5.2 – Information Visualization

In class presentation

Psych 549: Perception
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Presentation Outline

1. Why do we visualize data?
   - External cognition
   - Knowledge crystallization
   - Discovery

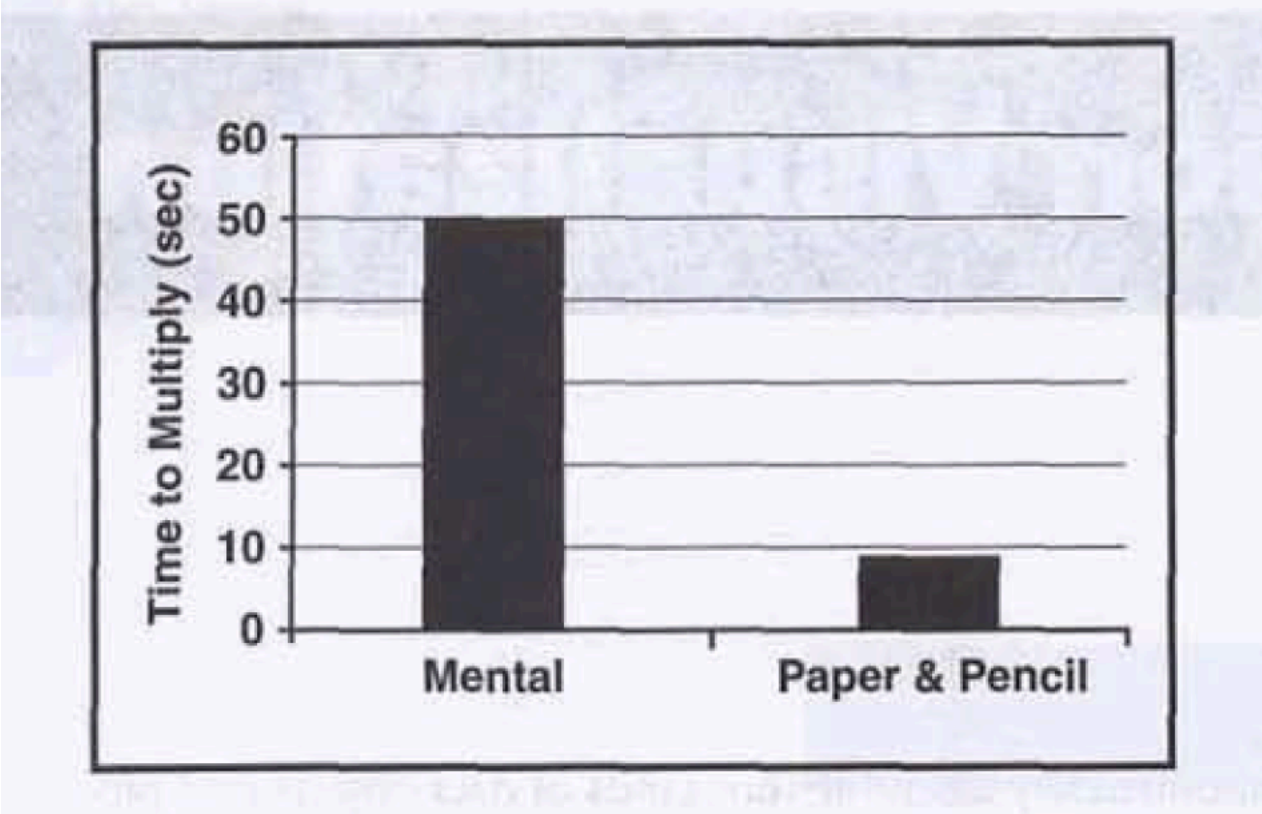
2. How do we visualize data?
   - Limitations
   - Human centered design
   - Basic visual encoding principles and approaches

1 - Why do we visualize data?

