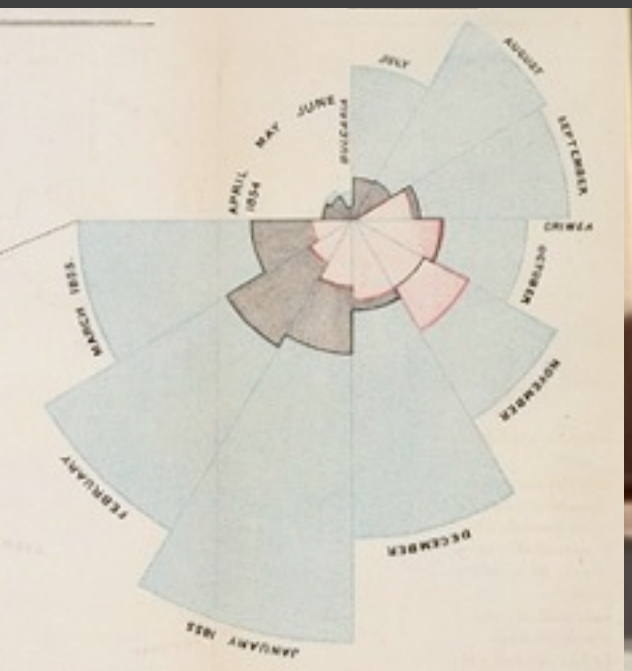
CSE512 :: 13 Mar 2014

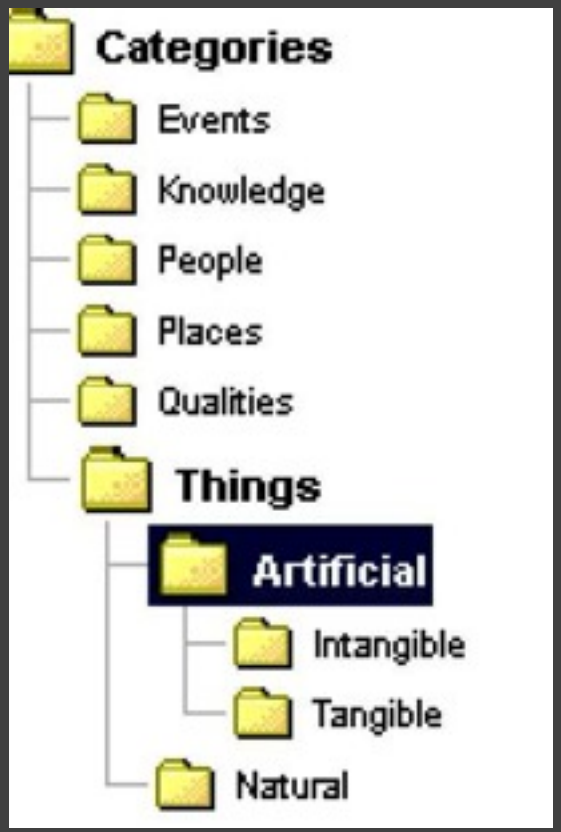
Evaluation



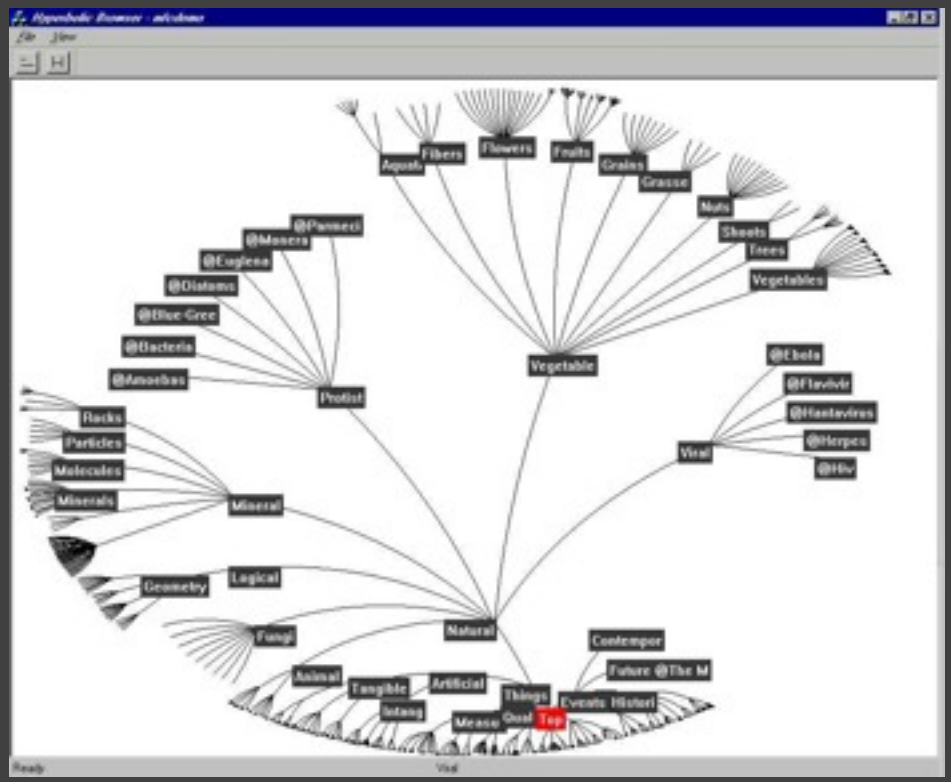
Jeffrey Heer University of Washington

How do we determine if a visualization is “*effective*”?

Example: Tree Browsers



vs.



Evaluation Methods

Inspection or Principled Rationale
Apply design heuristics, perceptual principles

Informal User Study
Have people use visualization, observe results

Controlled Experiment
Choose appropriate tasks / users to compare
Choose metrics (time, error, **what else?**)

Evaluation Methods

Field Deployment or Case Studies
Observation and Interview
Document effects on work practices

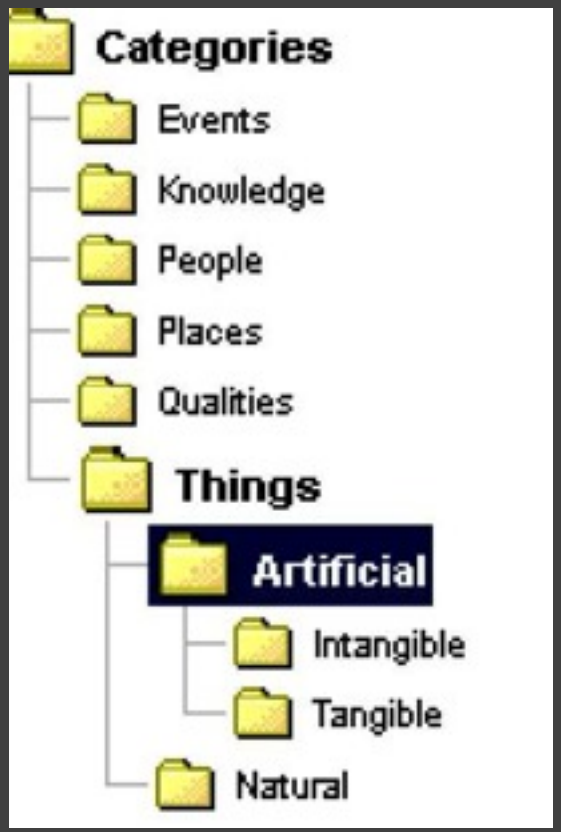
Theoretical Analysis
Algorithm time and space complexity

Benchmarks
Performance (e.g., interactive frame rates)
Scalability to larger data sets

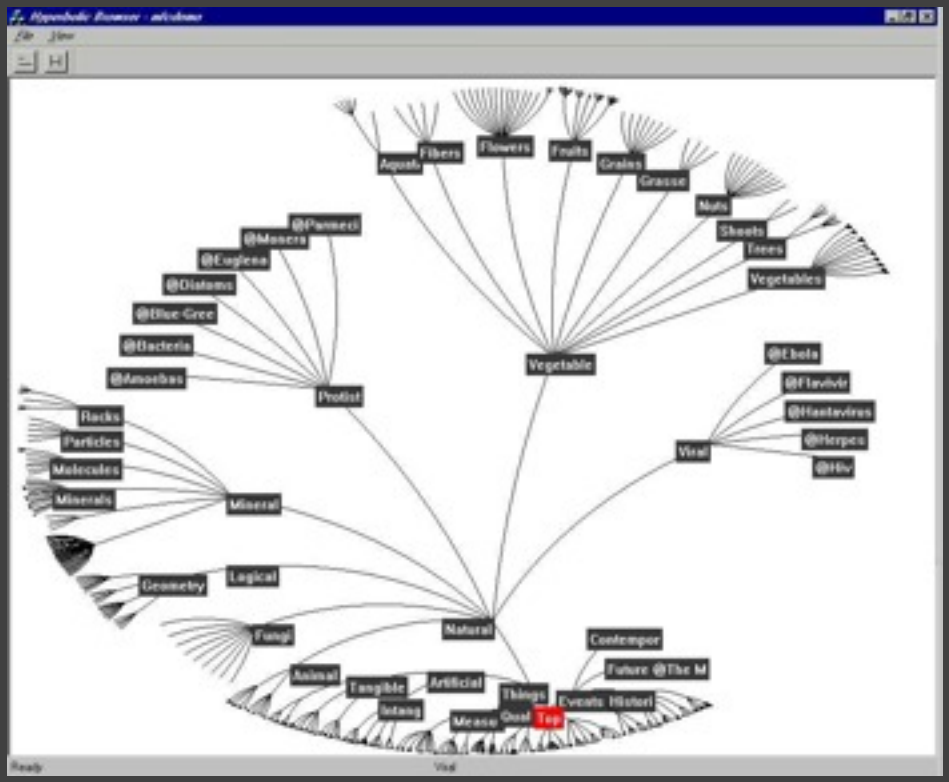
Topics

Evaluating Focus + Context Visualizations
Evaluating Time-Series Visualizations
Perceptual Organization of Graphs
Contextual Effects on Visualization Use
Discussion and Course Evaluation

The Great CHI'97 Browse-Off



vs.



The Contest Winner!

Can we conclude that the hyperbolic tree is the better browser?

No. At least not yet...

Different people operating each browser.
"Is it the car or the driver?"

Tasks were not ecologically valid.

Xerox PARC researchers conducted eye-tracking studies to investigate...

[Pirolli, Card, & van der Wege, AVI 2000]

Task Types

Simple retrieval tasks – "Find Lake Victoria"

Complex retrieval tasks – "Which army is led by a Generalissimo?"

Local relational tasks – "Which religion has the most holidays?"

Complex relational tasks – "Which Greek deity has the same name as a space mission?"

Ambiguity and Information Scent

Which tree branch would you follow to answer these questions?

“Find a hammer”

vs.

“What's the highest rank in the British Royal Air Force?”

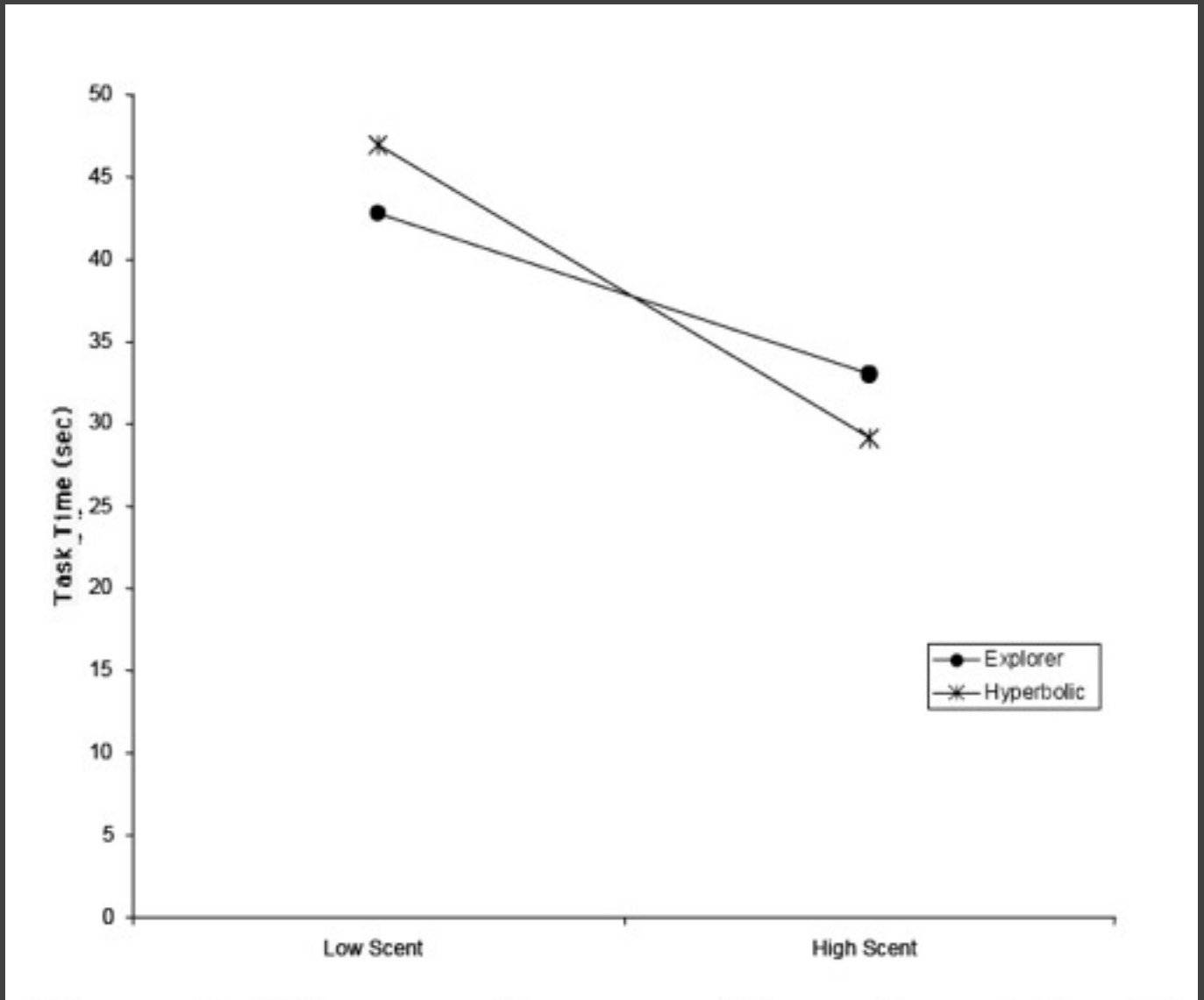
Initial Results: No Difference?

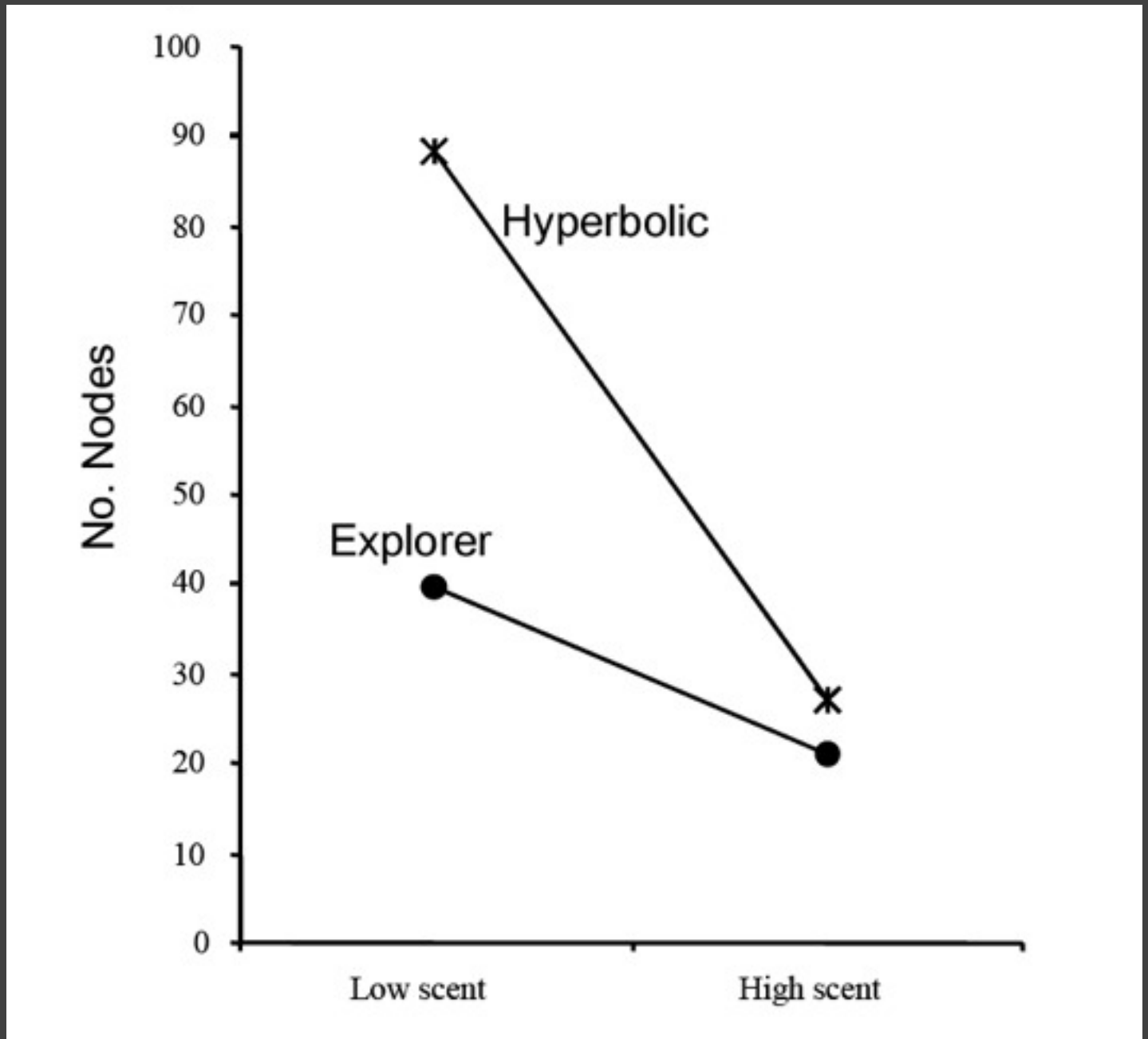
Question Type	Browser	
	Explorer (sec)	Hyperbolic (sec)
Retrieval Tasks		
Simple	35.55	34.37
Complex	41.55	42.02
All retrieval	38.55	38.20
Comparison Tasks		
Local	42.78	41.91
Global	71.07	73.19
All comparison	56.93	57.55
All questions	47.74	47.87

Operationalizing Scent

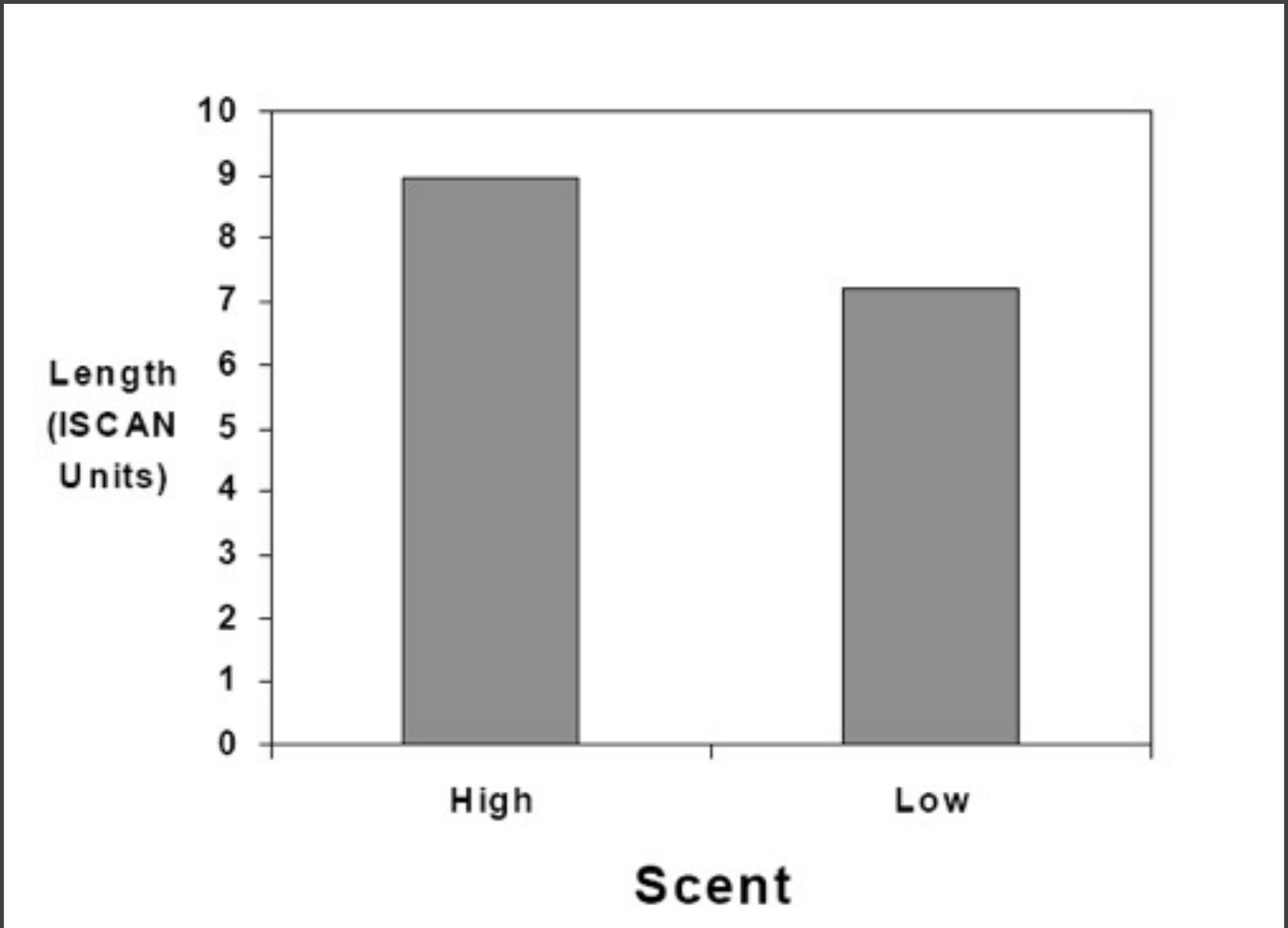
How useful is a text label on a node?

Information scent = the proportion of participants who correctly identified the location of the task answer from looking at upper branches in the tree.

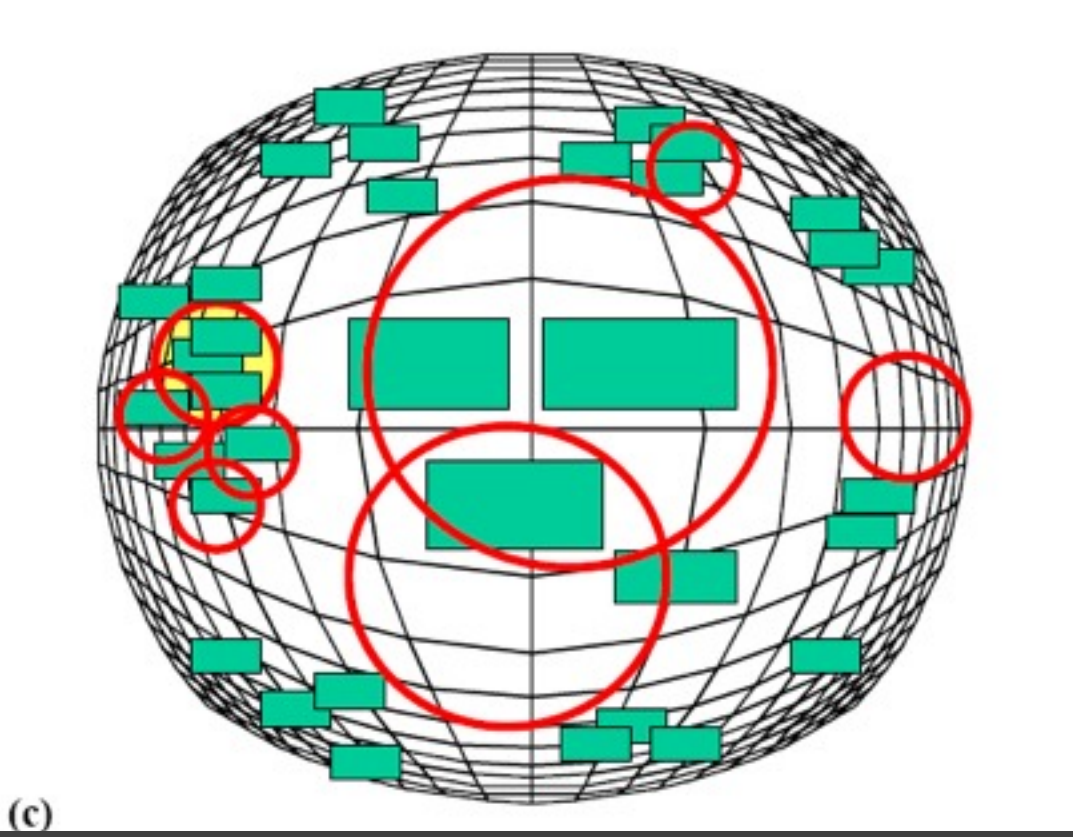

50
45
40
35
30
25
20
15
10
5
0
Task Time (sec)
Low Scent
High Scent
Explorer
Hyperbolic

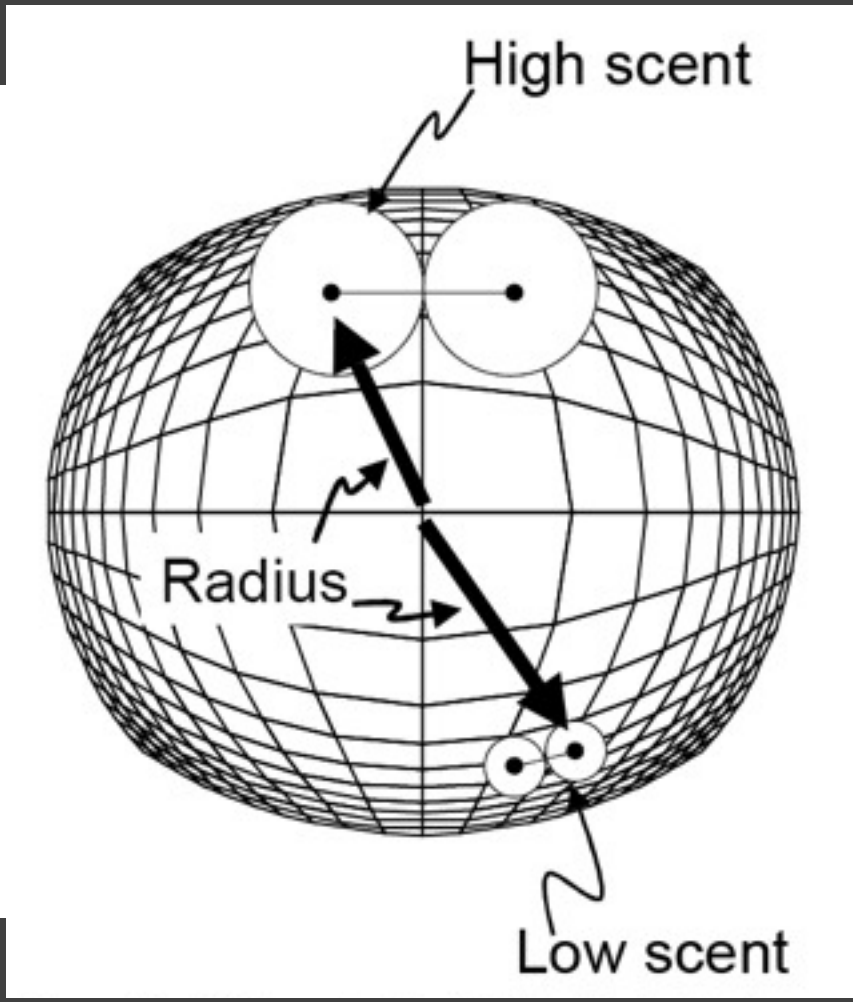

100
90
80
70
60
50
40
30
20
10
0
No. Nodes
Hyperbolic
Explorer
Low scent
High scent

Length of eye movements

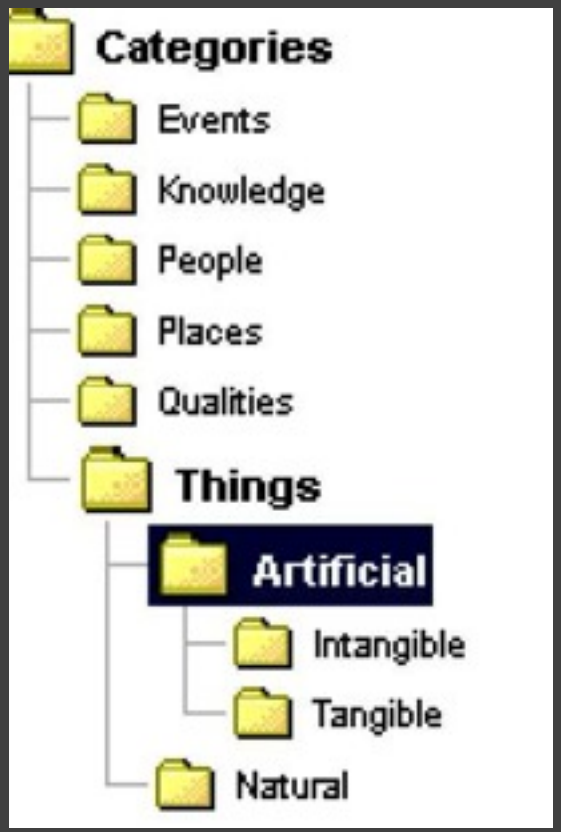


Adaptive Field of View?

