**Summary of Healey, *Perception in Visualization*, and Fusion Charts, *Principles of Data Visualization—What We See in a Visual.***

A data visualization is designed to convey information that would not otherwise be as salient to a viewer who is simply looking at the raw data. But it is not entirely accurate to say that a visualization “conveys” information, in the sense that the image somehow inherently embodies that information and simply transports it to a viewer. Rather, the viewer will make meaning from a particular image; whether that meaning is the one intended by the designer, and whether different viewers will make the same meaning from the same image, will depend in large part on the image’s design. A visualization will be most effective when its components and their arrangements are chosen with an understanding of the human visual system and cognitive processes, so the viewer will essentially be led to the meaning that the designer would like to convey.

Humans process visual information through a combination of processes that operate at different speeds and make use of different parts of the brain. These processes occur in an overlapping and reciprocal way, sometimes independently and in parallel, and at other times interacting and providing mutual feedback. Effective visualizations will take advantage of these processes so that the most salient features of the data are grasped quickly.

The initial analysis of visual information occurs during what is called “preattentive processing.” As Healey points out, we now know that what we “see” is affected significantly by what we are paying attention to, but the term “preattentive” is still used to describe those visual perceptions that happen more quickly than the eyes can be intentionally brought to focus on a particular element—on the order of 200 milliseconds. These initial perceptions are aspects of similarity and difference among elements of the image, but not all types or degrees of similarity and difference can be detected with equal speed. The Fusion Charts article identifies preattentive attributes that can be perceived in less than ten milliseconds; these include such things as the length, width, and orientation of lines; differences in size, shape, curvature, and color of shapes; and the presence or absence of extra lines or borders. The position or movement of items in a two-dimensional plane is also very quickly perceived by our visual systems. In addition to these attributes of a target item, Healey shows we can also quickly identify features that are composites of multiple items, such as boundaries between sets of items and relative quantities of items. If we want viewers to see patterns and features in our visualizations quickly, then important portions of the graph should have attributes that can be detected preattentively.

But Healey’s article looks at these preattentive attributes in more detail, and notes that they are not all equally easy to perceive, and that the surrounding context of the image can have a significant impact on their salience. For example, he shows that finding a red circle in a field of red squares and blue circles cannot be done through preattentive processing—in other words, the red circle will not “pop out” of the image—because there isn’t a single unique feature that the visual system can latch on to and identify. Research has also shown that there is a hierarchy to these preattentive attributes; the brain favors certain attributes over others in different discriminatory tasks. Healey shows, for example, that it is easier for us to detect a boundary between objects of different colors than between objects of different shapes.

This has significance for visualization design because we often want to convey as much information as possible in one image. The Fusion Charts article quotes Edward Tufte’s description of graphical excellence as, “that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.” To do this, we are likely to have objects that vary in a number of different attributes across the visualization. Since the brain will find it easier to make some distinctions than others, our choice of attributes will have a large impact on what differences viewers can and can’t see.

Healey summarizes a number of different theoretical models of visual processing that have attempted to account for the observed patterns in what we can and can’t discriminate preattentively, but he points out that no single model yet explains all of the experimental results. As a biologist, I found the models themselves hard to understand, and difficult to connect with my (admittedly limited) neurobiological understanding of how the brain works. But there were a few concepts that emerged from those models that seemed useful. One of the most intuitive concepts was the idea from similarity theory that the speed with which we can identify a target depends not only on the difference between the target and the non-target items, but also on how similar the non-target items are to one another. Less uniformity in the non-target items makes it harder to find the target, even if the target is different from the non-targets in unique ways. In a sense, this argues for a “simpler is better” approach to visualization design. The less “clutter” there is in the background, the more quickly a viewer will be able to identify the salient features.

Preattentive processing allows a viewer to recognize quickly the presence or absence of certain features in an image. But discerning relationships among elements—analytical patterns, as the Fusion Charts article calls them—requires somewhat more time, and interaction with both short-term and long-term memory. The Fusion Charts article uses the analogy that,”[i]f preattentive attributes are the alphabets of visual language, analytical patterns are the words we form using them.” Here too, we can take advantage of what we know of visual processing and meaning-making to help ensure that viewers see the patterns we want the visualization to convey.

Discerning patterns and relationships requires separating features of the image into different groups and looking for similarities and differences among those groups. The Fusion Charts article identifies a dozen different types of relationships that the brain can easily recognize, and Stephen Few, in his article “Effectively Communicating Numbers,” lists seven of the most common quantitative relationships in business communications. But aspects of image design can highlight some relationships over others. The Fusion Charts article points to the fact that our minds will automatically group elements and separate them from others, based on their spatial and visual relationships to one another. These tendencies are known as “Gestalt principles,” and they are an important part of the cognitive process known as “chunking”, by which the brain quickly groups sensory inputs into collective units that can be manipulated as a group, rather than as unique individual data points. For example, we naturally group items that are visually close to one another, that are similar or symmetrical to one another, or are enclosed or connected. We separate aspects of the image that appear to be in the foreground from those in the background, and we infer continuity among items that appear to be collinear. Because the brain will be making these inferences automatically, whether we want it to or not, it behooves us as visualization designers to work in concert with these processes, rather than in opposition to them.

A final aspect of visual processing that Healey discusses is what happens when we stop looking at an image. This obviously has relevance for how much a viewer might remember from a visualization once he or she stops looking at it, but it is also important when our visualization itself consists of more than one image. As Stephen Few points out, displaying more than three variables in a single graph can make the image overly confusing. A better solution would be to have a series of several smaller graphs, each showing relationships among a smaller number of variables. But for the viewer to obtain all of the information, he or she necessarily needs to stop looking at one graph in order to look at another. As Healey points out, our brain does not record a faithful, photographic image that can then be compared with another, subsequent image. Moving from one image to another can make it difficult to see differences between them, even if they are fairly substantial. This “change blindness” can be overcome if attention is drawn to the difference that is present. For designers of visualizations, this means we need to intentionally highlight the differences we want our viewers to see when comparing different graphs or other images. This could be done using preattentive attributes (e.g., making elements that differ between the images a different color, shape, size, etc.), or by explicitly pointing out the differences in a caption, legend, or label.

The authors of the Fusion Charts article open with the statement that, “[w]e visualize information to meet a very basic need - to tell a story.” While that may be our intent, we also have to realize that from a cognitive standpoint, what is really happening is that our viewers are making up their own story from the images we provide. When we create exploratory visualizations, we are clearly doing this—looking for stories in the data—and we will see different stories depending on how we choose to visualize the data. The same is true when we think we are creating an explanatory visualization. The key to effective visual communication—to conveying the particular story we think we want to tell—is understanding and using the sensory and cognitive processes that will be going on automatically in our viewers’ minds. If we recognize those and work with them, our visualizations will be not only clearer and more useful, but perhaps also more beautiful and more compelling.