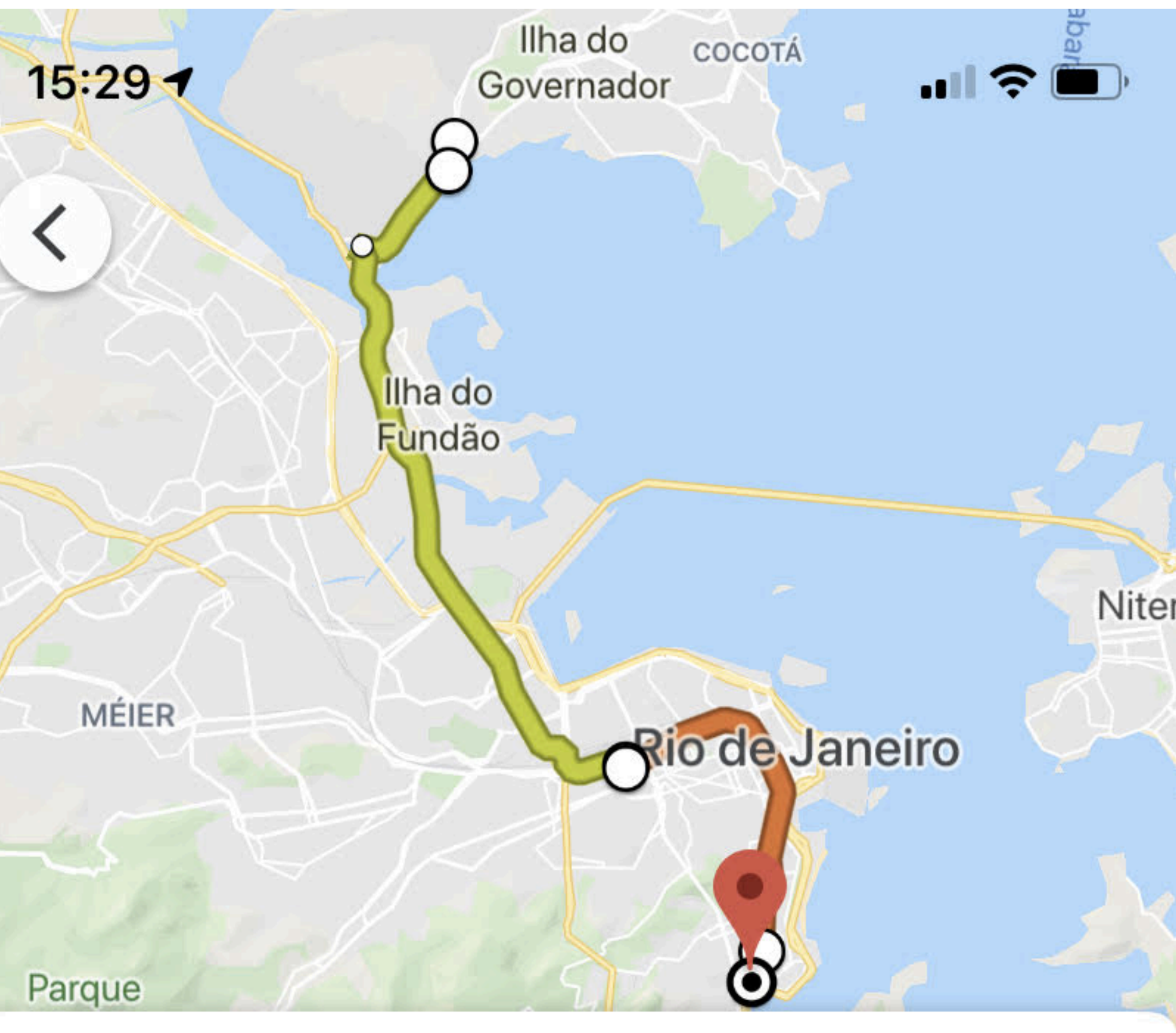


Visualization of Uncertain Spatial Data

Nivan Ferreira












15:29

6 > 323 > M L1, L4 > 8

1 h 42 min

Galeão 15:30

Rio de Janeiro - RJ

Estrada do Galeão próximo ao 6008-6362		
Conexões para Rua Carmo Neto próximo ao 63-91		
 323 Castelo	Previsto · 15:37	8 min
 321 Castelo	Previsto · 15:40	11 min
 323 Castelo	Previsto · 15:47	18 min
 321 Castelo	Previsto · 15:50	21 min
 323 Castelo	Previsto · 15:57	28 min

 321 Castelo		
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Estrada do Galeão próximo ao 6008-6362

Conexões para Rua Carmo Neto próximo ao 63-91

 323 Castelo

Previsto · 15:37

8
min

 321 Castelo

Previsto · 15:40

11
min

 323 Castelo

Previsto · 15:47

18
min

 321 Castelo

Previsto · 15:50

21
min

 323 Castelo

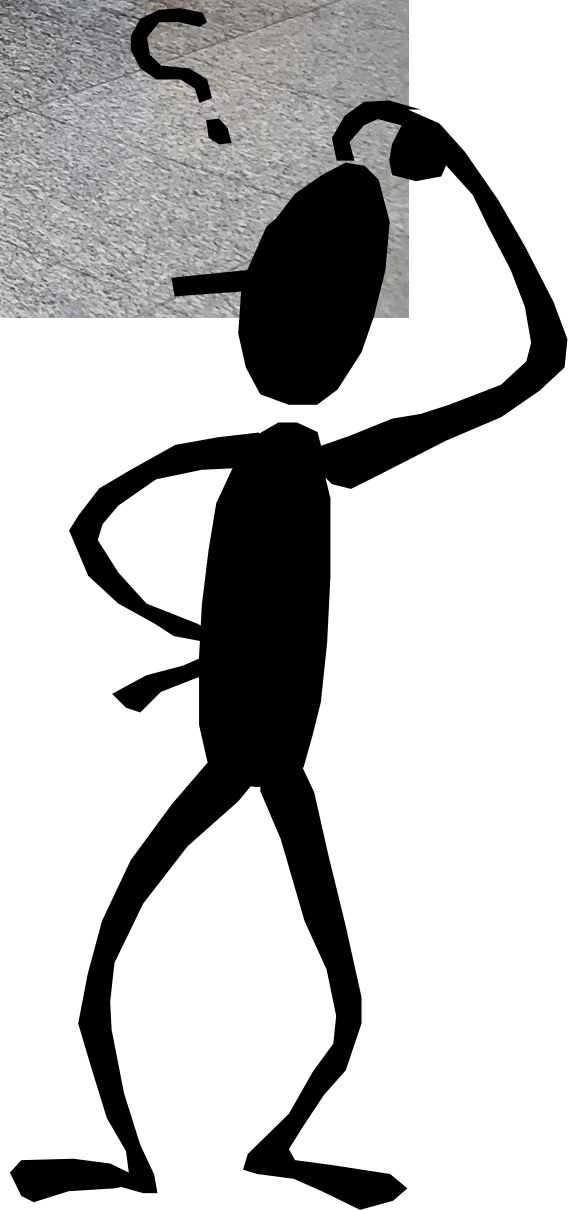
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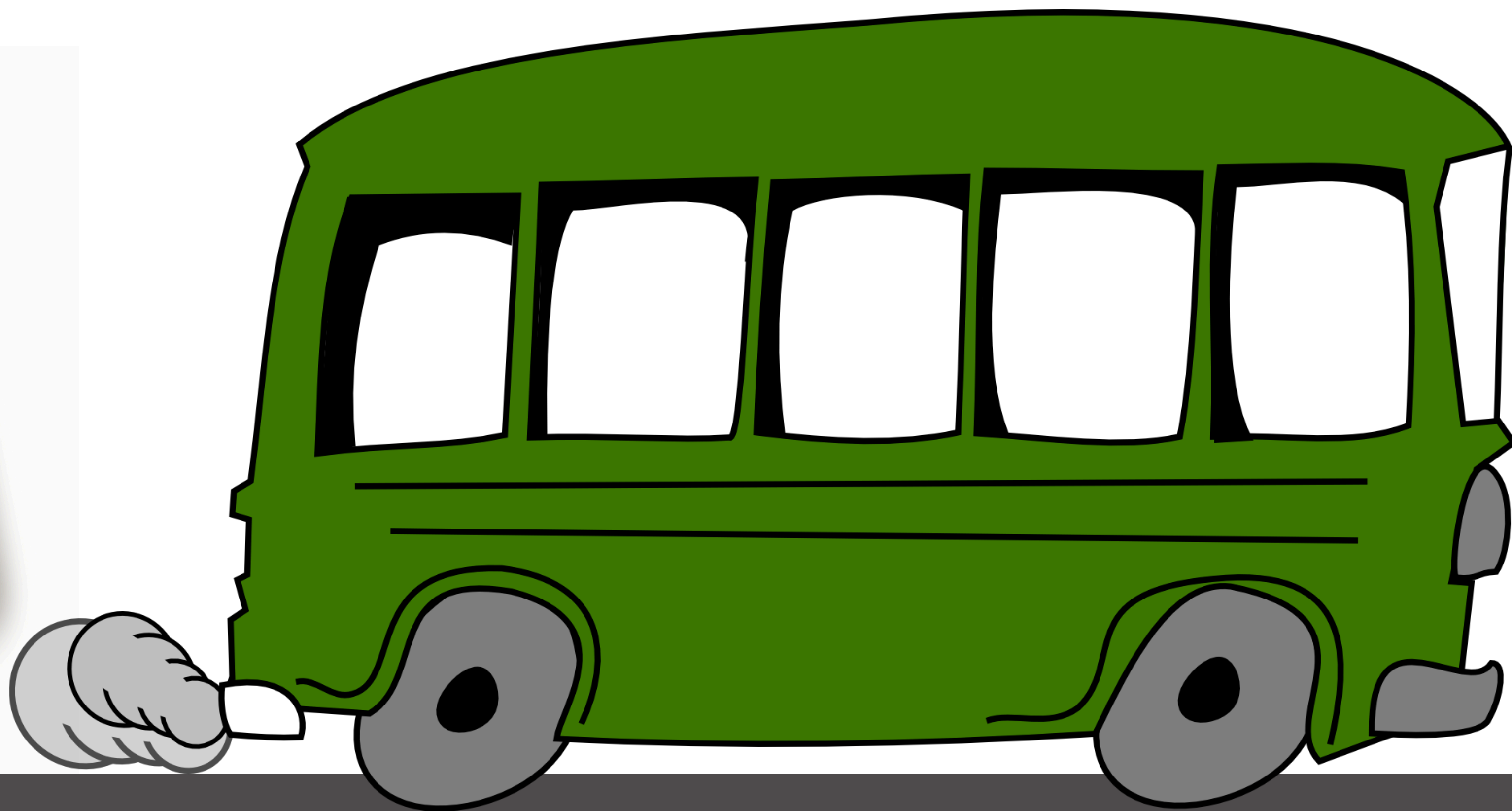
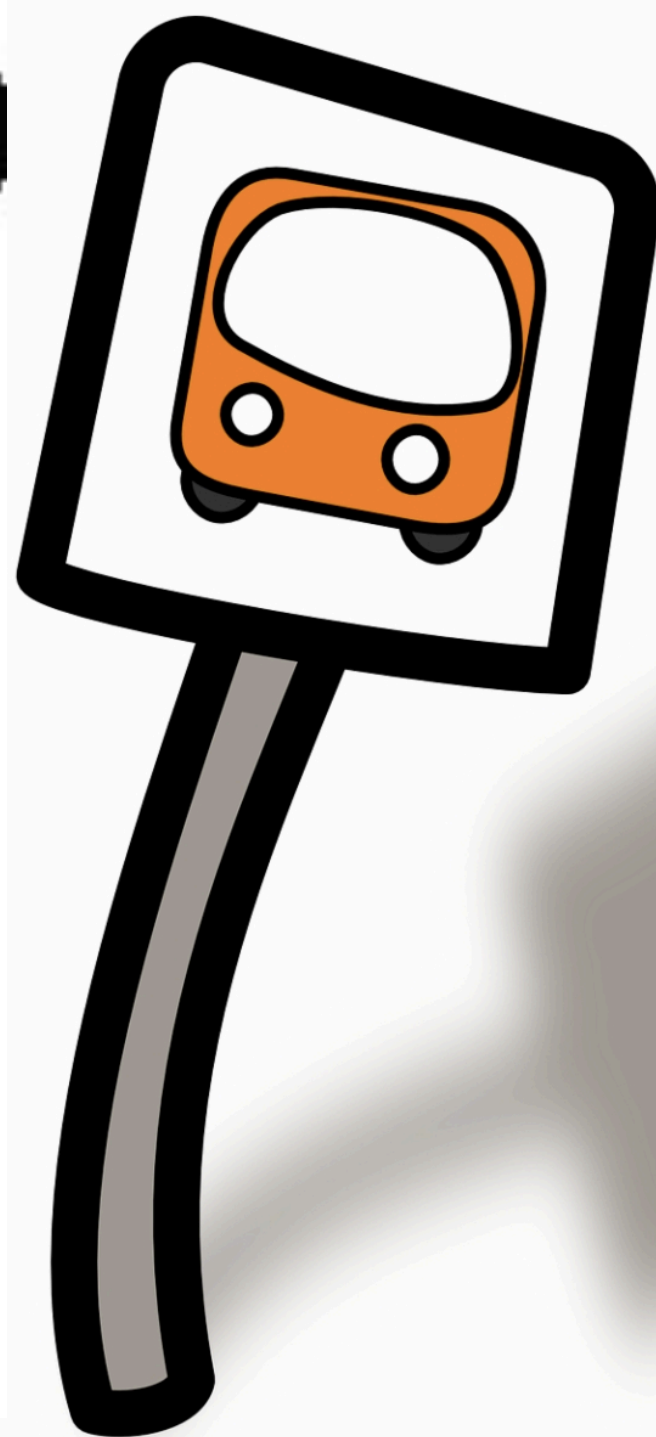
28
min

 321 Castelo



31
min



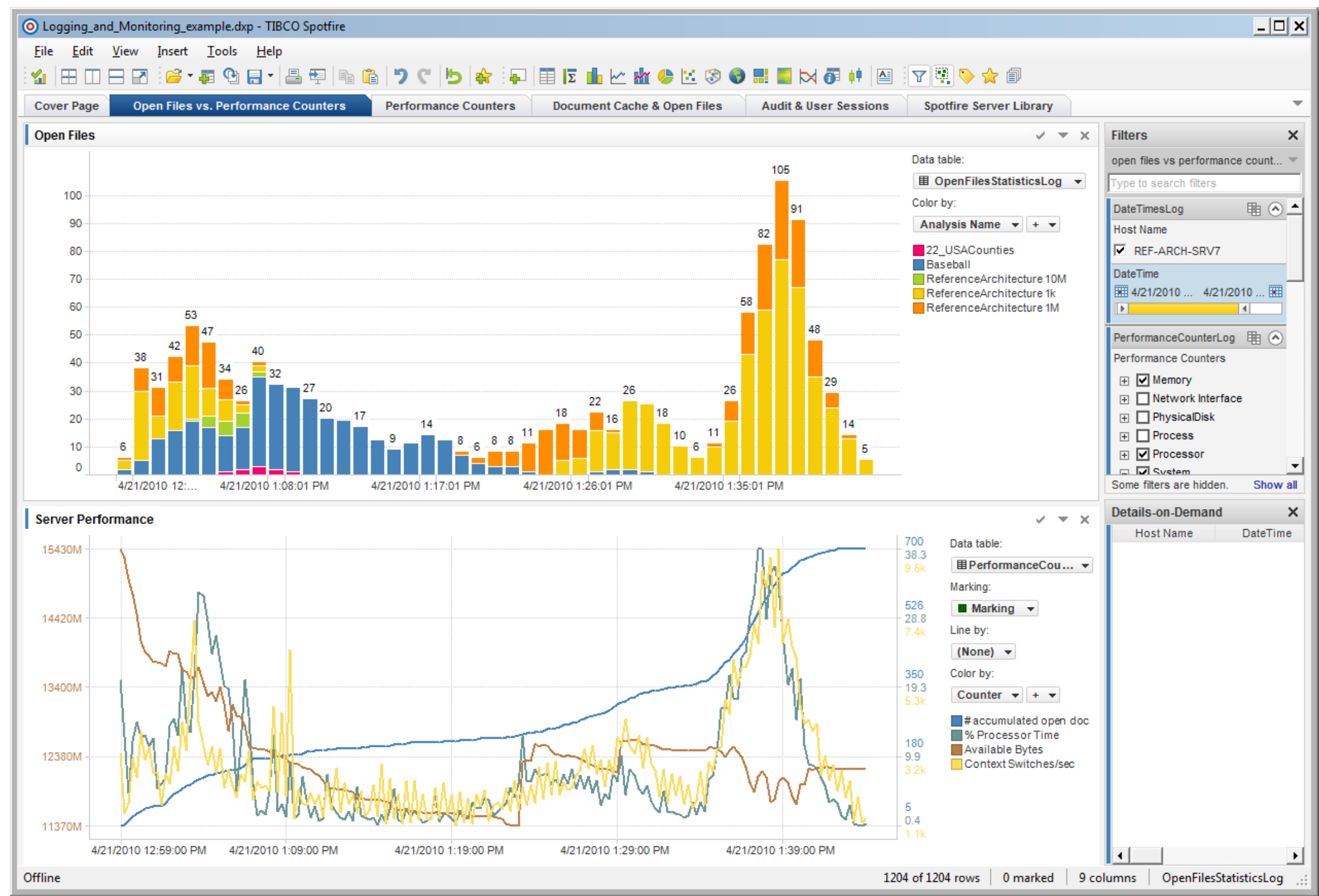
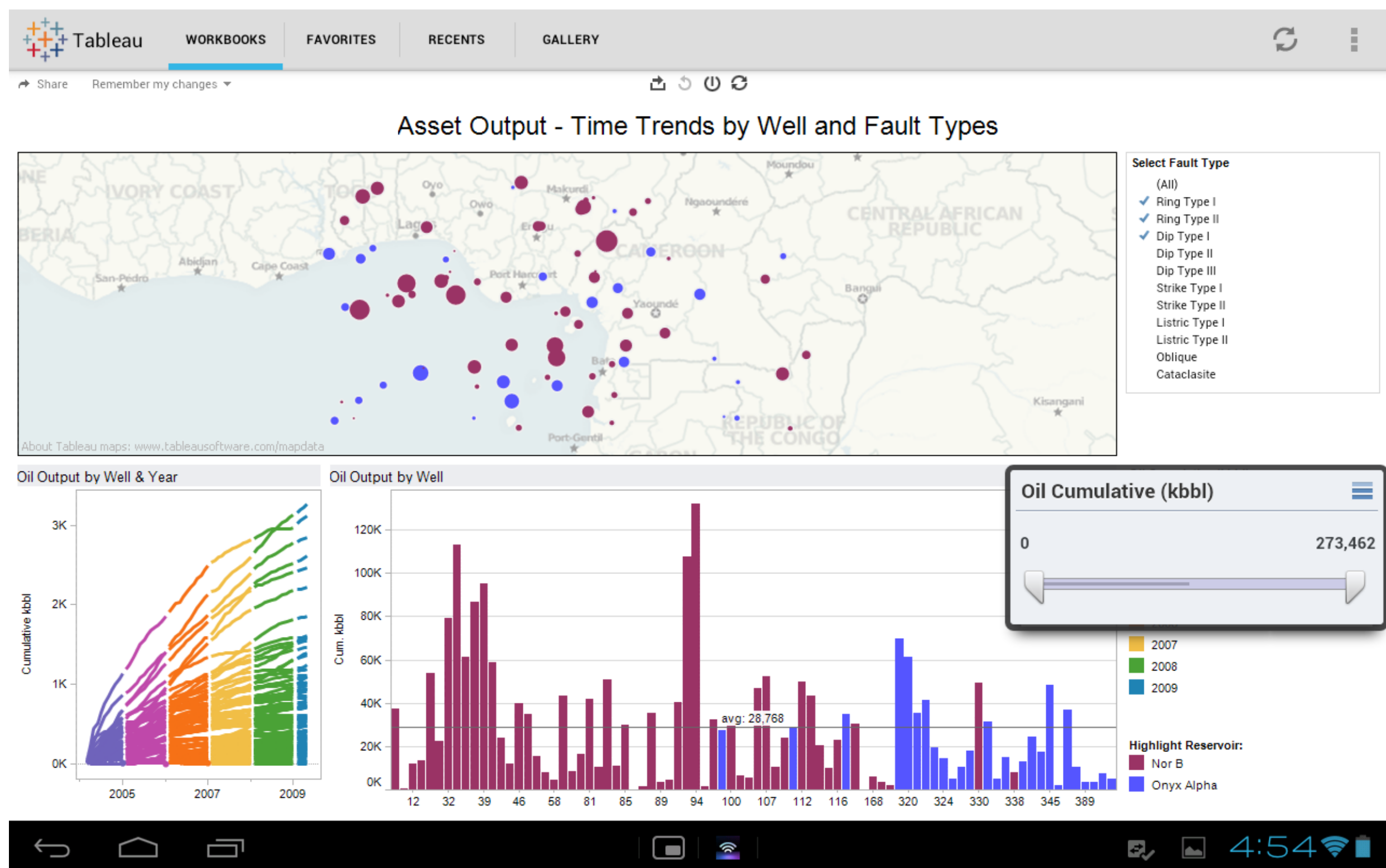


**Uncertainty is key for decision making
and therefore for data analysis**

[Kay et al. 2016][Fernandes et al. 2018]

[Potter et al. 2010]