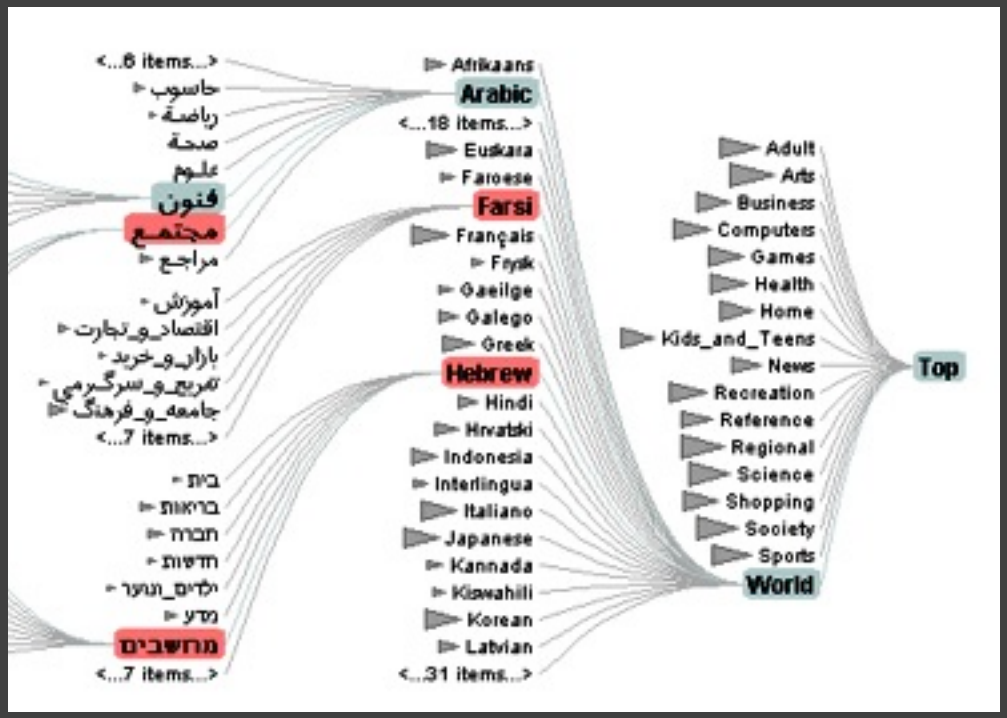




More Evaluations



vs.



Evaluation of DOITrees

DOITree vs. Windows Explorer [Budiu, AVI 06]

Nodes visited (avg):	DOI 83	Exp 53	$p<.005$
Revisitation (avg):	DOI 6.60	Exp 8.15	$p<.005$
Divergence (avg):	DOI 4.57	Exp 3.96	$p<.001$

DOITree more forgiving to navigation errors
BUT no significant difference in task time

DOITree vs. Google Directory [Pirolli, CHI 06]
DOITree has superior task knowledge transfer

Lessons Learned

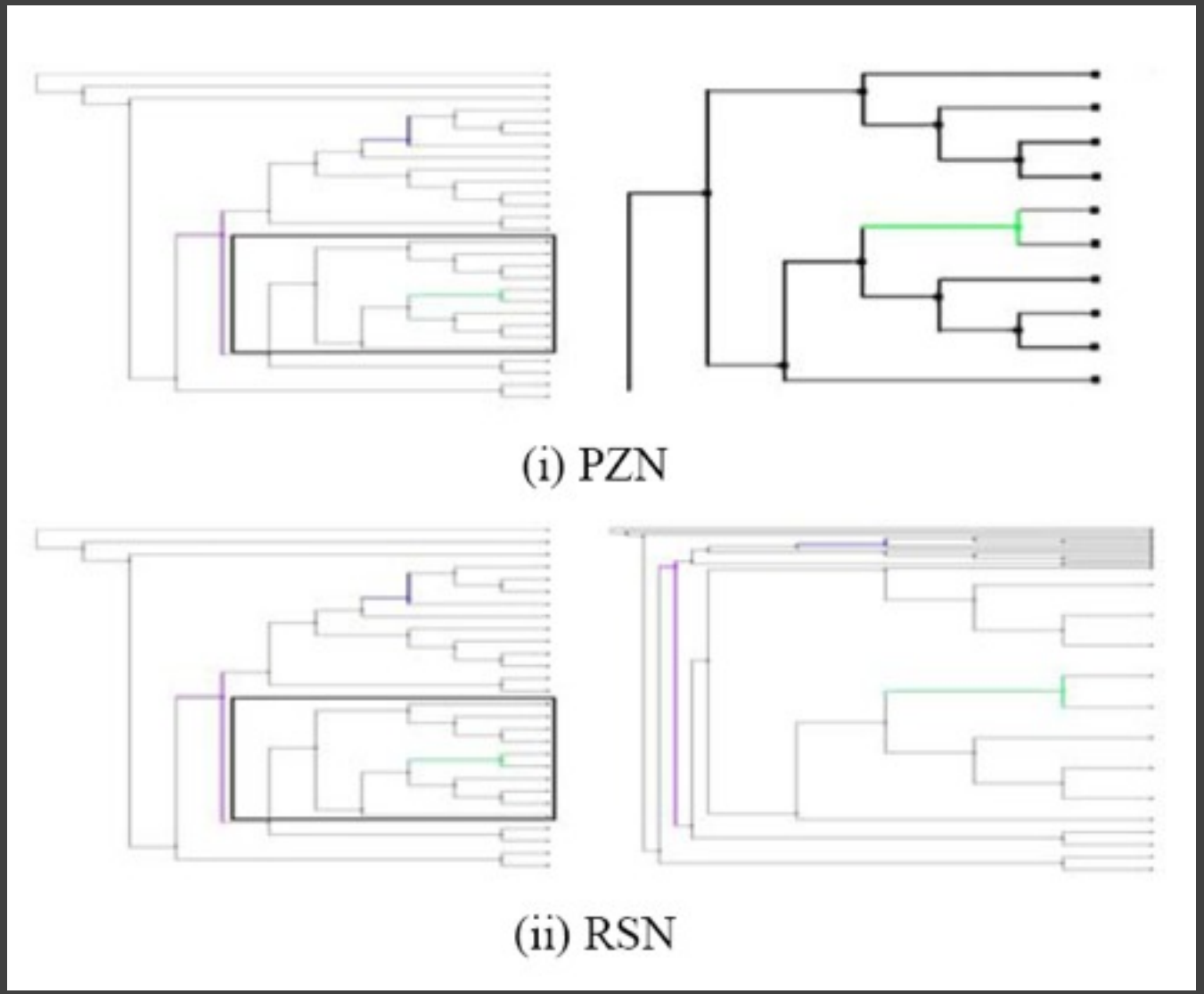
Both the **task** and **data properties** (in this case *information scent*) may interact with the visualization type in unexpected ways.

Equal **performance** in terms of accuracy or response time is **not the whole picture**. In this case, we saw differences in learning effects.

An Evaluation of Pan & Zoom and Rubber Sheet Navigation with and without an Overview

Dmitry Nekrasovski, Adam Bodnar, Joanna McGrenere,
François Guimbretière, Tamara Munzner

Pan and Zoom / Rubber Sheet Navigation



Experimental Task

Compare topological distance between nodes in a dendrogram.

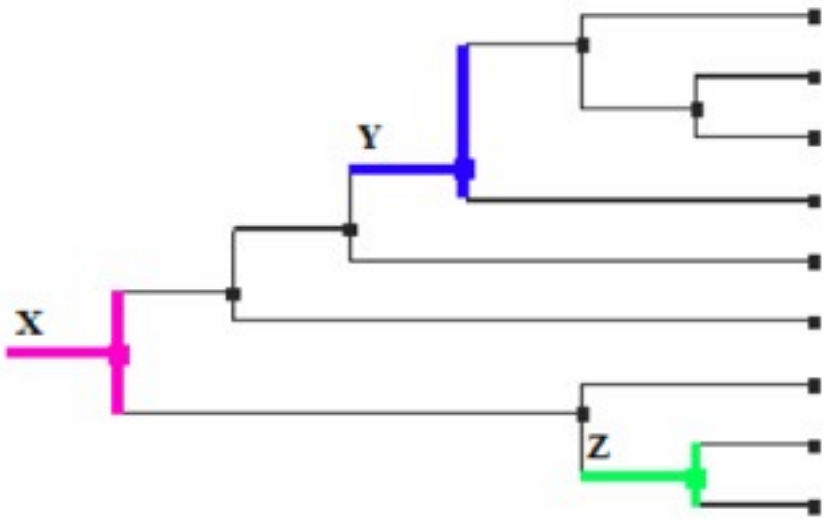
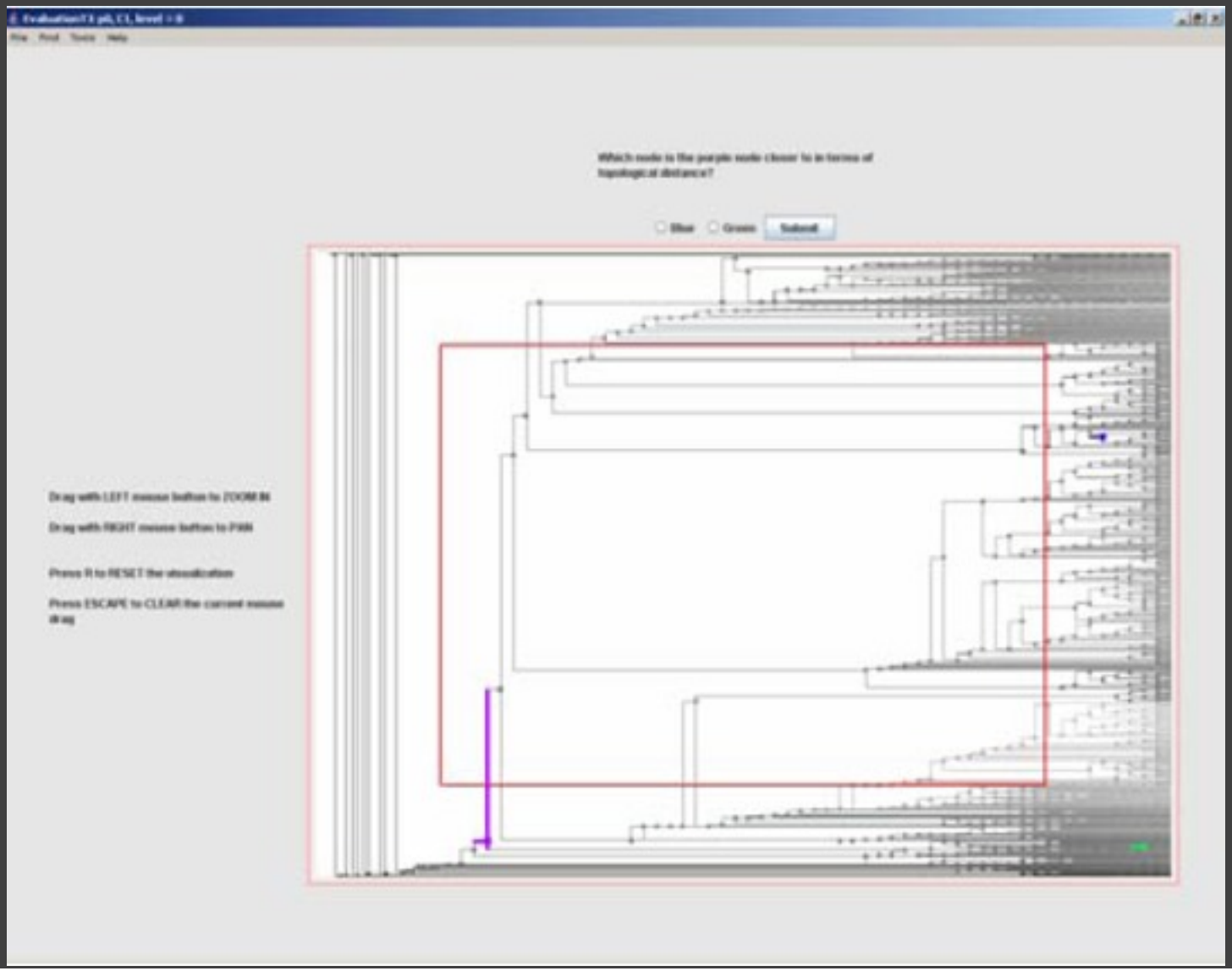
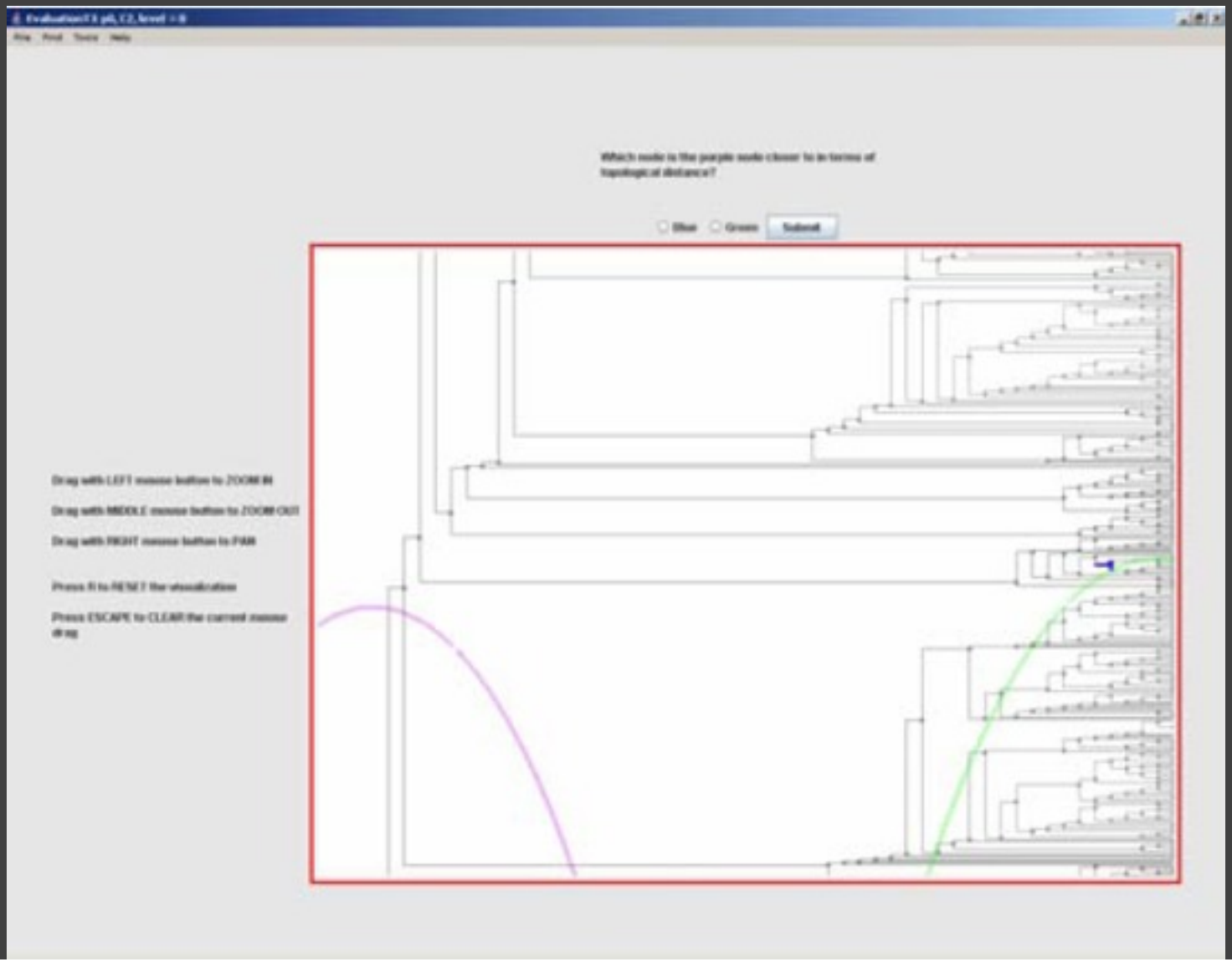


Figure 2: Illustration of the experimental task on a small tree. Subjects were asked to determine whether the pink node (labeled X) was closer to the blue node (labeled Y) or the green node (labeled Z) in terms of topological distance. In this case, the green node (Z) is closer.

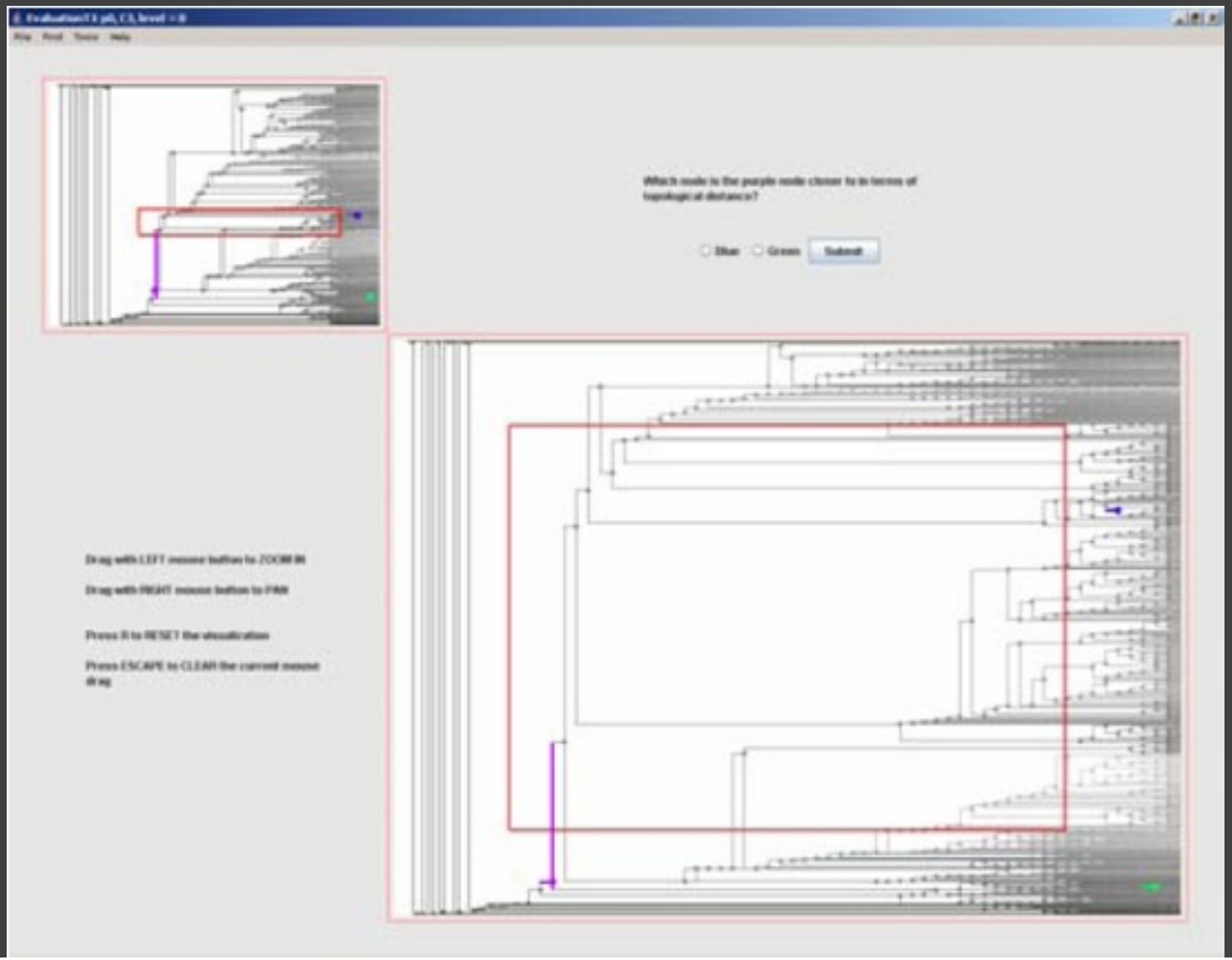
Condition 1: Rubber Sheet – No Overview



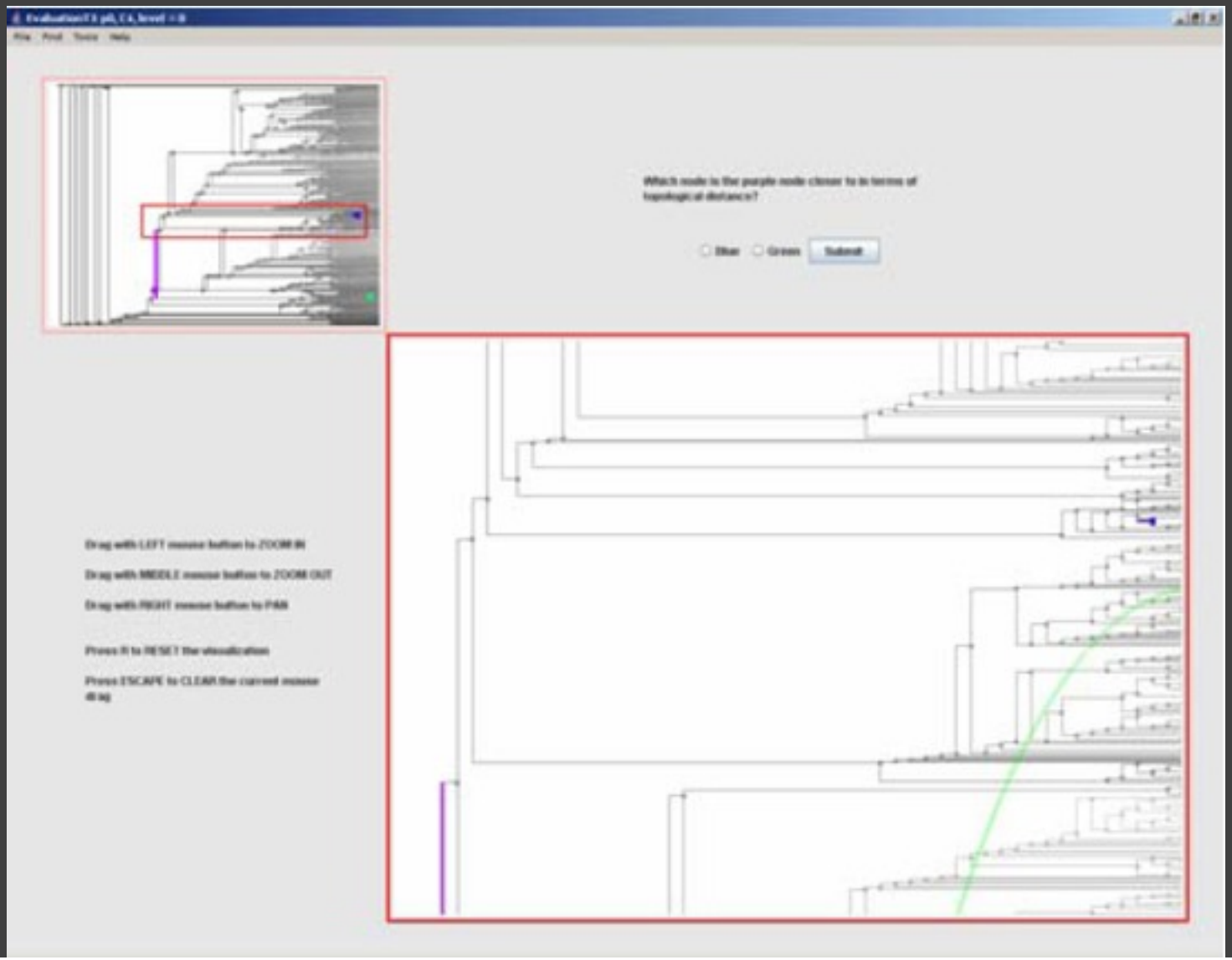
Condition 2: Pan & Zoom – No Overview



Condition 3: Rubber Sheet with Overview



Condition 4: Pan & Zoom with Overview



Experiment

Compare performance in 4 conditions:

1. Pan and Zoom (no overview)
2. Pan and Zoom (with overview)
3. Rubber Sheet (no overview)
4. Rubber Sheet (with overview)

40 subjects (24F/16M), between 18-39 years old.
Right-handed, normal vision.

Between-subjects design.

Hypotheses

1. RSN interfaces perform better than PZN interfaces independently of the presence or absence of an overview.
2. For RSN, the presence of an overview does not result in better performance.
3. For PZN, the presence of an overview results in better performance.

Results – H1 False

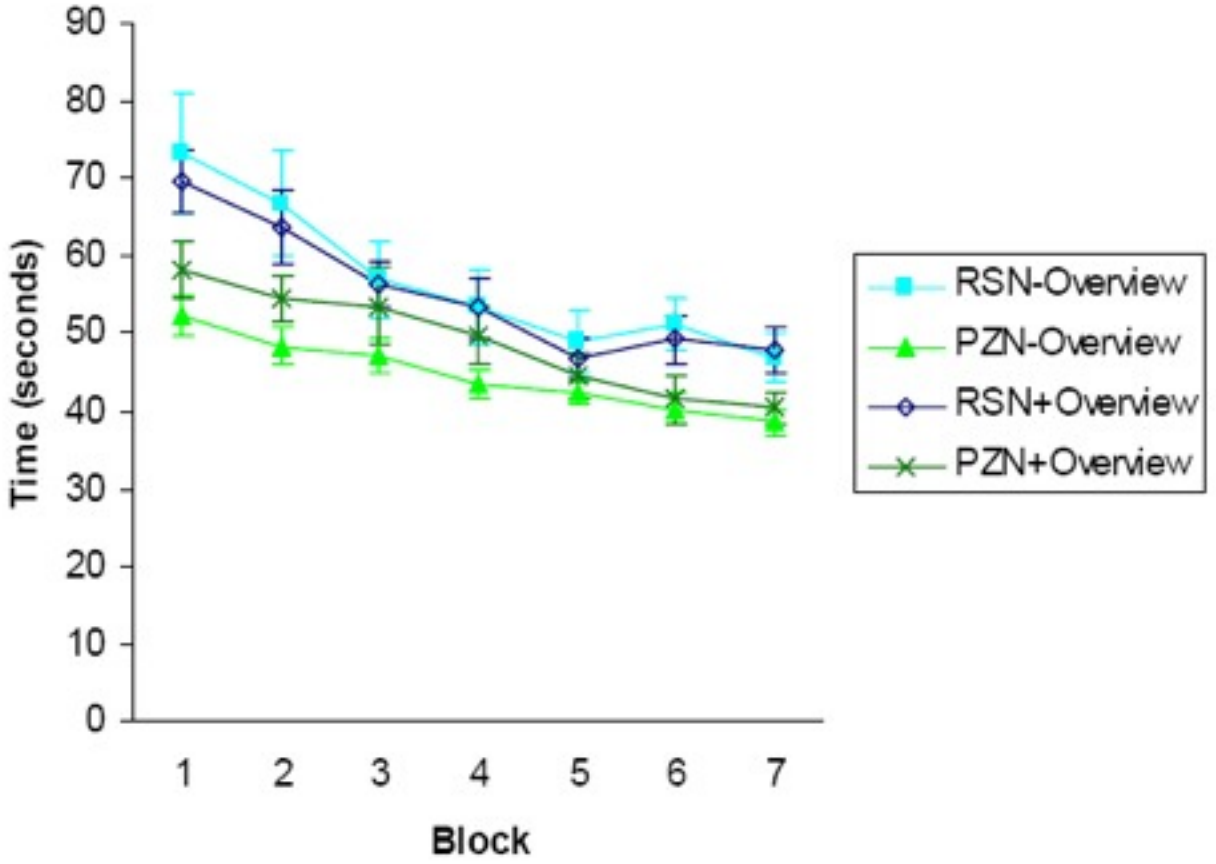


Figure 7: Mean completion times per trial for each interface by block in seconds (N=40).

Results – H2 True, H3 False

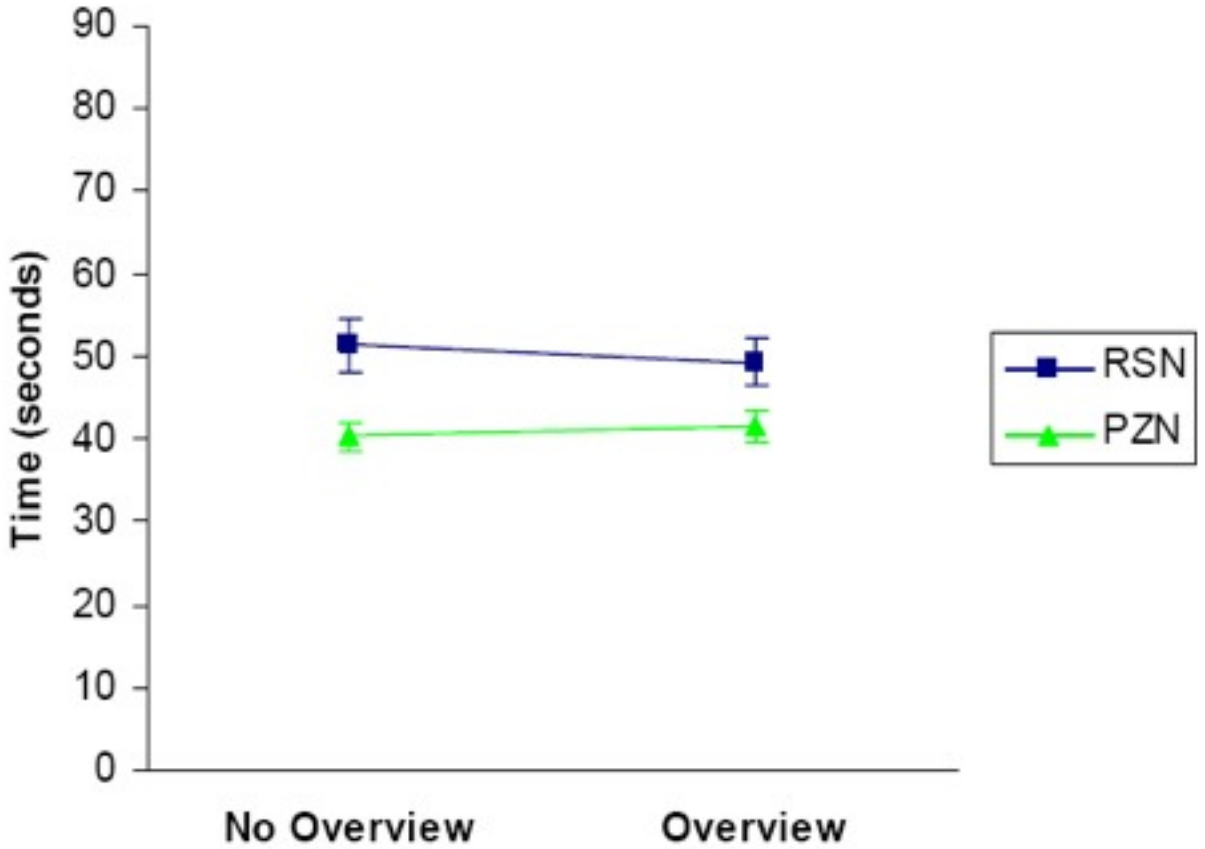


Figure 9: Block 7 mean per-trial completion times in seconds by navigation technique with and without an overview.

