Four Futures and a History

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(Commentary on Steven Few, "*Data Visualization for Human Perception*")

Stephen Few provides a nice overview of the reasons why we should design data visualizations to be effective, and why it's important to understand human perception when doing so. In fact, he's done this so well that I can't add much to his arguments. But I can, however, push the basic message a bit further, out into the times before and after those he discusses. Out into areas that are not as well known, or not really developed, where new opportunities and new dangers may lie…

Perhaps the best place to begin is the beginning. Discussing the beginning of visualization is not without its problems, if only for the fact that there exist several different kinds of visualization—for example, data visualization, information visualization, and scientific visualization. But whatever adjective used, we generally find a history more extensive than commonly imagined. For example, although Descartes did contribute to the graphic display of quantitative data in the 17^{th} century, graphs had already been used to represent things such as temperature and light intensity three centuries earlier. Indeed, as Manfredo Massironi discusses in his book (Massironi, 2002; p. 131), quantities such as displacement were graphed as a function of time as far back as the 11^{th} century. But while these facts may be of interest in their own right, the more important point is that techniques in graphic representation have been developed over many centuries, and many of these techniques have been subsequently forgotten—perhaps fallen out of vogue, or never found wide use to begin with. But the reasons for their dismissal may not necessary apply in this day and age. Indeed, several techniques might lend themselves quite well to modern technology, and so might be worth resurrecting in one form or other. Books such as Massironi's are helpful in discovering such possibilities.

On to the future. Or more precisely, on to ways of further developing useful connections between visualization and psychology. To begin with, there is potential for considerably more integration between vision and visualization than currently exists; much more processing could be offloaded to the viewer's visual cortex. As Stephen Few mentions, one way of doing so is by making use of simple preattentive properties such as length, orientation, and hue. But recent work in vision science has shown that the preattentive level of vision contains far more visual intelligence than that. Among other things, preattentive processes can determine shadows, extract three-dimensional orientation, and link scattered elements of the image into unified groups. These abilities could be exploited in higher-powered visualizations. Another area of recent progress is our understanding of visual attention and scene perception. Our visual perception of the world seems to be based on a just-in-time architecture in which attention is directed to the right object at the right time. If the co-ordination mechanisms involved can be handled correctly, it would open up the prospect of "seeing" abstract datasets in a way that is as natural and effortless as seeing the physical world. (A brief overview of these developments and their implications can be found in Rensink, 2002.)

A related opportunity is the greater use of visual analogy (or metaphor). Here, the emphasis is no longer on bypassing conscious thought, but on using modes of thought best suited for reasoning about visuospatial objects and processes. For example, when reasoning about physical force, a highly useful metaphor is the directed line, or arrow. A more modern example is the desktop, which allows a user to reason about possible actions on their computer. As in the case of visual perception, many—if not most—developments to date have been based on a relatively shallow understanding of the mechanisms involved. But given that cognitive scientists have learned much more about metaphor, it may be time to consider its use in a more sophisticated fashion. Ultimately, visualizations might be able to create mental images that correspond in a natural way to the structure of any process or task. (For an interesting discussion of this, see Paley, 2009.)

A third direction of potential importance is the creation of more powerful evaluation methods based on the methodologies developed in experimental psychology. Psychologists have spent centuries learning what to do (and not to do) to obtain precise measurements of various aspects of human behaviour. It would be good to learn from this. Of course, some of these techniques have already been adapted to evaluation. But as in the case of cognitive and perceptual mechanisms, the transfer of knowledge here is far from complete, and there is much that could still be done. For example, consider evaluating how well a given scatterplot design conveys the correlation in a dataset. In the past, this was done by presenting the viewer with the scatterplot and asking for a numerical estimate of the (perceived) correlation. But a more powerful approach is to borrow the experimental methodology of measuring just noticeable differences (jnds): the viewer is presented with two side-by-side scatterplots, and asked to choose the more correlated one. Results based on this approach show both precision and accuracy to be specified over all correlations by two functions governed by only two parameters. As a consequence, a given scatterplot design can be completely evaluated based on just two simple measurements. (For details, see Rensink and Baldridge, 2010.)

A final direction to consider—perhaps the most challenging of all—is to develop a systematic way of ensuring that visualization designs make optimal (or at least, good) use of human perception and cognition. In theory, this could result in a "science of design". In practice, this might not be possible, if only because the number of possible designs is so immense and our understanding of human cognition so incomplete. But it may be possible to follow the example of several other areas of design, and aim for a set of principles that would at least constrain the space of possibilities to consider. For example, constraints based on physical forces or material properties can be applied to any architectural design, determining whether or not it is viable. There is no *a priori* reason why a similar approach would not also work for visualization. The efforts of Bertin are perhaps a start in this direction, providing suggestions about the kinds of graphic representation that might be applied to various kinds of problems. Work by Tufte, Mackinlay, Ware, and others have extended this further. But however useful these suggestions are, we are still a long way from a solid foundation for thinking about effective visualizations. Many foundational issues are still poorly understood. What is really going on in a visualization? Is there a way to describe this process precisely and objectively? Is it even possible in principle to determine if a given visualization draws upon the perceptual and cognitive resources of the viewer in an optimal way? The answers to these questions and others like them will be difficult to find. But they will determine the extent to which we can enable humans and machines to best combine their respective strengths.

References

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