Animation

Data Visualization

Frank Elavsky
Based on slides by Adam Perer, Dominik Moritz, and Jeffrey Heer

Why Use Motion?

Visual variable to encode data

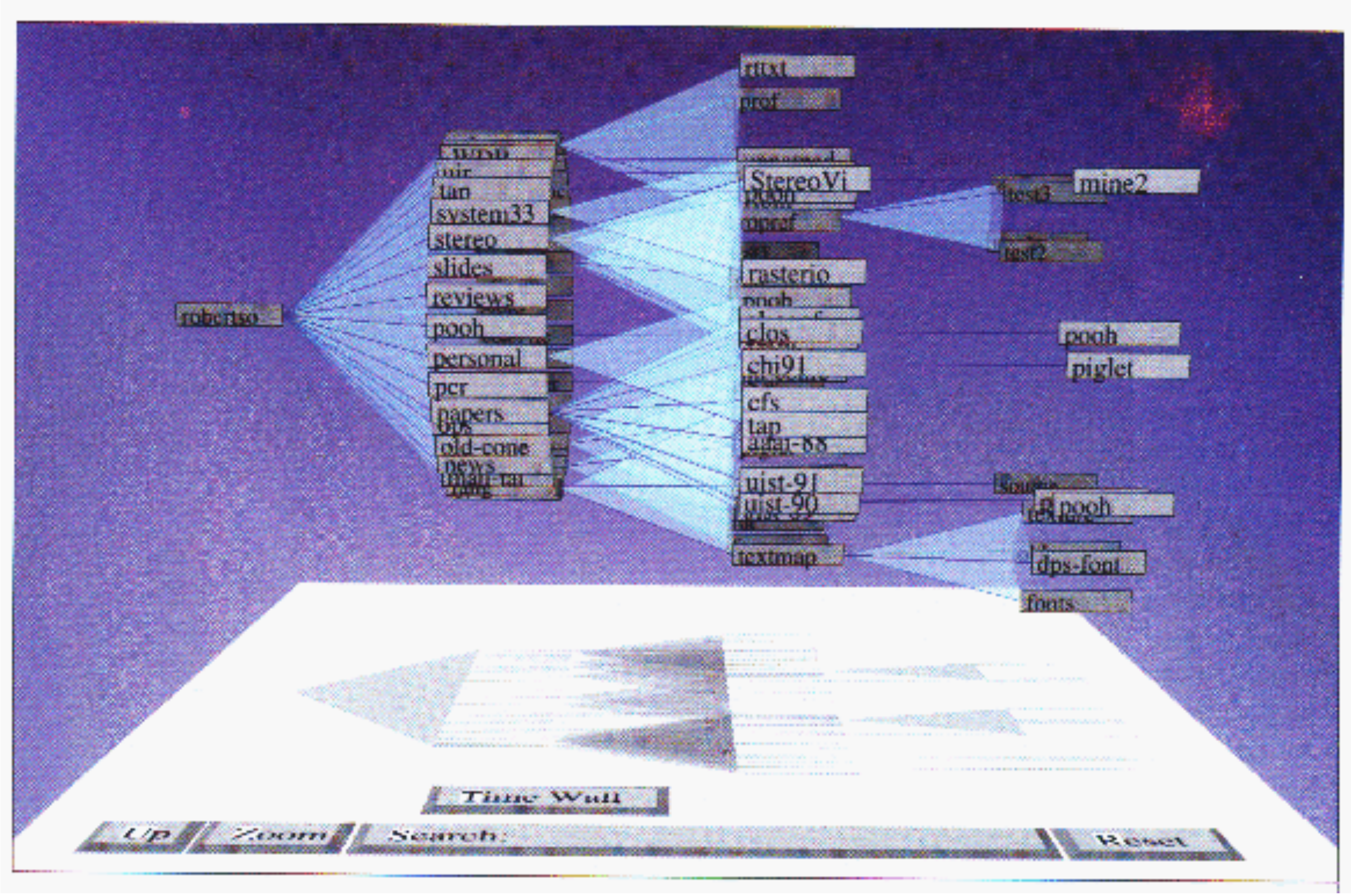
Direct attention

Understand system dynamics

Understand state transition

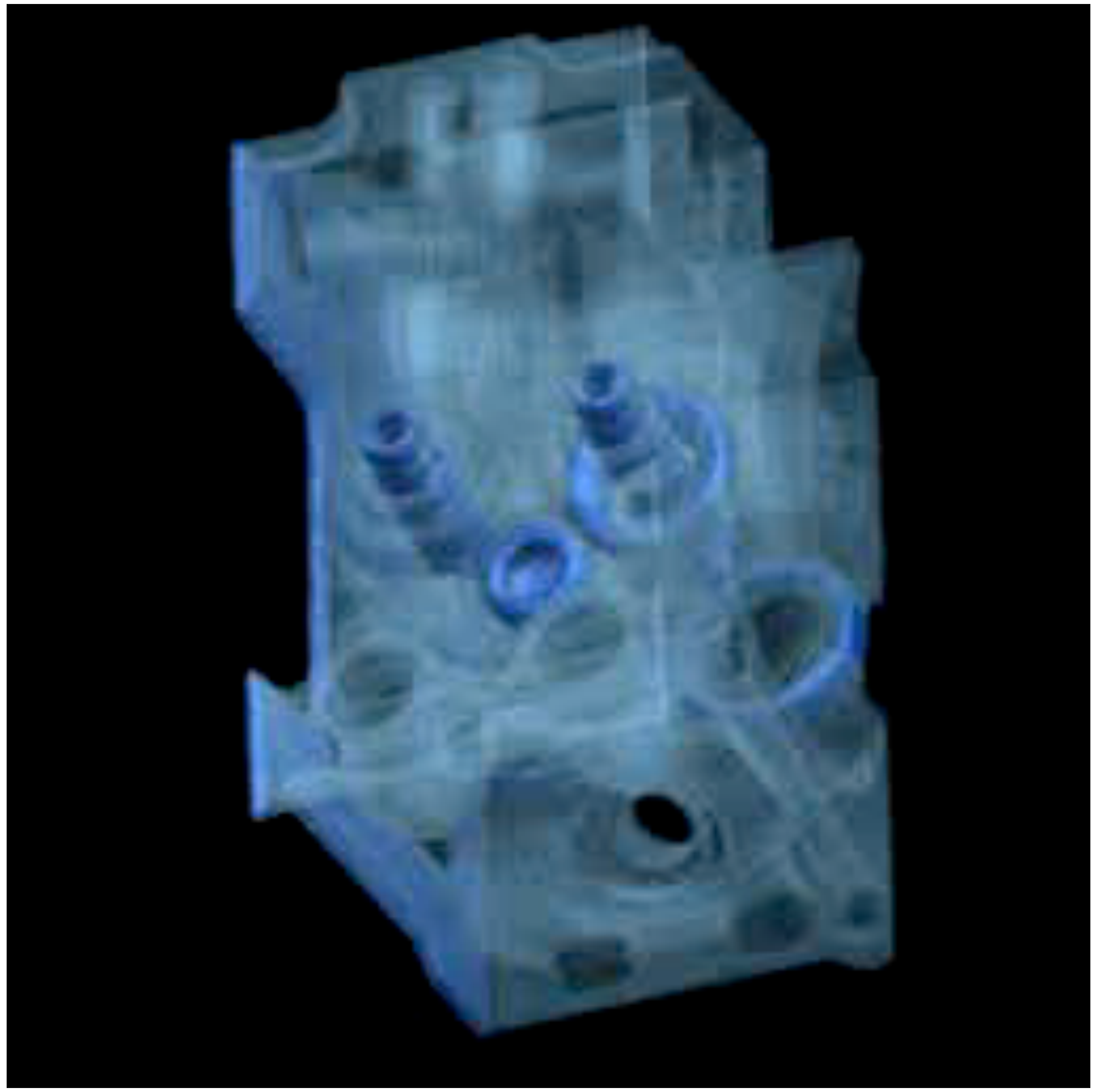
Increase engagement

Cone Trees [Robertson 91]



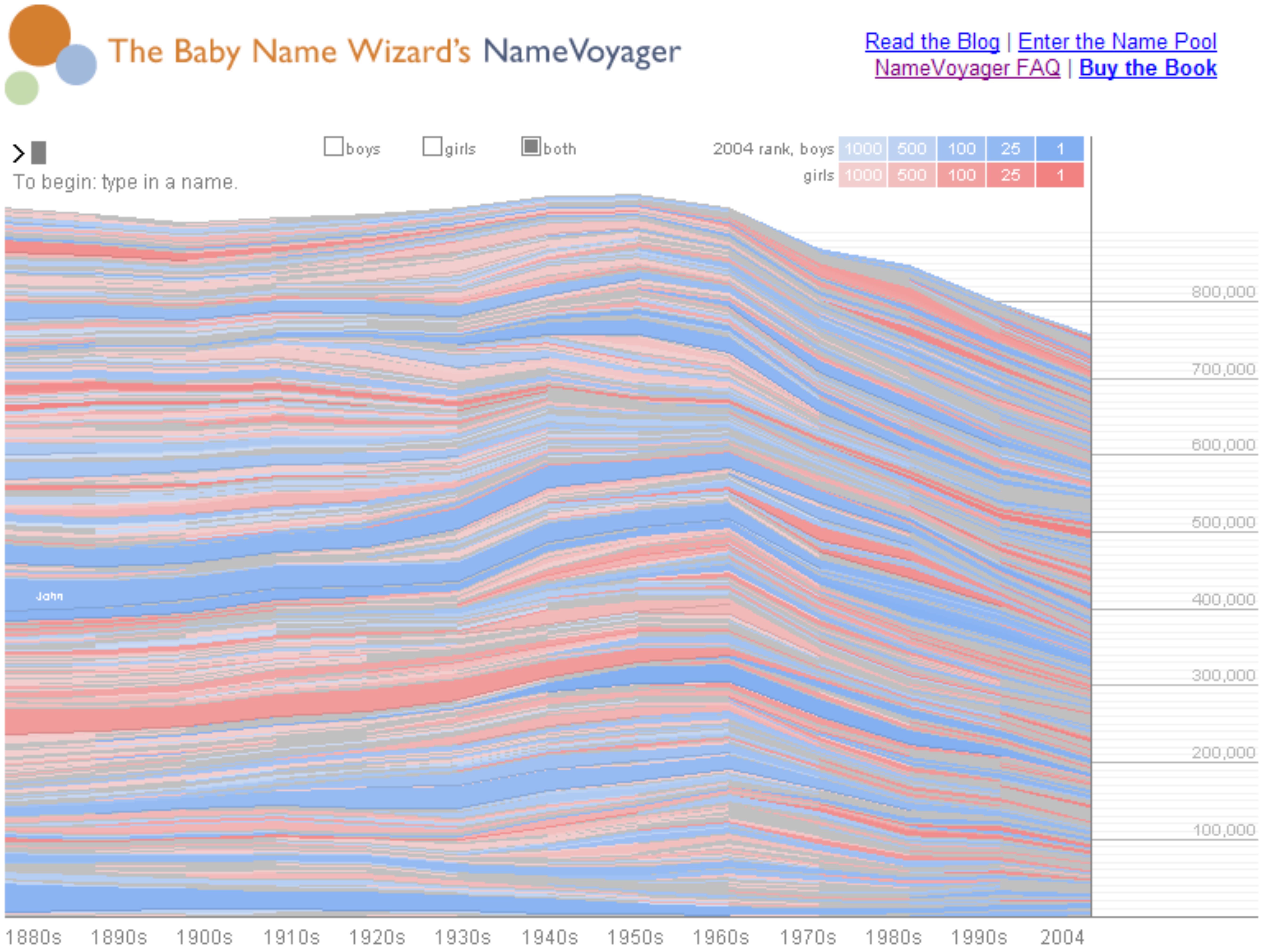
Video

Volume Rendering [Lacroute 95]



Video

NameVoyager [Wattenberg 04]



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

What you will learn today

Motion perception

Animated transitions in visualizations

Implementing animations

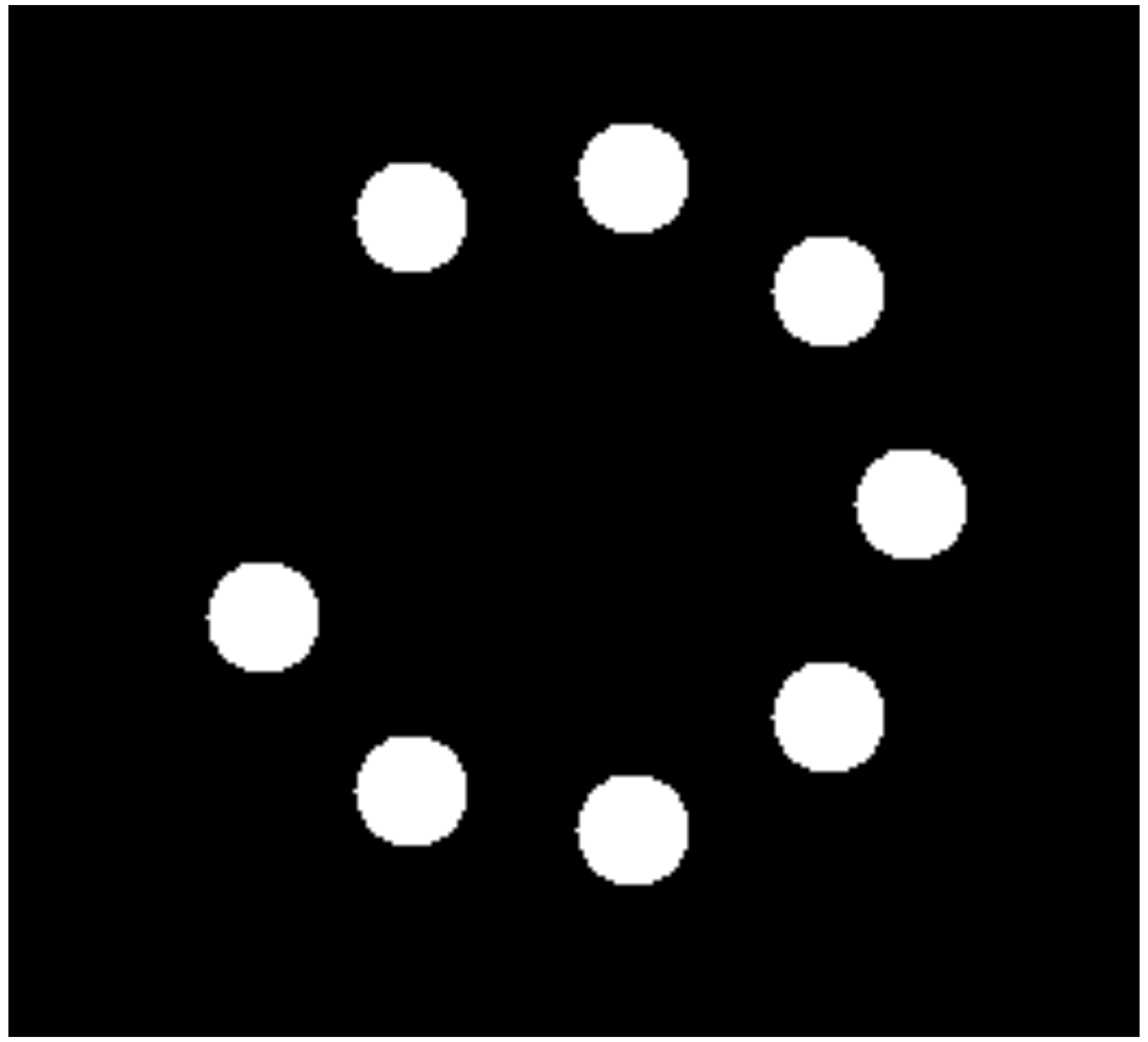
Motion Perception

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

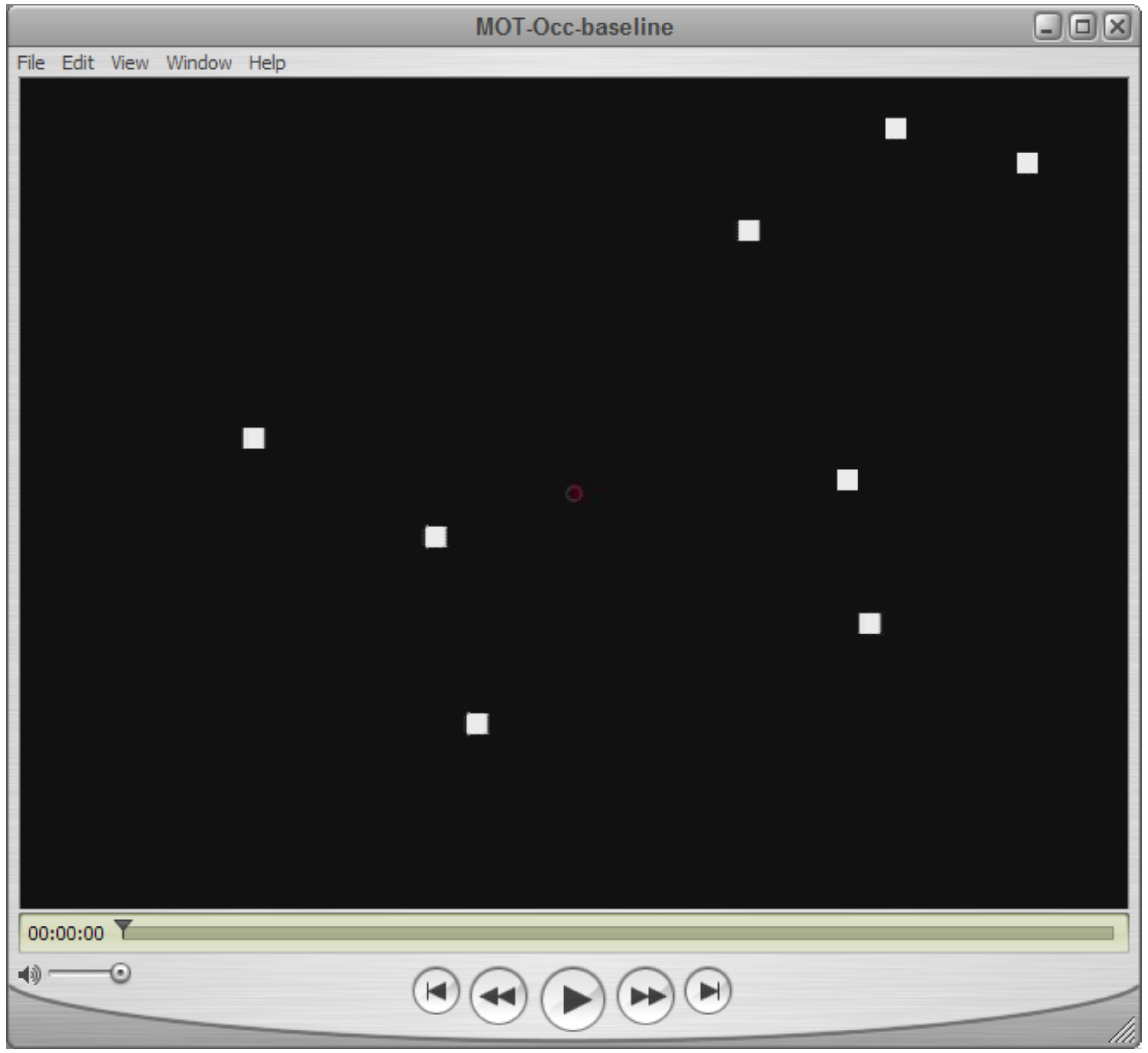
Pre-attentive, stronger than color, shape, …

More sensitive to motion at periphery

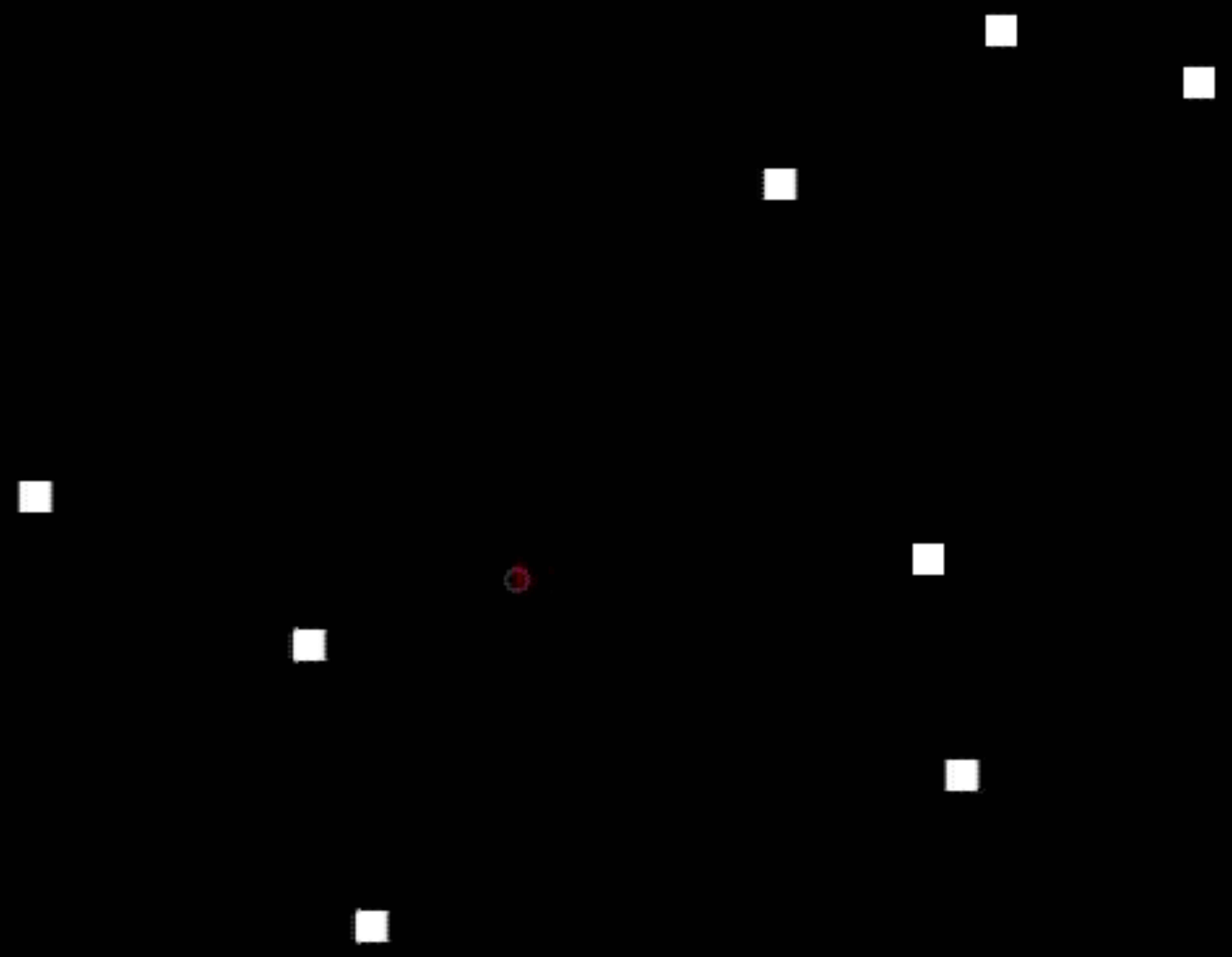
Similar motions perceived as a group

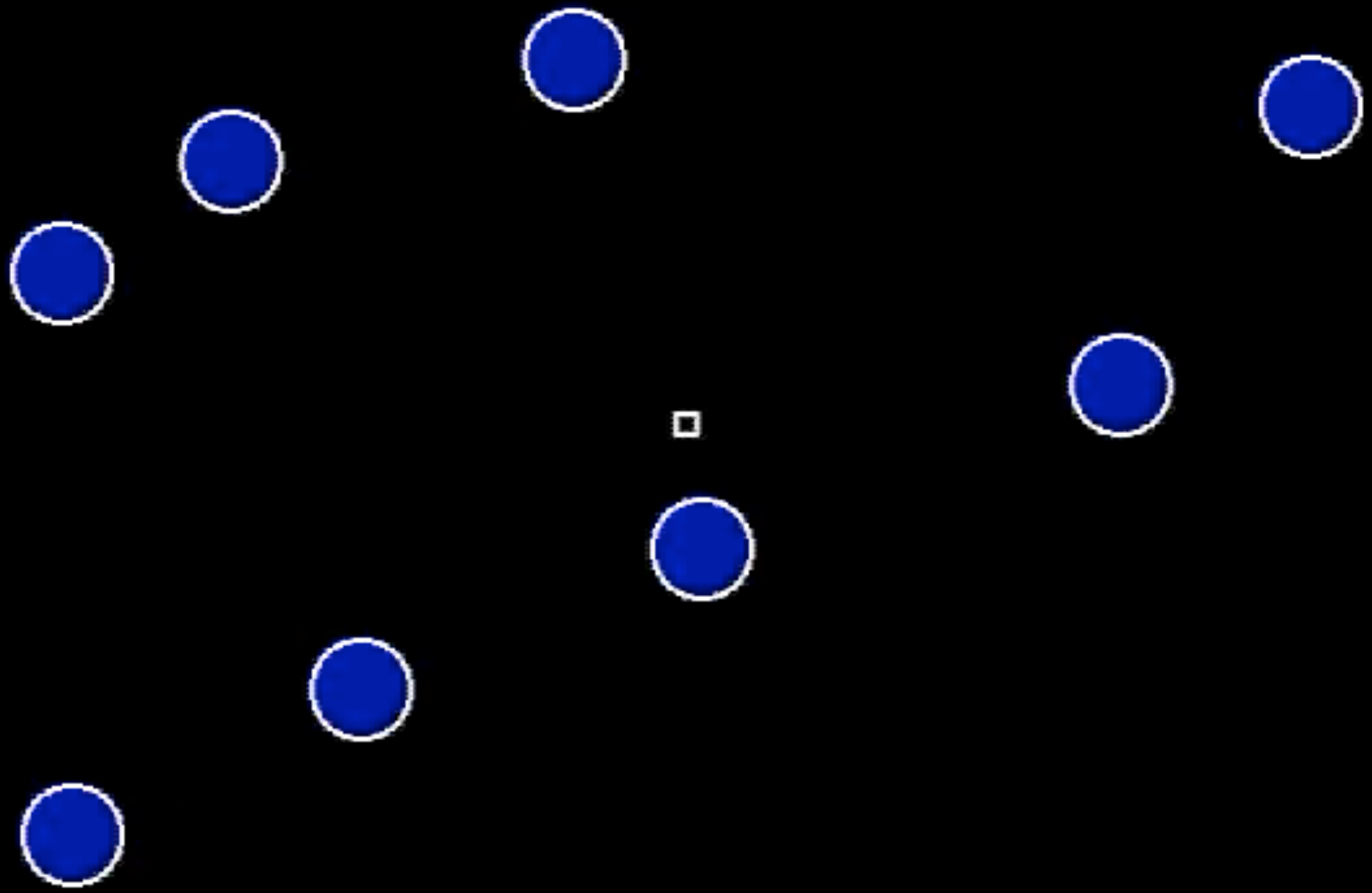
Motion parallax provides 3D cue (like stereopsis)