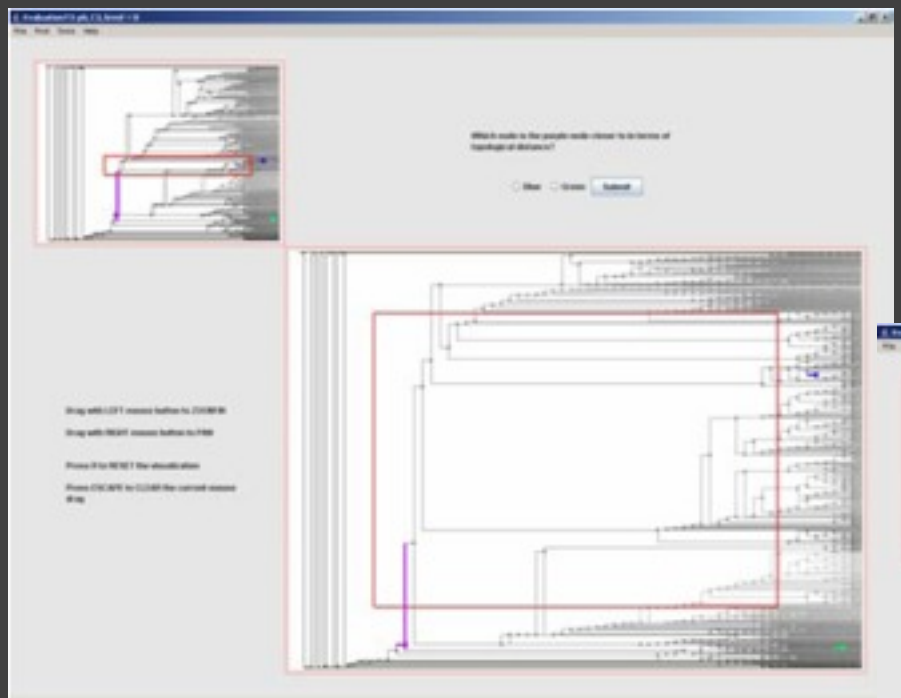
Results

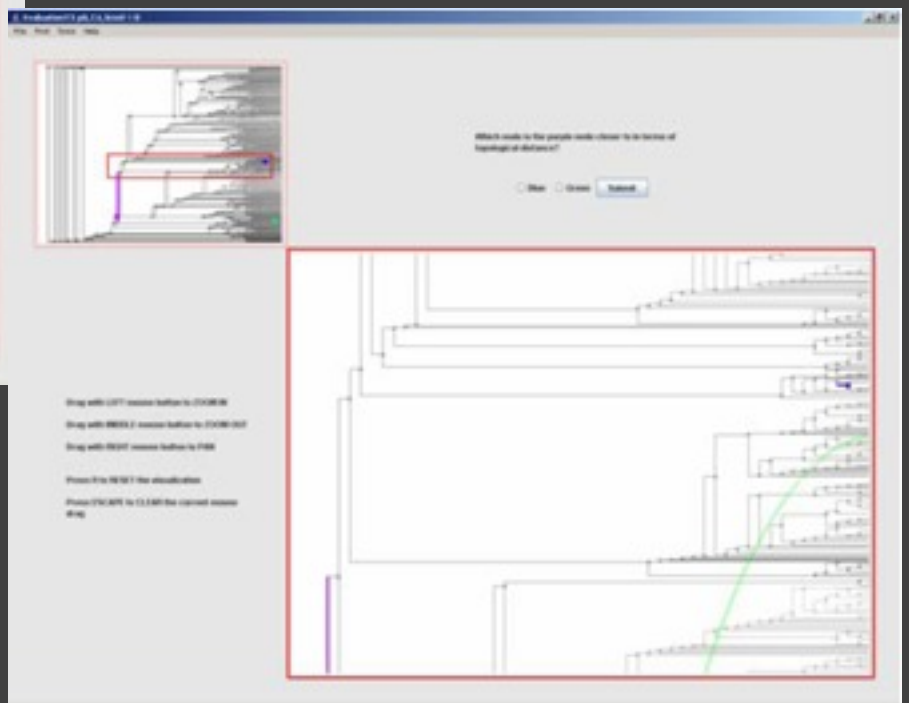
R1. Pan & Zoom had lower completion times, navigation actions, resets, and reported mental demand.

R2. Overview has no significant impact on rubber sheet navigation, though it was reported to reduce physical demand.

R3. Overview has no significant impact on pan & zoom navigation, though it was reported to reduce physical demand.

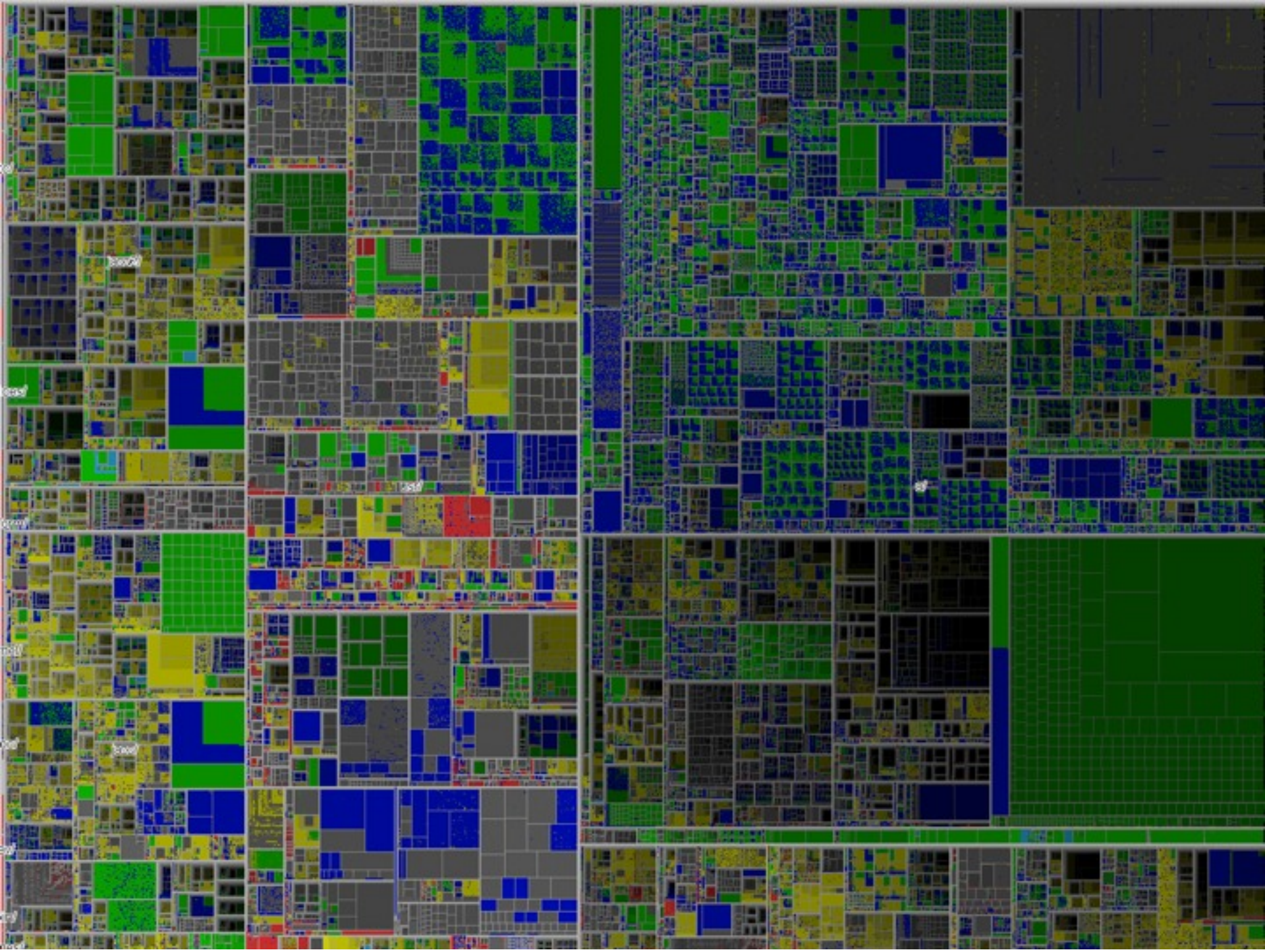
Thoughts?





Does this generalize
for overview displays?

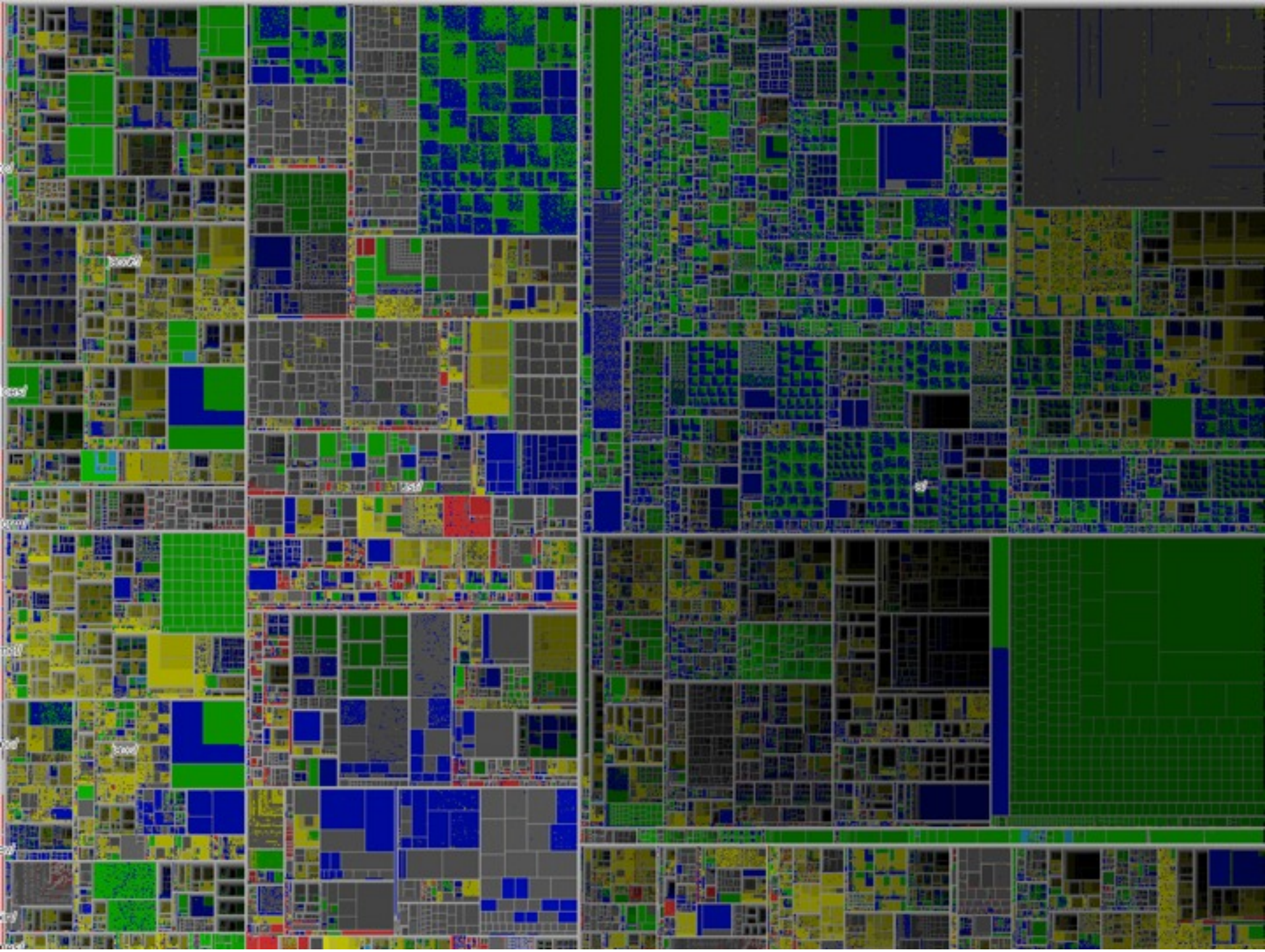
Evaluating Data-Dense Time Series Visualizations

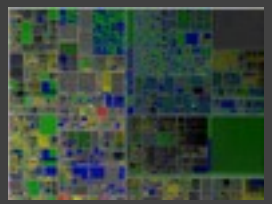


$$\text{Data Density} = \frac{(\#\ \text{entries in data})}{(\text{area of graphic})}$$

"Graphical excellence... gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space"

Tufte '83

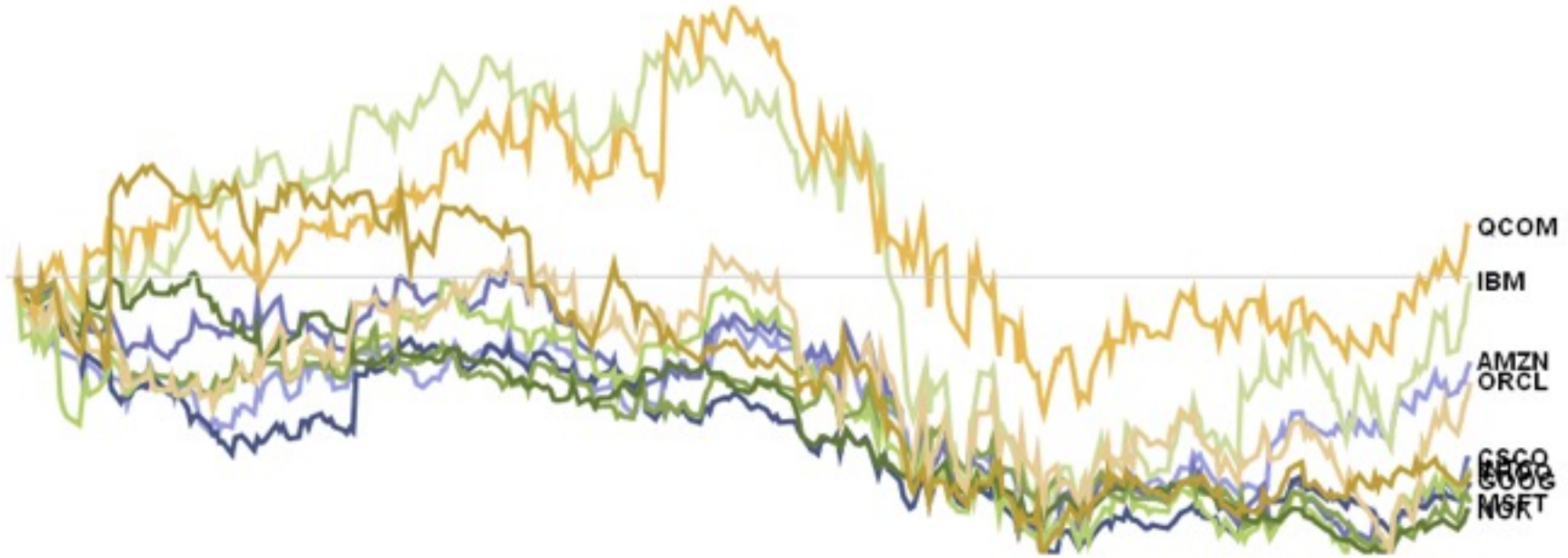




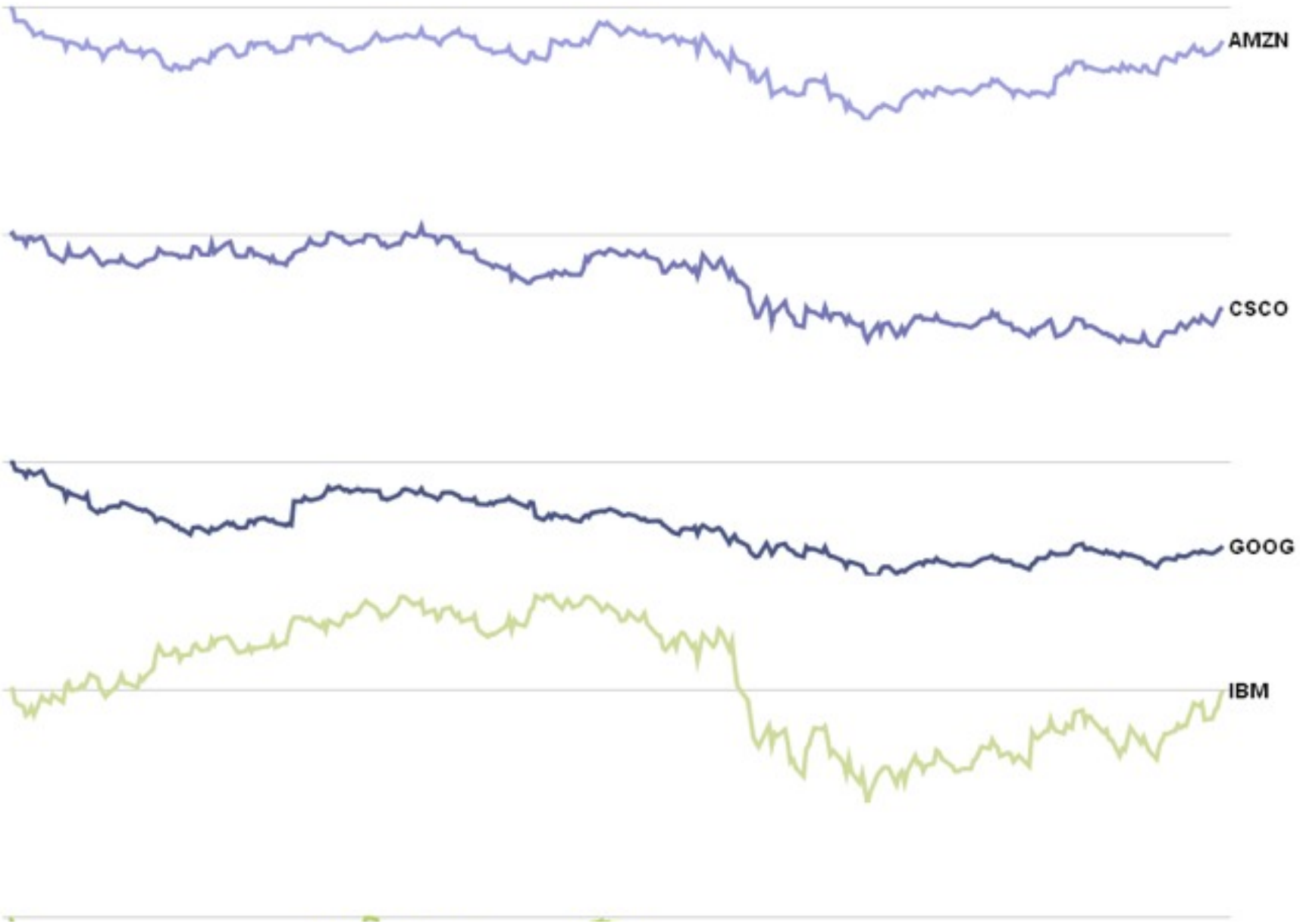
Time-Series Visualization

Relative Technology Stock Performance: Jan 2008 - Present

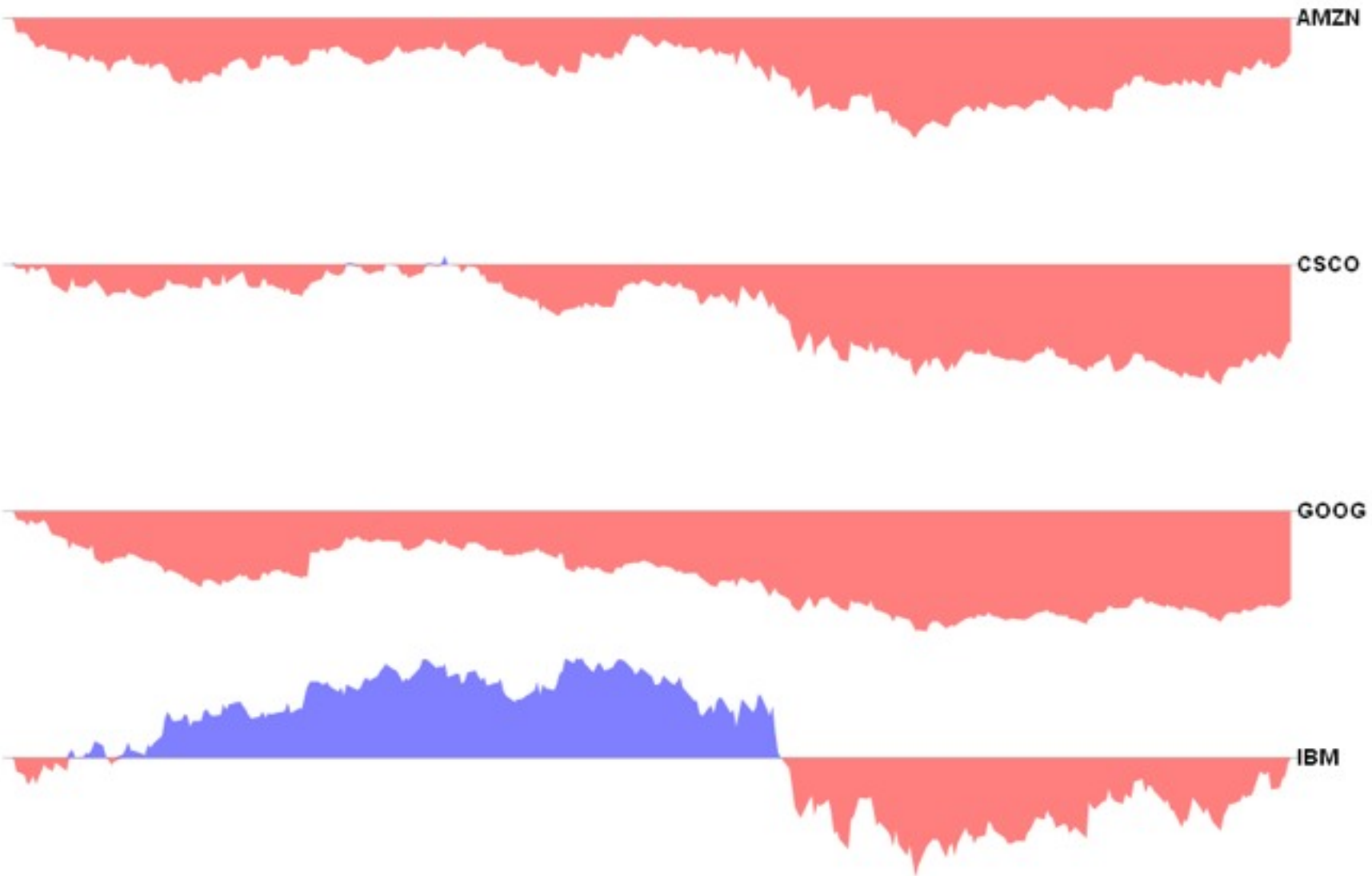
Relative Technology Stock Performance: Jan 2008 - Present

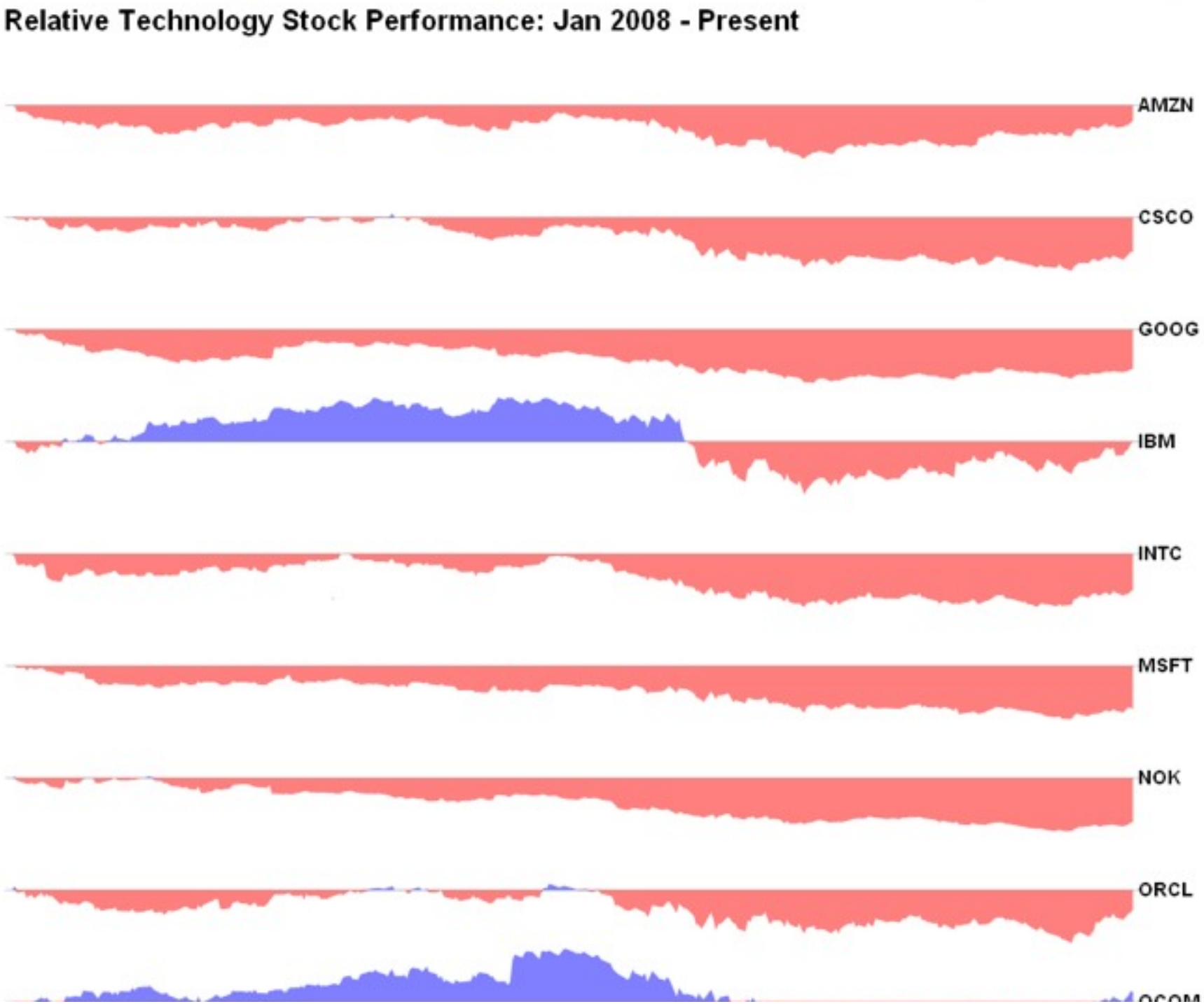


Relative Technology Stock Performance: Jan 2008 - Present

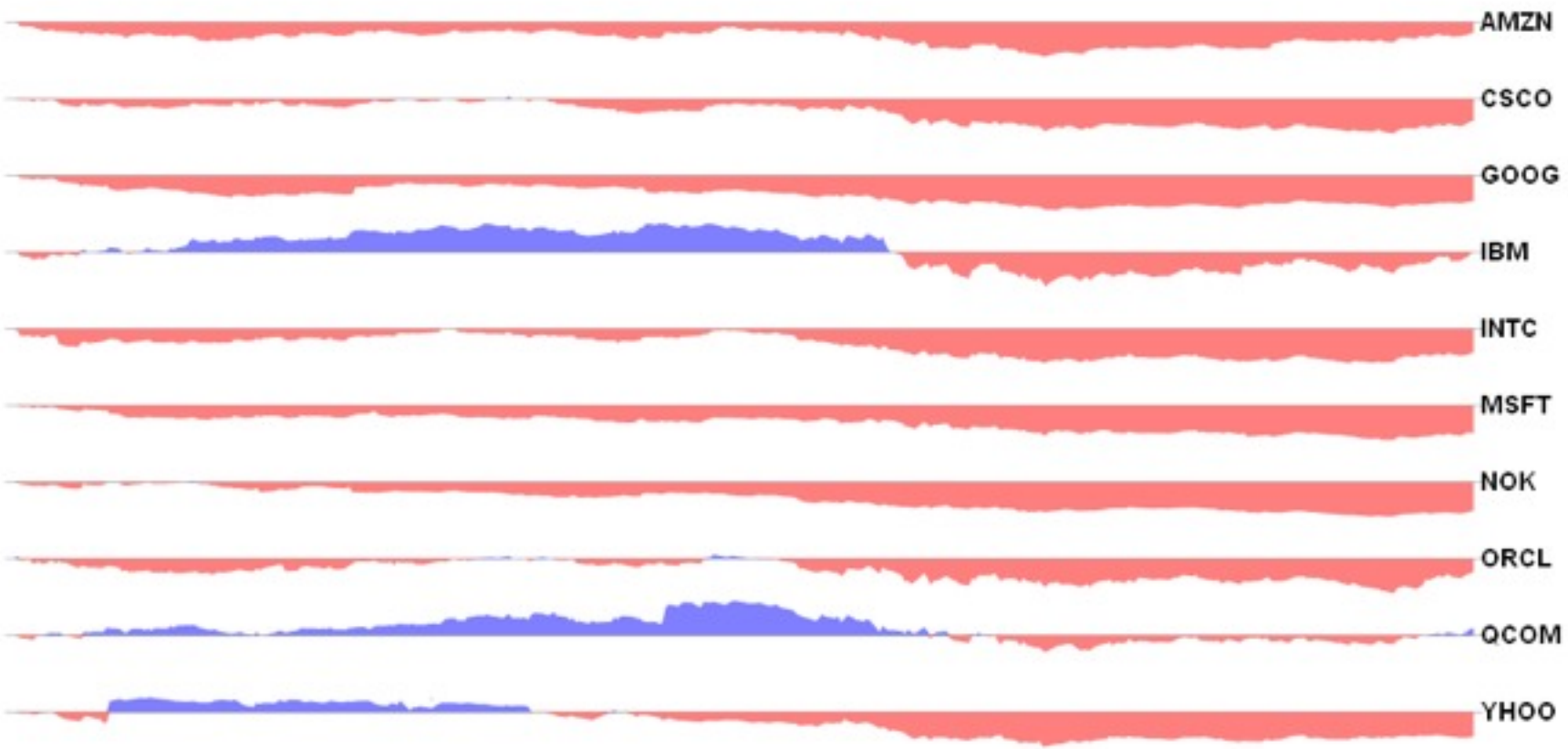


Relative Technology Stock Performance: Jan 2008 - Present

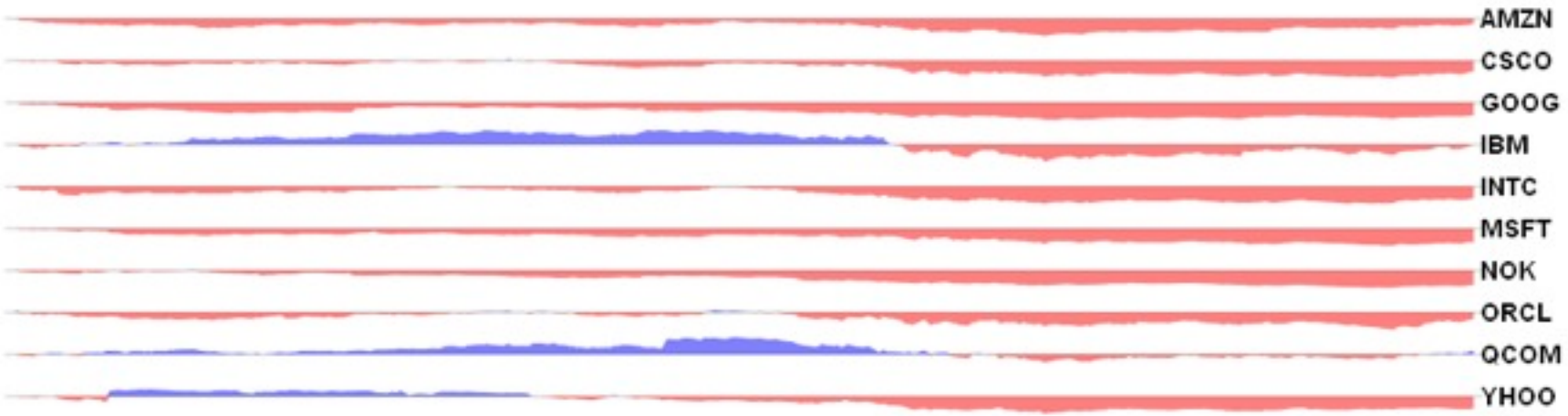



Relative Technology Stock Performance: Jan 2008 - Present
AMZN
CSCO
GOOG
IBM
INTC
MSFT
NOK
ORCL