- External cognition (Scaife & Rogers, 1996)
  - Use cognitive artifacts and the external world to increase our internal cognitive abilities

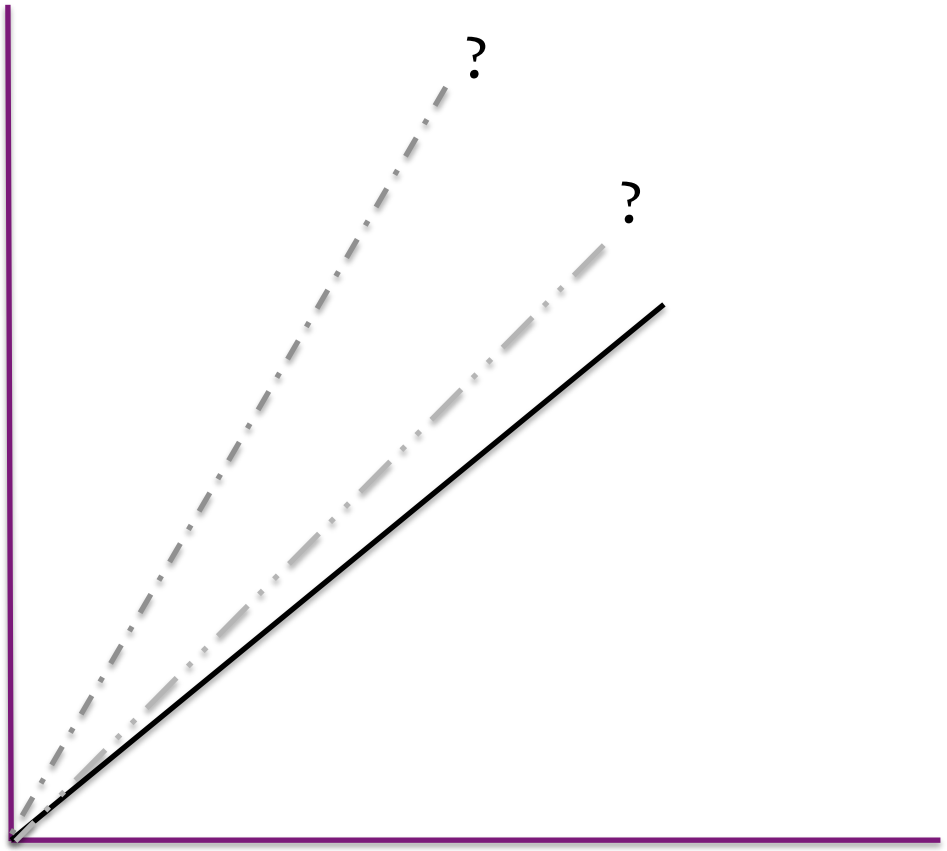
$$\begin{array}{r} 34 \\ \times\, 72 \\ \hline 68 \\ \\ 23^{2}80 \\ \hline 24^{1}48 \end{array}$$

Why do we visualize data?