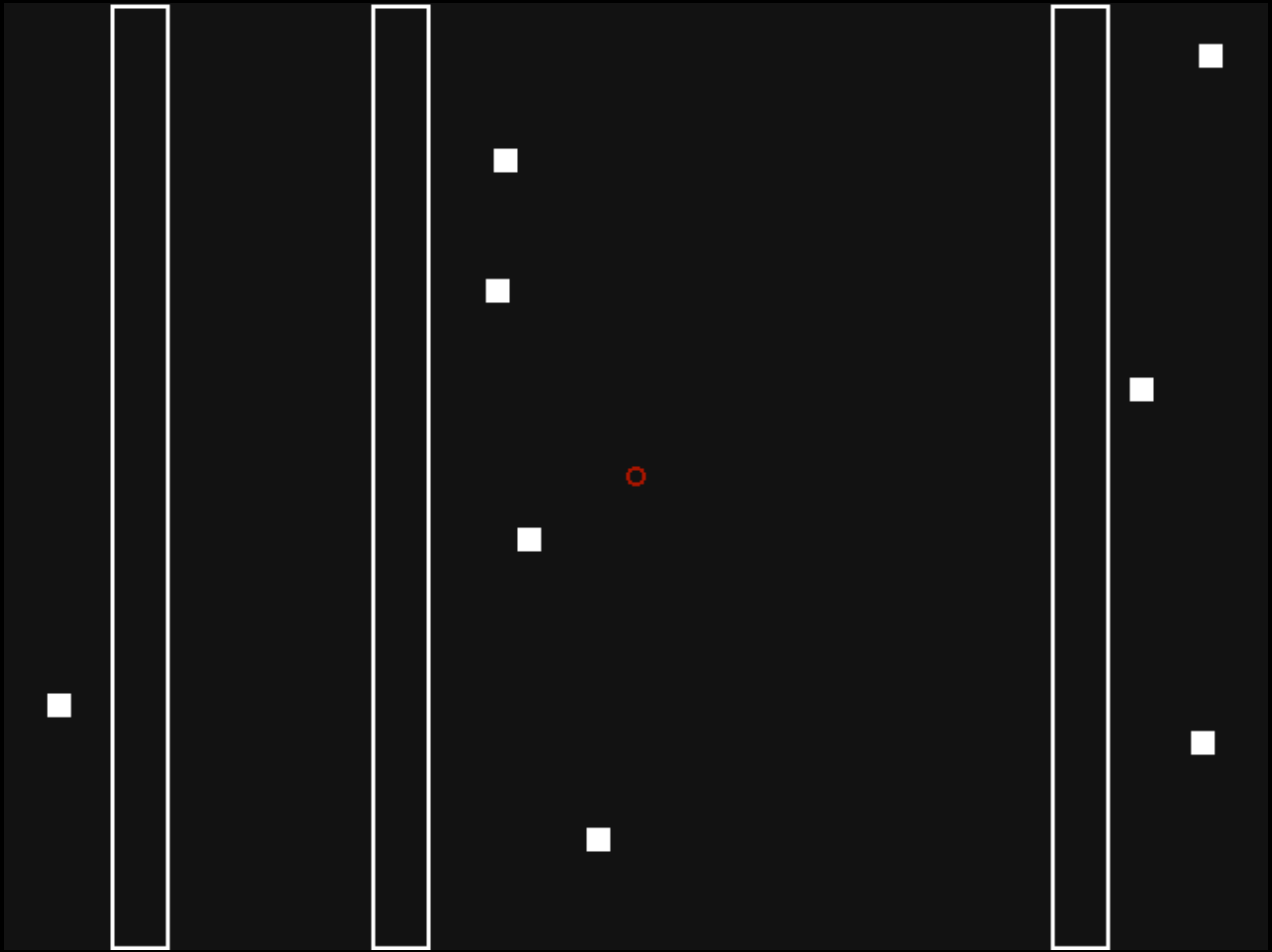
Tracking Multiple Targets

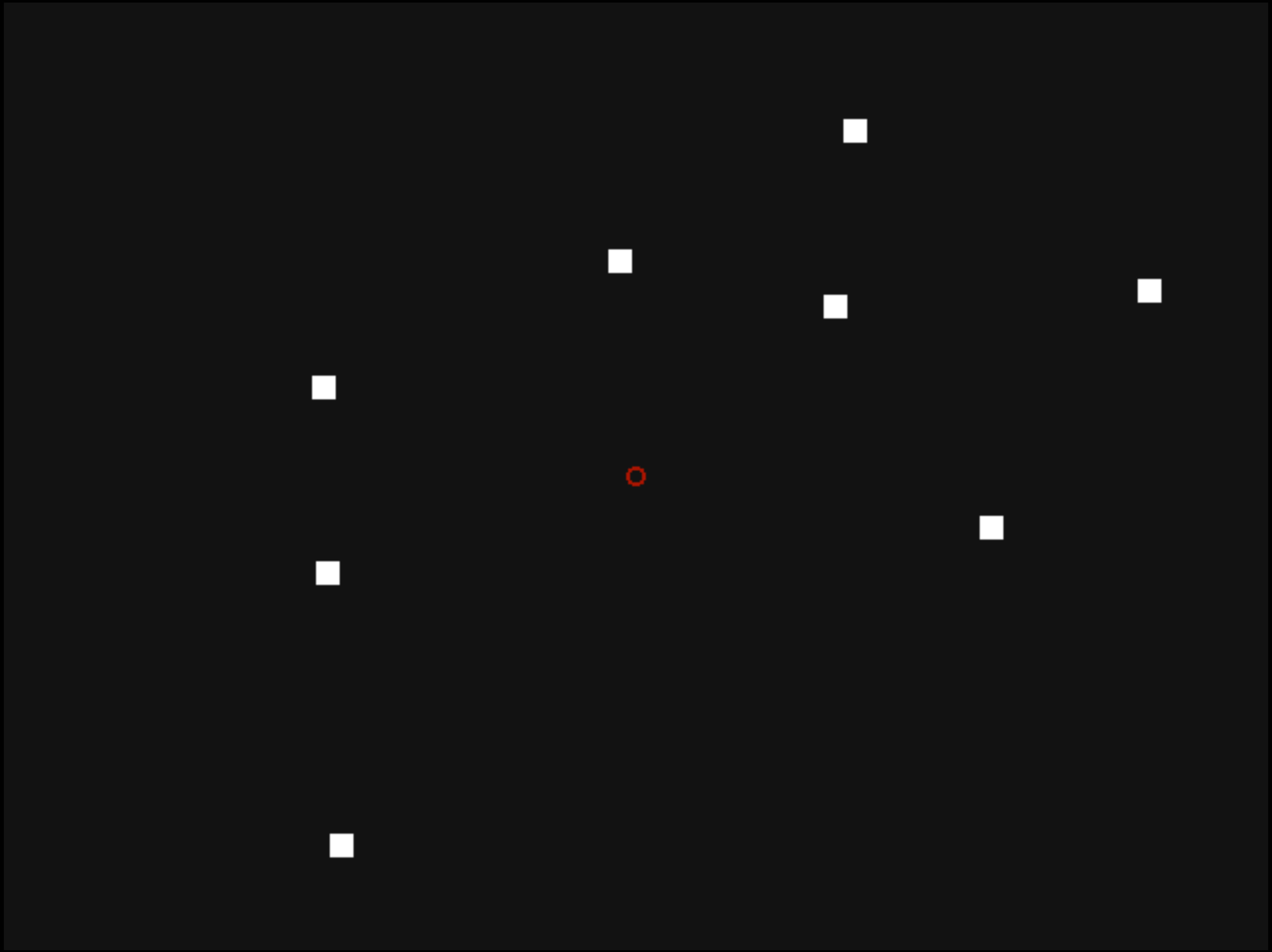


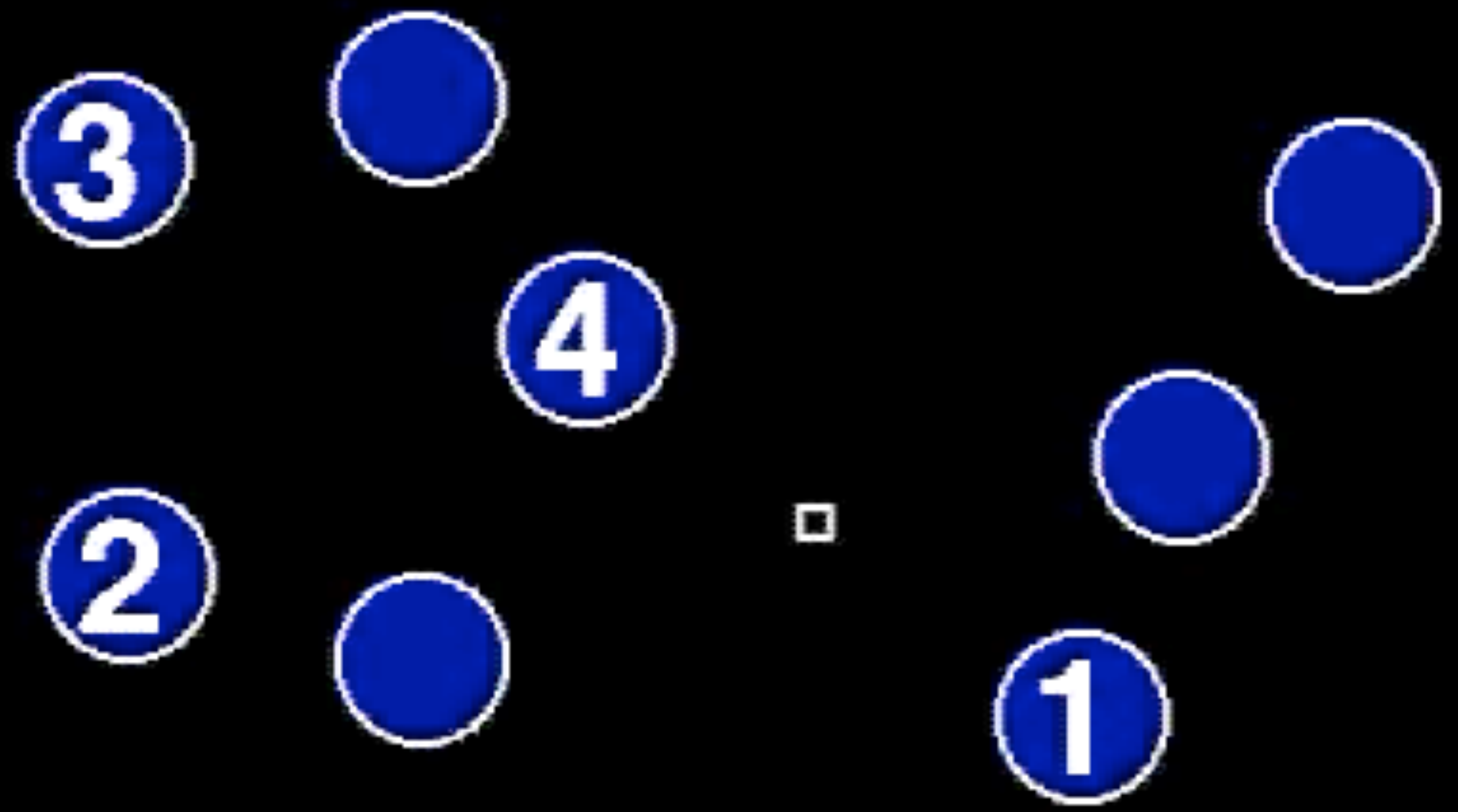
How many dots can we simultaneously track?









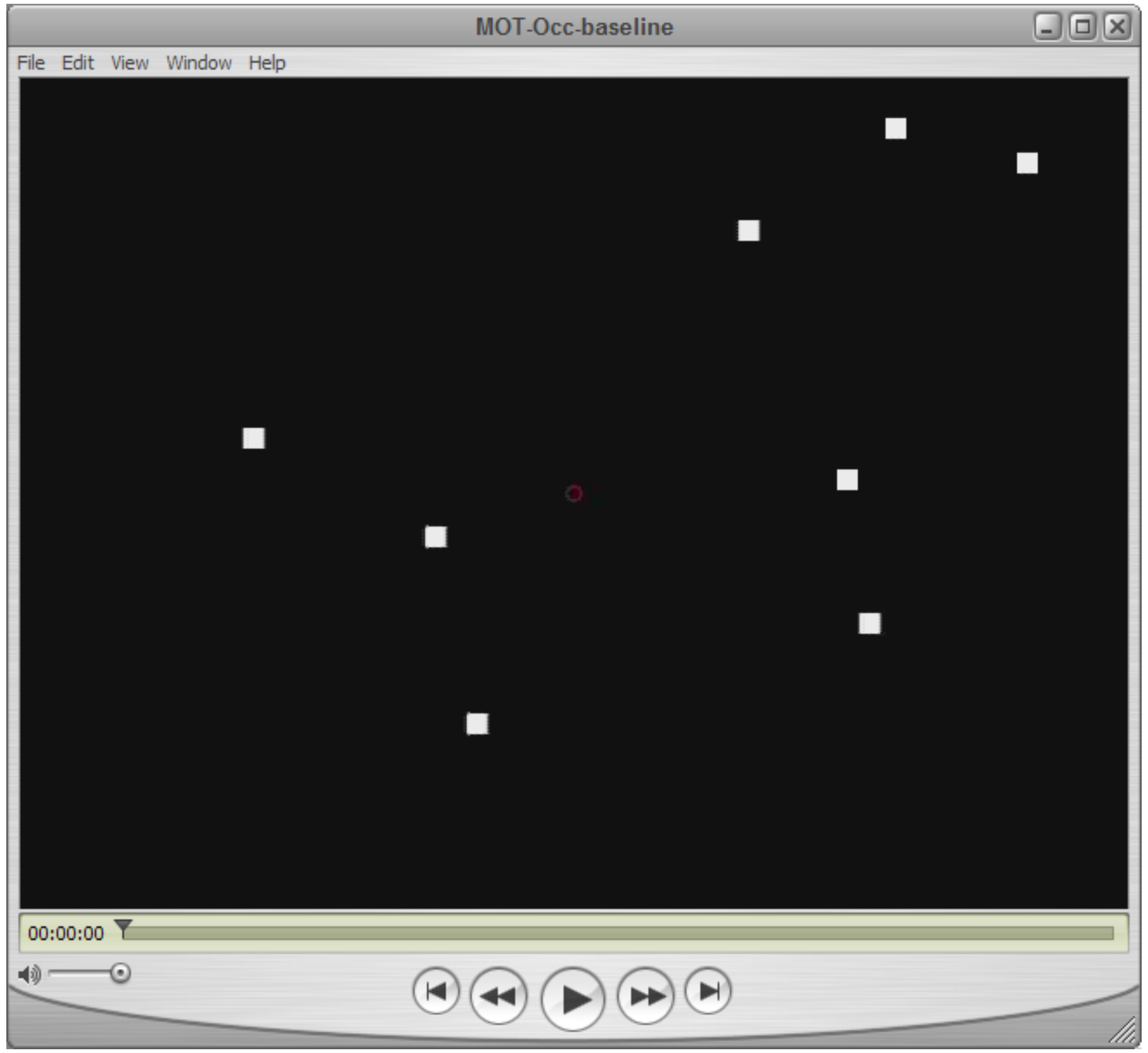

3
4
2
1

Tracking Multiple Targets

How many dots can we simultaneously track?

We can track ~4-6 dots.

Difficulty increases *significantly* at 6.

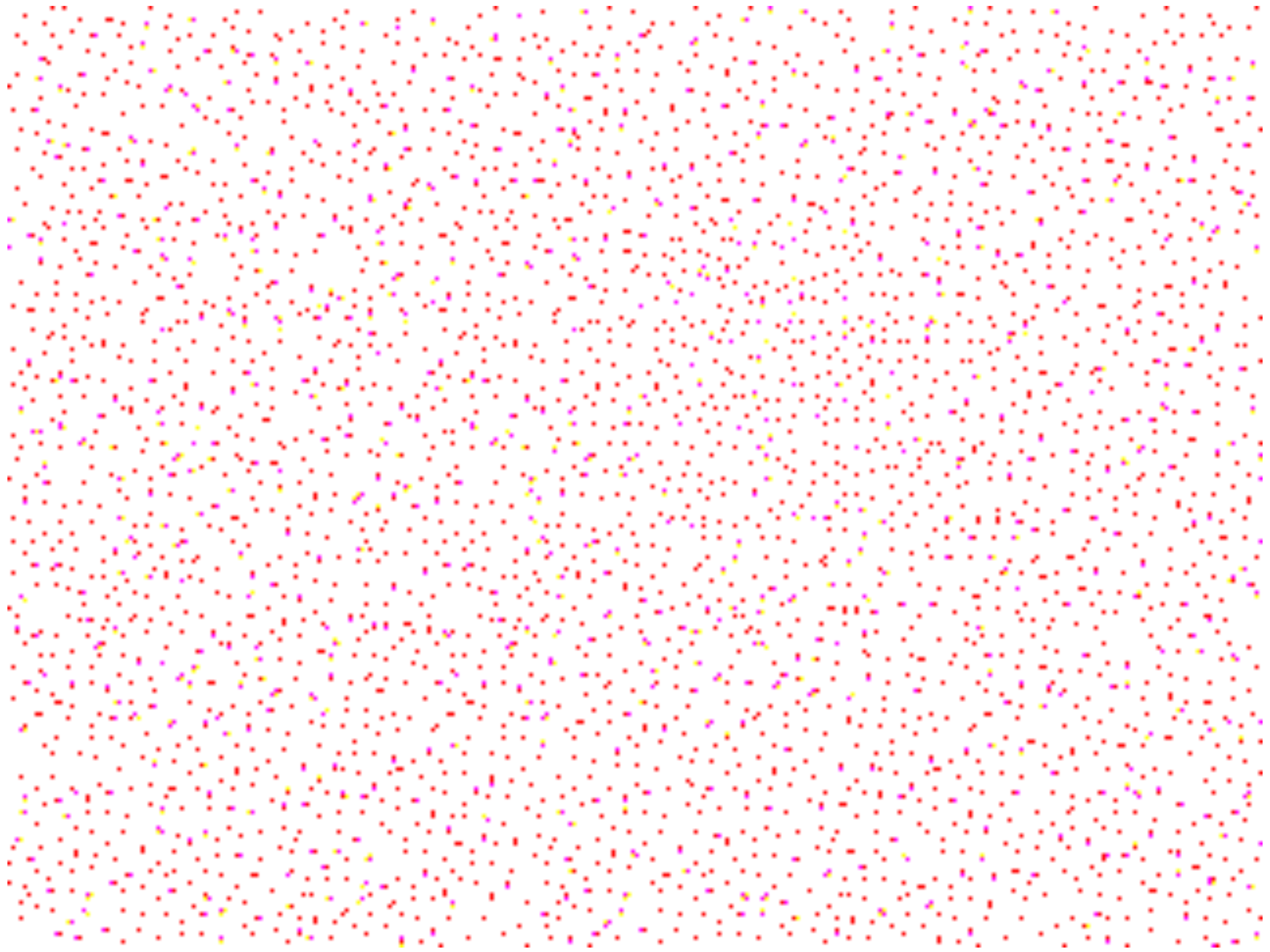


[Yantis 92, Pylyshn 88, Cavanagh 05]

Grouped Dots Count as 1 Object

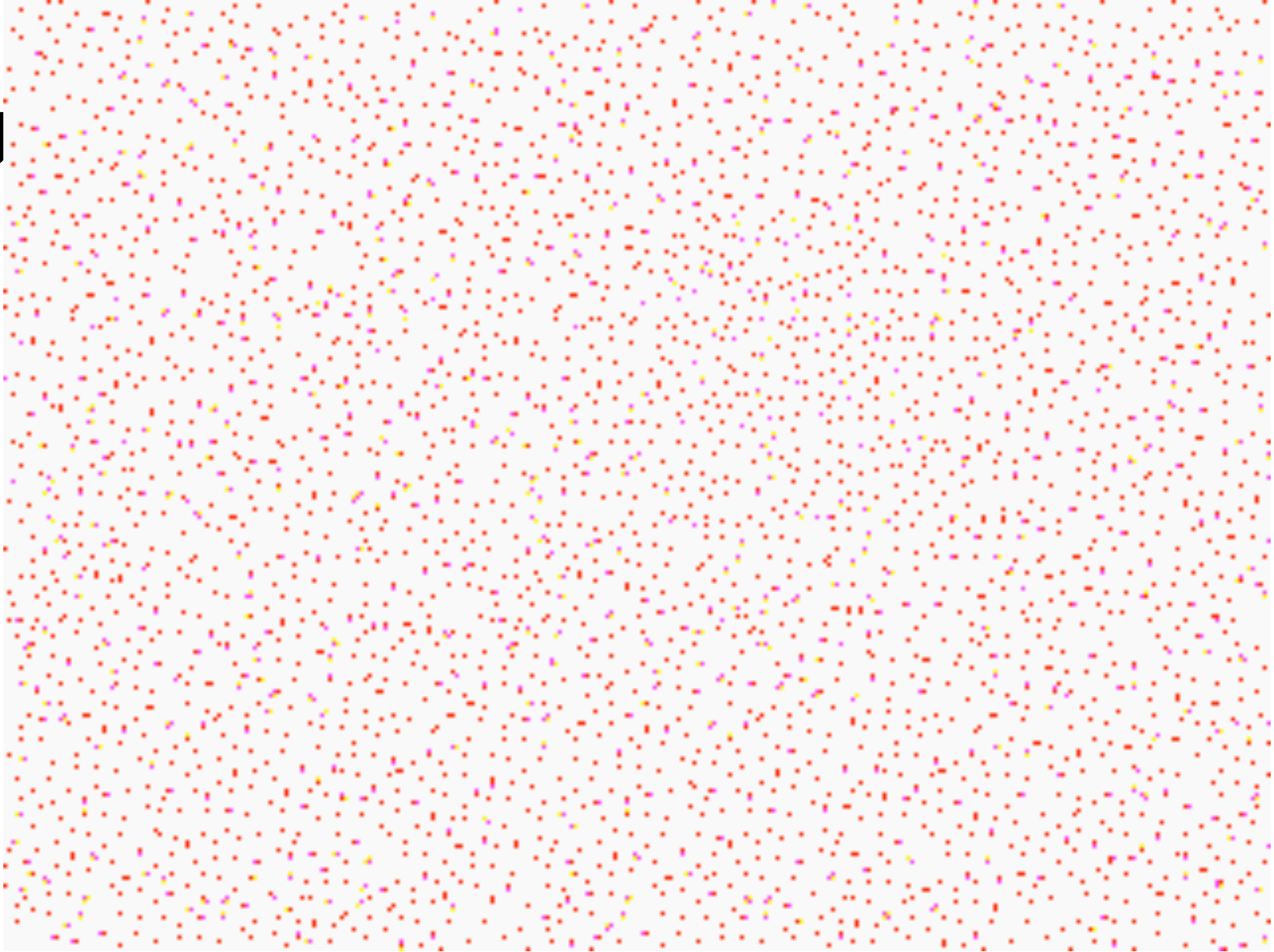
Dots moving together are grouped

Segment by Common Fate

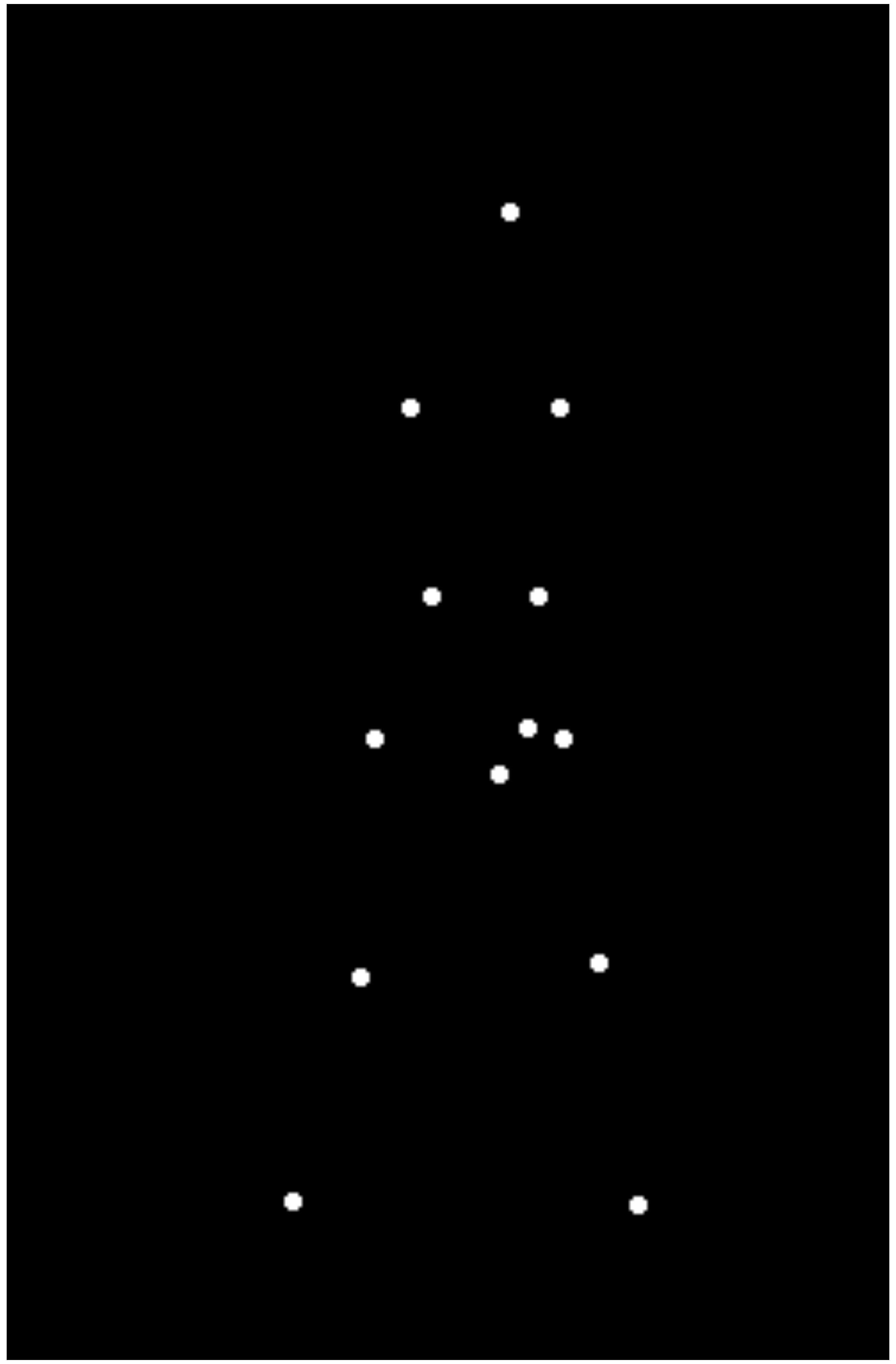


http://dragon.uml.edu/psych/commfate.html

Seg



Grouping of Biological Motion

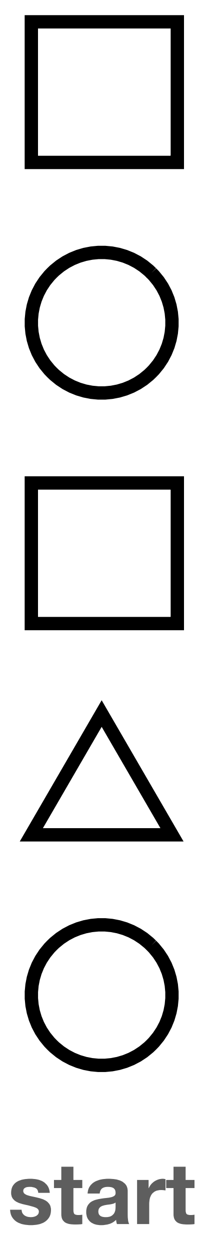


http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/WALK.MOV

[Johansson 73]