However in many cases it is ignored



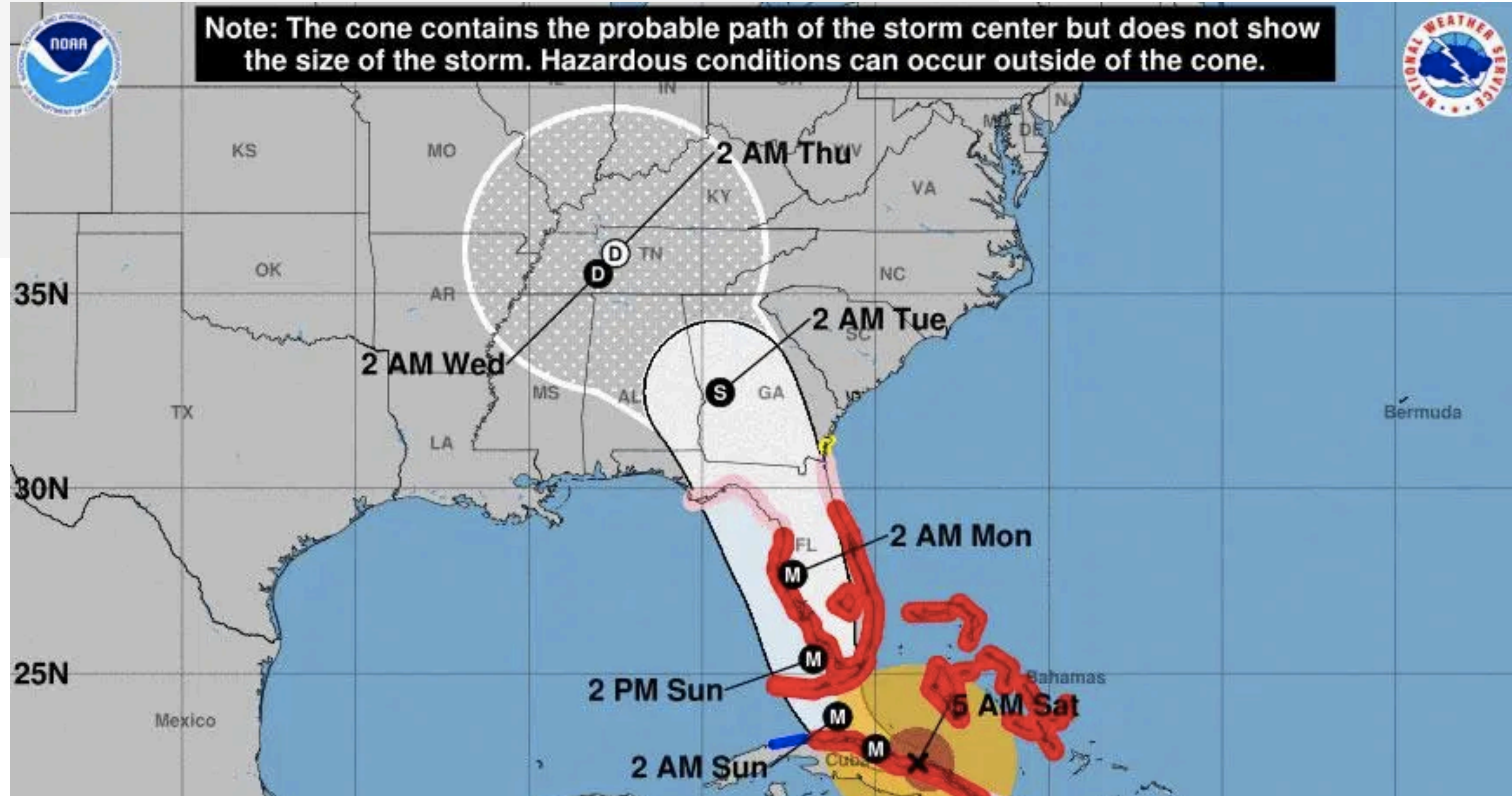
DESIGN FLAW

Hurricane Irma: Many Floridians are now in danger because they didn't know how to read a hurricane map

September 9, 2017

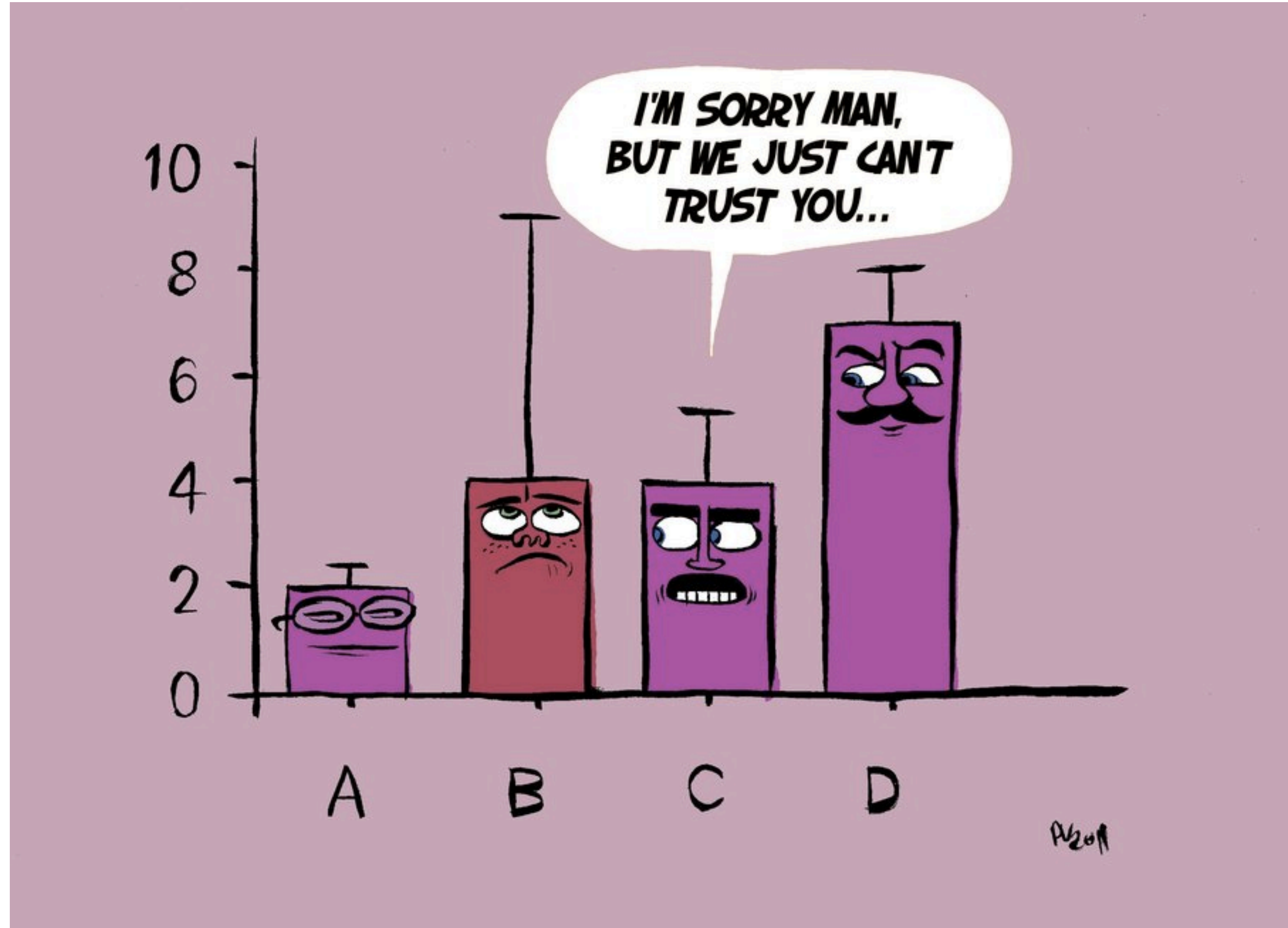


By **Dave Gershgorn**
Artificial intelligence reporter

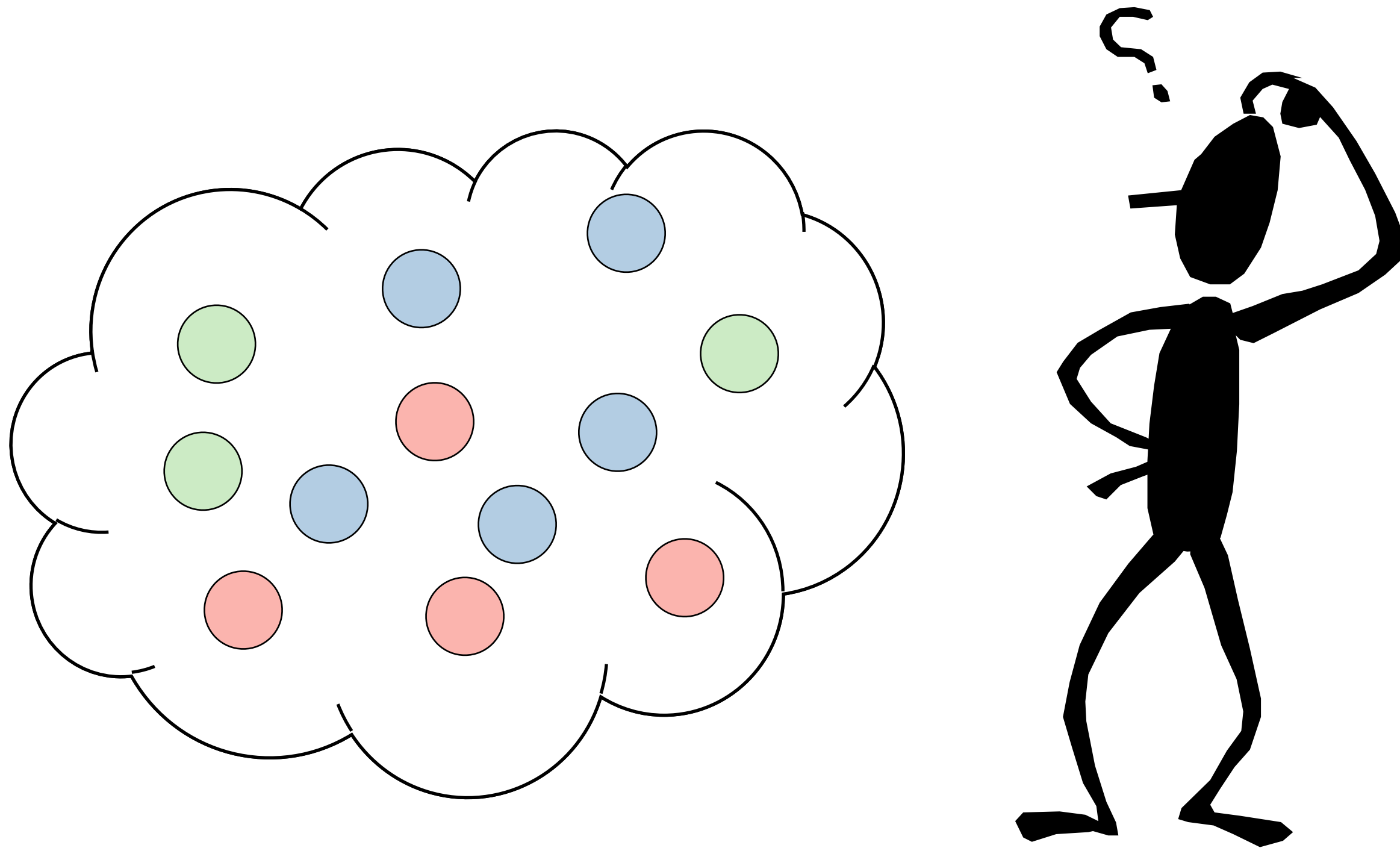


What is Uncertainty Anyway?

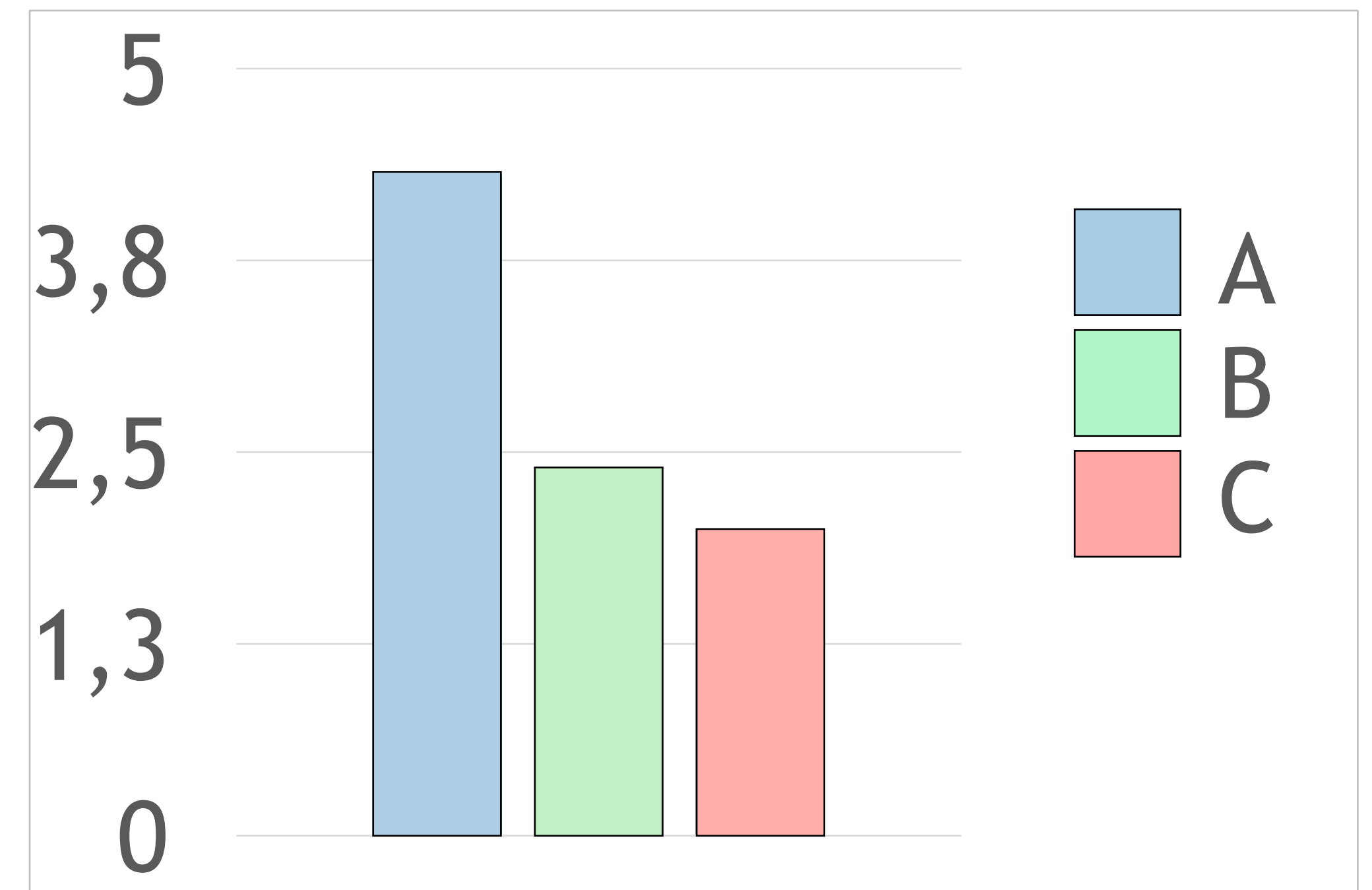
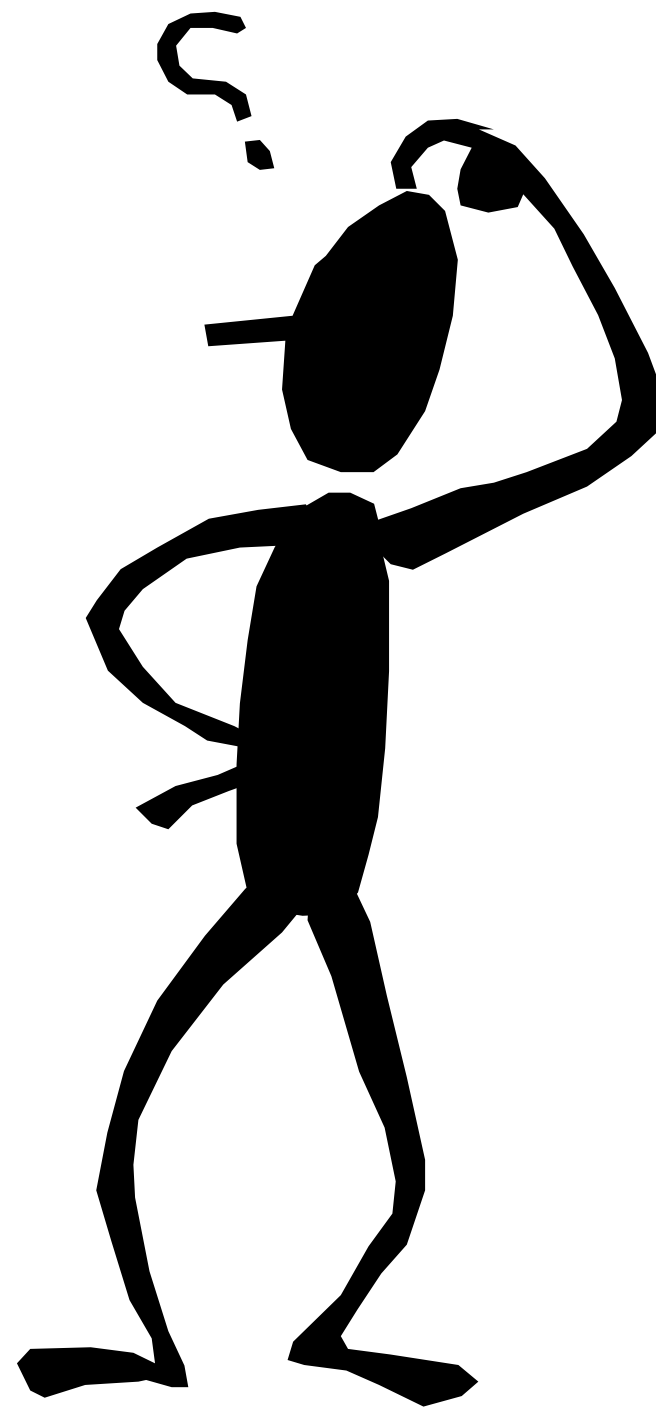
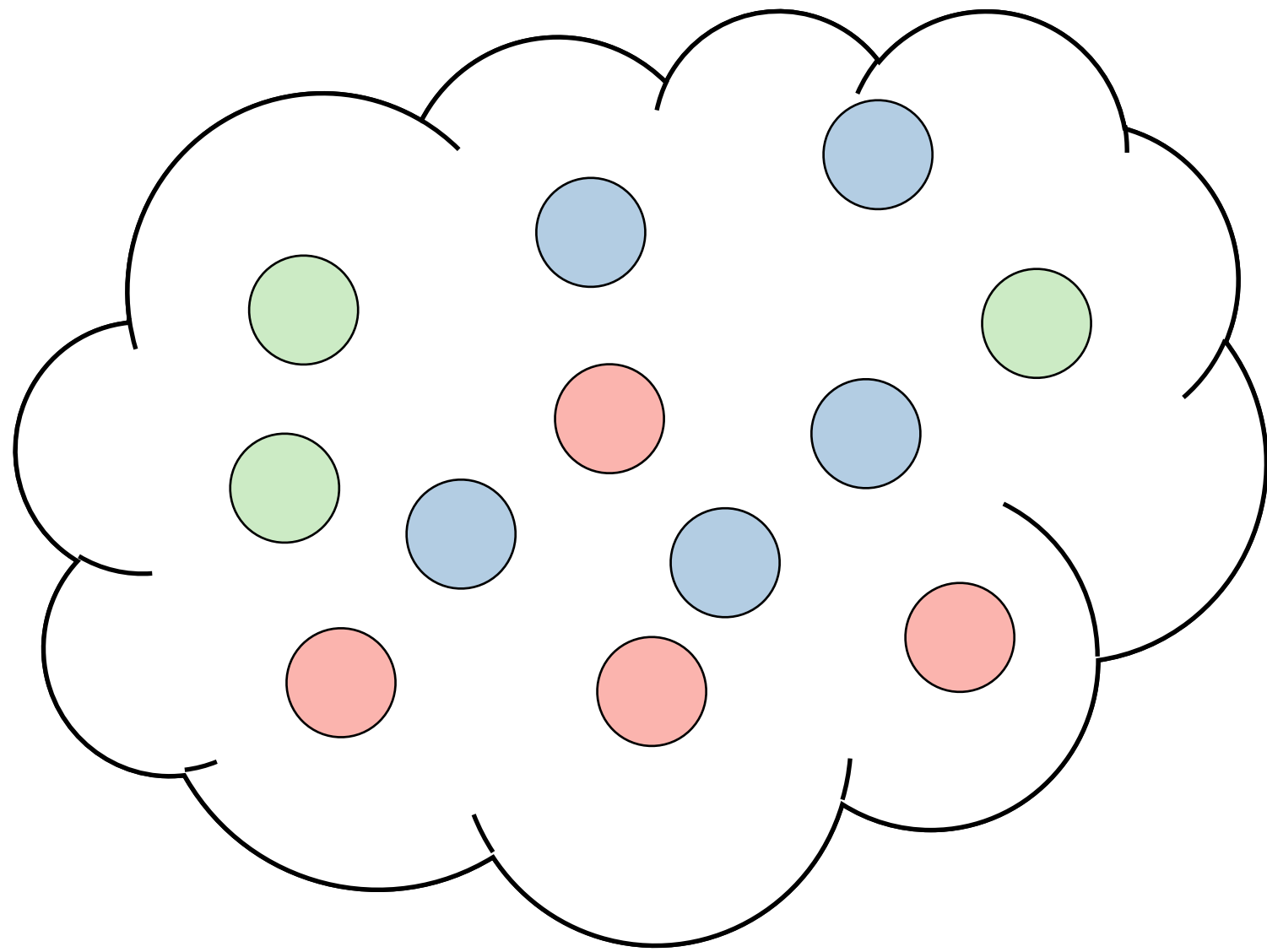
- Error
- Accuracy
- Confidence Level
- Missing Data
- Randomness