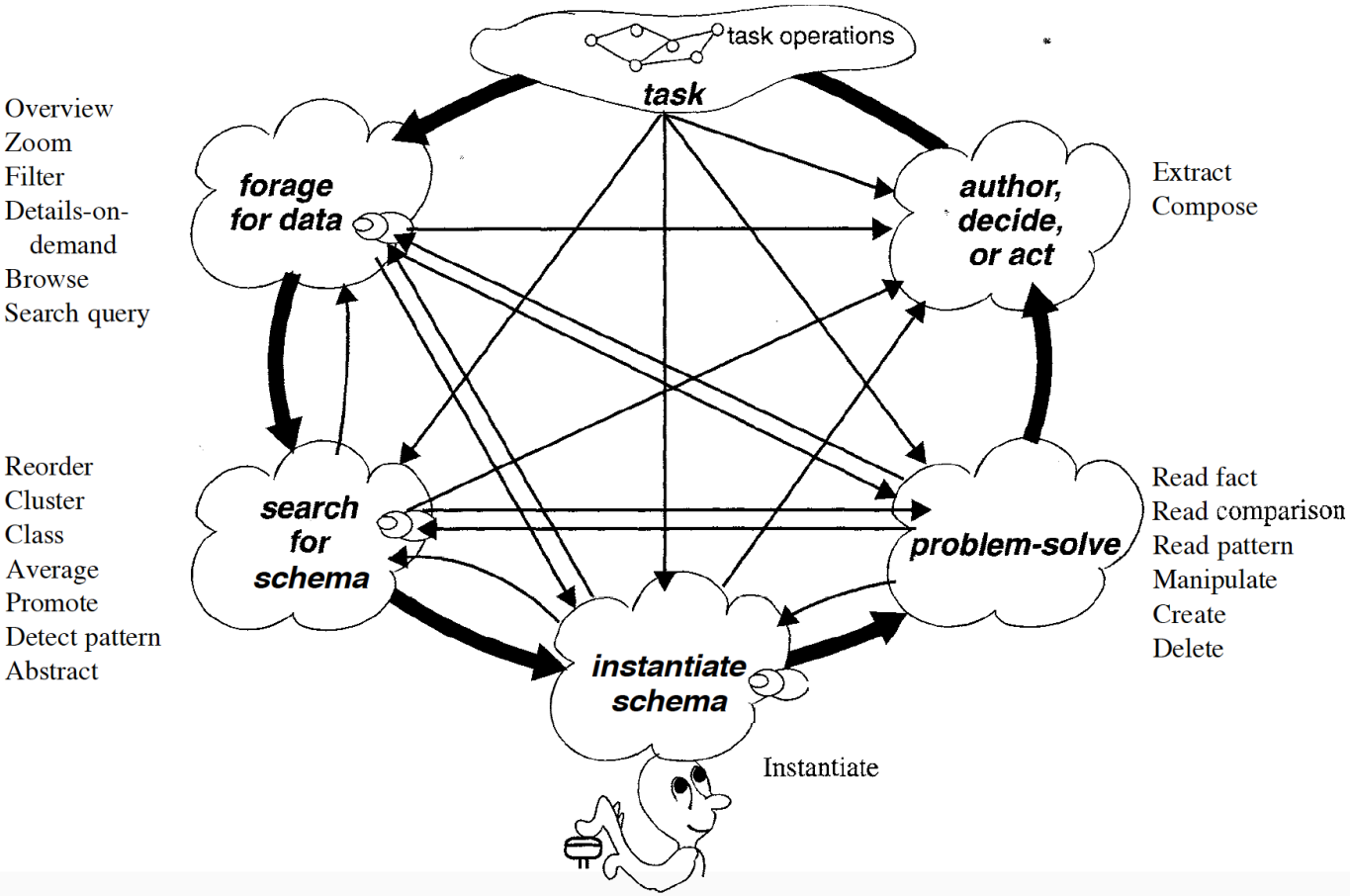
6 Ways that Visualizations Amplify Cognition

1. Increasing the memory and processing resources available to the users
2. Reducing the search for information
3. Using visual representations to enhance the detection of patterns
4. Enabling perceptual inference operations
5. Using perceptual attention mechanisms for monitoring
6. Encoding information in a manipulable medium



Why do we visualize data?

- Knowledge crystallization (Card, et al.)
  - Gather information
  - Make sense of it with representational framework
  - Package results for communication or action


task operations
task
forage for data
author, decide, or act
search for schema
problem-solve
instantiate schema
Overview
Zoom
Filter
Details-on-demand
Browse
Search query
Extract
Compose
Reorder
Cluster
Class
Average
Promote
Detect pattern
Abstract
Read fact
Read comparison
Read pattern
Manipulate
Create
Delete
Instantiate

Levels at which visualization can be used…

- Infosphere
- Information Workspace
- Visual Knowledge Tools
- Visual Objects

Discovery/Visual Sense Making

- Complex loops of interactions between data, visualization, and cognition
- Can use imagination and exploration to leverage visualization and discover new ideas
  - use external world to increase our ability to think
- Use visualization as *external memory*

2 - How do we visualize data?