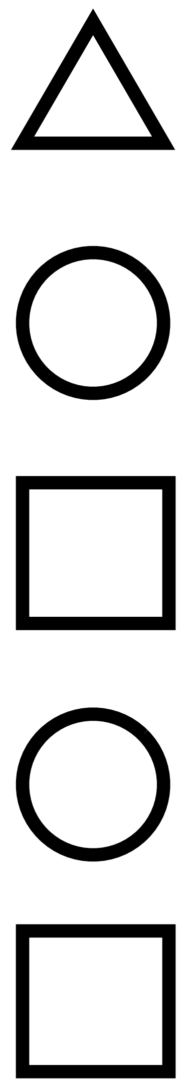
Motions Show Transitions

See change from one state to next



Motions Show Transitions

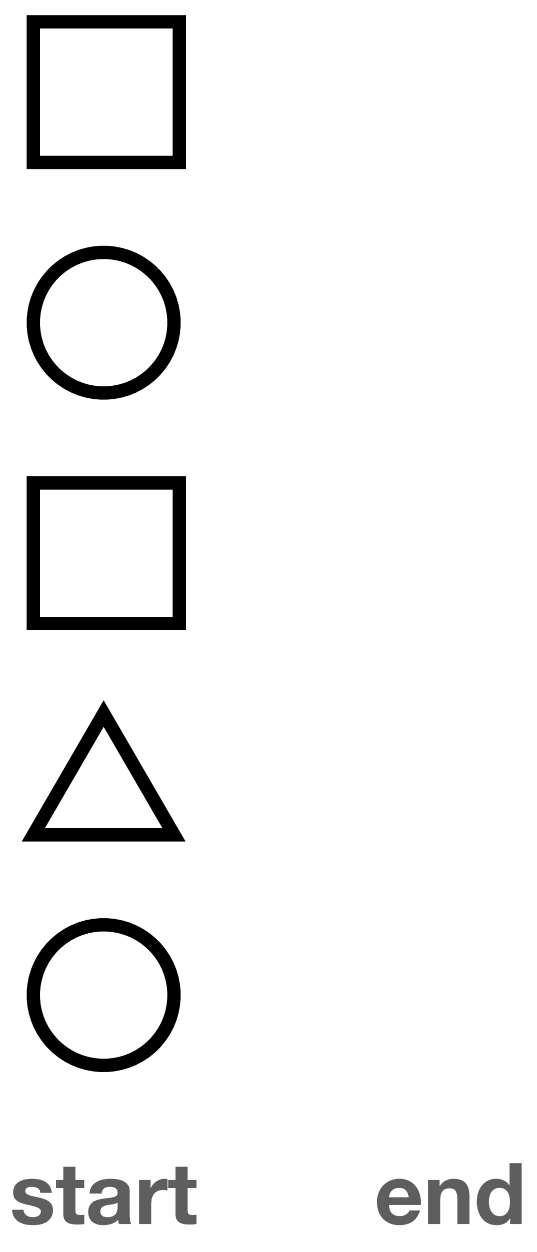
See change from one state to next



end

Motions Show Transitions

See change from one state to next

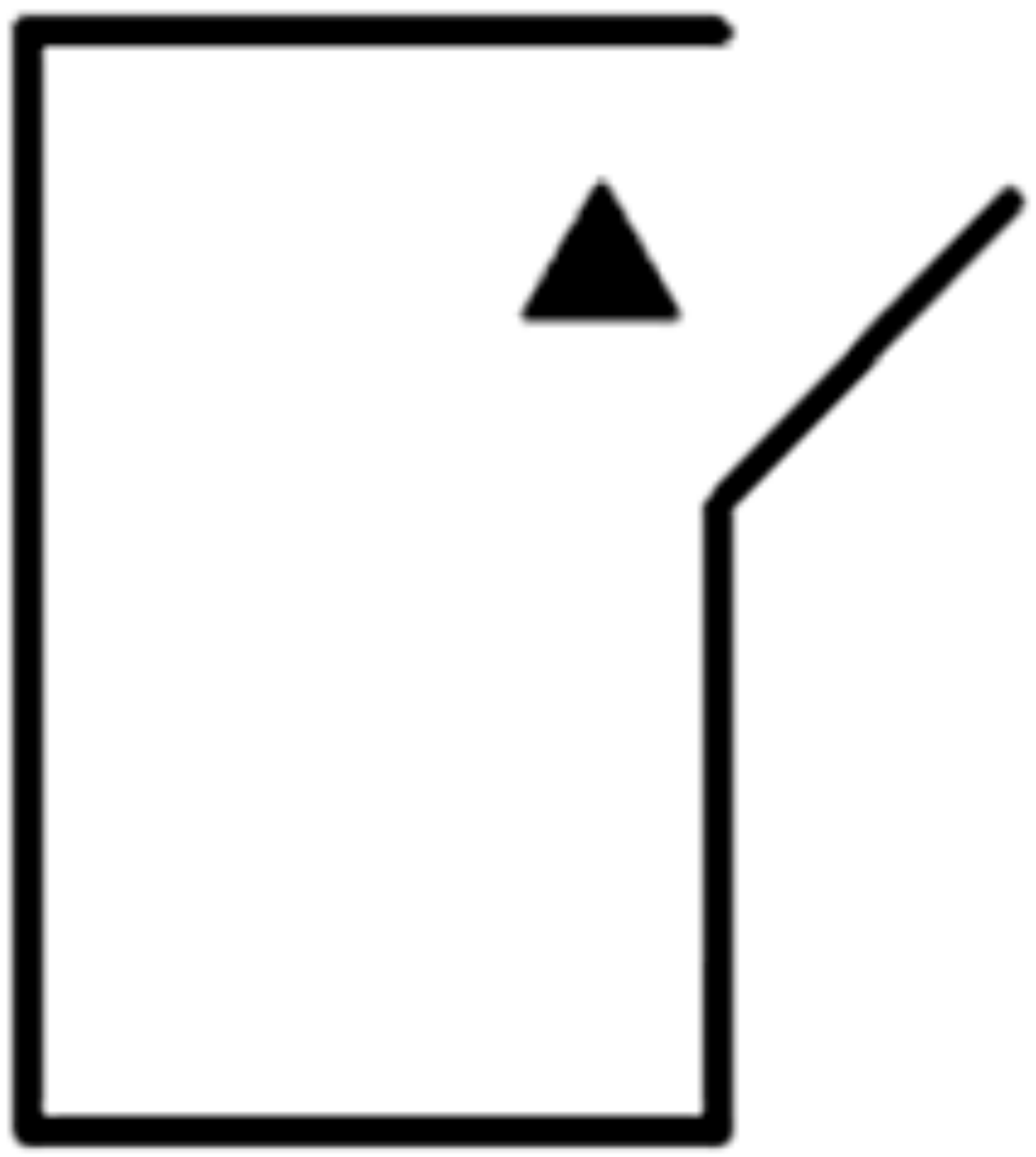


Shows transition better, but

Still may be too fast, or too slow

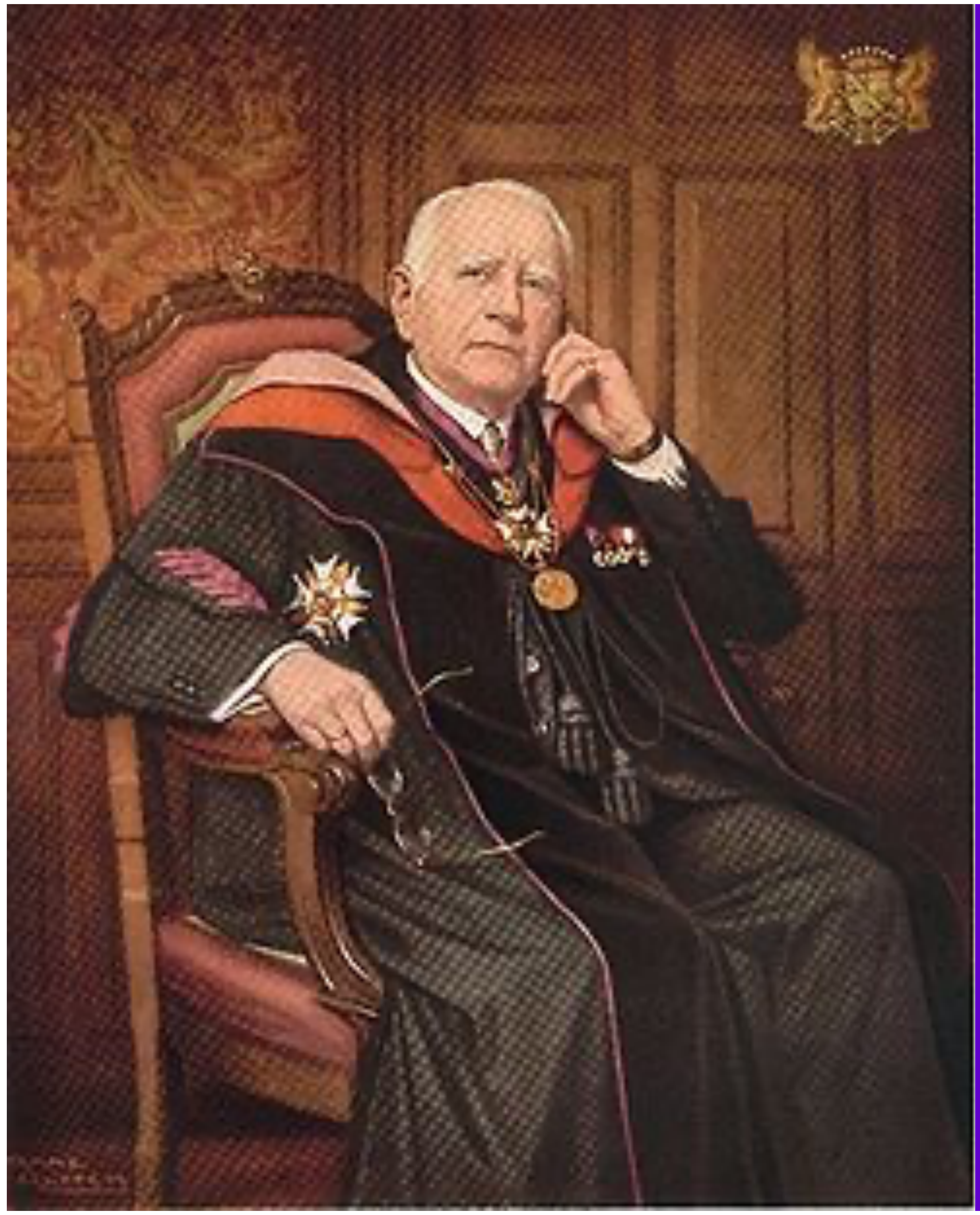
Too many objects may move at once

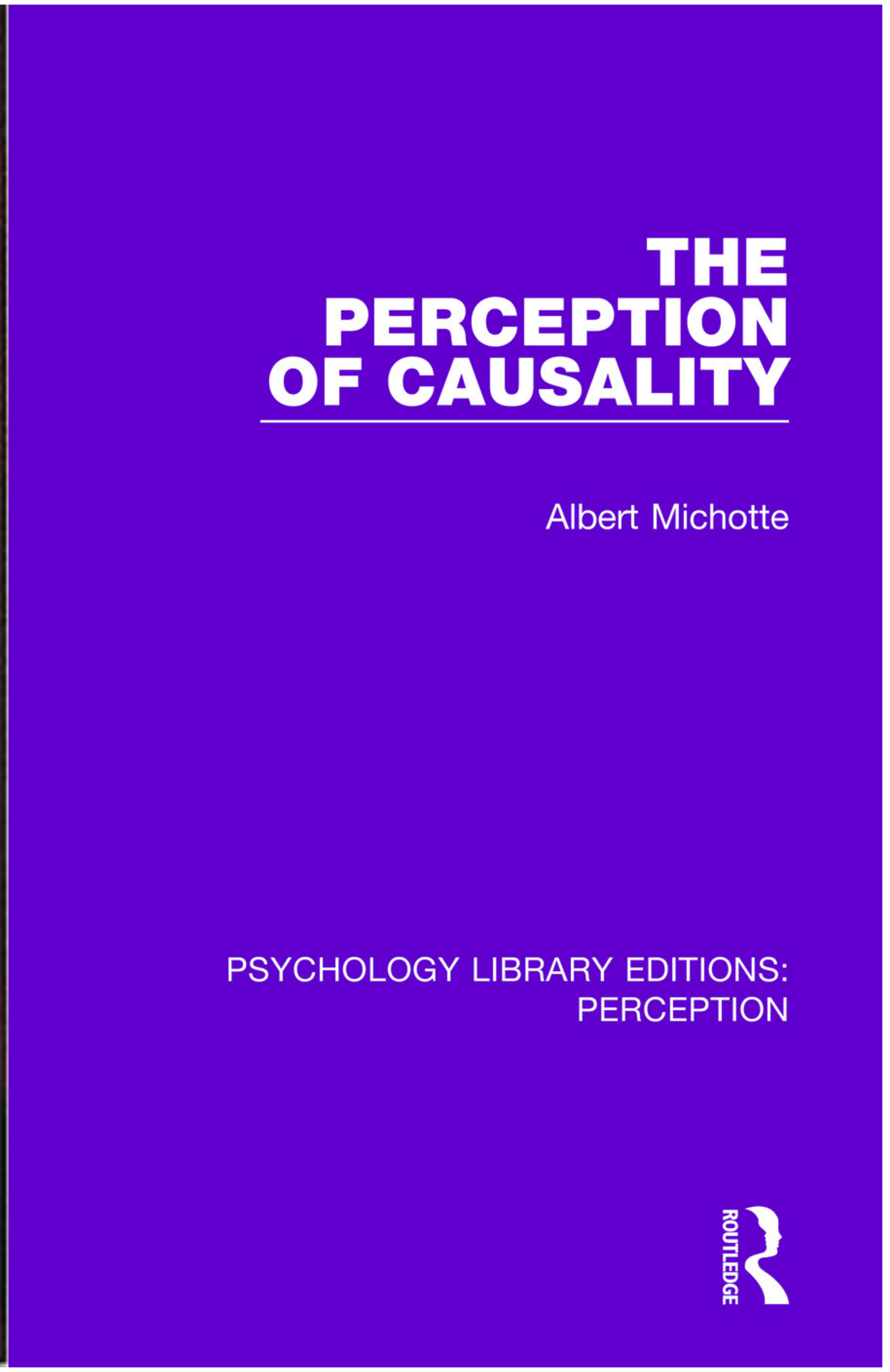
Constructing Narratives



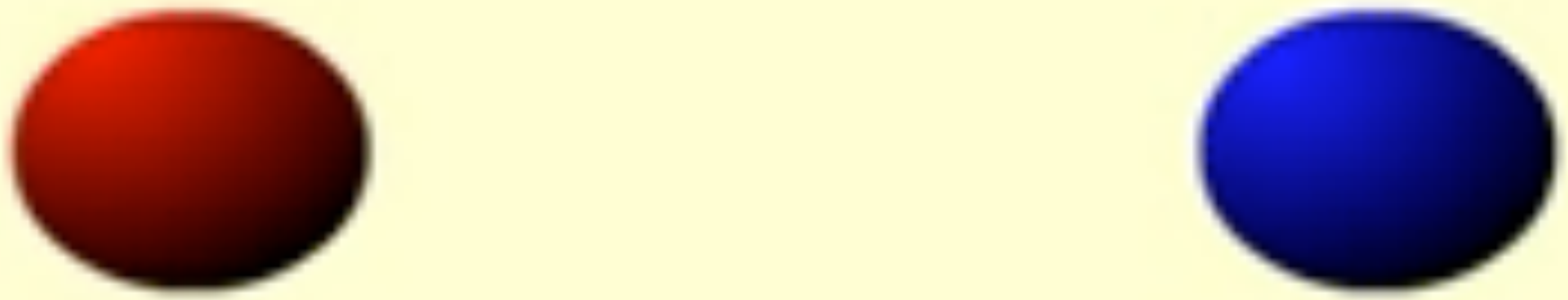
https://www.youtube.com/watch?v=sx7lBzHH7c8

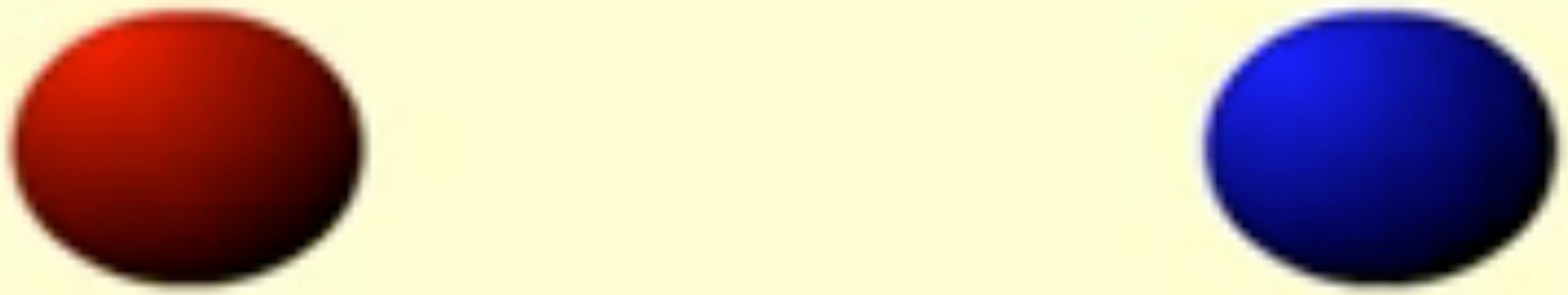
Attribution of Causality [Michotte 46]



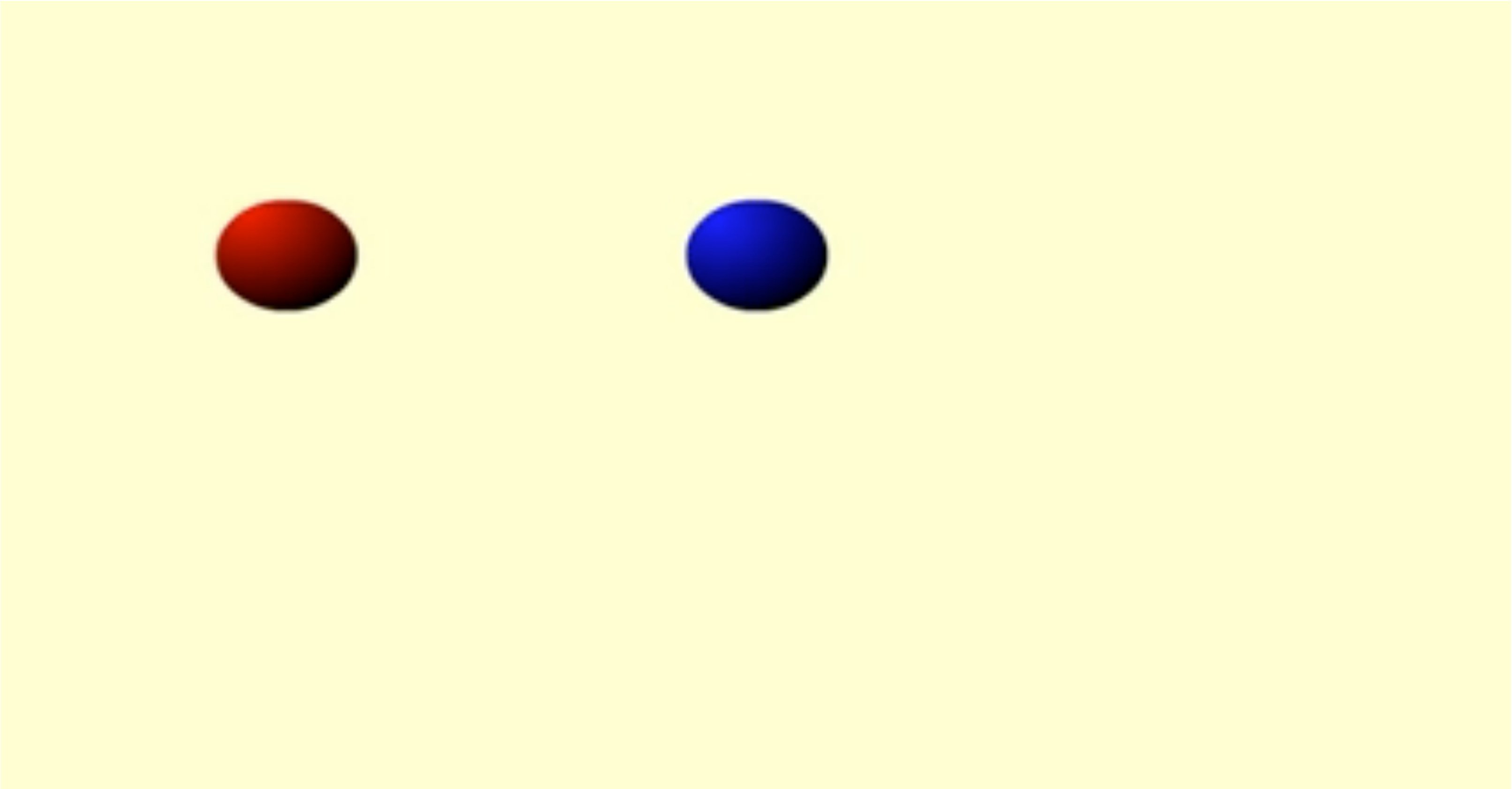


Albert Michotte of Louvain University in Belgium

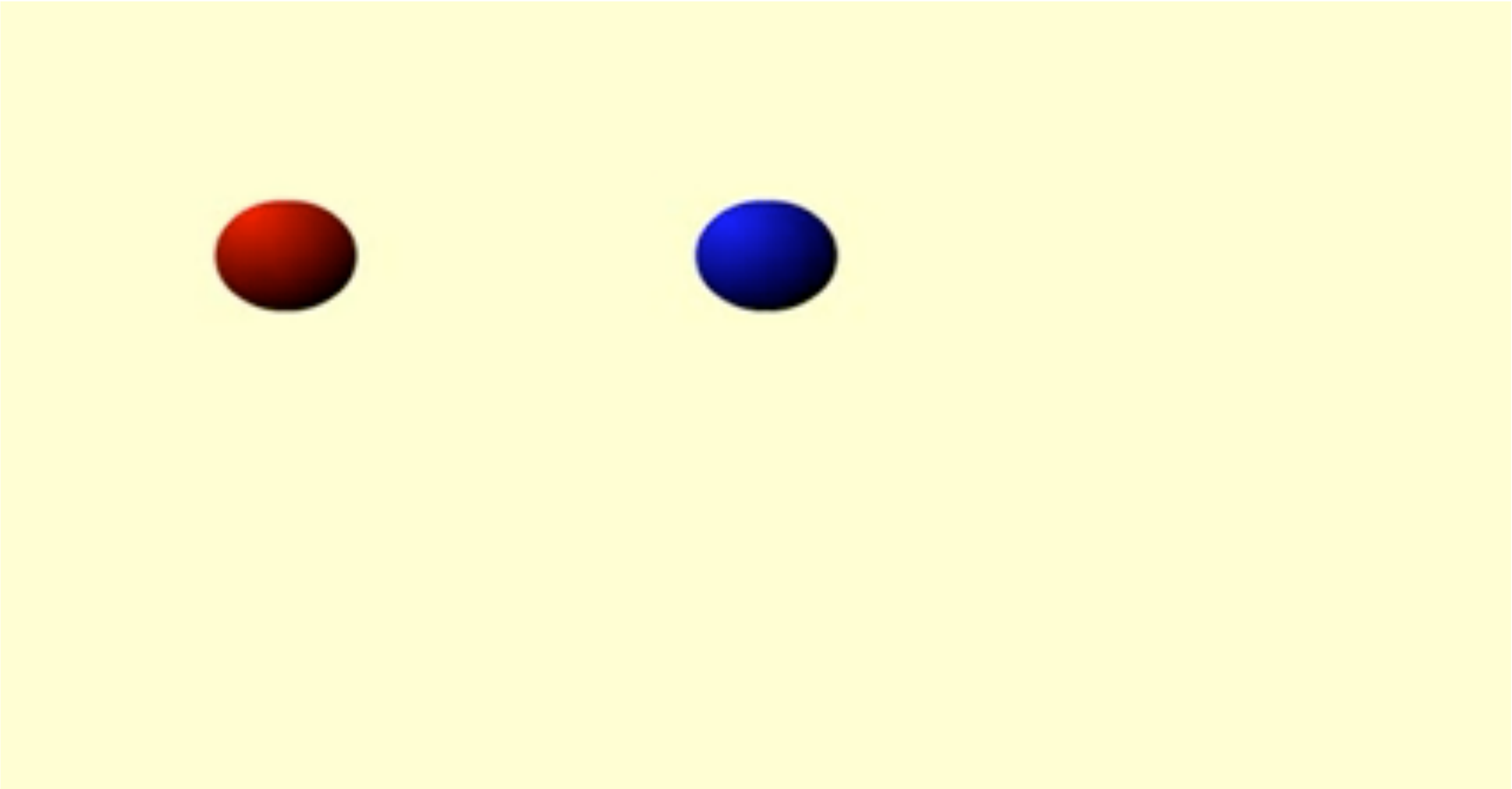




Attribution of Causality [Michotte 46]

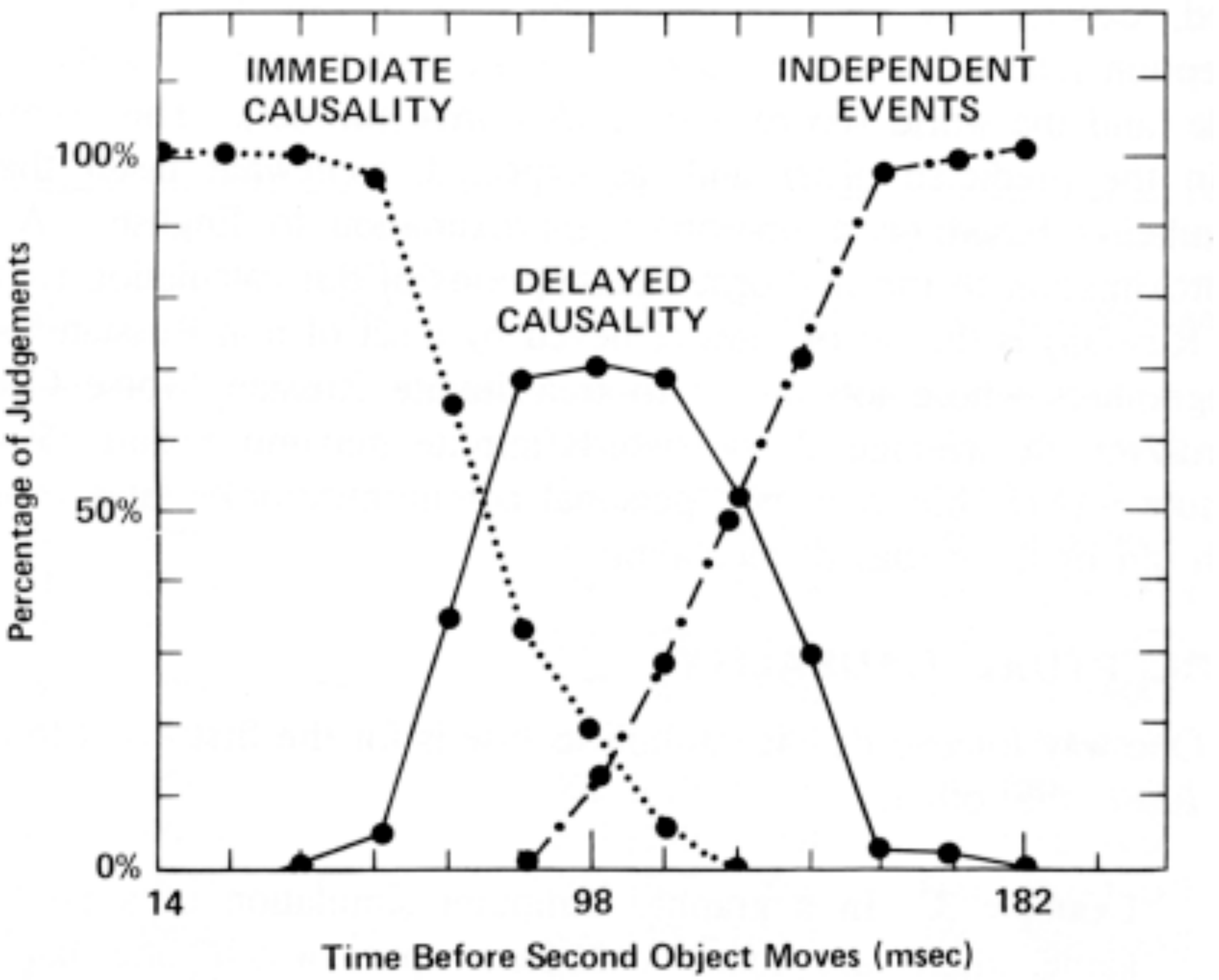


This demo shows *immediate* motion of the blue ball; subjects infer causality



This demo shows shows *delay*; causal connection is broken

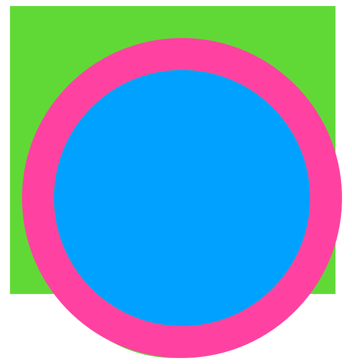
Attribution of Causality [Michotte 46]

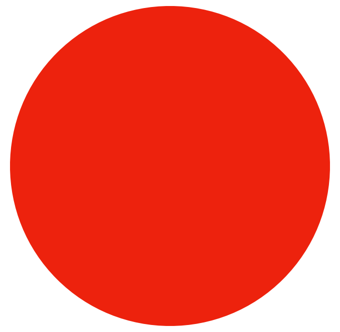


[Reprint from Ware 04]

Animation

	Helps?	**Hurts?**
Attention	Direct attention	Distraction
Constancy	Change tracking	False relations
Causality	Cause and effect	False agency
Engagement	Increase interest	“Chart junk”
		Too slow: Boring
		Too fast: Errors





Problems with Animation [Tversky]

Difficult to estimate paths and trajectories

Motion is fleeting and transient

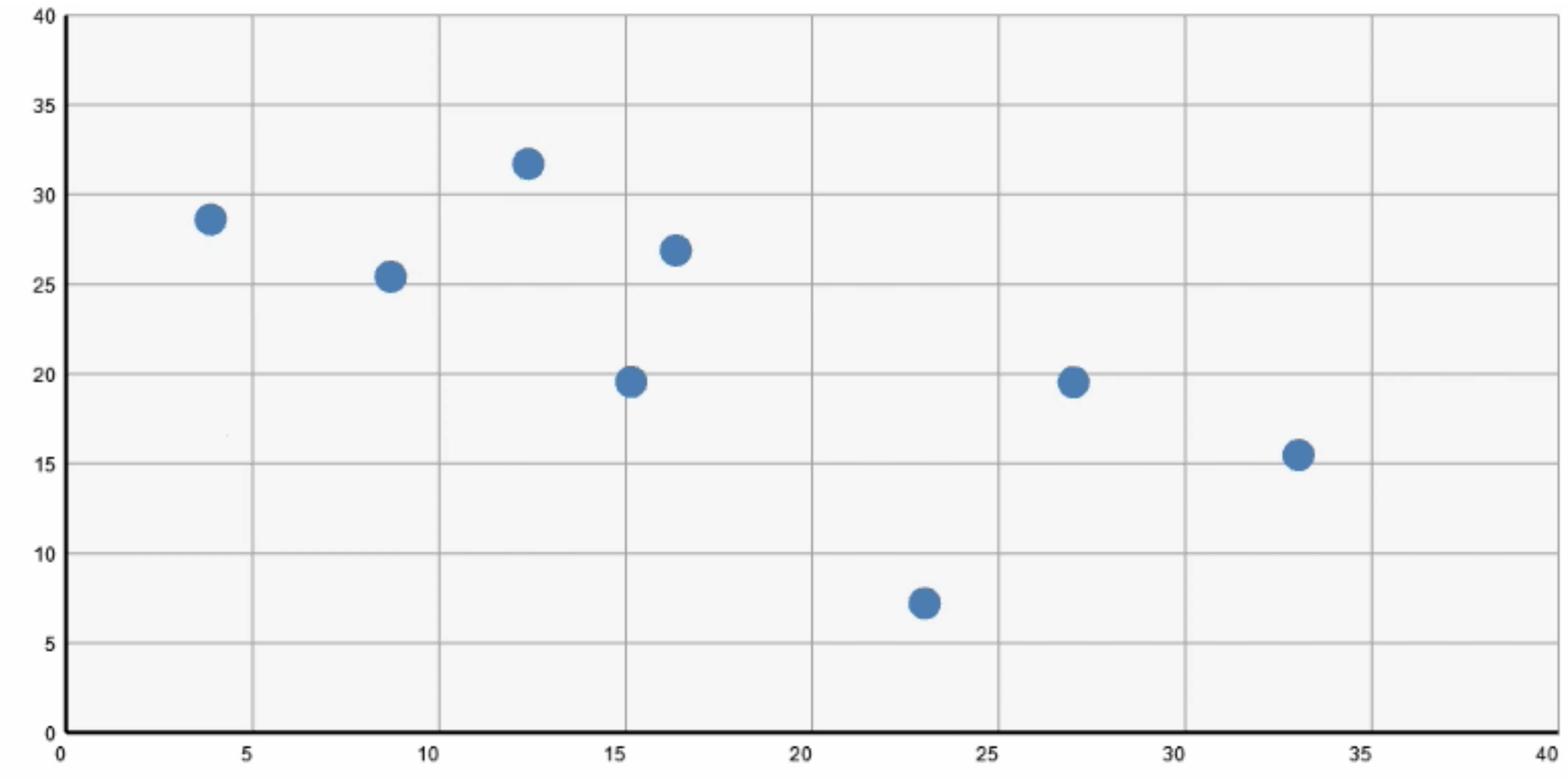
Cannot simultaneously attend to multiple motions

Parse motion into events, actions and behaviors

Misunderstanding and wrongly inferring causality

Anthropomorphizing physical motion may cause confusion
or lead to incorrect conclusions

