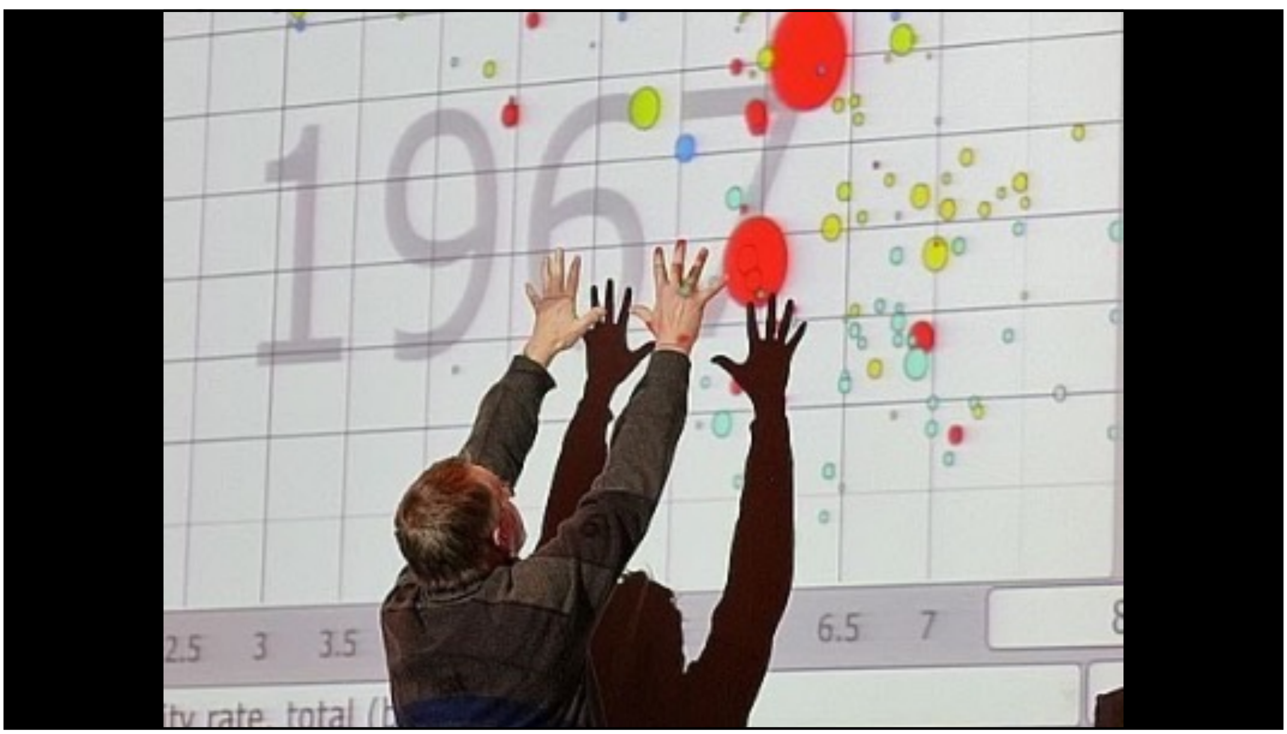
# ANIMATION

CS 448B | Fall 2025

MANEESH AGRAWALA

1

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# READING RESPONSE: QUESTIONS/THOUGHTS

Corum states that "annotation is the most important thing that we do on the graphics desk, that it's more important than the design." ... What's largely absent from Corum's presentation is ***how you decide whether your remade graphics really are more understandable***. Has he tested whether readers actually understand the graphics better, whether they recall things longer, and whether they draw correct conclusions?

Many graphs I see today are more so overloaded with information or data in such a way that is confusing to understand. But I also feel like if any information was lost, some context may be lost as well....I wonder if there has been research done on the ***optimal balance of clarity and narration***.

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# ANIMATION

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# QUESTION

The goal of visualization is to convey information

How does animation convey information?

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# CONE TREES [

**[Robertson 1991]**

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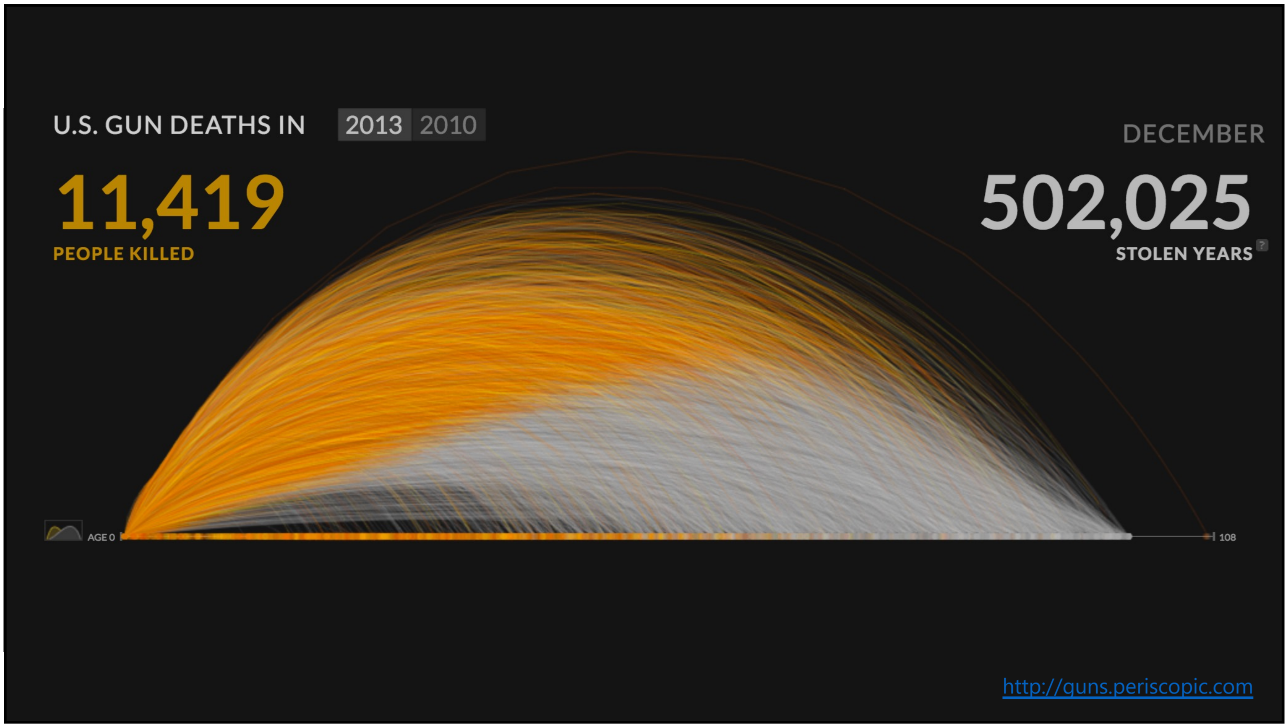


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# WHY USE MOTION?

