Visualizing Uncertainty

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PSYC 6135

Outline

Introduction to uncertainty visualization

Cognitive Theories Behind Uncertainty Visualization

12-Step Strategy

Padilla, Kay,Hullman (2020)

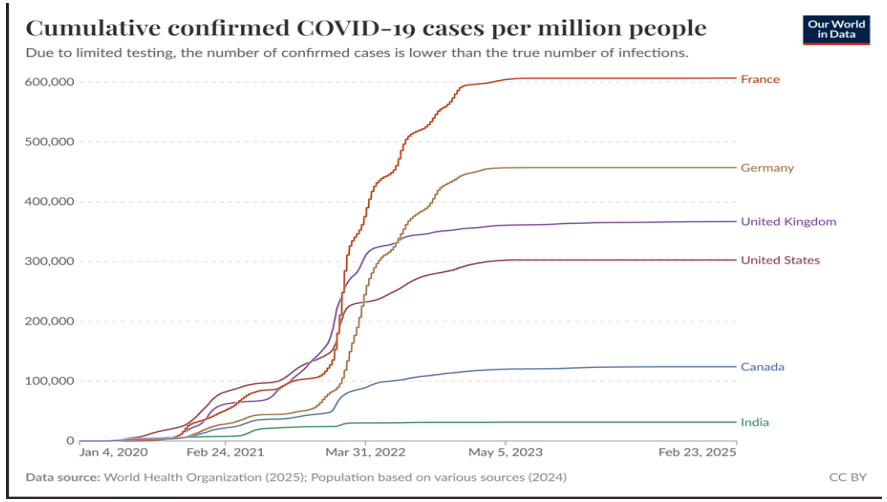
What is visualizing uncertainty?

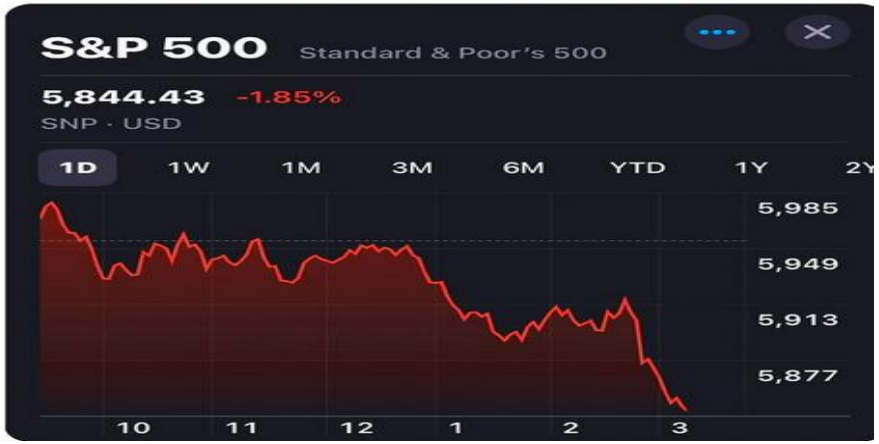
Visualizing uncertainty refers to the process of representing uncertain, incomplete, or probabilistic information using graphs, charts, colours, symbols, or other visual methods

Padilla, Kay,Hullman (2020)

Why is visualizing uncertainty important?

- Enhances understanding and decision-making in the presence of ambiguity or variability
- Effectively communicating uncertainty is necessary for establishing scientific transparency
- Understanding and managing uncertainty is critical in many fields:
  - 🔬 Science & Engineering
  - 🩺 Medicine
  - 💰 Finance & Economics
  - 🌦️ Everyday Life





Literature review

Frans, N., Hummelen, B., Albers, C. J., & Paap, M. C. (2023). Visualizing Uncertainty to Promote Clinicians' Understanding of Measurement Error. *Assessment*, *30*(8), 2449-2460.

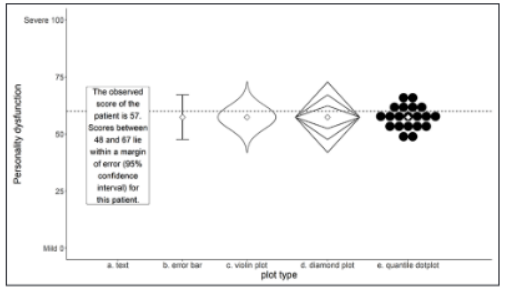
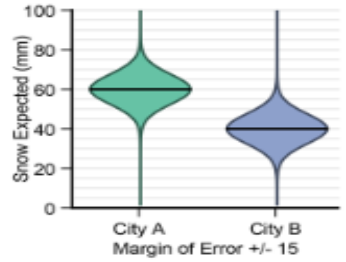


Figure 1. Five Formats Used in This Study: Text, Error Bar, Violin Plot, Diamond Plot, Quantile Dot Plot.

Correll, M., & Gleicher, M. (2014). Error bars considered harmful: Exploring alternate encodings for mean and error. *IEEE Transactions On Visualization And Computer Graphics,* 20(12), 2142-2151.



(d) **Violin plot**: the width of the colored region corresponds to the probability density function of a t-distribution.

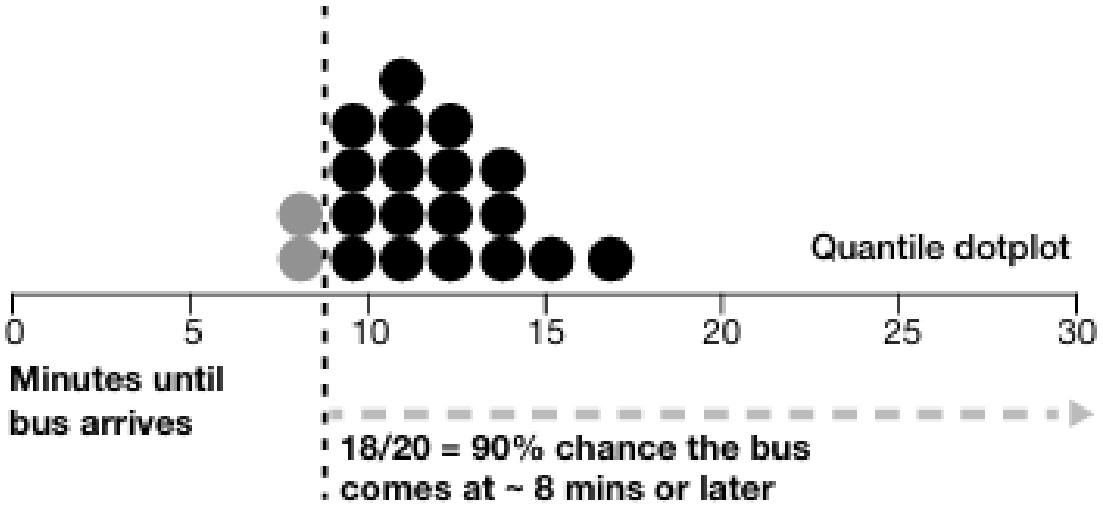
Belia, S., Fidler, F., Williams, J., & Cumming, G. (2005). Researchers misunderstand confidence intervals and standard error bars. Psychological Methods, 10(4), 389–396

