Perception
Lecture 6 CPSC 533C, Fall 2004
29 Sep 2004
Tamara Munzner

Readings
Ware, Chapter 5: Visual Attention and Information That Pops Out
Ware, Chapter 6: Static and Moving Patterns
Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models

External Representation
reduces load on working memory
• offload cognition
familiar example: multiplication/division

External Representation: multiplication
paper       mental buffer
57           48
×             
57           48
[ 7*8=56 ]
External Representation: multiplication

<table>
<thead>
<tr>
<th>Paper</th>
<th>Mental Buffer</th>
</tr>
</thead>
</table>

\[
\begin{align*}
57 & \times 48 & \frac{5 \times 8 = 40}{\text{[5*8=40 + 5 = 45]}} & \text{[5*8=40 + 5 = 45]} \\
6 & & 456 & 456
\end{align*}
\]
External Representation: multiplication

<table>
<thead>
<tr>
<th>paper</th>
<th>mental buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td></td>
</tr>
<tr>
<td>x 48</td>
<td></td>
</tr>
<tr>
<td>456</td>
<td></td>
</tr>
<tr>
<td>228</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8 + 5 = 13</td>
<td></td>
</tr>
</tbody>
</table>

External Representation: multiplication

<table>
<thead>
<tr>
<th>paper</th>
<th>mental buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td></td>
</tr>
<tr>
<td>x 48</td>
<td></td>
</tr>
<tr>
<td>1456</td>
<td></td>
</tr>
<tr>
<td>228</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
</tr>
<tr>
<td>4 + 2 + 1 = 7</td>
<td></td>
</tr>
</tbody>
</table>

External Representation: multiplication

<table>
<thead>
<tr>
<th>paper</th>
<th>mental buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td></td>
</tr>
<tr>
<td>x 48</td>
<td></td>
</tr>
<tr>
<td>456</td>
<td></td>
</tr>
<tr>
<td>258</td>
<td></td>
</tr>
<tr>
<td>736</td>
<td></td>
</tr>
<tr>
<td>[4 + 2 + 1 = 7]</td>
<td></td>
</tr>
</tbody>
</table>

External Representation: multiplication

<table>
<thead>
<tr>
<th>paper</th>
<th>mental buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td></td>
</tr>
<tr>
<td>x 48</td>
<td></td>
</tr>
<tr>
<td>456</td>
<td></td>
</tr>
<tr>
<td>258</td>
<td></td>
</tr>
<tr>
<td>2736</td>
<td></td>
</tr>
<tr>
<td>[4 + 2 + 1 = 7]</td>
<td></td>
</tr>
</tbody>
</table>
**External Representation**

reduces load on working memory
- offload cognition

familiar example: multiplication/division

synthetic example: information visualization
- interactive visual representation of abstract data
- help human perform some task more effectively

---

**External Representation: topic graphs**

[Godel, Escher, Bach. Hofstadter 1979]

Paradoxes – Lewis Carroll
Turing – Halting problem
Halting problem – Infinity
Paradoxes – Infinity
Infinity – Lewis Carroll
Infinity – Unpredictably long searches
Infinity – Recursion
Infinity – Zeno
Infinity – Paradoxes
Lewis Carroll – Zeno
Lewis Carroll – Wordplay

Halting problem – Decision procedures
Bloop and Floop – AI
Halting problem – Unpredictably long searches
Bloop and Floop – Unpredictably long searches
Bloop and Floop – Recursion
Tarski – Truth vs. provability
Tarski – Epimenides
Tarski – Undecidability
Paradoxes – Self-ref

---

**External representation example**

offload cognition to visual systems
read off answer

---

**Dimensional ranking**

Dimensional ranking varies by data type

spatial position best for all types

---

**Cleveland's study**

position along common scale
positions along nonaligned scales
length, direction, angle
area
volume, curvature
shading, color saturation

---

Human Perception

- sensors/transducers
  - psychophysics: determine characteristics

- relative judgements: strong
- absolute judgements: weak
  - continuing theme

- different optimizations than most machines
  - eyes are not cameras
  - perceptual dimensions not nD array
  - (brains are not hard disks)

Psychophysical Measurement

- JND: just noticeable difference
- increment where human detects change
- average to create "subjective" scale

Nonlinear perception of magnitudes

- sensory modalities not equally discriminable
- Stevens power law

\[ S = I^n \]

Dimensional dynamic range

- lineweight: limited discriminability

Weber's Law

- ratio of increment threshold to background intensity is constant
- relative judgements within modality

\[ \frac{\Delta I}{I} = k \]

Cleveland example: frame increases accuracy

Cleveland suggestions

- dot chart over pie or bars
- direct differences over superimposed curves
- framed rectangles over shading on maps
Preattentive visual dimensions

- color (hue) alone: preattentive
  - attentional system not invoked
  - search speed independent of distractor count

Non-preattentive: parallelism

- many preattentive dimensions of visual modality
  - hue
  - shape
  - texture
  - length
  - width
  - size
  - orientation
  - curvature
  - intersection
  - intensity
  - flicker
  - direction of motion
  - stereoscopic depth
  - lighting direction

Preattentive visual dimensions

- color alone: preattentive
- shape alone: preattentive
- combined hue and shape: multimodal

- requires attention
- search speed linear with distractor count

Integral vs. separable dimensions

- red-green
- x-size
- y-size
- orientation
- shape
- color
- color
- motion
- location

Gestalt Laws

- principles of pattern perception
  - “gestalt” German for “pattern”
  - original proposed mechanisms wrong
  - rules themselves still useful

- Pragnanz
  - simplest possibility wins

- subsequent examples from
  - Information Visualization: Perception for Design
  - Colin Ware
  - Morgan Kaufmann, 2000
**Gestalt Principles**

- Proximity, similarity, continuity/connectedness, good continuation, closure, symmetry
- Common fate (things moving together)

[psychlab1.nanower.edu/classes/Sensation/nld013.htm](psychlab1.nanower.edu/classes/Sensation/nld013.htm)

- Figure/ground, relative sizes

**Proximity**

![Proximity Diagram](image)

**Similarity**

![Similarity Diagram](image)

**Continuity**

- Smooth not abrupt change
- Overrules proximity

![Continuity Diagram](image)

**Transparency**

- Needed for perception
  - Continuity
  - Color correspondence

![Transparency Diagram](image)

**Connectedness**

- Can overrule size, shape

![Connectedness Diagram](image)
**Closure**
overrules proximity

**Symmetry**
emphasizes relationships

**Common Fate**

**Relative Size**
smaller components perceived as objects

**Figure/Ground**
determined by combination of previous laws

**Graph Drawing Tension**
node placement
- close proximity
- far visual popout of long edge
- either connectedness

tradeoffs abound in infovis!
Foveal Vision

thumbnail at arm’s length
small high resolution area on retina

Foveal Touch

star-nosed mole

Ears

perceived as temporal stream
- but also samples over time
- hard to filter out when not important
  visual vs auditory attention

implications
- harder to create overview?
- hard to use as separable dimension?

'sonification' still very niche area
- alternative: supporting sound enhances immersion

Equal Legibility

if fixated on center point

Eyes

saccades [video]
- fovea: high-resolution samples
- brain makes collage
- vision perceived as entire simultaneous field
- fixation points: dwell 200–600ms
- moving: 20–100ms