- Quick history…
  - Originated largely in computer graphics/ statistical graphics
  - Developed for situations where a problem is not well-defined enough for a computer to handle in absolute terms, or algorithmically
  - Early recognition that we need to take human perceptual system into account when designing visualizations

How do we visualize data?

- Capacity Limitations:
  1. Computational
  2. Perceptual/Cognitive
  3. Display

Types of Data

- Consider a table…
  - Rows = Items
  - Columns = Dimensions

Types of Data

- Three dimensions:
  1. Quantitative
  2. Ordered
  3. Categorical

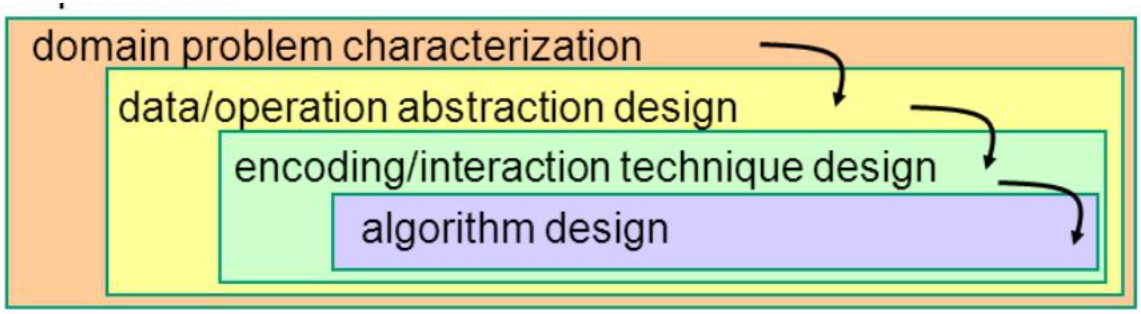
Types of Data

- Relational data…
  - Graphs
    - Networks (node-link diagrams)
    - Trees

Human Centered Design

- Task characterization
  - Task abstraction
    - Technique and algorithm design
      - Validation

Human Centered Design



- Actually three individual design problems
- Each level contains pitfalls & threats to validity
- Each level is dependent on the other
  - Outputs from upstream levels become inputs for downstream levels