Animated Transitions in Statistical Graphics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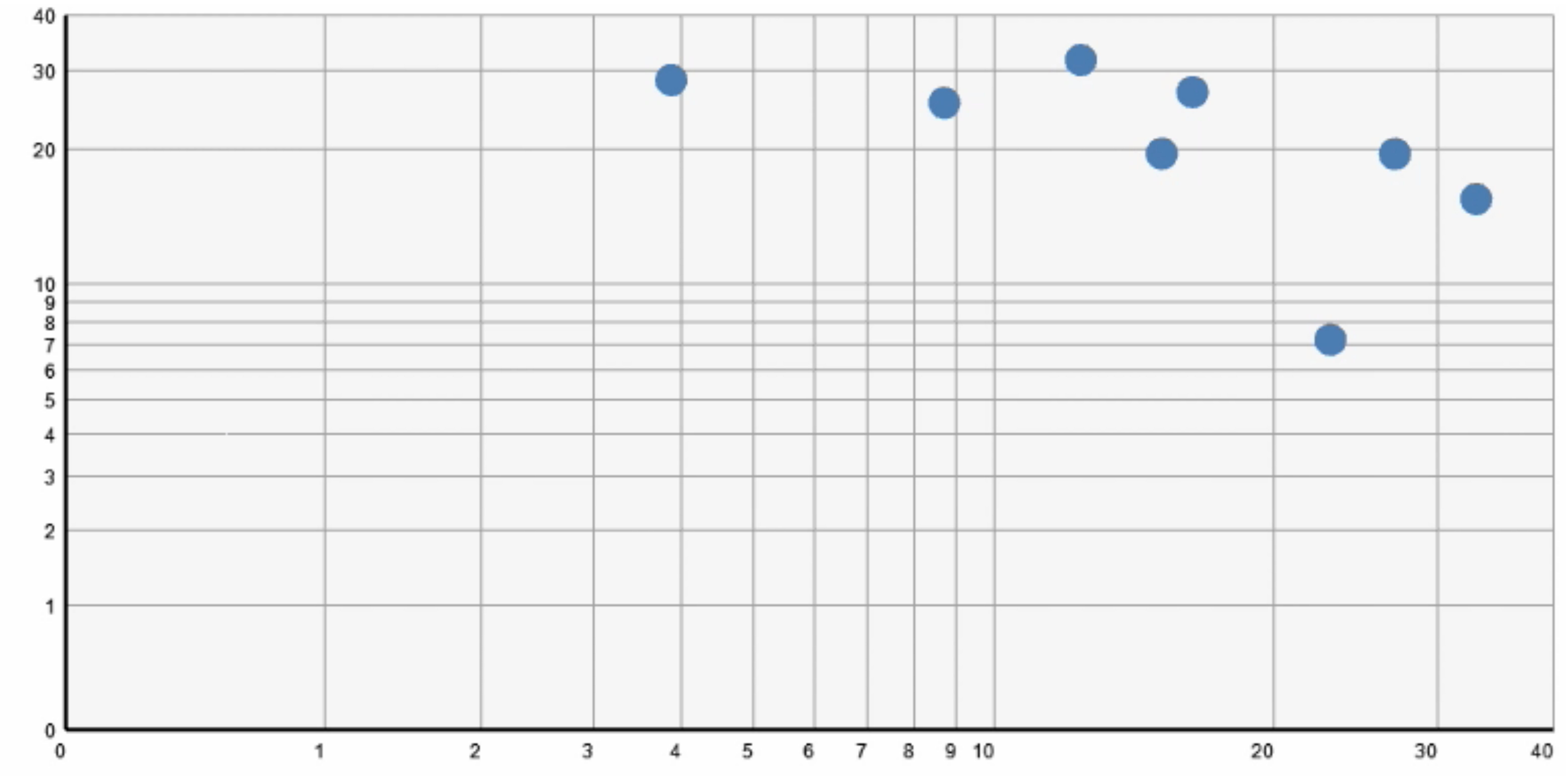
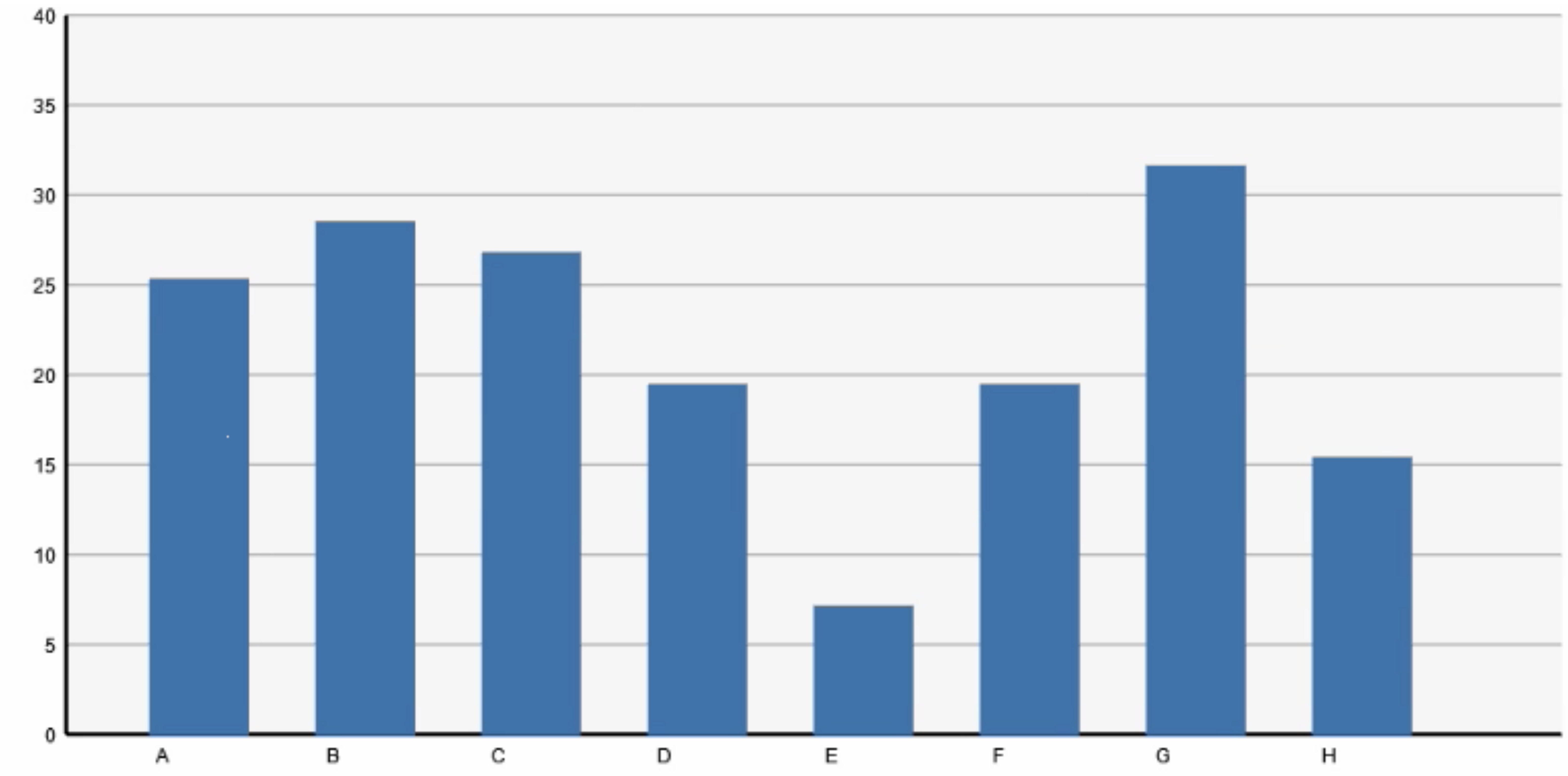
Log Transform





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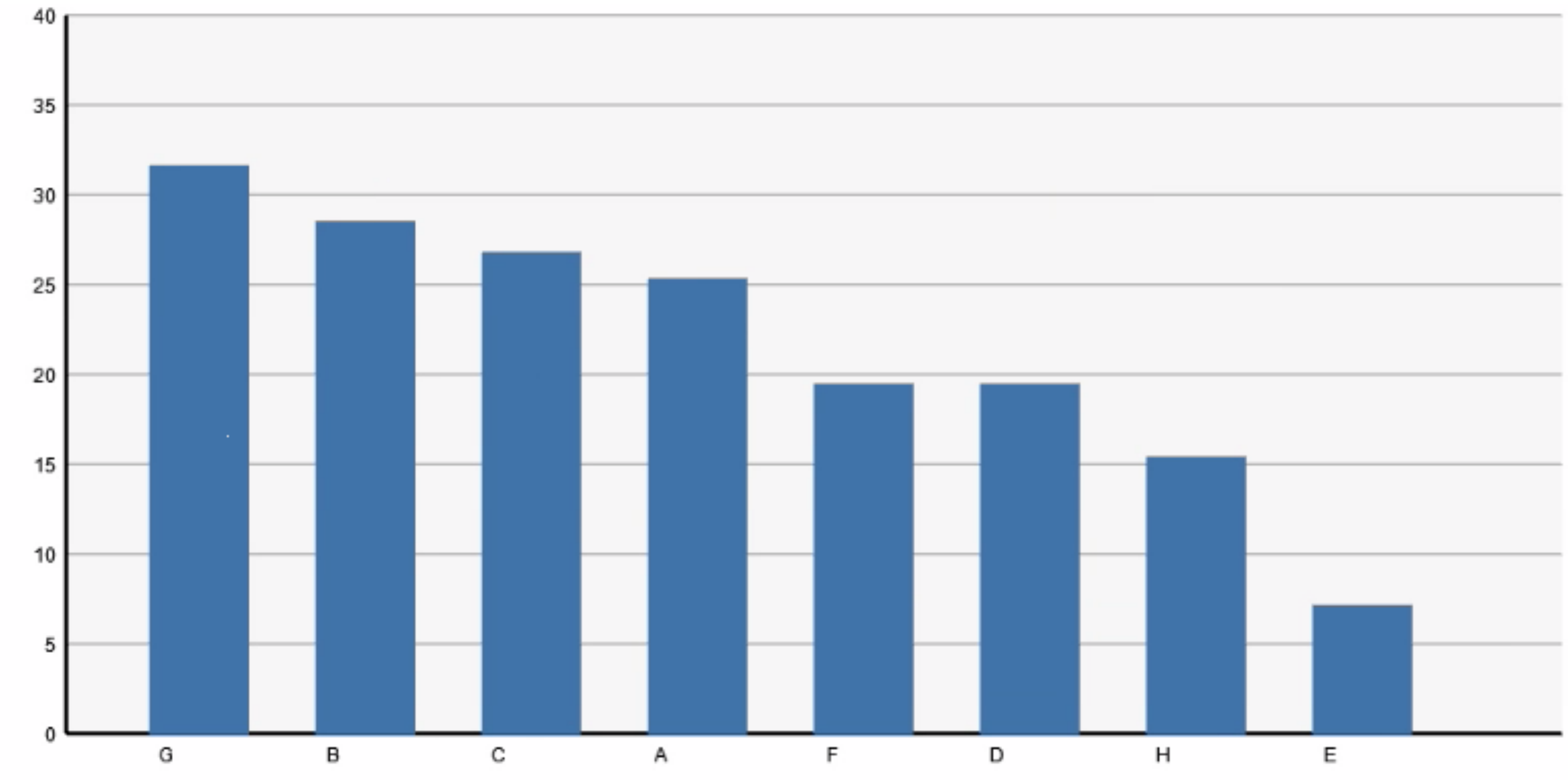
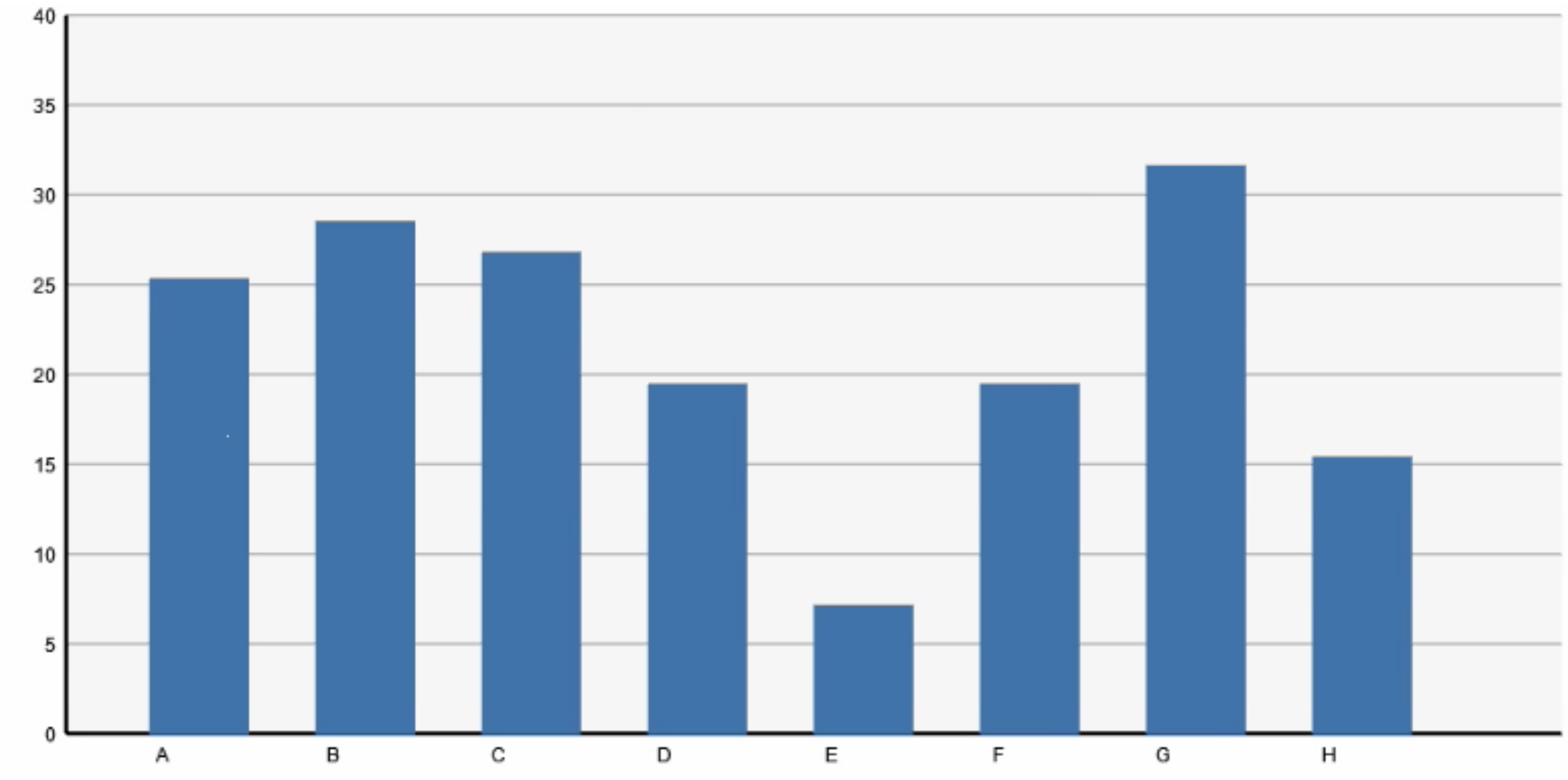
Sorting

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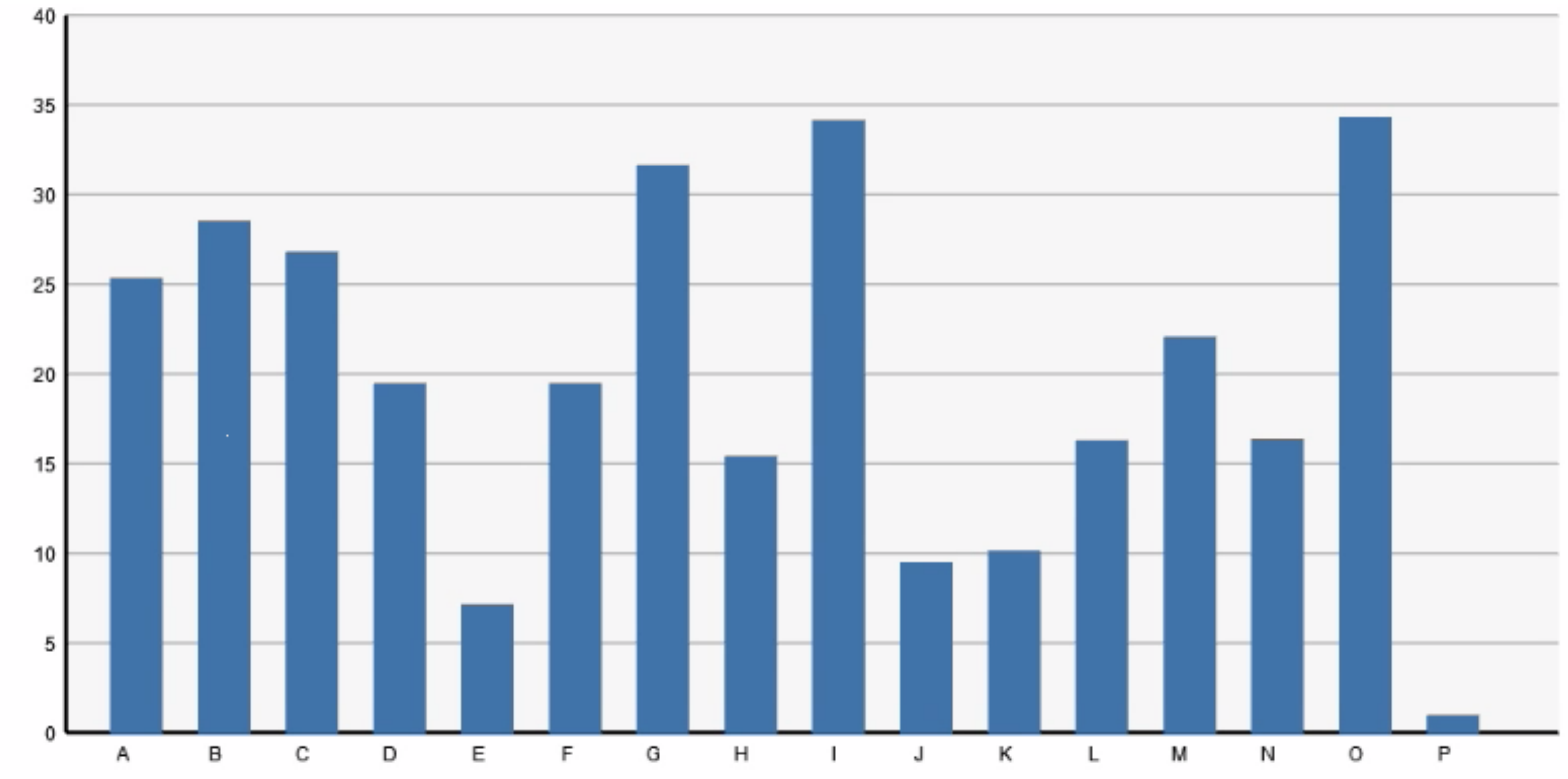
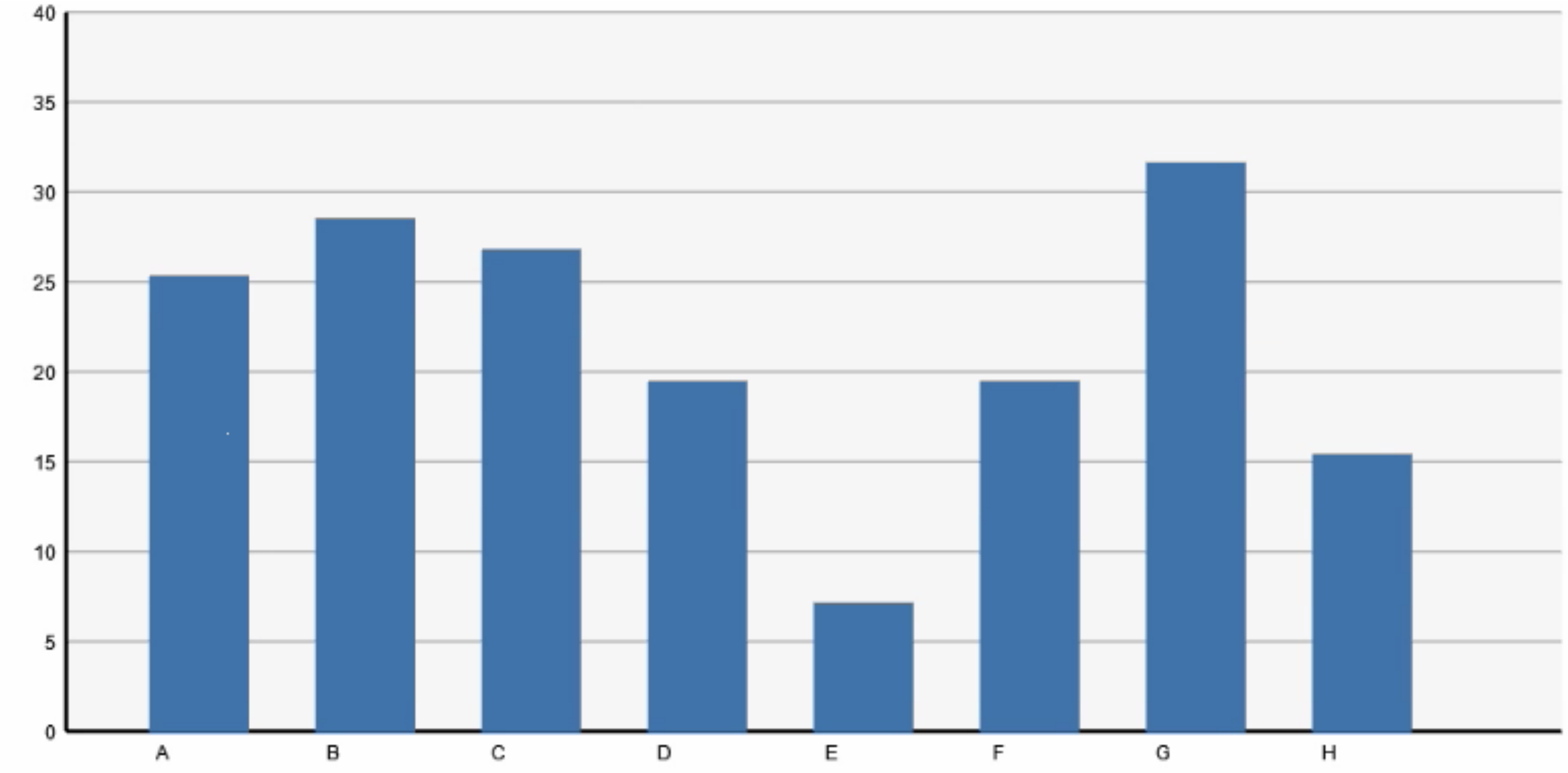
Filtering