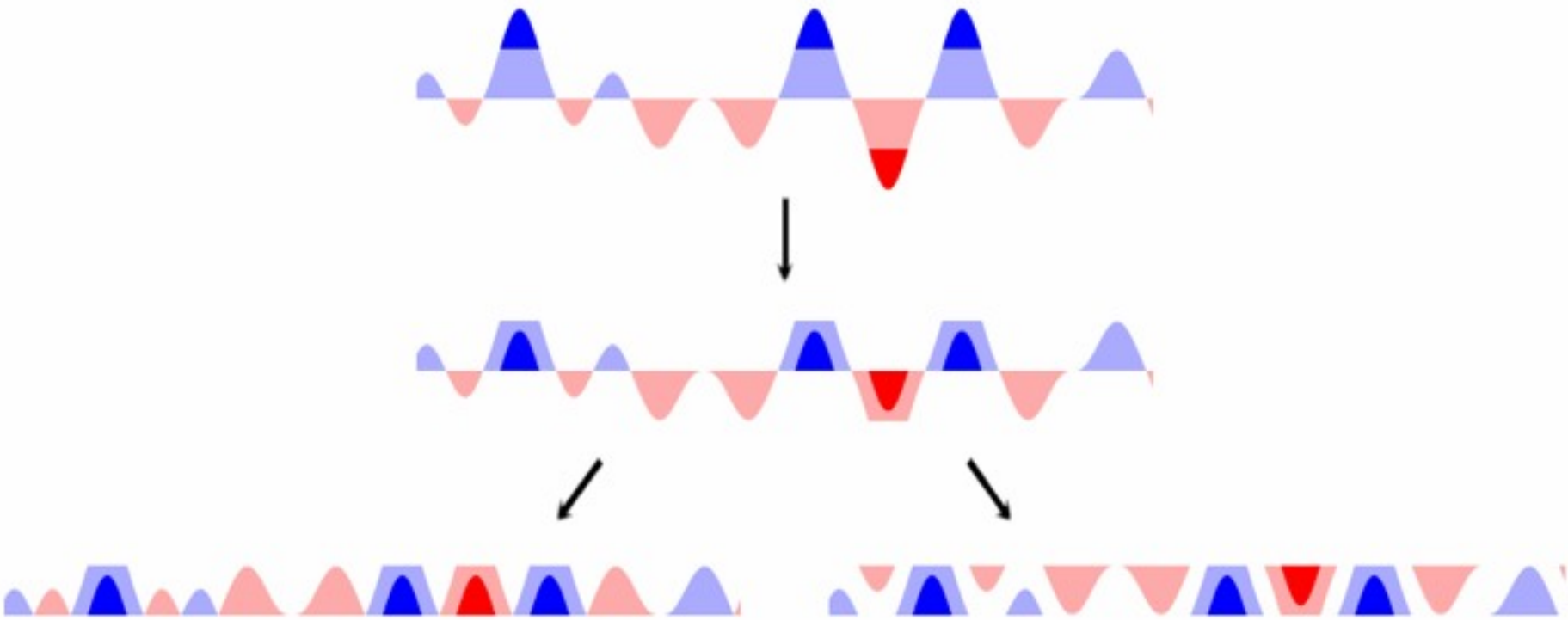
Relative Technology Stock Performance: Jan 2008 - Present



Relative Technology Stock Performance: Jan 2008 - Present



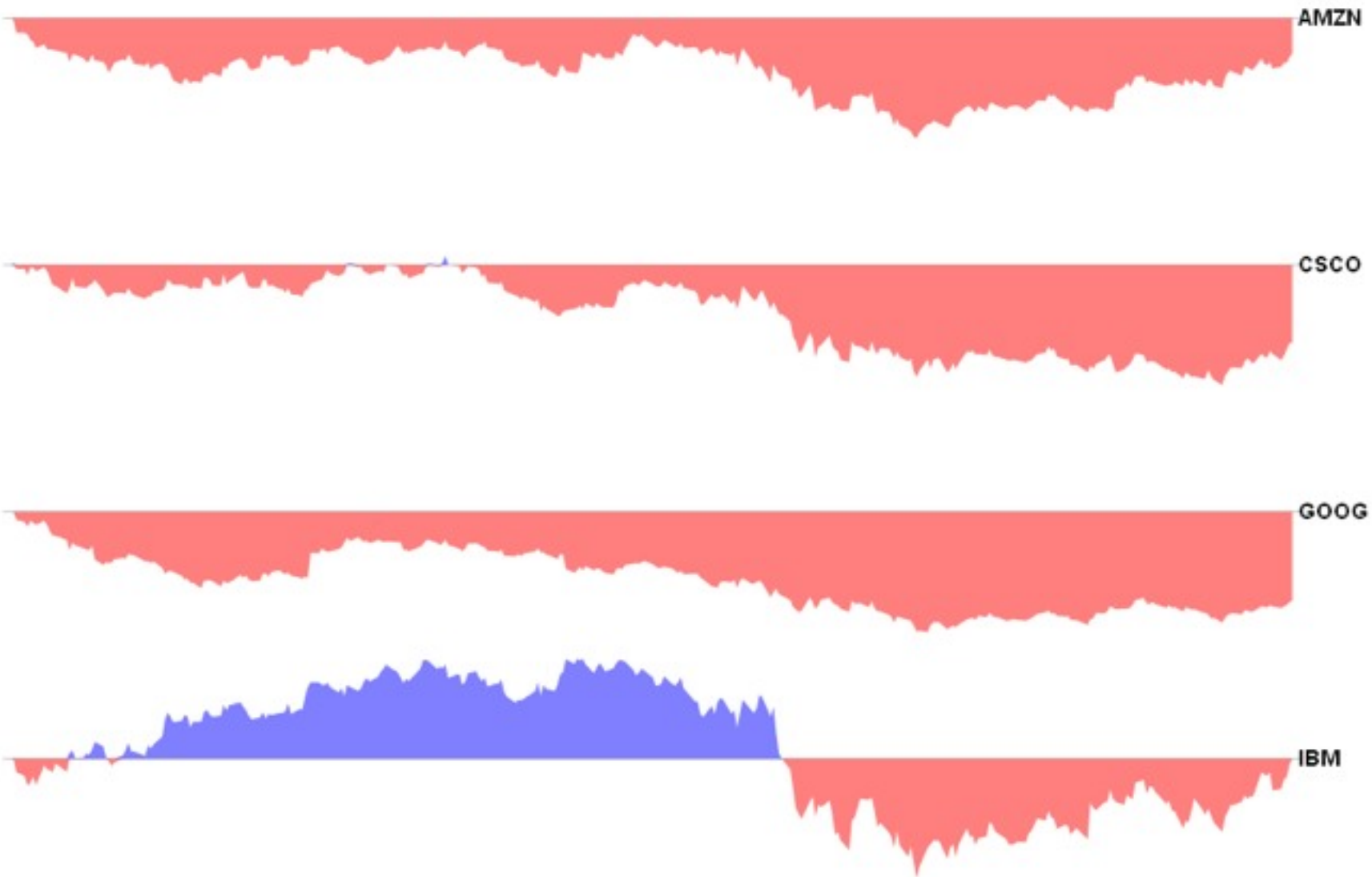
Horizon Graphs

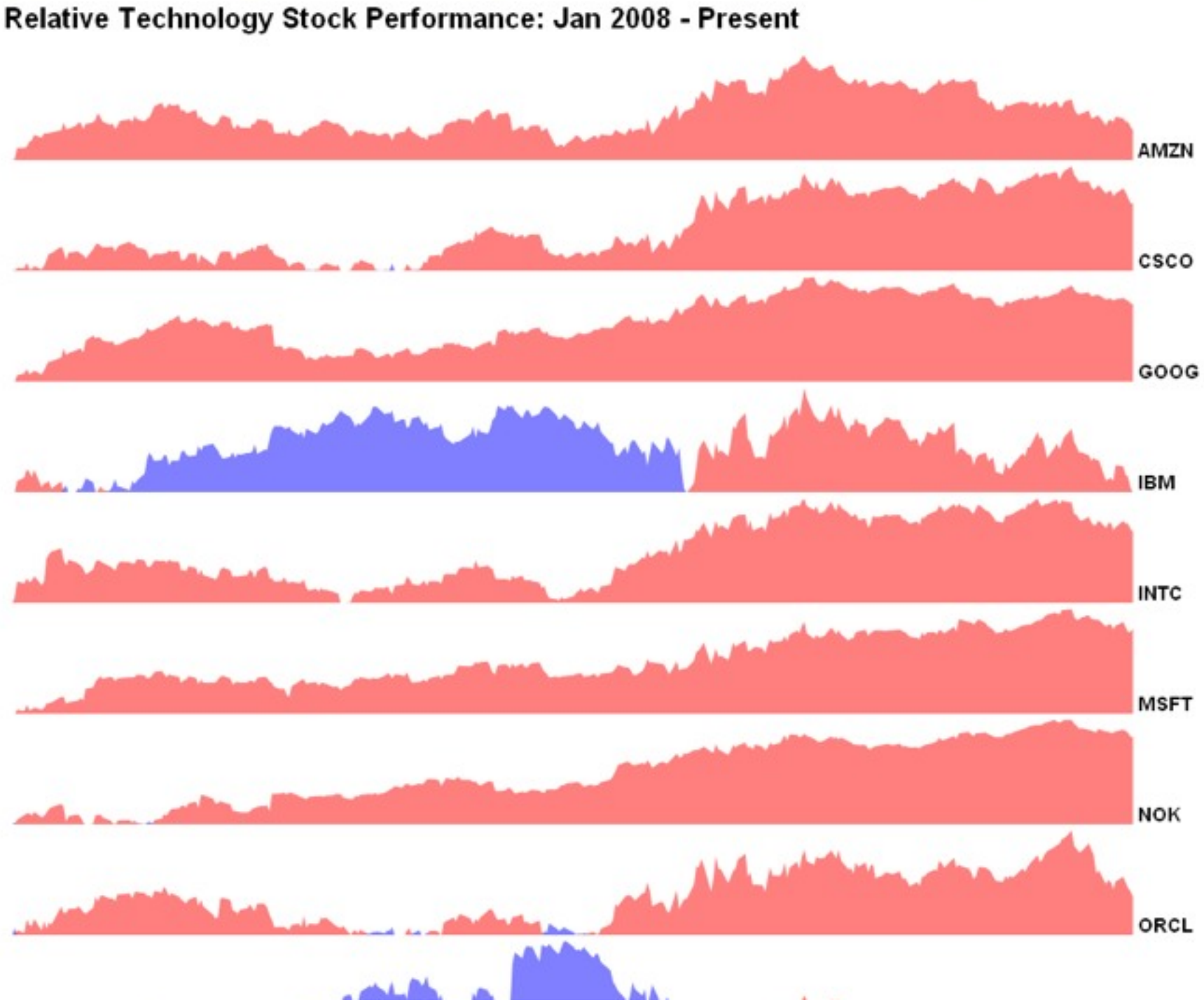


Mirror Horizon Graph

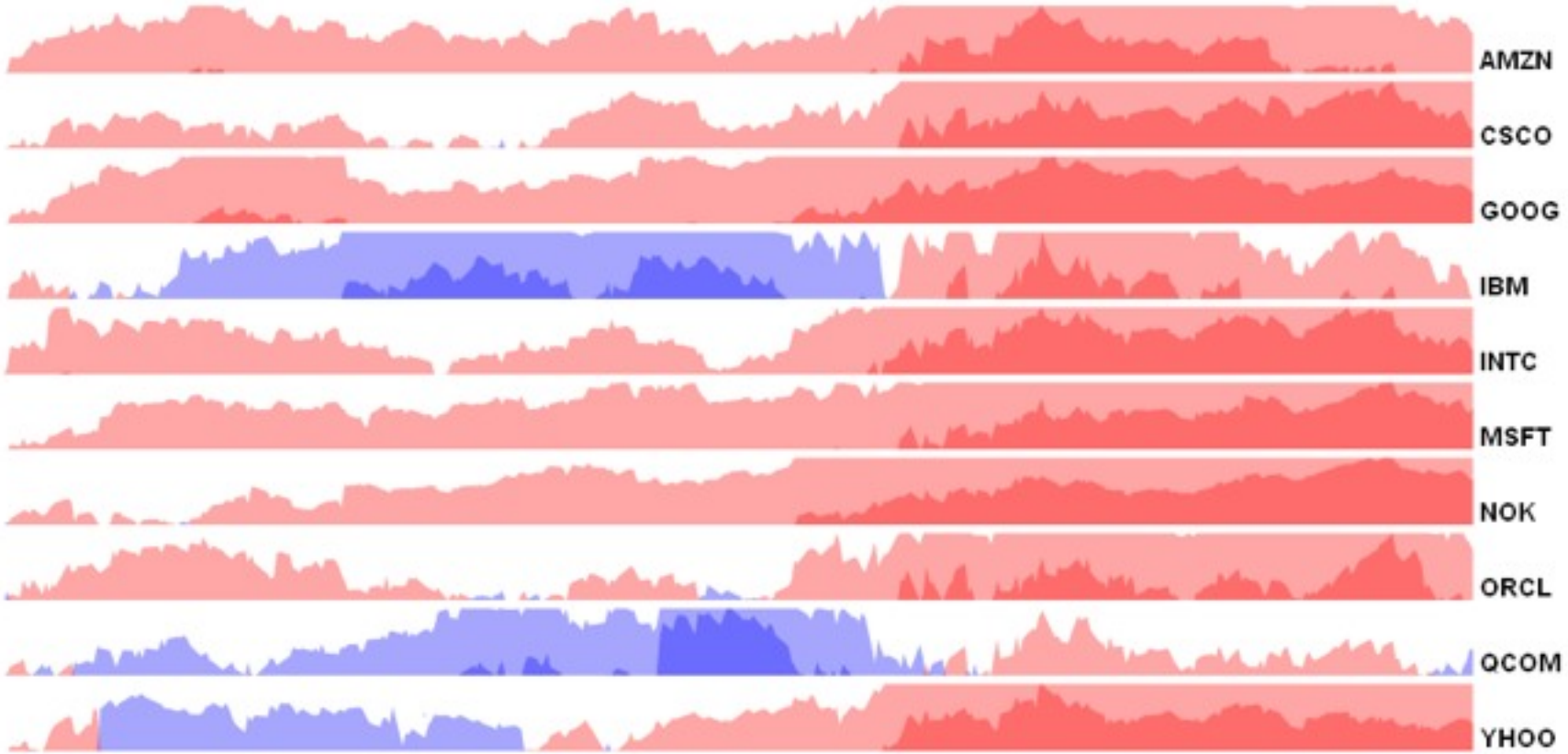
Offset Horizon Graph

Relative Technology Stock Performance: Jan 2008 - Present

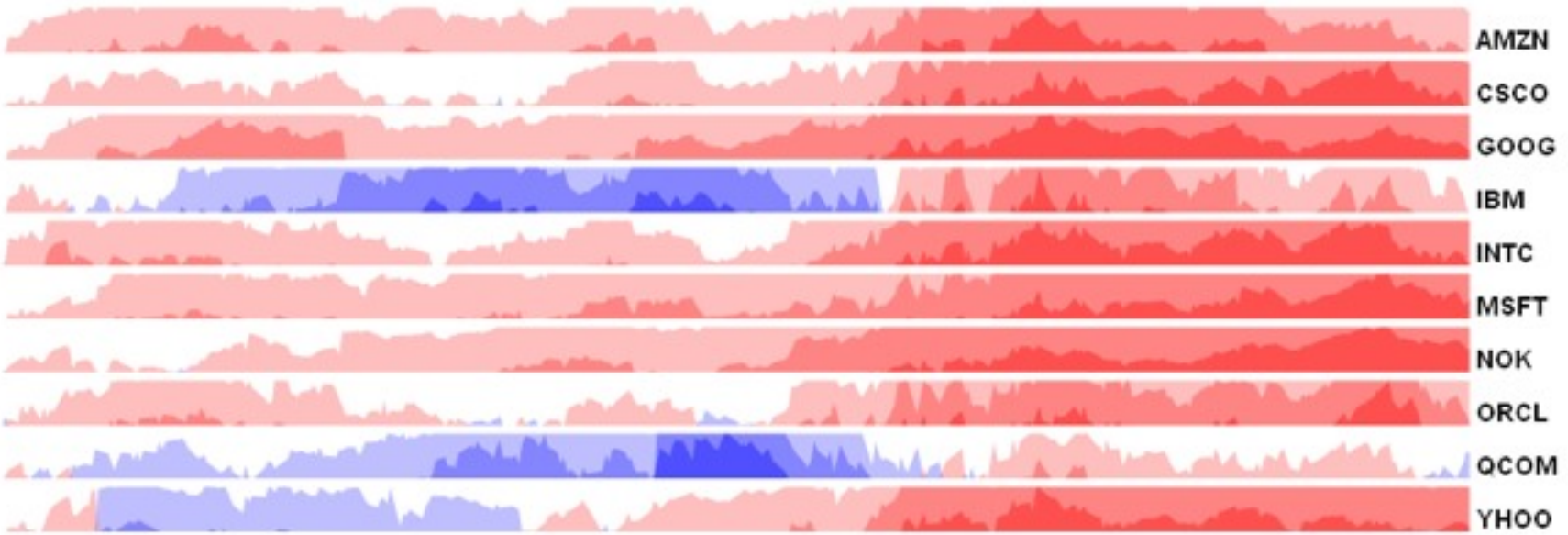



Relative Technology Stock Performance: Jan 2008 - Present
AMZN
CSCO
GOOG
IBM
INTC
MSFT
NOK
ORCL

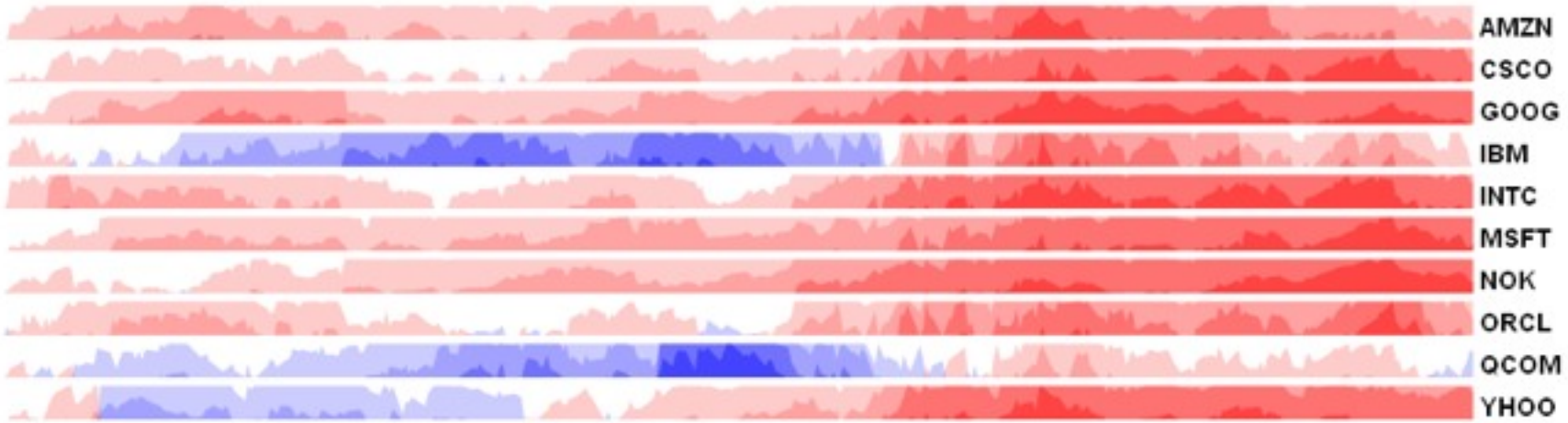
Relative Technology Stock Performance: Jan 2008 - Present



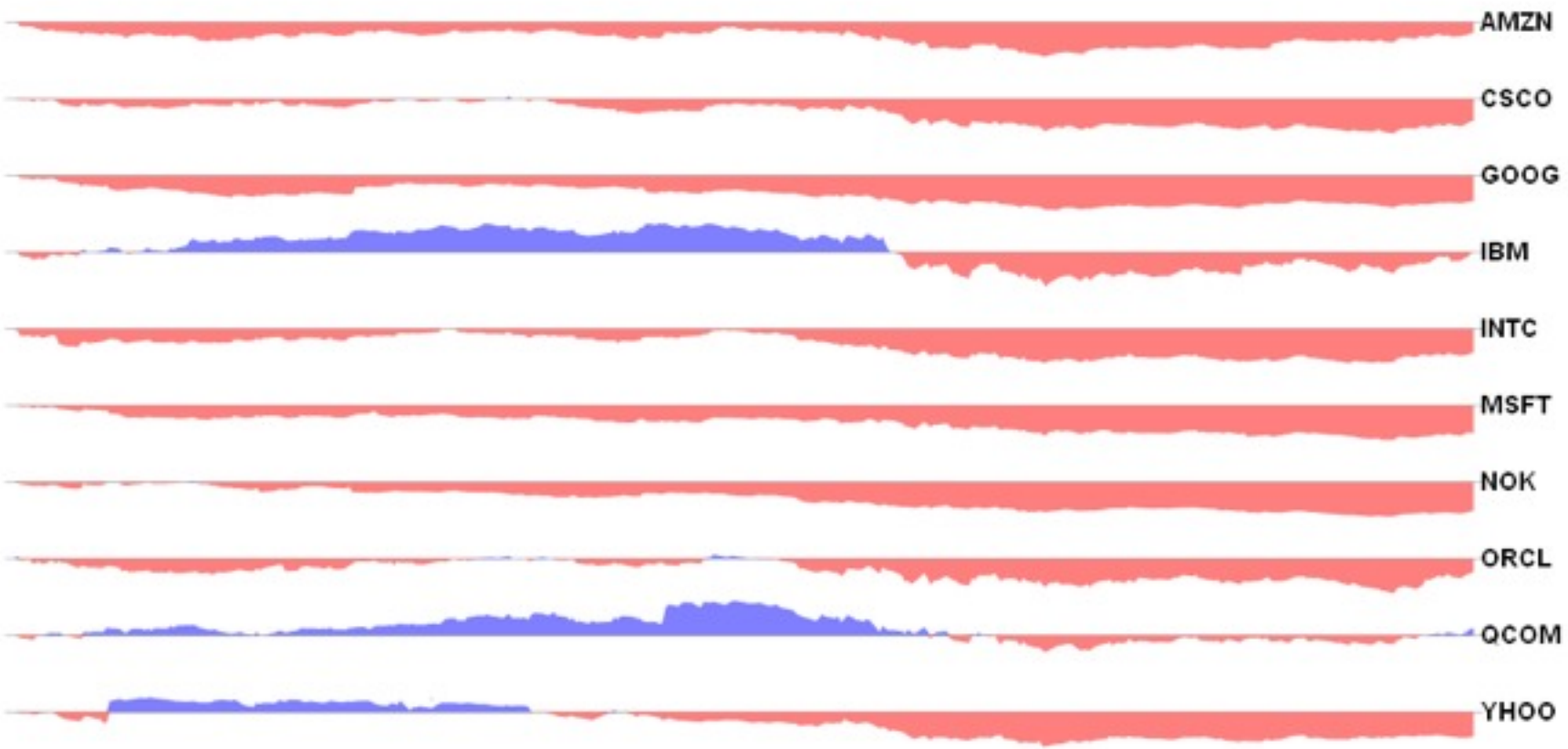
Relative Technology Stock Performance: Jan 2008 - Present



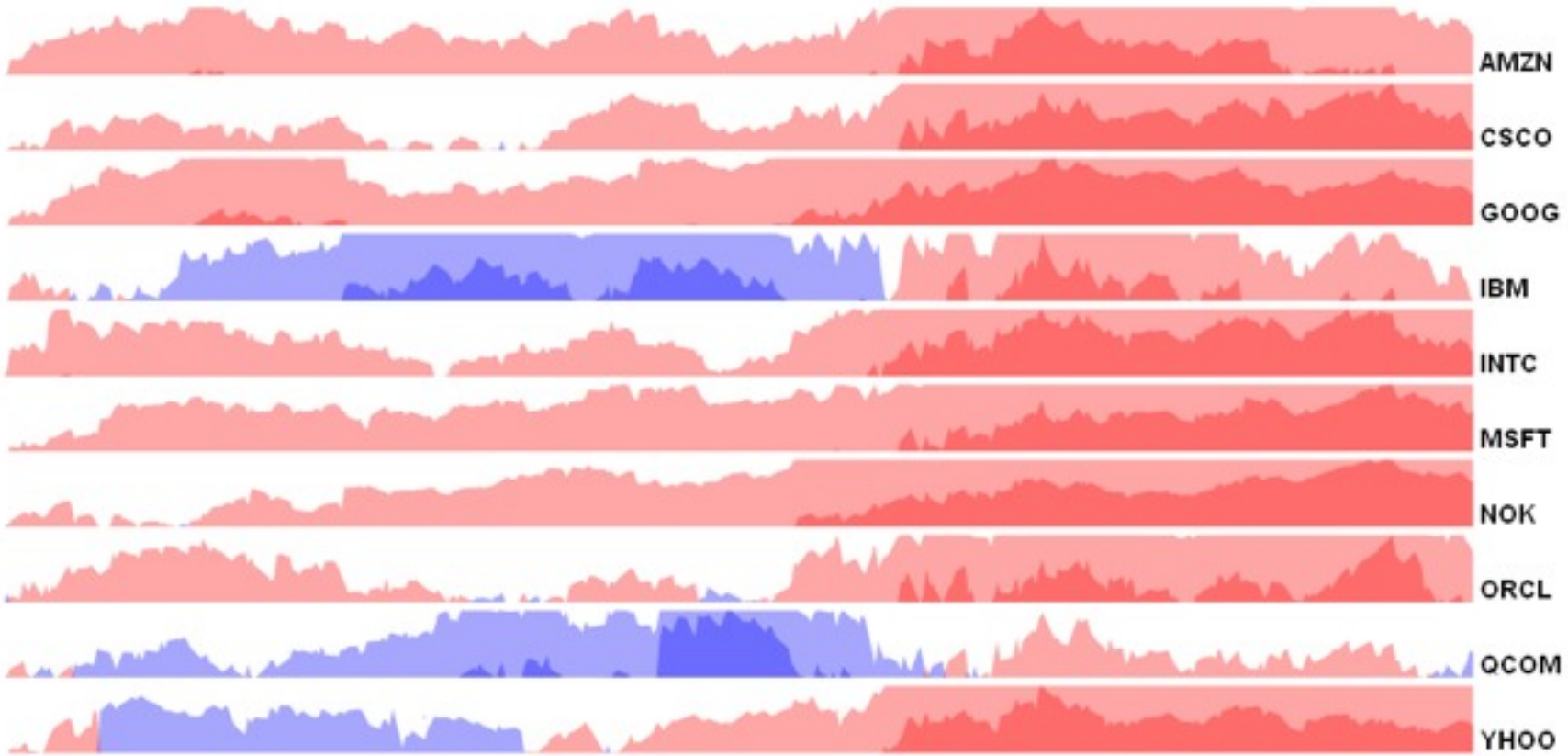
Relative Technology Stock Performance: Jan 2008 - Present