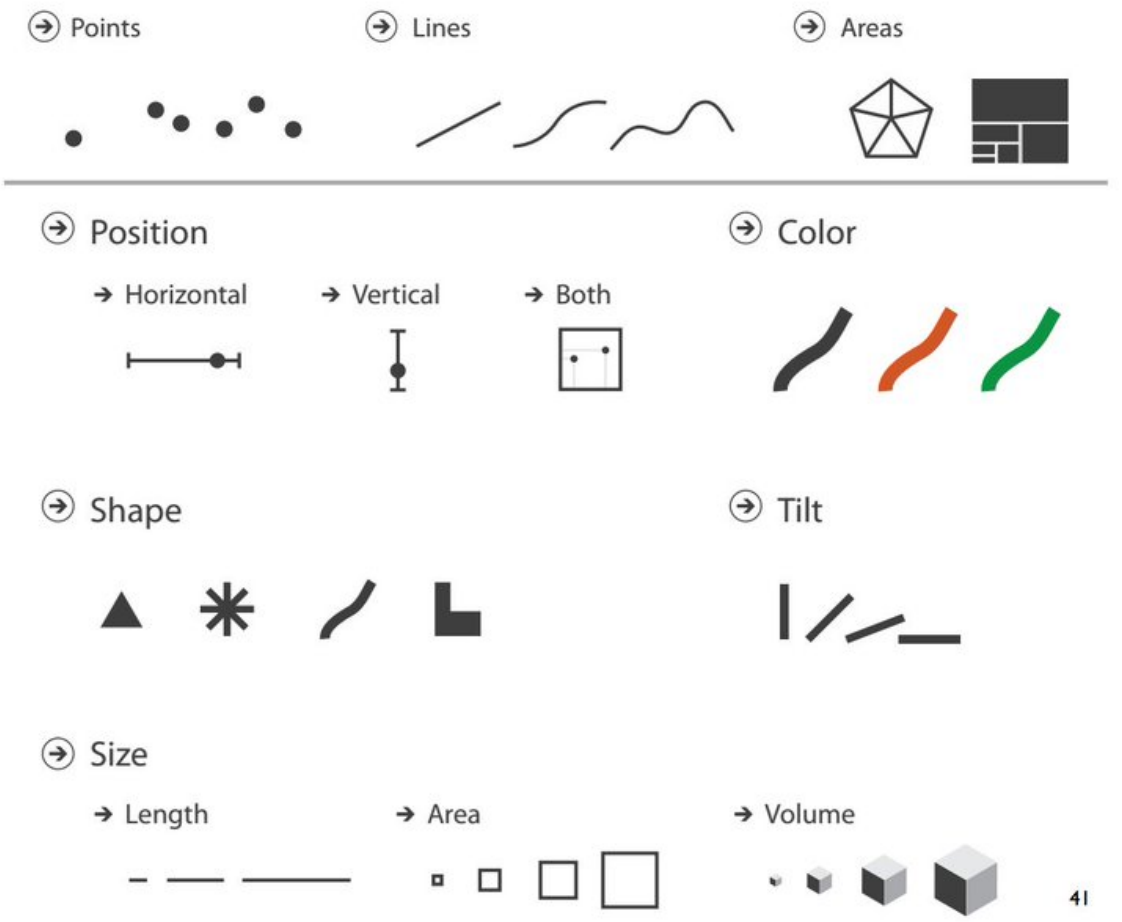
Visual Encoding Principles

- Marks
  - Dot = 0D
  - Line = 1D
  - Area = 2D
  - Volume = 3D
- Channels
  - Position
  - Size
  - Color
  - Shape
  - Orientation
  - Motion
  - Etc…