Uncertainty visualization theories

1. Frequency Framing

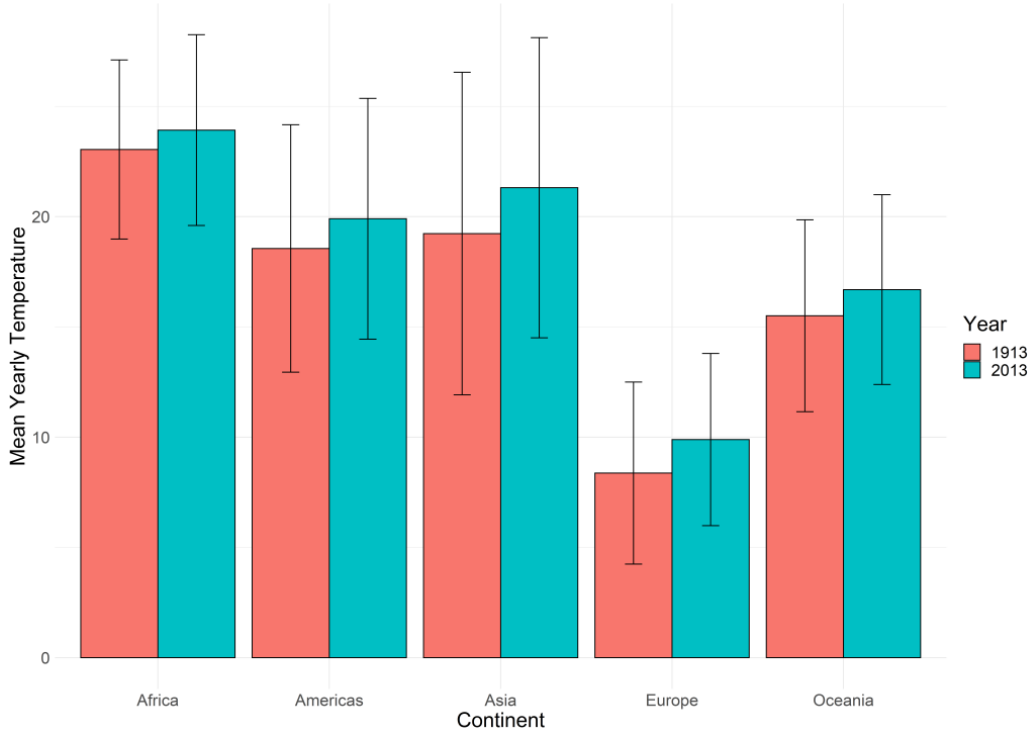
- People understand uncertainty better when expressed as frequencies
  - (e.g., "1 in 8") rather than (e.g., "12.5%")

- Icon arrays and quantile dot plots effectively communicate uncertainty, reducing common biases like denominator neglect.



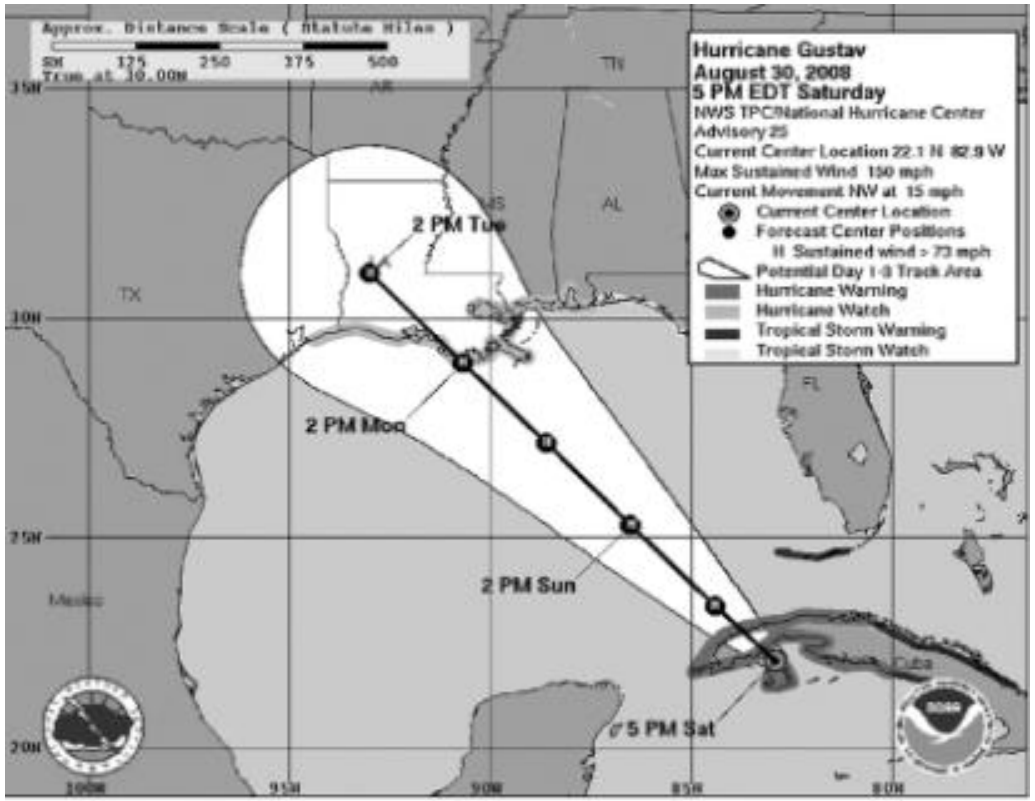
2. Attribute Substitution & Deterministic Construal Error

- People replace complex uncertainty information with simpler, deterministic interpretations.
  - Example: When given confidence intervals in weather forecasts, people misinterpret them as high and low-temperature bounds.



3. Visual Boundaries = Cognitive Categories

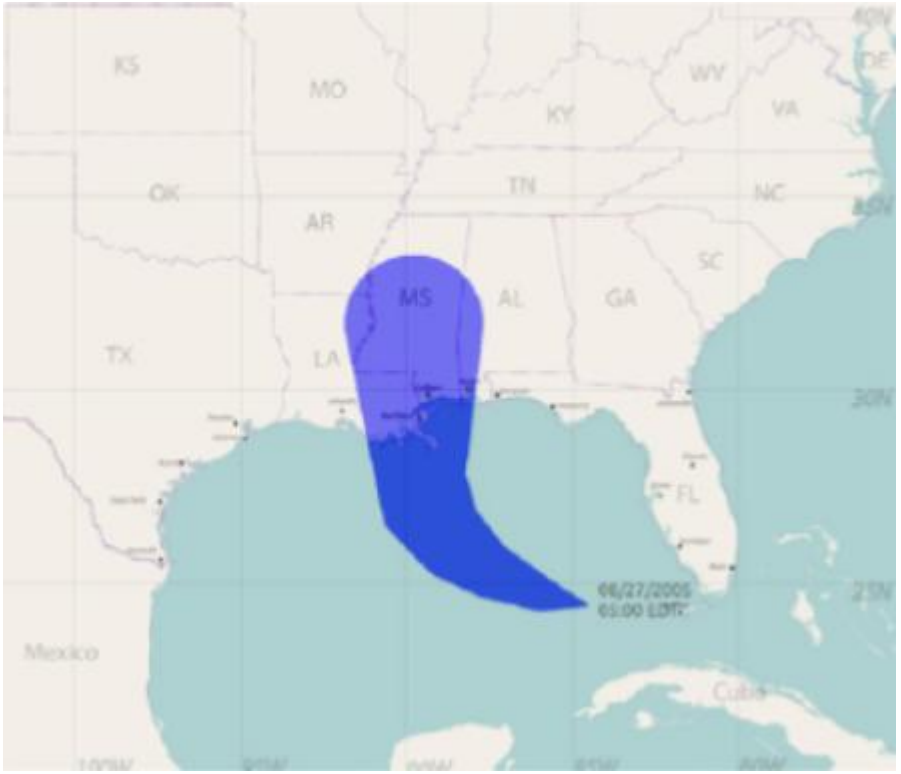
Boundaries lead people to believe that data inside and outside the boundaries are categorically different



