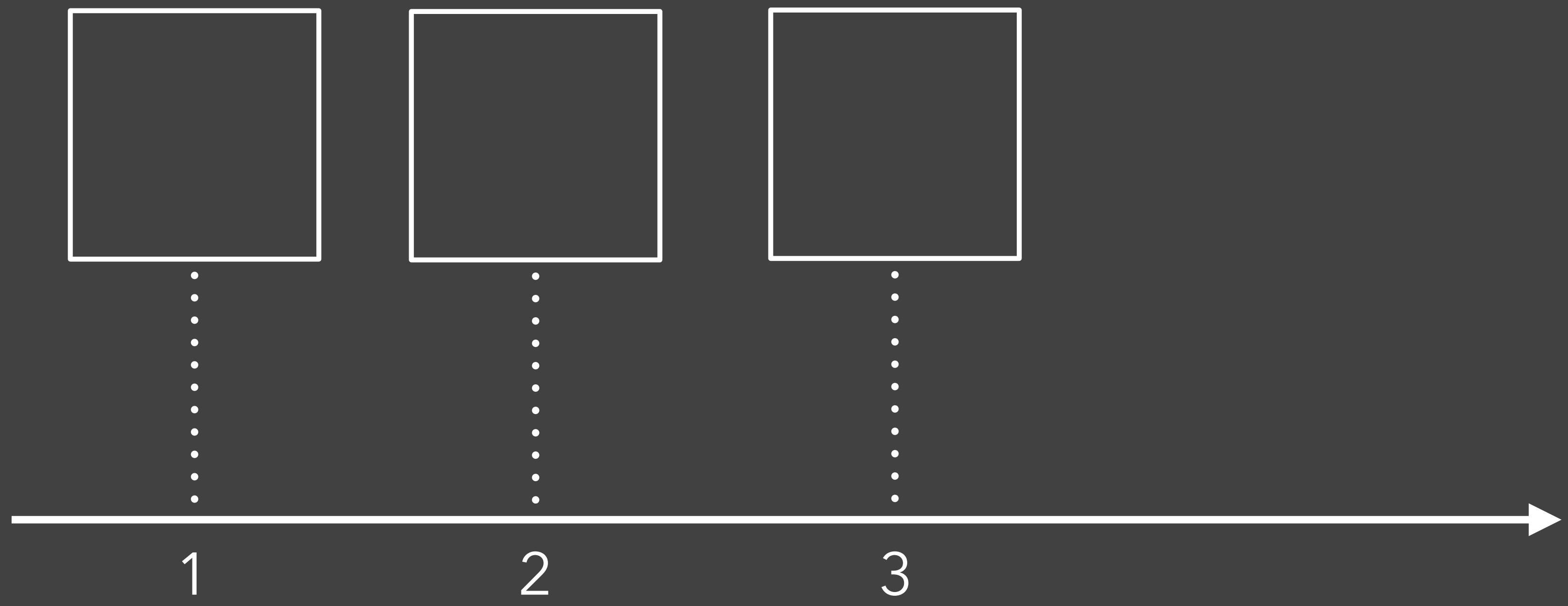

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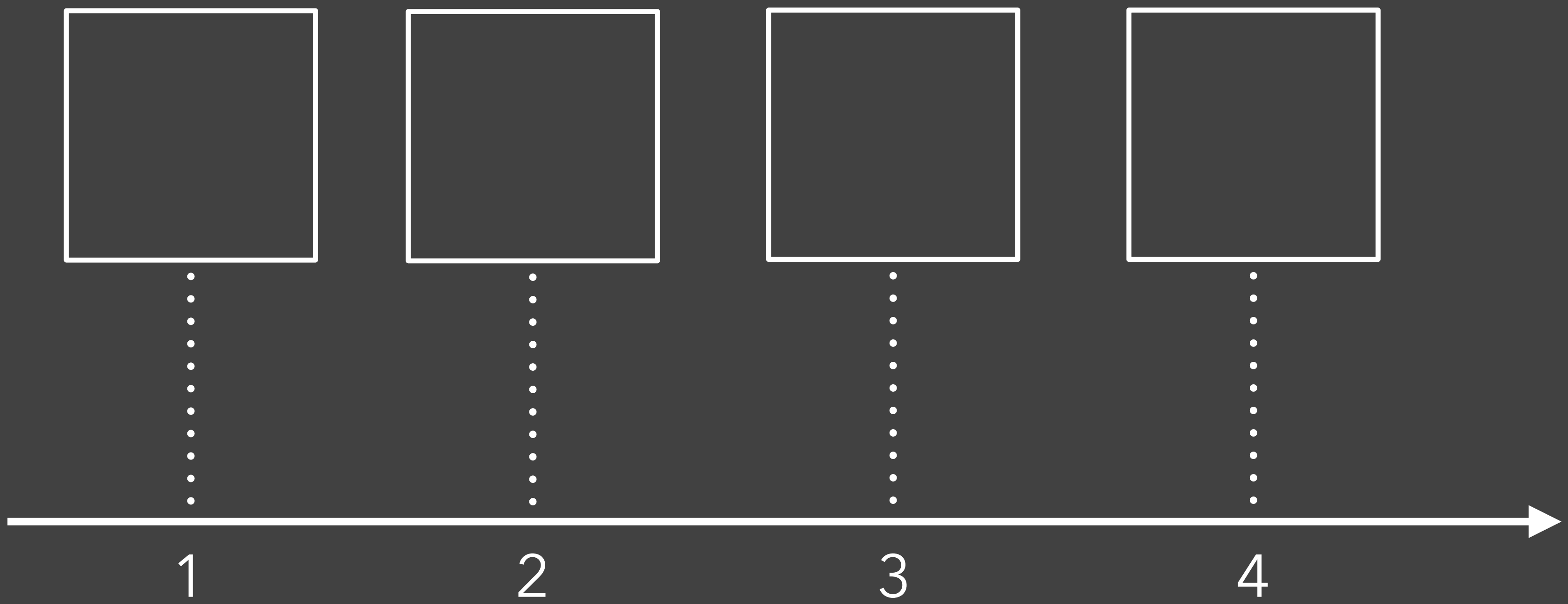

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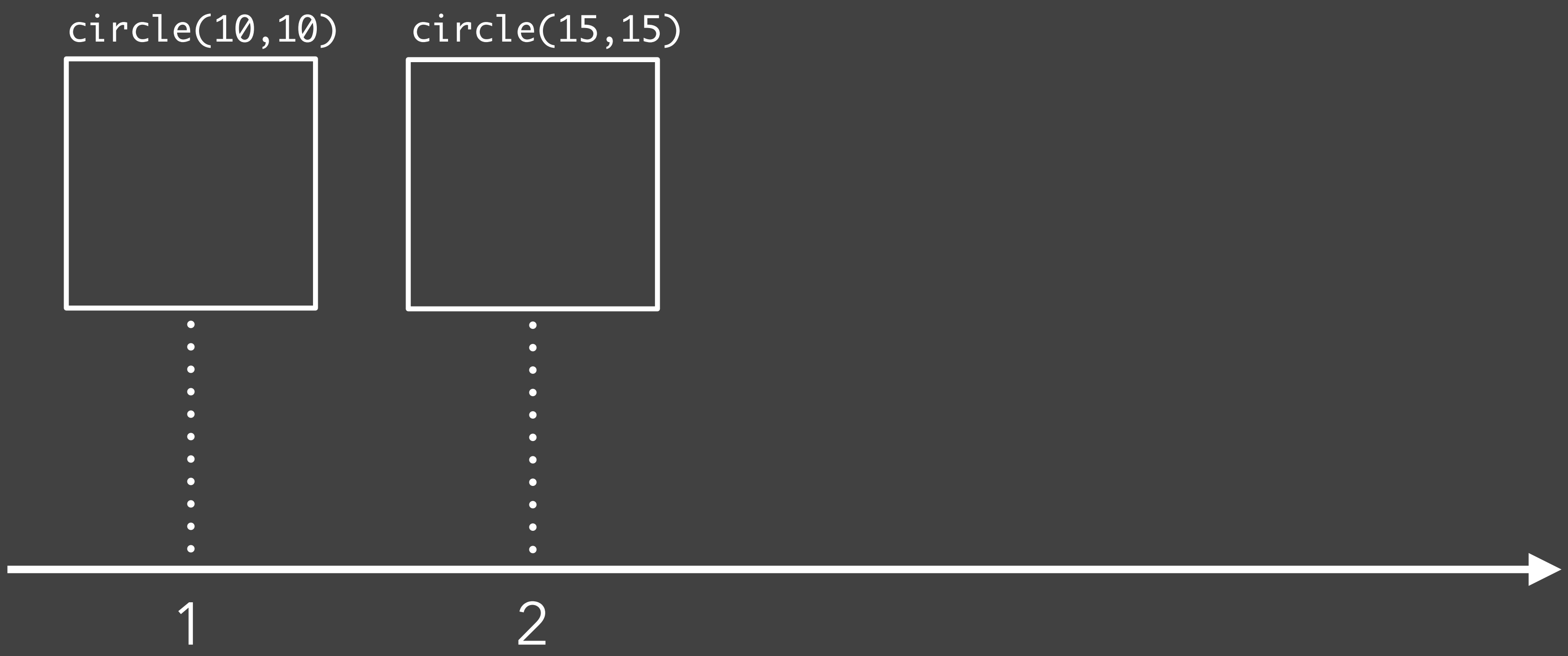