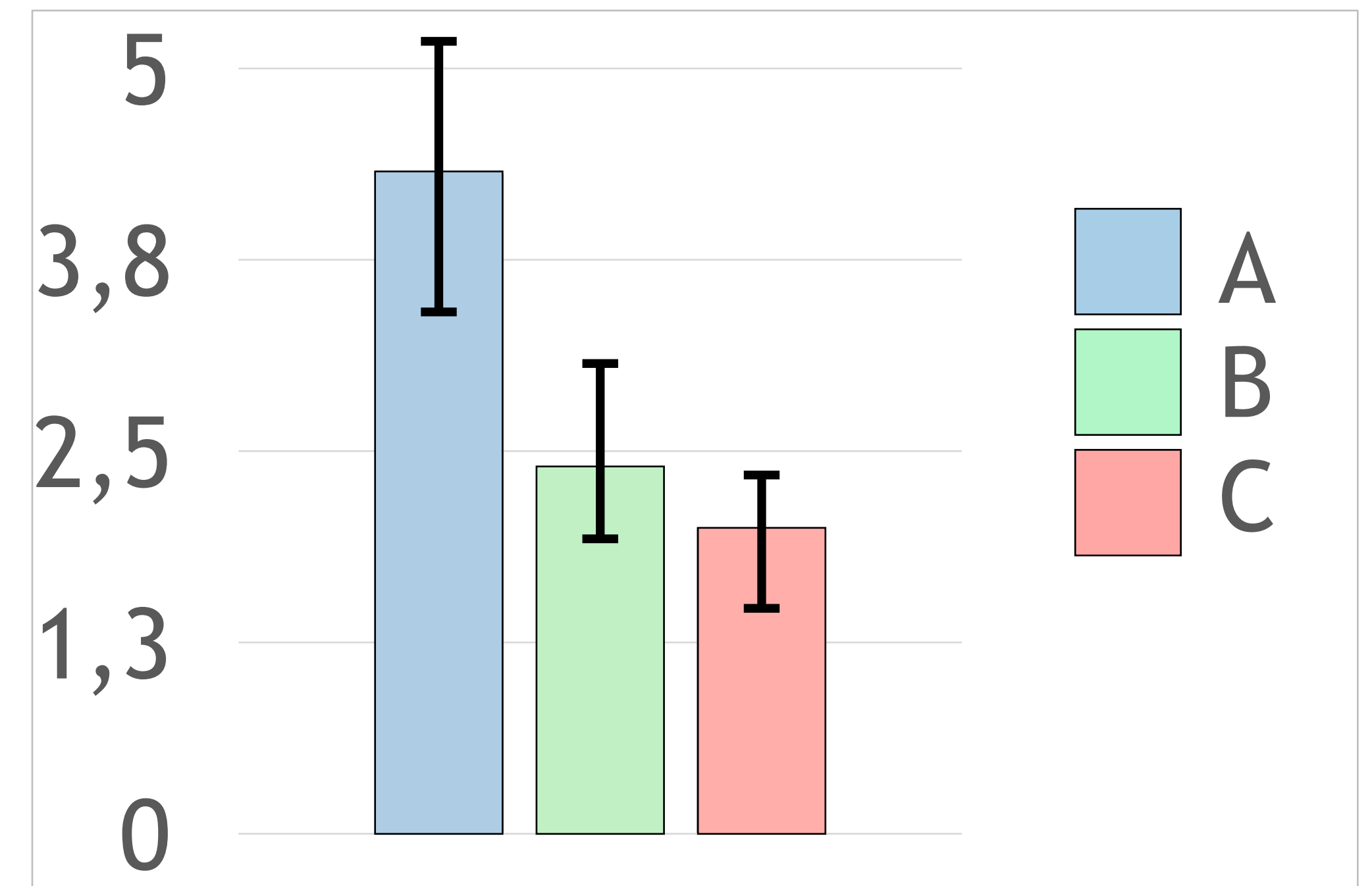
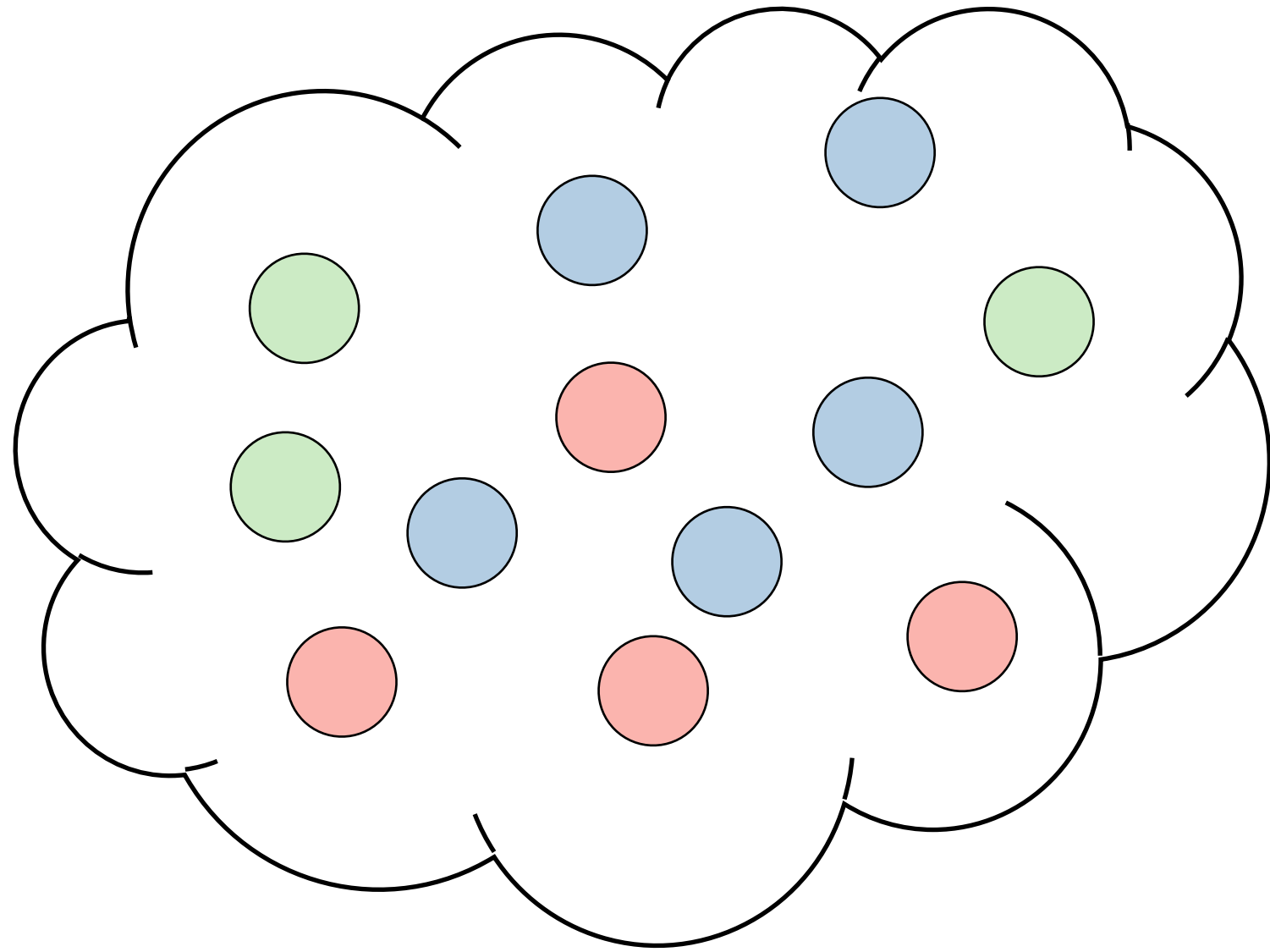
What is Uncertainty Anyway?



What is Uncertainty Anyway?



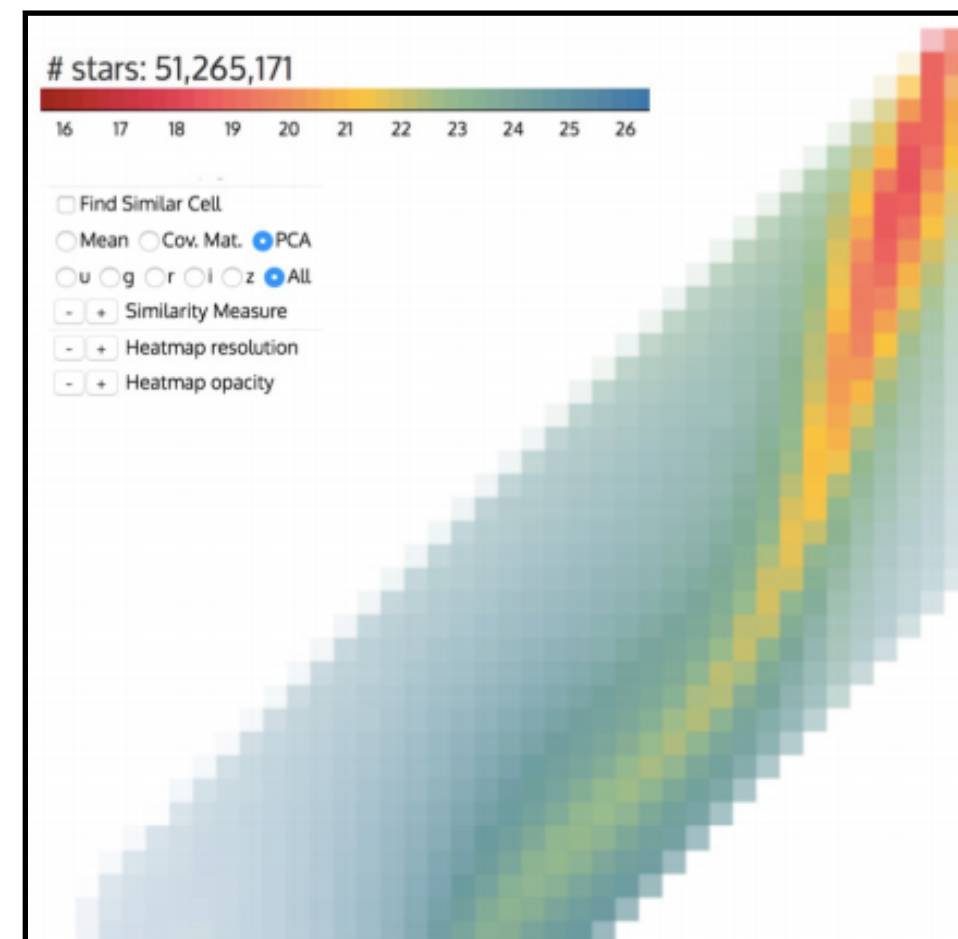
Data Modeled by Probability Distributions



Data Modeled by Probability Distributions



QDS
[Pahins et al., 2019]

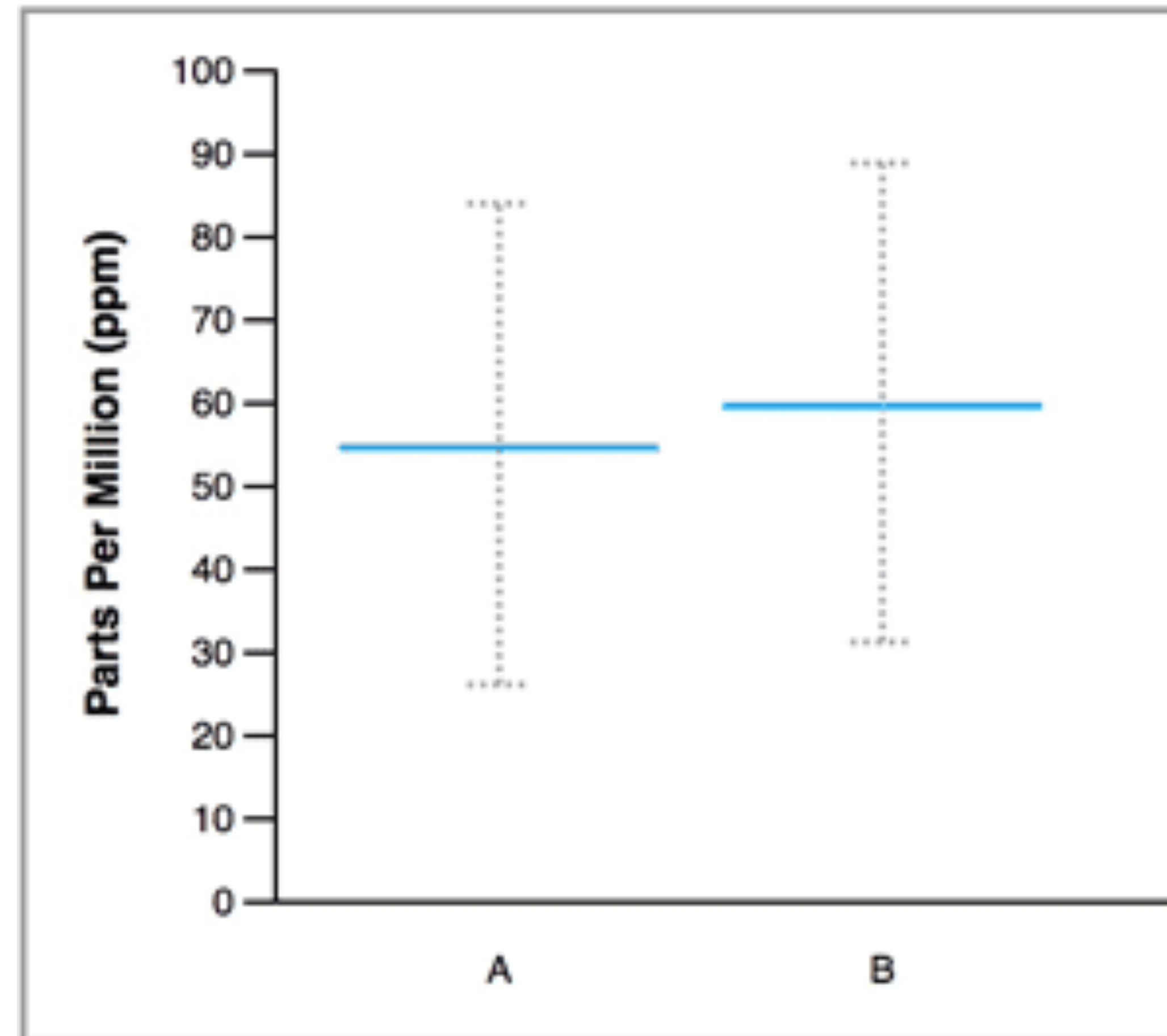


Gaussian Cubes
[Wang et al., 2016]



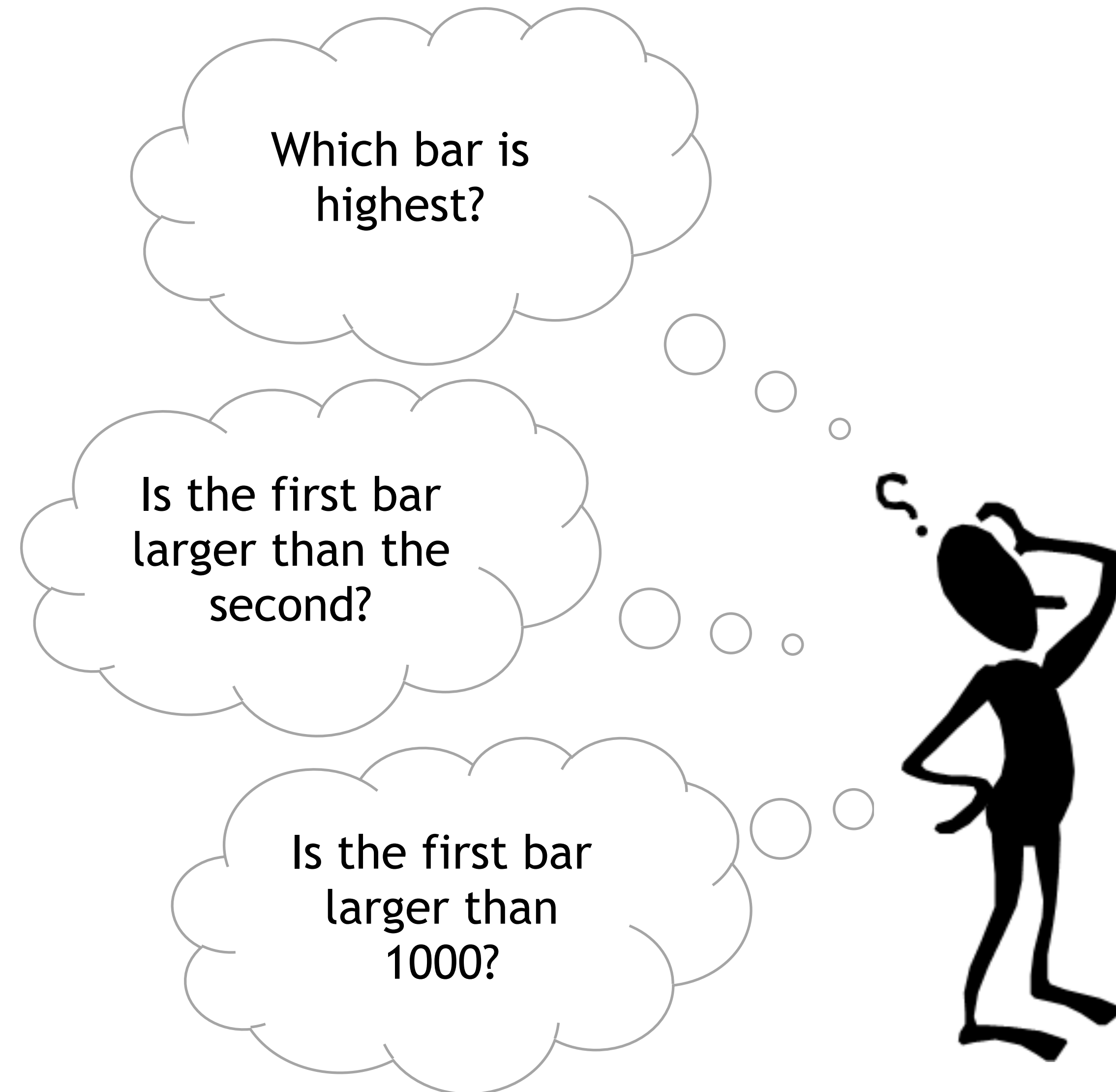
Progressive Analytics
[Moritz et al., 2017]