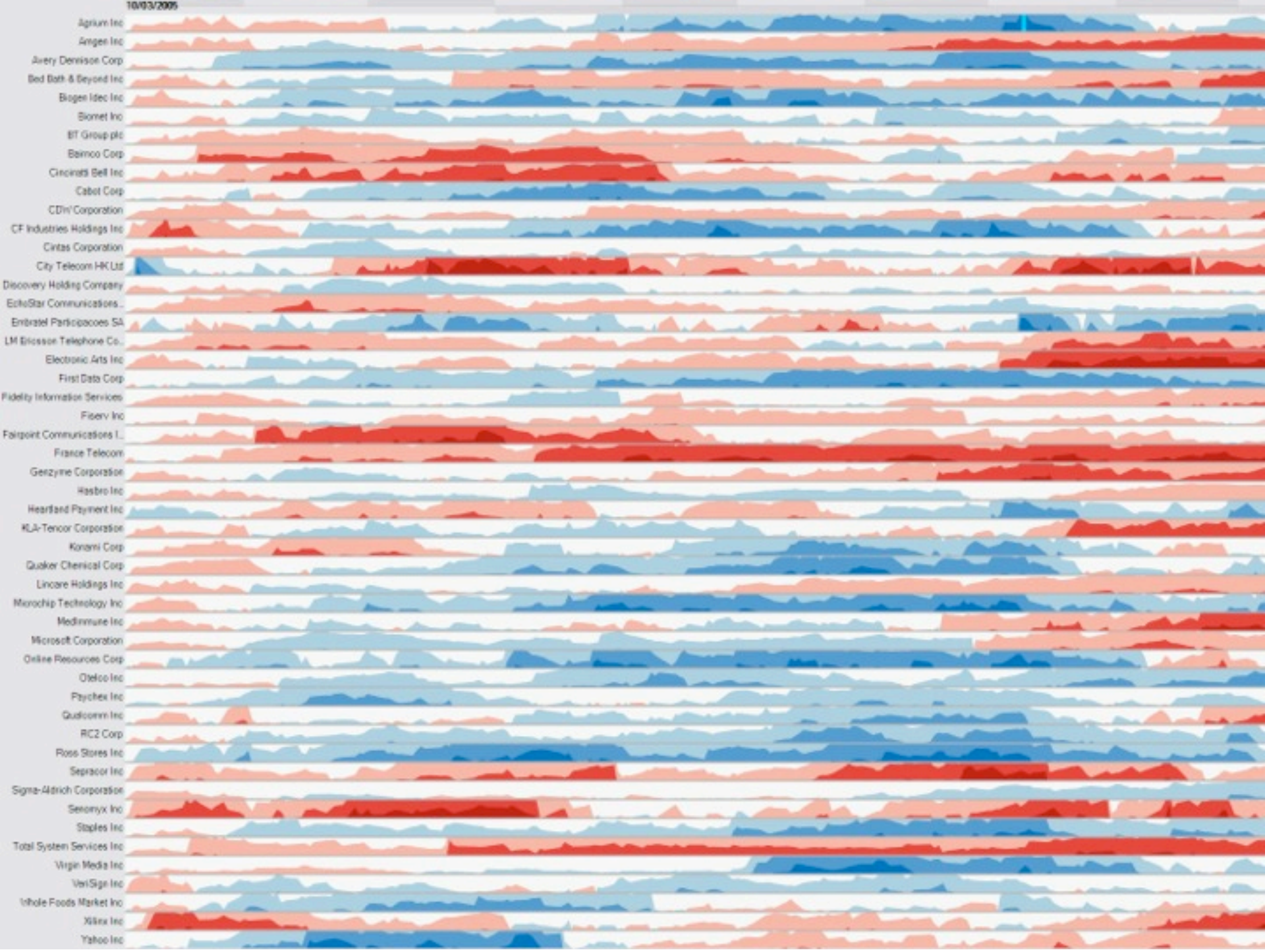


Relative Technology Stock Performance: Jan 2008 - Present



Relative Technology Stock Performance: Jan 2008 - Present




10/03/2005
Agrium Inc
Amgen Inc
Avery Dennison Corp
Bed Bath & Beyond Inc
Biogen Idec Inc
Biomet Inc
BT Group plc
Bairnco Corp
Cincinati Bell Inc
Cabot Corp
CDW Corporation
CF Industries Holdings Inc
Cintas Corporation
City Telecom HK Ltd
Discovery Holding Company
EchoStar Communications...
Embratel Participacoes SA
LM Ericsson Telephone Co...
Electronic Arts Inc
First Data Corp
Fidelity Information Services
Fiserv Inc
Fairpoint Communications I...
France Telecom
Genzyme Corporation
Hasbro Inc
Heartland Payment Inc
KLA-Tencor Corporation
Konami Corp
Quaker Chemical Corp
Lincare Holdings Inc
Microchip Technology Inc
Medimmune Inc
Microsoft Corporation
Online Resources Corp
Otelco Inc
Paychex Inc
Qualcomm Inc
RC2 Corp
Ross Stores Inc
Sepracor Inc
Sigma-Aldrich Corporation
Seronyx Inc
Staples Inc
Total System Services Inc
Virgin Media Inc
VeriSign Inc
Whole Foods Market Inc
Xilinx Inc
Yahoo Inc

Experiment 1
Horizon Graph Variants

Exp 1: Mirror/Offset & Banding

Q1: How does the choice of mirrored or offset horizon graph affect estimation time and accuracy?

Mirror Horizon Graph

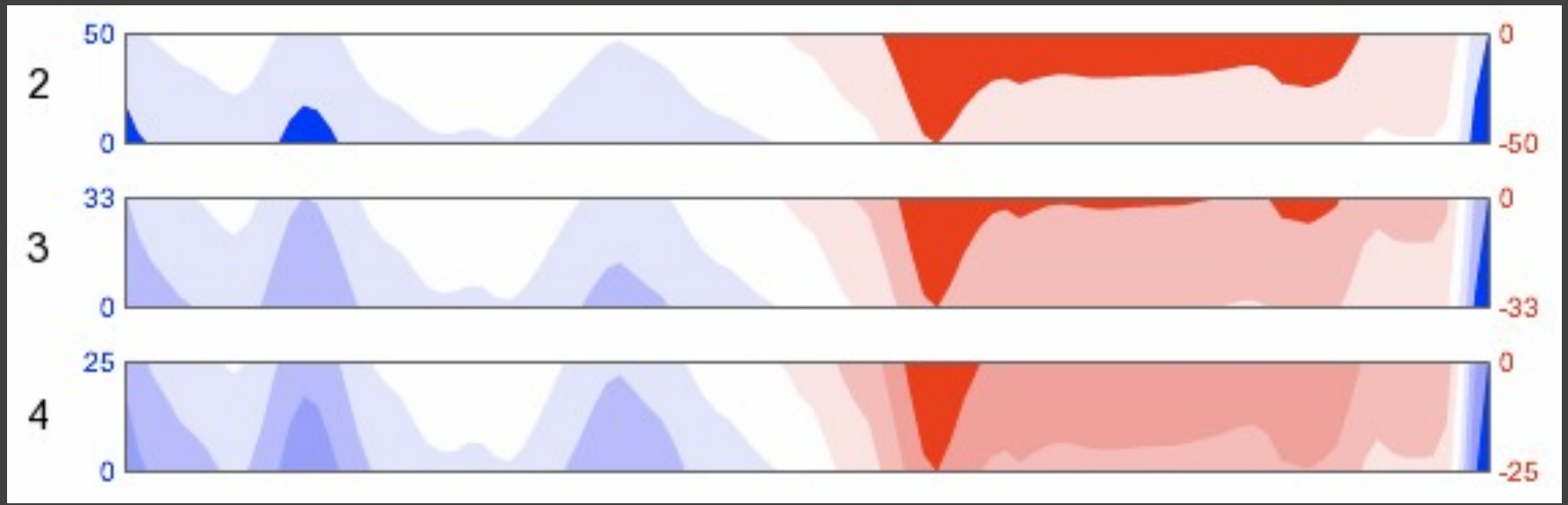
Offset Horizon Graph

Exp 1: Mirror/Offset & Banding

Q1: How does the choice of mirrored or offset horizon graph affect estimation time and accuracy?

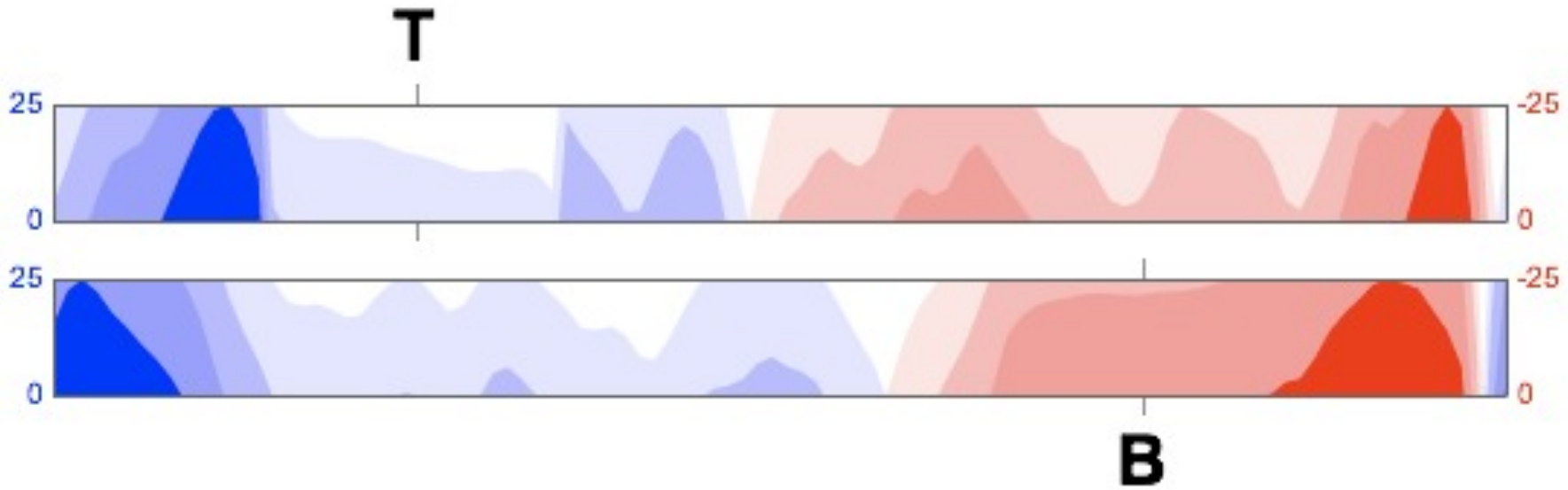
Q2: How does the number of bands in a horizon chart affect estimation time and accuracy?

Experiment 1 Design

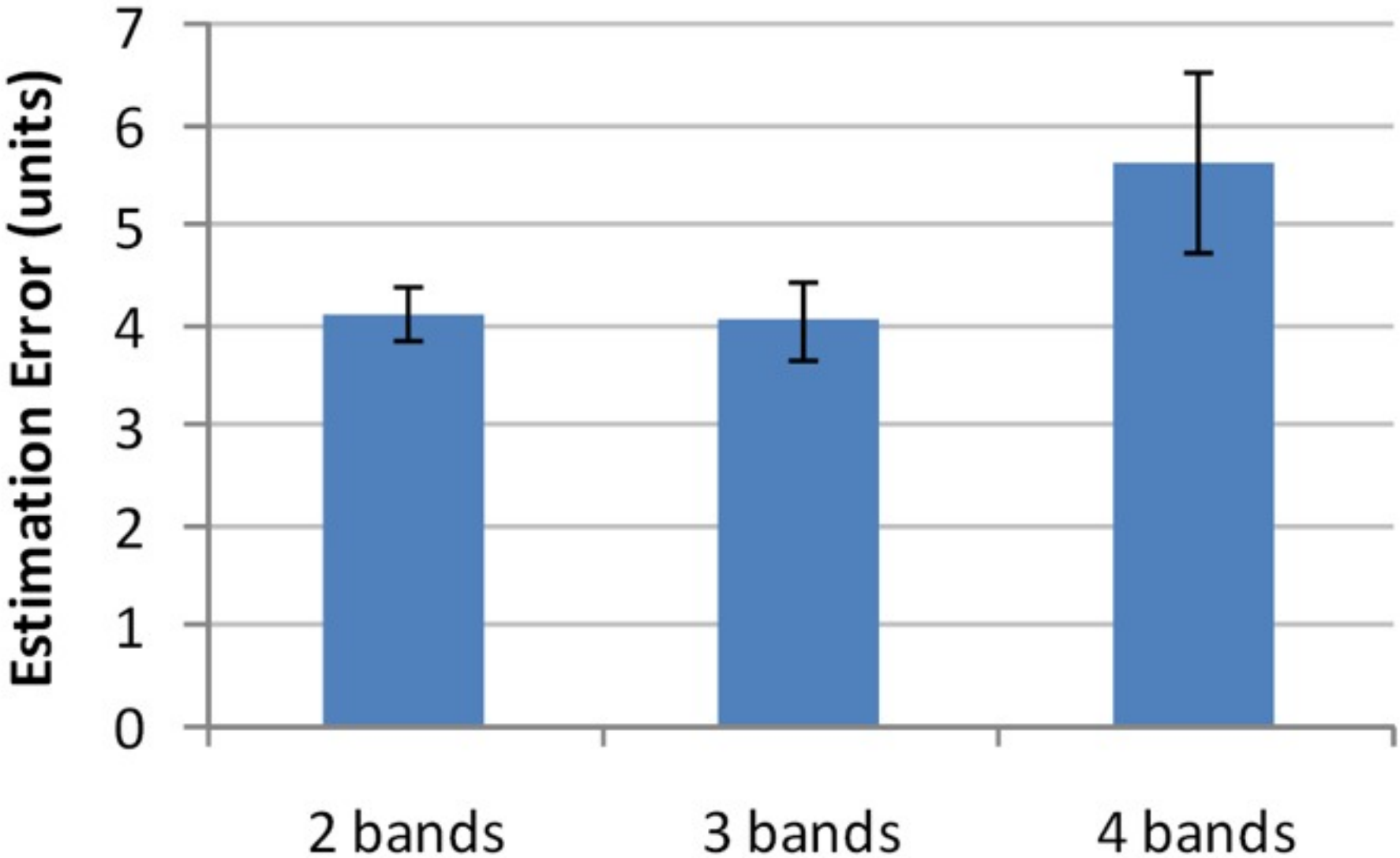


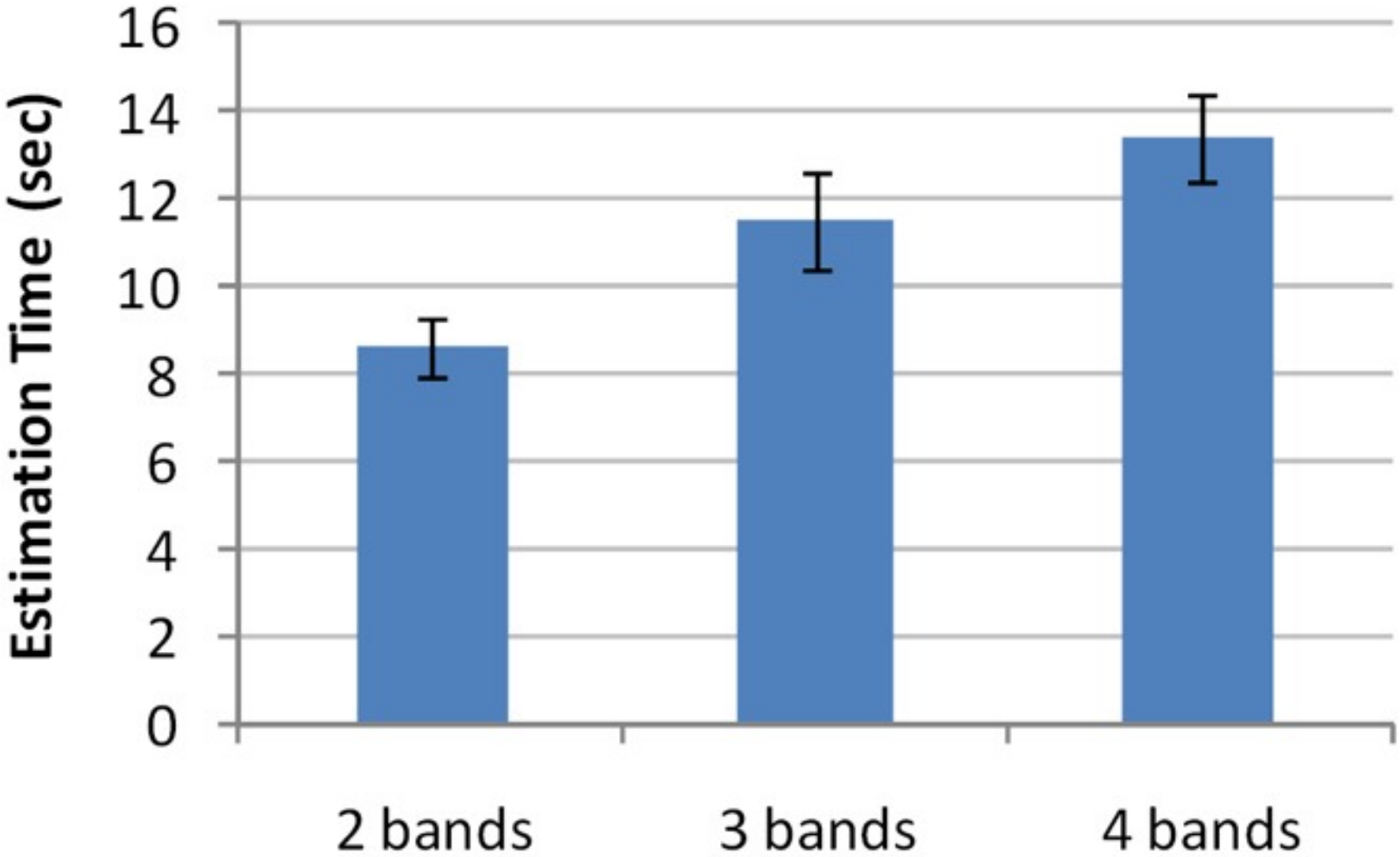
2 (type) x 3 (band count) within-subjects design

- N = 18 (13 male, 5 female), UCB students
- Deployed on the web as a Flash applet



Estimate the difference between T and B (0-200) to within 5 values.


Estimation Error (units)
7
6
5
4
3
2
1
0
2 bands
3 bands
4 bands


Estimation Time (sec)
16
14
12
10
8
6
4
2
0
2 bands
3 bands
4 bands

Experiment 1 Results

Q1: No significant difference between mirrored and offset horizon graphs.

Q2: Both estimation time and error increased with more bands.

→ Higher band counts led to **difficulty identifying bands** and **fatigue from mental mathematics**.

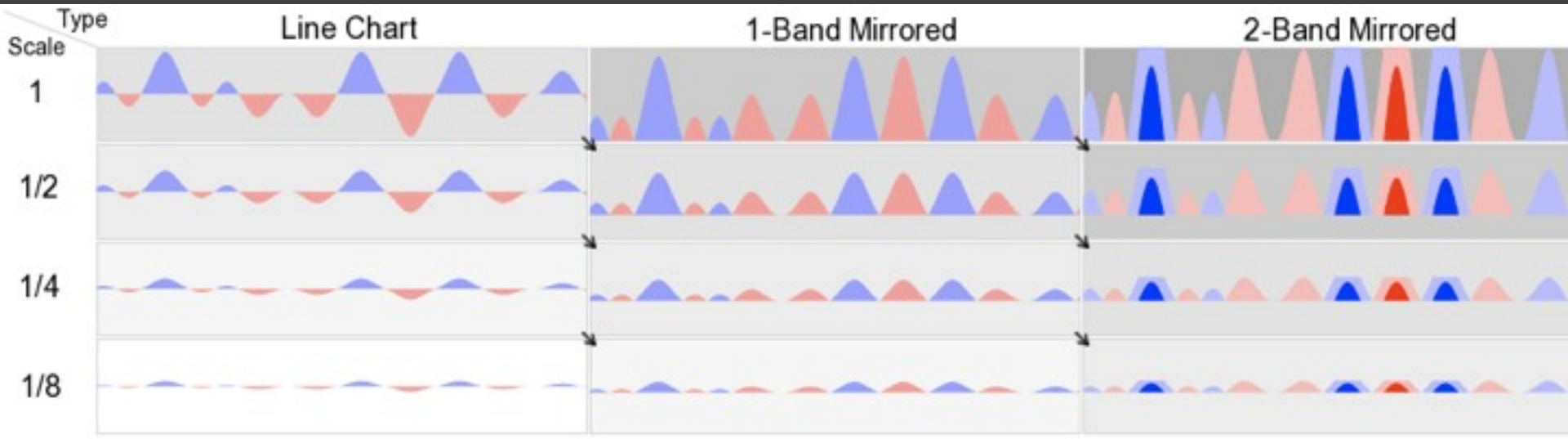
Experiment 2
Chart Type and Size

Exp 2: Chart Type & Size

Q1: How do mirroring and layering affect estimation time and accuracy compared to line charts?

Q2: How does chart size affect estimation time and accuracy?

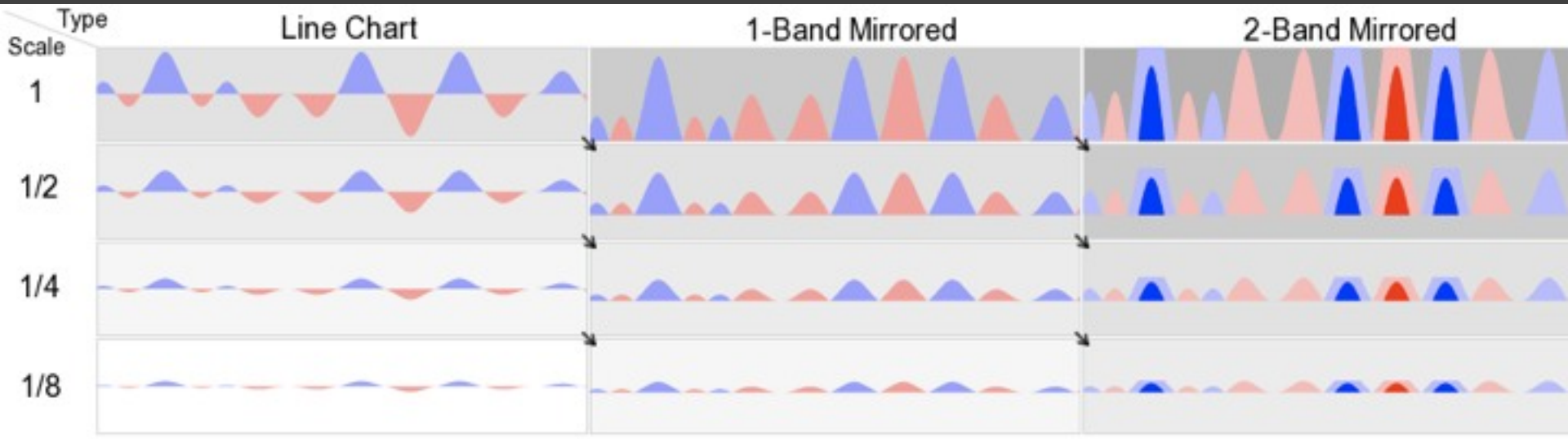
Experiment 2 Design



3 (chart type) x 4 (size) within-subjects design

- N = 30 (17 male, 13 female), UCB undergrads
- 14.1 inch LCD display at 1024 x 768 pixel resolution
- At scale = 1, chart was 13.9 x 1.35 cm (48 pixels)

Experiment 2 Design

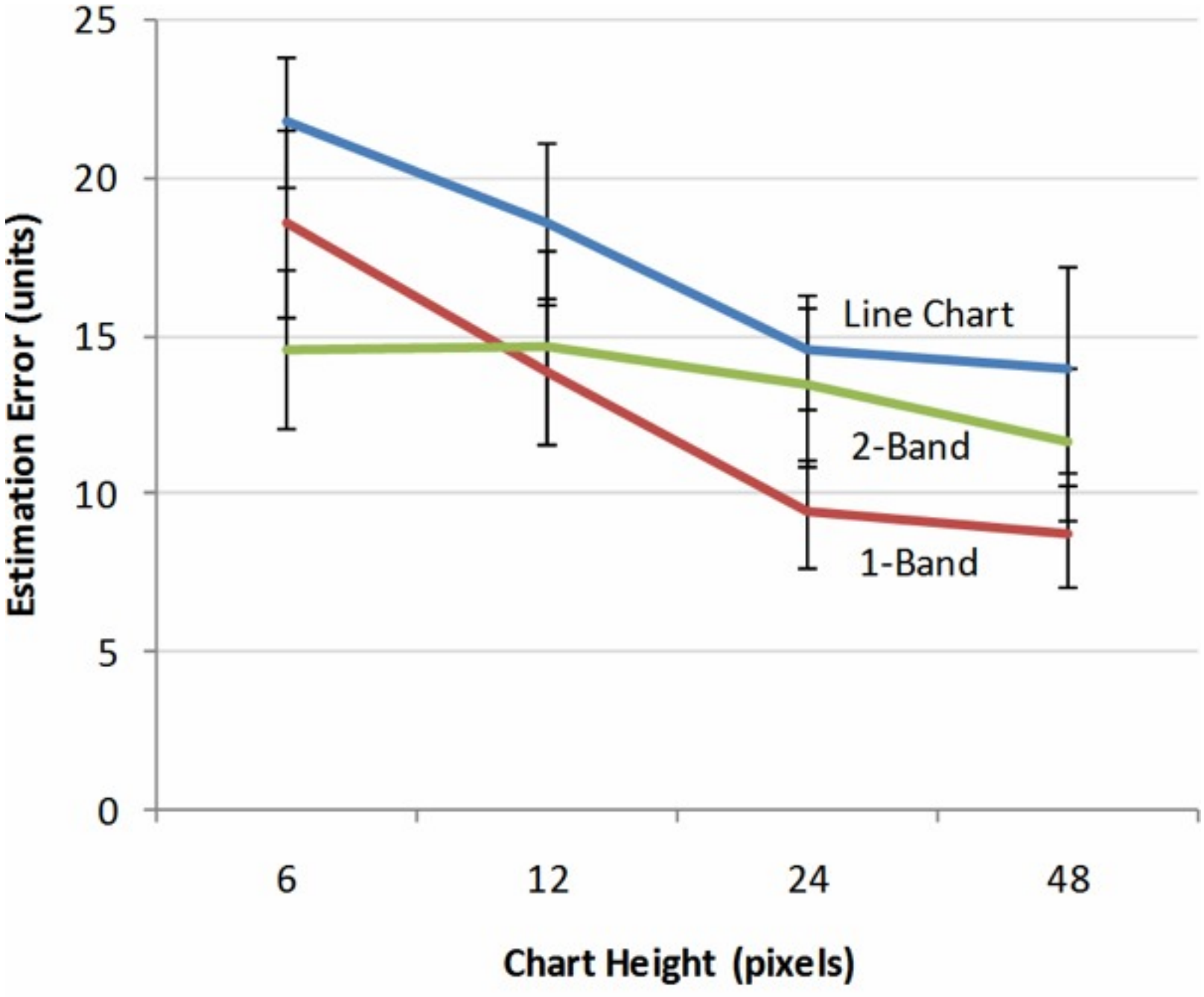


3 (chart type) x 4 (size) within-subjects design

- N = 30 (17 male, 13 female), UCB undergrads

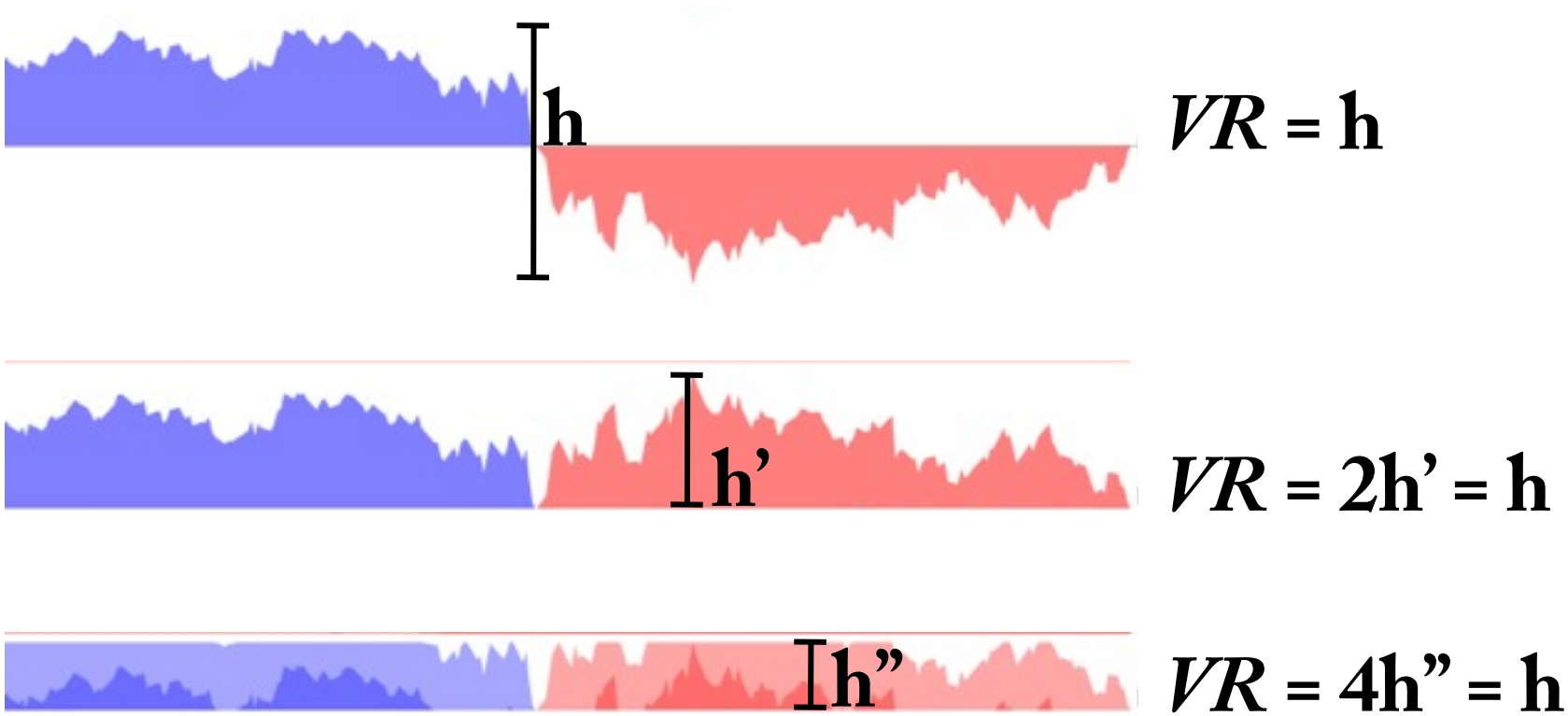
2 (chart type) x 3 (size: 1/8, 1/12, 1/24) follow-up study

