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Depicting Temporal Patterns

Information changes over time, and the mind readily extracts temporal regularities (Schapiro, Kustner, & Turk-Browne, 2012). While the most intuitive way to depict such patterns would be to temporally present each element one after another, this method is uncommon. Traditional print publications cannot present information temporally due to physical limitations, yet temporal presentation is still uncommon in electronic visualizations. Why?

To answer this question, the fundamental features of the visual system need to be discussed. The visual system processes information largely in parallel (Nassi & Callaway, 2009), meaning that it can detect information from different spatial locations all at once. In particular, basic visual features such as colour can be quickly processed (Cave & Wolfe, 1990). Temporal patterns that can be simplified into binary sequences, such as winning/losing outcomes in gambling, can exploit the parallel nature of visual processing. For example, a perfectly alternating binary sequence is more efficiently extracted if all bits in the sequence are presented spatially (Figure 1). A viewer can quickly detect such pattern upon seeing the image. If each bit in the sequence were to be temporally presented (black, then red, then black …), it would take longer for a viewer to extract the pattern. For a designer, this means that temporal patterns that can be represented by simple visual features should be spatially presented.

Not all temporal information can be simplified into a binary sequence. Often, a viewer needs to be informed of the exact value of each data point. For example, in visualizations of global temperature change over time (Figure 2), exact values are often used for an accurate representation. While we experience the temperature over the years temporally, data points for global temperature are rarely presented one after another. Such datasets often are put together in spatial coordinates where the x-axis represents time and the y-axis represents temperature. This is to take advantage of another feature of the visual system: it effortlessly extracts summary statistics with fine accuracy. For example, the visual system can quickly perceive the average temperature value in the graph, learning the temperature norm (Szafir, Haroz, Gleicher, & Franconeri, 2016). The visual system can also extract any correlation between time and temperature (Rensink, 2017), allowing the mind to extract trends such as the gradual increase/decrease of temperature over time.

Sometimes, the information to be depicted over time is quite stable. For example, a house changes very gradually over the years of its lifetime. Technologies such as time lapse photography allows viewers to capture the state of the house over time by presenting images of the house temporally. With the images presented in quick and smooth succession using such technologies, small changes can be quickly picked up by motion detectors (Borst & Egelhaaf, 1989). The quick onset of the new information resulting from the small changes will automatically capture attention (Hillstrom & Yantis, 1994). On the other hand, if the images of the house over time are presented side-by-side spatially, such small changes are much less likely to be picked up. For such stable information, a designer should use a design that is consistent with the purpose of the visualization. If small changes are frequent, but the stability of the house were to be emphasized, then time lapse photography may not be a good idea. On the other hand, if the changes are small but important to the visualization, then the images over time should be presented in quick succession.

Like many other design choices, the depiction of temporal patterns requires a designer to understand the fundamental capabilities of the visual system, and the purpose of the visualization.

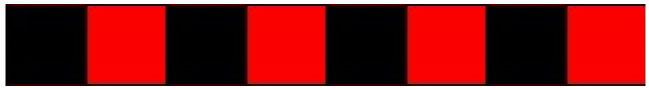

Figure 1. a spatially presented binary sequence with a perfectly alternating pattern.

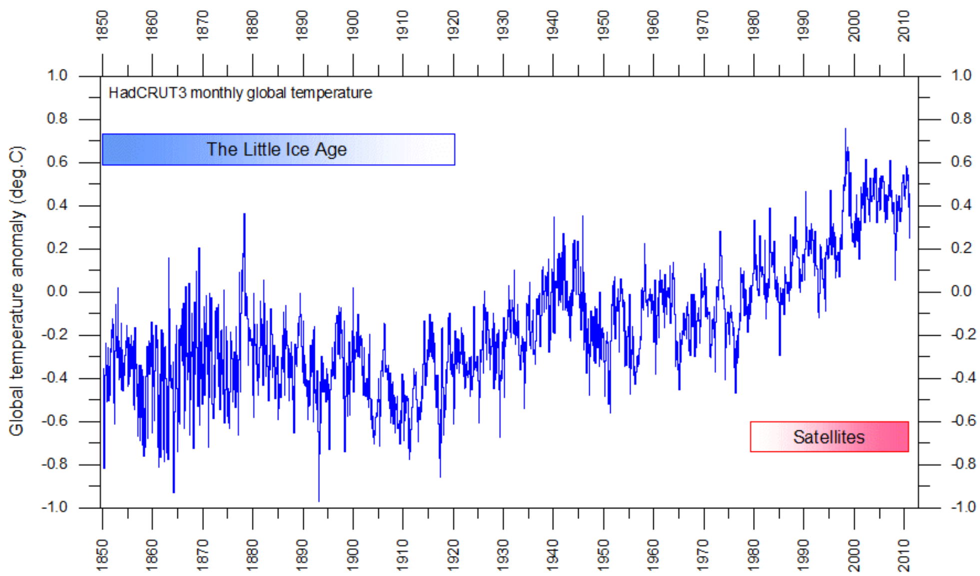

Figure 2. Global temperature from 1850 to 2010.

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