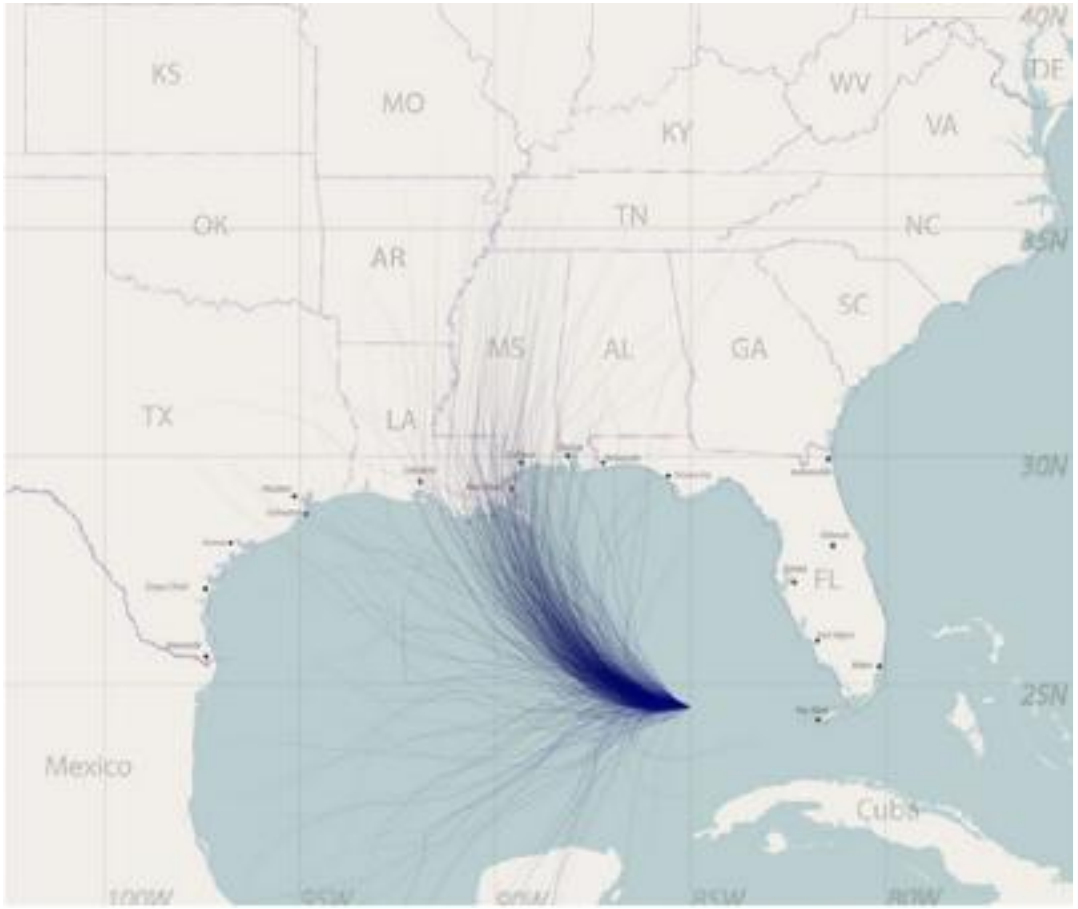
Padilla et al., 2020

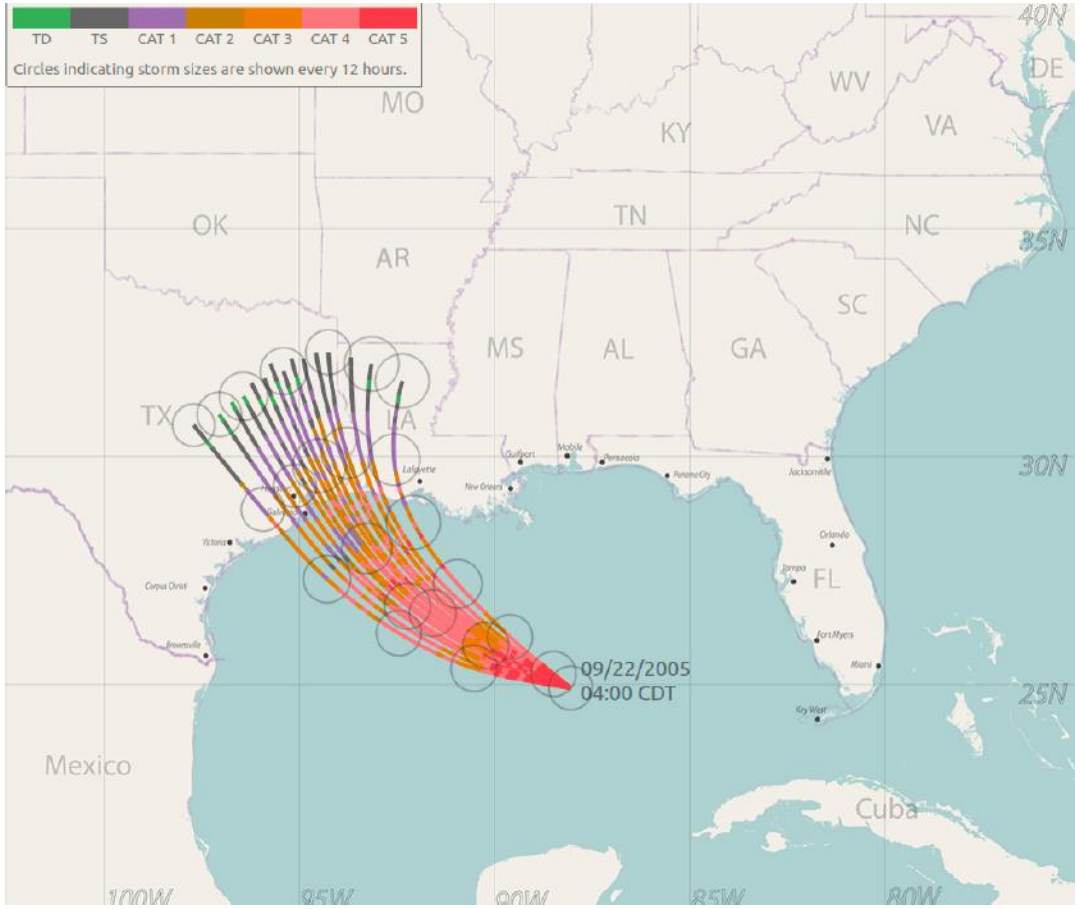
Visual Boundaries = Cognitive Categories

- Readers cannot ascertain that there's a distribution of uncertainty in the path
- By plotting a hard boundary, readers assume that the value of boundary is meaningful.
- However, the boundaries are often not well considered.
  - Why is the boundary located at 60%? Why not 70%, or 95%?



