A Few Things about Perception and Cognition
“Visualization is really about external cognition, that is, how resources outside the mind can be used to boost the cognitive capabilities of the mind.”

Stuart Card
Visual perception

We see things:
Shapes, colors, sizes, texture, orientation, transparency, etc.

Cognition

Mental process of acquiring knowledge from perception, experiences and others:
How to interpret/understand what we see
Visual perception

We see things:
Shapes, colors, sizes, texture, orientation, transparency, etc.

Cognition
Mental process of acquiring knowledge from perception, experiences and others:
How to interpret/understand what we see.

Perception is about how our brain perceives and interprets visuals
Moving Illustrations

http://www.youtube.com/watch?v=lw8idyw_N6Q
“Visualization is really about external cognition, that is, how resources outside the mind can be used to boost the cognitive capabilities of the mind.”

We plan to utilize some properties of our visual perception to generate effective visualizations.
A few properties of our visual perception
Selective Attention Test
from Simons & Chabris (1999)
Let us look at another example
This is what is called change-blindness.
These examples tell us that people need to pay a lot of attention in order to capture the changes.

Therefore, visualization should emphasize /highlight changes to help relieve the cognition load.
Our visual perception system is good at observing relative difference and is easy to be drawn to the boundaries of different regions / objects.
Relative vs. Absolute

Weber’s Law

We judge based on the relative difference rather than the individual absolute values.
Relative vs. Absolute

Tiles A and B, which one is brighter?

Weber’s Law
We judge based on the relative difference rather than the individual absolute values.
Seeing is NOT ALWAYS believing
Shepard’s Rotated Table
This effect is called vertical dominant.
A couple more things about cognition via visual perception
What we **SEE** is **more** than what is actually there.
“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”

Polyshyn
Pre-attentive vs. attentive

<table>
<thead>
<tr>
<th>Pre-attentive</th>
<th>Attentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 500ms</td>
<td>&gt; 500ms</td>
</tr>
<tr>
<td>&lt; 10ms</td>
<td>&gt; 10ms</td>
</tr>
<tr>
<td>Task</td>
<td>Individual object</td>
</tr>
<tr>
<td>Parallel processing</td>
<td>Sequential processing</td>
</tr>
</tbody>
</table>
Pre-attentive processing

“An understanding of what is processed pre-attentively is probably the most important contribution that visual science can make to data visualization” (Ware, 2004, p. 19)
How many 3’s?

How do we make things pop-out?
How many 3’s?

How do we make things pop-out?
Different shapes can often pop out
A single lack of enclosure can quickly be identified pre-attentively
Pre-attentive processing: ‘odd one out’
A different color can be pre-attentively identified: ‘odd one out’
But, do you notice the red square?
But, do you notice the red square?

With conjunction encoding (more than one feature, shape, color, and boundary highlight), the red square is not pre-attentively identified.
Pre-attentive features - summary
### Visual attributes / cues that can be used for encoding

<table>
<thead>
<tr>
<th>Space</th>
<th>Hue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Color scheme</td>
</tr>
<tr>
<td>Annotation</td>
<td>Transparency</td>
</tr>
<tr>
<td>Size</td>
<td>Orientation</td>
</tr>
<tr>
<td>Color</td>
<td>Shapes</td>
</tr>
<tr>
<td>Brightness</td>
<td>Texture</td>
</tr>
<tr>
<td>Saturation</td>
<td>Animation</td>
</tr>
</tbody>
</table>
How much bigger is the lower bar?
How much bigger is the lower bar?
How much bigger is the right circle?
How much bigger is the right circle?
Accuracy of the judgement of the encoded quantity data

- Position
- Length
- Angle
- Slope
- Area
- Volume
- Colour
- Density
Choice of encoding

- Bertin’s guidance
- suitability of various encoding methods
- to support common tasks
Quantitative, ordinal and categorical data

Guidance for the encoding of quantitative, ordinal and categorical Data (Mackinlay 1986)
Gestalt Principles

Useful for generating effective visual representation!
Why we like to consider/separate background and foreground when seeing things?

Why can we separate object with different shapes and/or other attributes?

What is a good shape?

......

People started thinking these questions in the beginning of 1900
The overall layout is more important than the individual elements, as the visual representation is perceived and understood as a whole in the beginning.

**proximity**

We tend to think of objects that are physically close together as belonging to part of a group.

Example 1

Example 2

From Storytelling with Data
Similarity

Objects that are of similar color, shape, size, or orientation are perceived as related or belonging to part of a group.

Example 1

Example 2

This can be leveraged in tables to help draw our audience’s eyes in the direction we want them to focus.

From Storytelling with Data
Enclosure

We think of objects that are physically enclosed together as belonging to part of a group.

Example 1

Example 2

One way we can leverage the enclosure principle is to draw a visual distinction within our data.

From Storytelling with Data
Closure

People like things to be simple and to fit in the constructs that are already in our heads.

Example 1

Example 2

We can remove chart borders and background shading and our graph still appears as a cohesive entity.

From Storytelling with Data
Continuity

When looking at objects, our eyes seek the smoothest path and naturally create continuity in what we see even where it may not explicitly exist.

Example 1

Example 2

Remove unnecessary axis if things are aligned.

From Storytelling with Data
Connection  
We tend to think of objects that are physically connected as part of a group.

Example 1

Example 2

One way that we frequently leverage the connection principle is in line graphs, to help our eyes see order in the data.

From Storytelling with Data
Other useful principles

Simplicity

Common fate

Symmetry

Past experience
Expressiveness and Effectiveness

• Expressiveness

It requires the visual representations accurately encode the information of the data that needs to be conveyed, i.e., fidelity or authentic to the data.

• Effectiveness

The use of the visual attributes/cues should reflect the importance of the information (or the characteristics) of the data.
Expressiveness and Effectiveness

Precision

Discernability/legibility

Differentiability

Visual Prominence