- Visual variable to encode data
- Direct attention
- Understand system dynamics (changes in time)
- Understand state transition
- Increase engagement

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# TODAY

## Learning Objectives

1. Understand motion perception and cognitive interpretation
2. When to use animated transitions in visualization
3. How to implement animation

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# MOTION PERCEPTION

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# MOTION AS A VISUAL CUE

- Pre-attentive
  - Stronger than color, shape, …
- Triggers an orientation response
- Motion parallax provides 3D cue
- More sensitive to motion at periphery

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# GROUPED DOTS COUNT AS 1 OBJECT

Dots moving together are grouped

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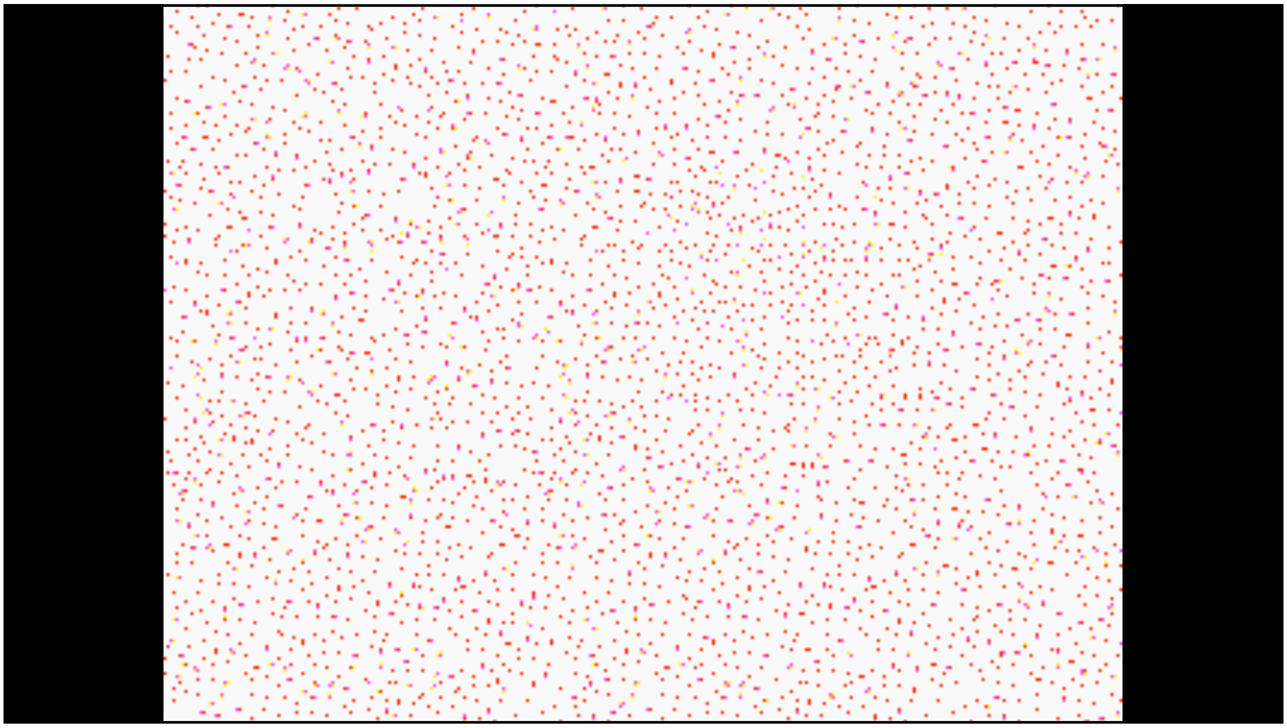

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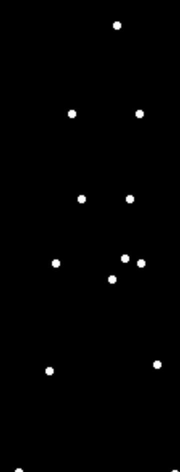
## GROUPING BASED ON BIOLOGICAL MOTION



[Johansson 1973]

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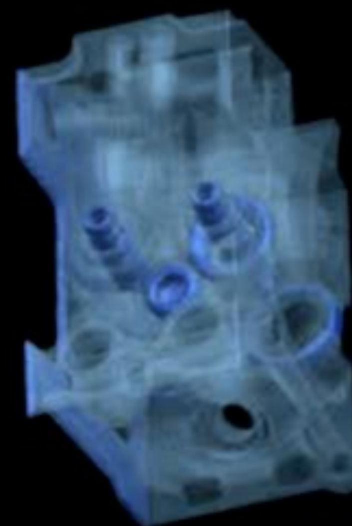
# VOLUME RENDERING [Lacroute 1995]



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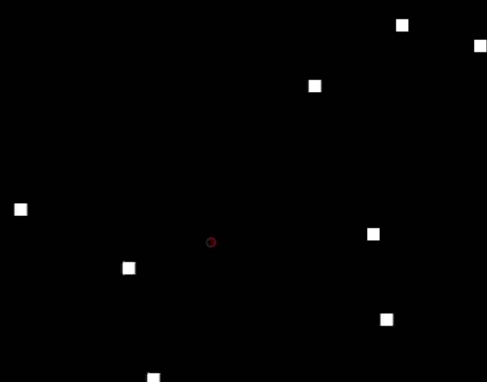
# TRACKING MULTIPLE TARGETS



How many dots can we simultaneously track?

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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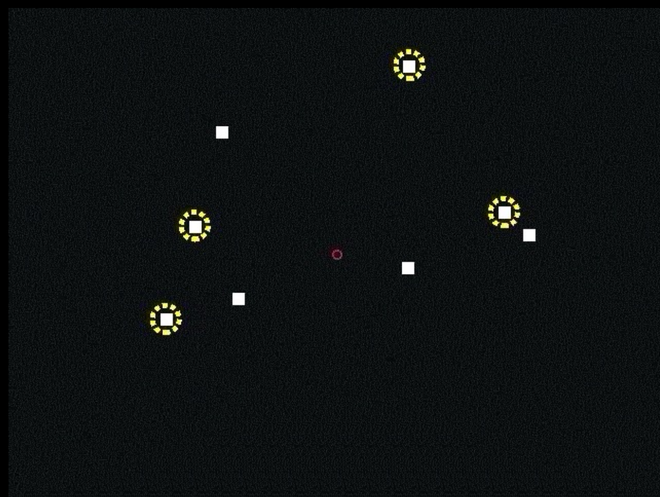
# TRACKING MULTIPLE TARGETS