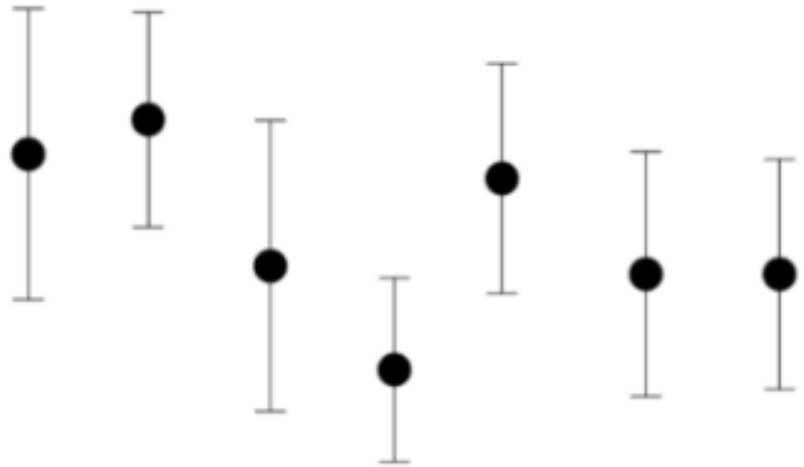
Ensemble Display





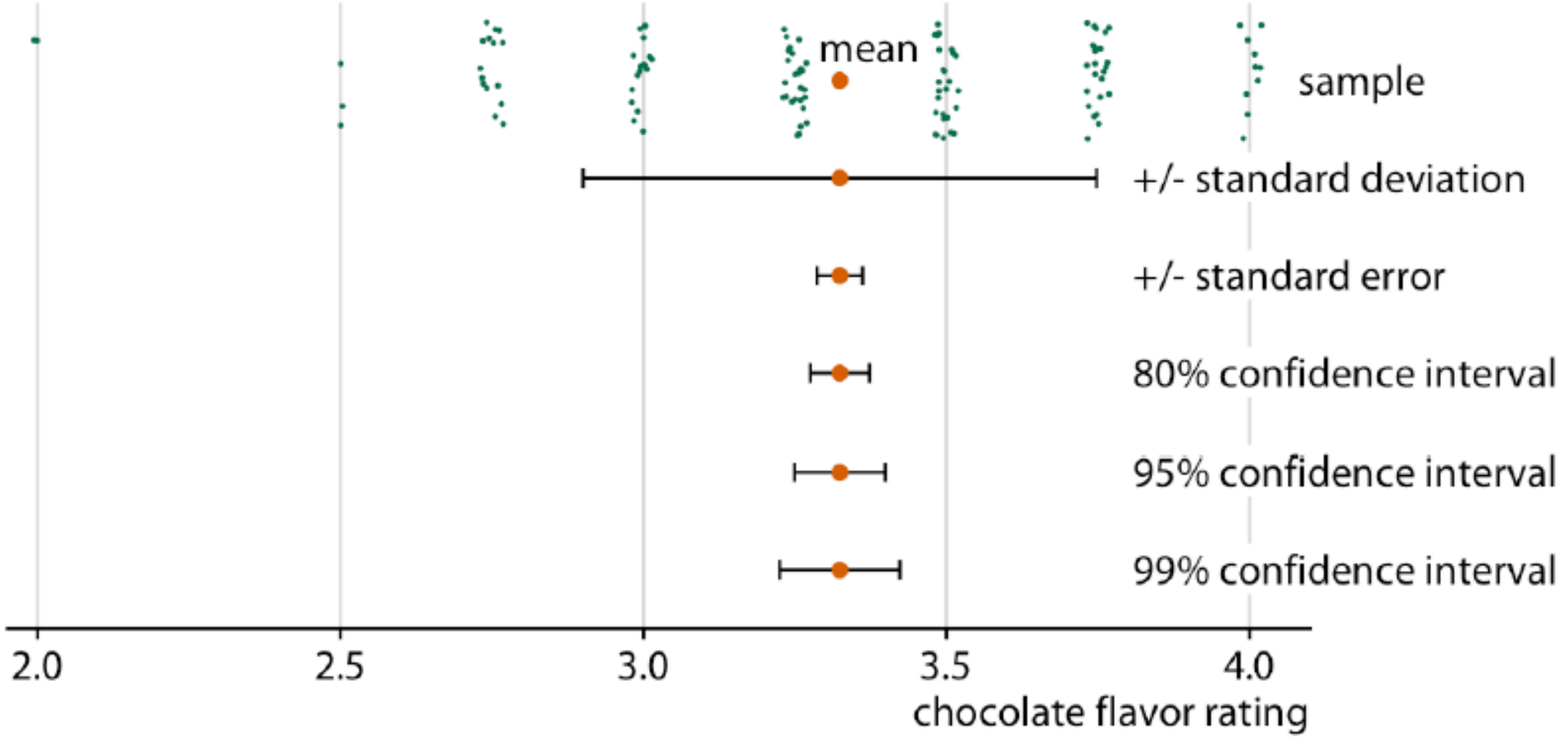
Liu et al., 2019; Padilla et al., 2020

Error bars



- Uncertainty can be visualized by using error bars because they show a range of values.
- It's useful to compare multiple estimates, because you can see overlap between categories.
- **But what do these error bars represent?**

Padilla et al., 2020; Wilke, 2019



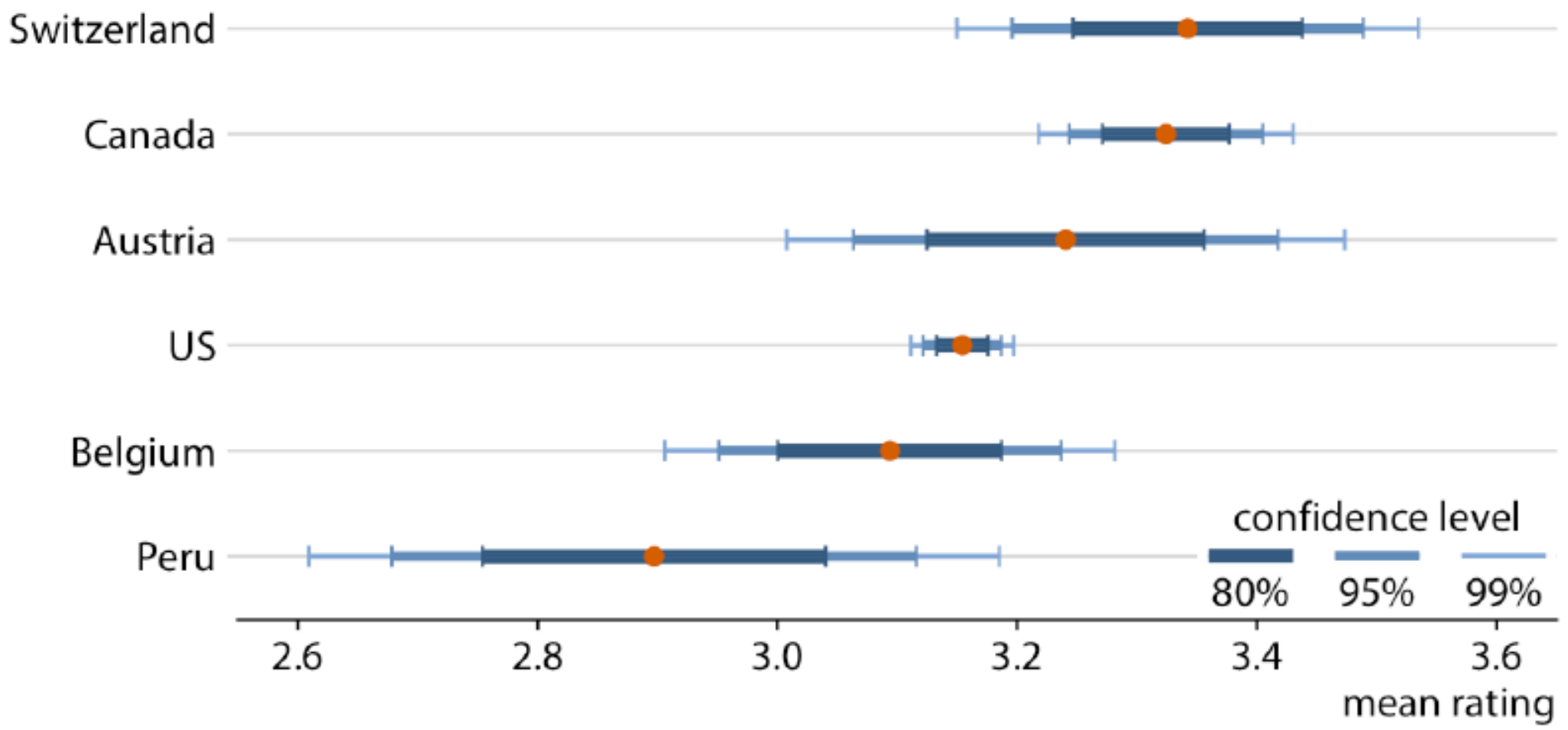
You must specify what quantity and/or confidence level the error bars represent.