Current Methods do not Solve the Problem

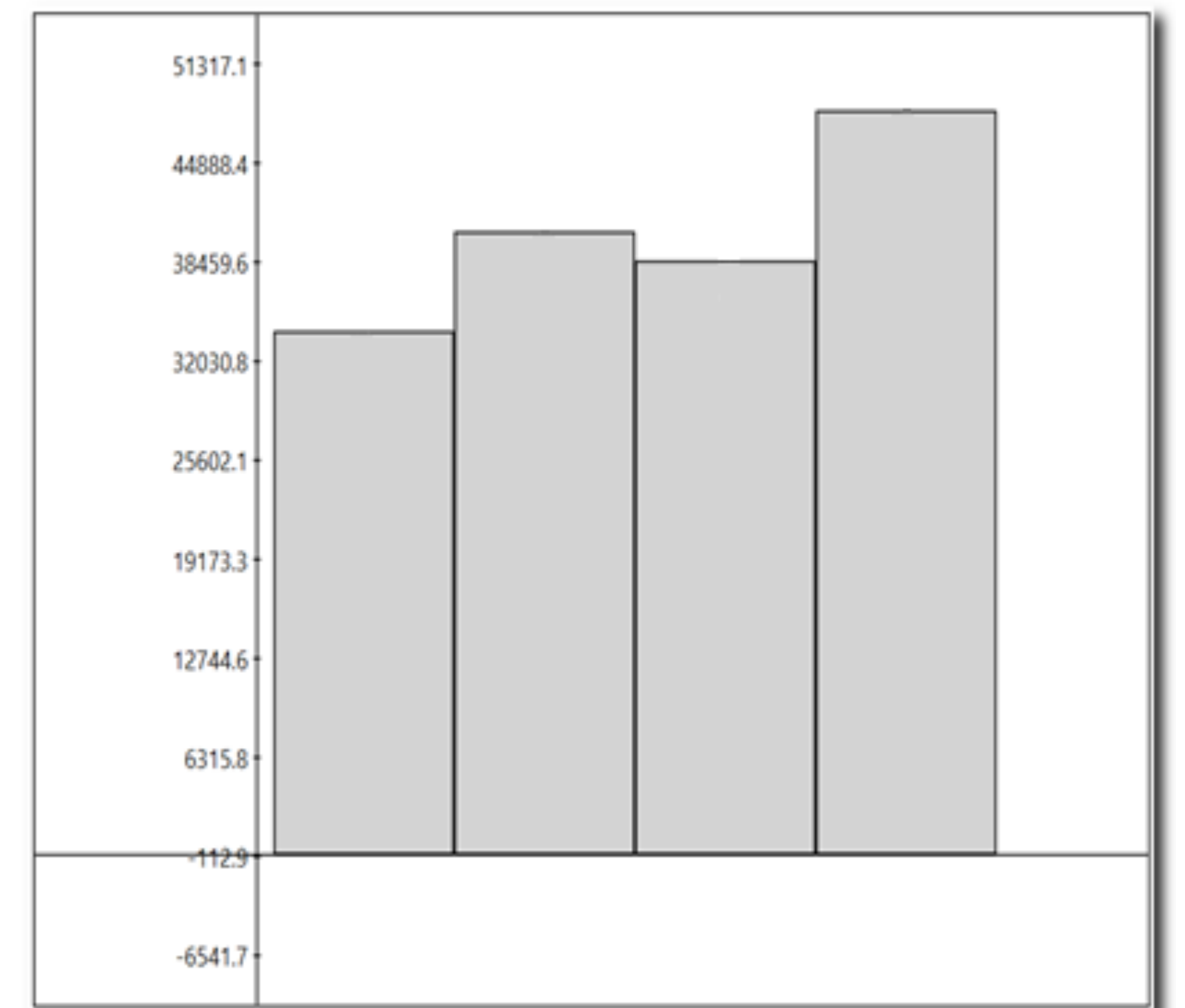


$\Pr(B > A)?$

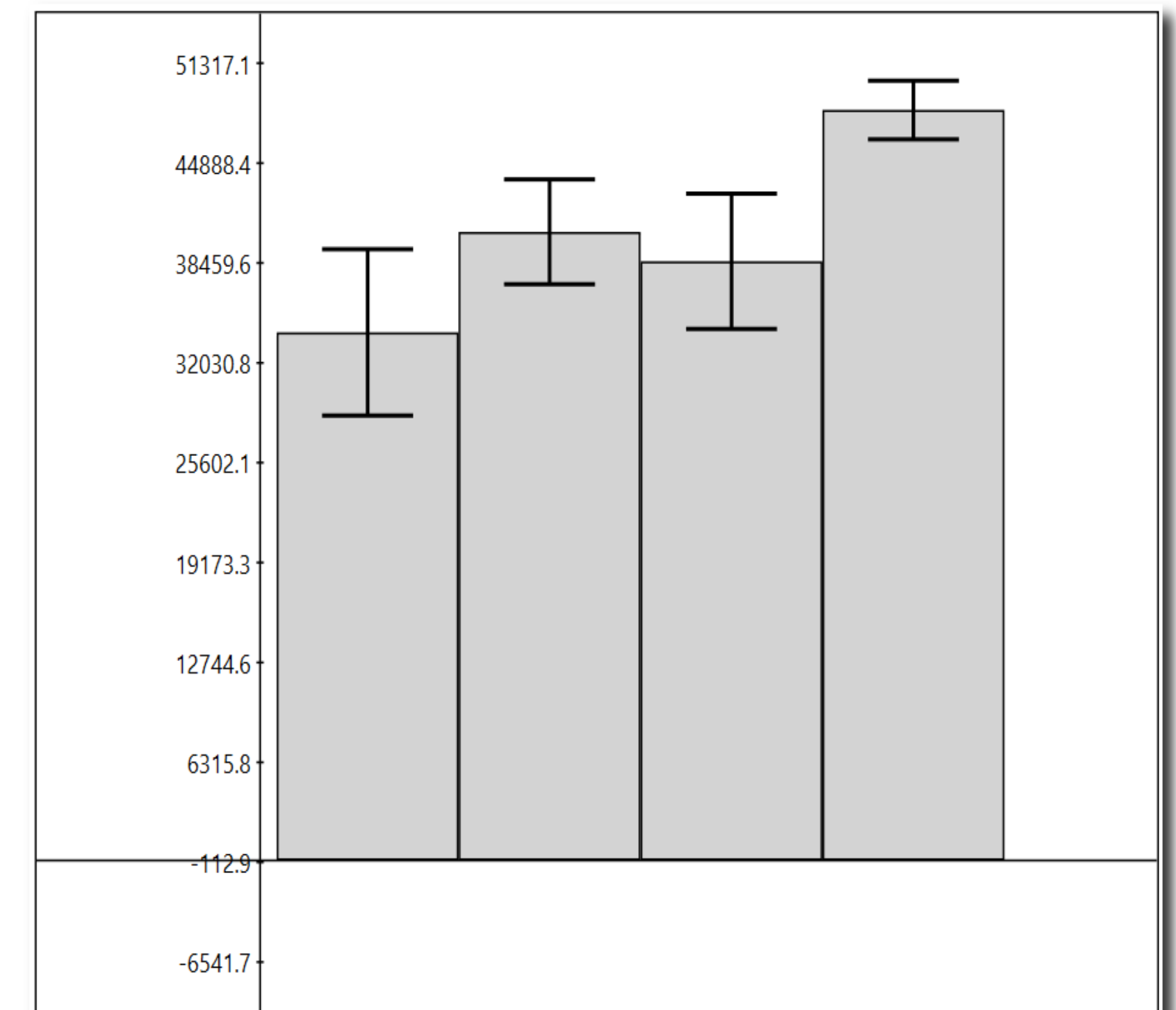
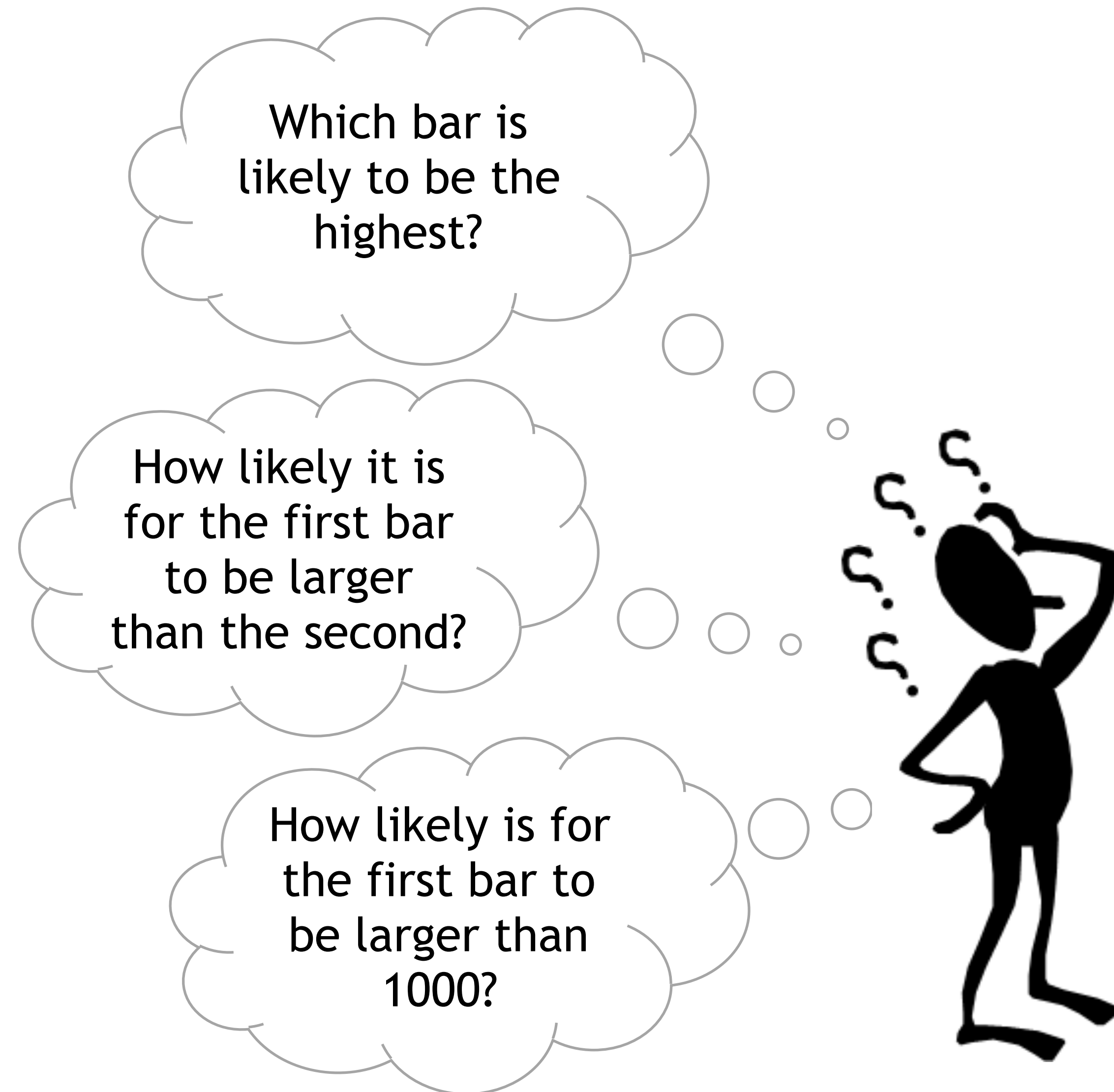
Turning Tasks Probabilistic



[Amar and Stasko 2005]



Turning Tasks Probabilistic



Experts don't fully get it

McCormack et al. *BMC Medical Research Methodology* 2013, **13**:134
<http://www.biomedcentral.com/1471-2288/13/134>



DEBATE

Open Access

How confidence intervals become confusion intervals

James McCormack¹, Ben Vandermeer² and G Michael Allan^{3*}

Abstract

Background: Controversies are common in medicine. Some arise when the conclusions of research publications directly contradict each other, creating uncertainty for frontline clinicians.

Discussion: In this paper, we review how researchers can look at very similar data yet have completely different conclusions based purely on an over-reliance of statistical significance and an unclear understanding of confidence intervals. The dogmatic adherence to statistical significant thresholds can lead authors to write dichotomized absolute conclusions while ignoring the broader interpretations of very consistent findings. We describe three examples of controversy around the potential benefit of a medication, a comparison between new medications, and a medication with a potential harm. The examples include the highest levels of evidence, both meta-analyses and randomized controlled trials. We will show how in each case the confidence intervals and point estimates were very similar. The only identifiable differences to account for the contrasting conclusions arise from the serendipitous finding of confidence intervals that either marginally cross or just fail to cross the line of statistical significance.

Summary: These opposing conclusions are false disagreements that create unnecessary clinical uncertainty. We provide helpful recommendations in approaching conflicting conclusions when they are associated with remarkably similar results.

Keywords: Confidence intervals, Evidence based medicine, Statistical analysis, Statistical significance

Most visualizations don't help!

al Methods
10, No. 4, 389–396

Copyright 2005 by the American Psychological
1082-989X/05/\$12.00 DOI: 10.1037/1082-989X

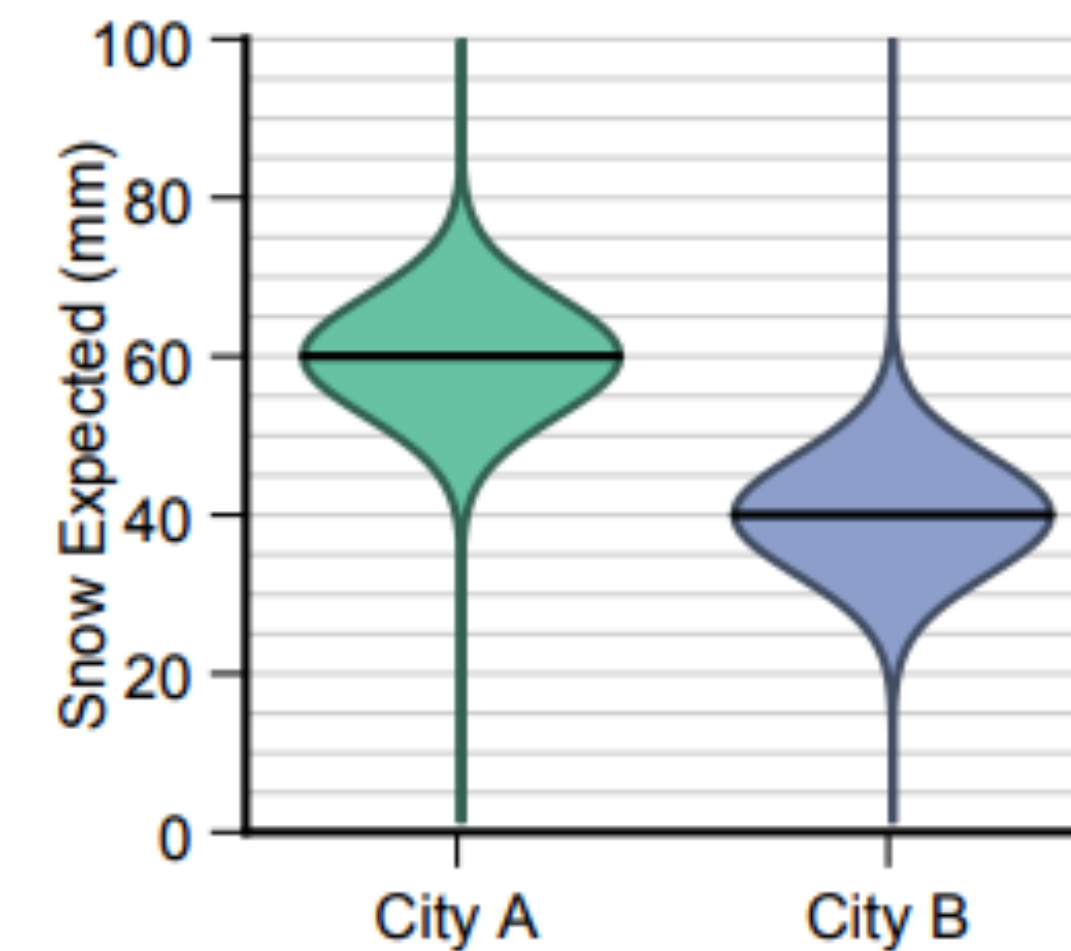
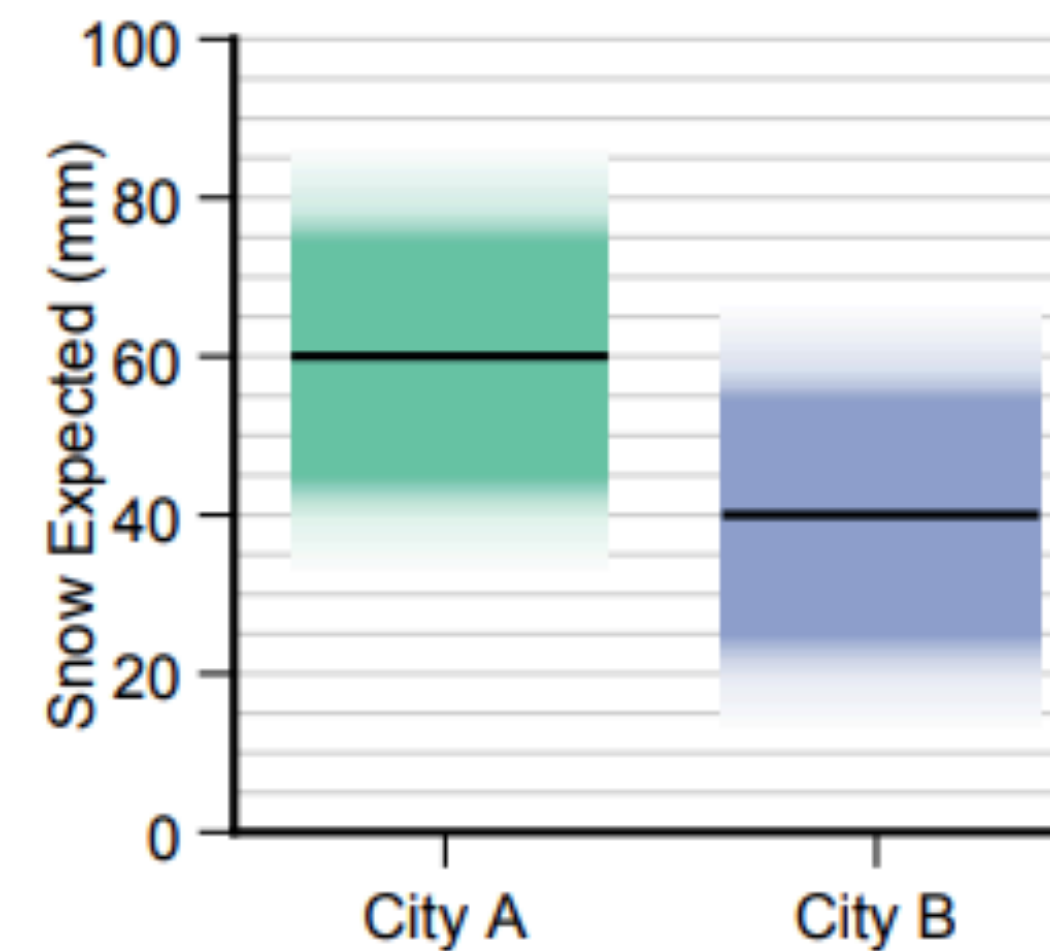
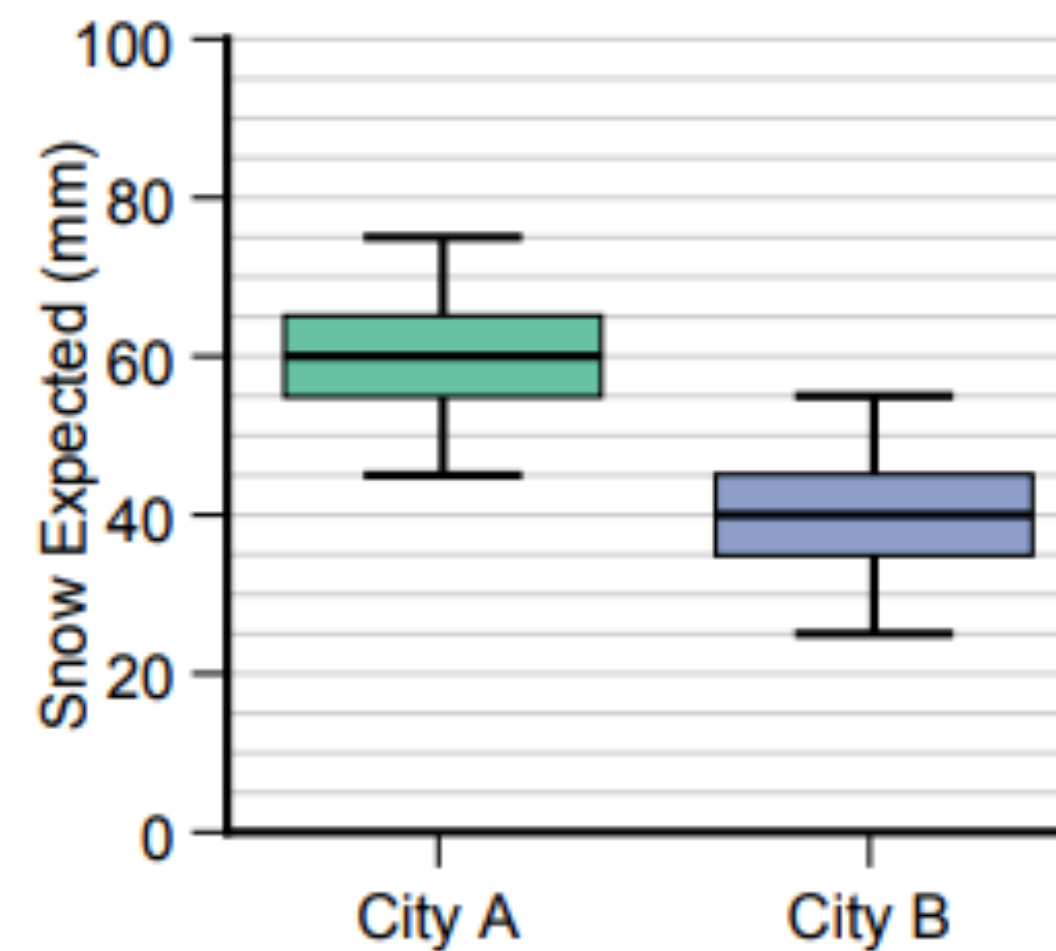
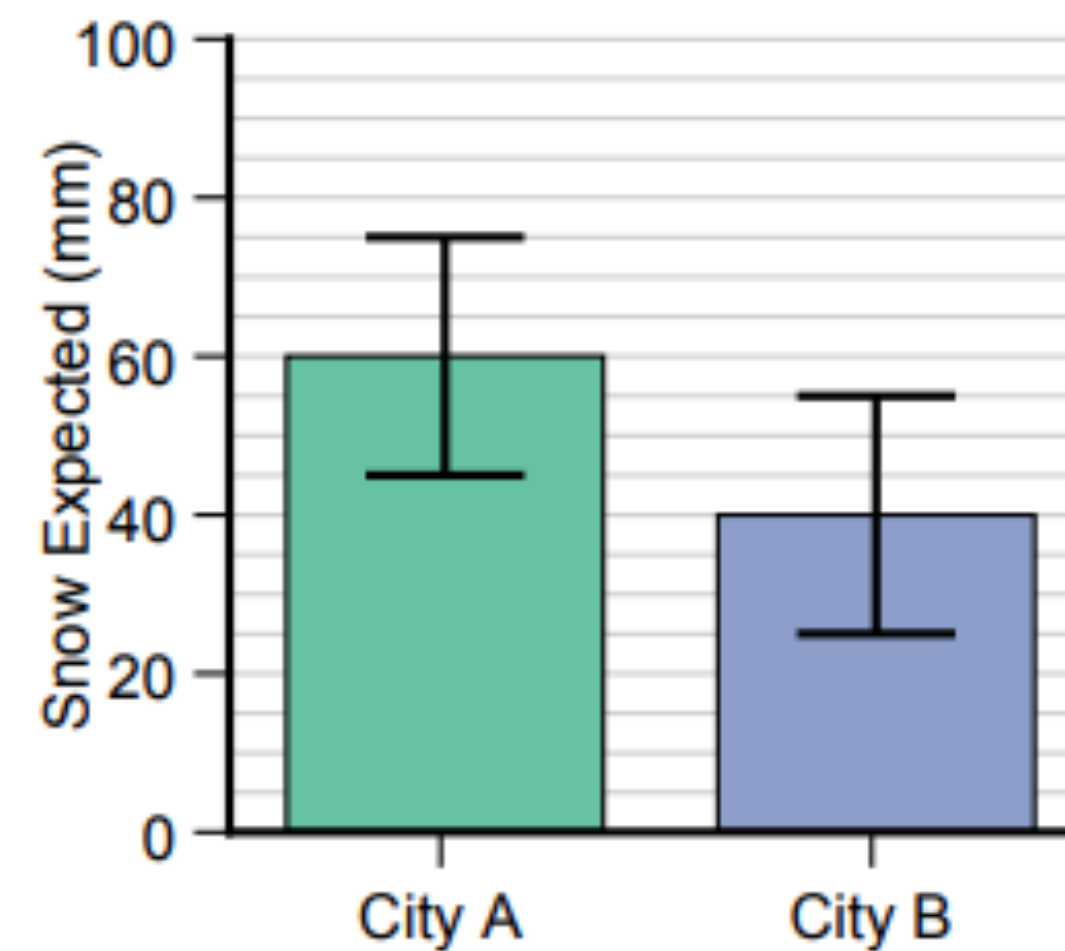
Researchers Misunderstand Confidence Intervals and Standard Error Bars

Sarah Belia, Fiona Fidler, Jennifer Williams, and Geoff Cumming
La Trobe University

Little is known about researchers' understanding of confidence intervals (CIs) and standard error (*SE*) bars. Authors of journal articles in psychology, behavioral neuroscience, and medicine were invited to visit a Web site where they adjusted a figure until they judged 2 means, with error bars, to be just statistically significantly different ($p < .05$). Results from 473 respondents suggest that many leading researchers have severe misconceptions about how error bars relate to statistical significance, do not adequately distinguish CIs and *SE* bars, and do not appreciate the importance of whether the 2 means are independent or come from a repeated measures design. Better guidelines for researchers and less ambiguous graphical conventions are needed before the advantages of CIs for research communication can be realized.