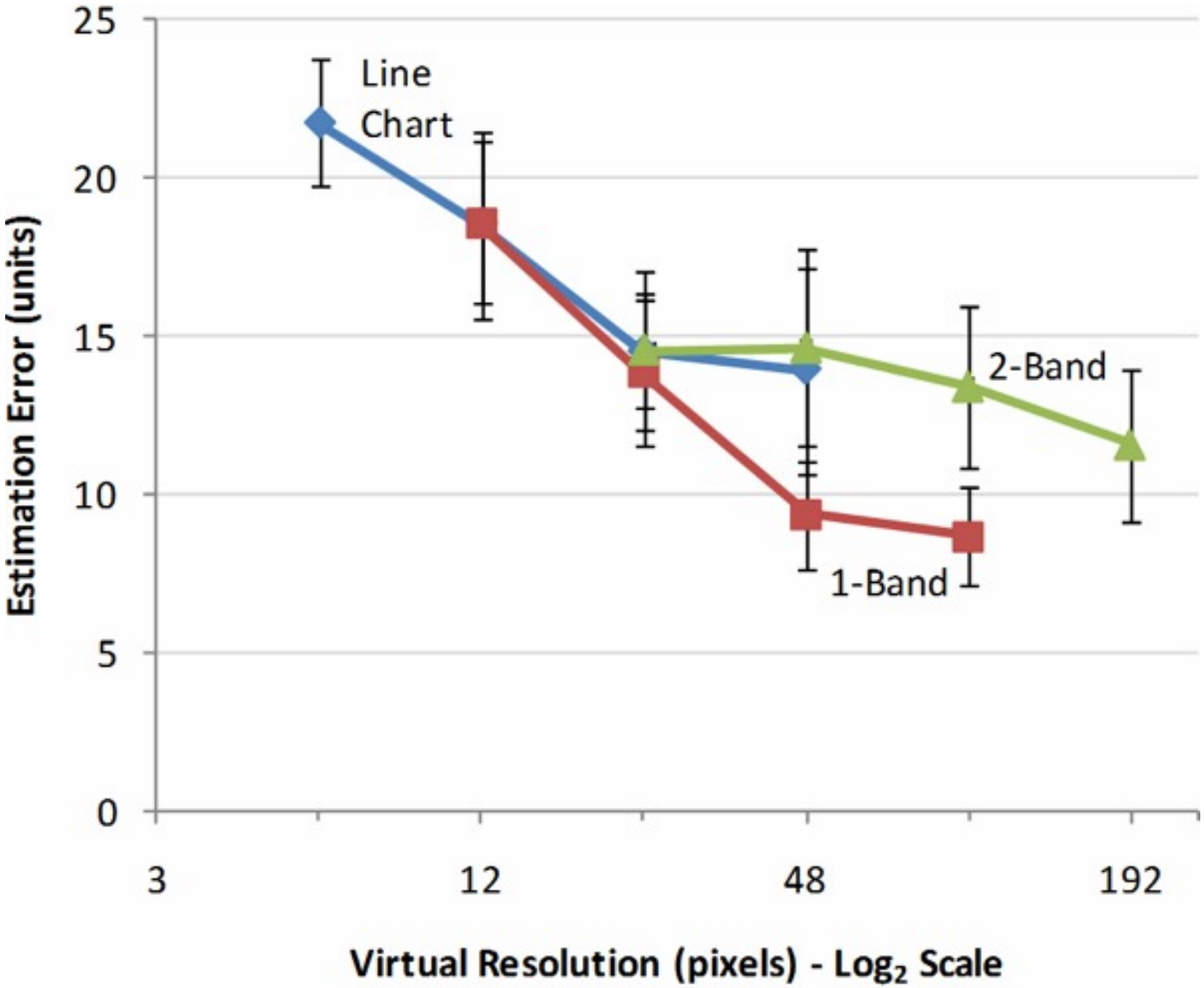
- N = 8 (6 male, 2 female), UCB engineering grads

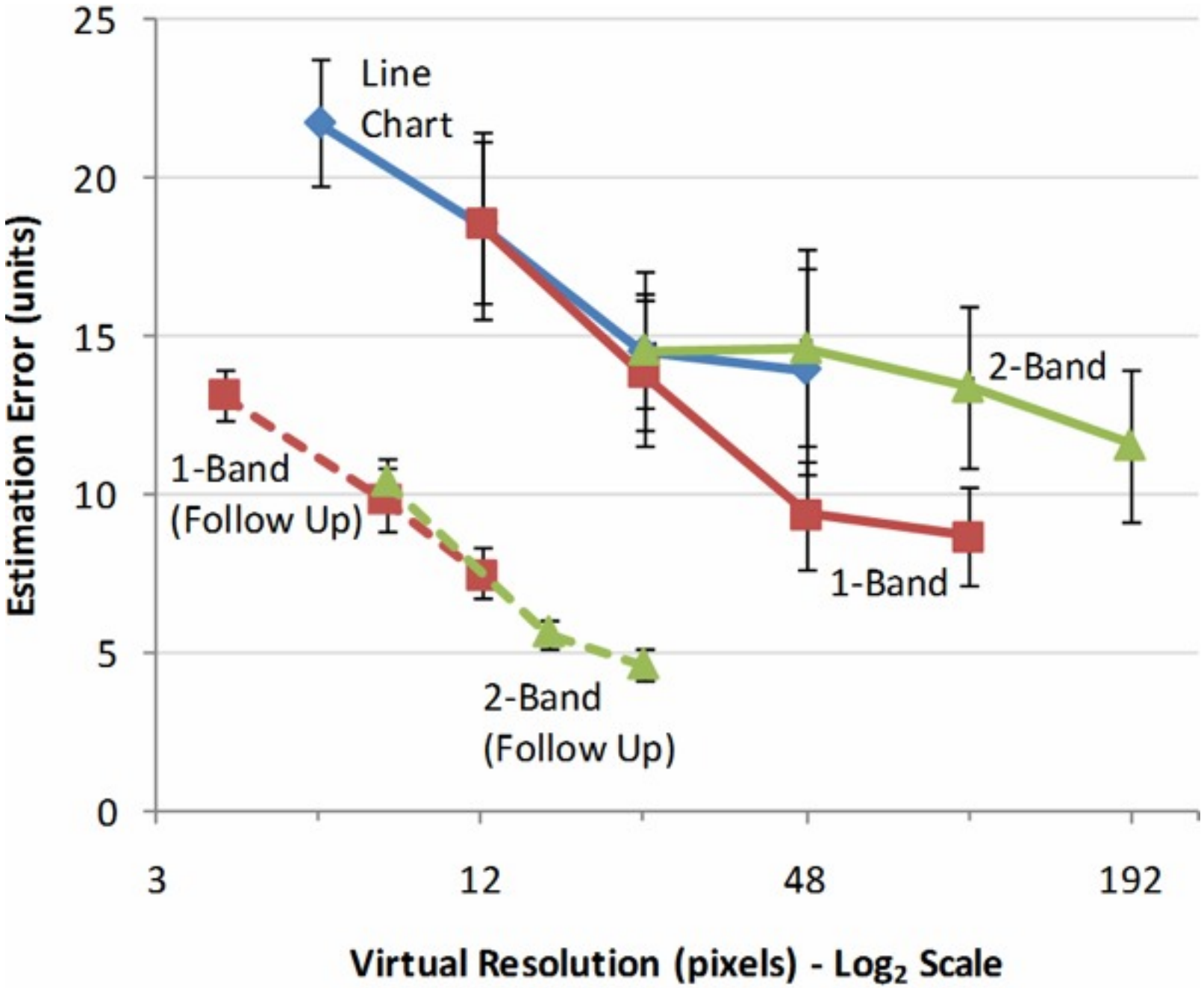

25
20
15
10
5
0
Estimation Error (units)
Line Chart
2-Band
1-Band
6
12
24
48
Chart Height (pixels)

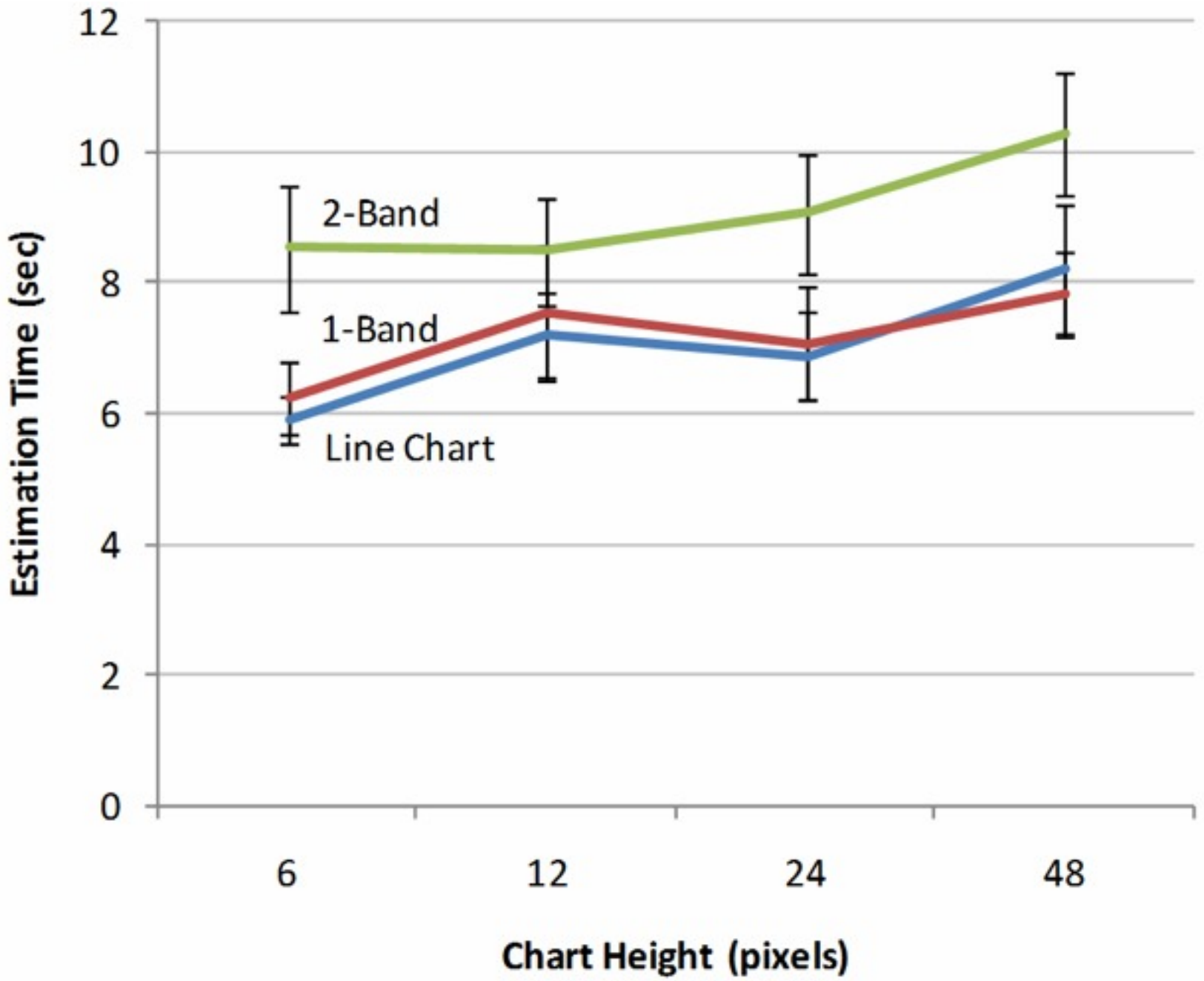
Virtual Resolution (*VR*)

The un-mirrored, un-layered height of a chart




25
20
15
10
5
0
Estimation Error (units)
Line
Chart
2-Band
1-Band
3
12
48
192
Virtual Resolution (pixels) - Log2 Scale


25
20
15
10
5
0
Estimation Error (units)
Line
Chart
2-Band
1-Band
(Follow Up)
1-Band
2-Band
(Follow Up)
3
12
48
192
Virtual Resolution (pixels) - Log2 Scale


12
10
8
6
4
2
0
Estimation Time (sec)
2-Band
1-Band
Line Chart
6
12
24
48
Chart Height (pixels)

Experiment 2 Results

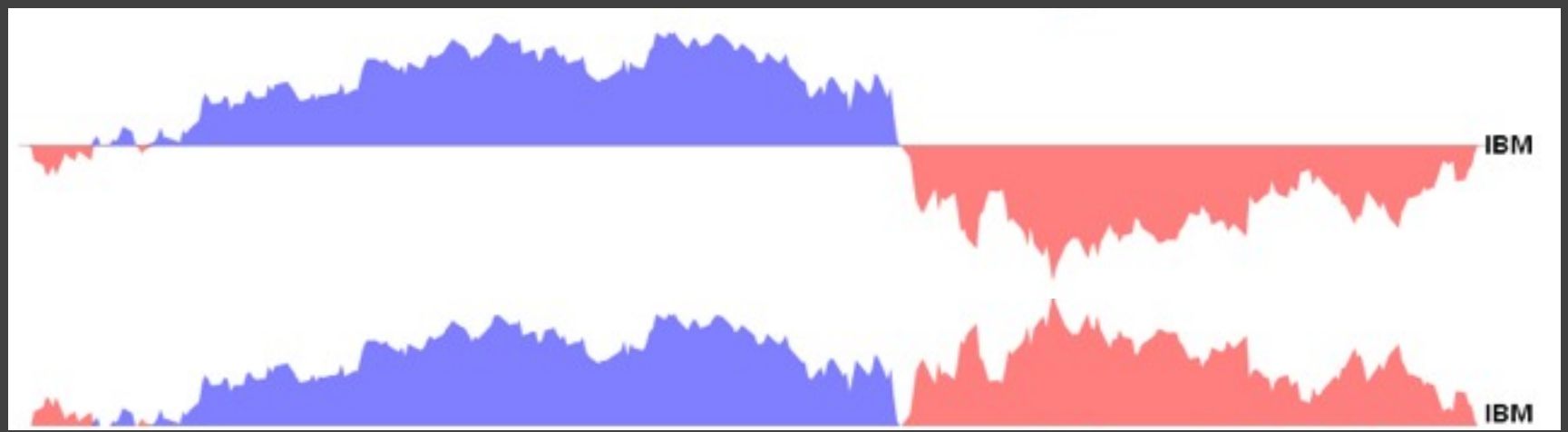
Q1: 2-band horizon graph (but not mirrored graph) had higher baseline estimation time and error.

Q2: Estimation error increased as the *virtual resolution* decreased.

Estimation time decreased as the *physical height* decreased.

Design Implications

Mirroring does not hamper perception

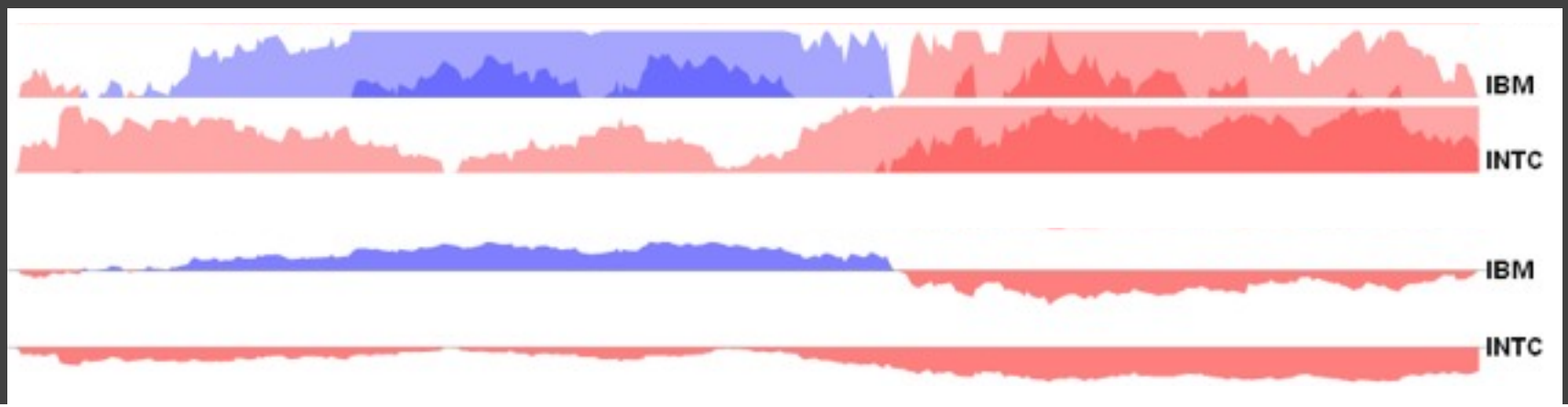


Design Implications

Mirroring does not hamper perception

Layered bands beneficial for smaller charts

- **2-band mirror** charts more accurate for heights under 6.8mm (24 pixels @ 1024x768)
- Predict benefits for 3 bands under 1.7mm (6 px)



Design Implications

Mirroring does not hamper perception

Layered bands beneficial for smaller charts

Optimal chart sizing

- **Sweet spots** in time/error curves
- 6.8mm (24 px) for line chart & mirrored chart
- 3.4mm (12 px) for 2-band horizon graph

Administrivia

Final Project

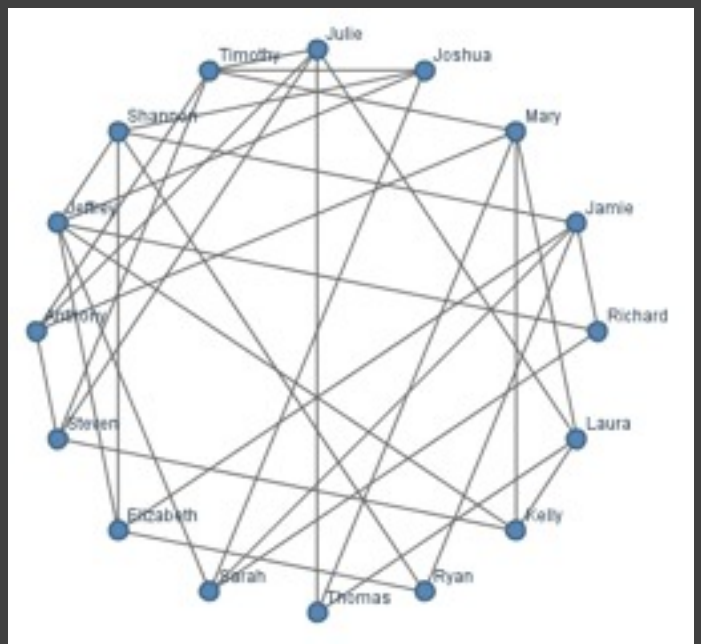
Poster Presentations
Session is **Thu Mar 13 5-8pm** in CSE Atrium
Bring **Poster** + **Laptop/Device** for demos
Arrive e*arly* to setup!

Post Webpage on GitHub Pages
List team members, title, abstract, link to paper
Include summary image for project!

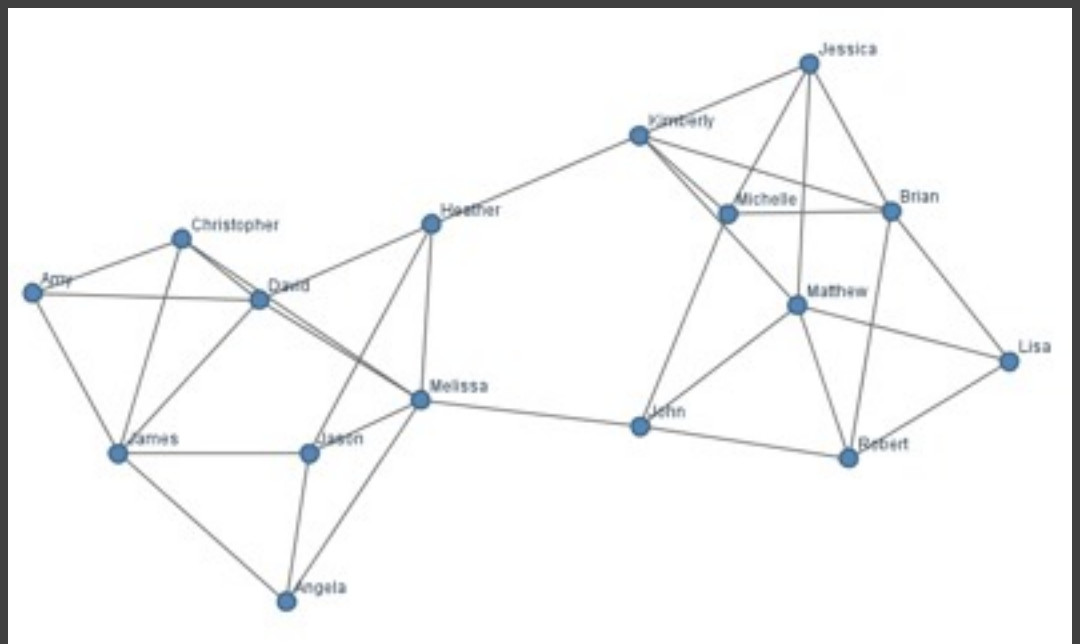
Final Project Reports
Due **Thu Mar 20**, by **7am**, posted to GitHub
4-6 pages in ACM or IEEE TVCG format

Perceptual Organization of Graphs

Perceptual organization of graphs



Circular



Force-Directed

Experiment Design

Factors

Circular or Force-Directed Seed Layout

# of Between-Cluster Edges (“masking”)

All graphs had two primary clusters

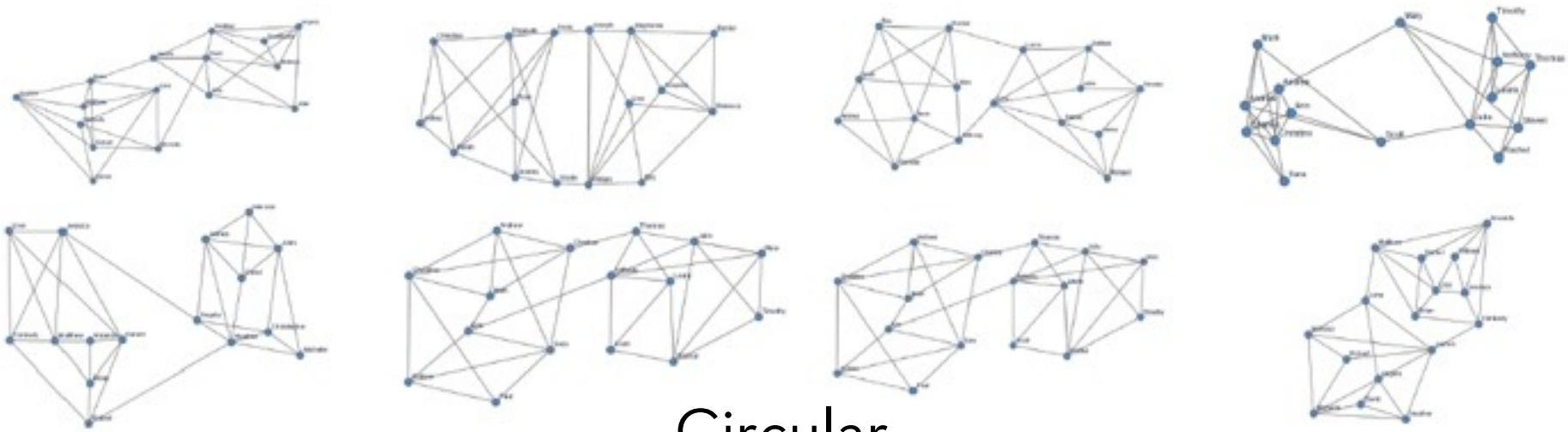
Measures

# of Edge Crossings

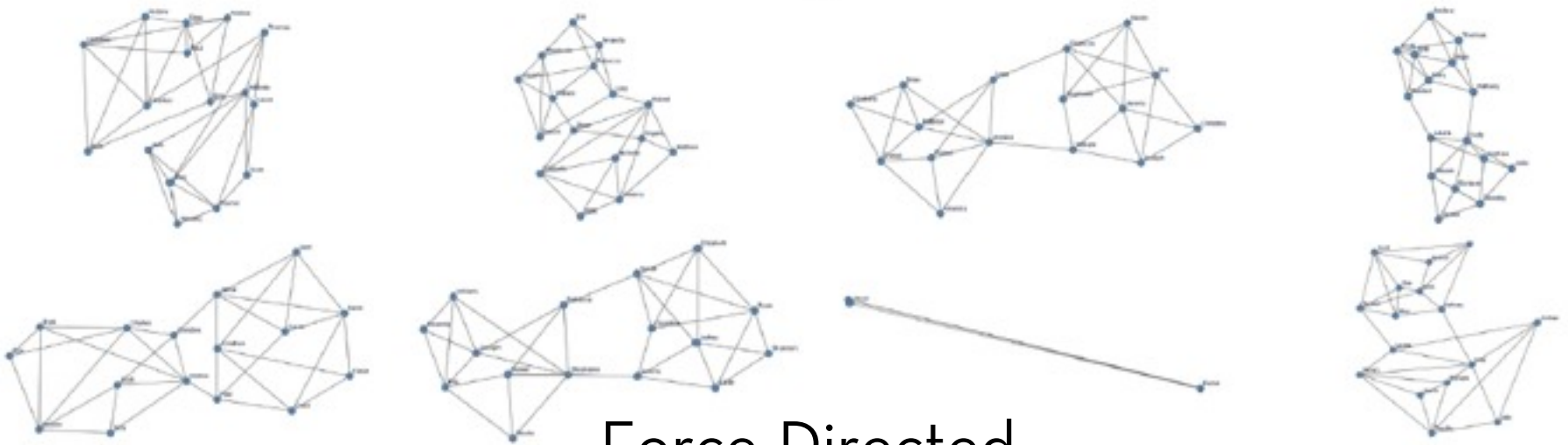
Average Edge Length

Average Node Distance

within or between clusters



Circular



Force-Directed

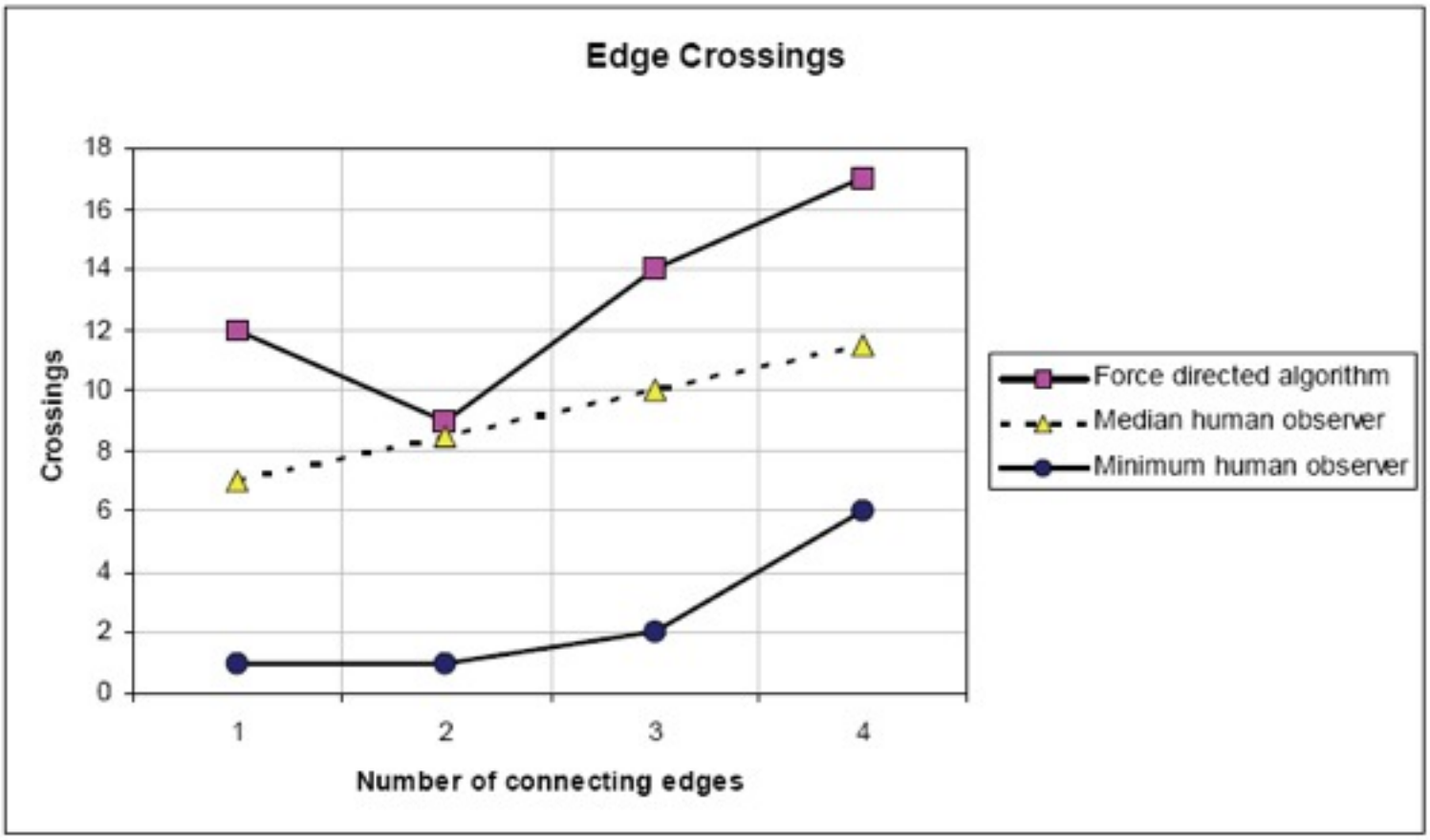


Figure 4. Edge Crossings. Human observers produced graph layouts with fewer edge crossings than the force-directed graph algorithm.