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[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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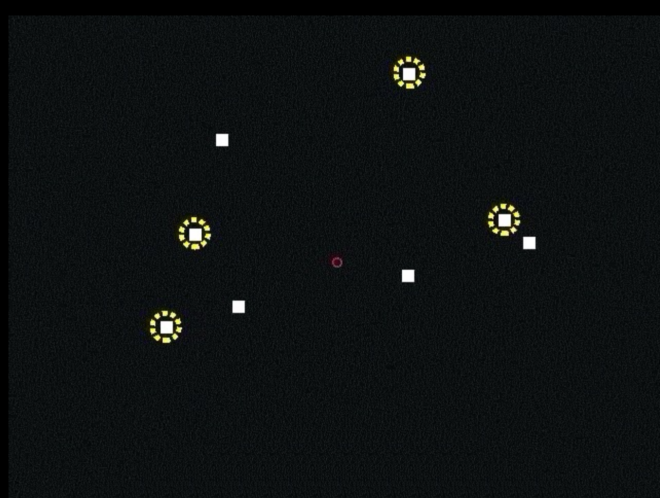

How many dots can we simultaneously track?

4 to 6 - difficulty increases significantly at 6

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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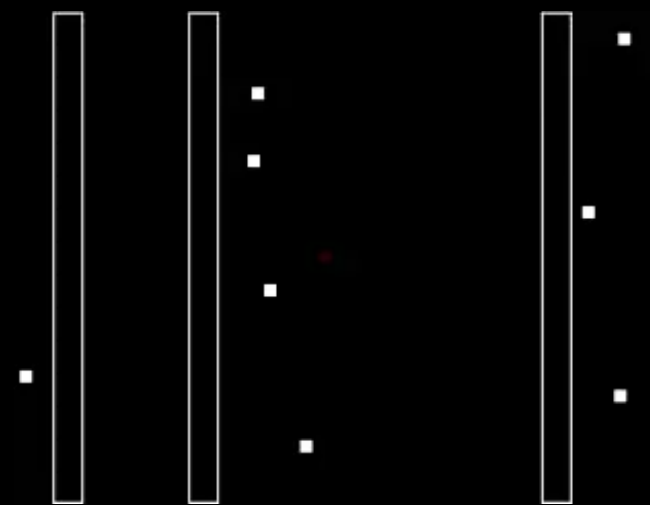
## TRACKING MULTIPLE TARGETS



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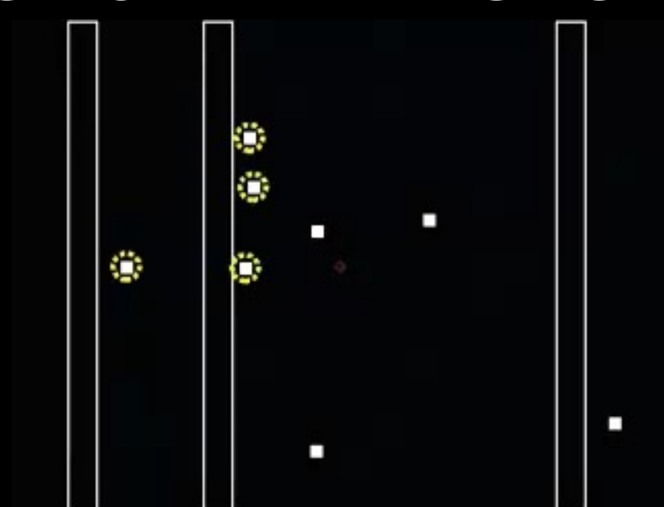

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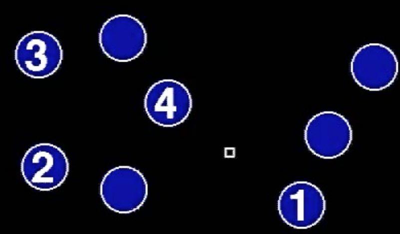
# TRACKING MULTIPLE TARGETS

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4 to 6 - difficulty increases significantly at 6

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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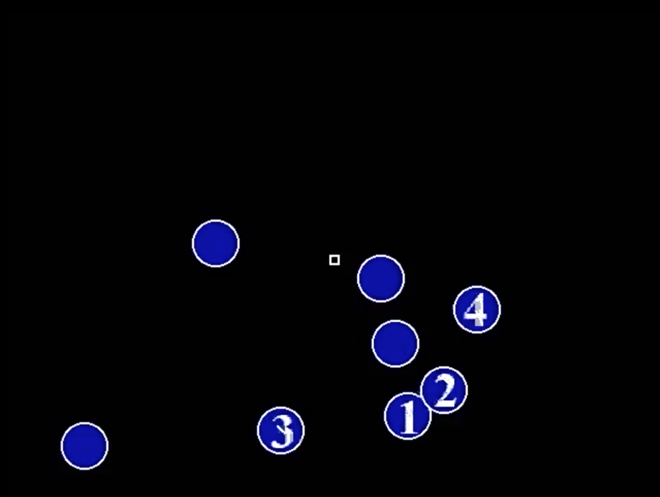


How many dots can we simultaneously track?

4 to 6 - difficulty increases significantly at 6

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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# STATE TO STATE TRANSITIONS

**Can see change from one state to next**

- States are spatial layouts
- Changes are simple transitions (translations, rotations, scale)

**start**

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# STATE TO STATE TRANSITIONS

**Can see change from one state to next**

- States are spatial layouts
- Changes are simple transitions (translations, rotations, scale)

**end**

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# MOTIONS DIRECTLY SHOW TRANSITIONS

**Can see change from one state to next**

States are spatial layouts

Changes are simple transitions (translations, rotations, scale)