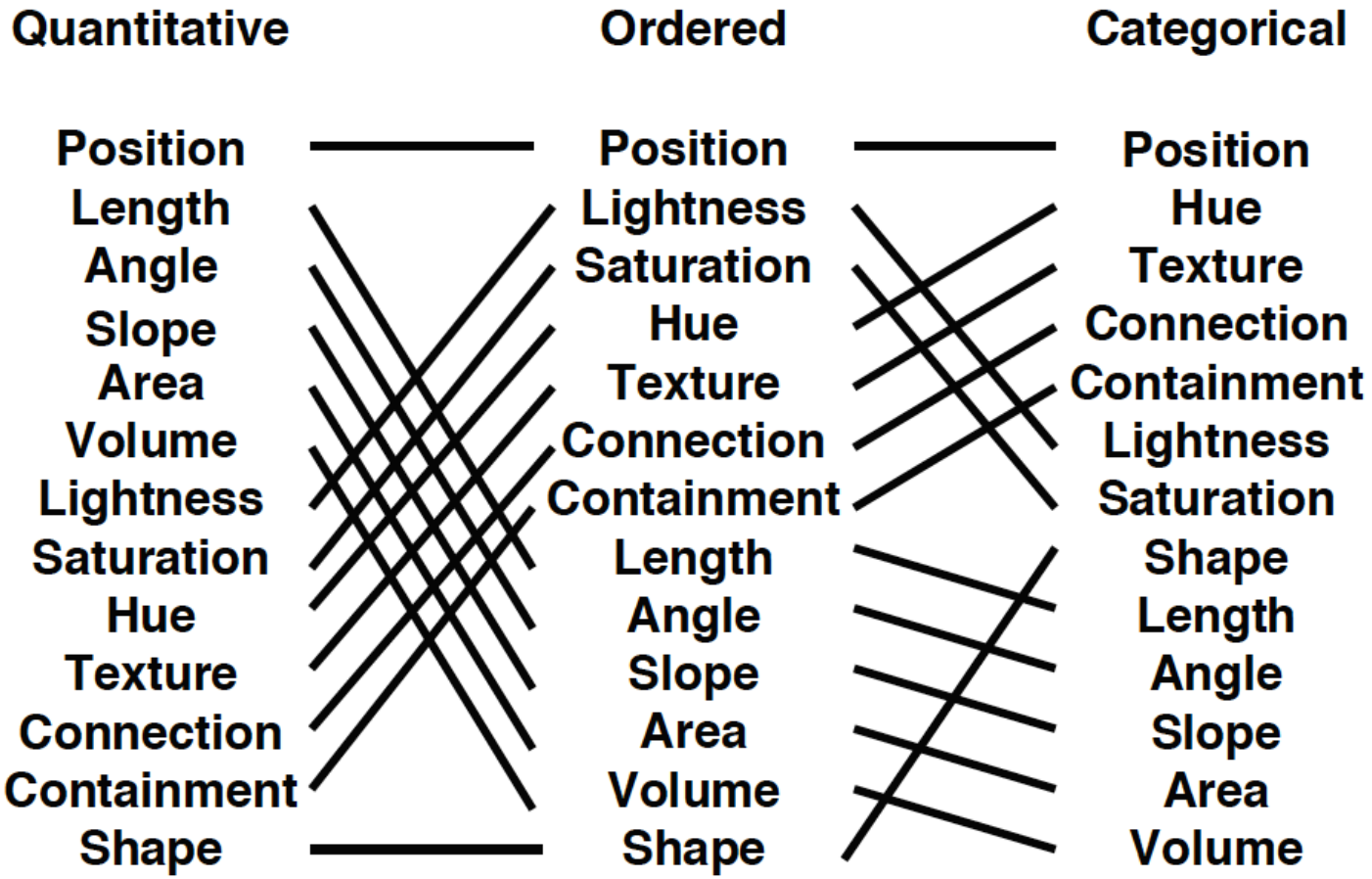
From *Visual Analysis & Design* (Munzner, 2014)

Analyzing visual encoding via marks and channels

- marks
  - geometric primitives
- channels
  - control appearance of marks
  - channel properties differ
    - type & amount of information that can be conveyed to human perceptual system
      - number of discriminable bins
      - show magnitude vs. identity
      - accuracy of perception



From Mackinlay (1986)



From *Visual Analysis & Design* (Munzner, 2014)