Keywords: confidence intervals, statistical cognition, standard error, error bars, statistical reform

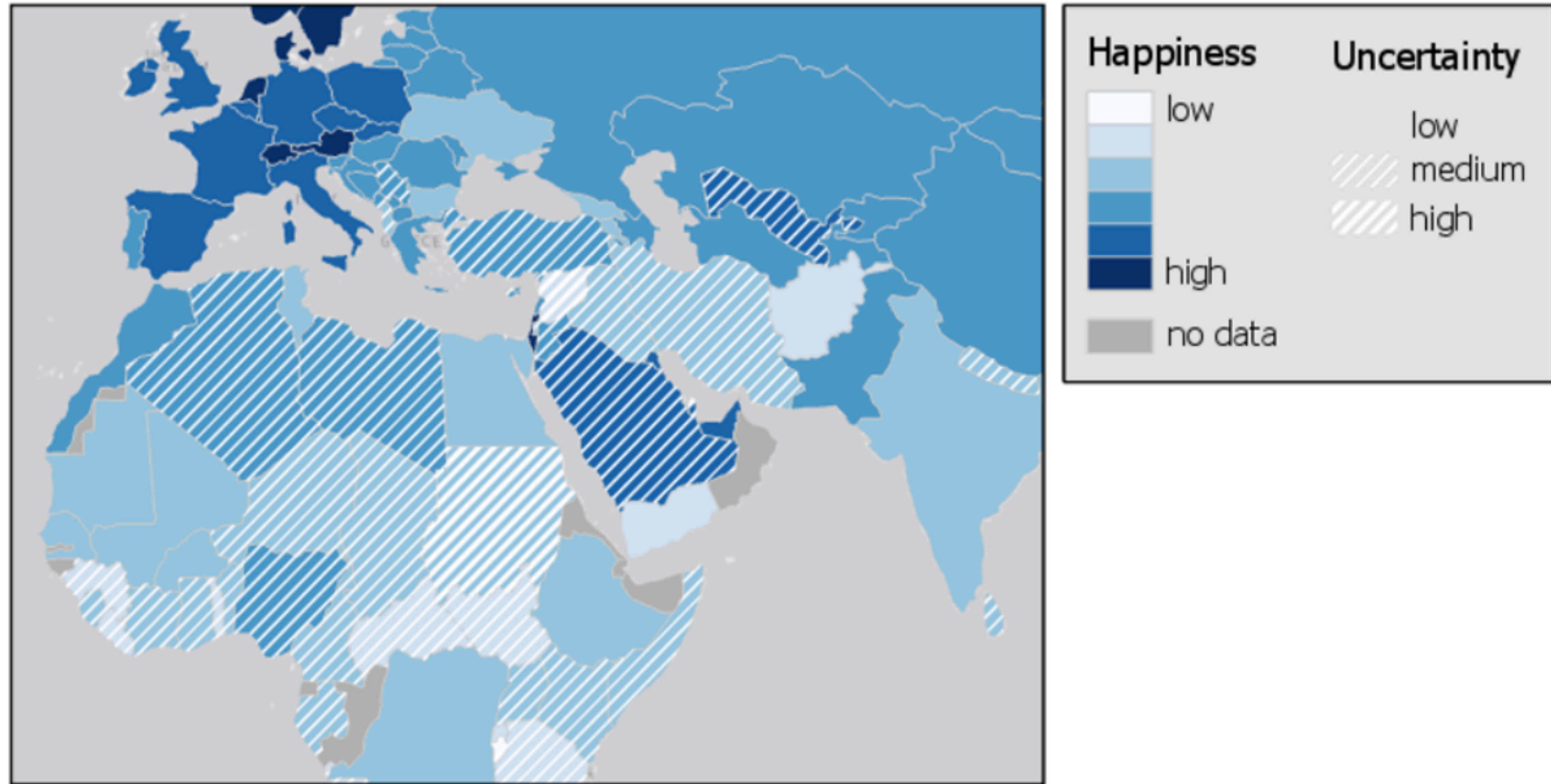
Current Methods do not Solve the Problem



[Correll and Gleicher 2014]

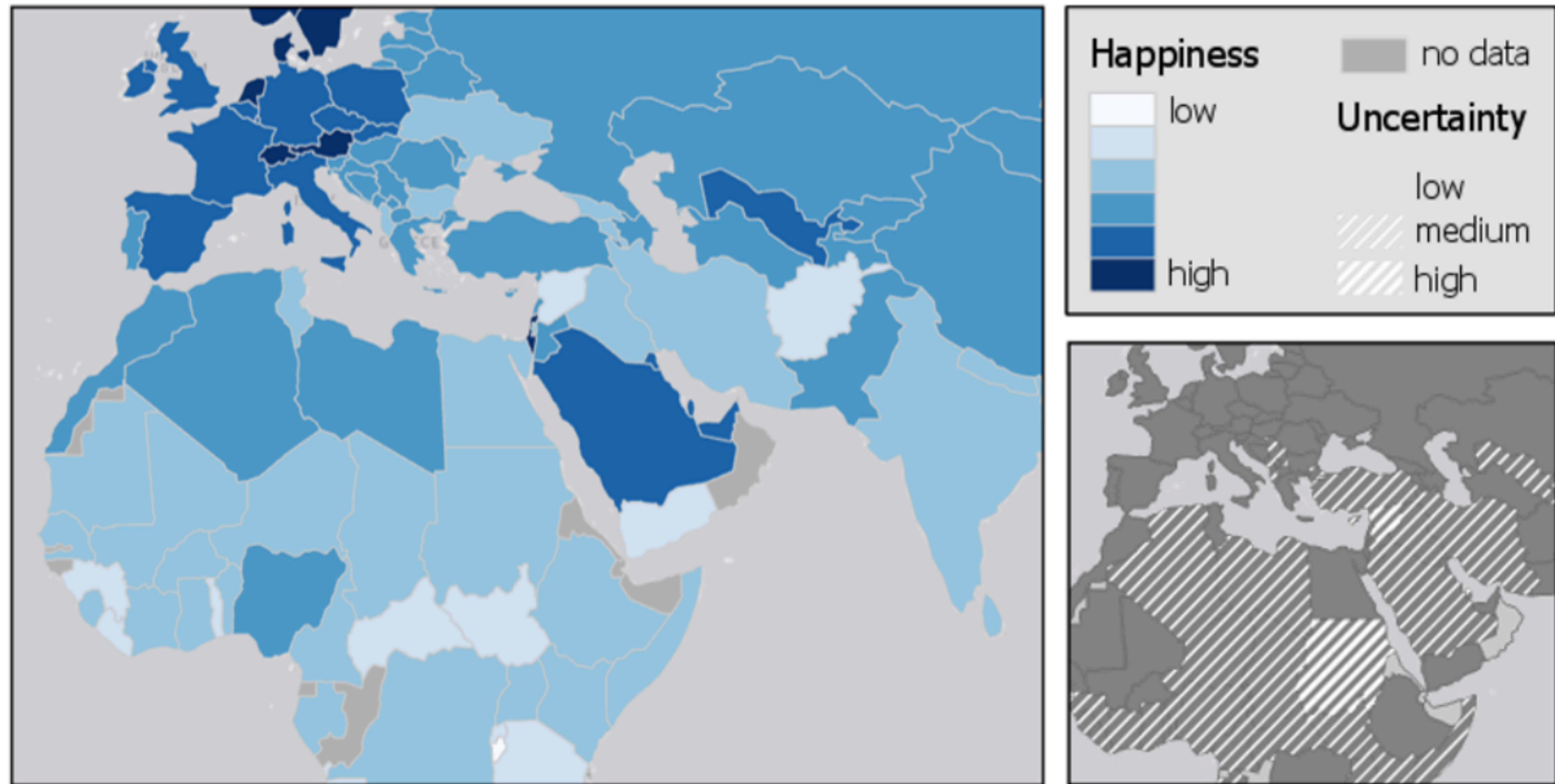
What about Geographical Data?

Uncertainty in Geographical Visualizations



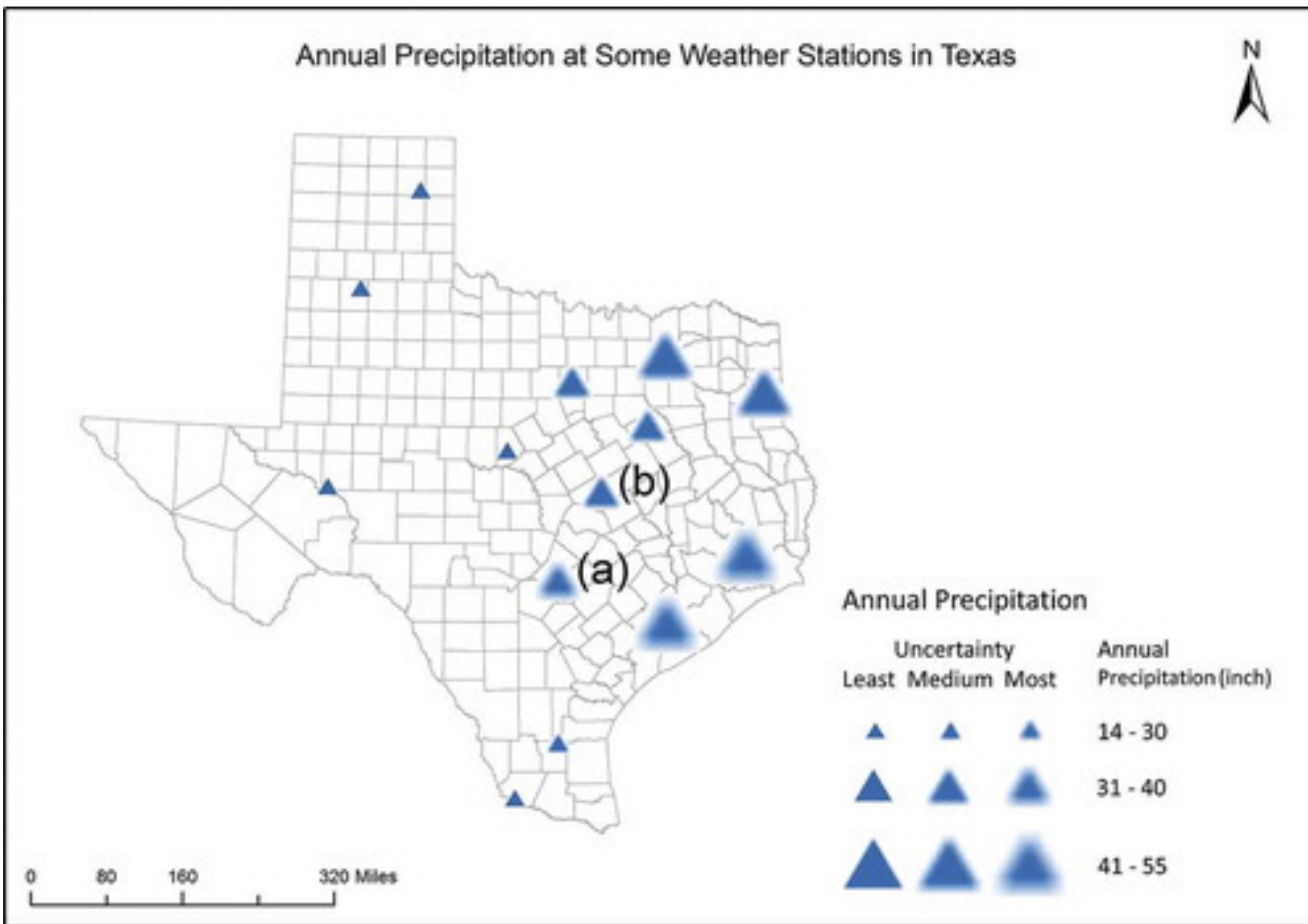
[Anderson 2018]

Uncertainty in Geographical Visualizations

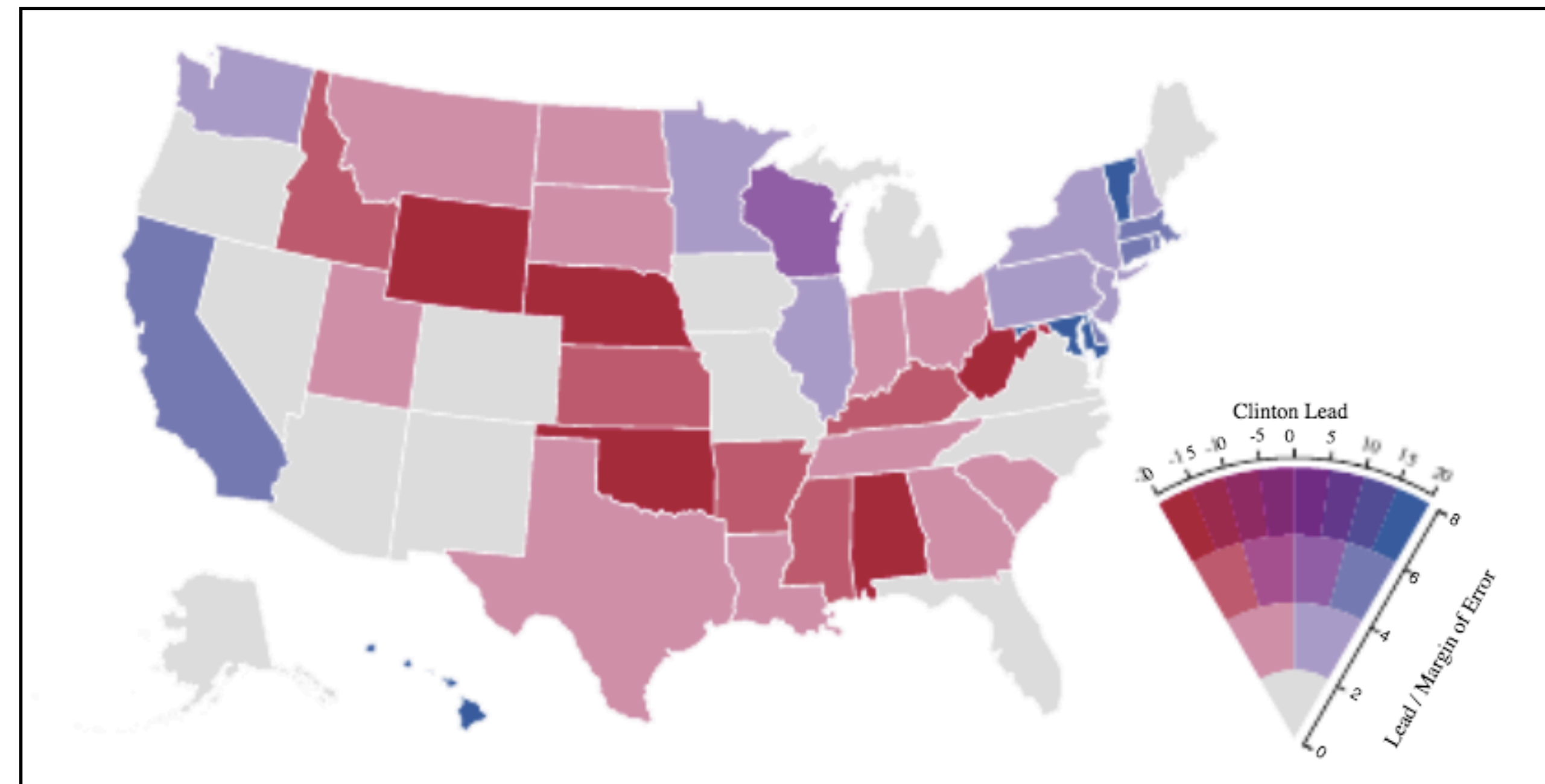


[Anderson 2018]

Uncertainty in Geographical Visualizations



[Scholz and Lu 2014]



[Correll et al. 2018]

**How to better support the use of uncertainty
in visual data analysis?**

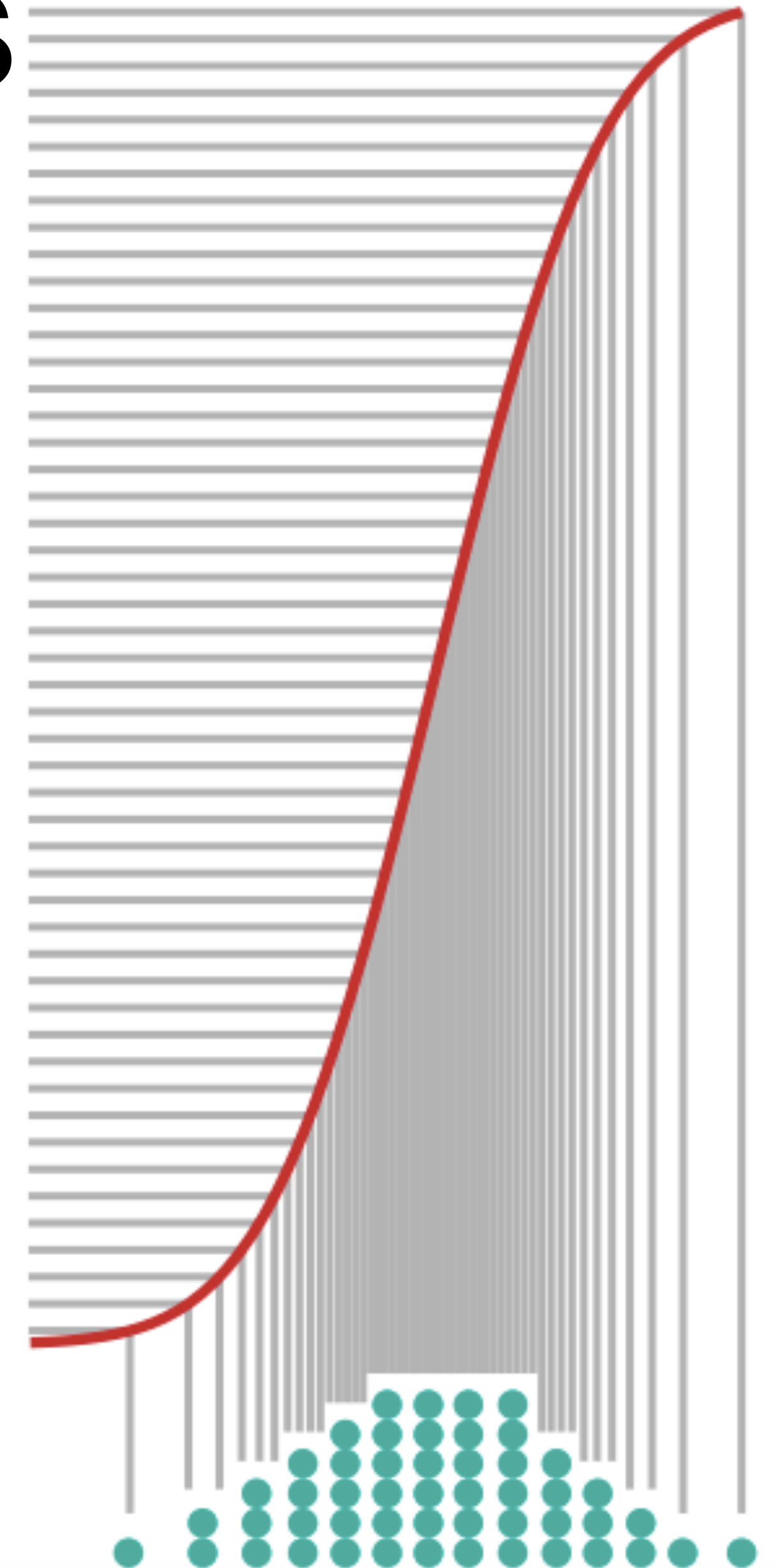
**How to improve analysts understanding of
uncertainty visualizations?**