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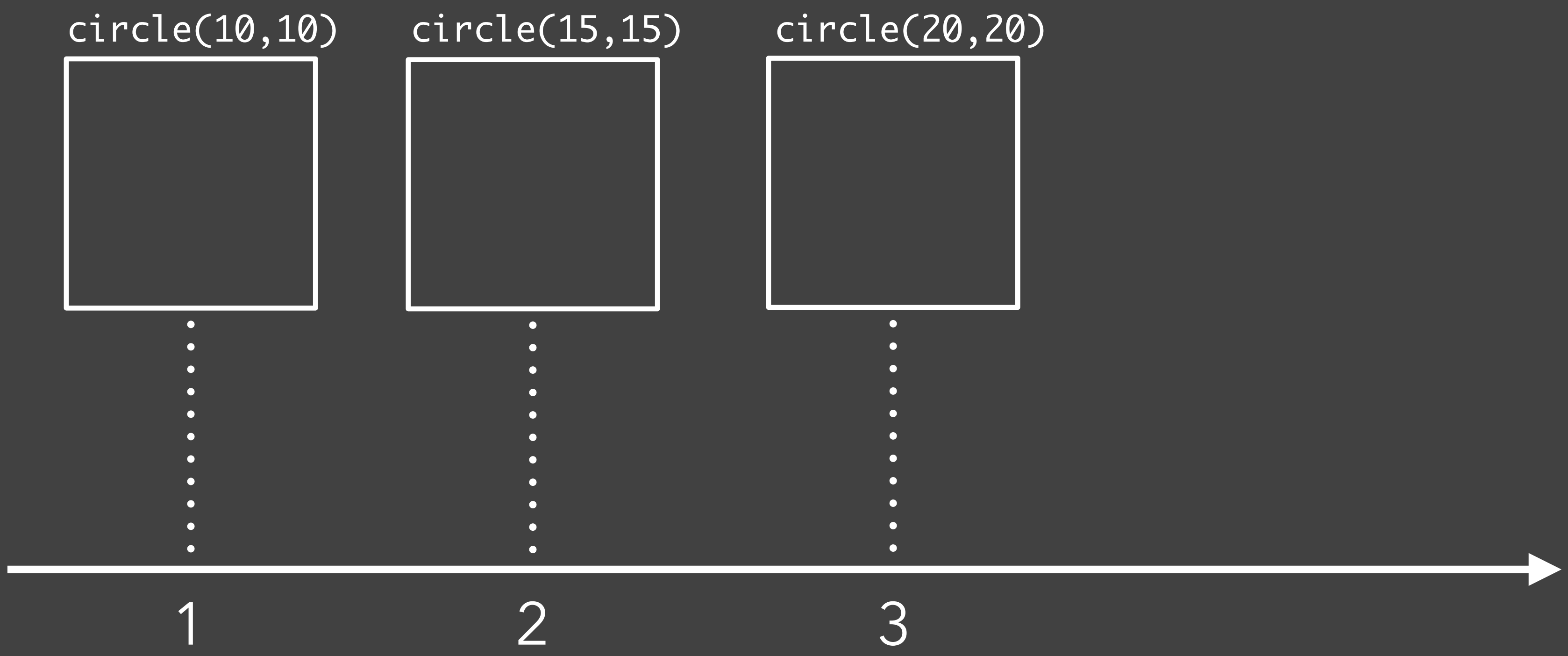

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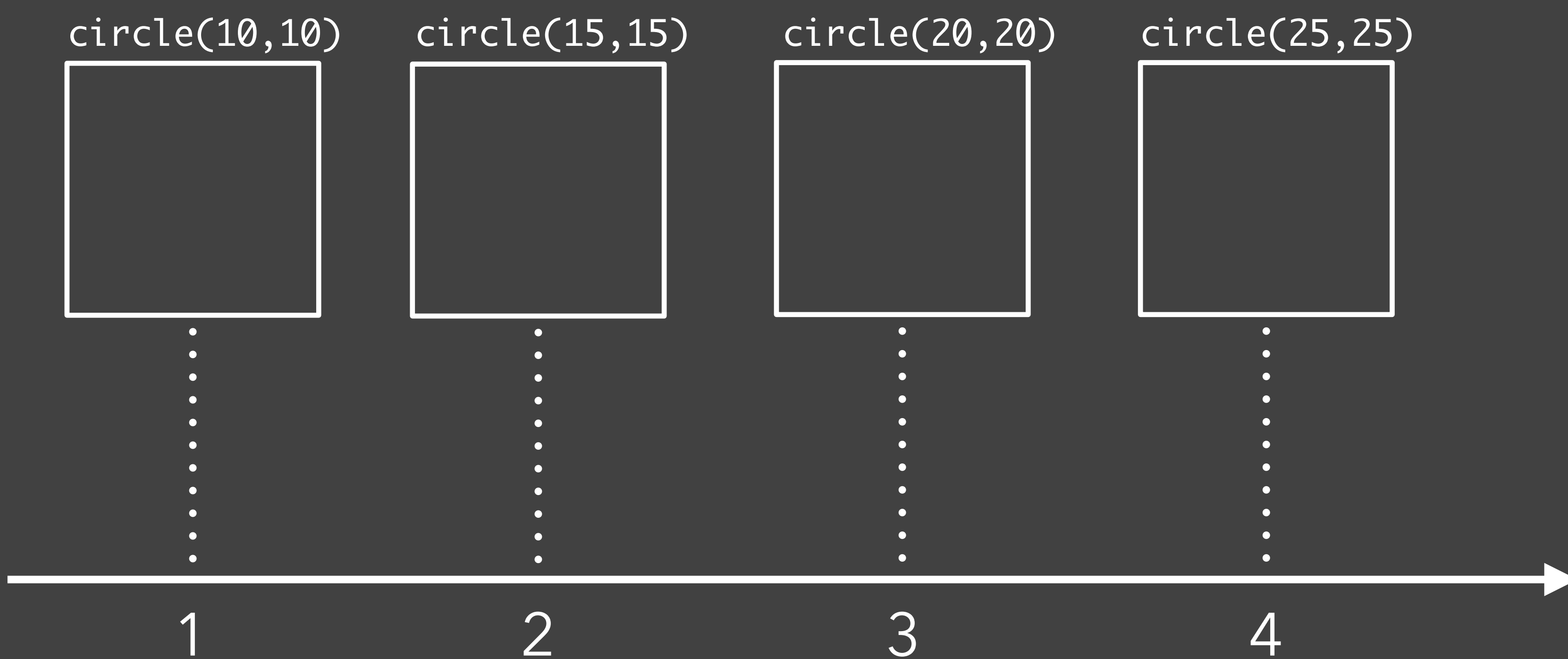