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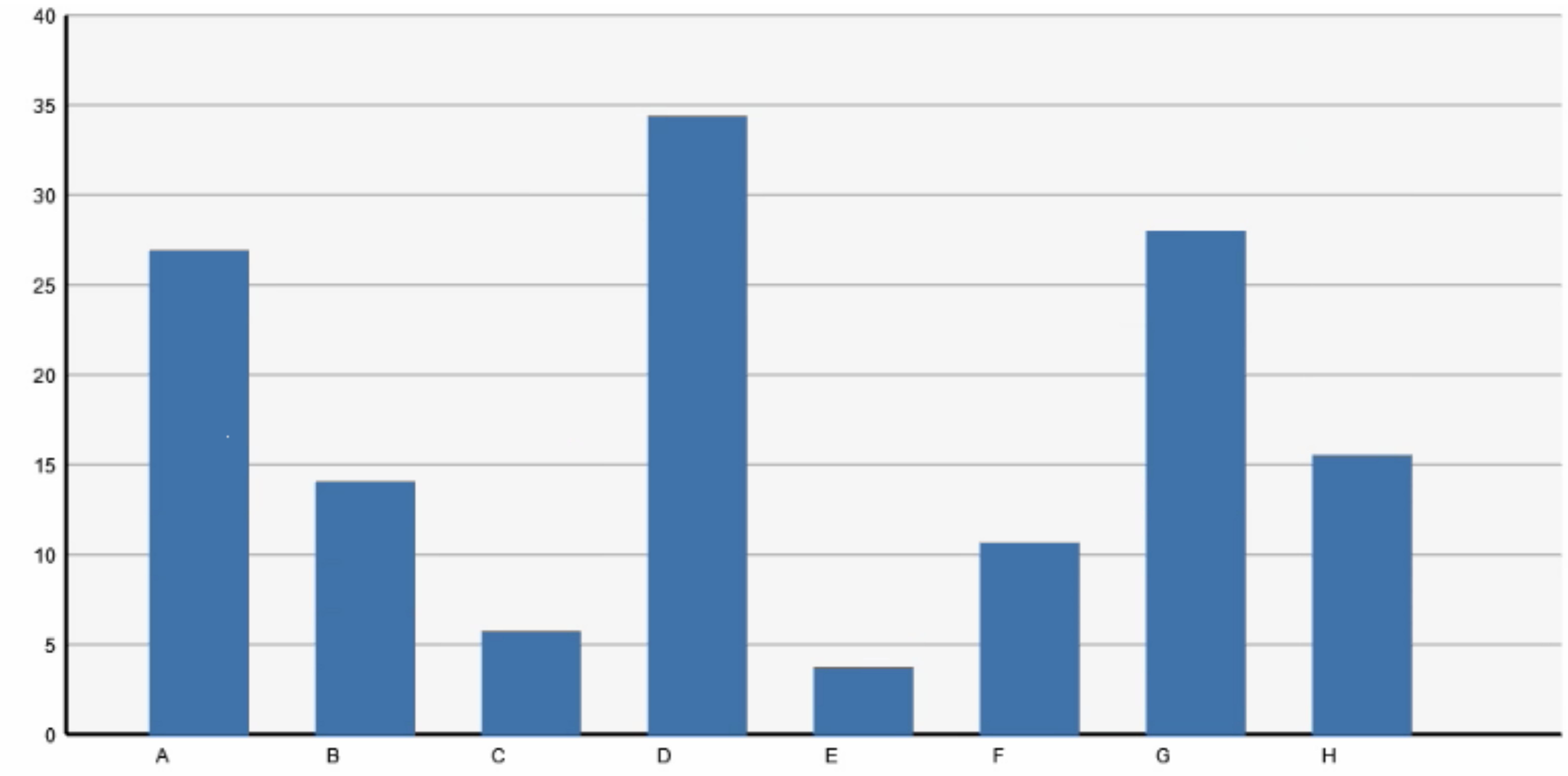
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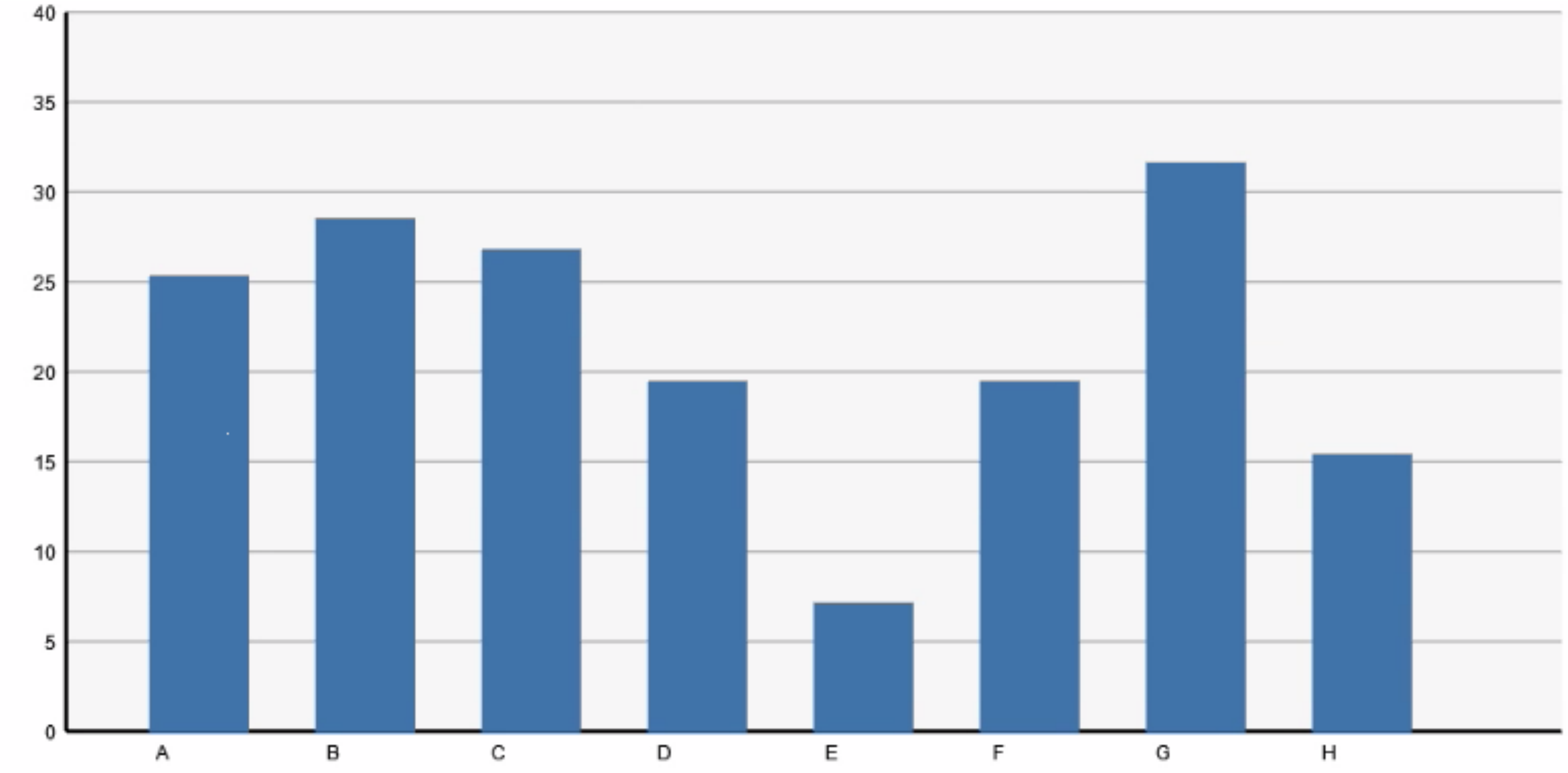
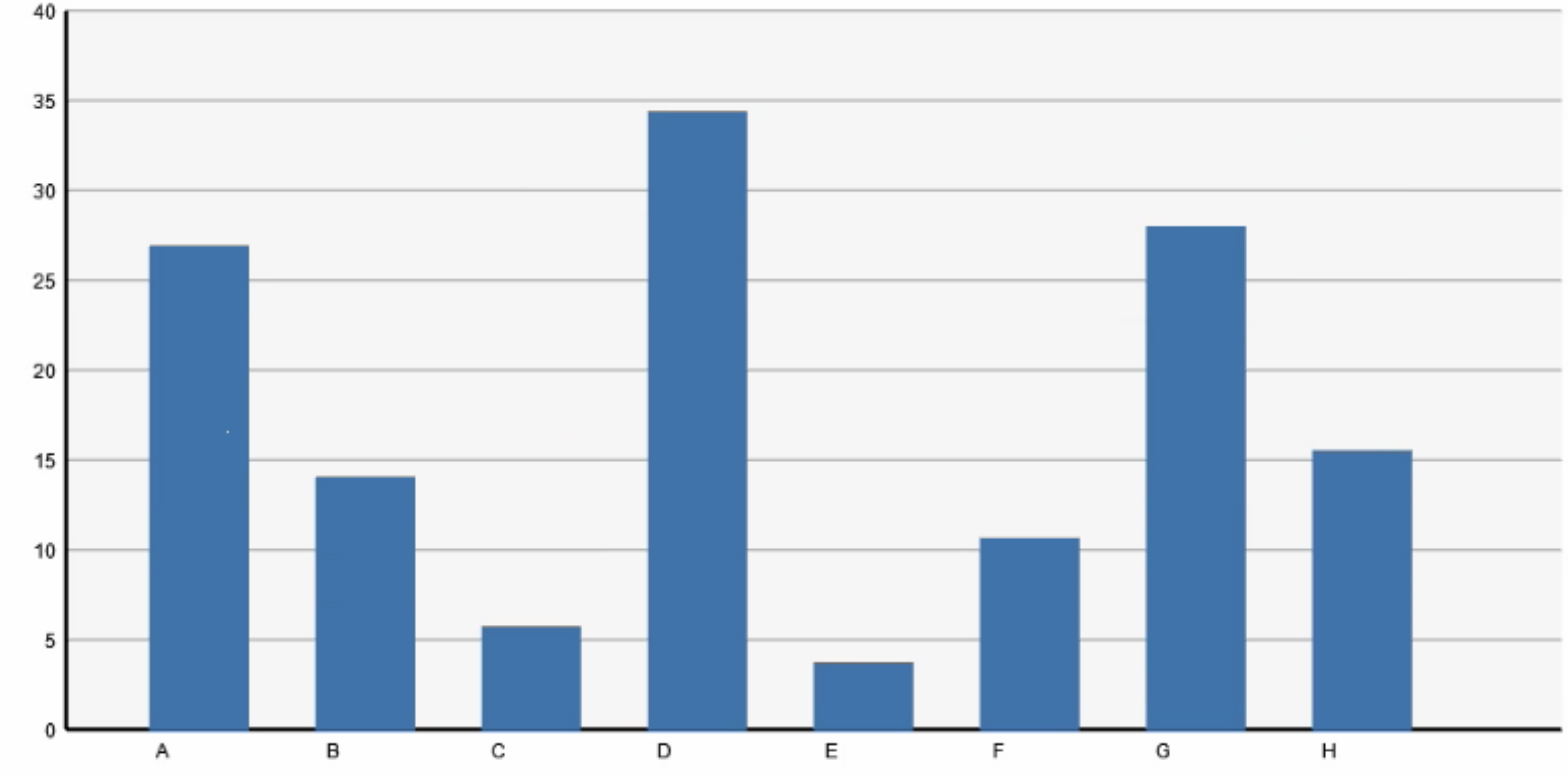
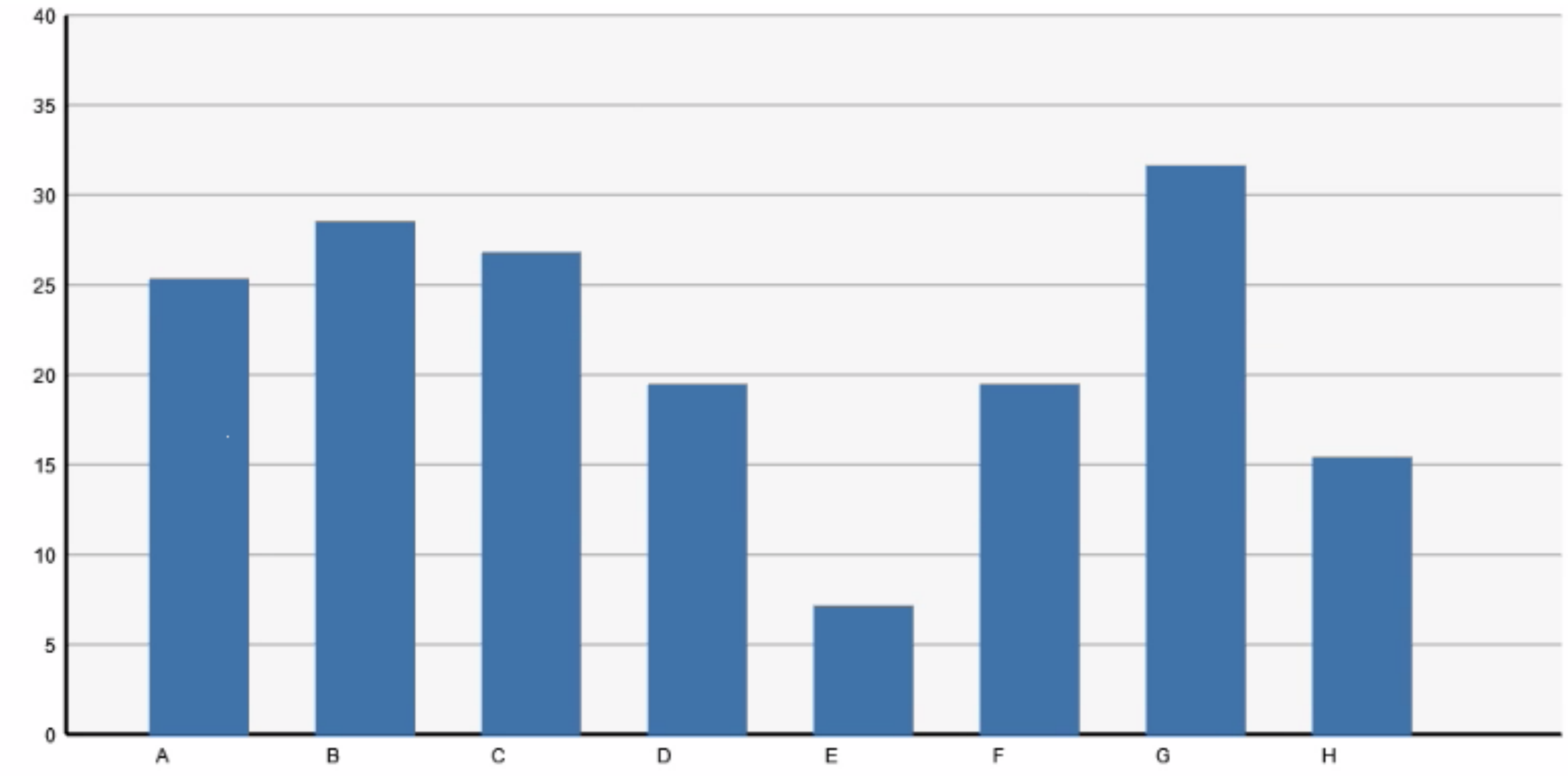


Month 1

Timestep



Month 2



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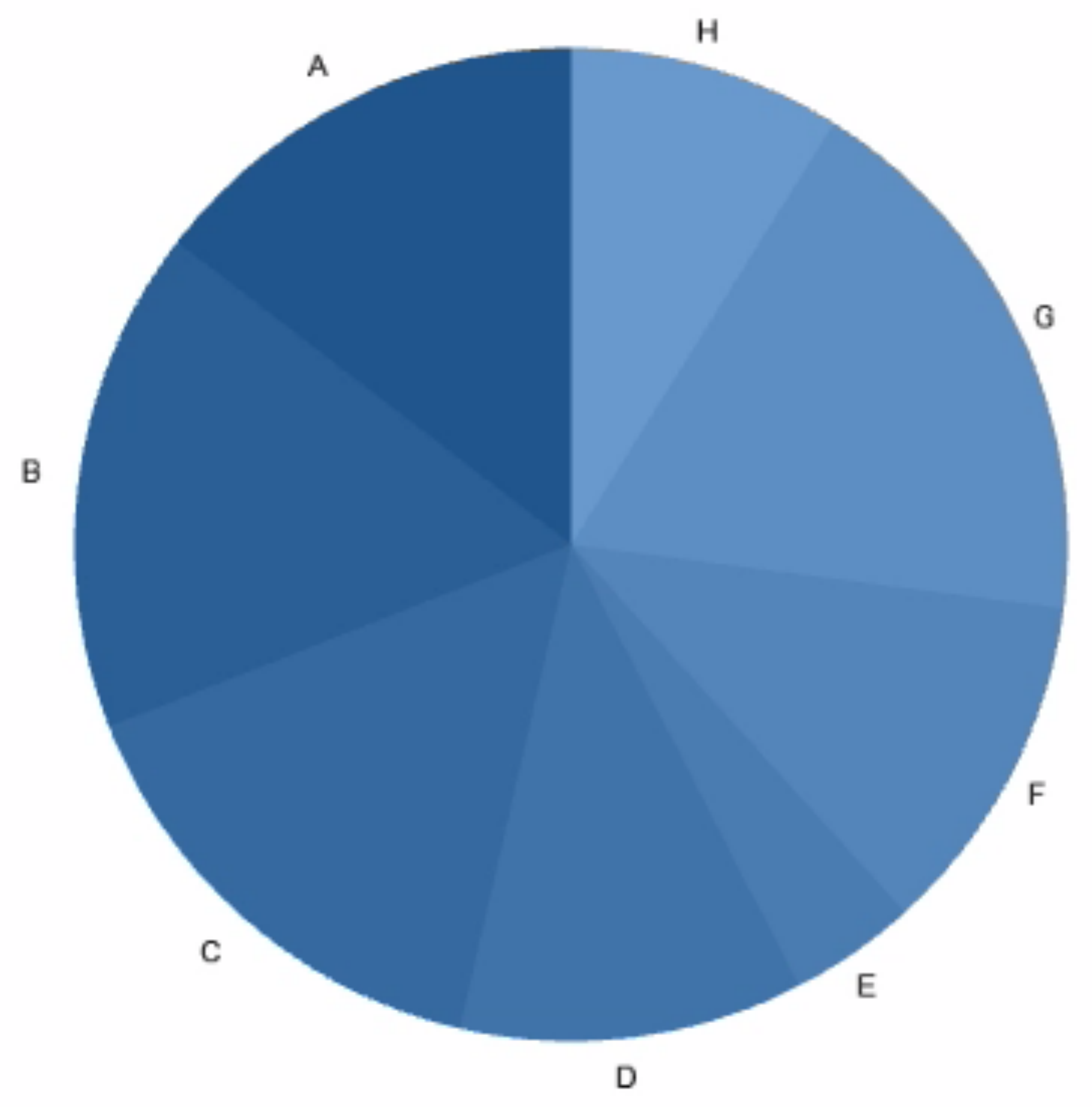
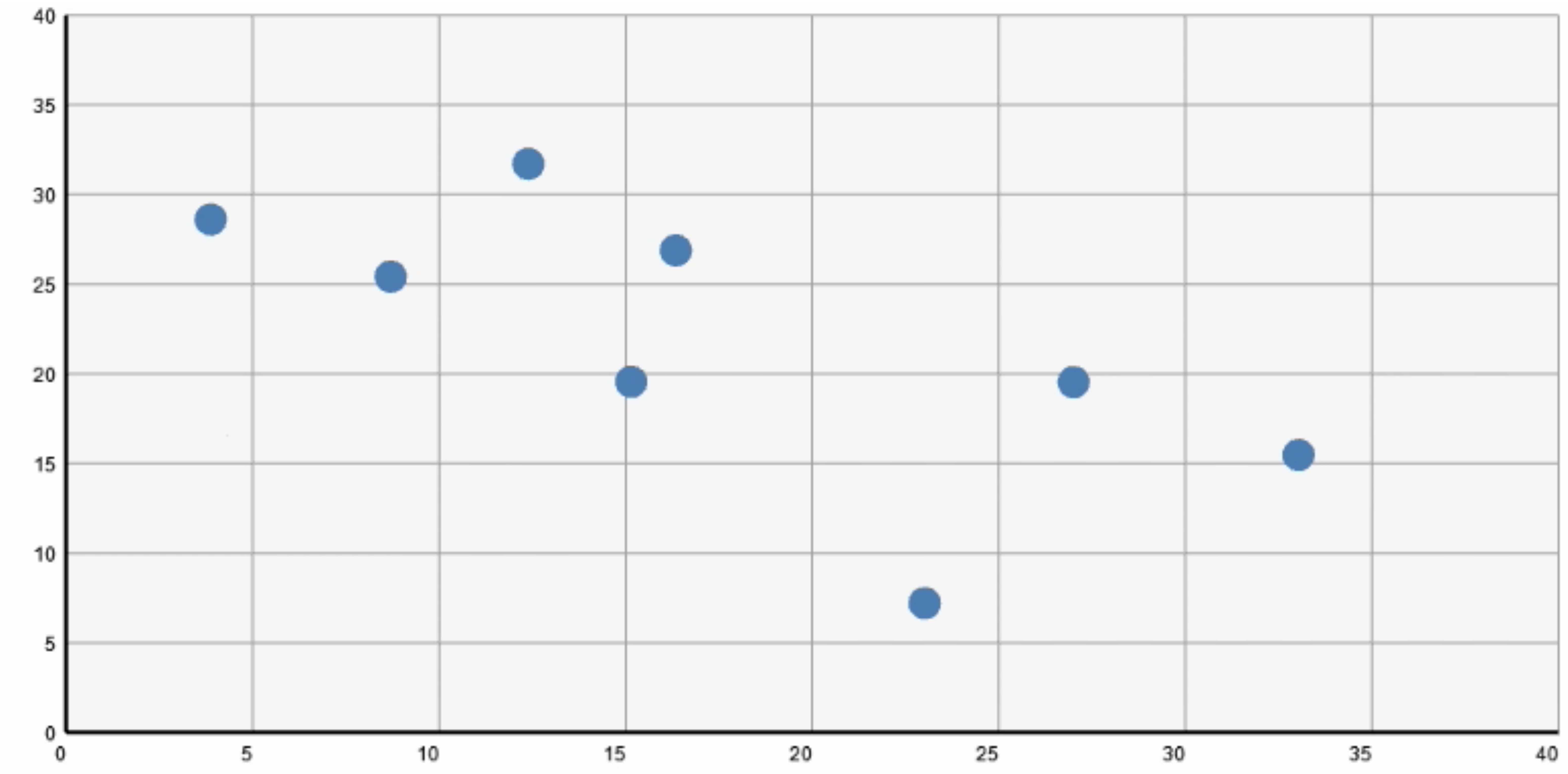
Change Encodings

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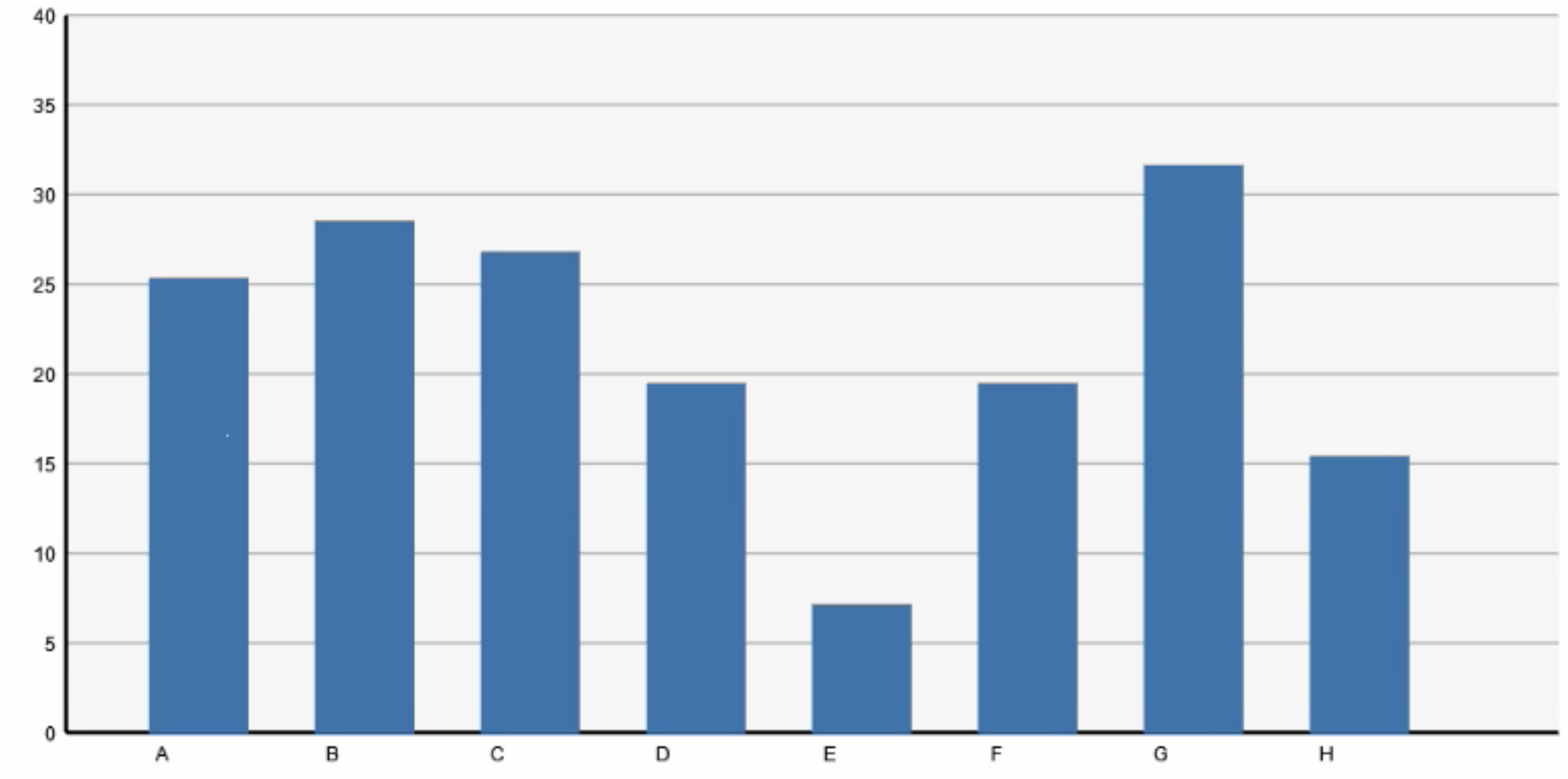
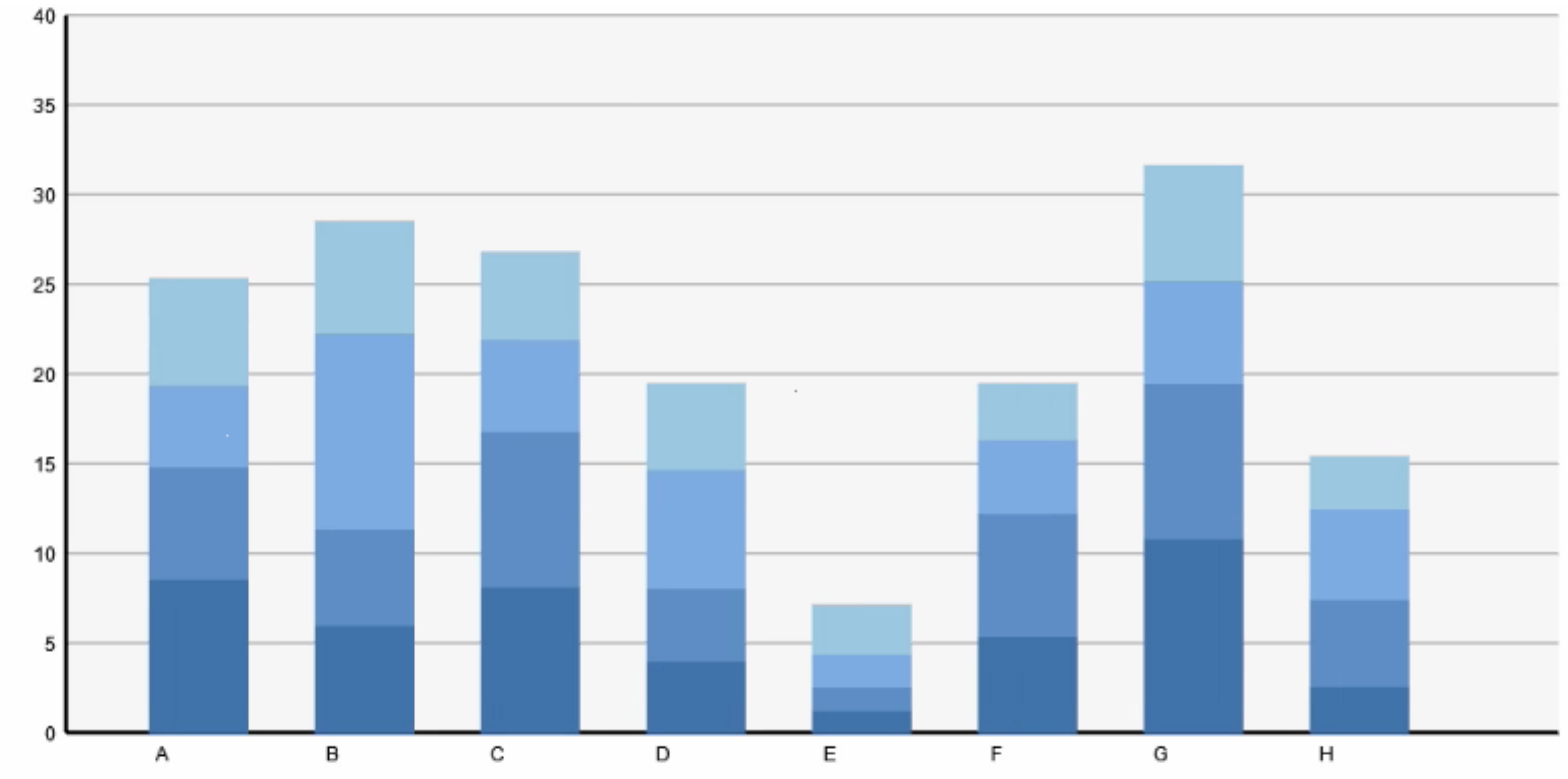
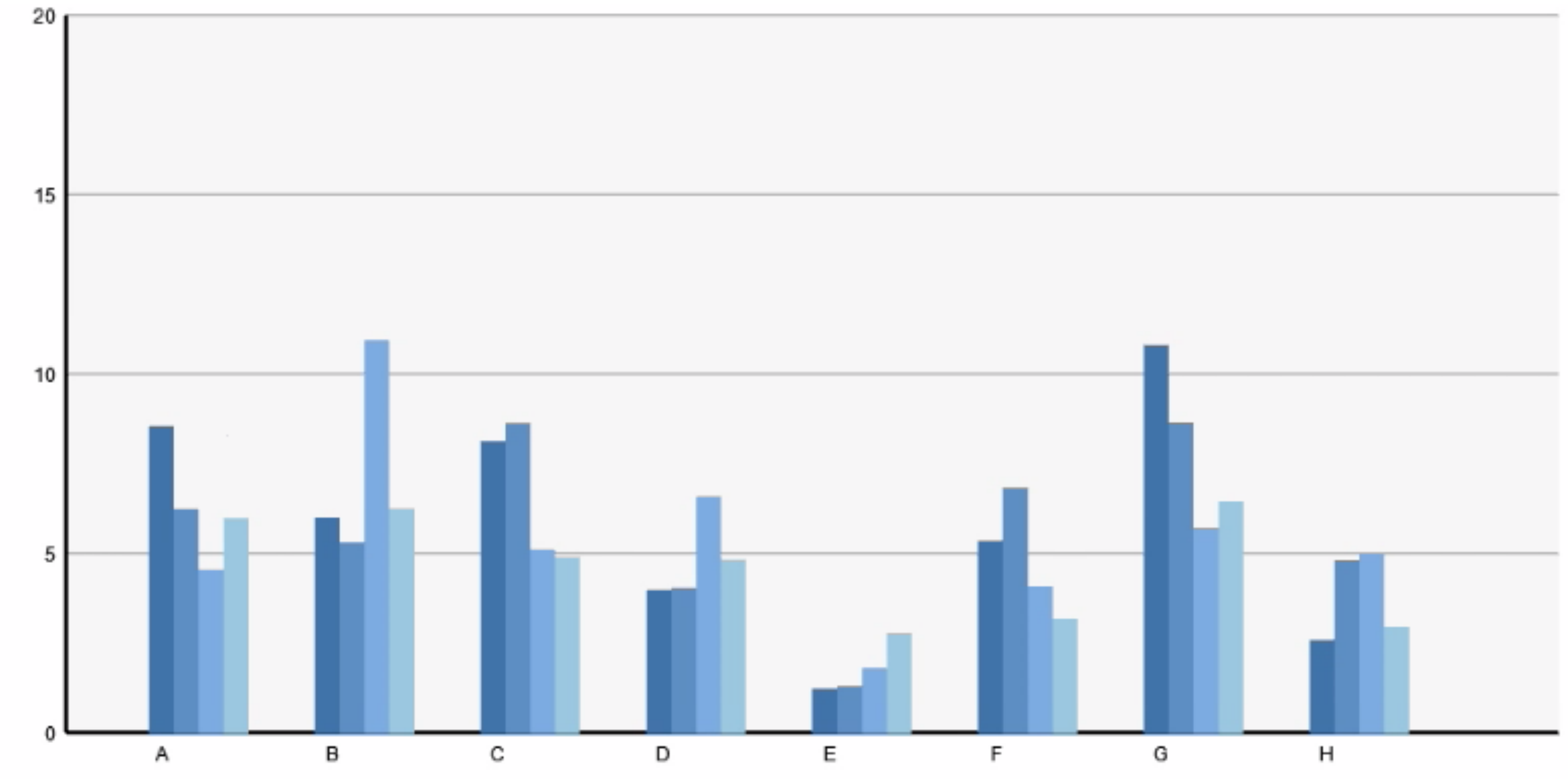
Change Data Dimensions



Change Data Dimensions



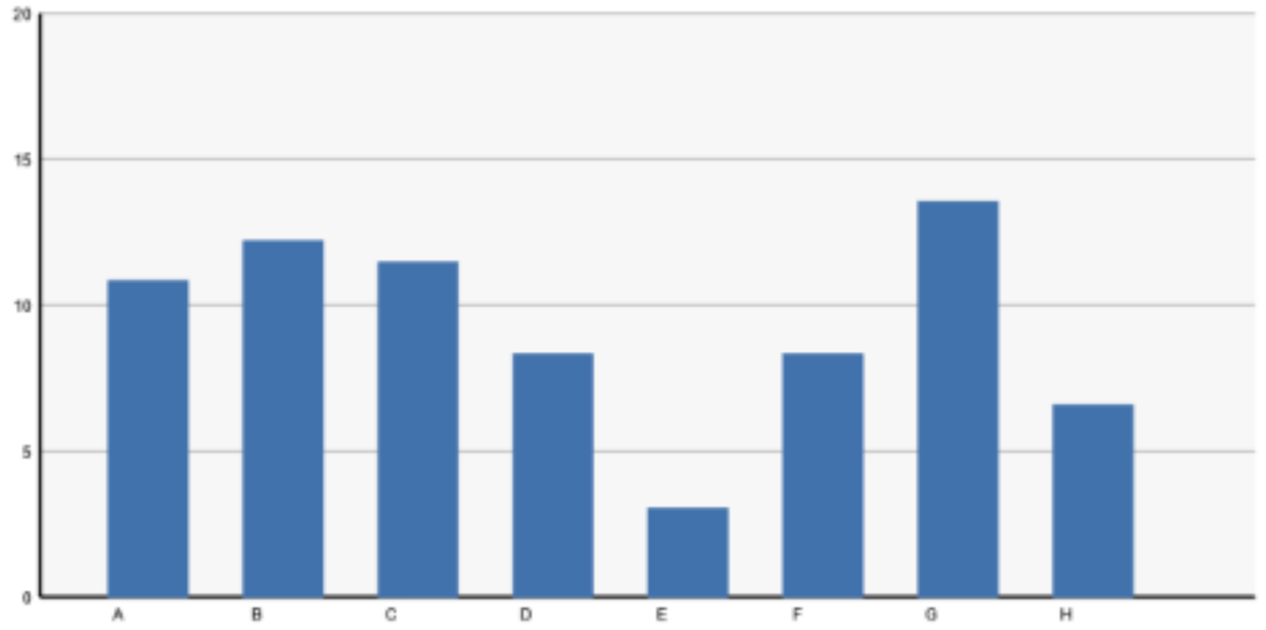
Change Encodings + Axis Scales



Data Graphics & Transitions

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

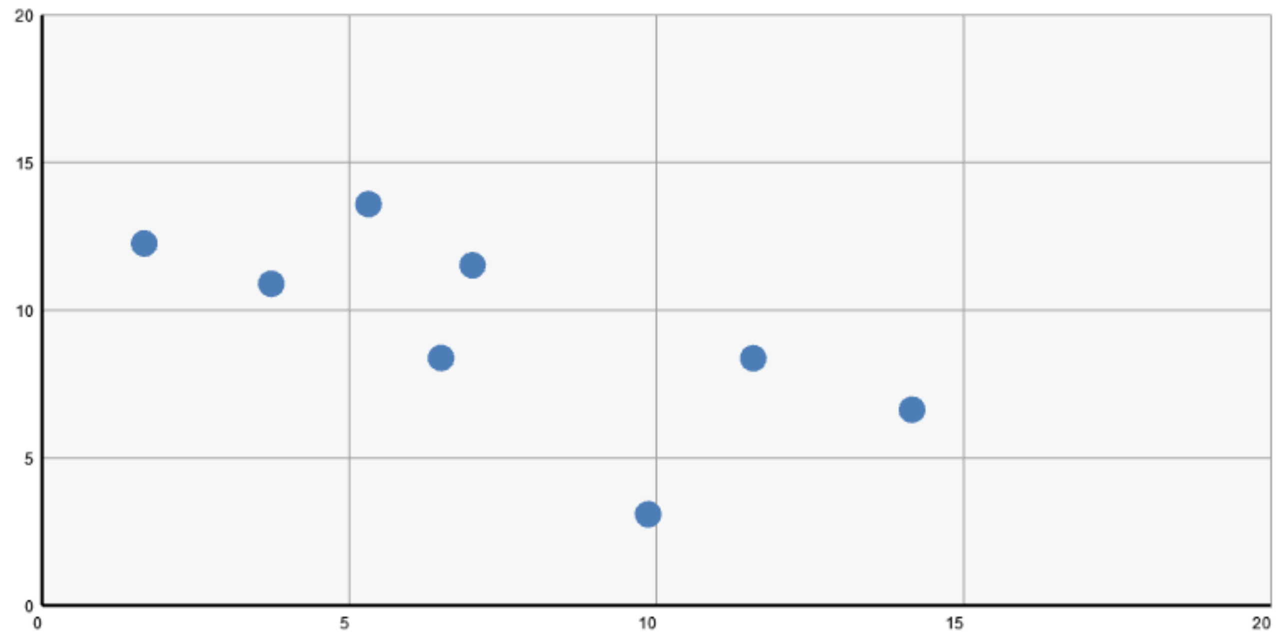
Visual Encoding



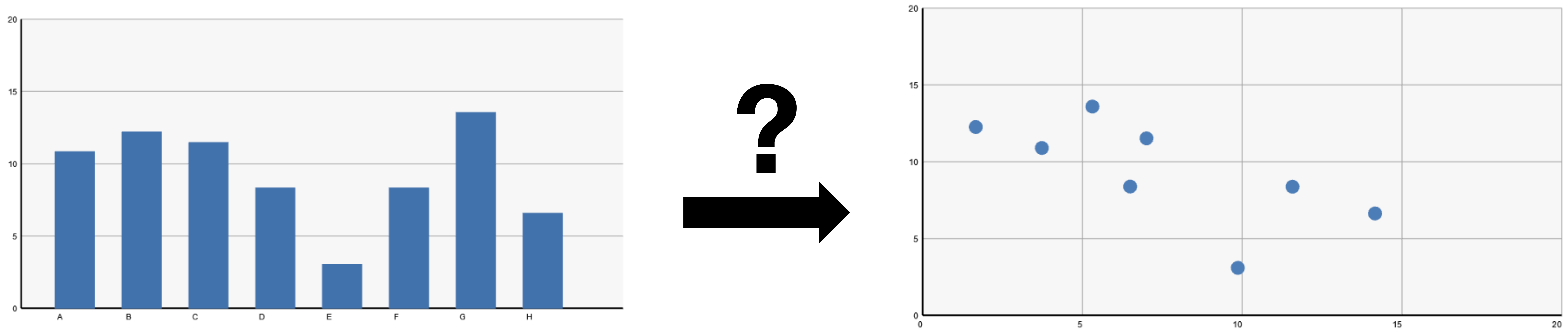
Change selected data dimensions or encodings

Animation to communicate changes?