Solution:
Frequentist Approach
Use Dynamics/Interaction

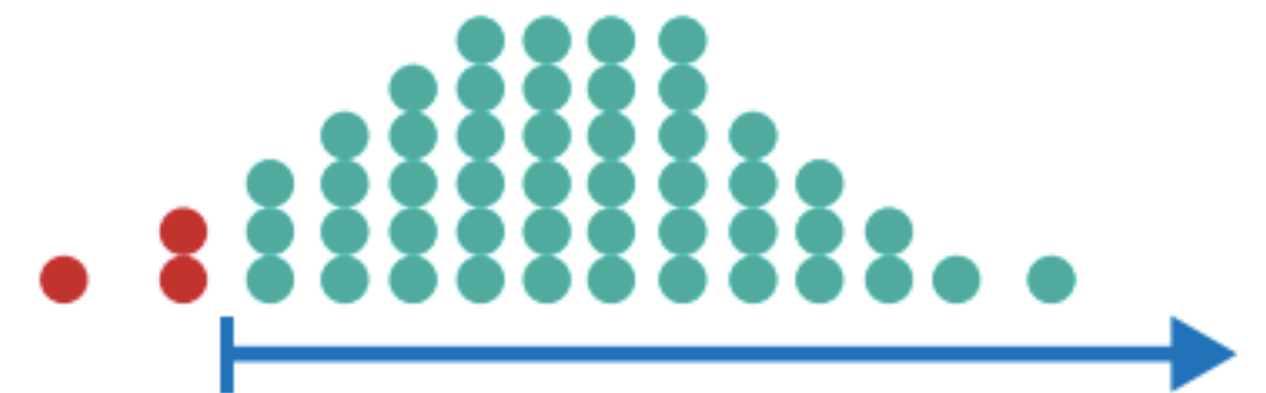
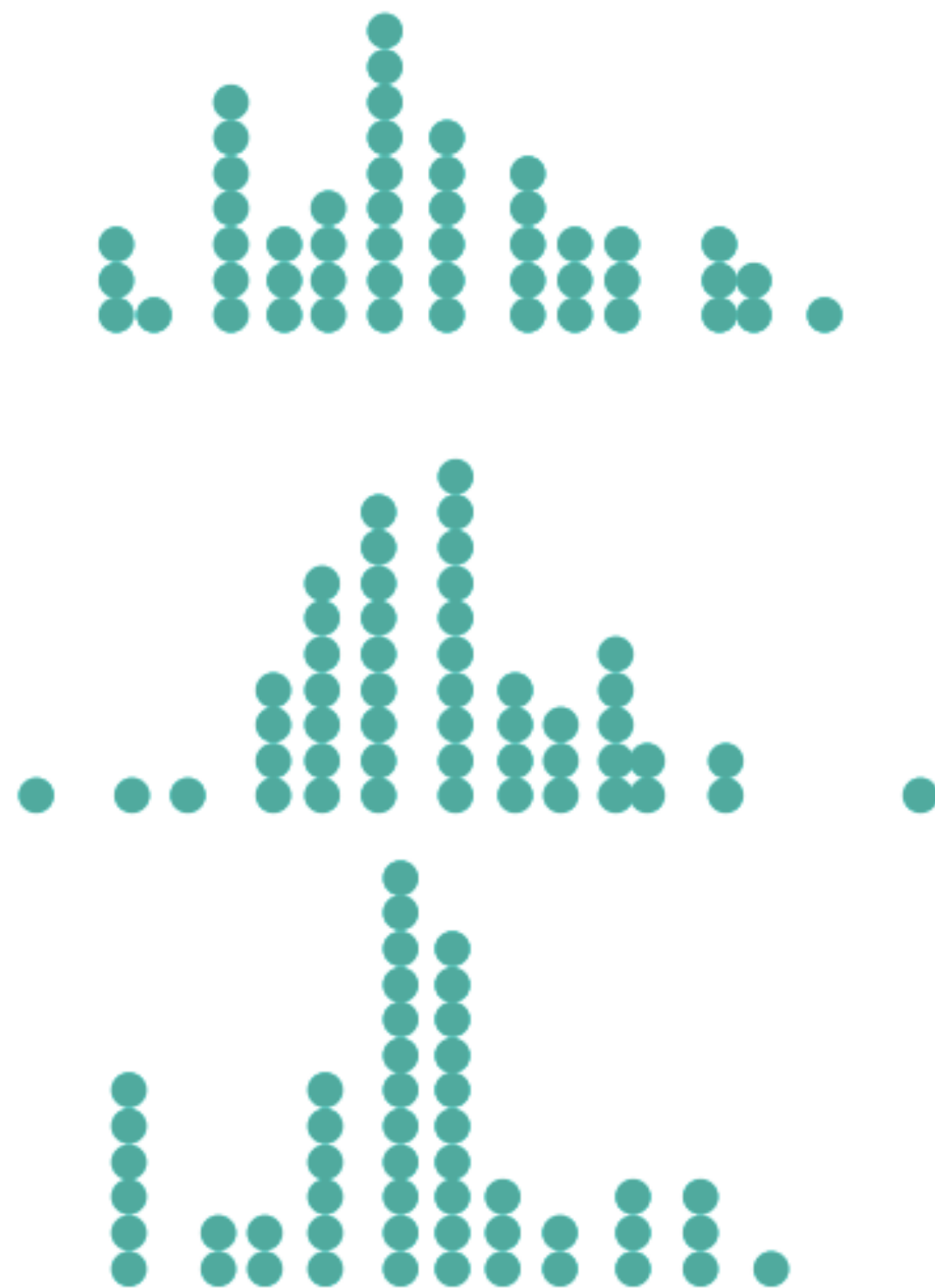
Quantile Dot Plots

- Shows evenly spaced quantiles as a dot plot
- Let to more accurate and consistent decisions compared to continuous depiction of the distribution
- The k -th dot represents the k -th quantile of the distribution

[Kay et al. 2016]

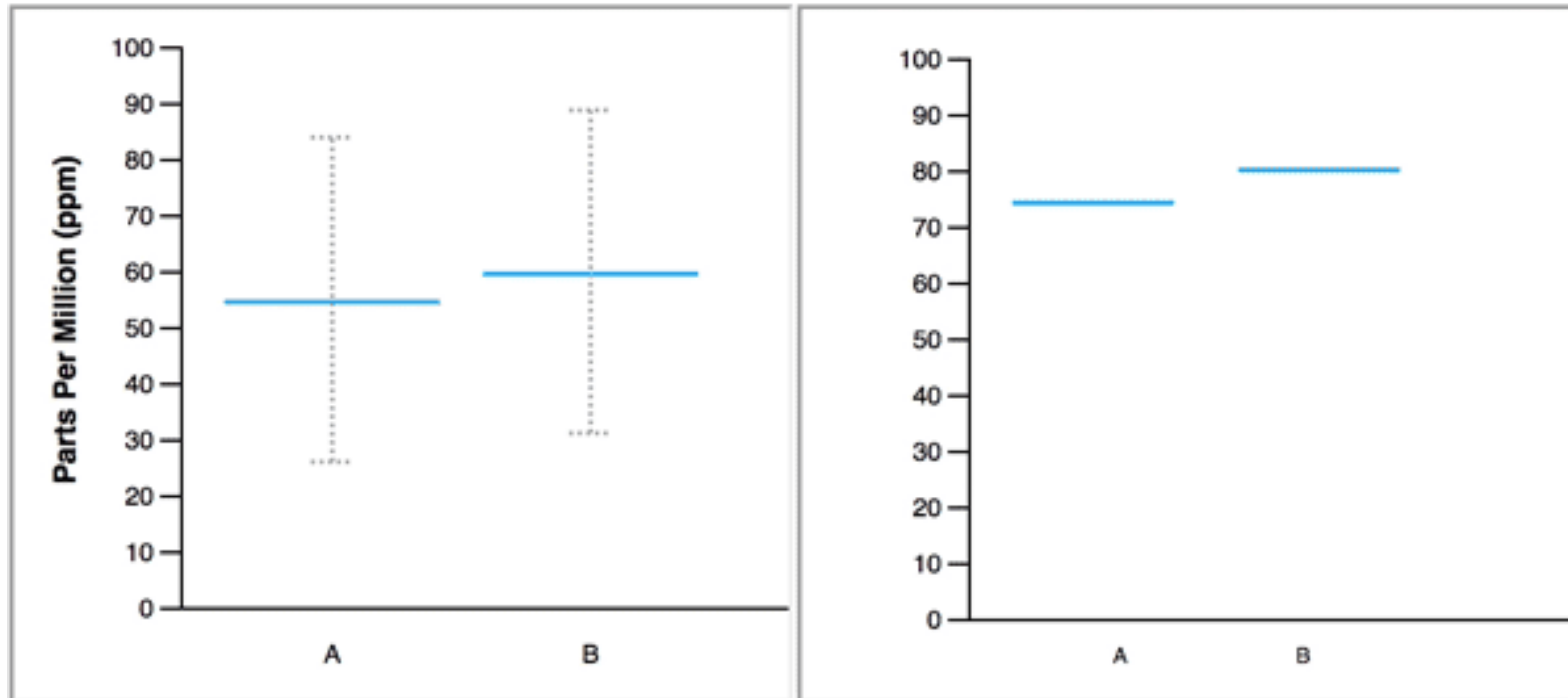


Quantile Dot Plots



[Kay et al. 2016]

Hypothetical Plots

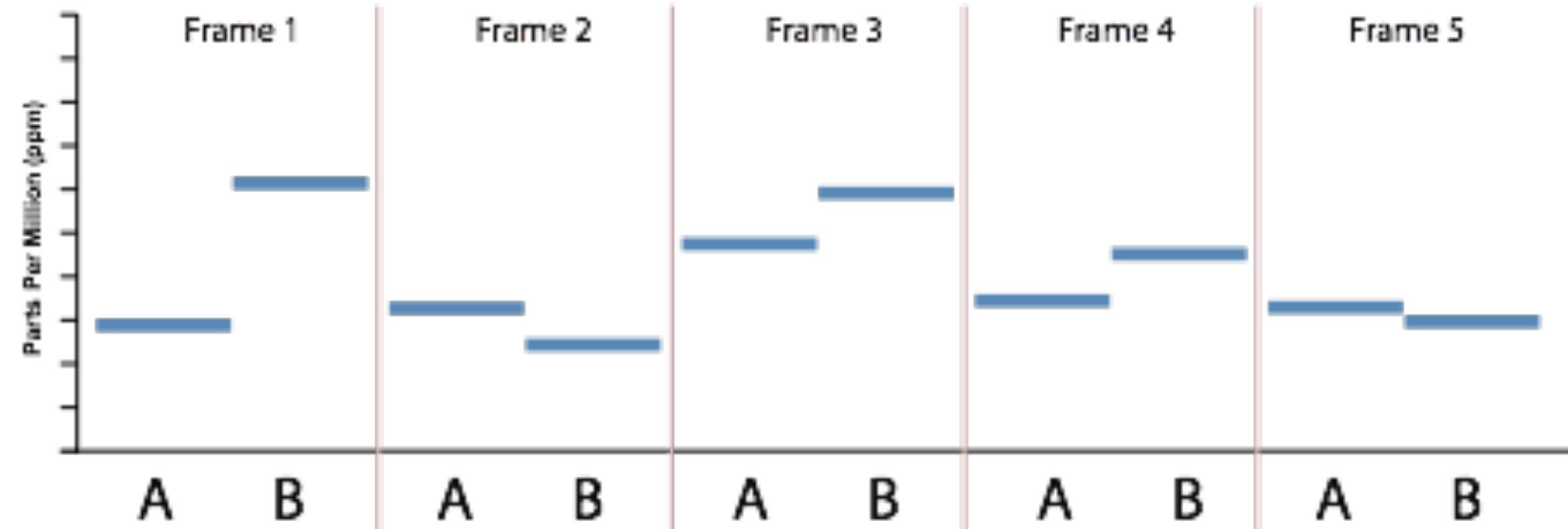


[Hullman et al. 2016]

Hypothetical Plots

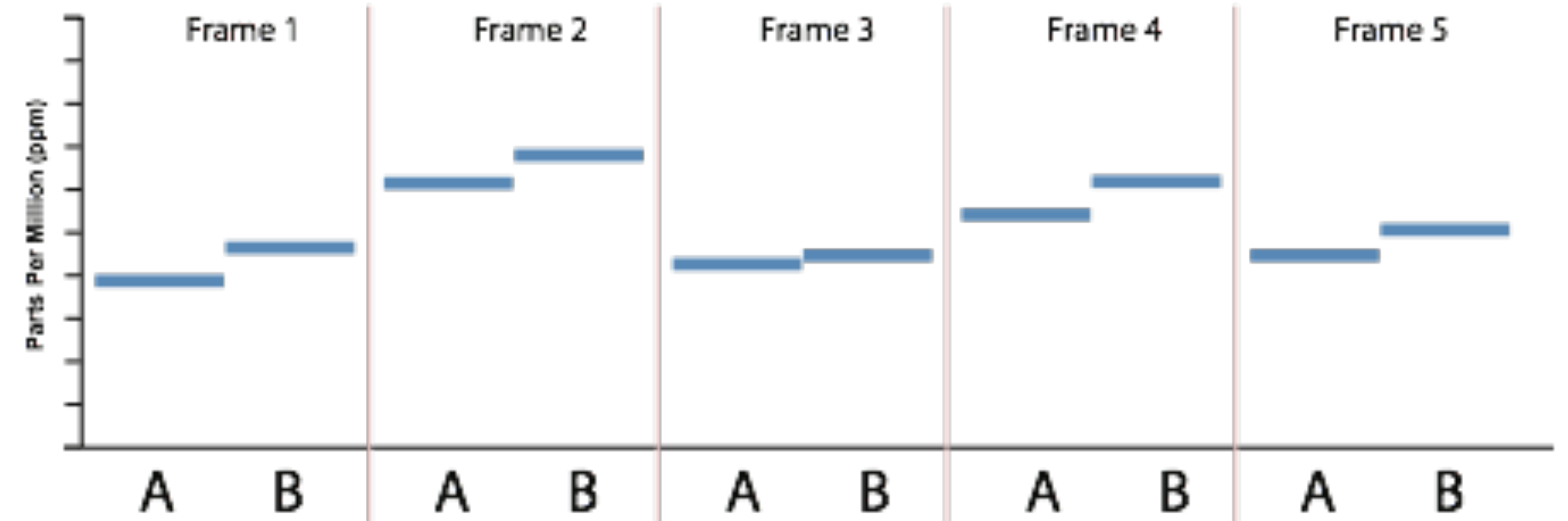
(2)

HOPs, A & B uncorrelated



(3)

HOPs, A & B strongly correlated



[Hullman et al. 2016]

Sample-Oriented Task-Driven Visualizations: Allowing Users to Make Better, More Confident Decisions

Nivan Ferreira

**NYU Polytechnic
School of Engineering**

Danyel Fisher

Microsoft Research

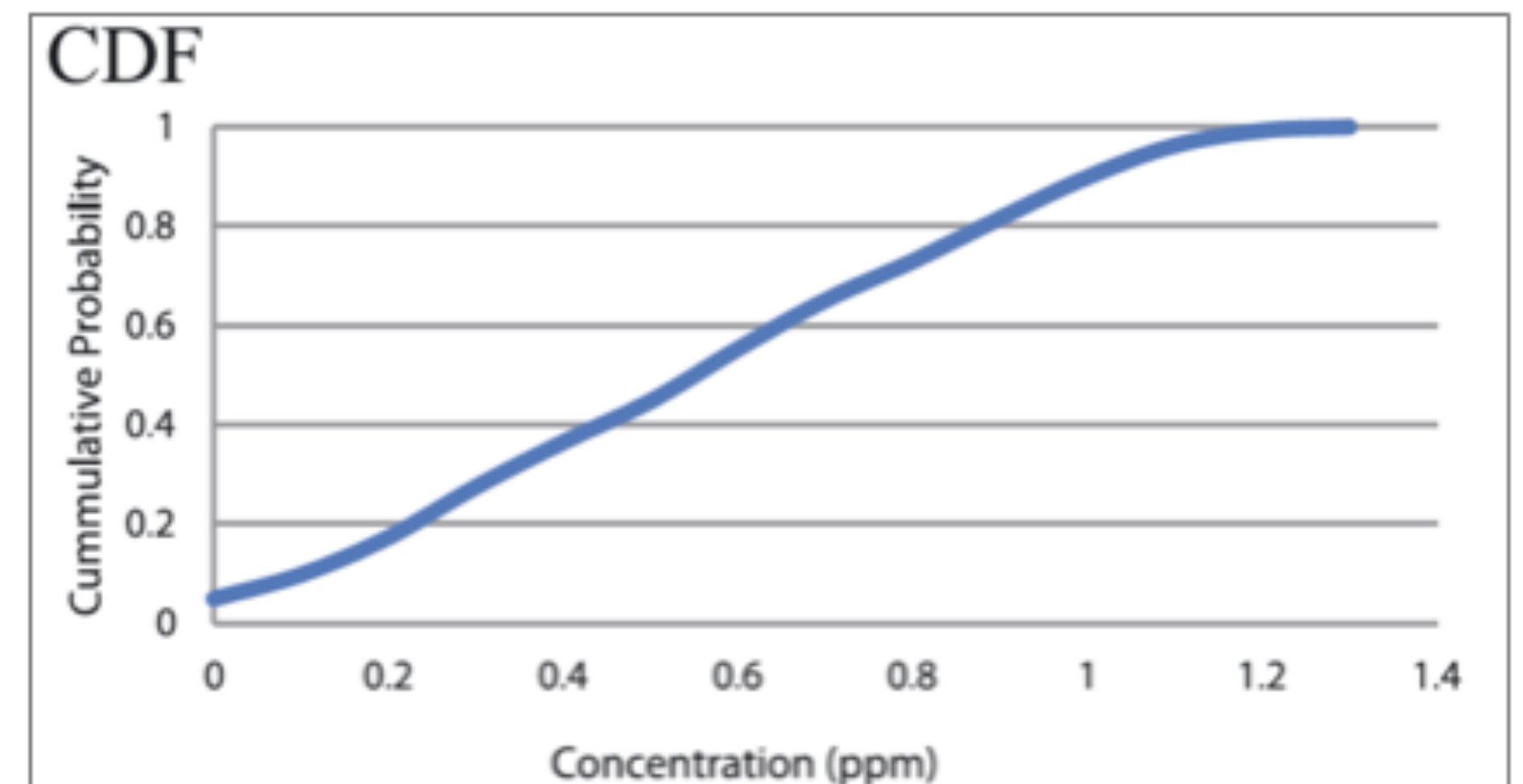
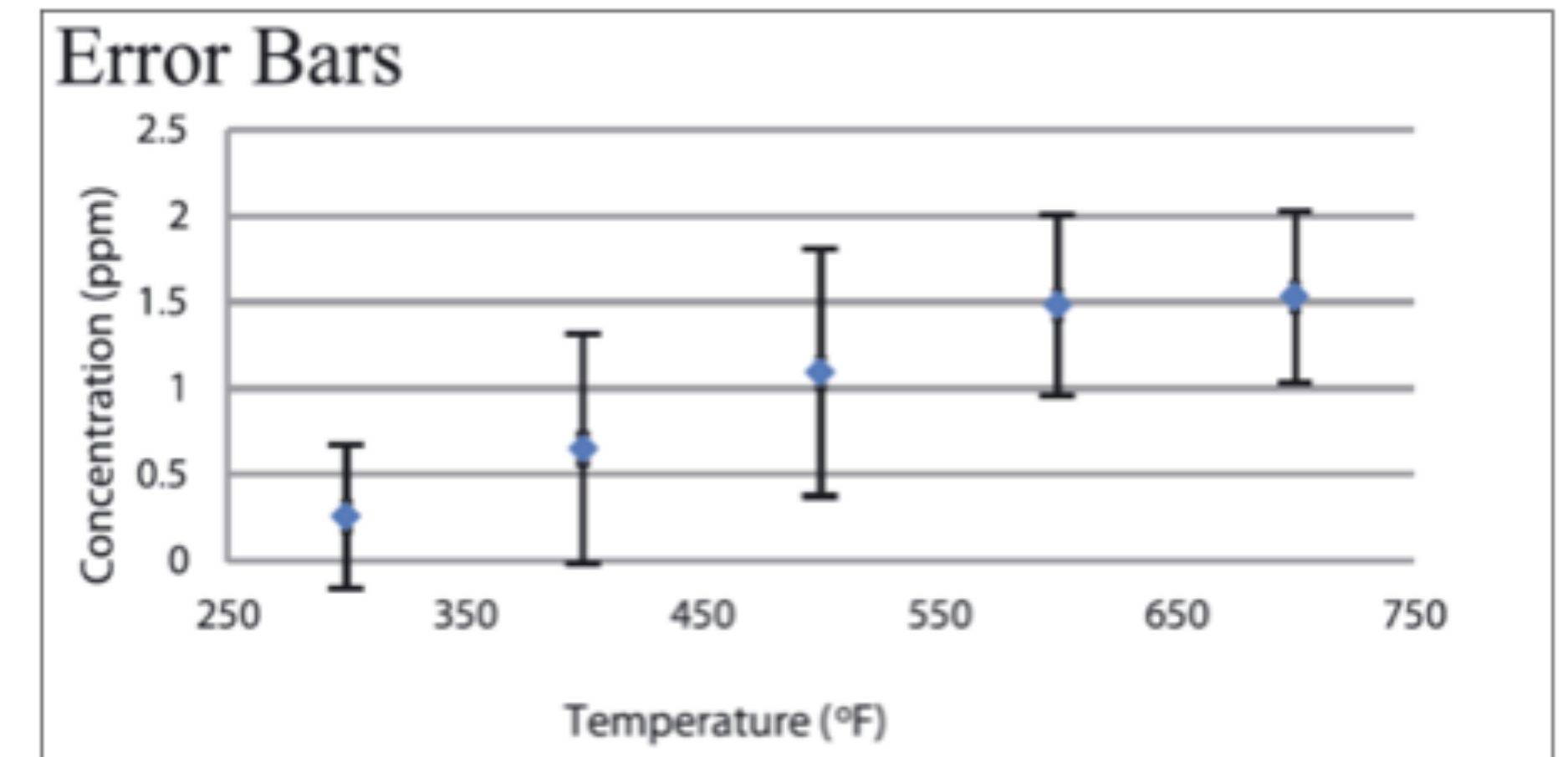
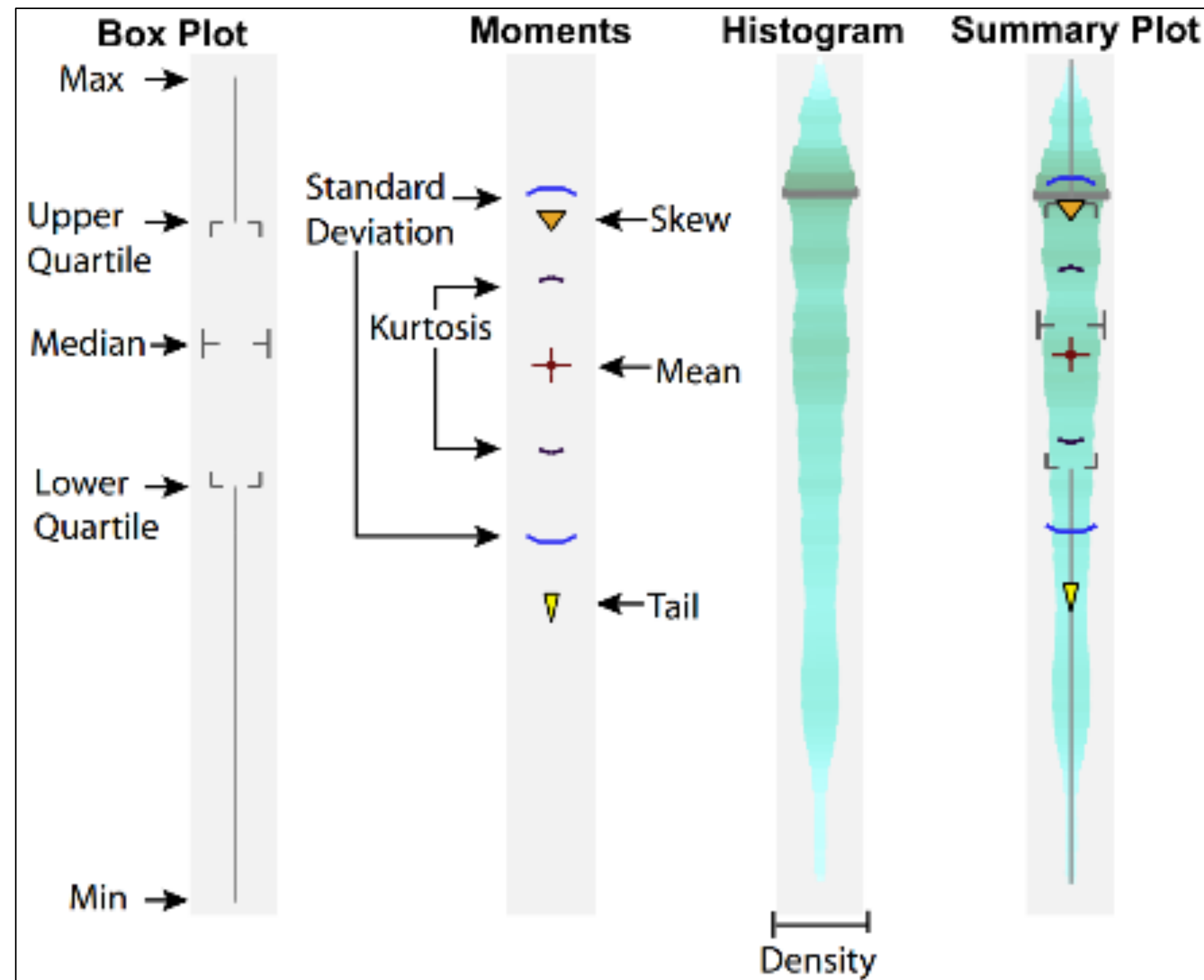
Arnd Christian König