Padilla et al., 2020; Wilke, 2019

Misconception in Error Bars: *Determinist Construal Errors*

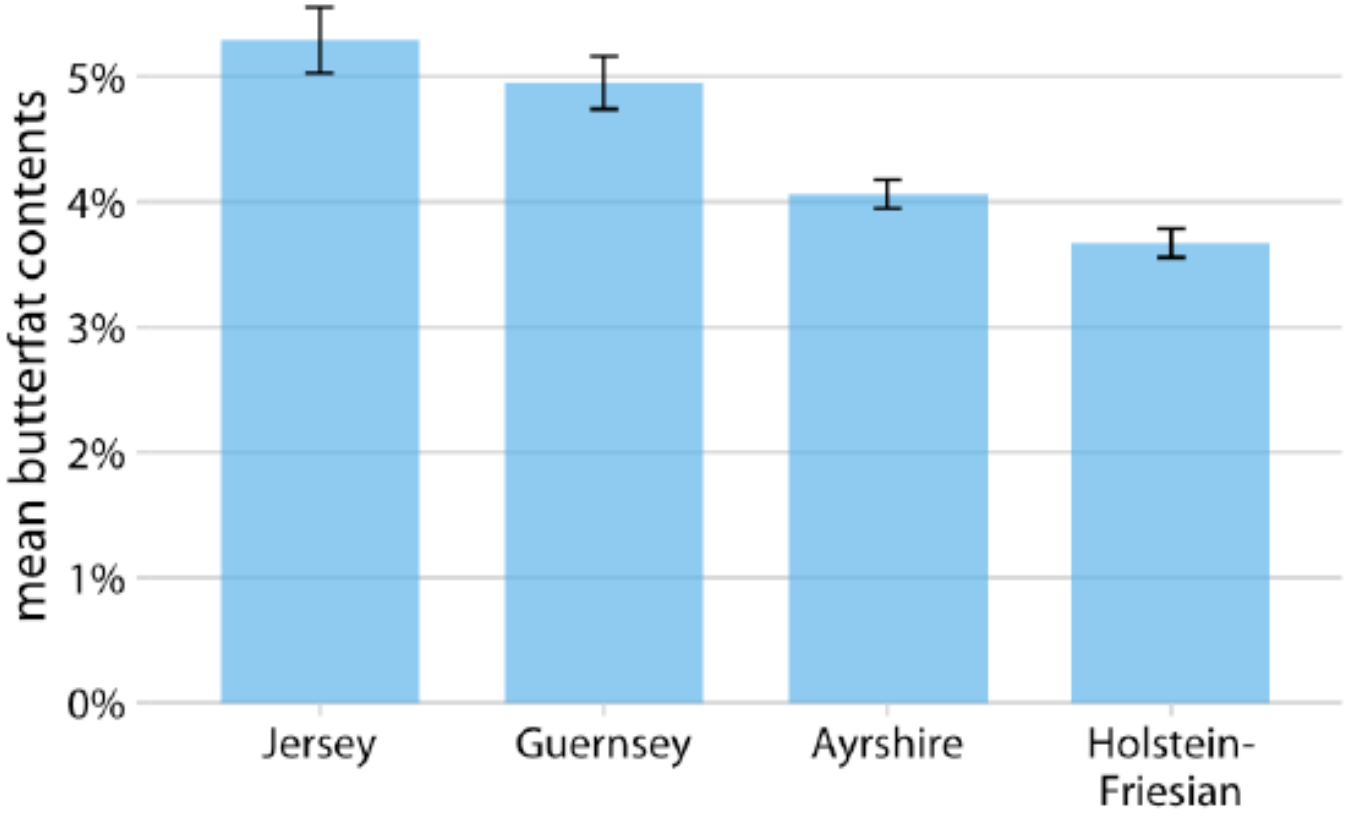
- Do error bars delineate the range of possible parameter estimate?
  - No, but readers might think the estimate could never fall outside the error bars. This misperception are called *deterministic construal errors*.
- To better visualize uncertainty, we want to minimize the risk of deterministic construal errors.