**start** **end**

**Shows transition better, but**

Still may be too fast, or too slow

Too many objects may move at once

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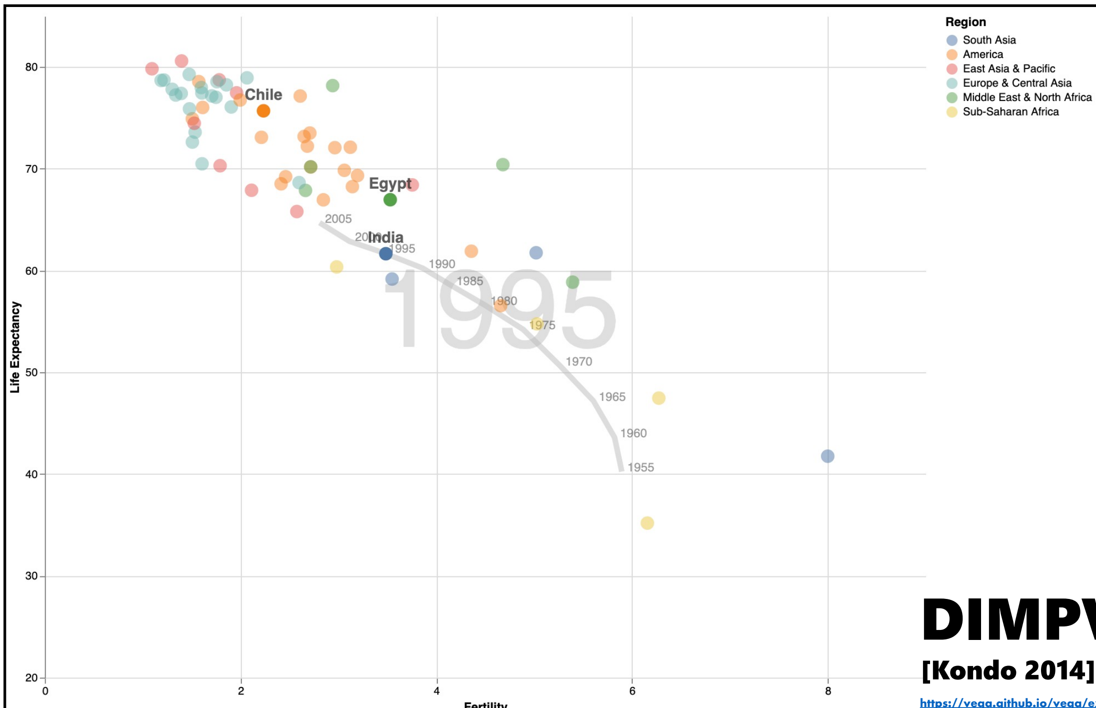


# DIMPVIS

**[Kondo 2014]**

https://vega.github.io/vega/examples/global-development/

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# ANNOUNCEMENTS

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# FINAL PROJECT

## Proposal due 11/3 10:30am

**Data analysis/explainer**

Analyze dataset in depth & make a visual explainer

**Deliverables**

An article with multiple different interactive visualizations
Short video (2 min) demoing and explaining the project

**Schedule**

Project proposal: Mon 11/3
Design Review and Feedback: 10th week of quarter
Final code and video: Sun 12/7 8pm

**Grading**

Groups of up to 3 people, graded individually
Clearly report responsibilities of each member

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# COGNITIVE INTERPRETATION OF MOTION

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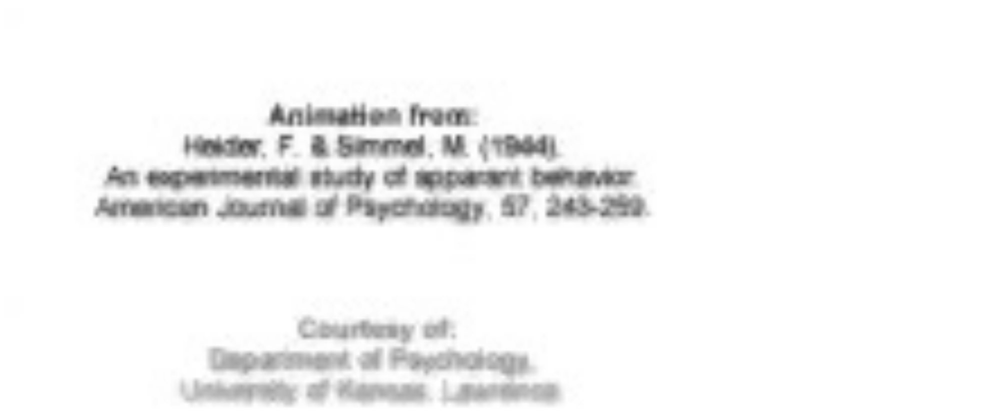
# CONSTRUCTING NARRATIVES [Heider & Simmel 1944]

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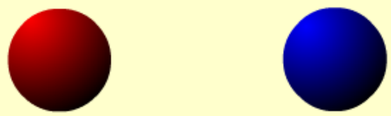
# ATTRIBUTION OF CAUSALITY [Michotte 1946]

**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/Heider_45.html

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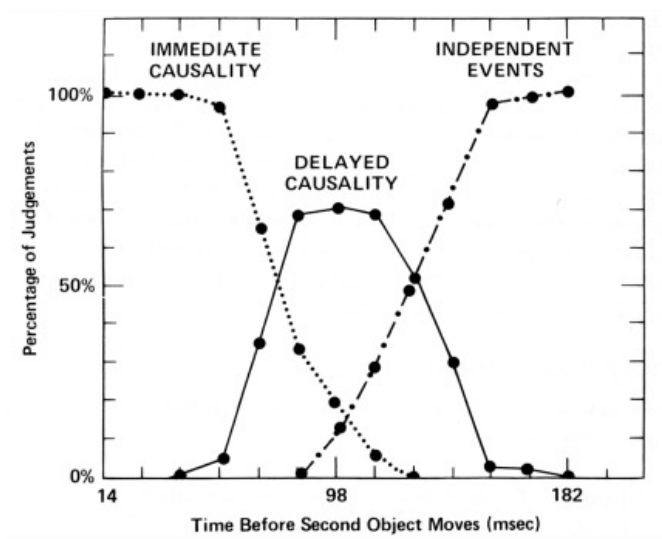
# ATTRIBUTION OF CAUSALITY [Michotte 1946]




**Reprint from Ware [2004]**

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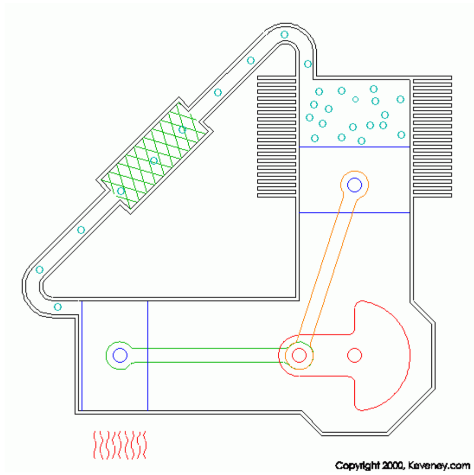
# HOW DOES IT WORK?