Microsoft Research-XCG



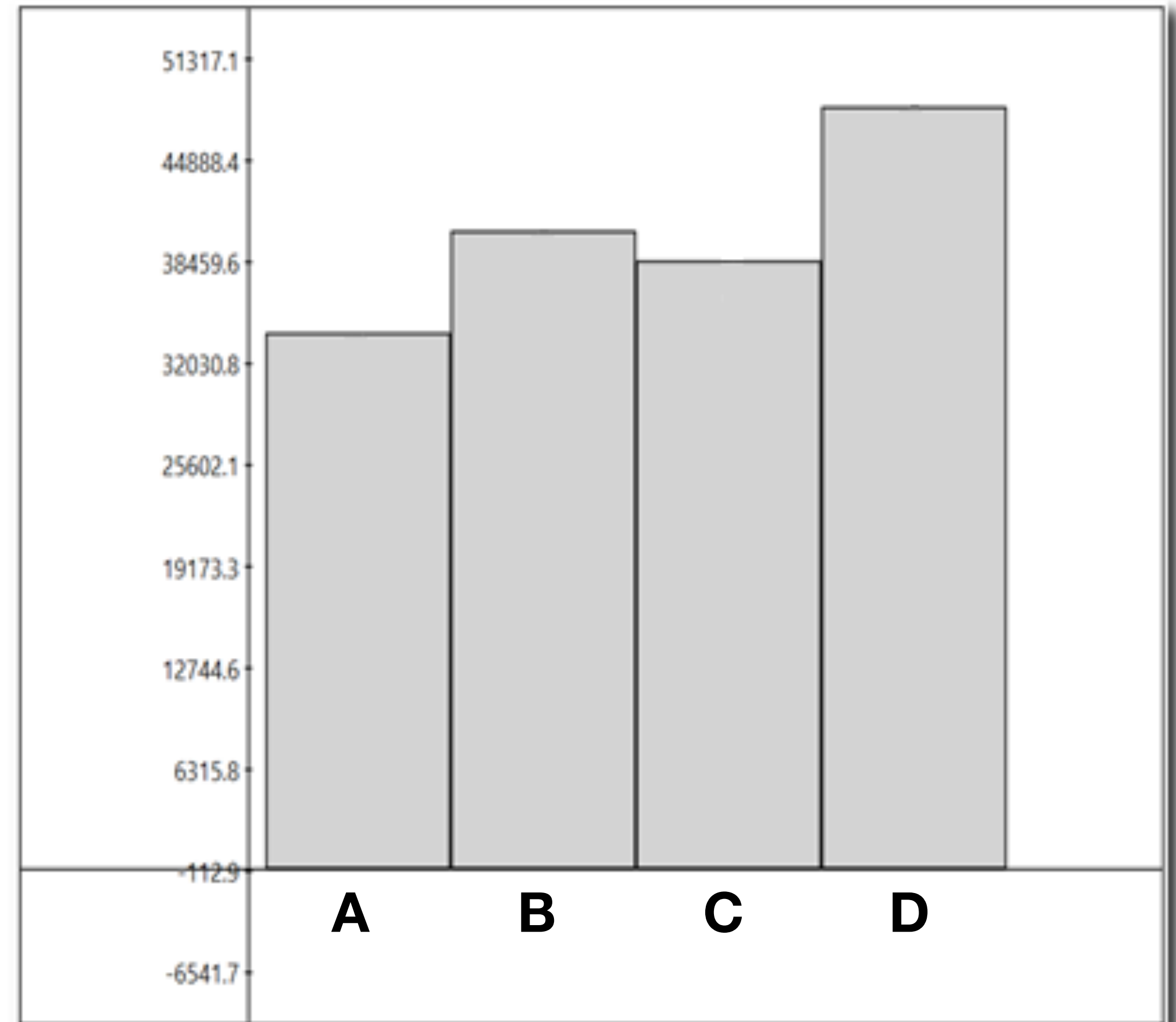
Quantile Dot Plots

- Easy to Interpret
- Consistency across Task



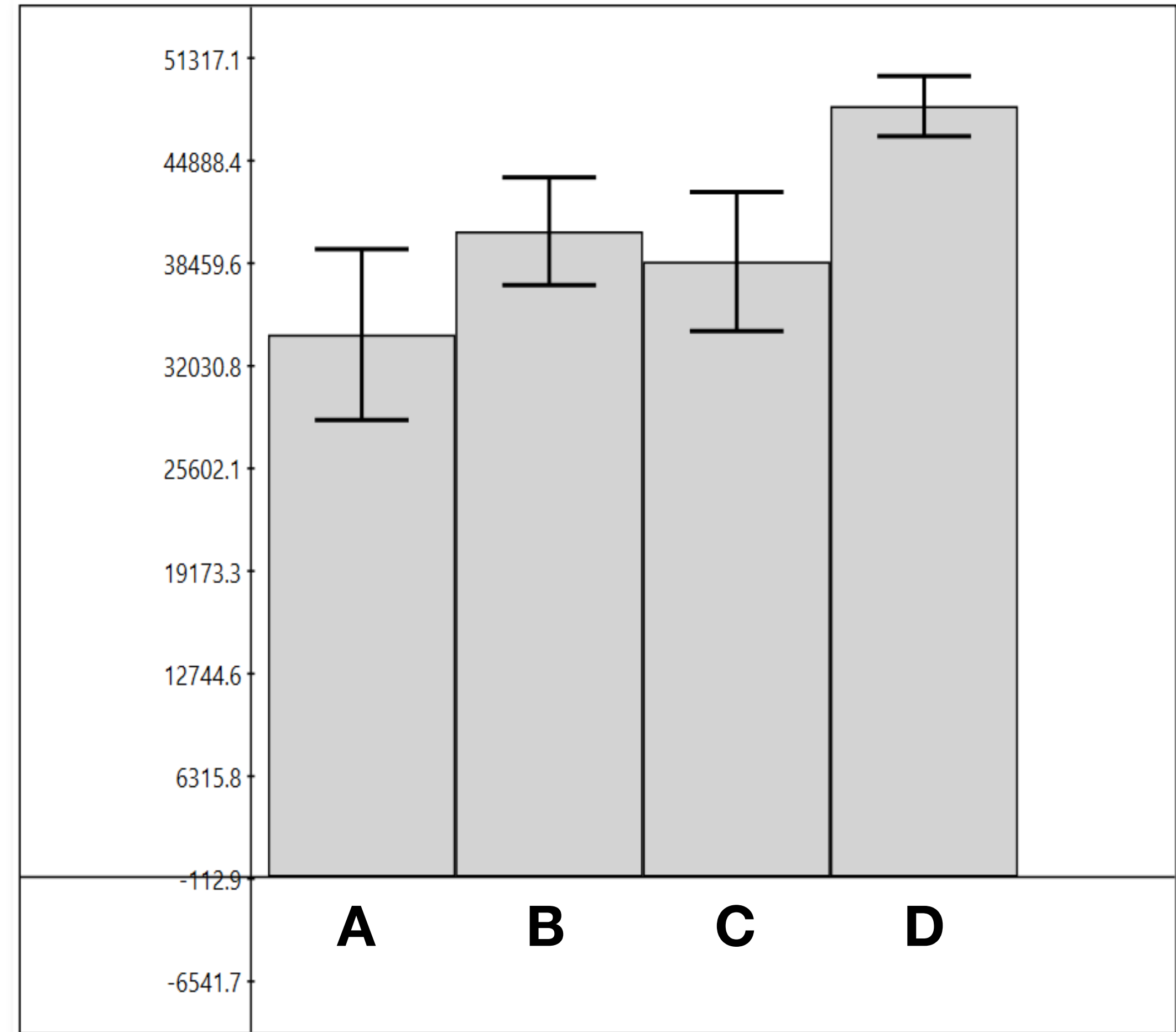
Selecting Tasks

- Retrieve Value
- Find Extremum
- Determine Range
- Ranking



Selecting Tasks

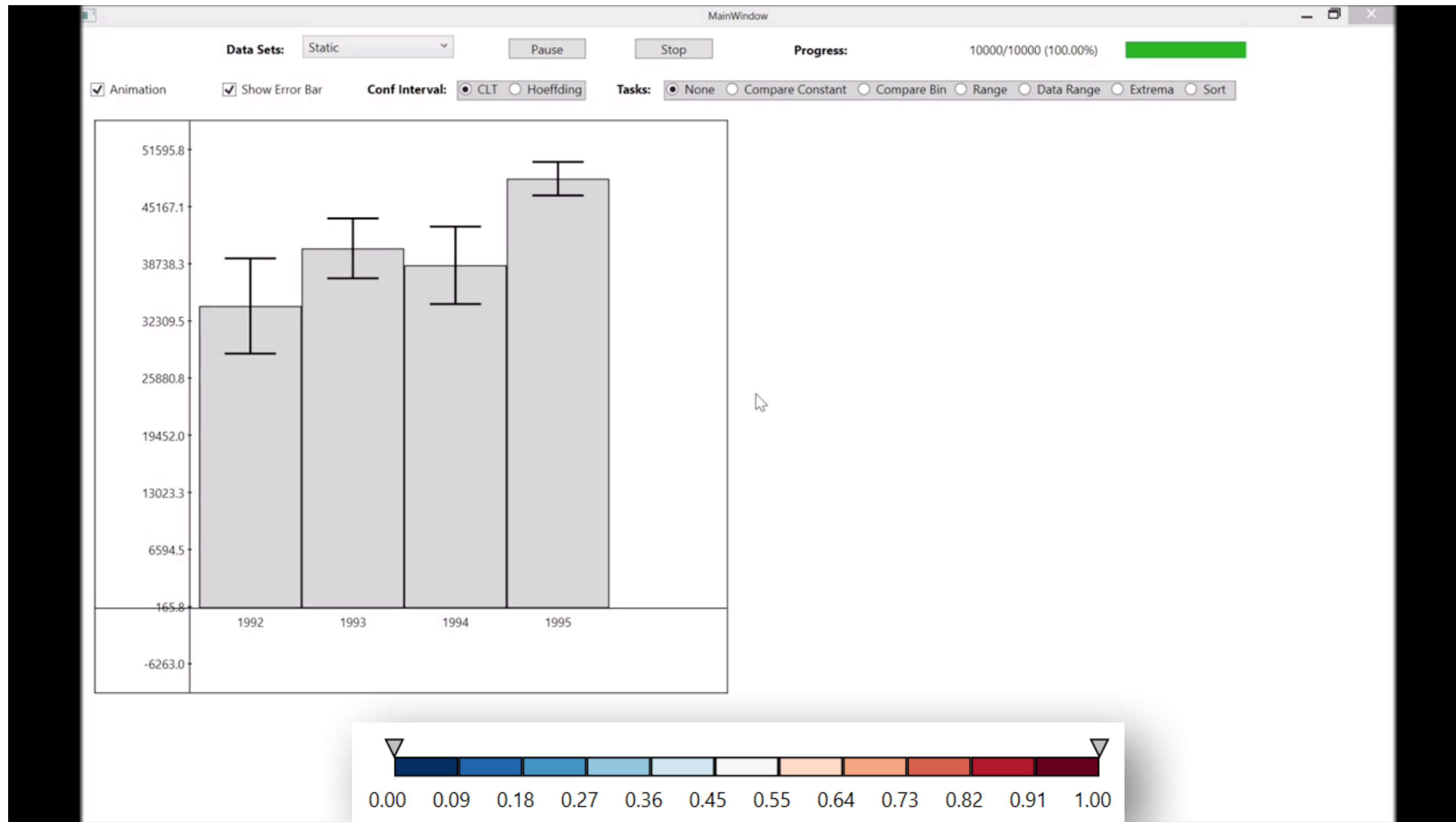
- How likely is A larger than given value?
- How likely is A in a given range?
- How likely is B larger than C?
- How likely is C the minimum?
- How likely C is in rank k?
- How likely A is in top-k?



Visual Design

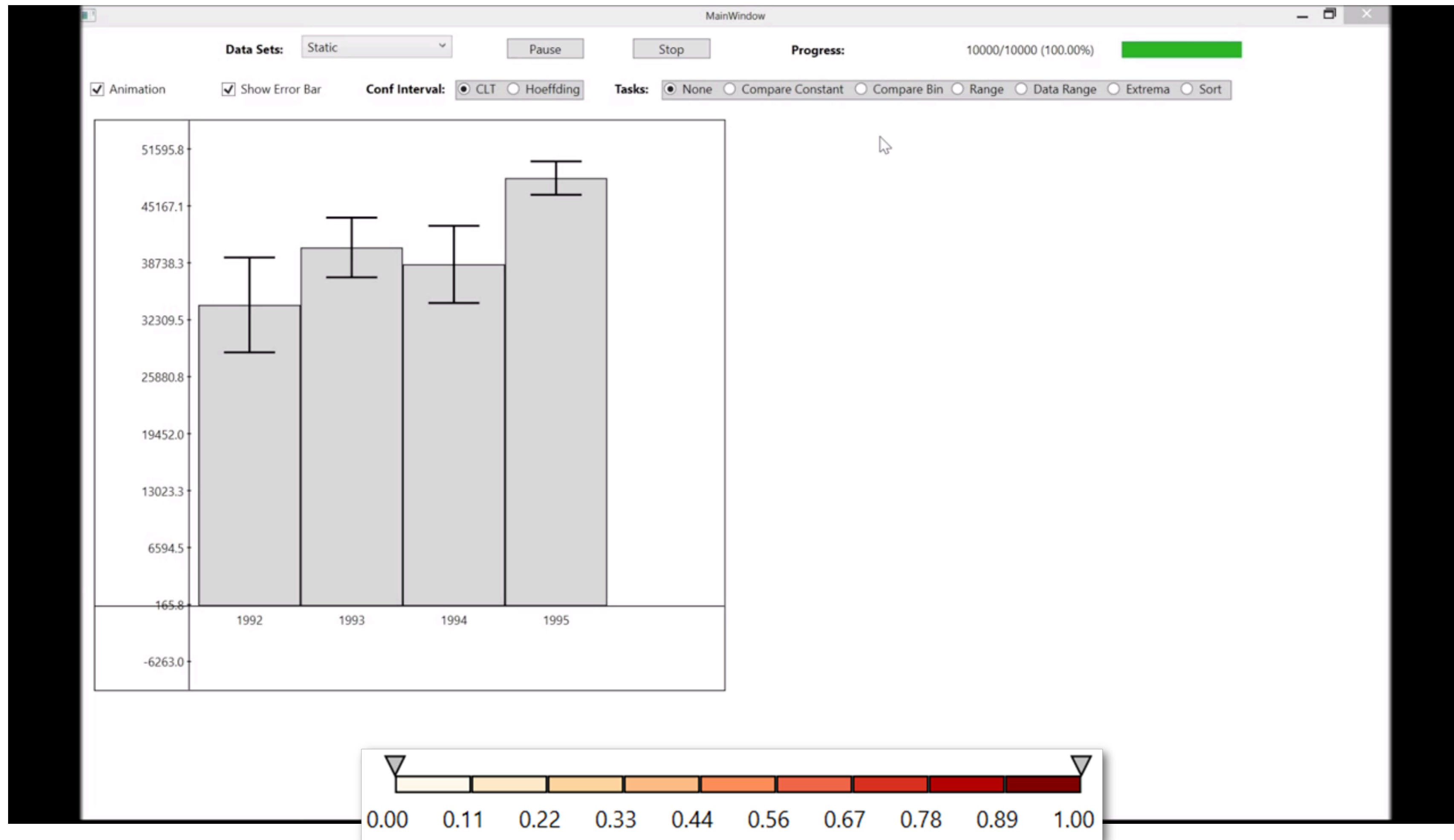
Compare to Constant

- How likely bar larger than given value?



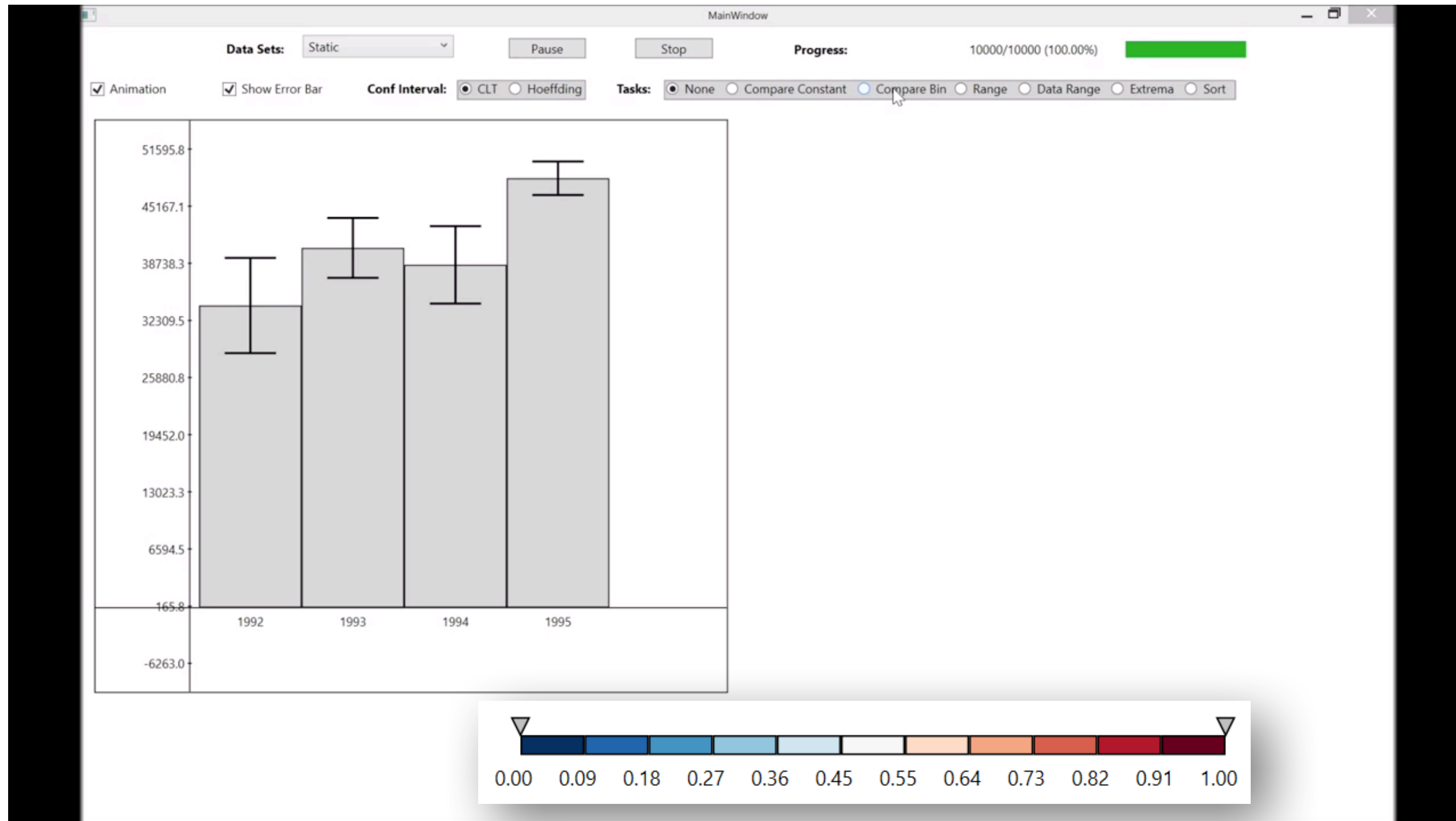
Compare to Range

- How likely bar is in a range?