An Alternative: Graded Error Bars



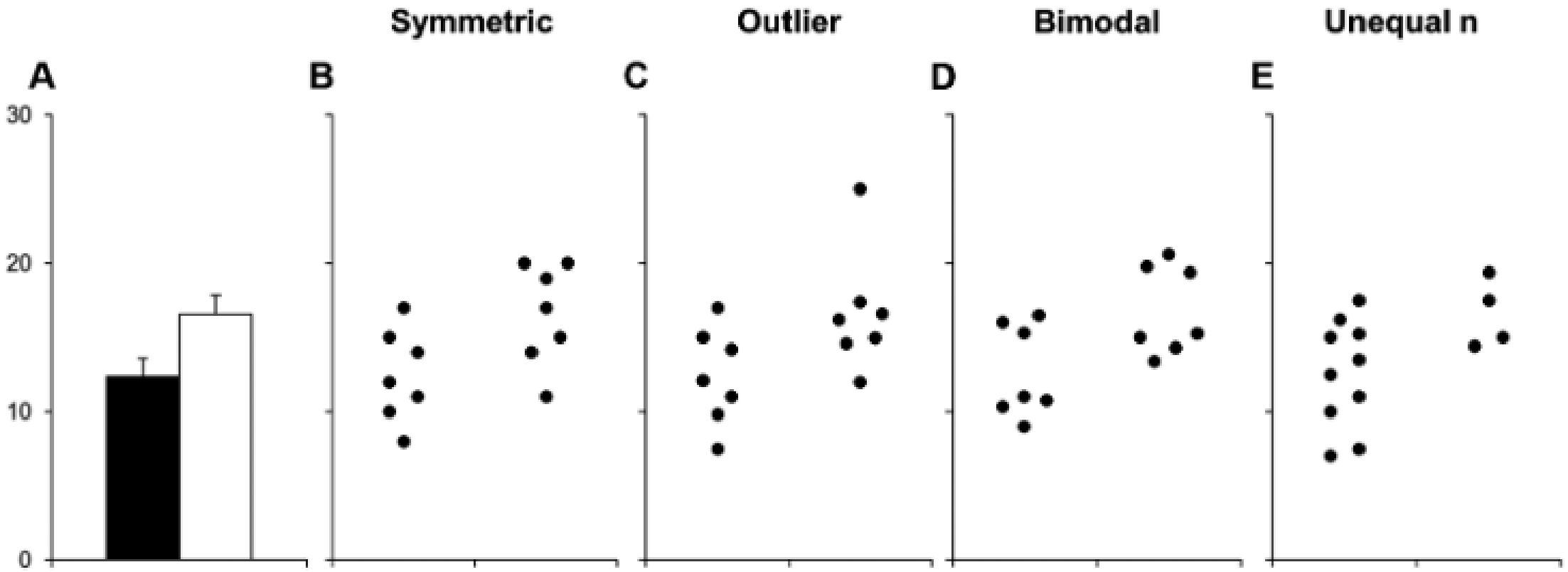
Wilke, 2019

Error bars combined with **bar plots** are commonly used



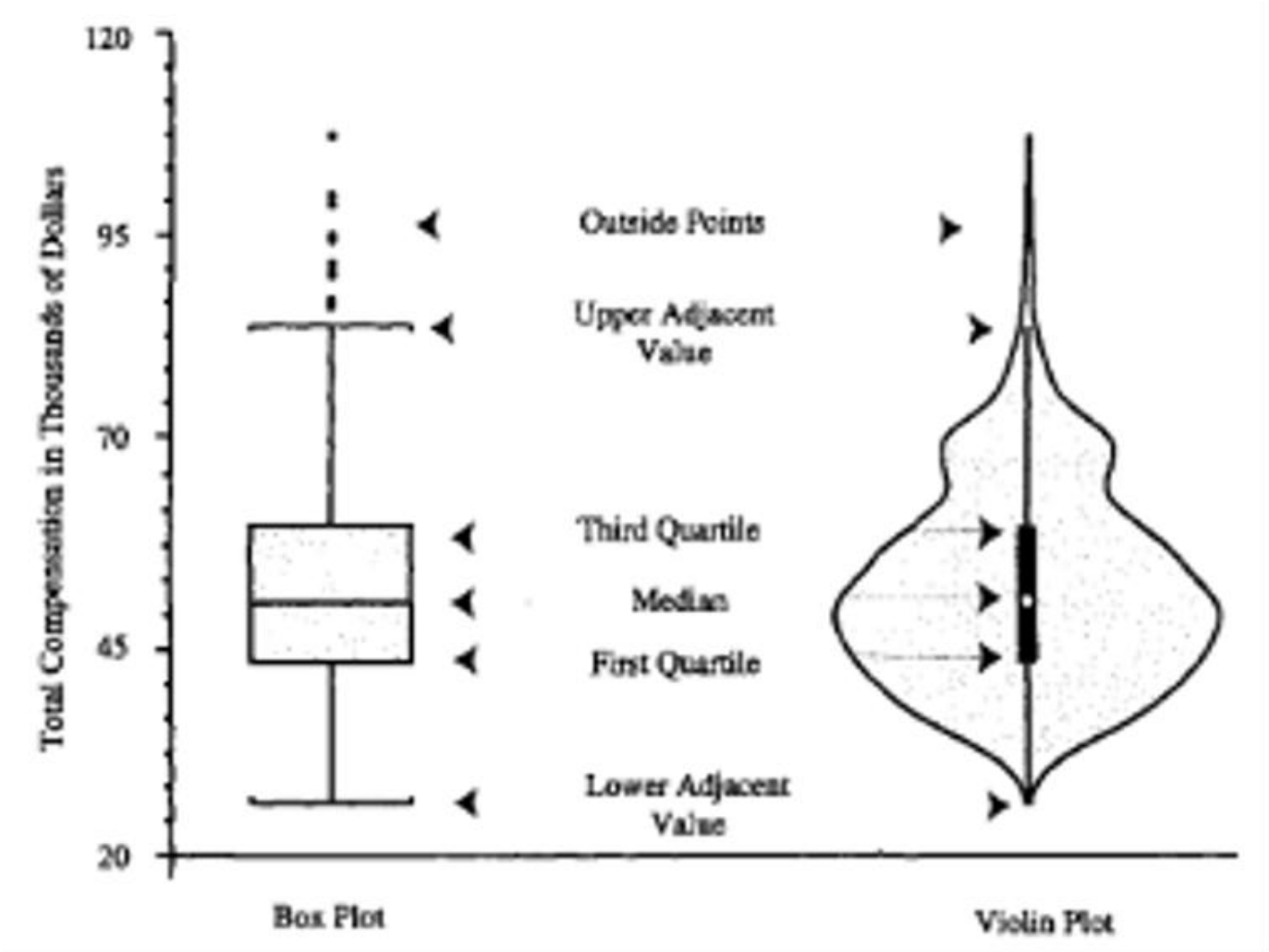
Wilke, 2019

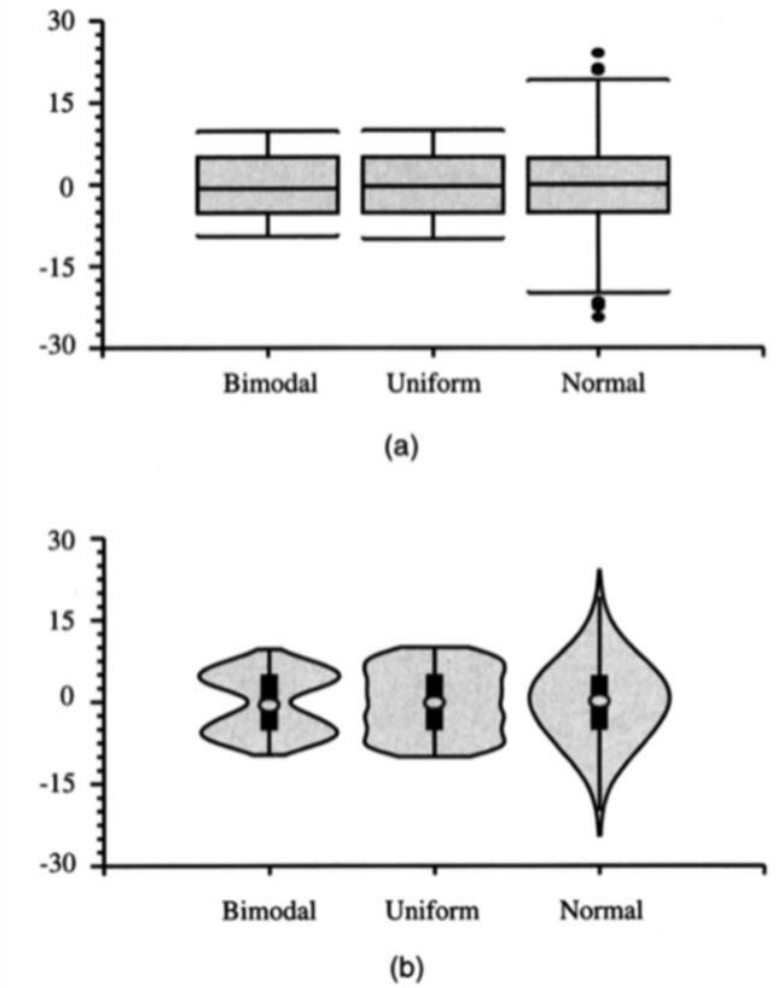
Limitation: It hides the characteristics of data