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



Transitions between Data Graphics



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

Can animation help?

How does this impact perception?

Principles for Animation [Tversky 02]

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.

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

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Use staging for complex transitions

Make transitions as long as needed, but no longer

Principles for Animation

Congruence

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Apprehension

Group similar transitions

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Maximize predictability

Use simple transitions

Use staging for complex transitions

Make transitions as long as needed, but no longer

Objects are harder to track when occluded.

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

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)

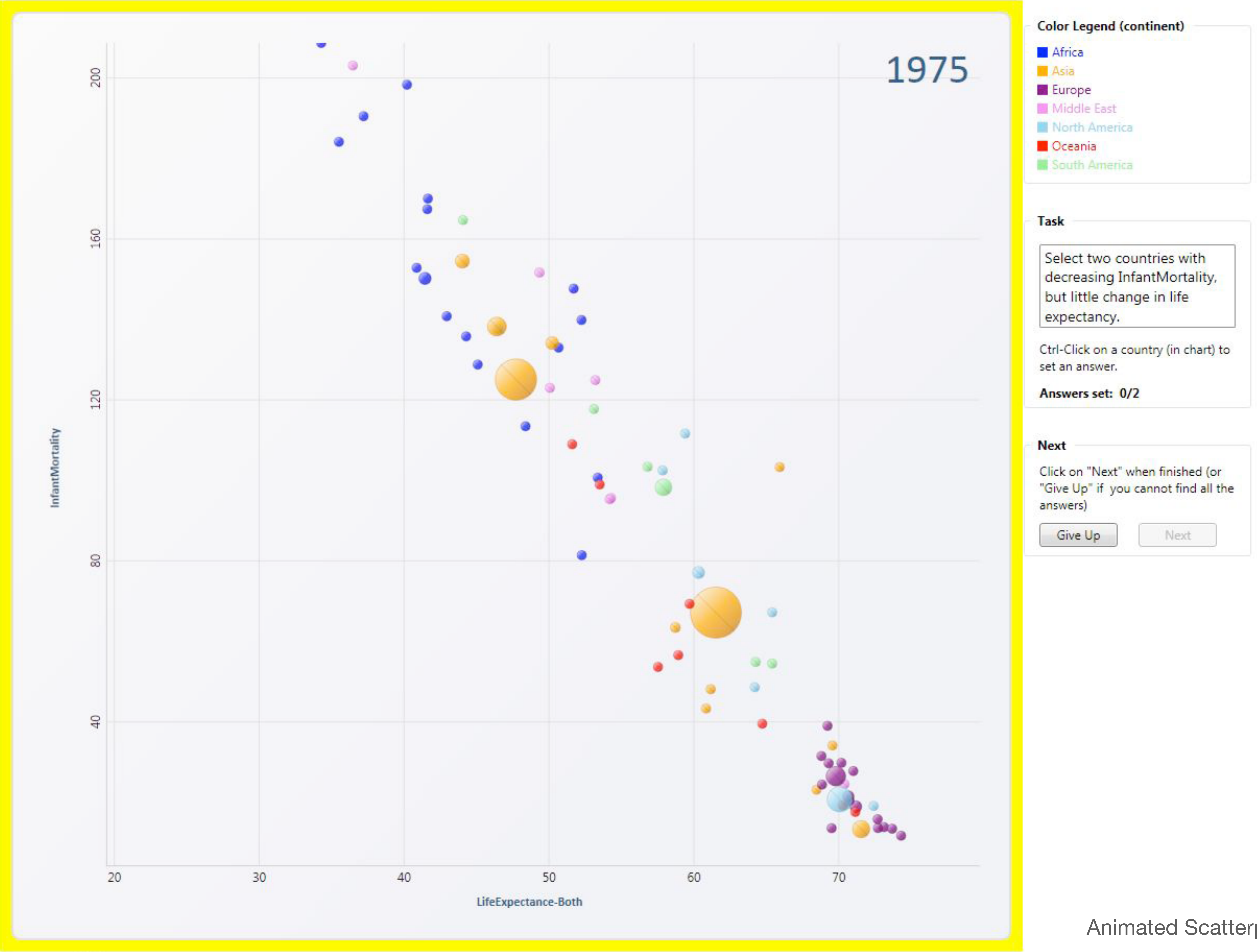
Subjects preferred animated transitions

Animation in Trend Visualization

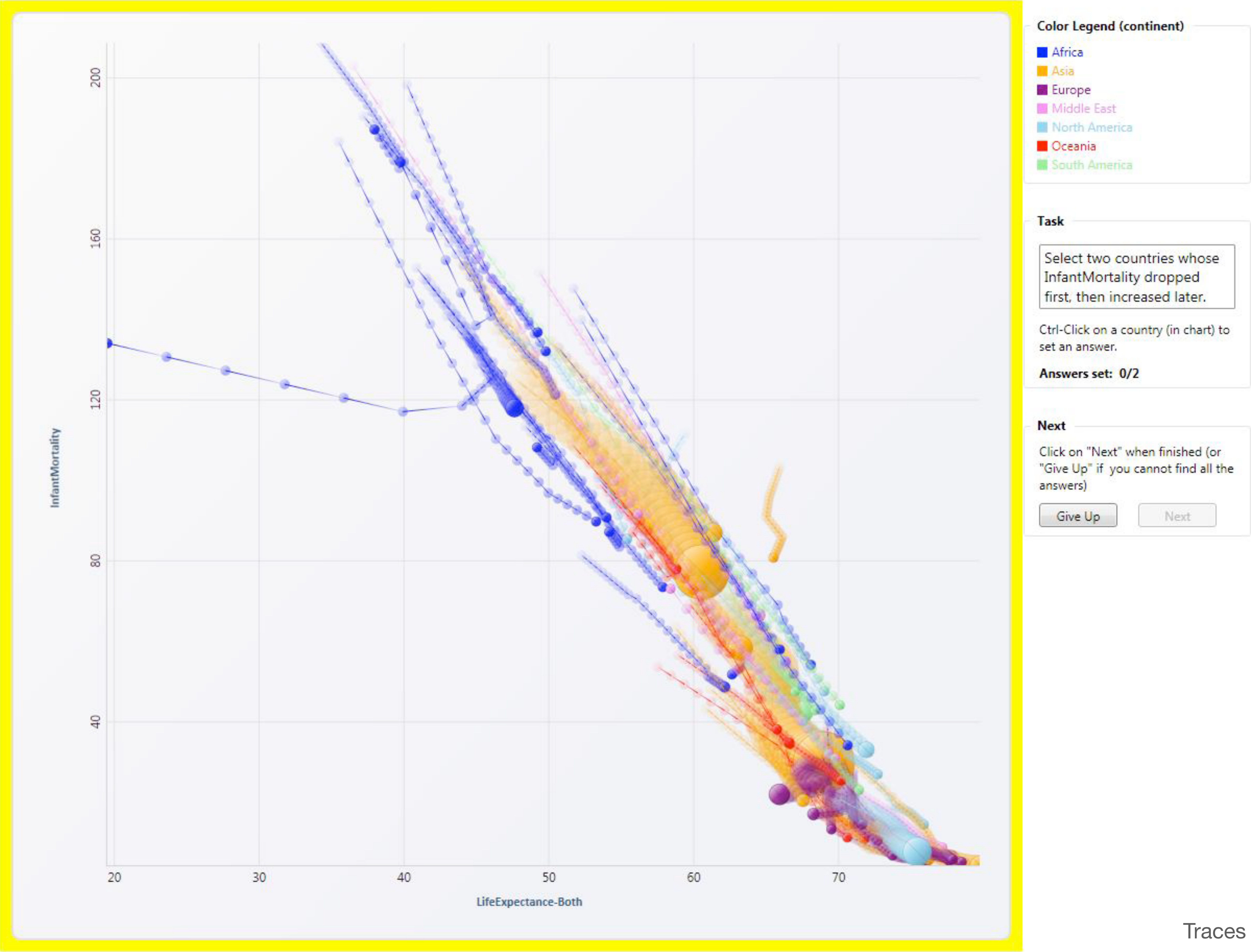
Heer & Robertson study found that animated transitions are better than static transitions for estimating changing values.

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

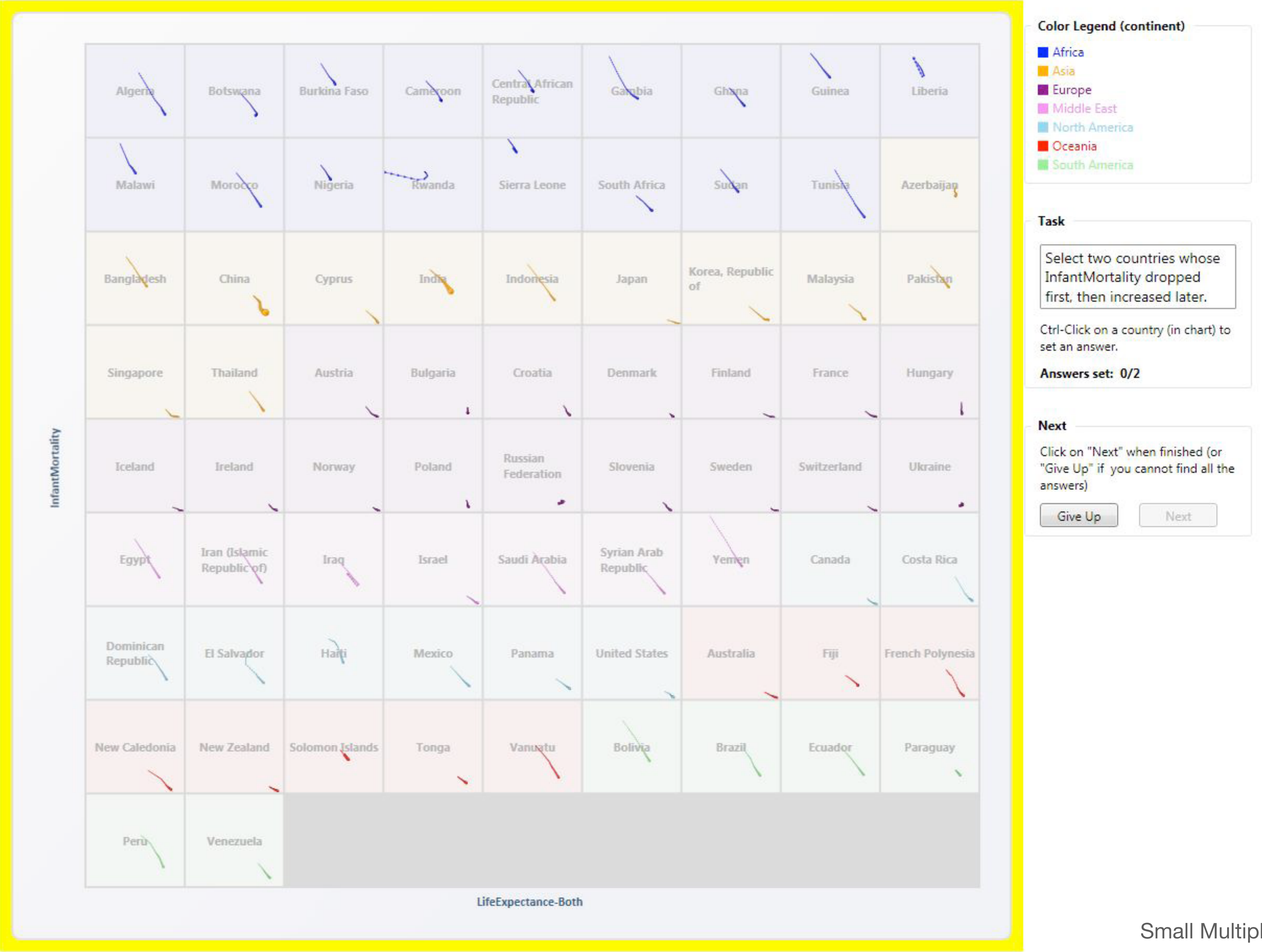
Experiments by Robertson et al, InfoVis 2008



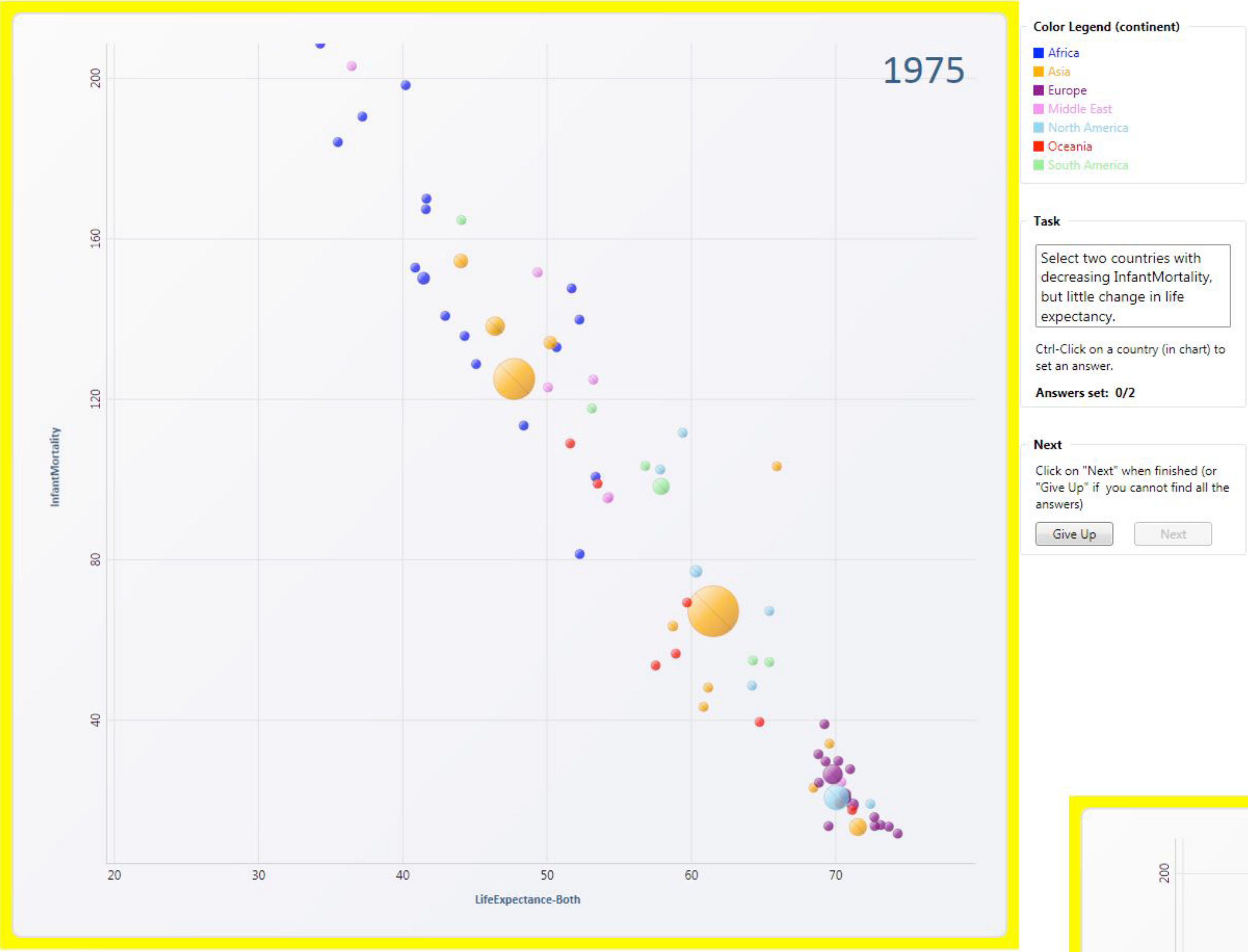
Animated Scatterplot [Robertson 08]

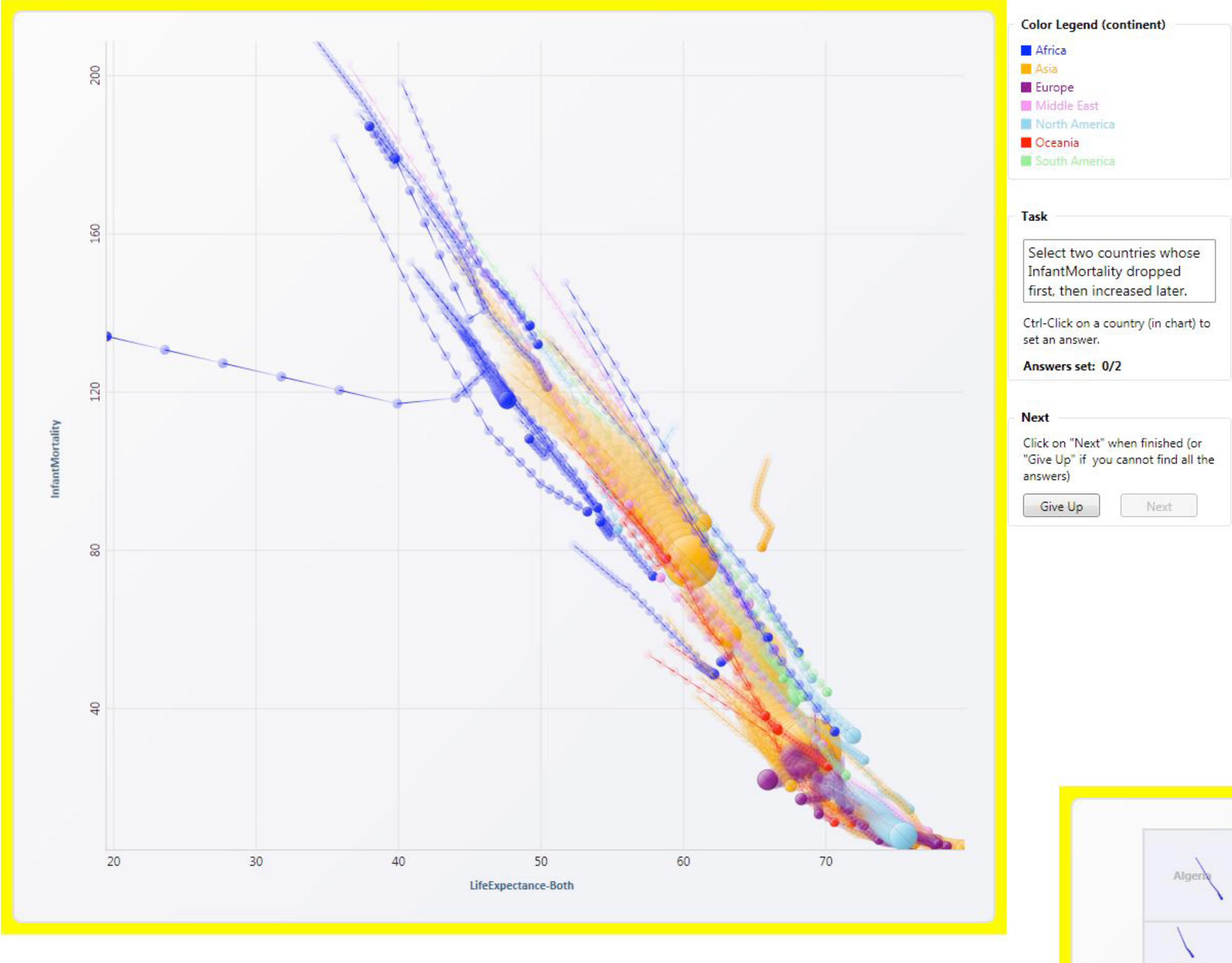


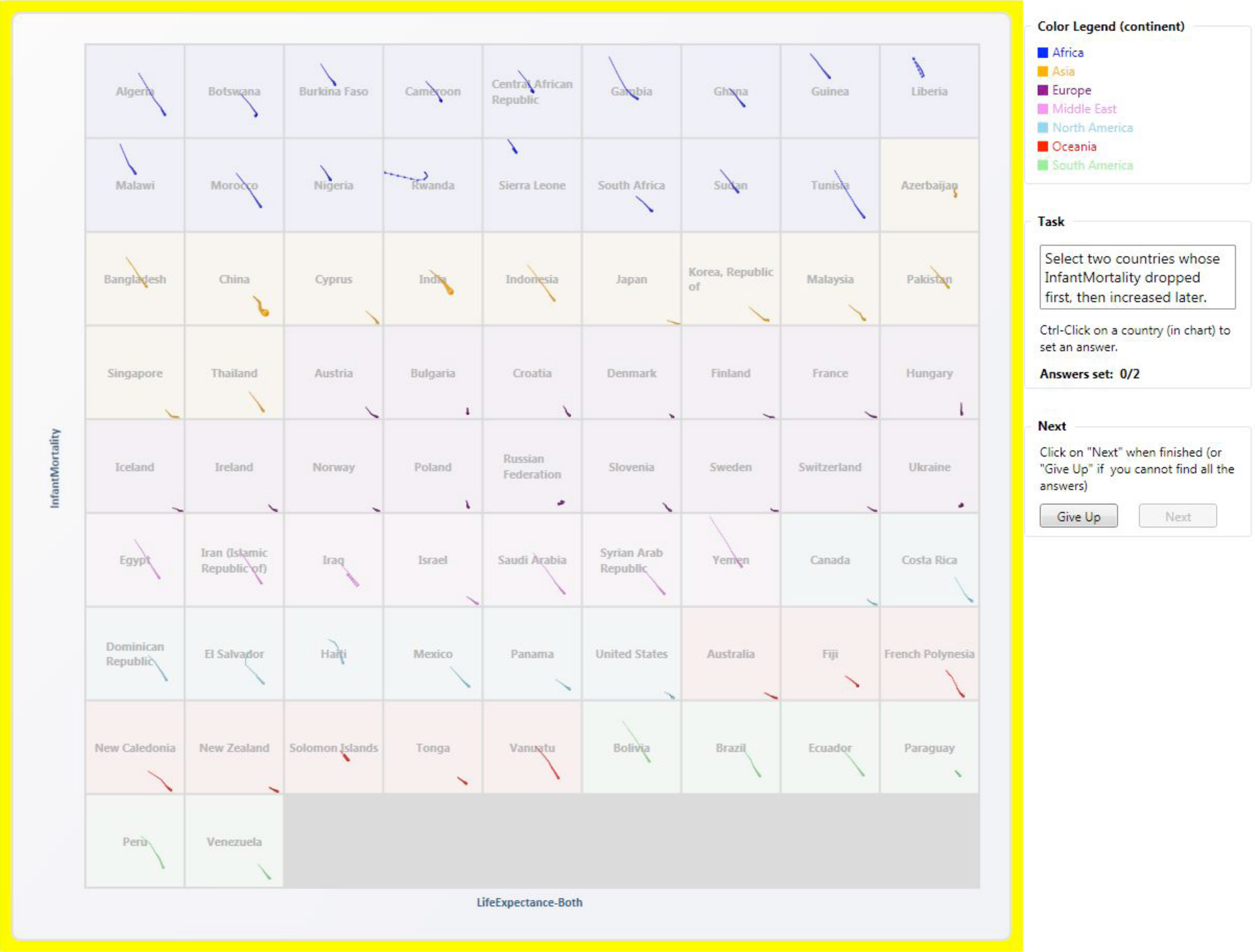
Traces [Robertson 08]



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

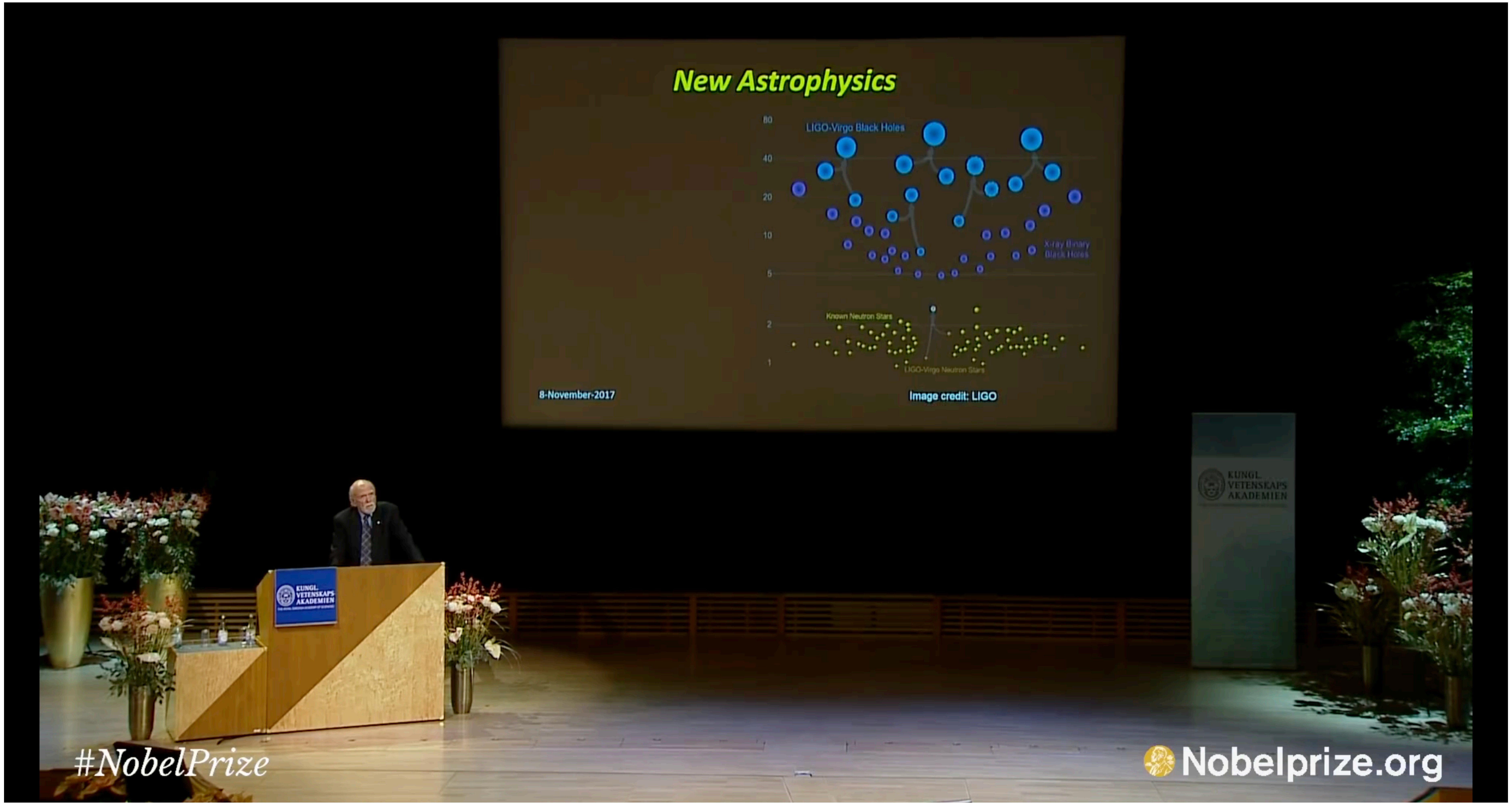
User preferences favor animation
(even though less accurate and slower for analysis!)

