Cognitive Biases behind Small Multiples

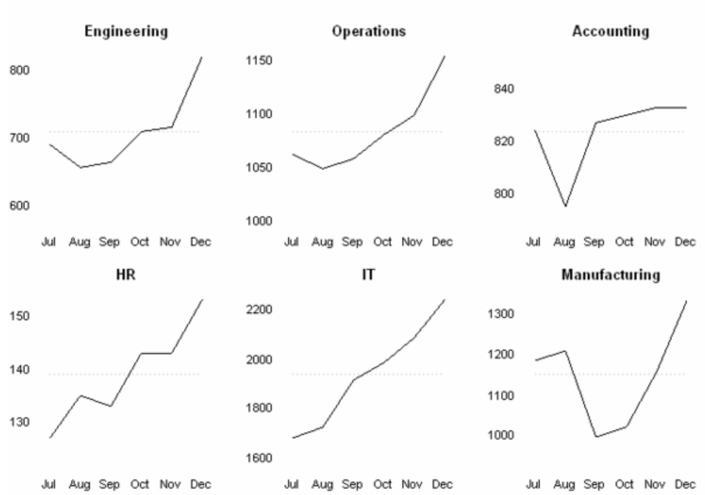
How we think changes what we see

Introduction

Our eyes and brains are designed to find patterns. Evolution clearly favored this trait and it's incredibly useful, but sometimes we see spurious or unintended patterns. What we see is often colored by how our brains process visual information around us. As Data Scientists, we have the challenge to both identify patterns and communicate them in easy to understand and interpretable way. If we cannot communicate a thought, our work is in vain. Visual communication becomes far more complex and challenging when working with more than a few dimensions or when trying to indicate changes over time, especially when there are multiple features changing in parallel.

What are Small Multiples?

Small Multiples is an approach popularized by Edward Tufte to describe a visual made up of multiple small visuals in sequence. Each small "frame" is a self-contained visual and the viewer is can compare these side-by-side. Typically a blocking or segmenting variable is used to separate out which data points are visualized in each frame. This is analogous to still frames or cells in a film. Each still frame captures a moment in time but put together, our brains can see not only what changed but how things are changing and creates a mental timeline. This is how we see - our brains process frames of information. While researchers have measured the "framerate" of our visual acuity, our brains don't actually process frames per se, but rather we have complex attention systems for identifying important visual cues and filtering or ignoring information our brain doesn't see as important. Small multiples are most easily interpreted when the blocking variable is linear time. When we start trying to more complex partitioning between frames or use a non-time based measure, our audience may have more difficulty with interpretation. Small Multiples are commonly used with maps, time-series, and financial data where we are showing change over time.



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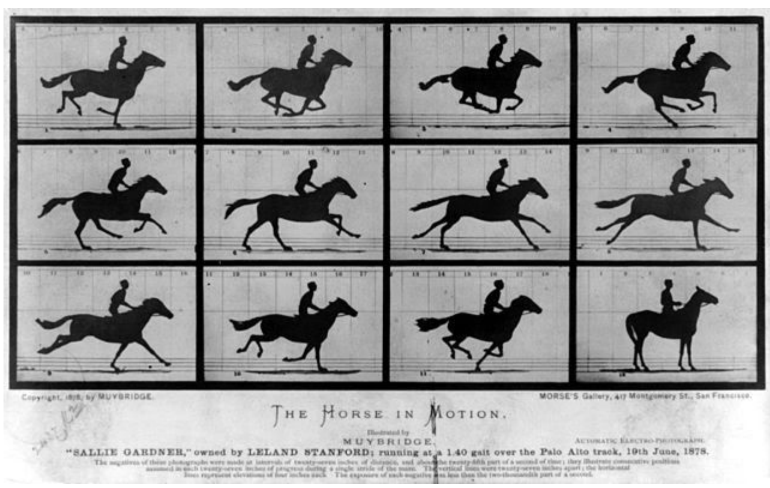

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Let's delve into how our viewers are actually interpreting what they see and how this can influence their understanding, what they notice, and the ease of which they can detect patterns we are trying to communicate. I will focus on just a few core concepts and encourage readers to learn more on their own regarding cognitive biases and memory biases.

Cognitive Biases at Work

Dimensionality

Surprisingly, humans evolved in a mostly 2D world glued to our planet (think latitude and longitude). Only in recent human times have we grappled with our 3D dimension, *altitude*. This may be surprising, but *time*, commonly referred to as our 4th dimension, isn't even consistently expressed across all human languages (see here for a more in-depth discussion). This poses a challenge for us as analysis involving more than a few simple features has to be mapped into a visual space our brains can interpret. With recent computer image generation, there was a move towards 3D charts depicting x, y, and z. We learned the hard way that 3D charts can be difficult to understand -- that 3D dimension is harder to visualize. Since non-interactive charts cannot change, communicating change over time (4D) can also be challenging. We leverage other visual cues to help communicate, like color, size, shape, but we have a limited pallet and if multiple things need to be communicated, we are back in a bind. Our brains have a hardwired cognitive bias that favors understanding fewer physical dimensions.