**Two-cylinder Stirling engine**
http://www.keveney.com/Vstirling.html

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# PROBLEMS OF ANIMATION **[Tversky 1992]**

1. Difficult to estimate paths and trajectories
2. Motion is fleeting and transient
3. Cannot simultaneously attend to multiple motions
4. Trying to parse motion into events, actions and behaviors
5. Misunderstanding and wrongly inferring causality
6. Anthropomorphizing physical motion may cause confusion or lead to incorrect conclusions

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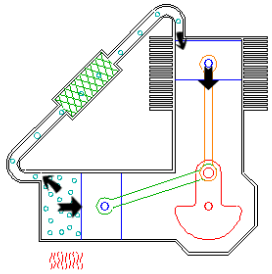
# BREAK INTO STATIC STEPS

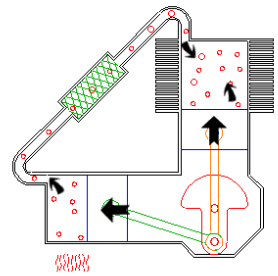
**1**

**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.



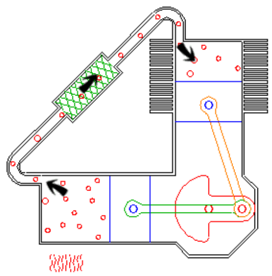
**3**

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



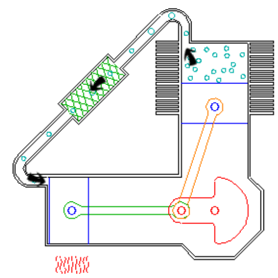
**2**

**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.



**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

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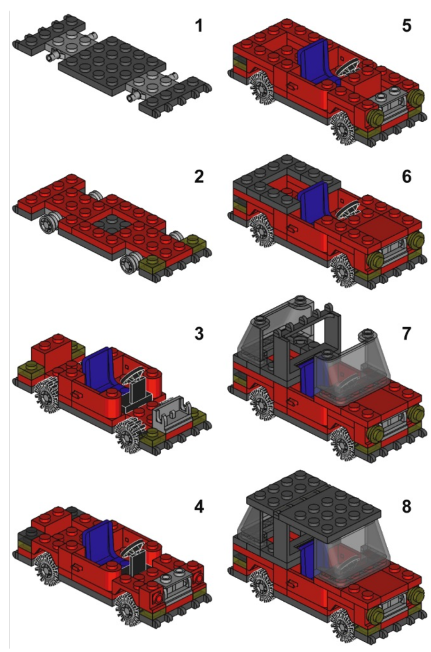
# CHALLENGES

## Choosing the set of steps
How to segment process into steps?

## Tversky suggests
Coarse level – segment based on parts
Finer level – segment based on actions

**Static depictions often do not show finer action-level segmentation**

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# ANIMATED TRANSITIONS IN STATISTICAL GRAPHICS

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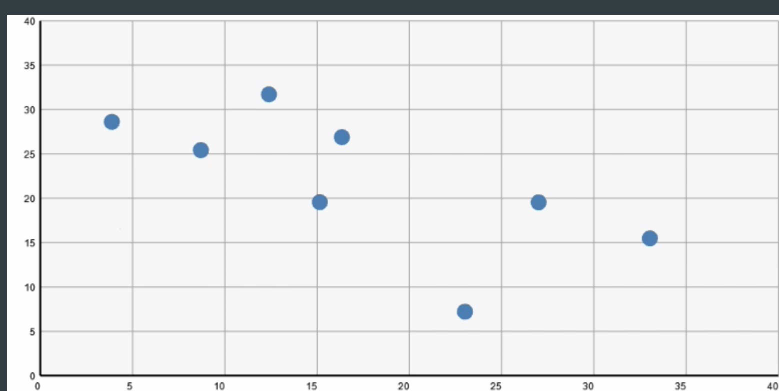


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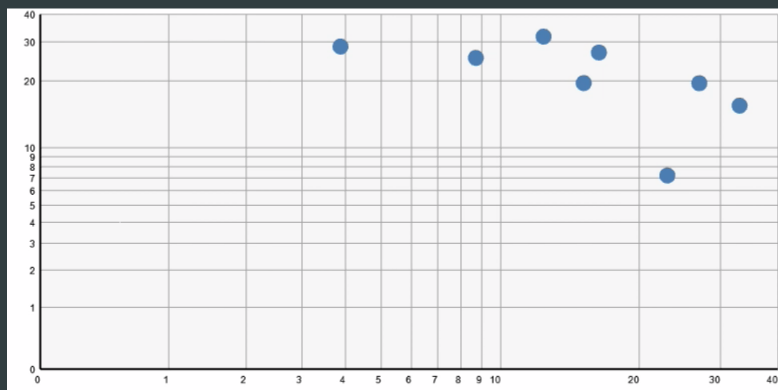
# LOG TRANSFORM

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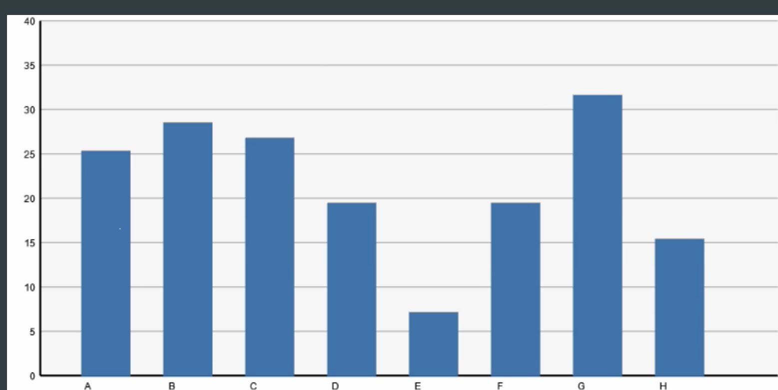


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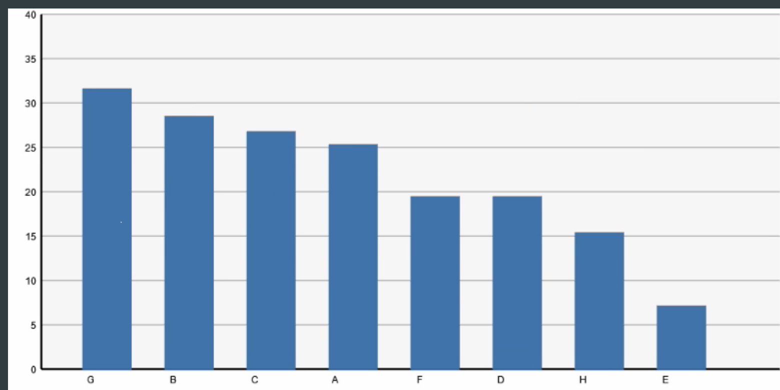
# SORTING