Designing Animation

Storytelling + Engagement

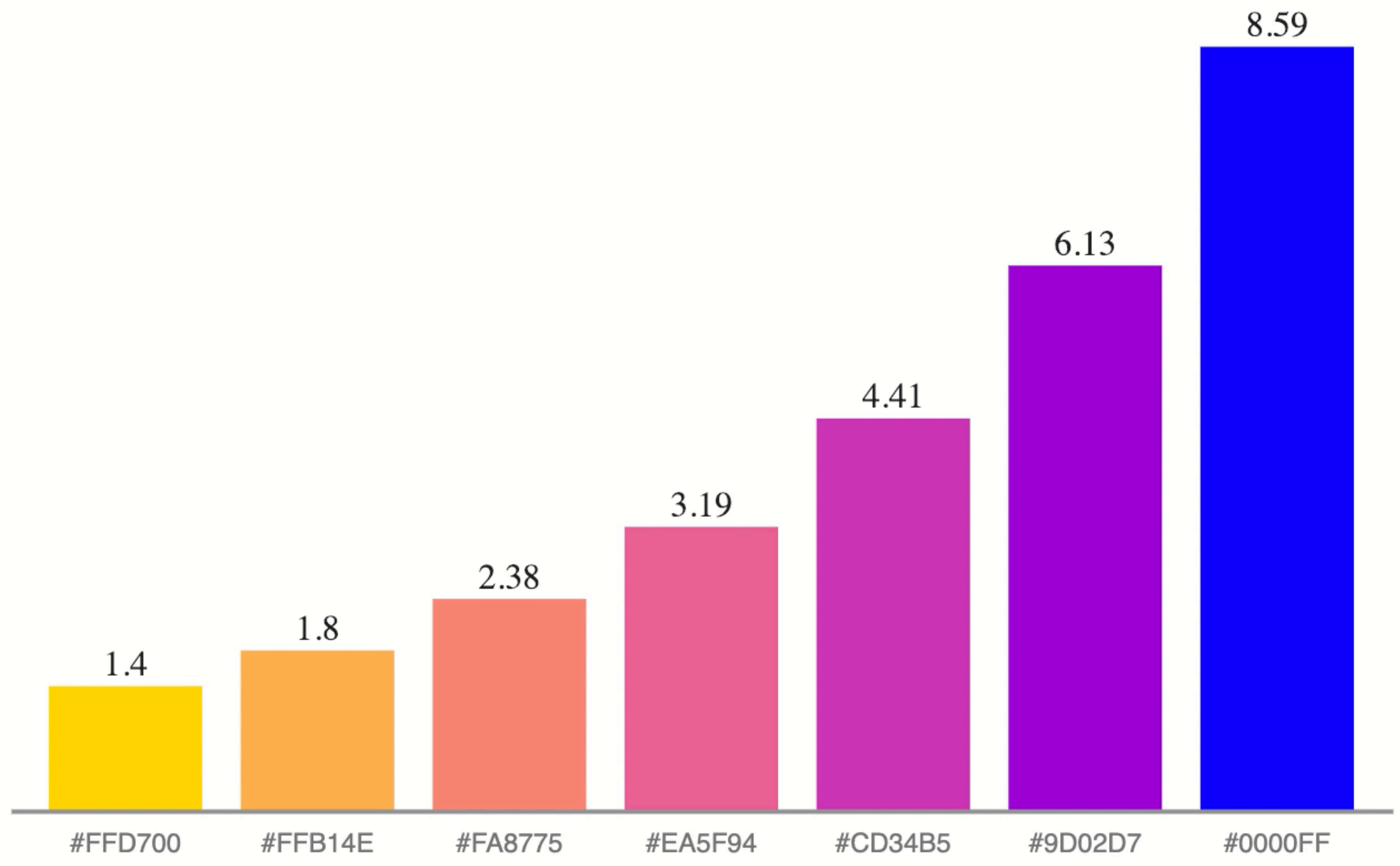
Each of these dots is a film by director Kathryn Bigelow.

(Might even be good enough for a Nobel lecture!)



Source

Communicating change


1.4
1.8
2.38
3.19
4.41
6.13
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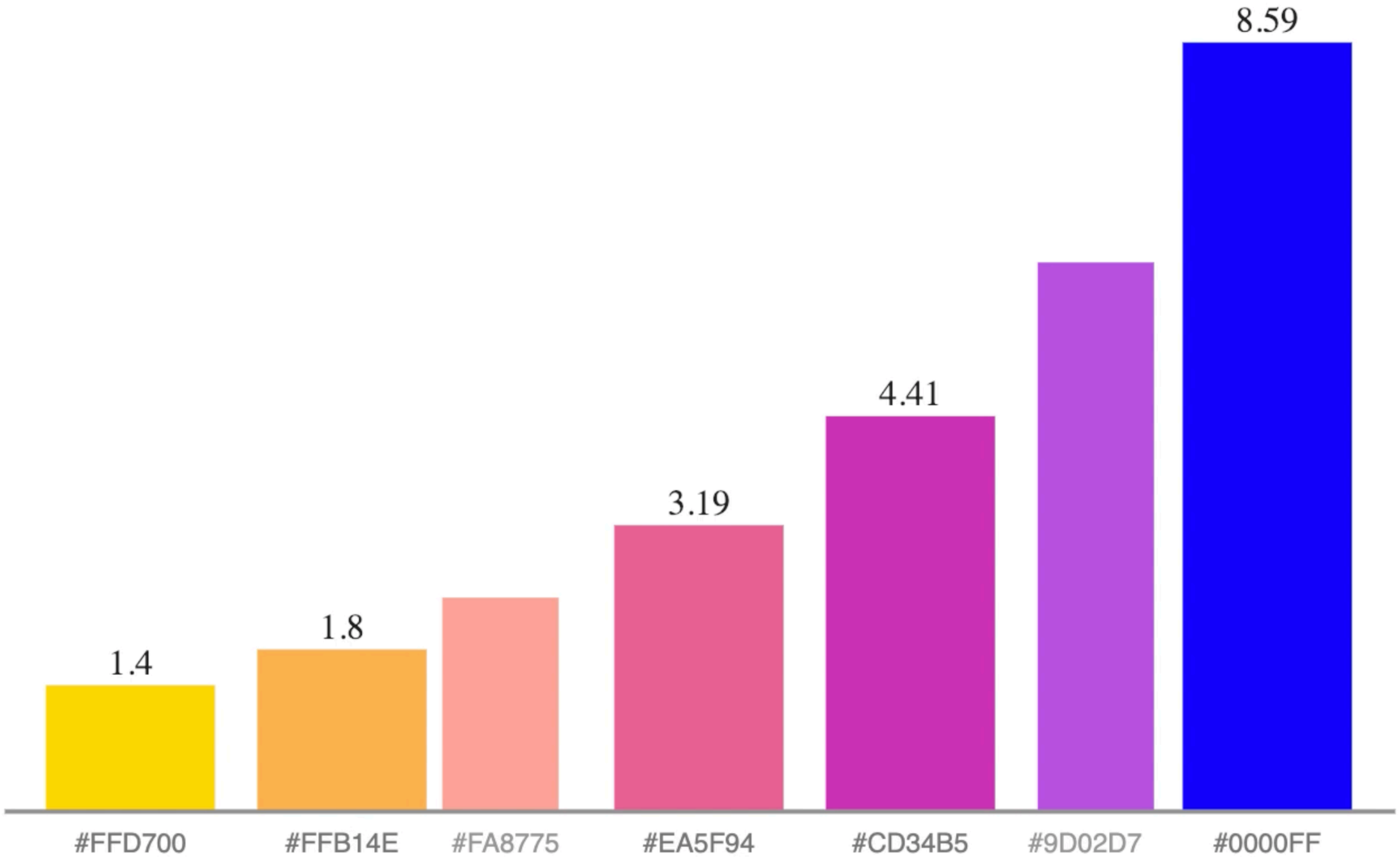
Exiting



8.59
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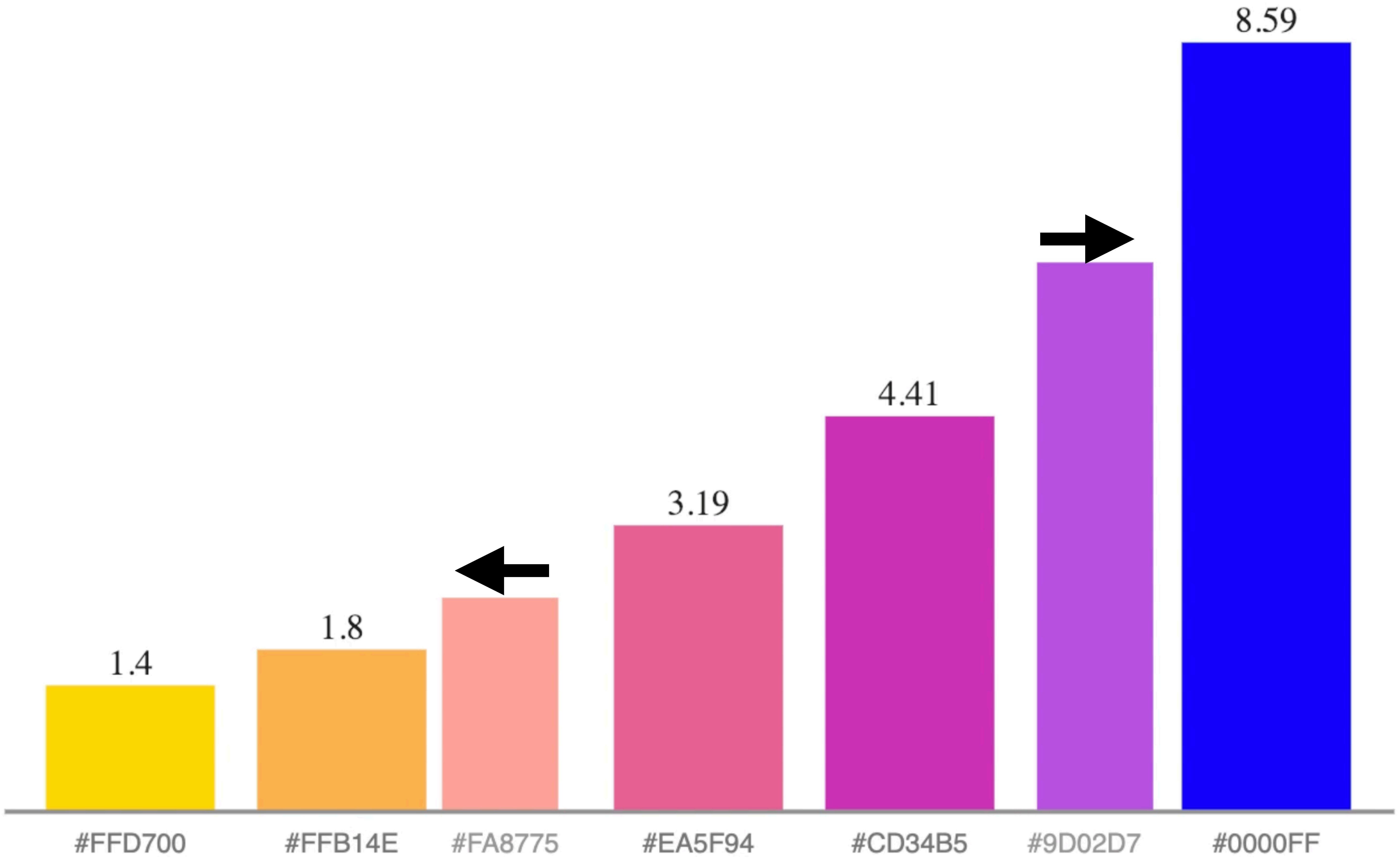
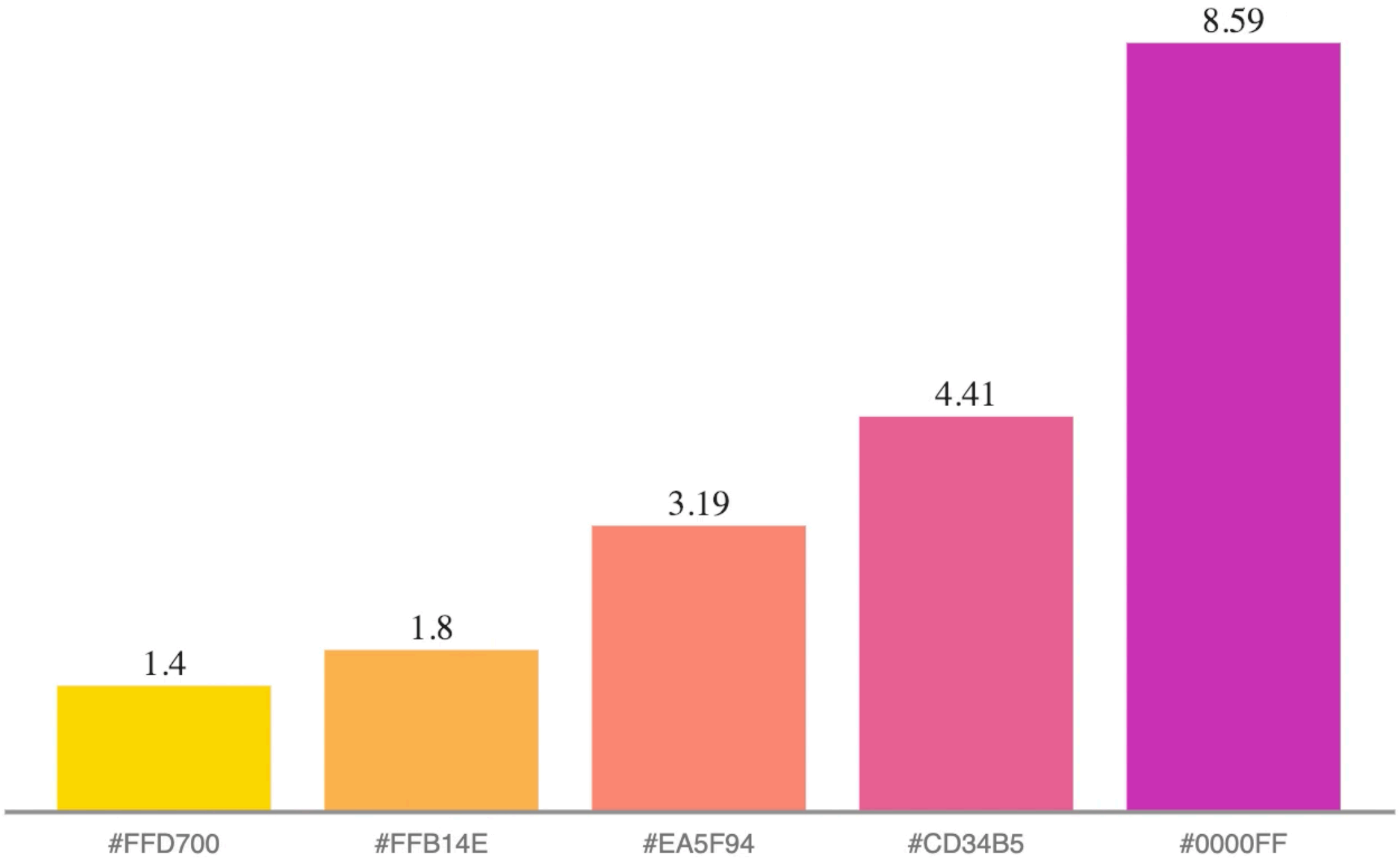
#0000FF

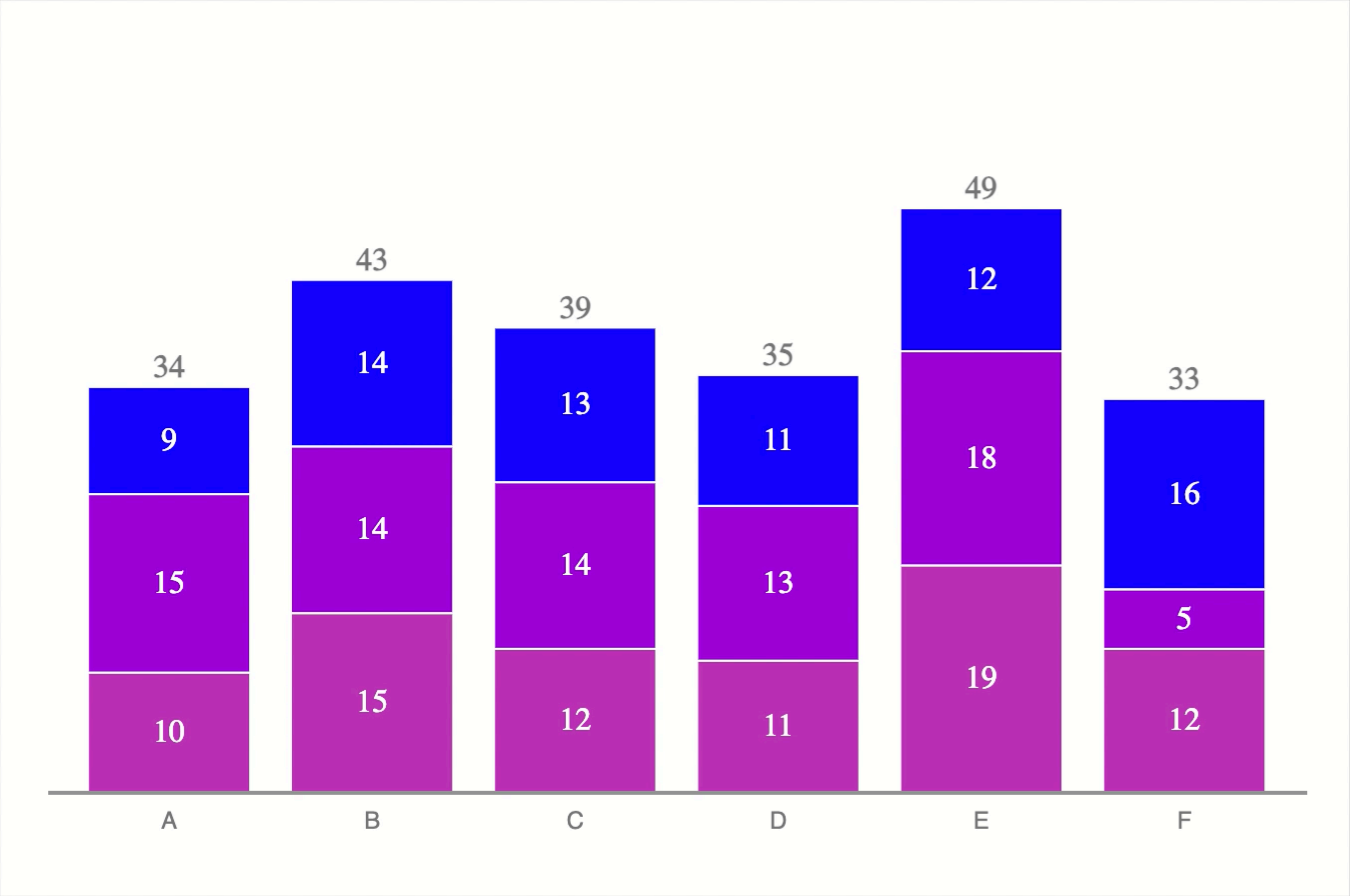
Exiting



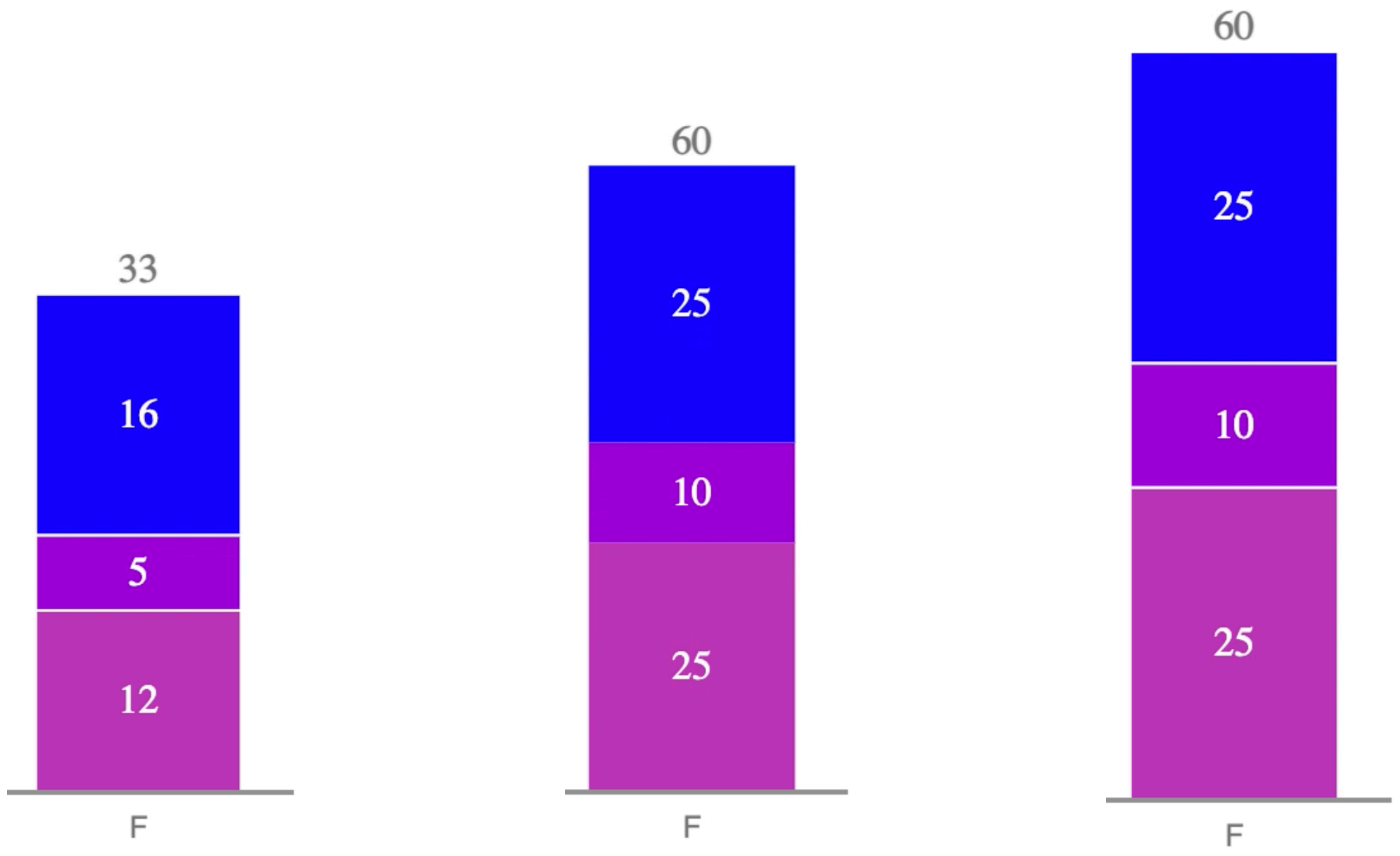
8.59
4.41
3.19
1.8
1.4
#FFD700
#FFB14E
#FA8775
#EA5F94
#CD34B5
#9D02D7
#0000FF

Exited

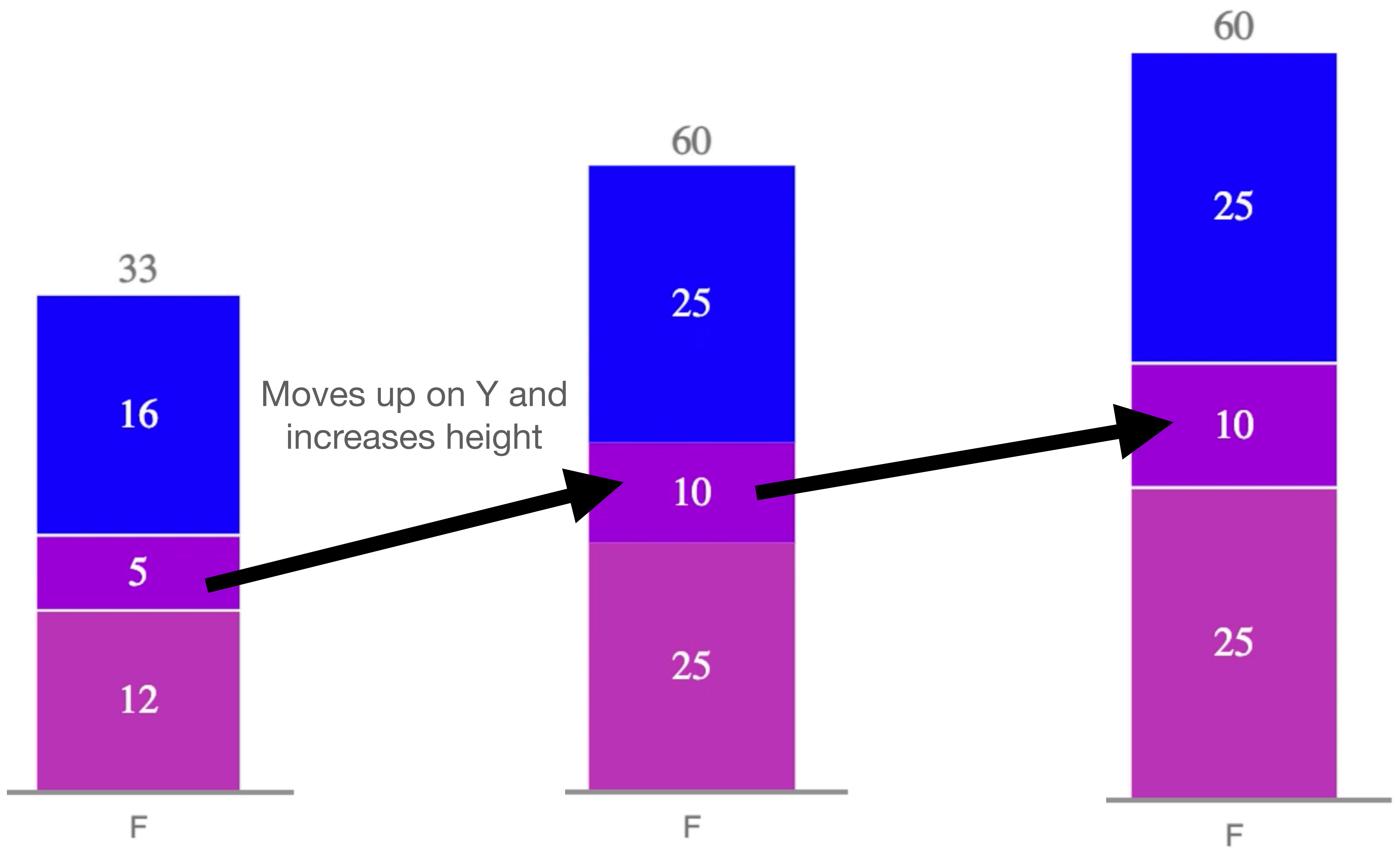



34
43
39
35
49
33
9
15
10
14
14
15
13
14
12
11
13
11
12
18
19
16
5
12
A
B
C
D
E
F

Updating



Updating


33
16
5
12
F
Moves up on Y and
increases height
60
25
10
25
F
60
25
10
25
F

Implementing Animation

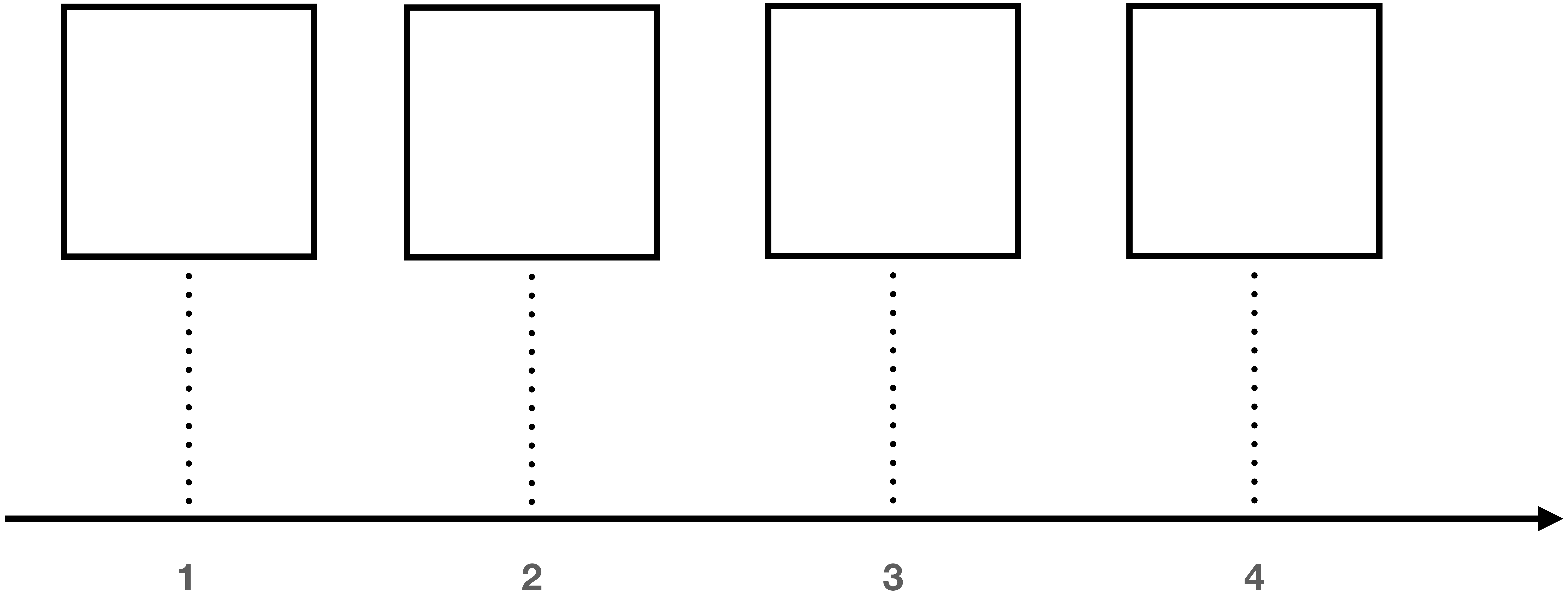
Animation Approaches

Frame-Based Animation

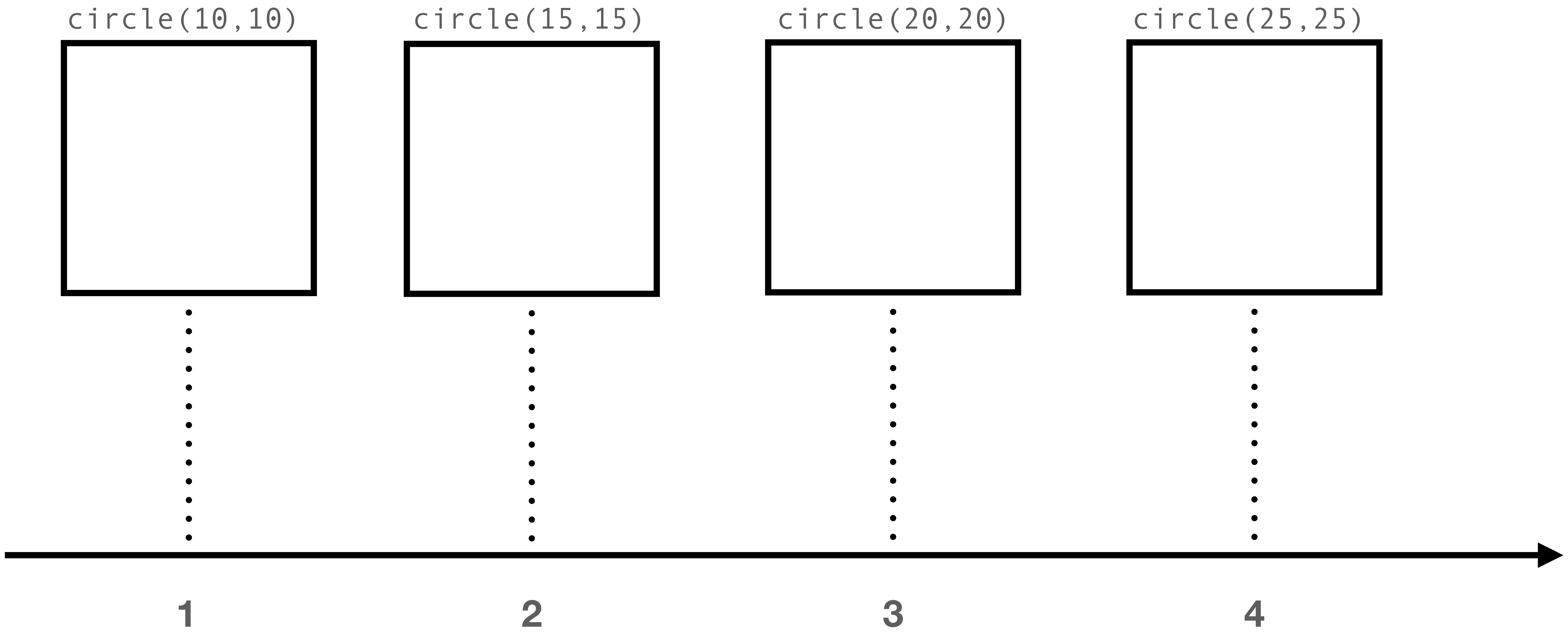
Redraw scene at regular interval (e.g., 16ms)

