Visual Perception and Data Presentation

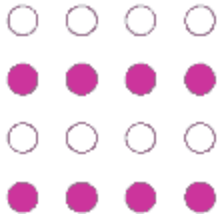
In his book "The Visual Display of Quantitative Information,"[1] Edward Tufte proposes that data should be displayed with a minimum of non-data elements (e.g., borders, grids, labels) and that non-data elements should be de-emphasized as much as possible. Work done in cognitive psychology, specifically the Gestalt Principles of the Organization of Perception, complements this approach by describing rules that aid in the visual organization of data. We commonly display data findings in reports, dashboards[2], PowerPoint presentations, and posters and increasing our understanding of the Gestalt principles can help to increase the viewer's comprehension even as we decrease non-data elements.

Gestalt is translated from the original German as "form" or "whole". Gestalt theory originated with a group of psychologists working in the early 20th century. It encompasses a broad range of concepts and the more common understanding of Gestalt is the sudden recognition of a pattern or whole from individual parts. This aspect of Gestalt Theory has applications in clinical psychology and therapy as well as philosophy.

The concepts discussed here are associated with the organization of data and focus on "grouping", characteristics that cause us to structure or interpret a visual field in a certain way. These principles of organization follow from the idea that there are universal ways that our brains process visual input.

The brain, where "sight" actually takes place, organizes visual information into patterns instantly and without conscious effort or attention. In the visual representation of data we can either use these principles to add meaning to our reporting or we can avoid these principles so that unintended meaning is not perceived.

For example, in this diagram we see the circles in horizontal rows, but in reality all the circles are equidistant from each other.



This principle is Similarity and the diagram illustrates the connection between the construction of forms and the way that we perceive them.

[1] Edward R. Tufte. The Visual Display of Quantitative Information. Cheshire, CT: Graphics Press; 2 edition, 2001

[2] Dashboards are single page reports, often viewed online, that are designed to give a high-level view of data and call attention to problem areas or excessive variance.

The Principles of the Organization of Perception[3] are:

- Proximity
- Similarity
- Enclosure and Closure (my grouping)
- Continuity
- Connection

The Principle of Proximity

Objects that are arranged close to one another are perceived as belonging to the same group. In this example, which would you get for free, water or food?

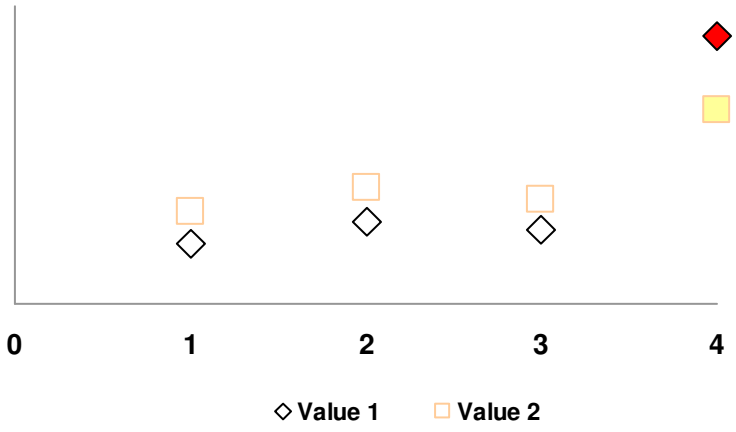
Free	**Water**
Food	**Sold**

The proximity of the vertical grouping suggests that they go together, even though we normally read left to right.

In the positive usage, we should group correlated items together for instant recognition of their relationship to each other. Conversely, we need to be aware that displaying items close to one another suggests a relationship even in cases where there is none.

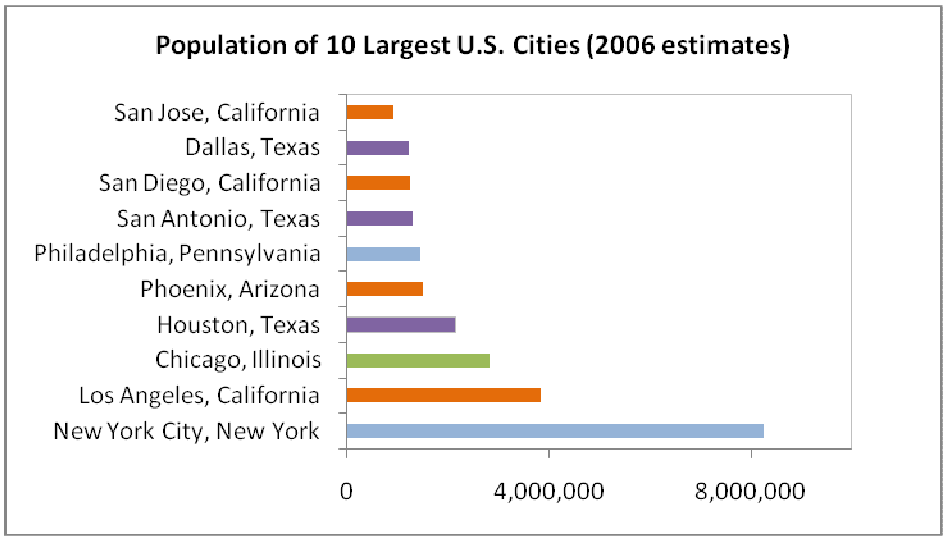
The Principle of Similarity

The brain will tend to group objects that are similar in color, size, shape, and orientation. We often use this in graphs to distinguish related values. We can expand it to tell even more, like adding qualitative information to a quantitative representation.



[3] There has been additional work done related to "figure and ground" that have less application here. The classic example of this type is the illustration that can look like either an urn or two faces, depending on which is seen as the figure and which is seen as the ground.