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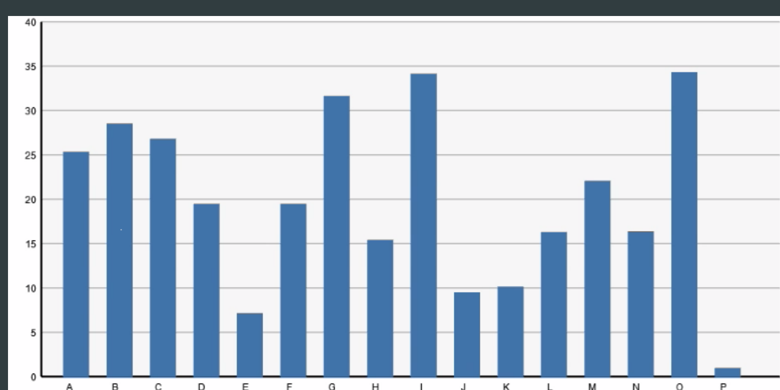


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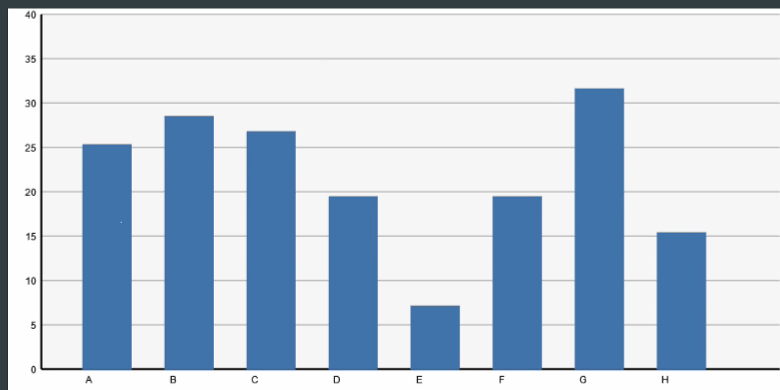
# FILTERING

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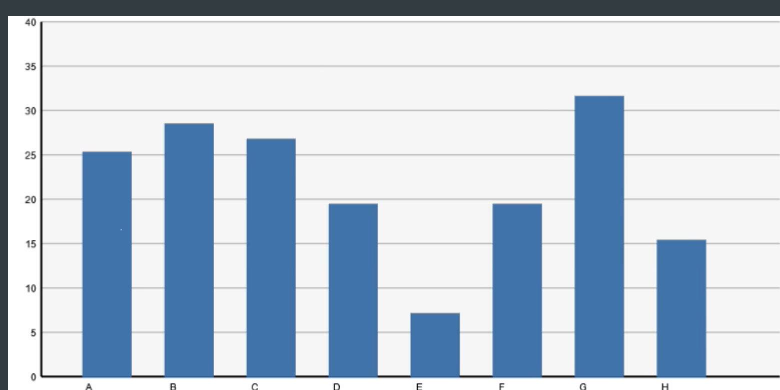


Month 1

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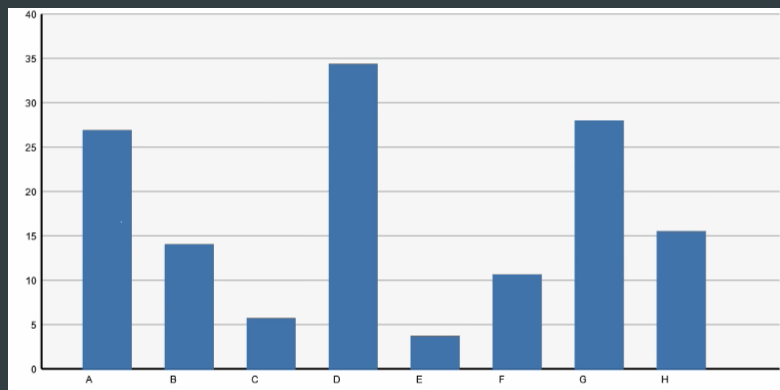
# TIMESTEP




Month 2

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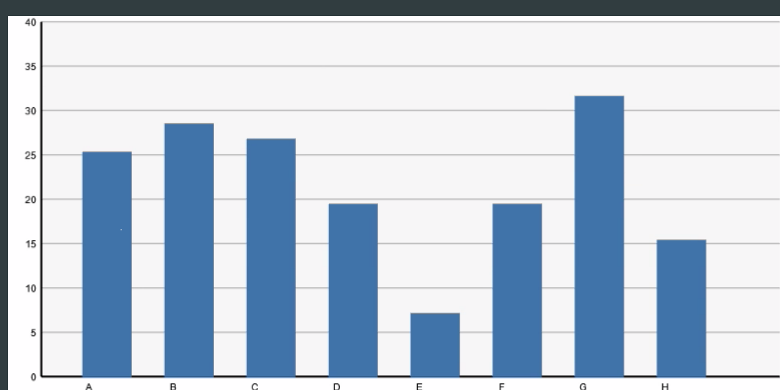


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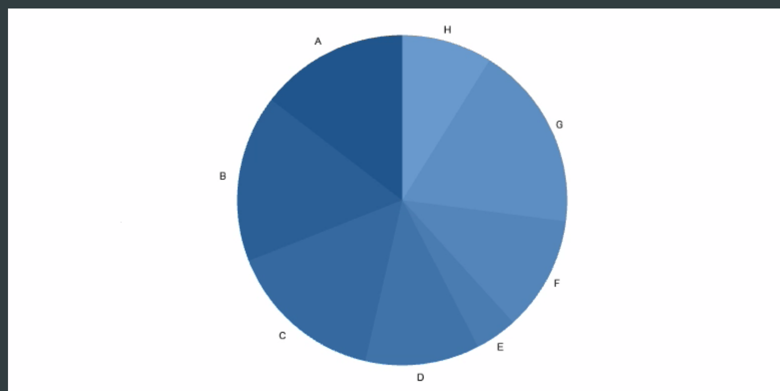
# CHANGE ENCODINGS

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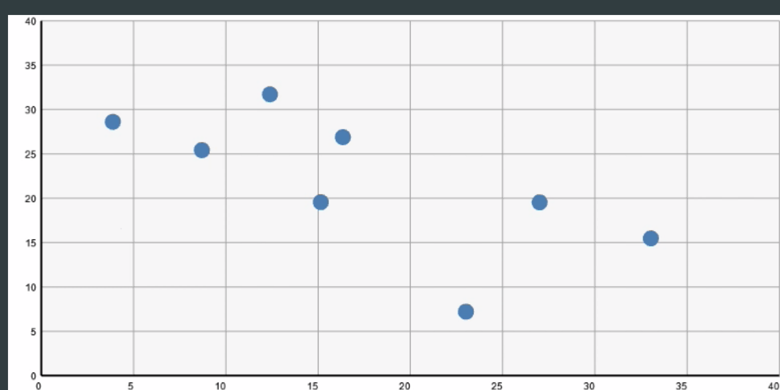