Developer defines the redraw function (e.g., Processing, p5.js)

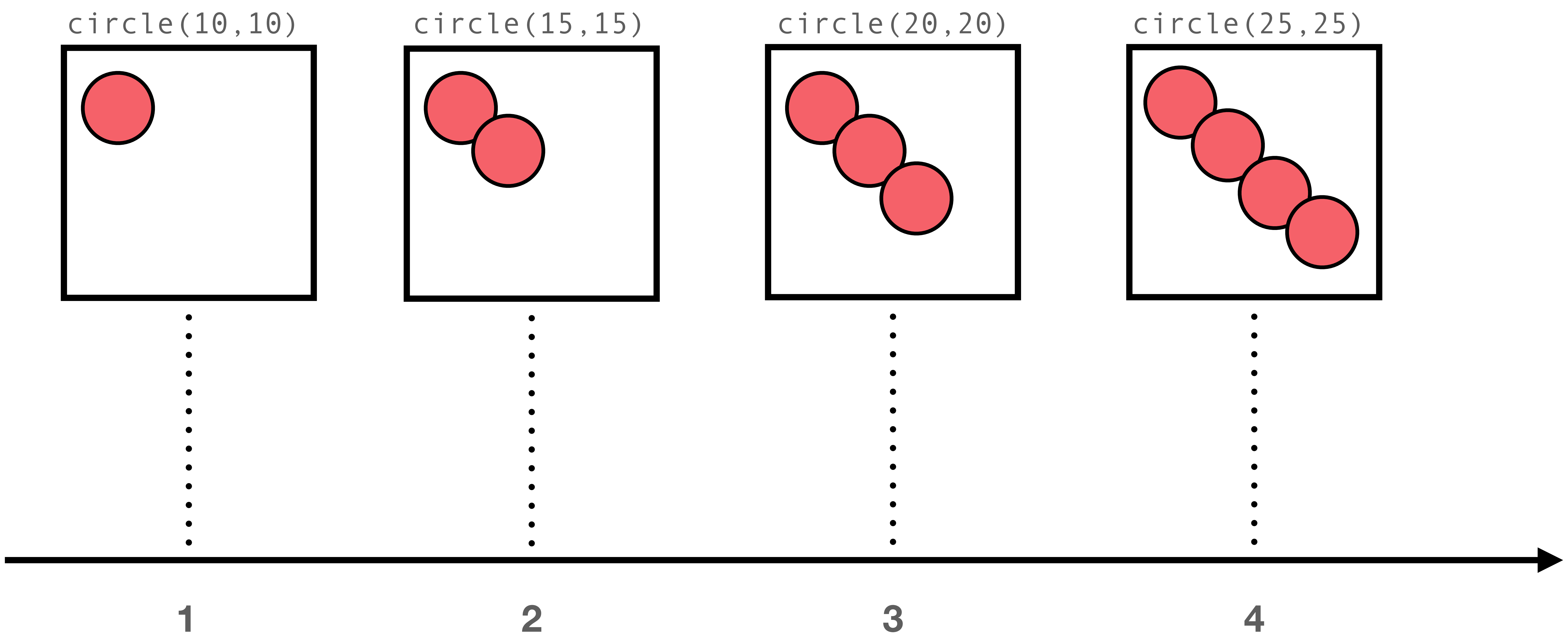
Frame-Based Animation



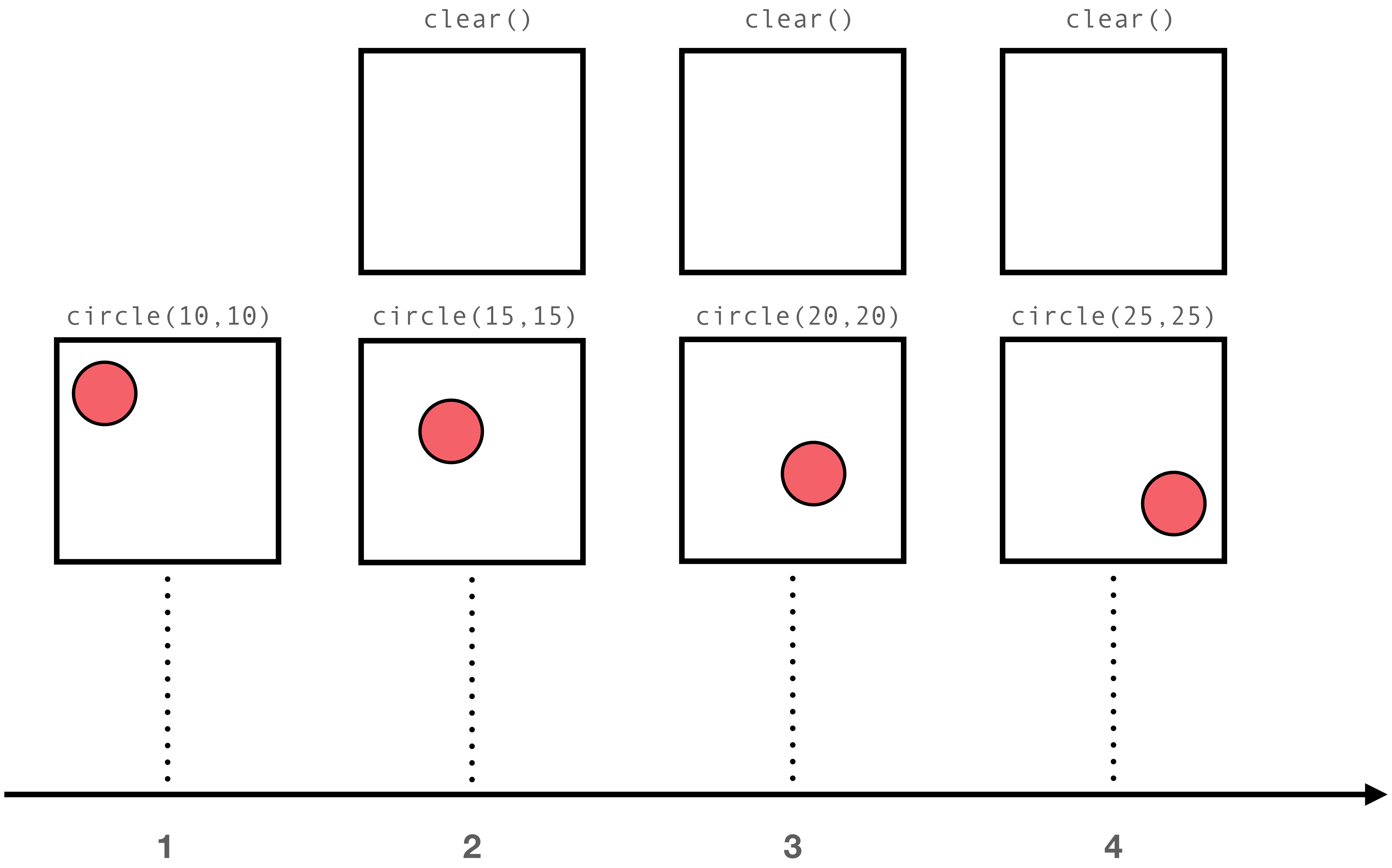
Frame-Based Animation



Frame-Based Animation



Frame-Based Animation



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Transition-Based Animation (Hudson & Stasko '93)

Specify property value, duration & easing

Also called **tweening** (for "in-betweens")

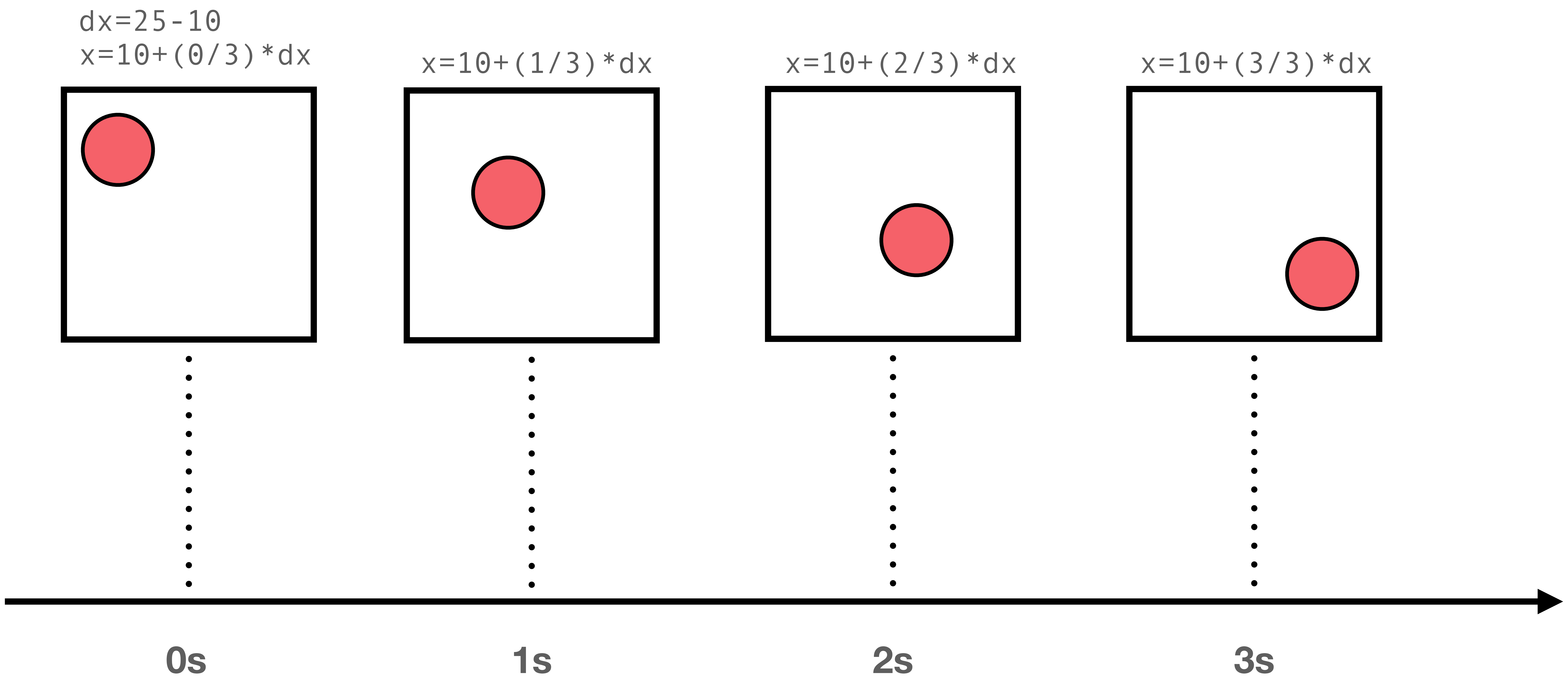
Typically computed via interpolation

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

Timing & redraw managed by UI toolkit

Transition-Based Animation

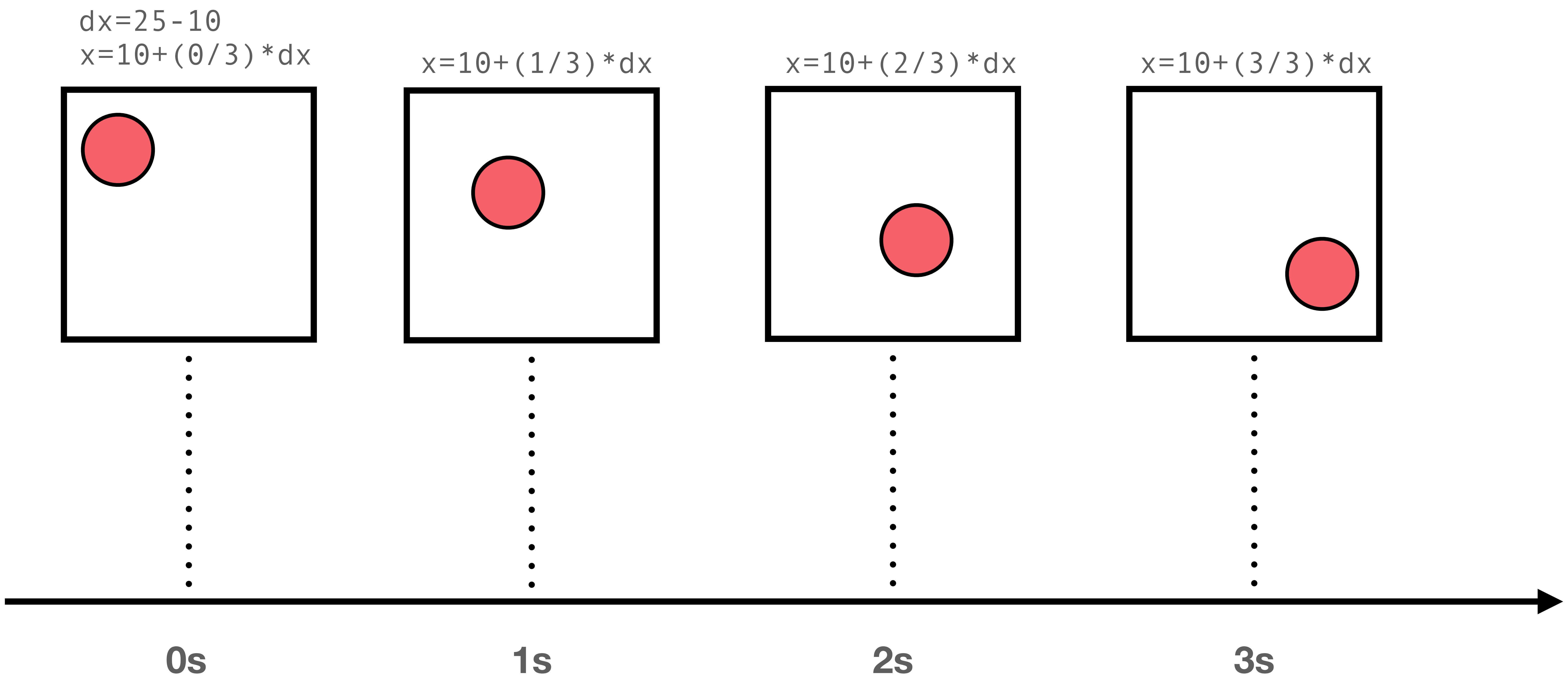
from: (10,10) **to:** (25,25) **duration:** 3sec



Transition-Based Animation

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

Toolkit handles frame-by-frame updates



D3 Transitions

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

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

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

D3 Transitions

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

```
// 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));
```

D3 Transitions

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

```
// 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()
    .attr(“x”, (d) => xScale(d.foo))
    .attr(“y”, (d) => yScale(d.bar))
    .style(“fill”, (d) => colorScale(d.baz));  // Animation is implicitly queued to run!
```

D3 Transitions

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))

    …

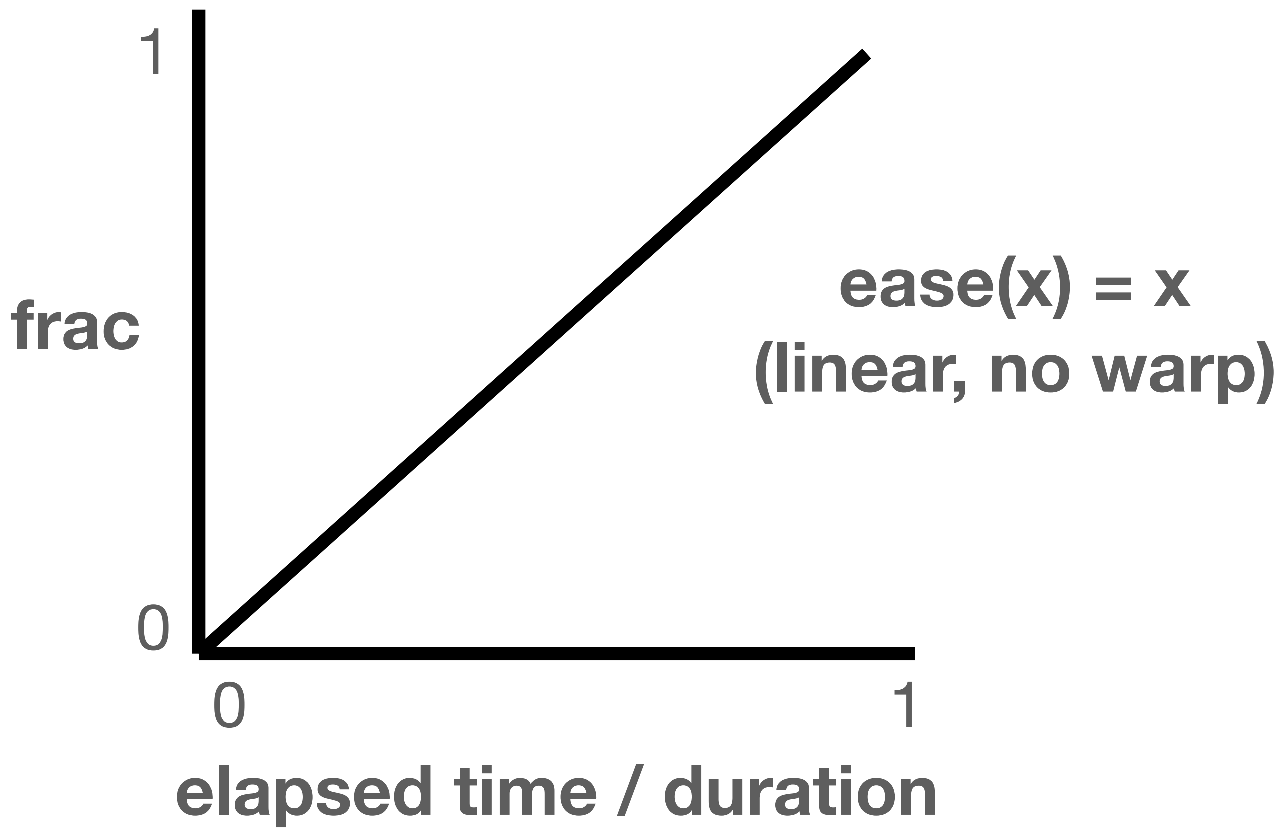
D3 Transitions

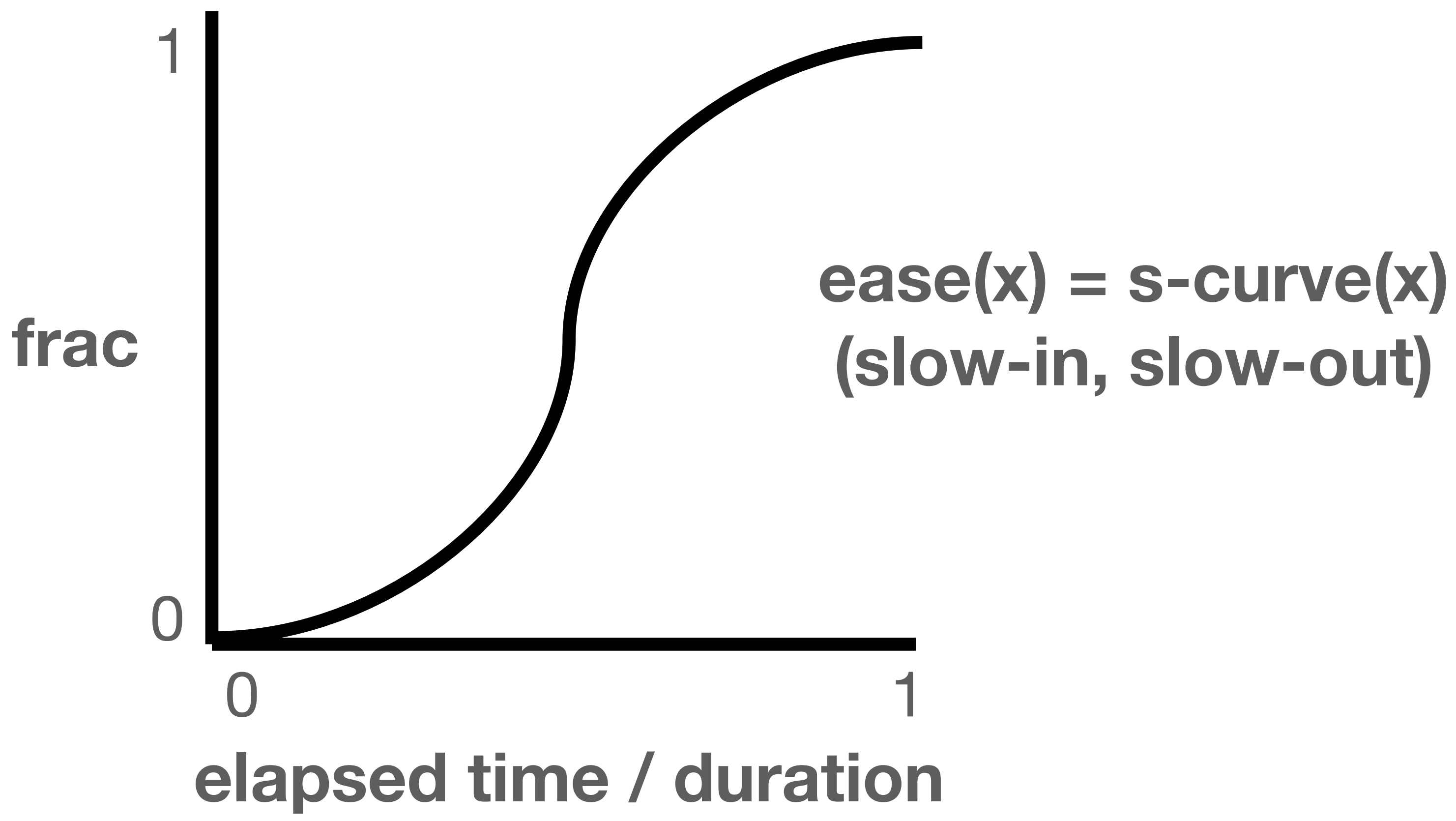
```
bars.transition()
    .duration(500)                    // animation duration in milliseconds
    .delay(0)                         // onset delay in milliseconds
    .ease(d3.easeBounce)              // set easing (or “pacing”) style
    .attr(“x”, (d) => xScale(d.foo))
    …

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

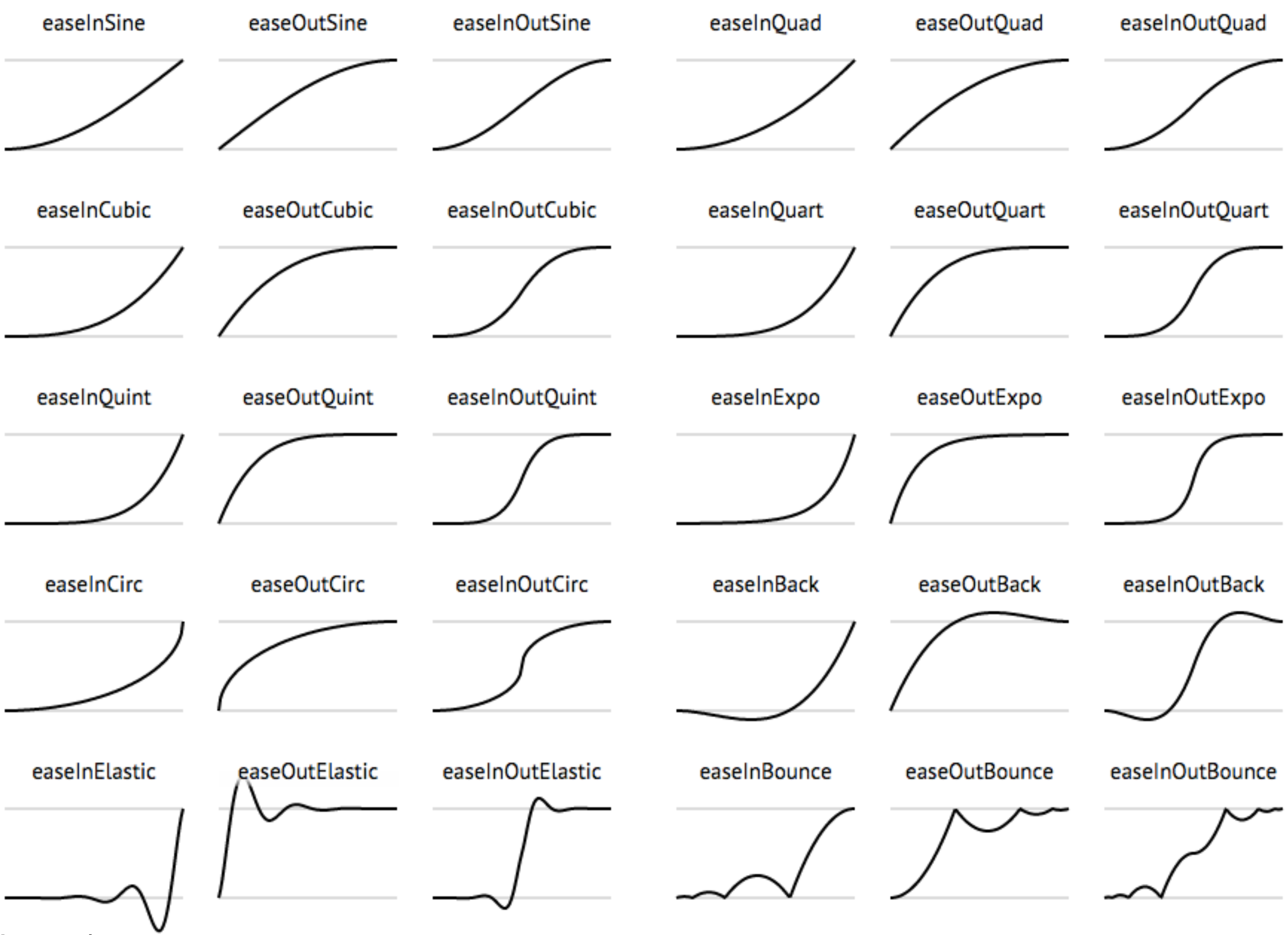
Easing (or “Pacing”) Functions

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**.







http://easings.net/

https://observablehq.com/@d3/easing-animations

What you can do now

Understand **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**