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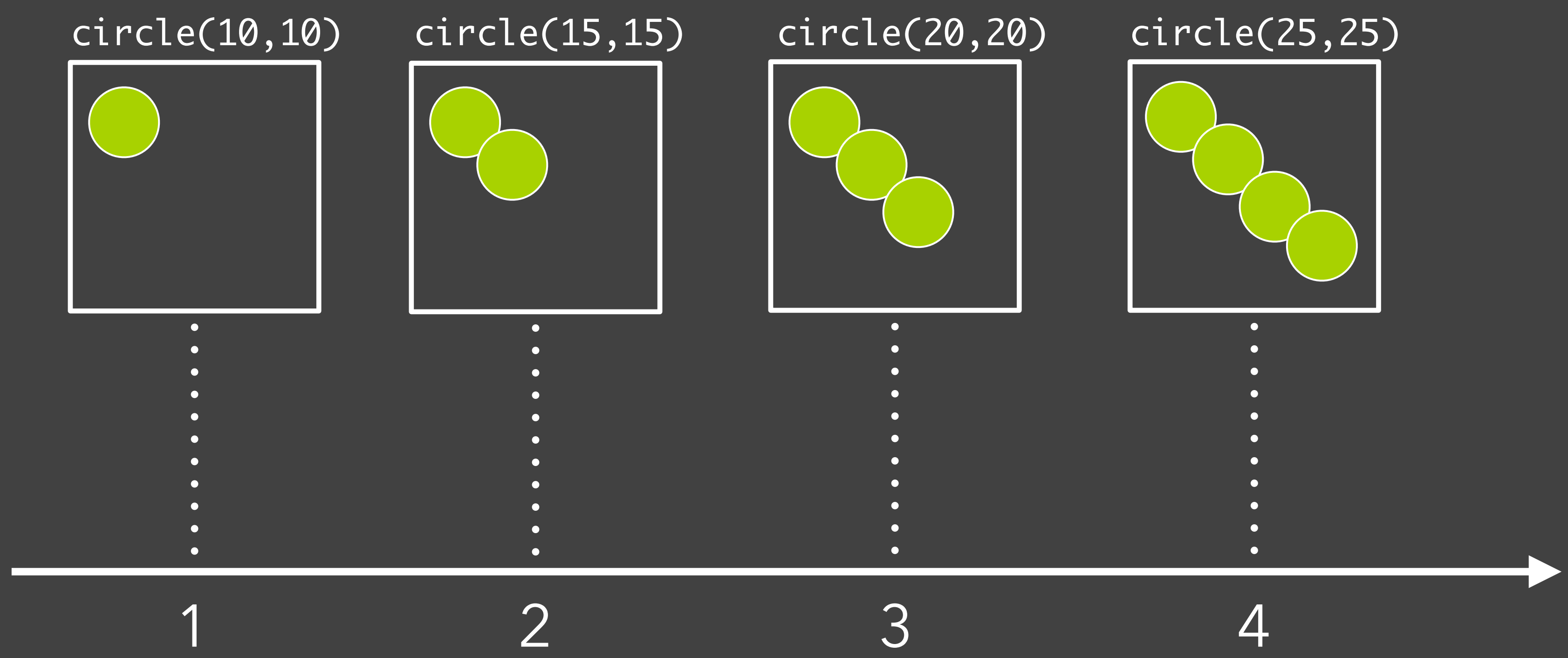

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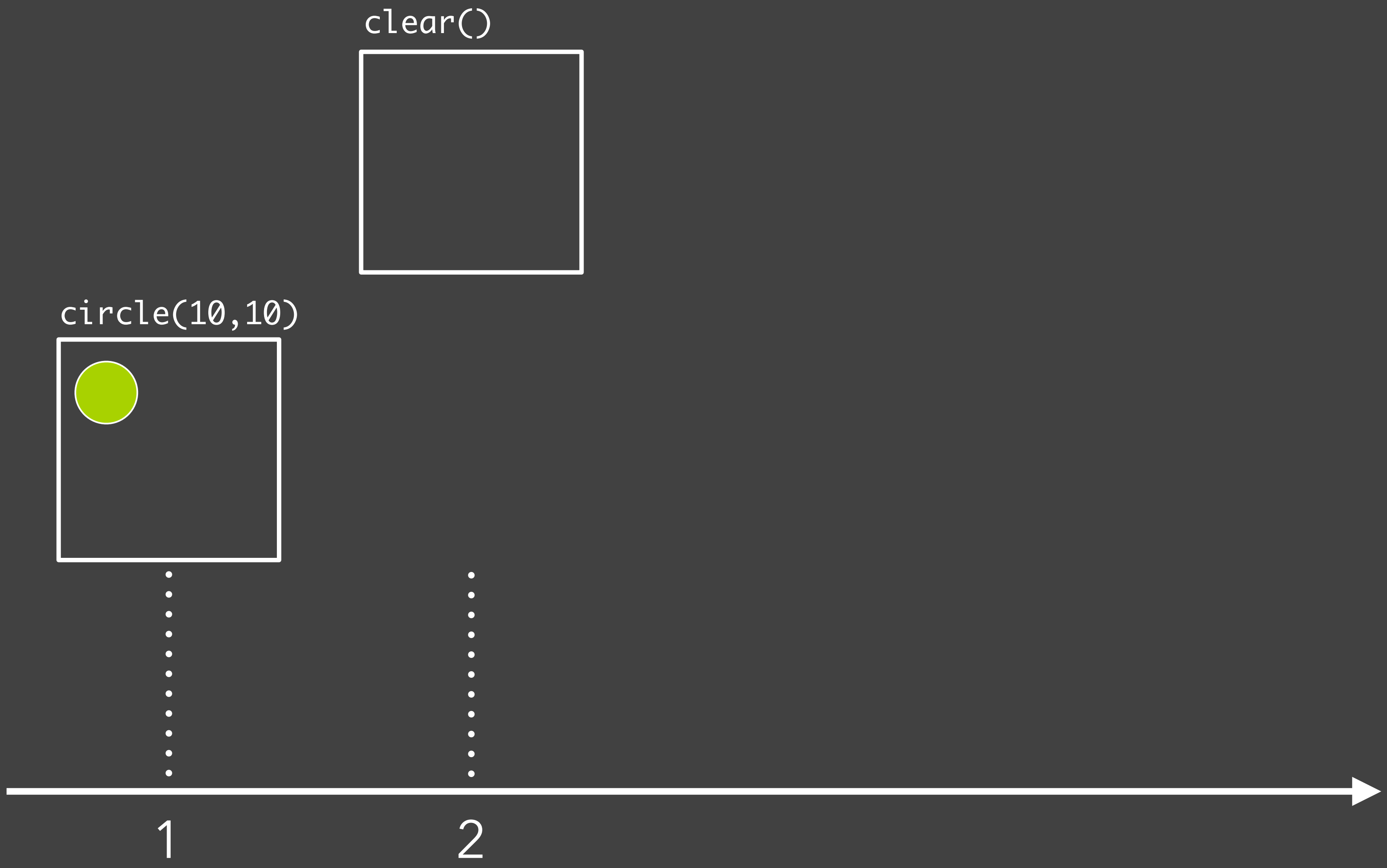