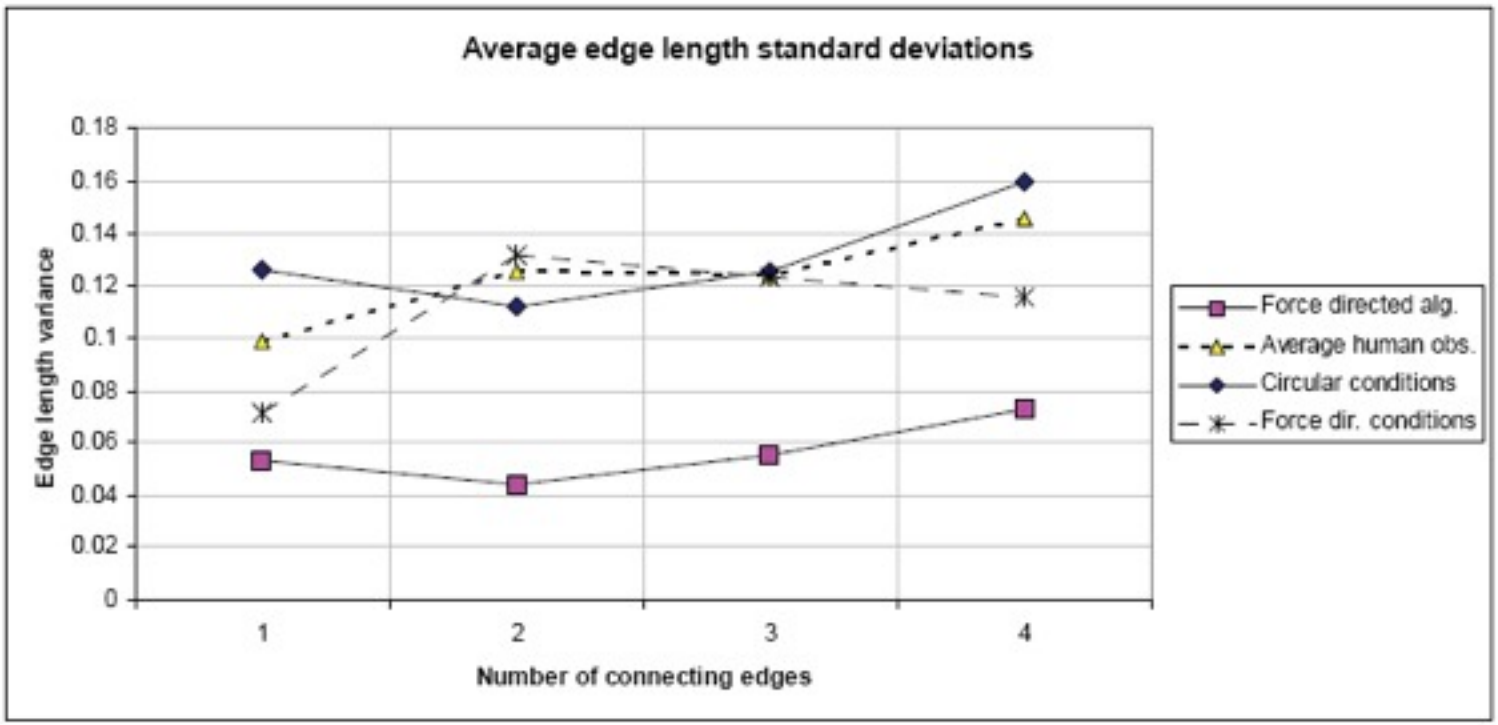


Figure 5. Edge Length Distribution. Human observers did not focus on maintaining equal edge length as much as the force directed algorithm.

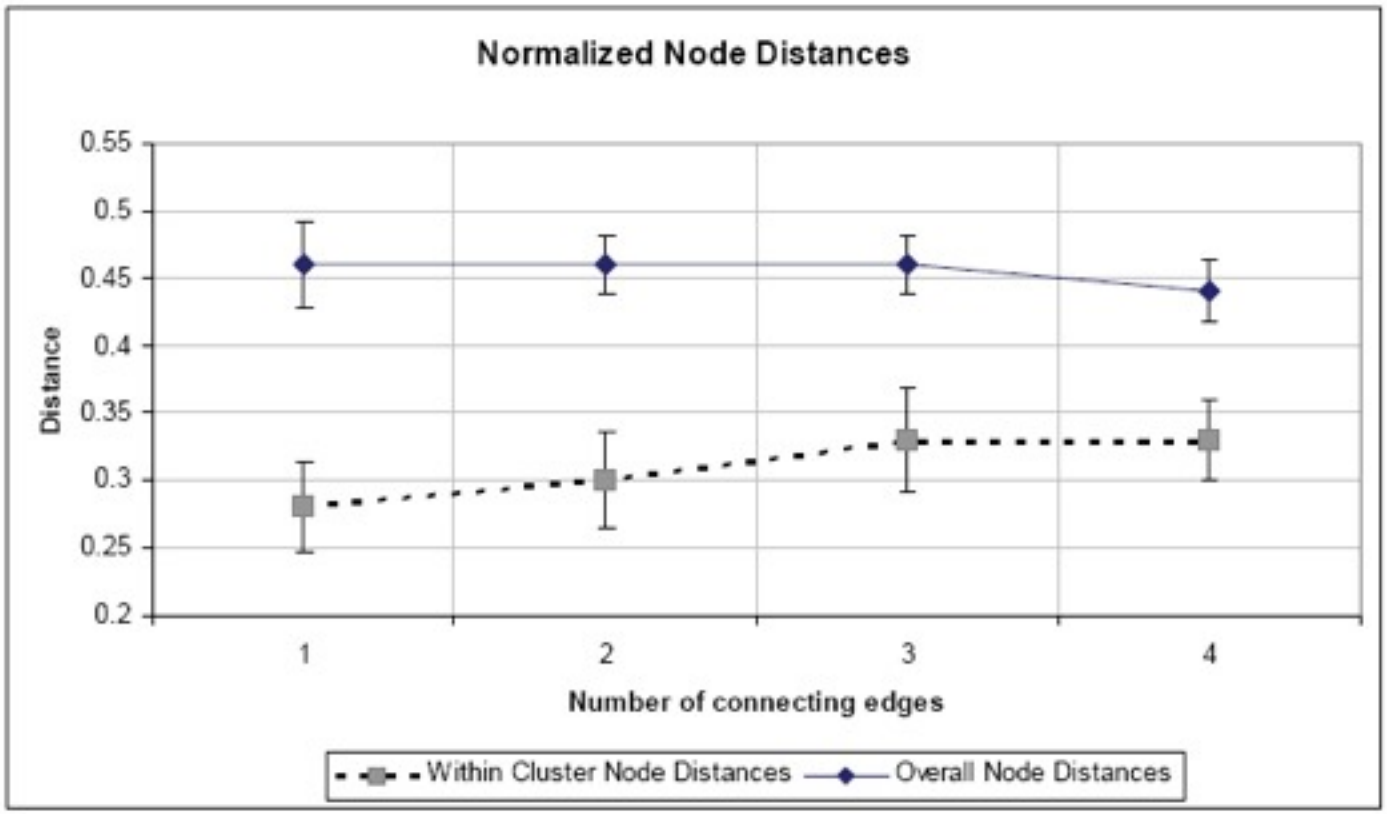
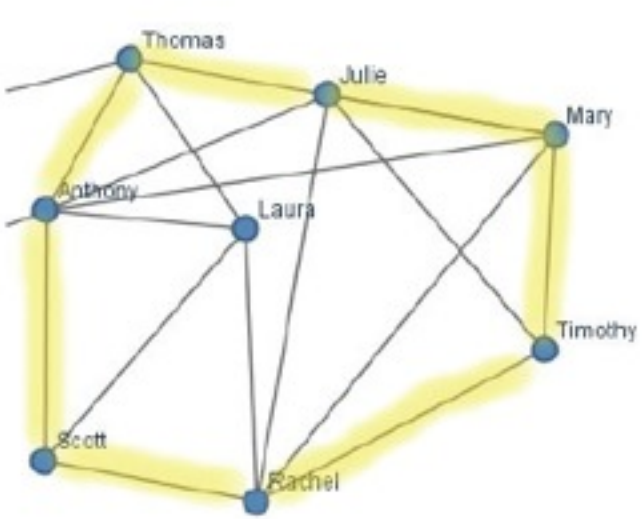


Figure 7. Cluster Extraction. For all levels of masking, the distance between nodes within a cluster is significantly smaller than the overall inter-node distance, demonstrating perceptual grouping. Error bars show 95% confidence intervals



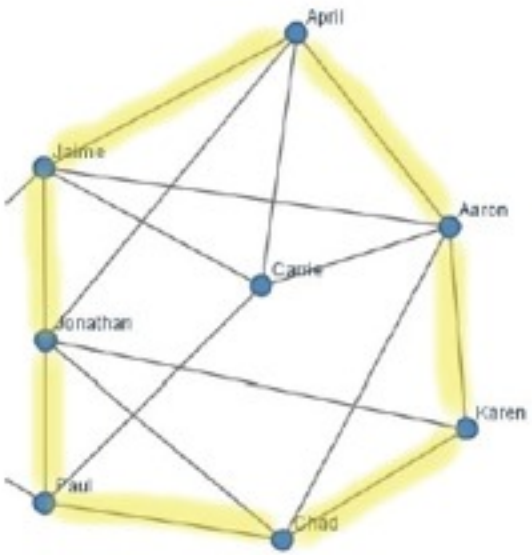
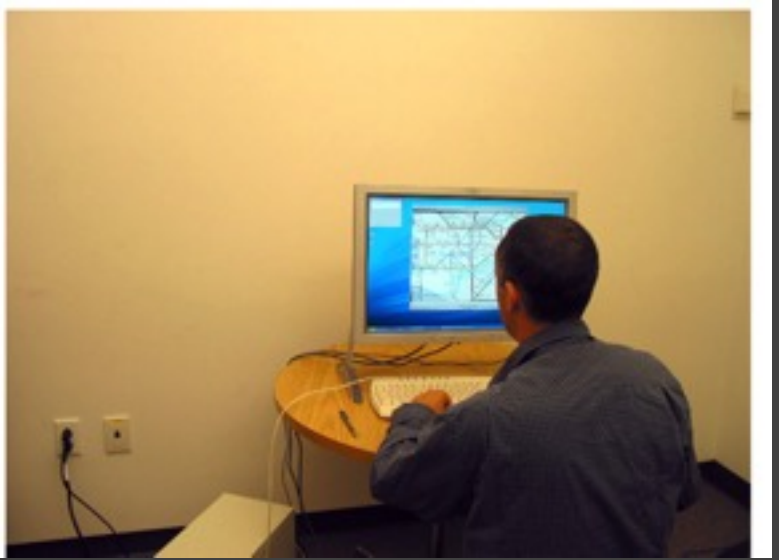


Figure 9. Cluster Hulls. Two examples of user-generated layouts where cluster edges formed a hull enclosing the cluster, organizing it into a single perceptual group.

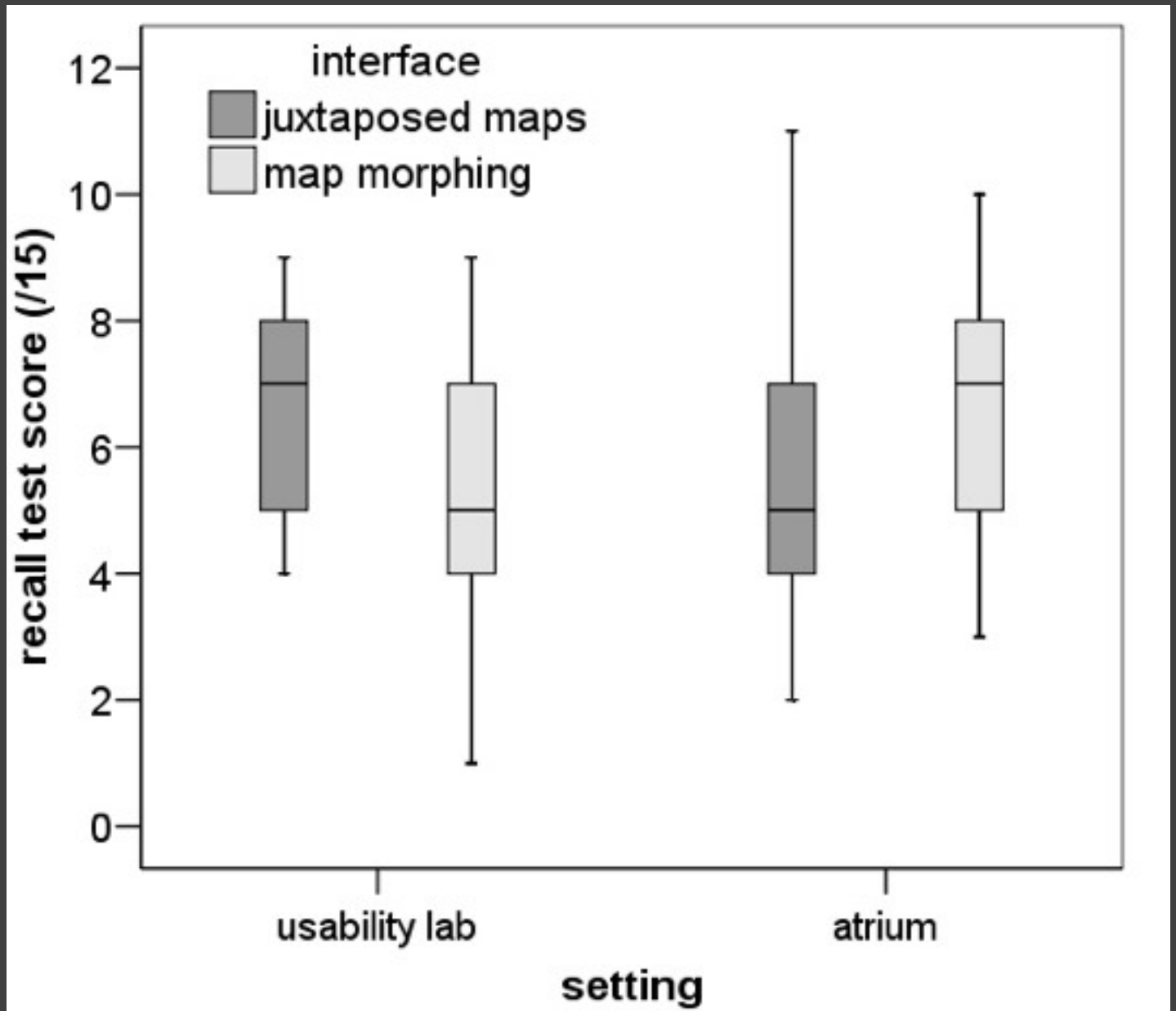
The role of environment [Reilly 07]



The slider was used to control the bidirectional morph. Shape blending (distortion) and alpha blending occurred simultaneously, in proportion to the distance of the slider from each endpoint.

The Tube map was at the left endpoint of the morph.

The right endpoint showed the tourist map.


interface
juxtaposed maps
map morphing
recall test score (/15)
12
10
8
6
4
2
0
usability lab
atrium
setting

Summary

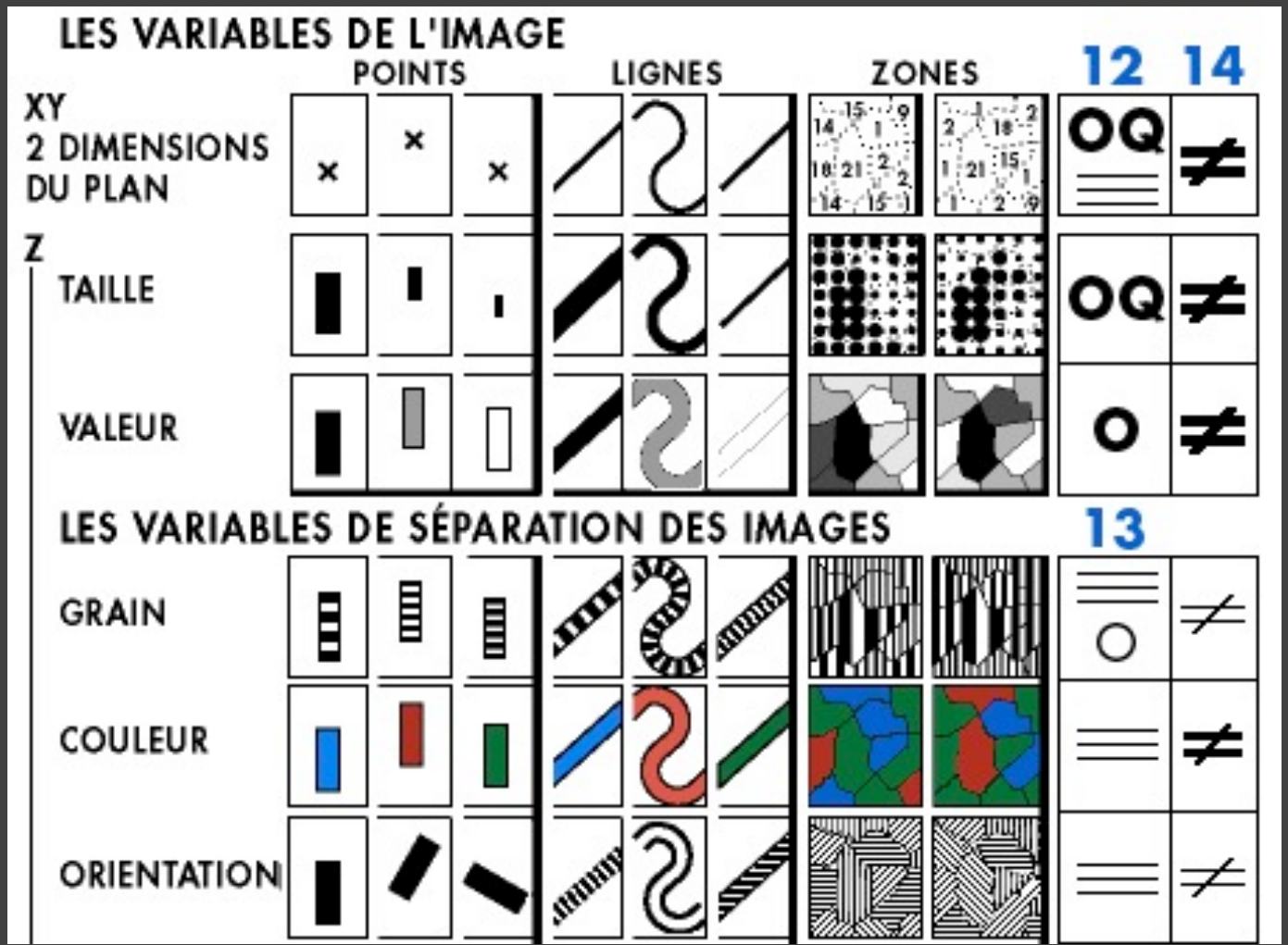
Design and analyze visualization techniques in context of real-world use

Time/error analyses can be insightful, but they don't provide a complete picture.

Performance measures may be more suited to serious analysis than casual use?

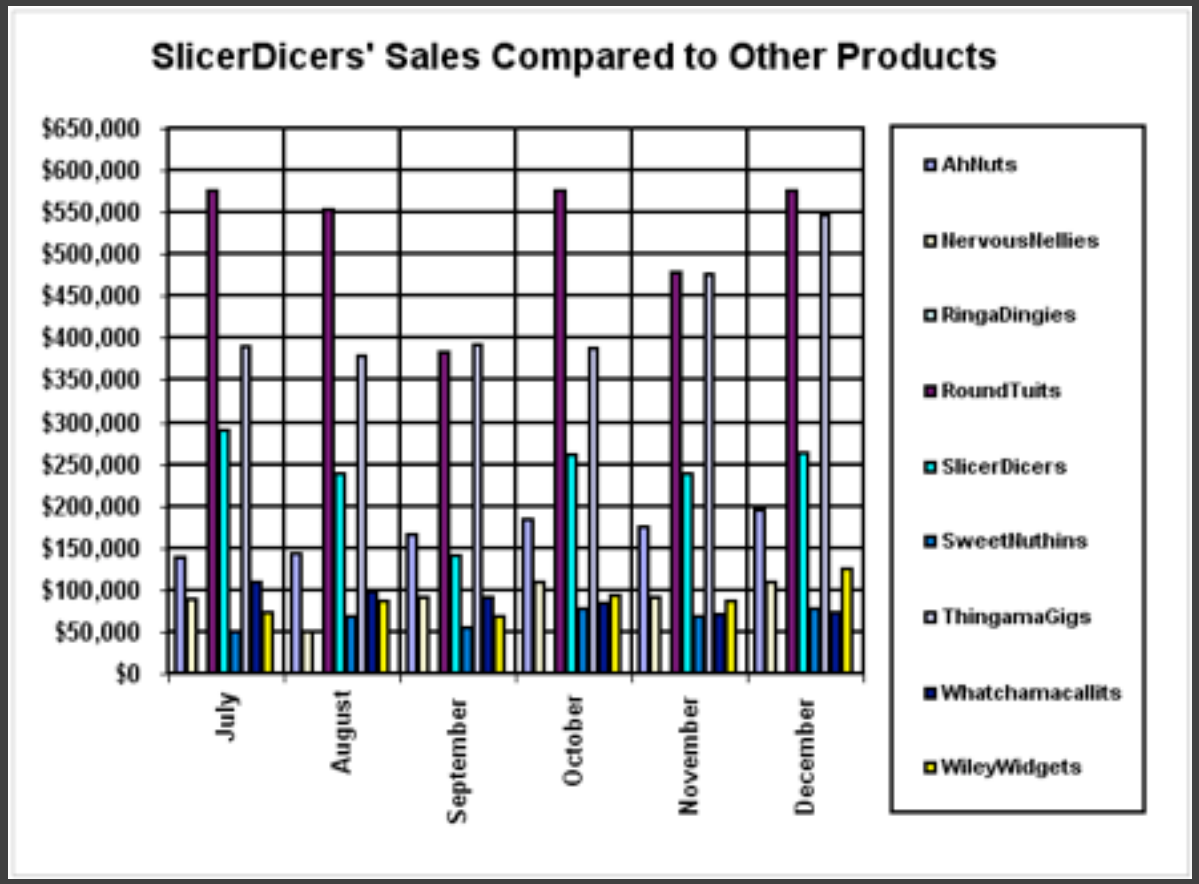
Course Summary

Data and Image Models



Sémiologie Graphique [Bertin 67]