Channels: Matching expressiveness

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

Same

Same

Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

- **expressiveness principle**
  - **match channel and data characteristics**

Attribute Types

→ Categorical

→ Ordered

→ *Ordinal*

→ *Quantitative*

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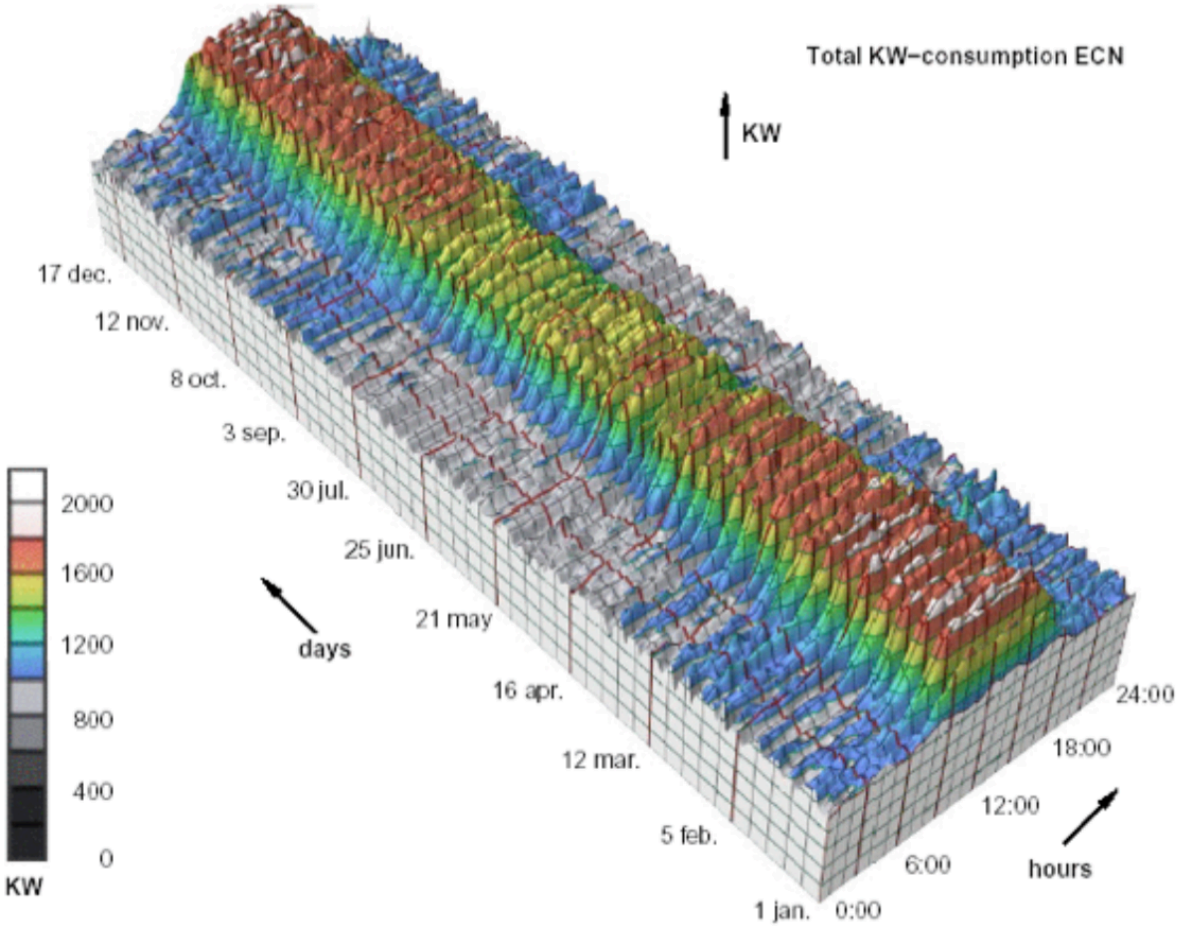
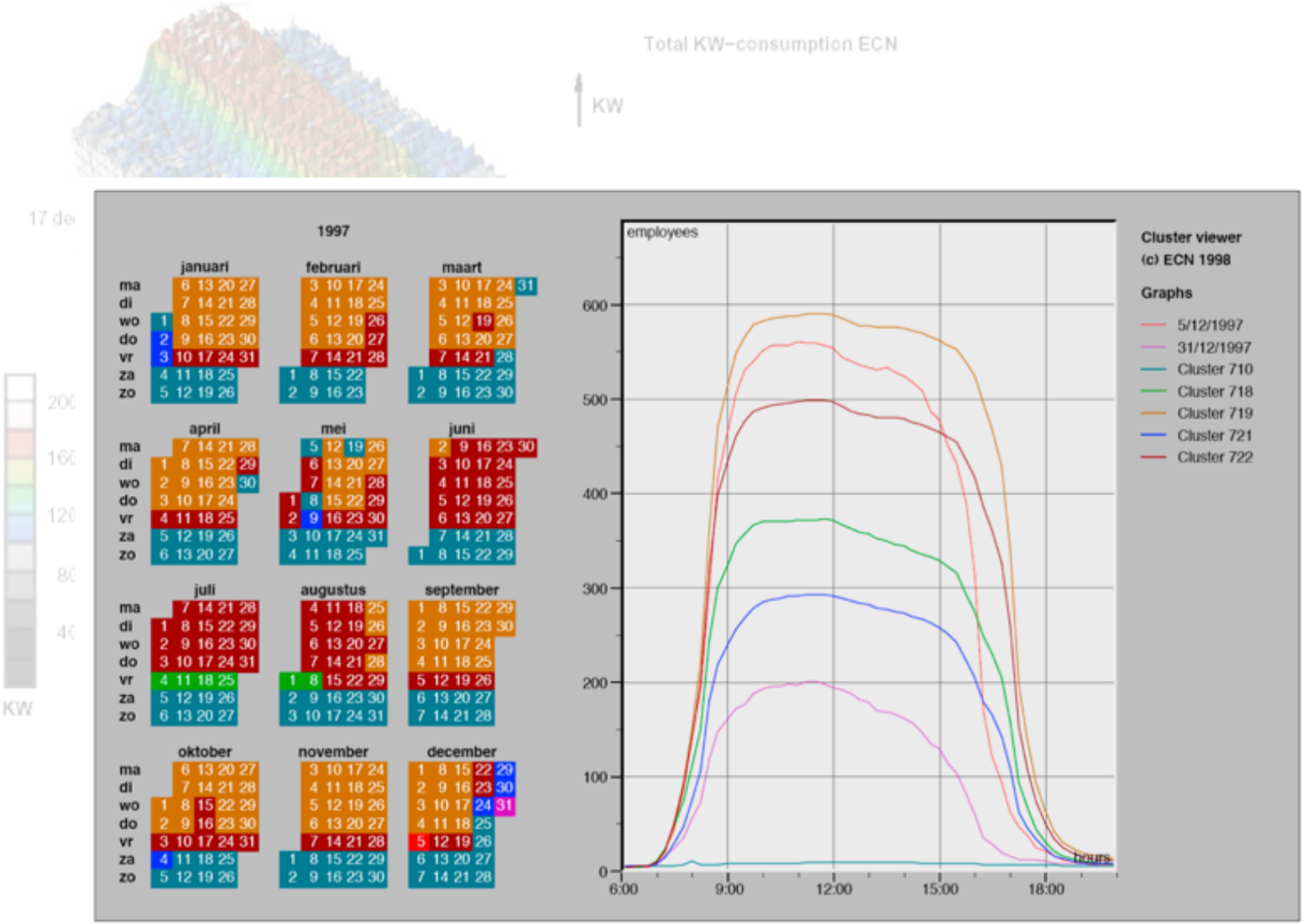
Tools for Color Mapping