Weissgerber et al.,, 2015

Alternatives: box plots, violin plots



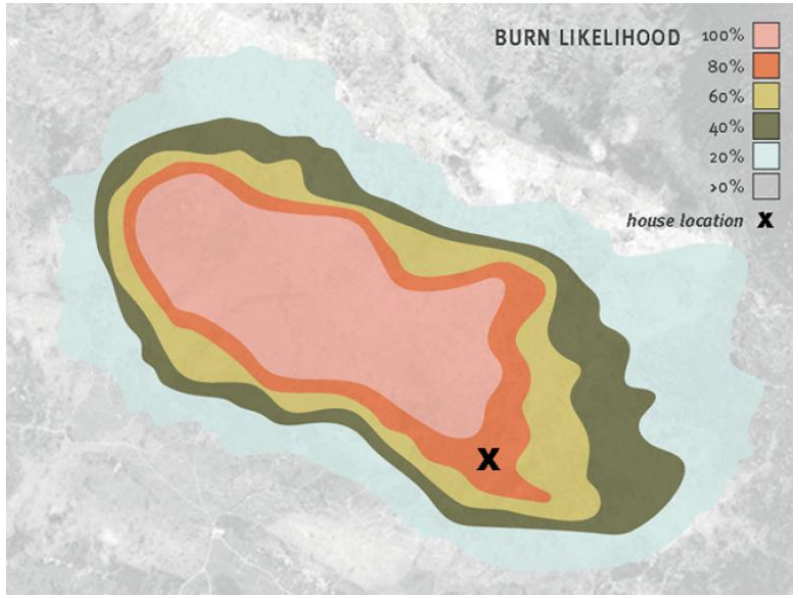


Hintze & Nelson,, 1998

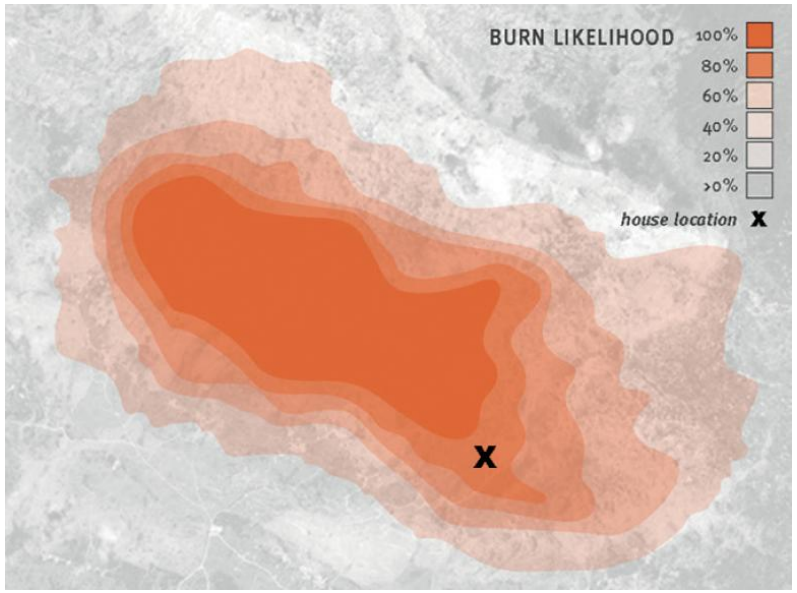
4. Visual Semiotics of Uncertainty

- Metaphoric associations with uncertainty; Intuitive ways to communicate uncertainty
- They can restrict viewers from making overly precise judgements when uncertainty is high.

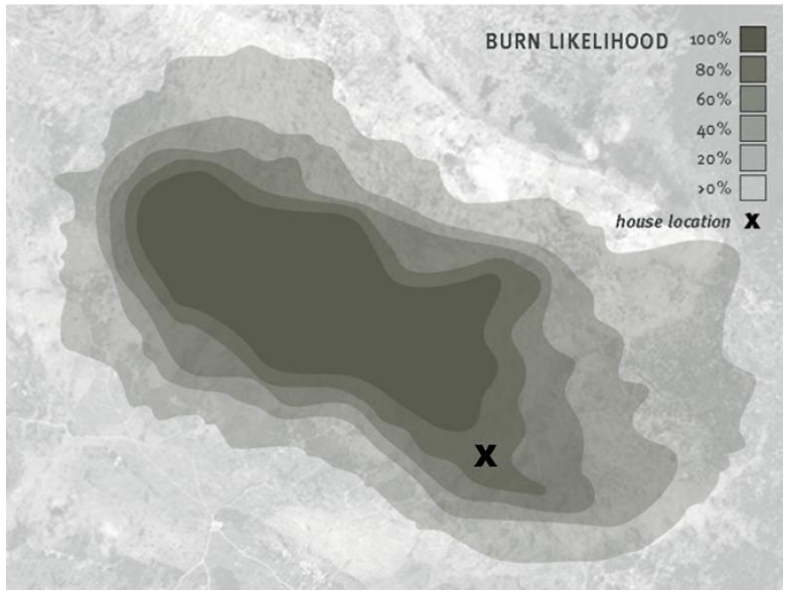
Levontin et al., 2020; Padilla et al., 2020