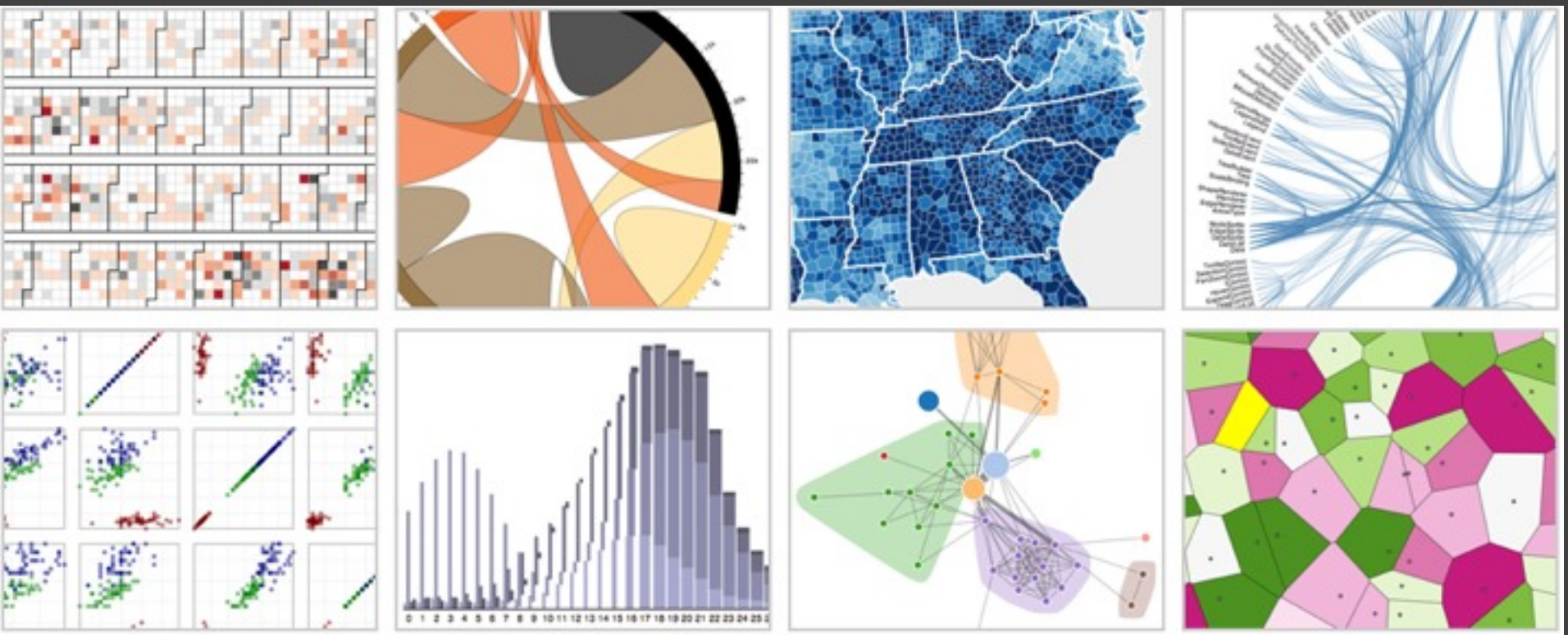
Visualization (Re-)Design



Problematic design

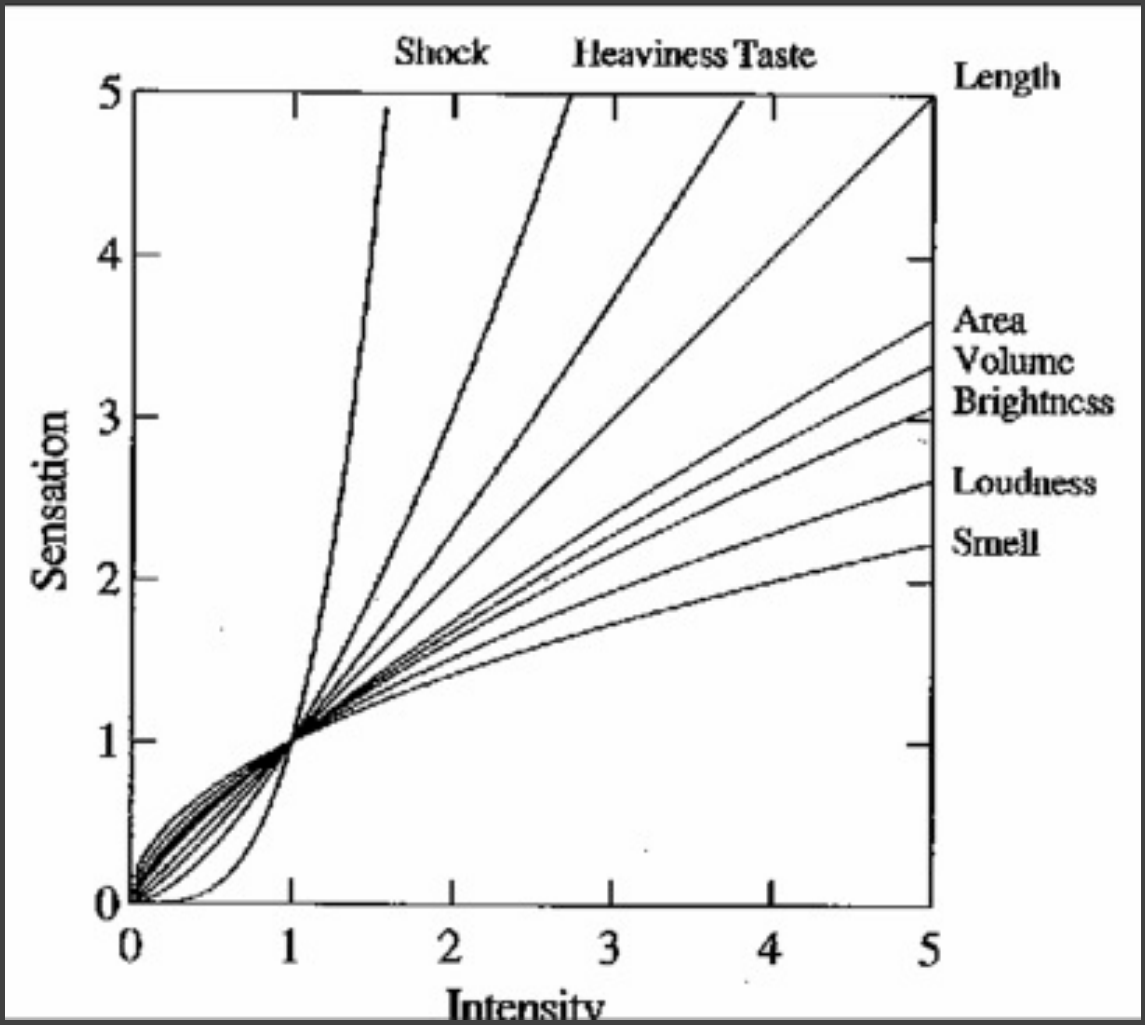
Redesign

Visualization Software



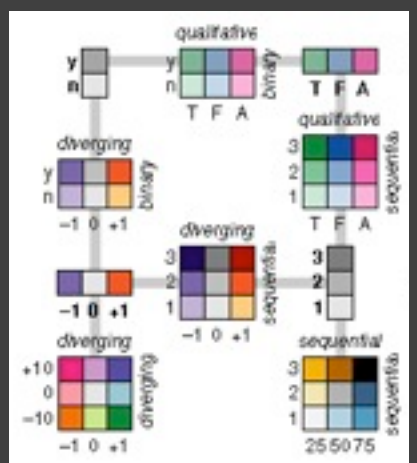
D3: Data-Driven Documents

Graphical Perception

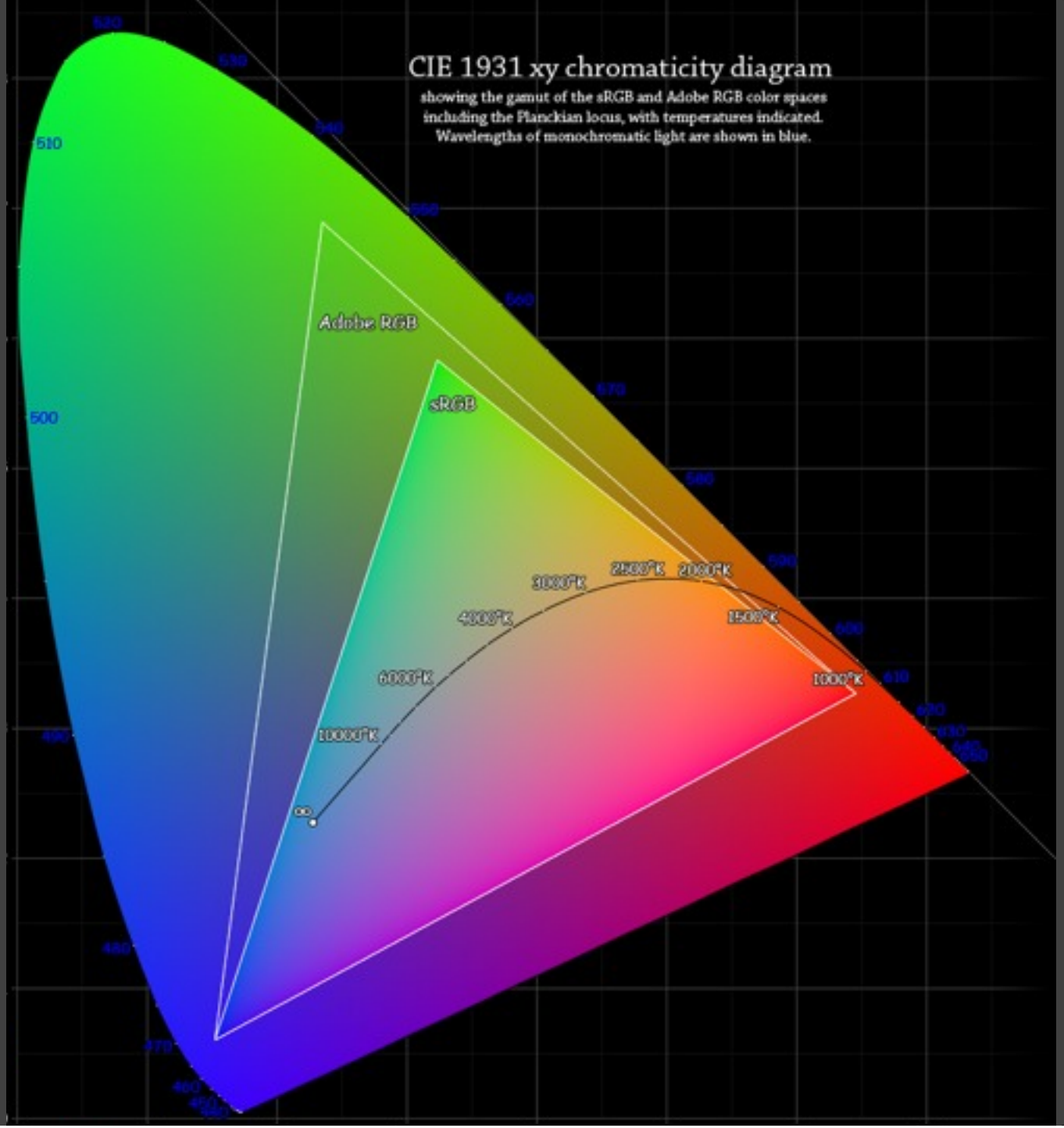


The psychophysics of sensory function [Stevens 61]

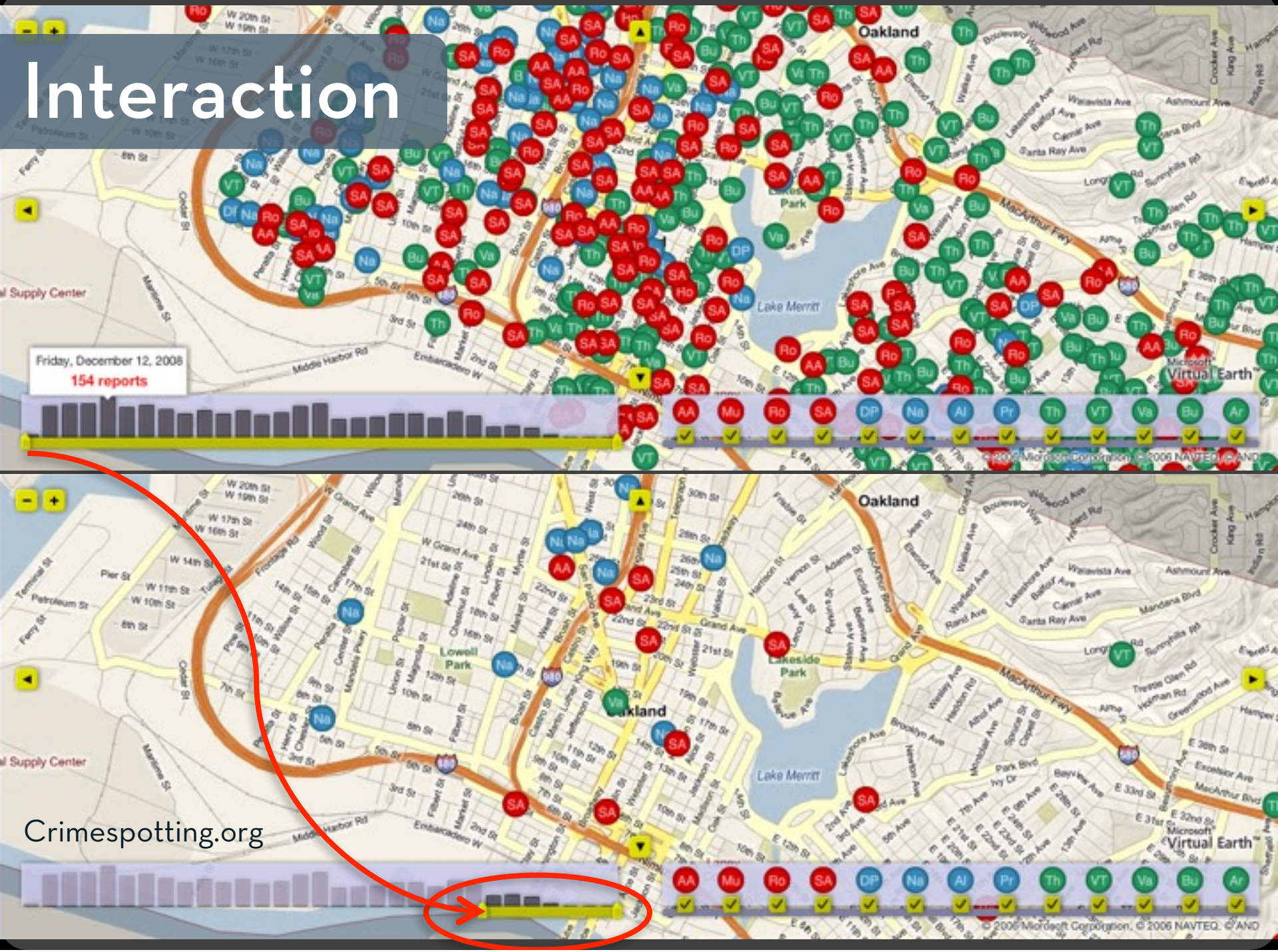
Color



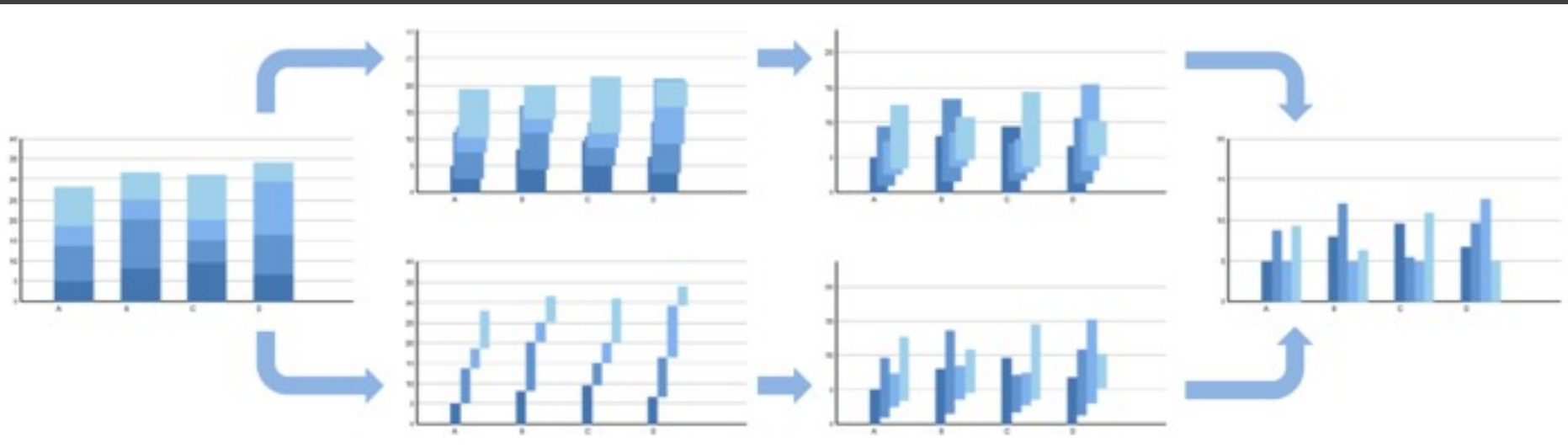
Color Brewer



Interaction

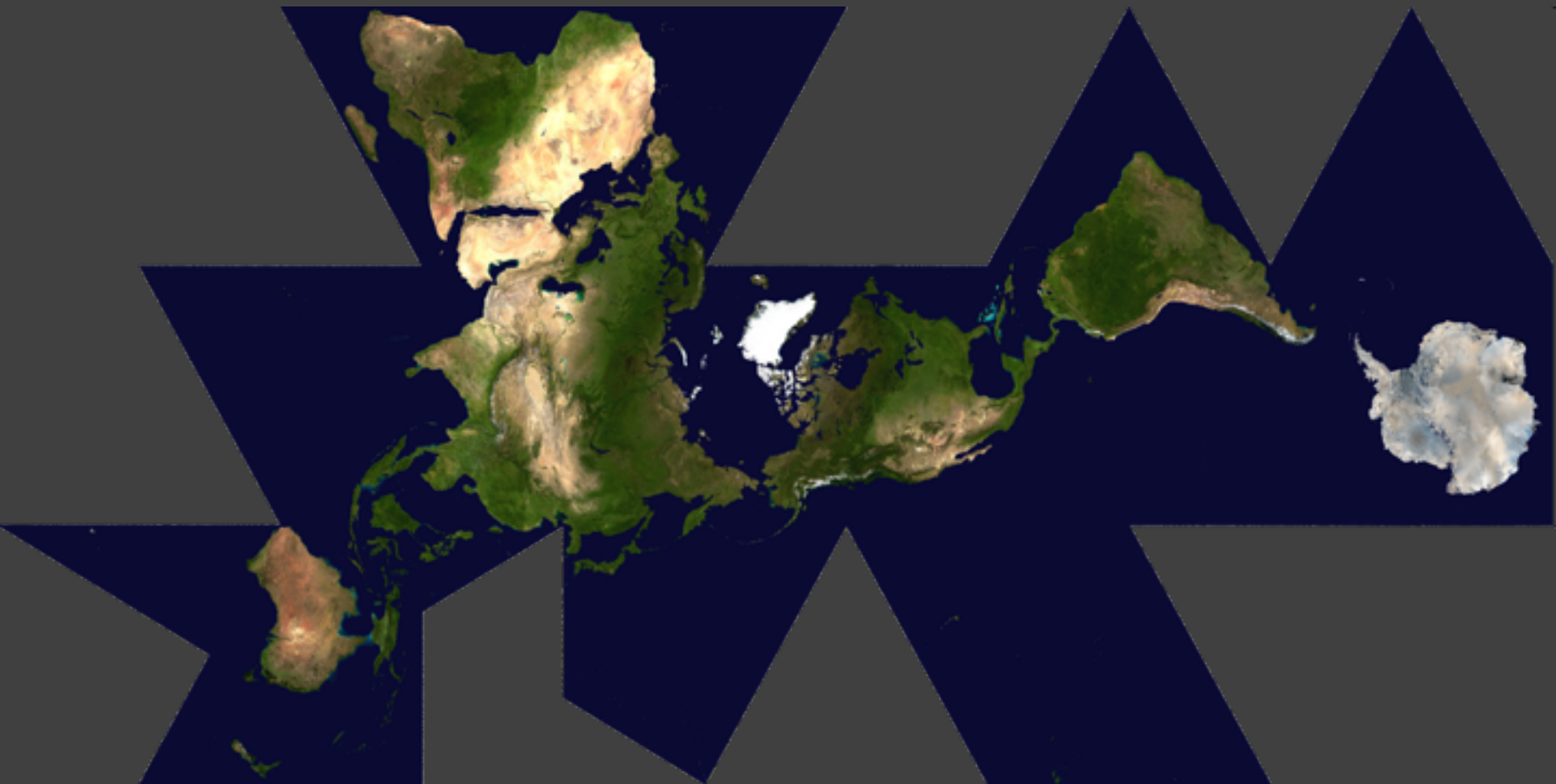


Animation



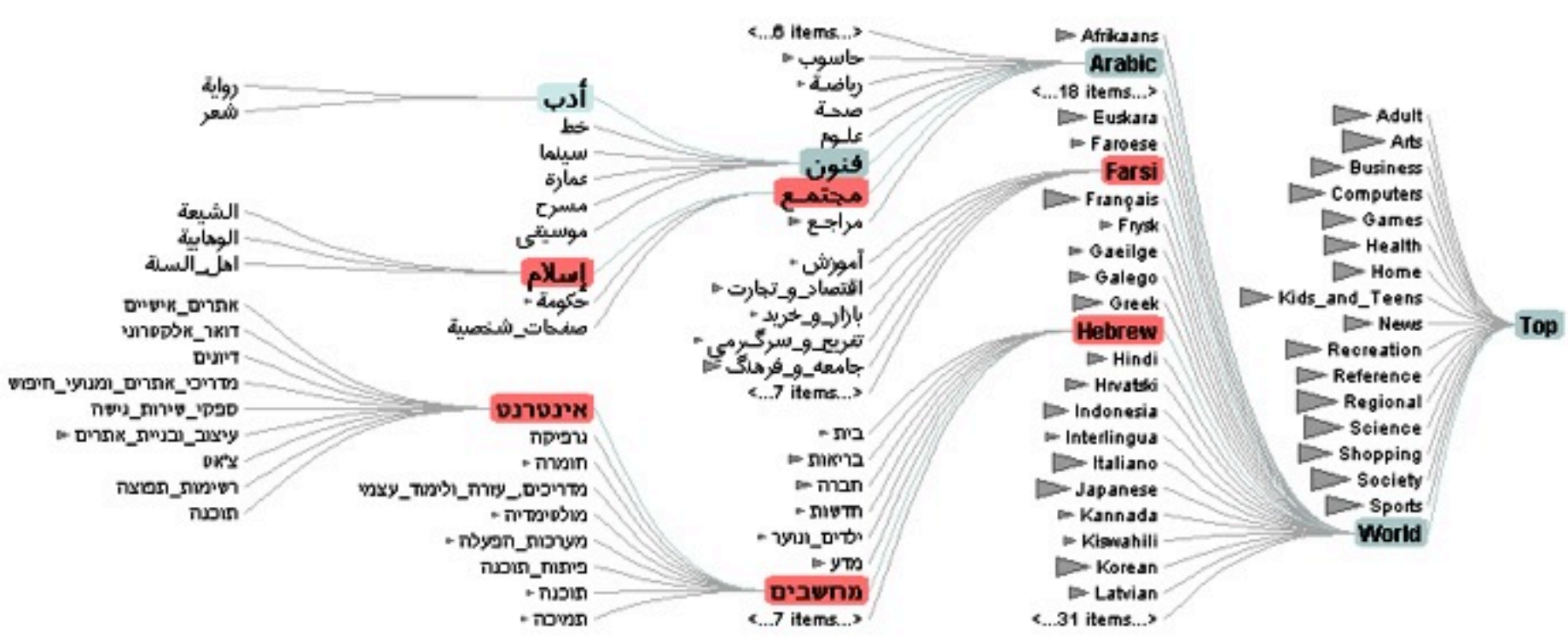
Animated transitions in statistical data graphics [Heer & Robertson 07]

Mapping / Cartography



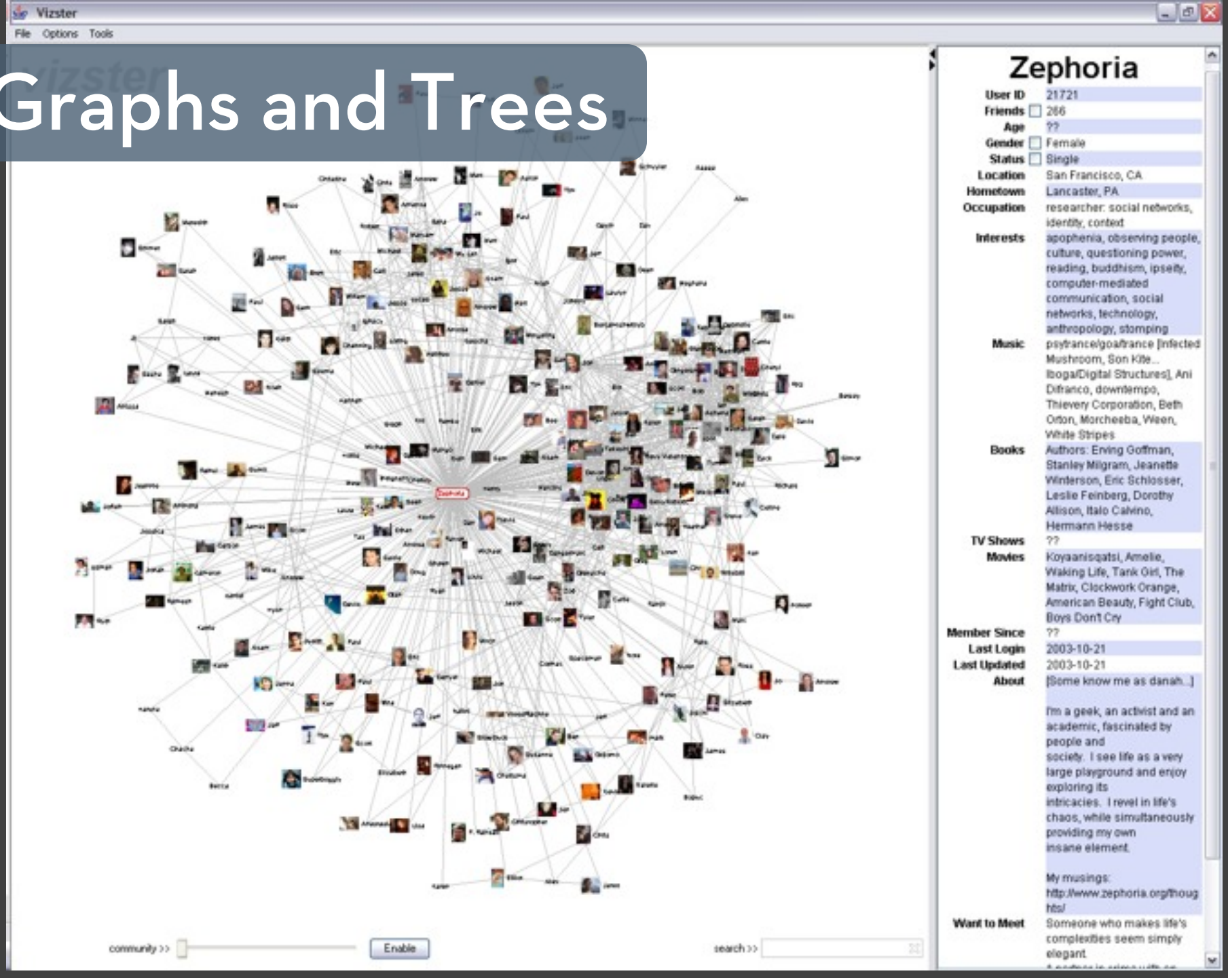
Dymaxion Maps [Fuller 46]

Graphs and Trees

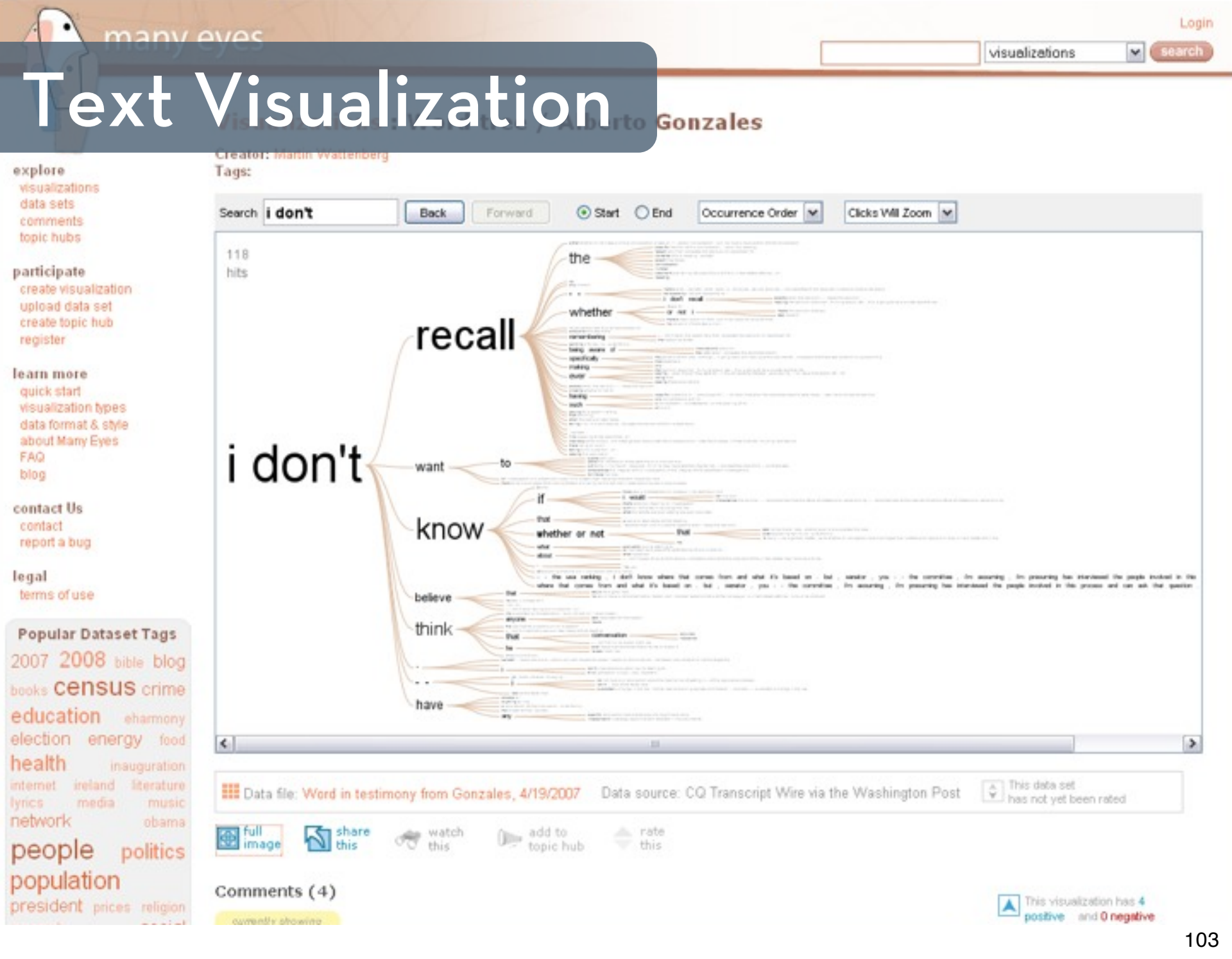


Degree-Of-Interest Trees [Heer & Card 04]

Graphs and Trees

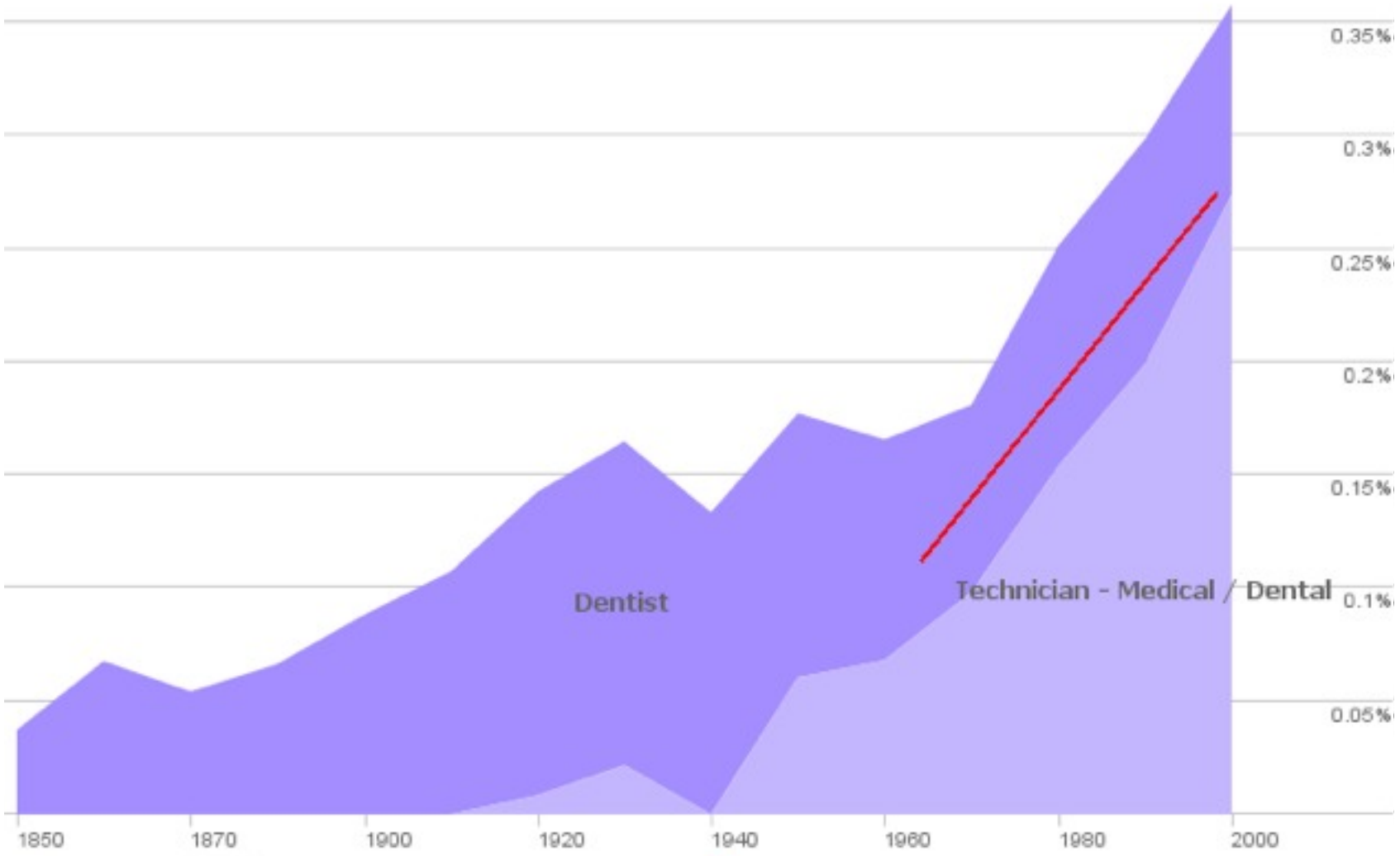


Text Visualization



Collaboration and History

Where have all the dentists gone?



The Future of Visualization

Where is more work required?

What emerging technologies and societal trends will impact visualization design?

What did you find most difficult in creating visualizations and designing techniques?

Thank You!


I DIDN'T HAVE ANYTHING USEFUL TO SAY SO I MADE THIS PIE CHART.
www.dilbert.com scottadams@aol.com
OOOH!
OOOH!
IT MUST BE TRUE BECAUSE IT'S PIE.
3-7-09 ©2009 Scott Adams, Inc./Dist. by UFS, Inc.
THAT WORKED TOO WELL.
I PLEDGE MY LIFE AND MY FORTUNE TO THE PIE!

Course Evaluation

Course Evaluation

Official campus course evaluation
Complete in class, then give to Ham.
Your opinion is valued!