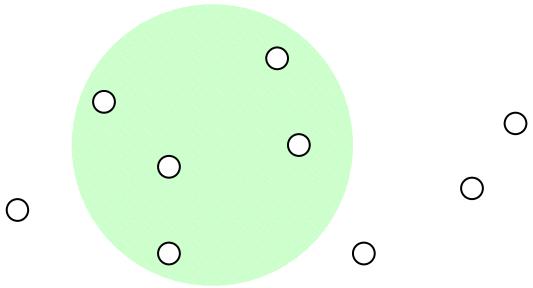
In the graph below, similar bars suggest similar sources for the values, but what do the colors represent? We suspect meaning but it is not too clear until we see (hopefully in a legend) that they represent the regions of the country. Would we have more meaning or less meaning if each bar were its own color? Most likely, it would suggest meaning where there was none—all the bars represent population and that metric is the message.



Another aspect of this is that if similarity suggests a relationship, then a lack of similarity will suggest no relationship. In a series of graphics that relate to each other, any differences in font, line weight, or size will break the sense that the items relate to each other.

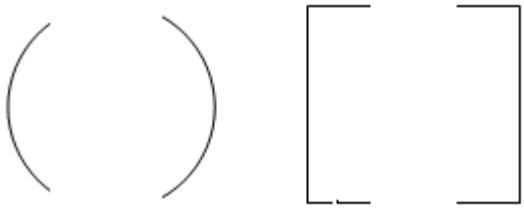
The Principles of Enclosure and Closure

Enclosing elements in anything that suggests a visual border causes the objects to appear to be set apart in a meaningful way.



These are just randomly placed small circles on the page, but we immediately consider that the ones enclosed in the colored area have significance or a relationship to each other.

Closure, which has the same effect, is a little different in that things that suggest enclosure are interpreted as full enclosure. The brain's tendency is to perceive ambiguous forms as whole forms. We can suggest enclosure without fully enclosing an object. For example, these are not viewed as two sets of curved or angled lines (below); they are seen as an enclosing circle and square.



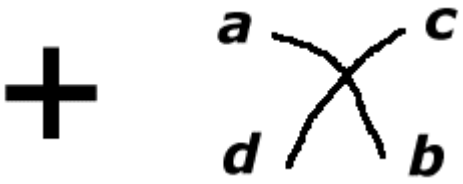
We will tend to see what is semi-enclosed as having a correlation or special significance. This is the same principle that allows us to show only the x and y axes in a graph without having to display every border and gridline. It can also be used in tables to draw attention to the line that we want the casual reader to notice without needing to clutter the page with a fully enclosed box.

In the following example, Excel's conditional formatting shows us that the score for KPI 3 is below the 25th percentile. Understanding that this is the element to look at is practically instinctive.

	Your Score	25th Percentile	50th Percentile	75th Percentile
KPI 1	**87%**	49%	65%	90%
KPI 2	**66%**	50%	60%	72%
KPI 3	**42%**	57%	64%	84%

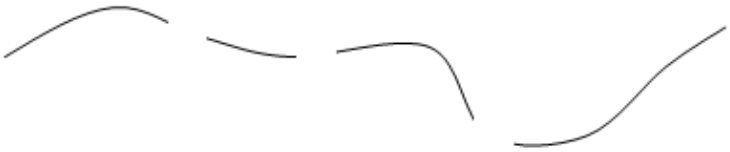
Principle of Continuity

We form a perception of continuity when continuity is not necessarily present. Look at these figures:



Why do we see two crossed lines (or a plus sign) instead of 4 lines meeting at the center? Or lines formed by a – b and c – d instead of angles formed by a – d and c – b? We naturally perceive continuity when it is suggested.

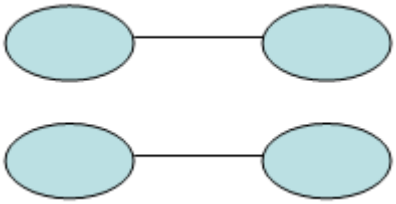
In this case, we don't see several curved lines but recognize the figure as an extended line:



The two lessons here are that continuity is perceived even if unintended and when faced with the choice of seeing abrupt changes in direction versus curved or soft changes our tendency will be to see the latter.

Principle of Connection

Objects that are connected in some way are seen as part of the same group.



The connecting line makes these ovals appear to be related by rows instead of columns. In other words, we can suggest relationships simply by connecting the elements. This is commonly used in organization charts and process diagrams.

No one needed to teach us that the lines connecting points in a line graph tell us that the data points are related or from the same source. The nature of the Principle of Connection leads us to that conclusion.

Graphs with data elements connected by lines should only represent interval data, items that display an axis with a distinct order, like months of the year or age. The key to line graphs is that we should learn something about the data by the shape of the line. In cases such as an axis representing East, West, North, and South, a bar graph is better since these four geographic regions do not have an intrinsic order.

Every report, presentation, document, and poster is a user interface to communicate information to the reader. Usability studies, psychology, and experience tells us that we can guide the viewer to see the most pertinent information at a glance by reducing the amount of non-data pixels or ink and using overt and covert ways of calling out the critical information. When proofing tables and graphs we should consider the subtle messages that our techniques for visual representation provide.

Dave Troland (July, 2008)

Additional sources:
Stephen Few. Information Dashboard Design. Sebastopol, CA: O'Reilly. 2006
Bonnie Skaalid. "Gestalt Theory of Perception," 1999.
<http://www.usask.ca/education/coursework/skaalid/theory/gestalt/gestalt.htm>