Visuals based on *Small Multiples* helps reduce this challenge by moving change-over-time to a separate visual cue that our brains can more readily process … side-by-side visuals. This leads to our next cognitive bias, Pattern Recognition.

Pattern Recognition

Humans are very adept at recognizing patterns and in psychology and neuroscience, this is referred to as the cognitive bias, Pattern Recognition. Our brains are wired to compare what we see with the memory of what we saw before. Assuming the visual input and memory do not differ much or we have a reference to help reinforce the memory, we can readily spot differences. However, the more we have to rely on working memory, the more difficult it becomes to recall the details necessary to find a difference.

From research, we know that images placed side-by-side aid pattern recognition. If two images are shown, people can compare/contrast and spot differences. However, with only two images, viewers can only spot what is different. Our brains are curious and when we see something different, we often ask, "Why is this different or how is it changing?" If we only provide two images, our audience may lean on a host of biases to try and fill in the gaps to answer that why question. Some examples, just to name a few, include Attention Bias, Attribute Bias, Confirmation Bias, Distinction Bias, Framing Effect, Apophenia, and Salience Bias. There are many more well understood and documented biases at play. Unfortunately, these biases can contribute to spurious interpretations and associations. As visual communicators, we need to keep all this in mind when designing side-by-side visuals.

It becomes more interesting when we show 3 or more side-by-side images -- now people can often notice trends, changes-over-time, and we can influence the "Why and how?" question. In fact, when shown three or more side-by-side images, different parts of our brains kick in bringing along a number of additional faculties that do a better job of directing attention to "How are these changing?"

When scanning multiple images, viewers will use working memory to hold one image, in the "mind's eye" when looking at the next image. Providing sequential frames that are as similar as possible and changing in only simple ways leverages our limited working memory and allows us to better focus attention on what changed and by how much. Notice that at we scan the frames in our visual, our working memory is limited and we will lose details from previous frames. Research shows that when Small Multiples spanning multiple rows and our eyes move to the new row, we have more difficulty with detecting patterns as we have to rely more heavily on our working memory to recall what is no longer in our visual field. For this reason, if we want viewers to notice a specific pattern, we should try very hard to keep that pattern visually adjacent.

Anchoring Bias

Anchoring is the bias where we use the first exposure to something as a baseline and compare all future things against it. The classic example can be found at most jewelry stores. They display their very expensive wares at the very front so those are the first thing your see. This anchors you to a higher price. For example, you first see a $25,000 necklace, then approach the counter and are shown a $2,500 necklace. We subconsciously will compare that price with $25,000 and perceive it as a good deal. However, if we saw a $25 necklace at the beginning and are then shown the $2,500 necklace, it will be perceived as expensive. In visual communication, the same thing happens. We need to be very cognizant of the first visual our viewers see, especially when showing side-by-side or Small Multiple frames. That first image can frame pr taint the interpretation of the entire sequence. Note that the effect is more pronounced when shown fewer frames. If shown many frames then we can suppress the anchoring effect somewhat but may run into a challenge with memory biases like Primacy Effect, Recency Effect, and Serial Position Effect. With Small Multiples, we are essentially faced with the task of presenting the least number of frames possible to convey the necessary visual cues to impart our most critical messaging.

Framing Bias

Another challenge we run into is with the Framing effect where people interpret information and make decisions and interpretations based on how the information is presented, either positively or negatively. The exact same information can be shown, but the surrounding context and connotations can greatly affect perception. Per Wikipedia,

> "People tend to avoid risk when a positive frame is presented but seek risks when a negative frame is presented. Gain and loss are defined in the scenario as descriptions of outcomes (e.g., lives lost or saved, disease patients treated and not treated, etc.)."

We need to understand that how we frame our visual communication can affect the takeaway our viewers have when looking at the visual.

Confirmation Bias

People tend to search out and give more credibility to information that confirms prior beliefs. This absolutely makes sense when we consider how our brains store information. When presented with new information, we make connections with existing memories. Confirming information is more easily stored as there is a framework of other information in our memory to help anchor it. New confirming information also strengthens the existing beliefs. However, when faced with information that contradicts, we have to unlearn and break existing connections and start forming a new memory network. When we visually communicate, we need to keep this in mind and think about our target audience. If we are trying to supplement existing knowledge and held beliefs, we have a much lower bar to hurdle. If we are trying to change minds and present information that likely contradicts our viewers' expectations, we may need to think hard how best to communicate this so it reframes their thinking rather than tries to confront their thinking.

Apophenia Bias

The last major bias I want to showcase is Apophenia. Clearly I included this as it has a great name, but if we had to pick the "*Seven Deadly Sins of Visual Communication*", Apophenia would make the list. Apophenia describes our cognitive bias to connect or form relationships between completely unrelated events. This is the propensity to see patterns in noise. Our brains are wired to try and make connections and look for patterns. While Small Multiples solves many challenges with communicating change over time, we are also presenting a lot more information and in the context of Small Multiples, we should proactively look for areas that might be misunderstood. This could include how we choose our axis scale, what colors we use, whether there are other confounding features we didn't include that could lead to incorrect causative associations. Our brains are wired to try and identify *cause and effect* patterns - that is how we learn. However, we often go too far and see patterns, especially causal relationships that don't exist.

References:

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