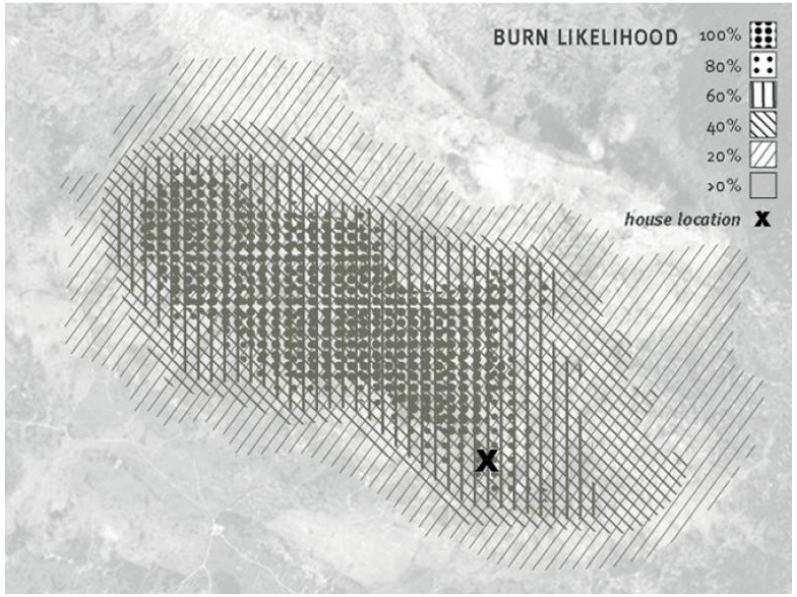
Colour hue



Colour value



Transparency

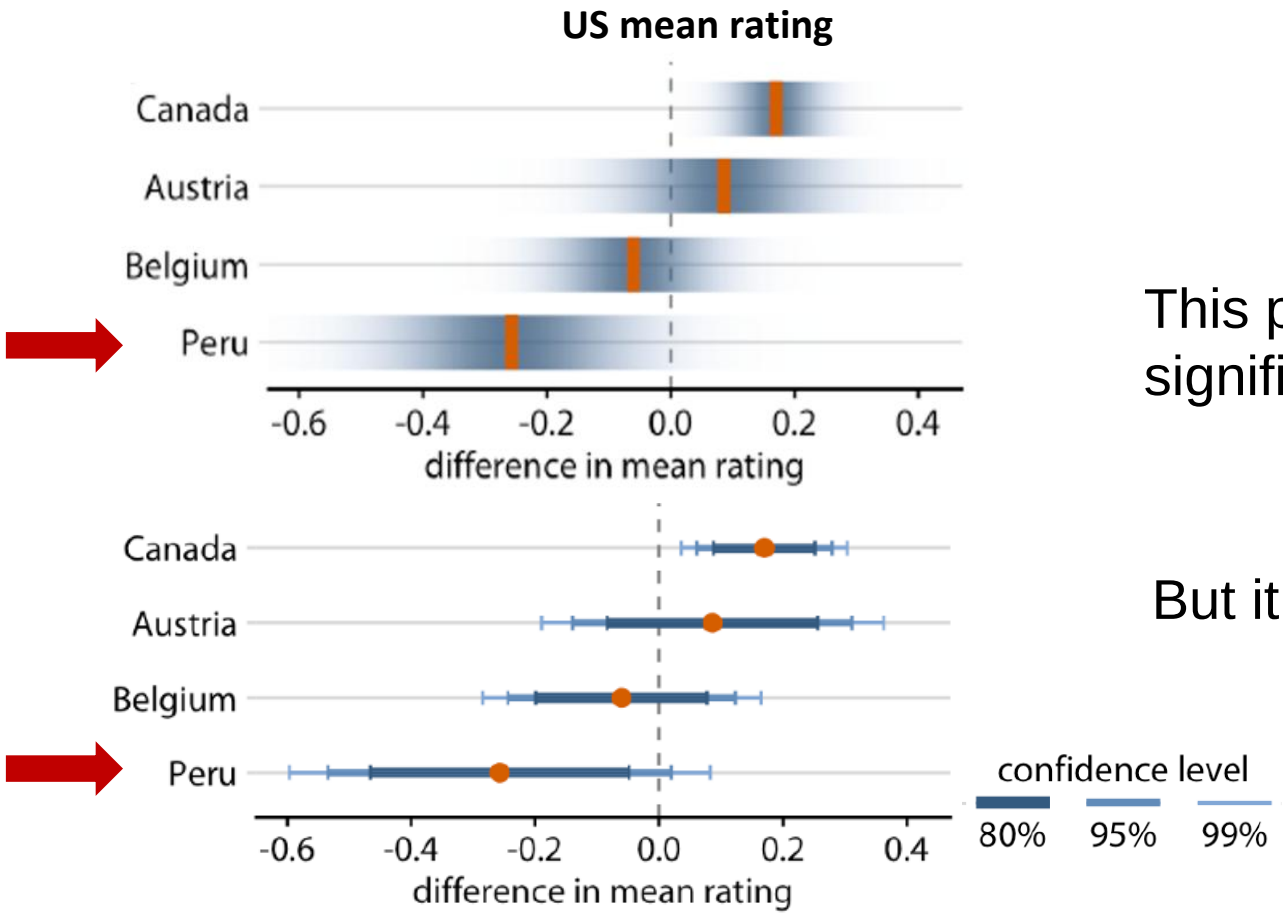


Texture

Levontin et al., 2020

Consider your purposes

- For task requiring readers to look up specific values, metaphoric uncertainty can produce worse performance

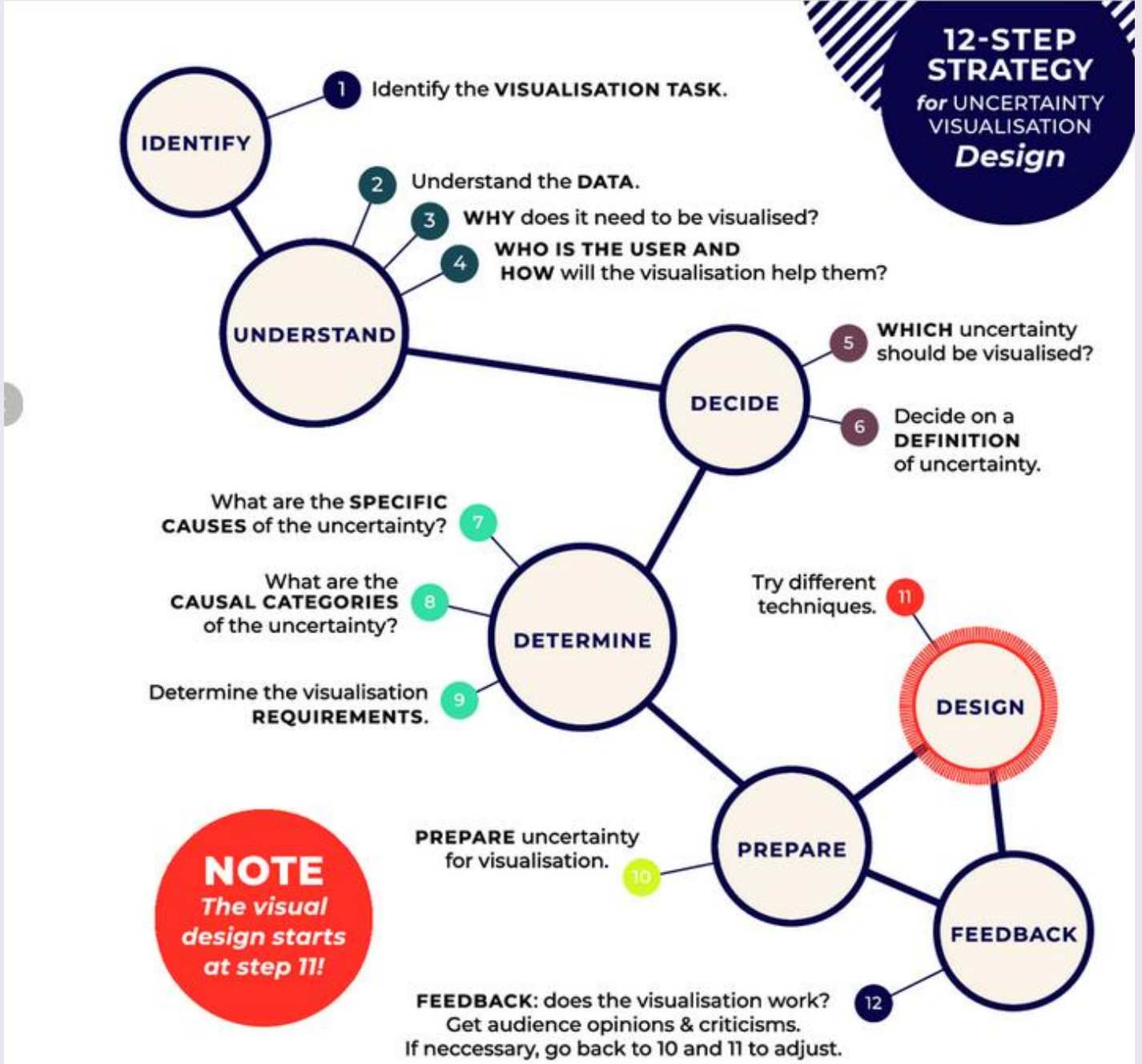


This plot can lead one to conclude that **Peru** is significantly different from US.

But it is actually not.

Padilla et al., 2020; Wilke, 2019

12-Step Strategy for Uncertainty Visualization Design



12-Step Strategy for Uncertainty Visualisation. Based on the Uncertainty Visualization Development Strategy (UVDS) by AnnaLiesa S. Lapinsky (2009). Created by Jana Kleineberg.

Thank you!

References

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