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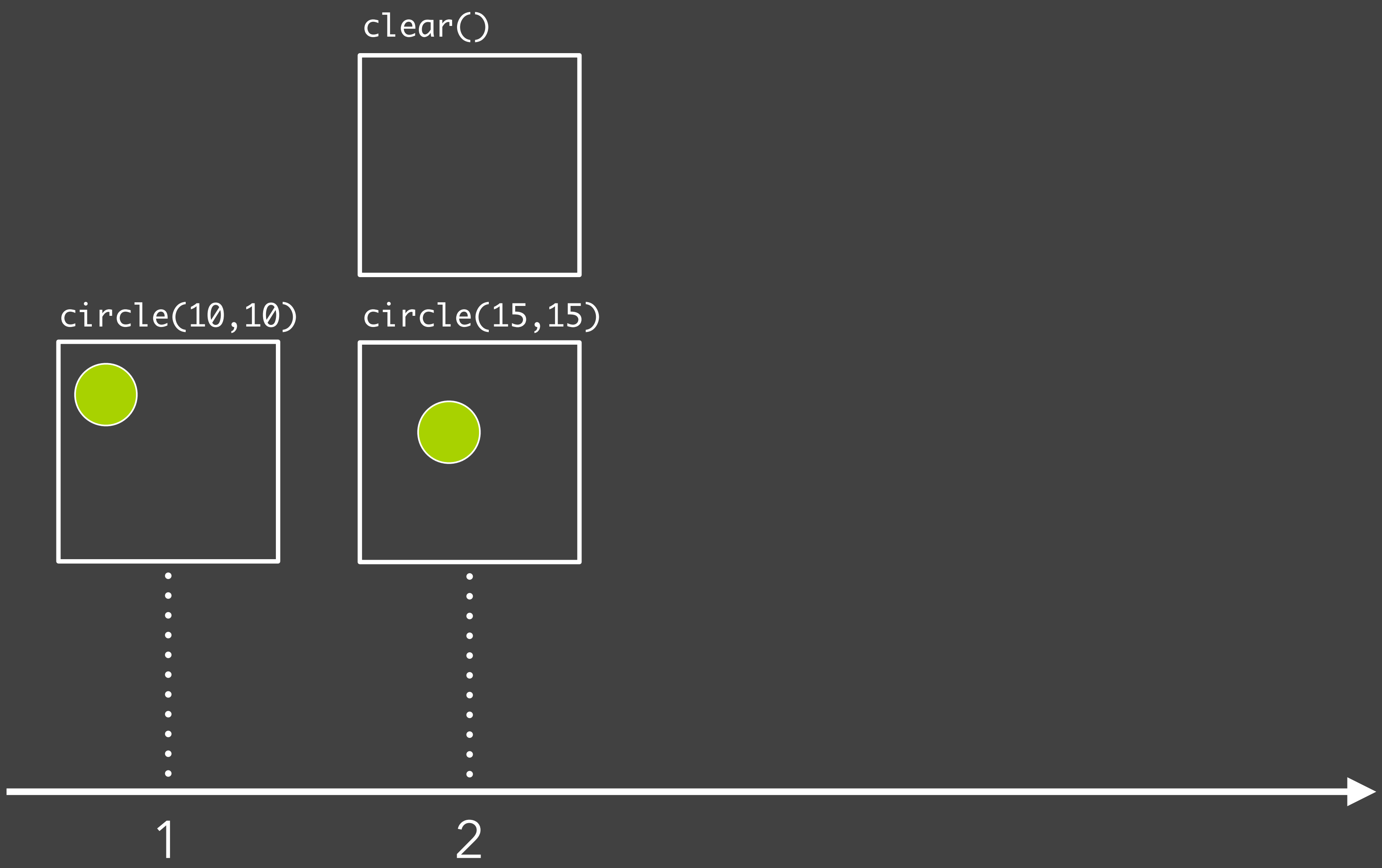

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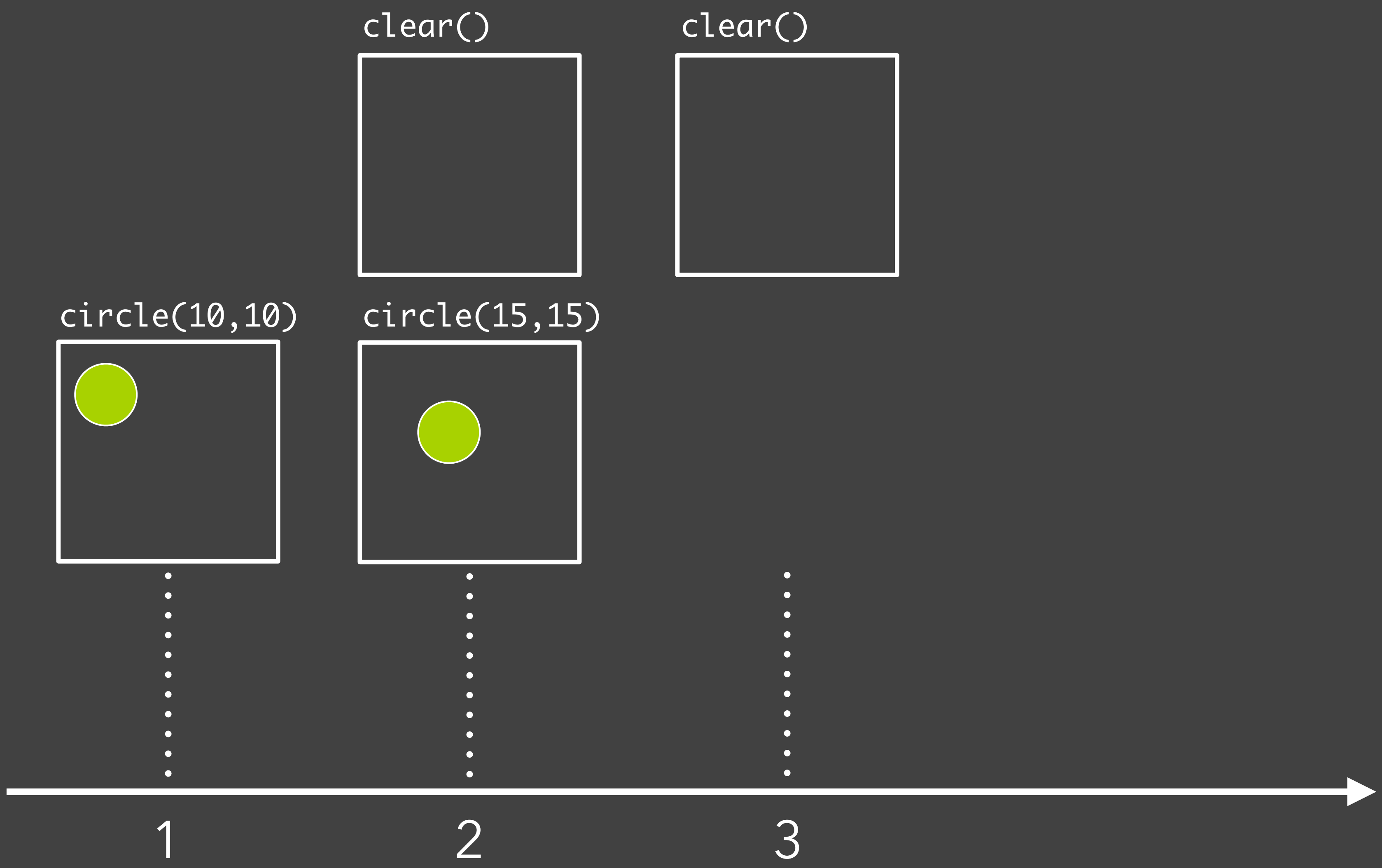