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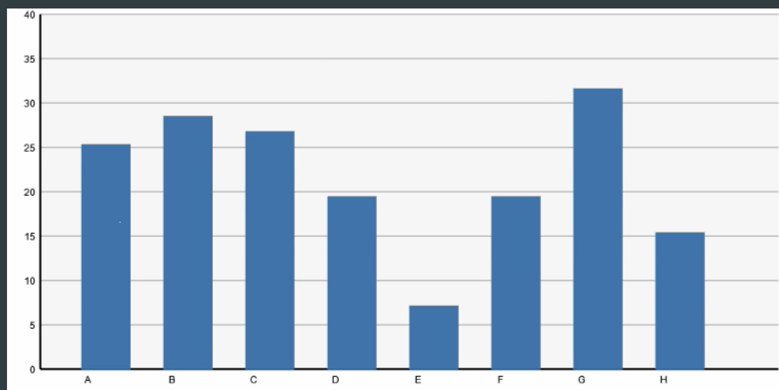
# CHANGE DATA FIELD

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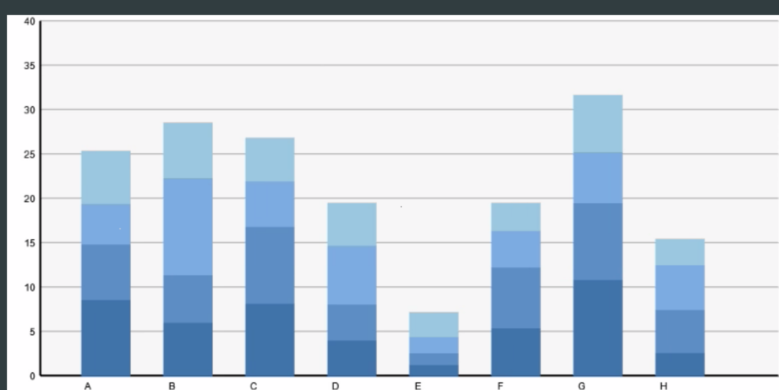
# ADD DATA FIELD

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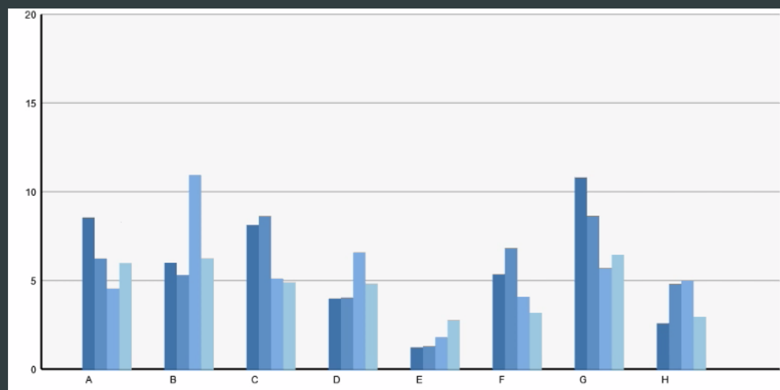
# CHANGE ENCODINGS + AXIS SCALE

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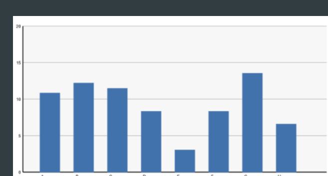
# DATA GRAPHICS & TRANSITIONS

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

Visual Encoding



Change selected data fields or encodings

Animation to communicate changes?

| Category | Sales | Profit |
|---|---|---|
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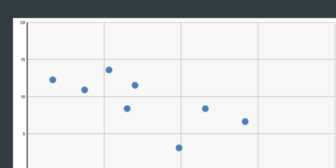

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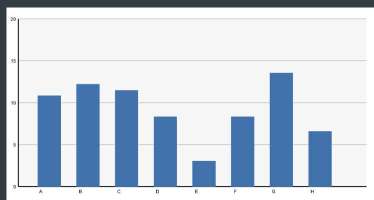
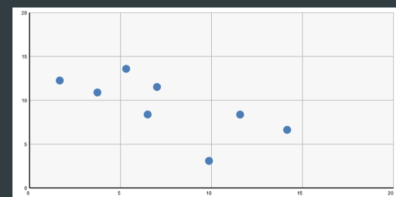
# TRANSITIONS BETWEEN CHARTS



?



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

**Can animation help?**
**How does this impact perception?**

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# PRINCIPLES FOR ANIMATION **[Tversky 2002]**

**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.

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# PRINCIPLES FOR ANIMATION [Heer 2007]

## Congruence
Maintain valid data graphics during transitions
Use consistent encodings
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

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# PRINCIPLES FOR ANIMATION [Heer 2007]

## Congruence
Maintain valid data graphics during transitions
Use consistent encodings
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


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# PRINCIPLES FOR ANIMATION [Heer 2007]

**Congruence**

Maintain valid data graphics during transitions
Use consistent encodings
Respect semantic correspondence
Avoid ambiguity → **Different actions 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

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# PRINCIPLES FOR ANIMATION [Heer 2007]

**Congruence**

Maintain valid data graphics during transitions
Use consistent encodings
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


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# PRINCIPLES FOR ANIMATION [Heer 2007]

**Congruence**

Maintain valid data graphics during transitions
Use consistent encodings
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.**

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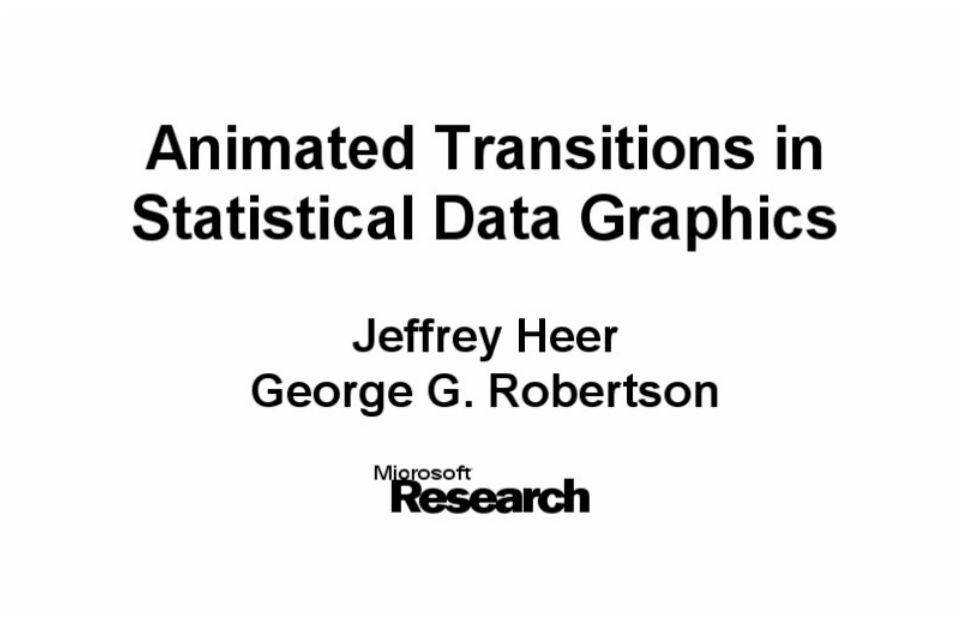