- ColorBrewer – colorbrewer.org
- "Which Blair" Project – Rogowitz & Kalvin (2001)
- Vischeck – vischeck.com

High-level advice

- Avoid 3D, if 2D solution exists
- Text labels should be useful (can be crucial)
- MASSIVE space of design possibilities/ alternatives
  - Be aware of tradeoffs (they are abundant)
  - Lots of research and mistakes to learn from (i.e., avoid random walk through parameter space)
  - Iterate and refine


Total KW–consumption ECN
KW
17 dec.
12 nov.
8 oct.
3 sep.
30 jul.
25 jun.
21 may
16 apr.
12 mar.
5 feb.
1 jan.
days
2000
1600
1200
800
400
0
KW
0:00
6:00
12:00
18:00
24:00
hours



van Wijk & van Selow (1999)

Design Mantra for Interactivity

"Overview first, zoom and filter, then details on demand"

– Shneiderman (1996)

Data Reduction

- Overviews + aggregation (drill down)
- Filtering + navigation (zooming)
- Focus + context (fish eye lens)
- Dimensionality reduction (MDS; tSNE)

Endless design possibilities

- Best starting place is checking out what others have already done/how they have handled a given problem

- Additional references…
  - Design Studies (developed by T Munzner)
  - IEEE Visualization conference
  - PerceptualEdge.com
  - Eagereyes.org

Questions?

Thanks for listening !