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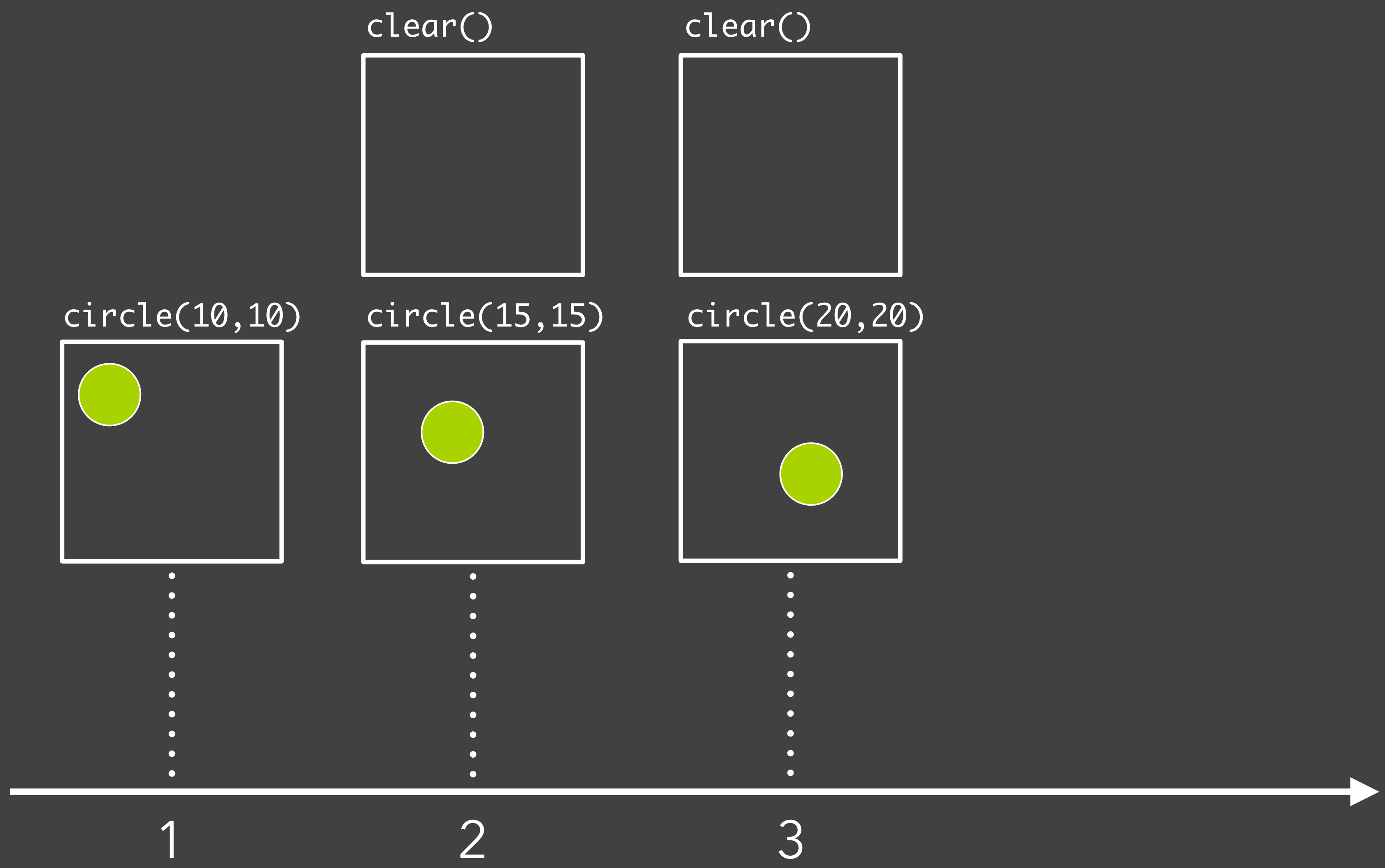

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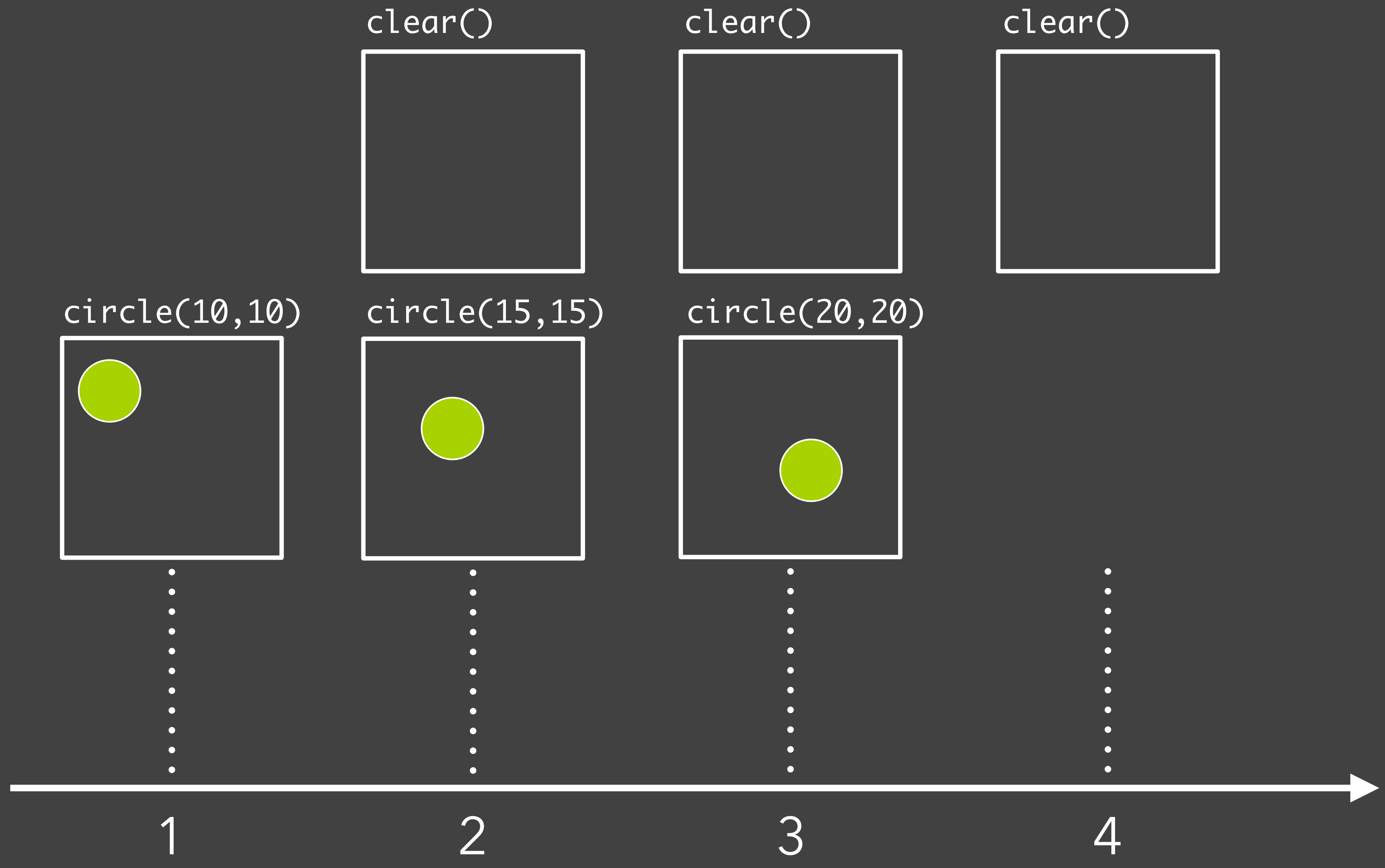