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# STUDY CONCLUSIONS [Heer 2007]

Appropriate animation improves graphical perception

Simple transitions beat "*do one thing at a time*"

Simple staging 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 gridlines)

Subjects preferred animated transitions

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# ANIMATION IN TREND VISUALIZATION

Heer's 2007 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, IEEE InfoVis 2008

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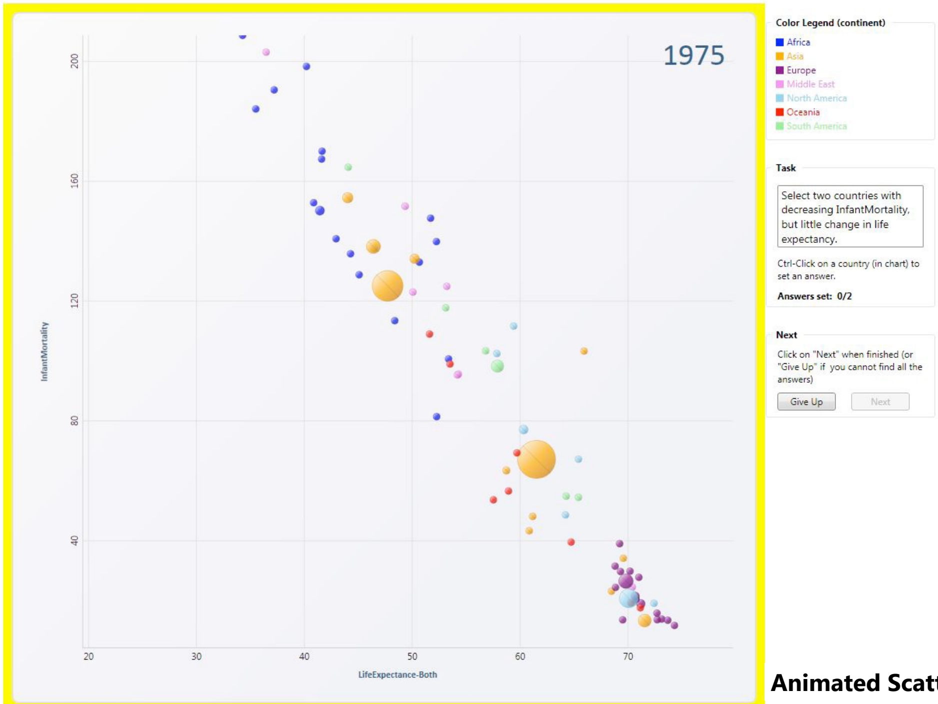


Animated Scatterplot [Robertson 2008]

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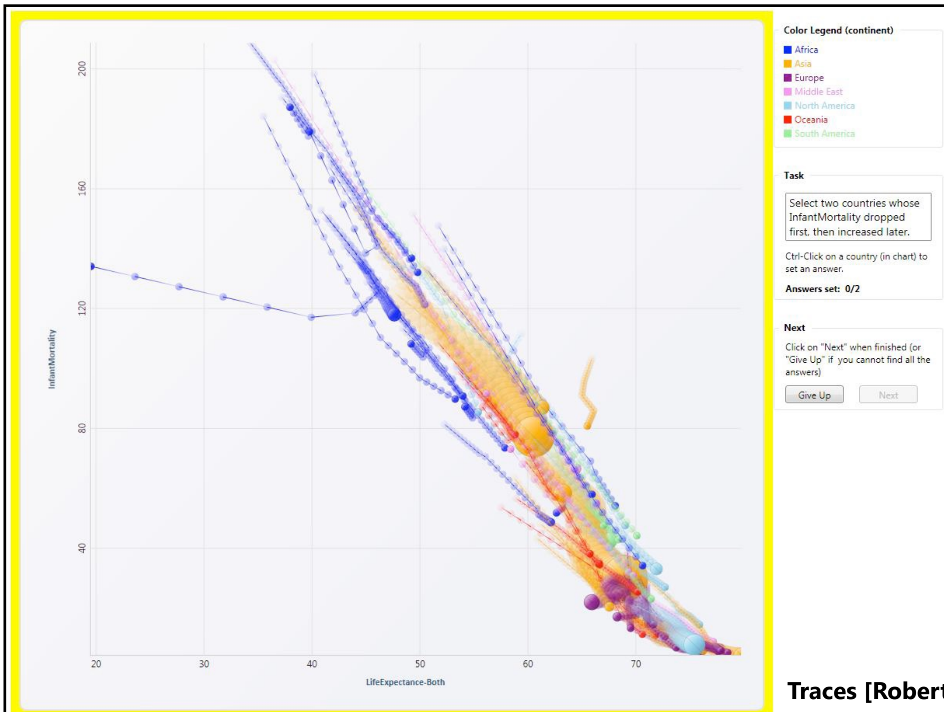


Traces [Robertson 2008]

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**Small Multiples [Robertson 2008]**

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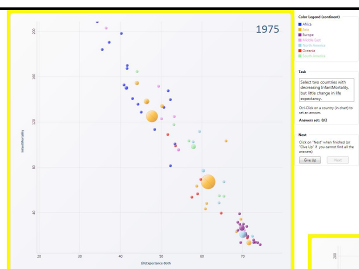
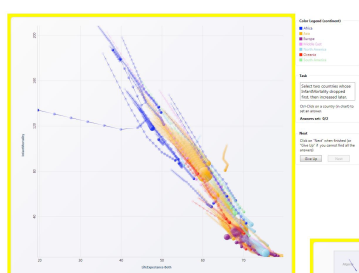



animated scatterplot



traces

small multiples

Which to prefer for **analysis?**
Which for **presentation?**

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# STUDIED ANALYSIS & PRESENTATION

Subjects asked comprehension questions
Presentation condition included narration

**Multiples** 10% *more accurate* than **animation**

***Presentation*: Animation 60% *faster*** than **multiples**
***Analysis*: Animation 82% *slower*** than **multiples**

But, users prefer animation (even though less accurate and slower for analysis!)

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