Employing Methods and Theories from Vision Science to Inspire and Evaluate New Visualizations of Uncertainty Information

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Problem: Ineffective communication of information about probability, randomness, and uncertainty undermine public understanding of (as well as confidence in) science and statistics. One contribution to this problem is that commonly used visualizations of uncertainty information (i.e., error bars, density plots) do not adequately support reasoning about probability and statistics in informal contexts where users may not have advanced statistical background. For example, using error bars in presenting polling data, or weather forecasts, to the public can lead to misinterpretations of the interval as a minimum or maximum value, or cognitive biases can lead observers to ignore uncertainty information when it is encoded separately from expected value. These issues suggest a need for uncertainty visualizations which better match human perceptual and reasoning faculties. However, to identify such techniques we need evaluations that go beyond typical foci on task accuracy to build explanatory accounts of why visualizations differ in their effectiveness.

Approach: We believe that distribution sampling visualizations, which display outcomes from a distribution over space or time (https://goo.gl/Mc2JgR), are a more cognitively natural way to communicate uncertainty information. Evidence from vision science suggests that the human visual system is capable of quickly, automatically, and accurately extracting summary statistics about ensembles of visual objects spread across space and time. Distribution sampling plots leverage this robust perceptual averaging capability of the visual system to communicate uncertainty information in the same way that distributional information is experienced in the natural environment (i.e., objects with statistically similar features are represented as categories). In terms of utility as a visualization format, distribution sampling visualizations are flexible across use cases since they don't require additional visual encodings for uncertainty. Thus, this kind of visualization might be used to convey information as disparate as projections of the possible paths of a hurricane or the possible arrival times of public transit. We employ methods from vision science in evaluating the impact of these visualizations on perceptions about uncertainty. We apply psychometric functions and modeling of confidence in perceptual decision making to estimate how different visualizations impact: (1) the perceptual sensitivity of observers to a trend in noisy data; (2) the noise internal to the observer in the perceptual decision making process; and (3) the correspondence between subjective confidence reporting and statistical confidence. These measures enable explanatory accounts of how distribution sampling visualizations and other uncertainty visualizations differently impact perceptions of probabilistic information and the fidelity of metacognitive impressions of performance ability, such as a person's perceived ability to make inferences based on visualized data.