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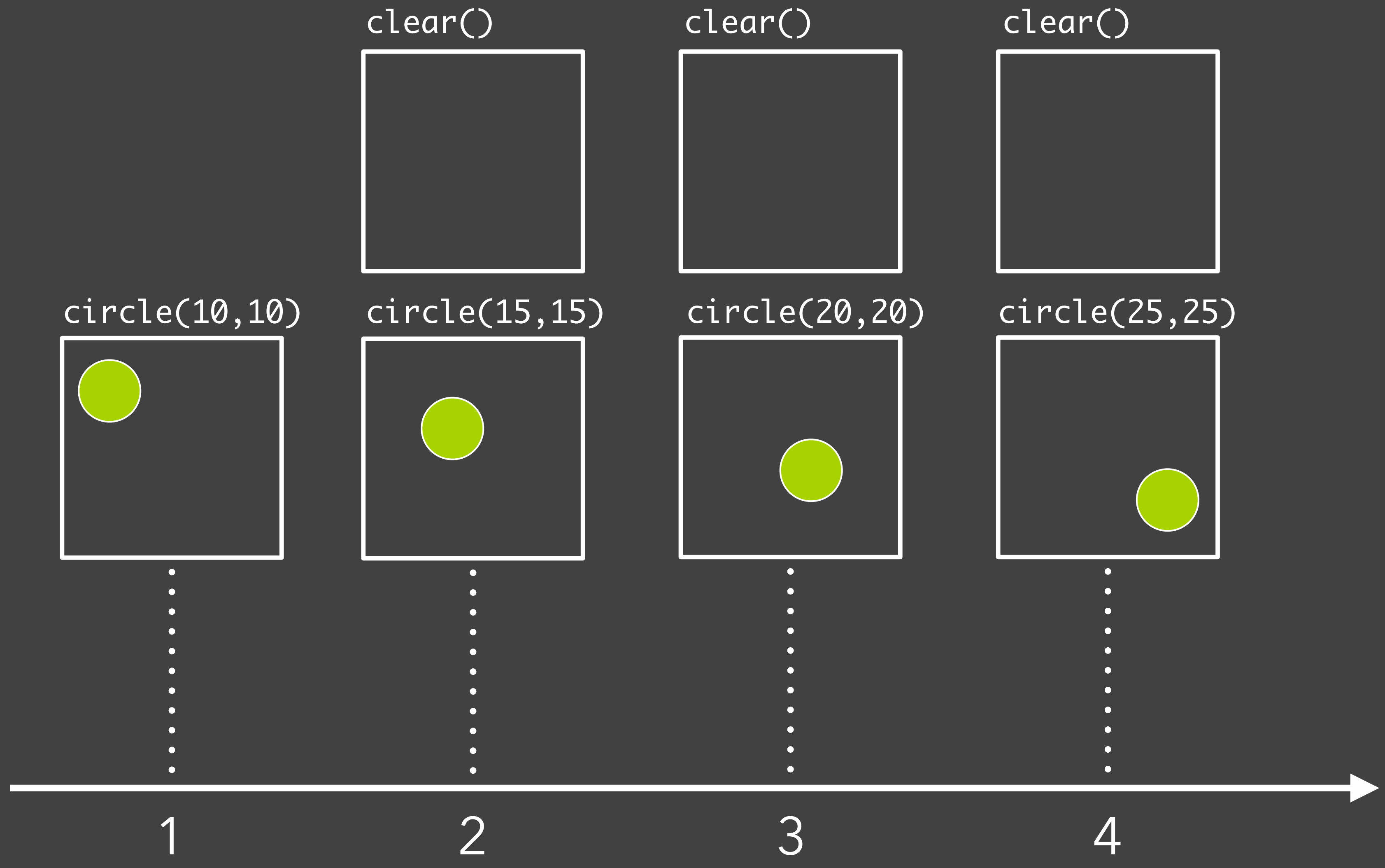

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Transition-Based Animation (Hudson & Stasko '93)
Specify property value, duration & easing
Also called **tweening** (for "in-betweens")
Typically computed via **interpolation**

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

Timing & redraw managed by UI toolkit

Transition-Based Animation

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

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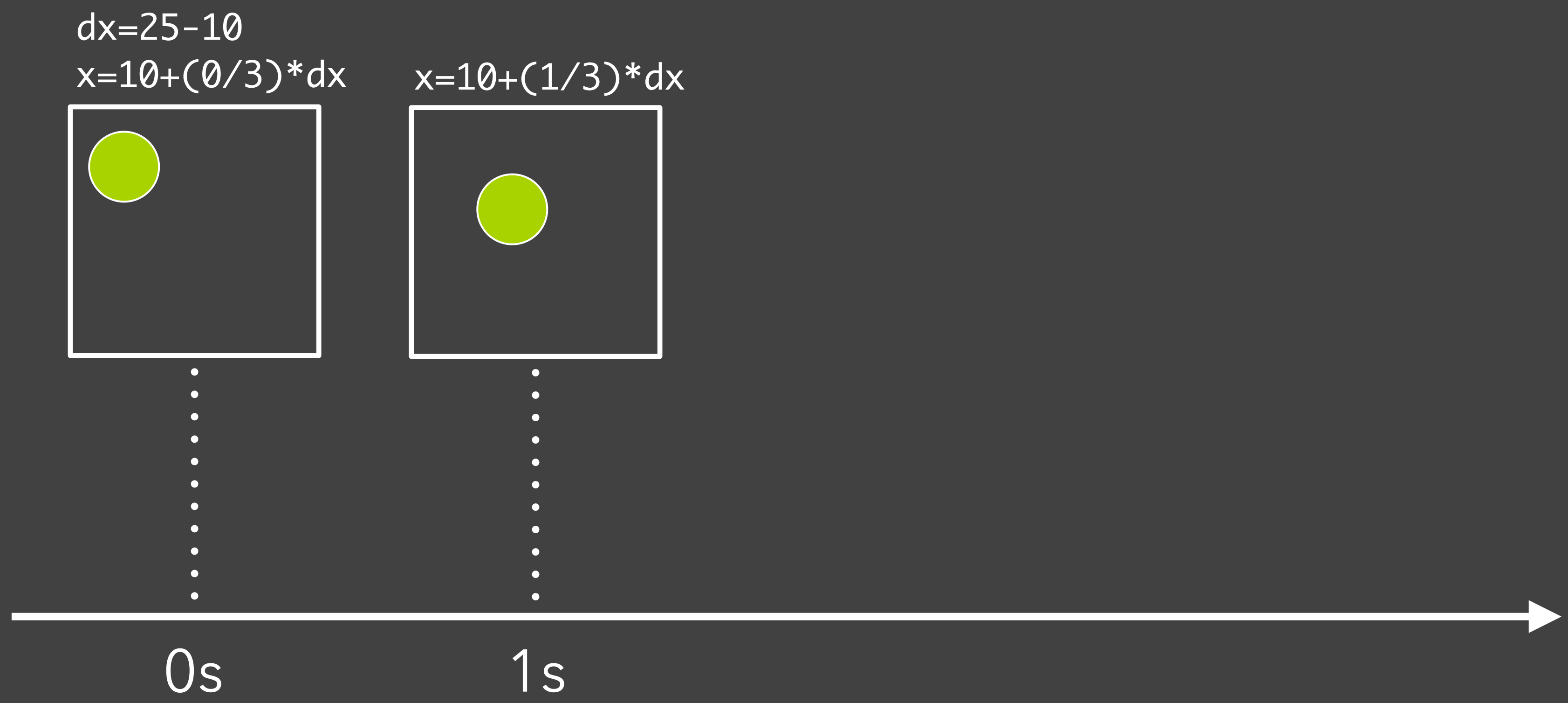

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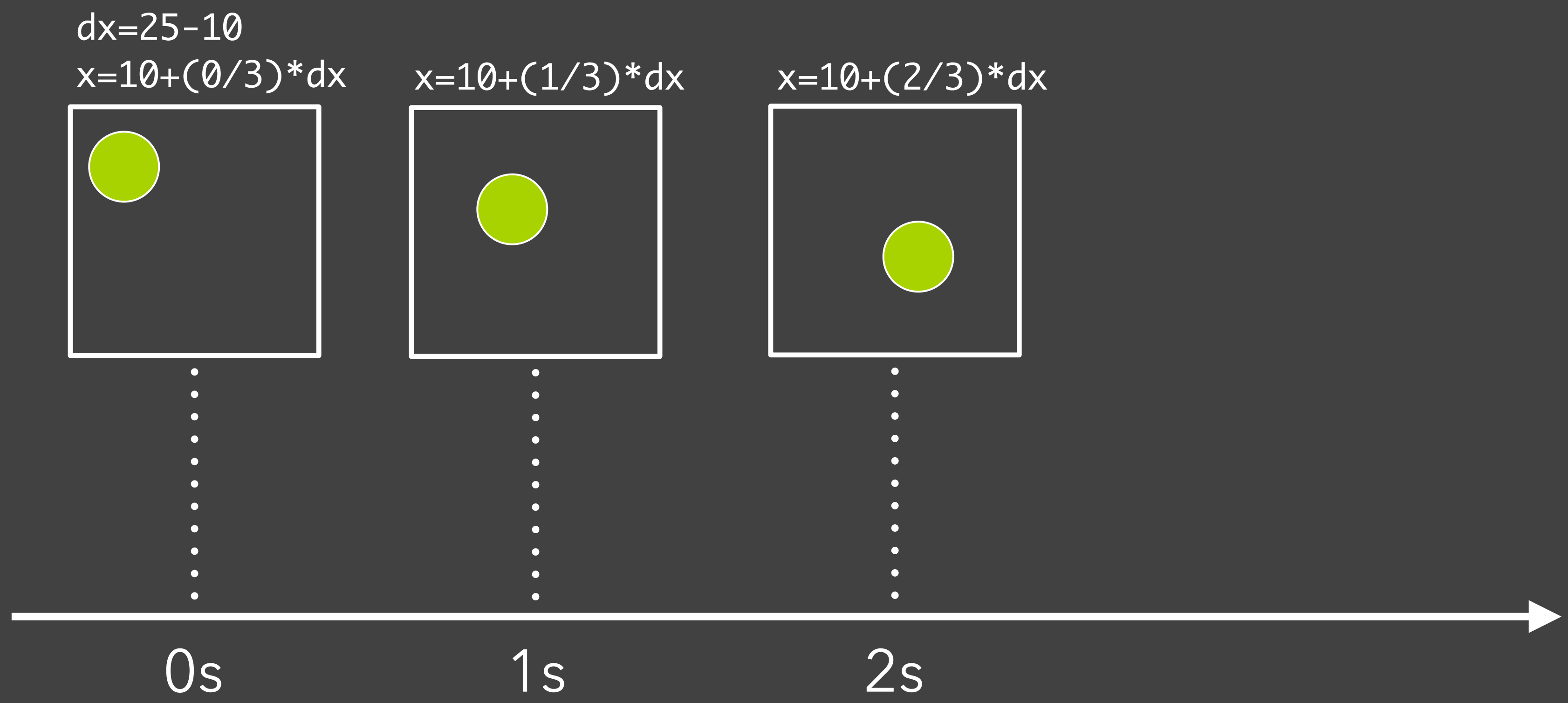

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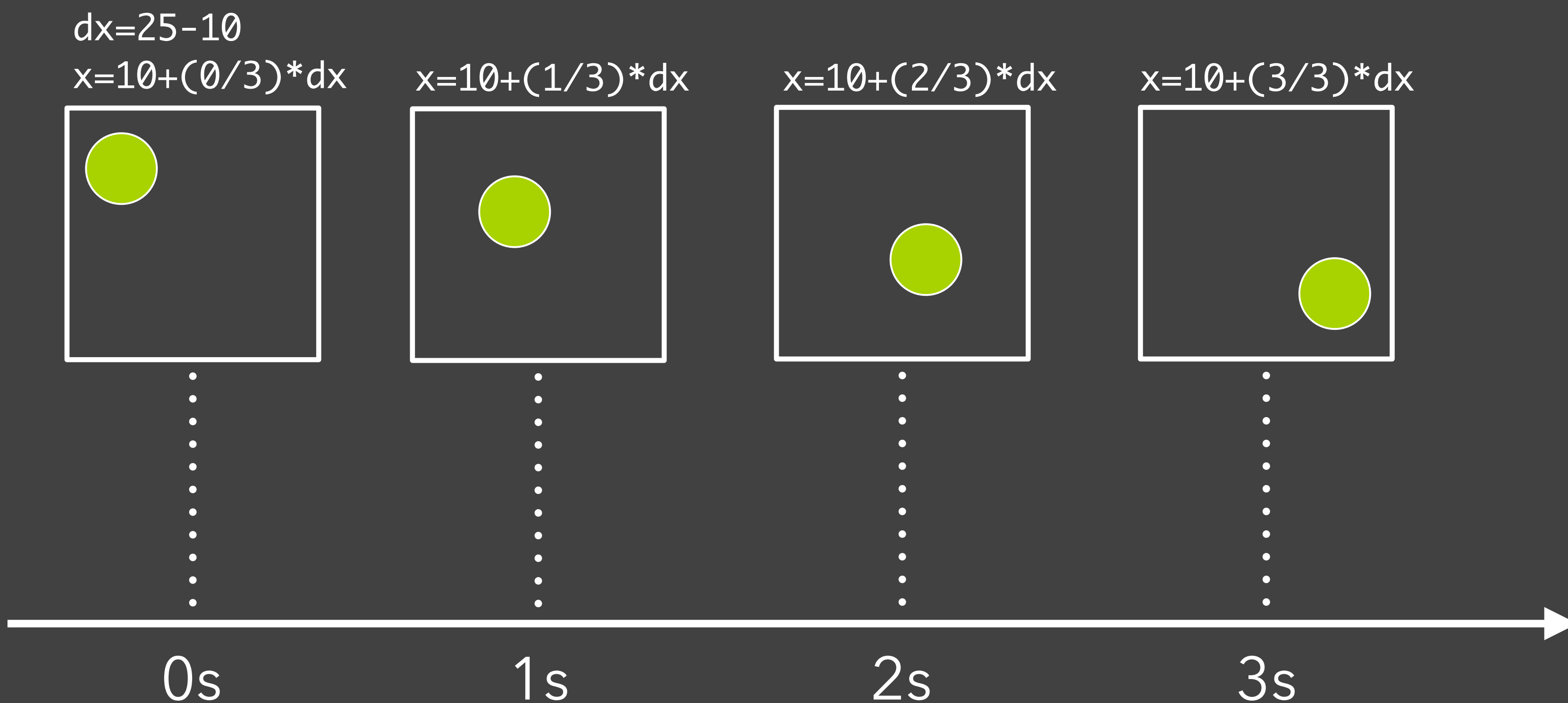

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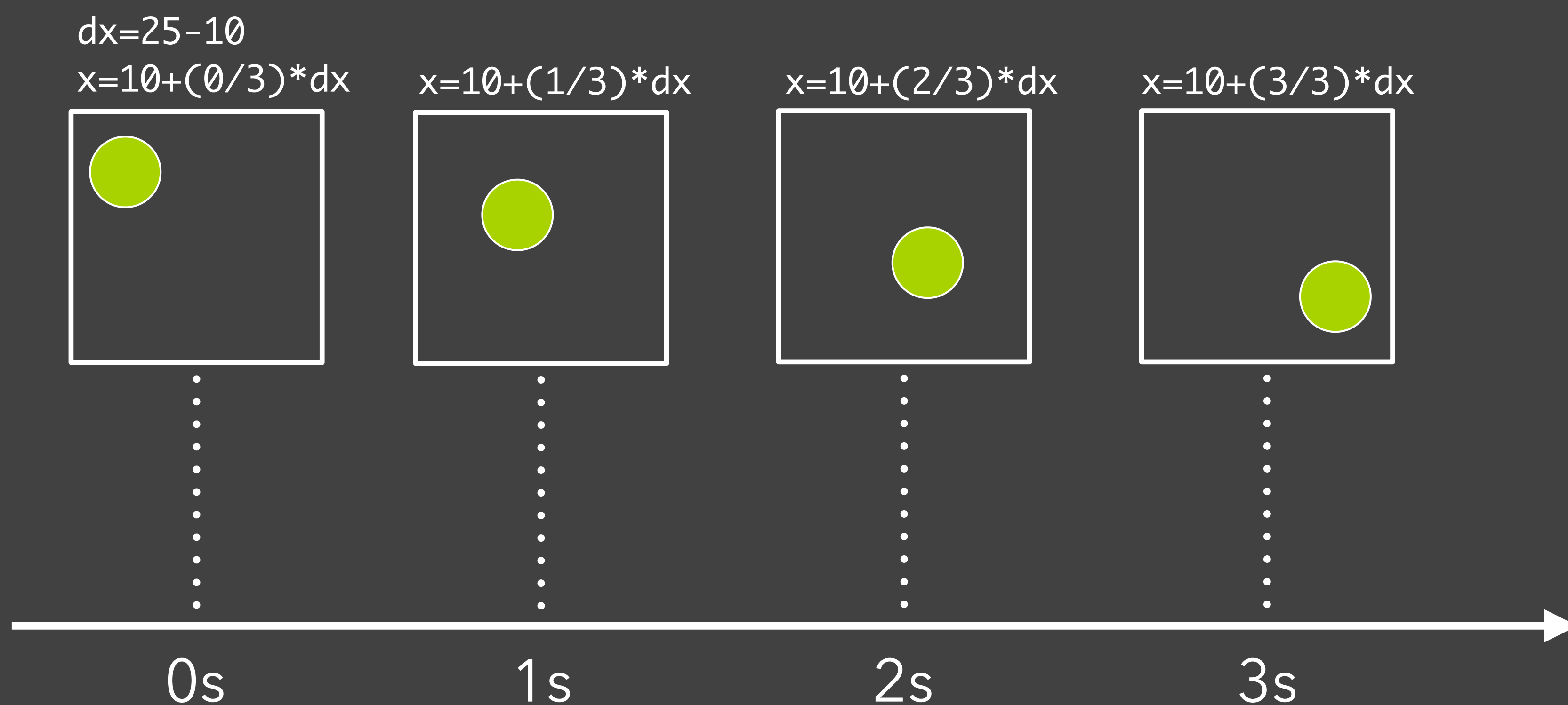
Toolkit handles frame-by-frame updates!



D3 Transitions

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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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// 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
    .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.

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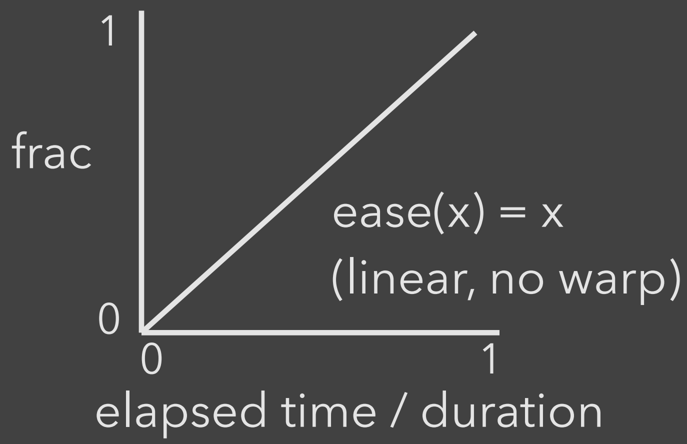

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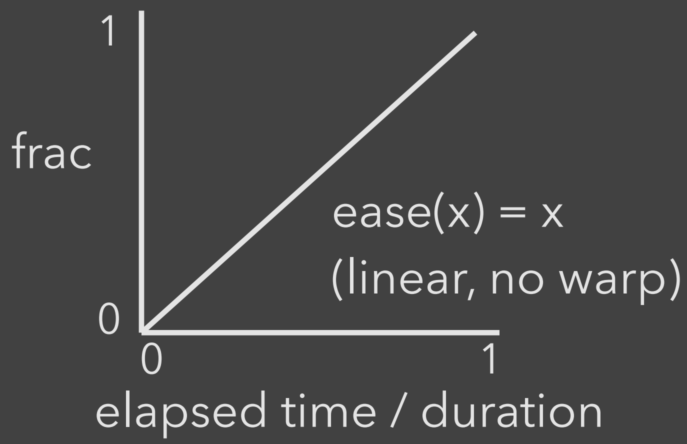

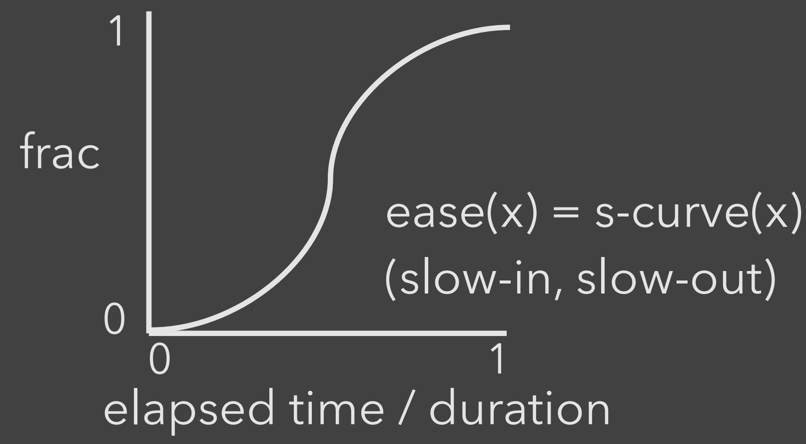

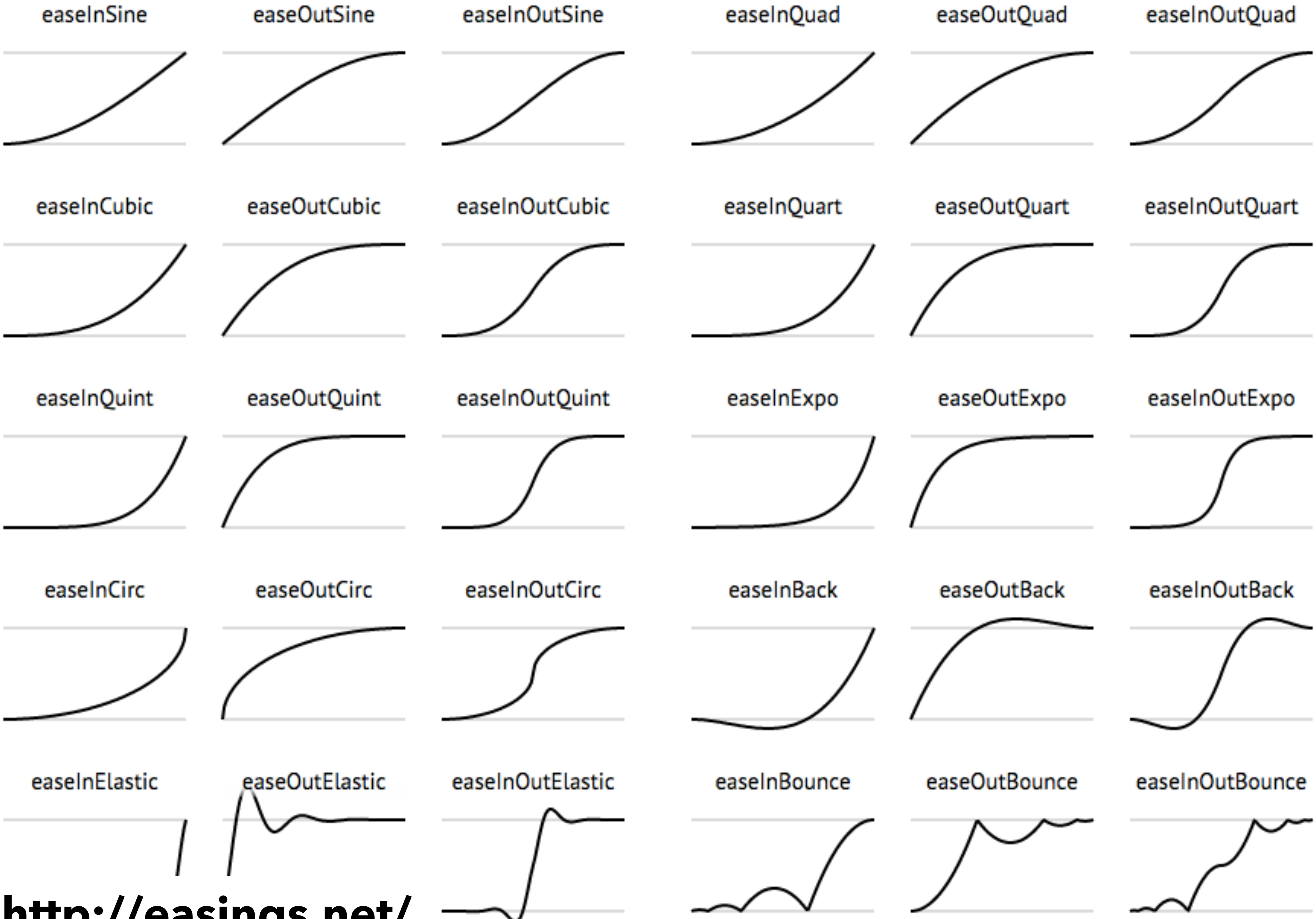

http://easings.net/

CSS Transitions

Extends CSS with Animated Transitions

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

a:hover {
  color: red;
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CSS Transitions

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Duration

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Property

Easing

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CSS Transitions

Extends CSS with Animated Transitions

```
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```

Duration — 1s

Property — color

Easing — ease-in-out

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**