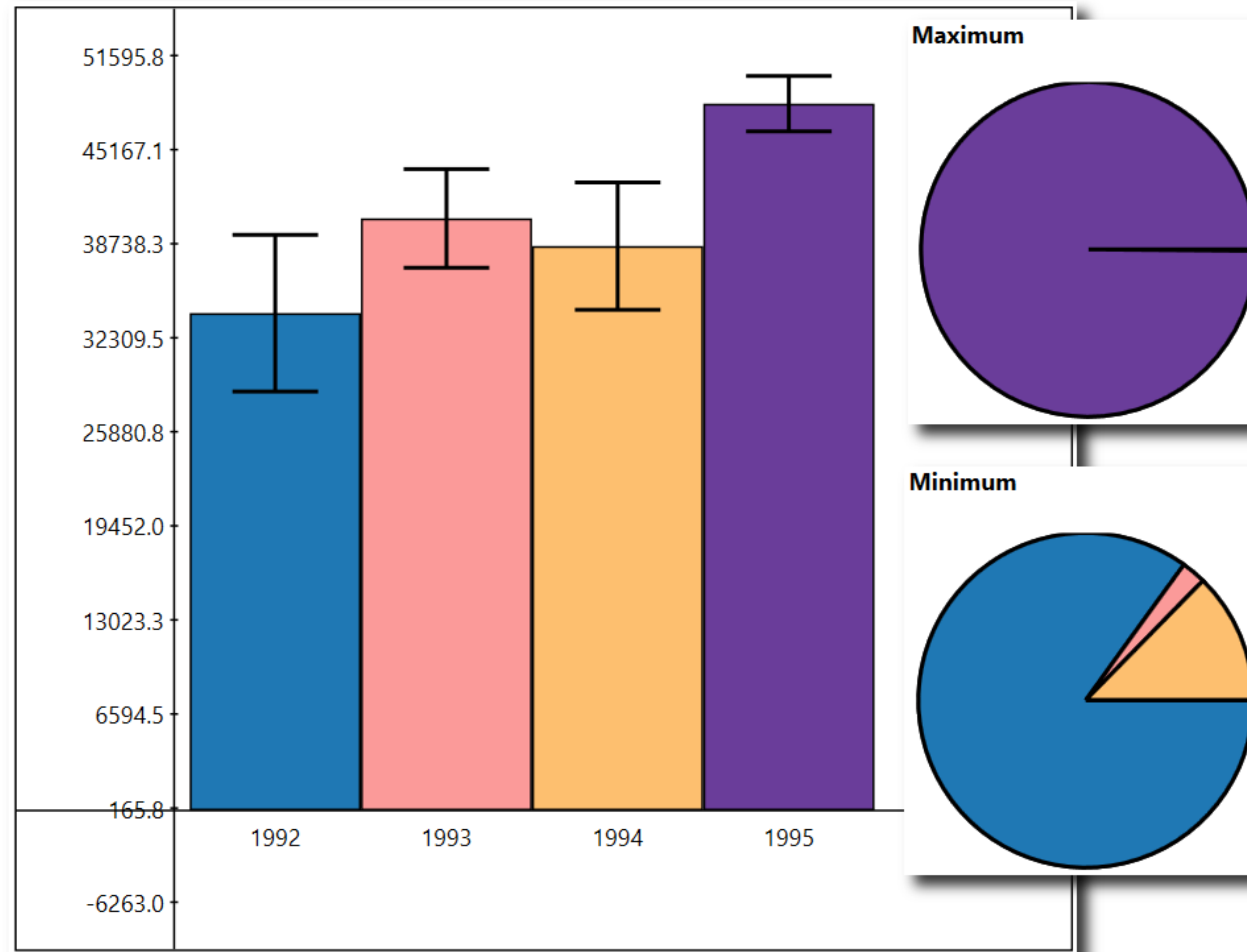
Compare Distributions

- How likely bar larger than another one?

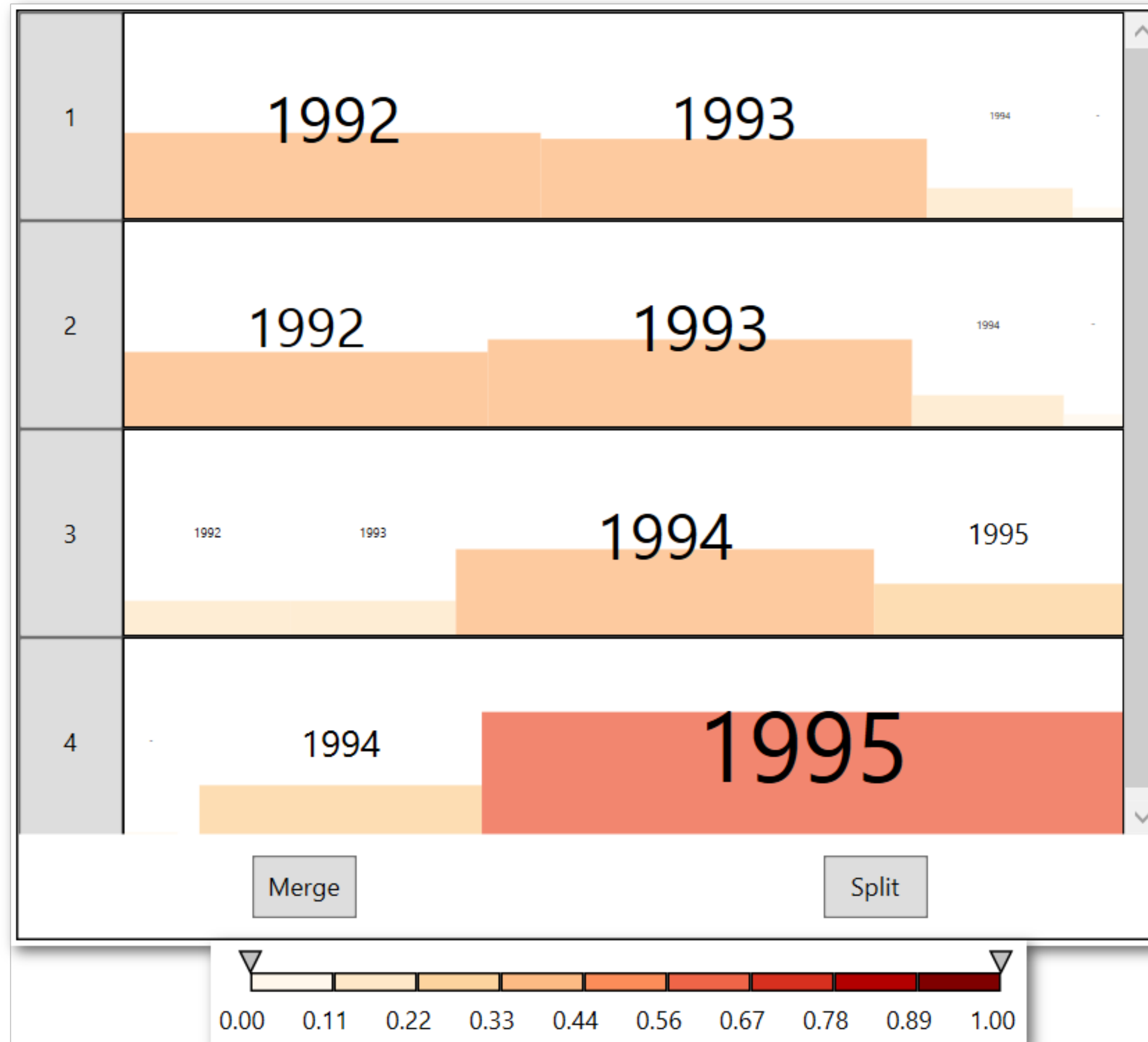


Find Extrema

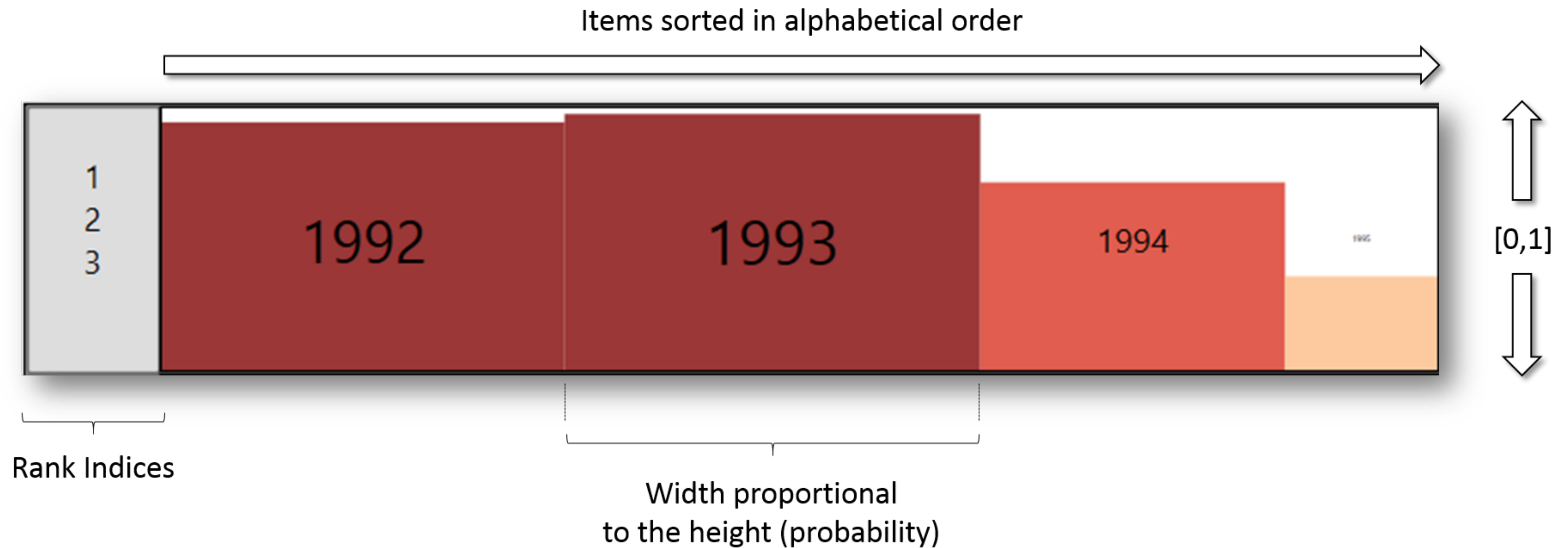
- How likely is extremum?



Ranking Distributions



Ranking Distributions



Ranking Distributions



Evaluation

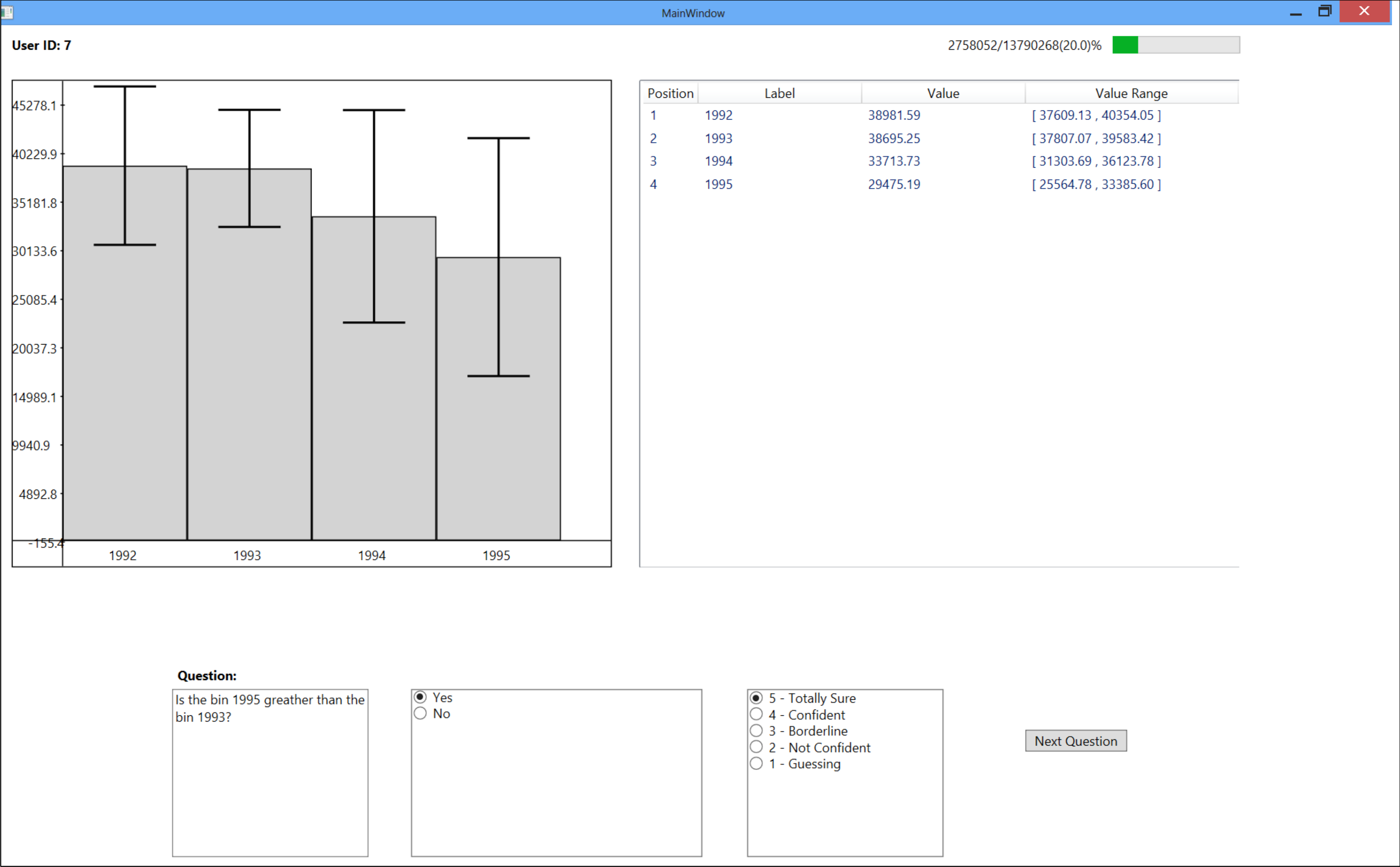
Evaluation

- Initial User Study
- 7 Participants
- Goal: Compares 3 data exploration scenarios
 - Neglected Uncertainty
 - Error Bars
 - Enhanced = Error Bars + Annotations
- Simulate real analysis environment
 - Benchmark TPCCH dataset used to generate study questions

Study Design

- Question of the type
 - Is bin X larger than the constant c?
 - Is bin X larger than bin Y?
 - What are the most probable top 3 bins?
- 75 Questions (3 Scenarios x 5 Sample sizes x 5 Question Types)
- Data collected
 - Answer (Multiple Choice)
 - Time
 - Confidence Report (1 – Completely Uncertain to 5 – Completely Certain)

Evaluation



Study Design

- Hypotheses
 - (H1) Users will give more accurate answers
 - (H2) Users will be more confident in their answers
- We expected that annotations would not be significantly slower than the other scenarios

Qualitative Results

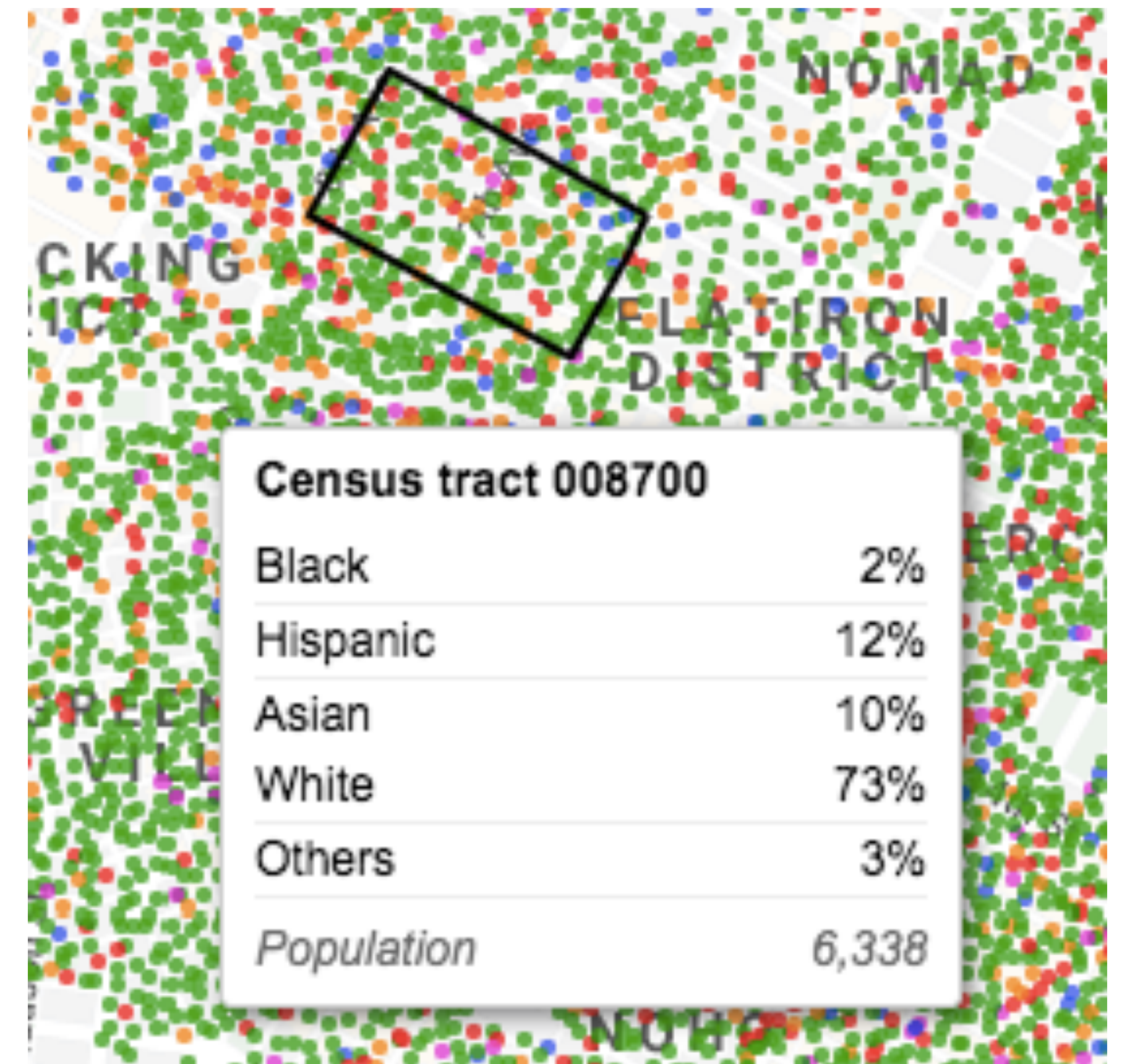
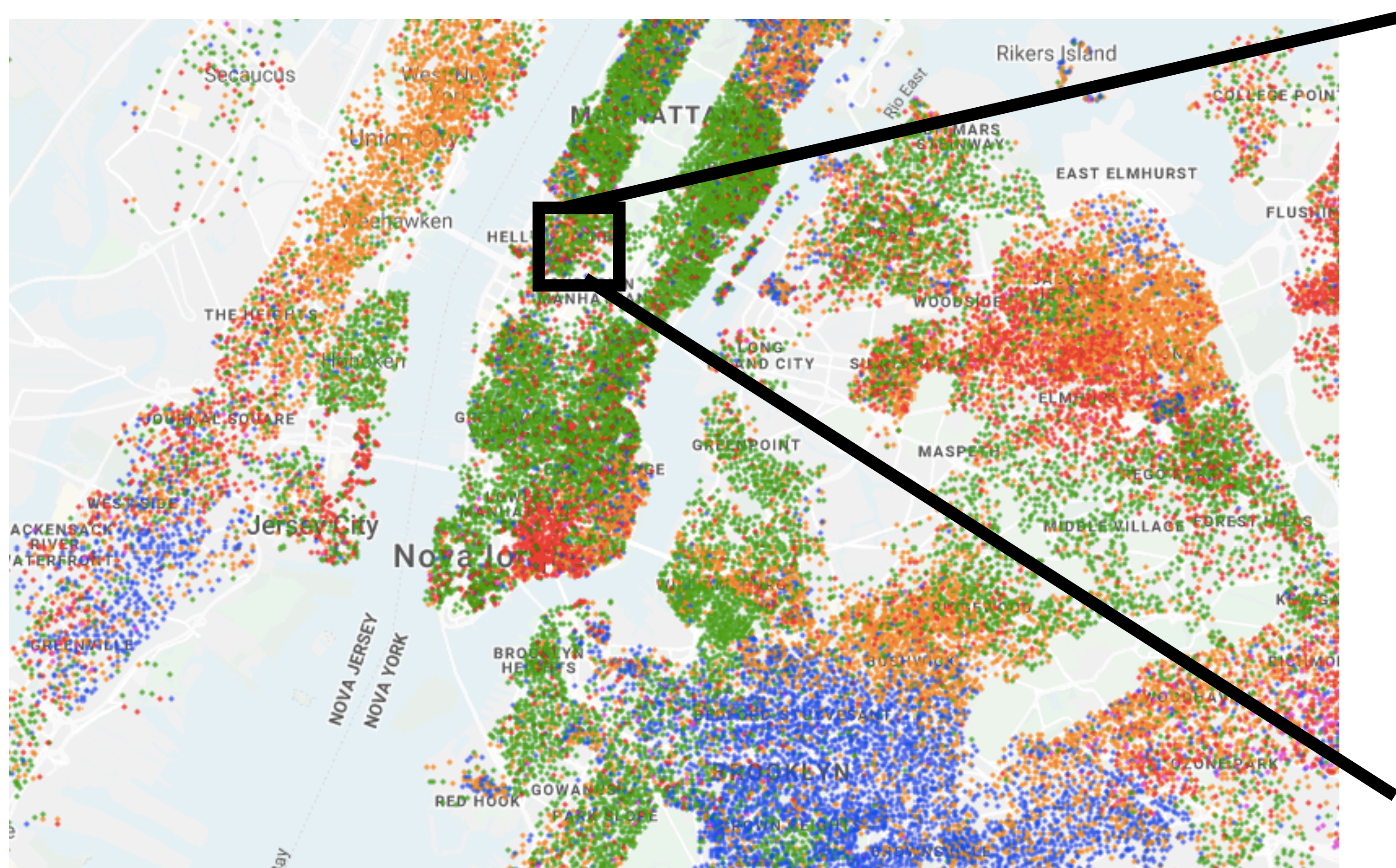
- All subjects reported being comfortable with the system
- Users reported were positive with “not having to do much thinking”
- The rank/sort tool was considered complex
- Sample size greatly influenced confidence judgment

Discussion

- Interactive annotations for better “reading” of uncertainty visualizations
- Initial study shows promising results
 - Enhanced justified confidence
 - Not significantly slower

How these generalize to Geographical Data?

Dot Maps



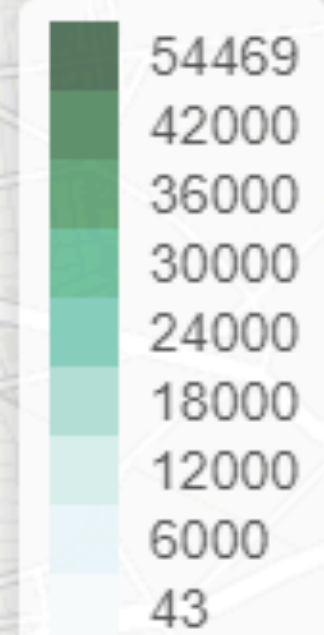
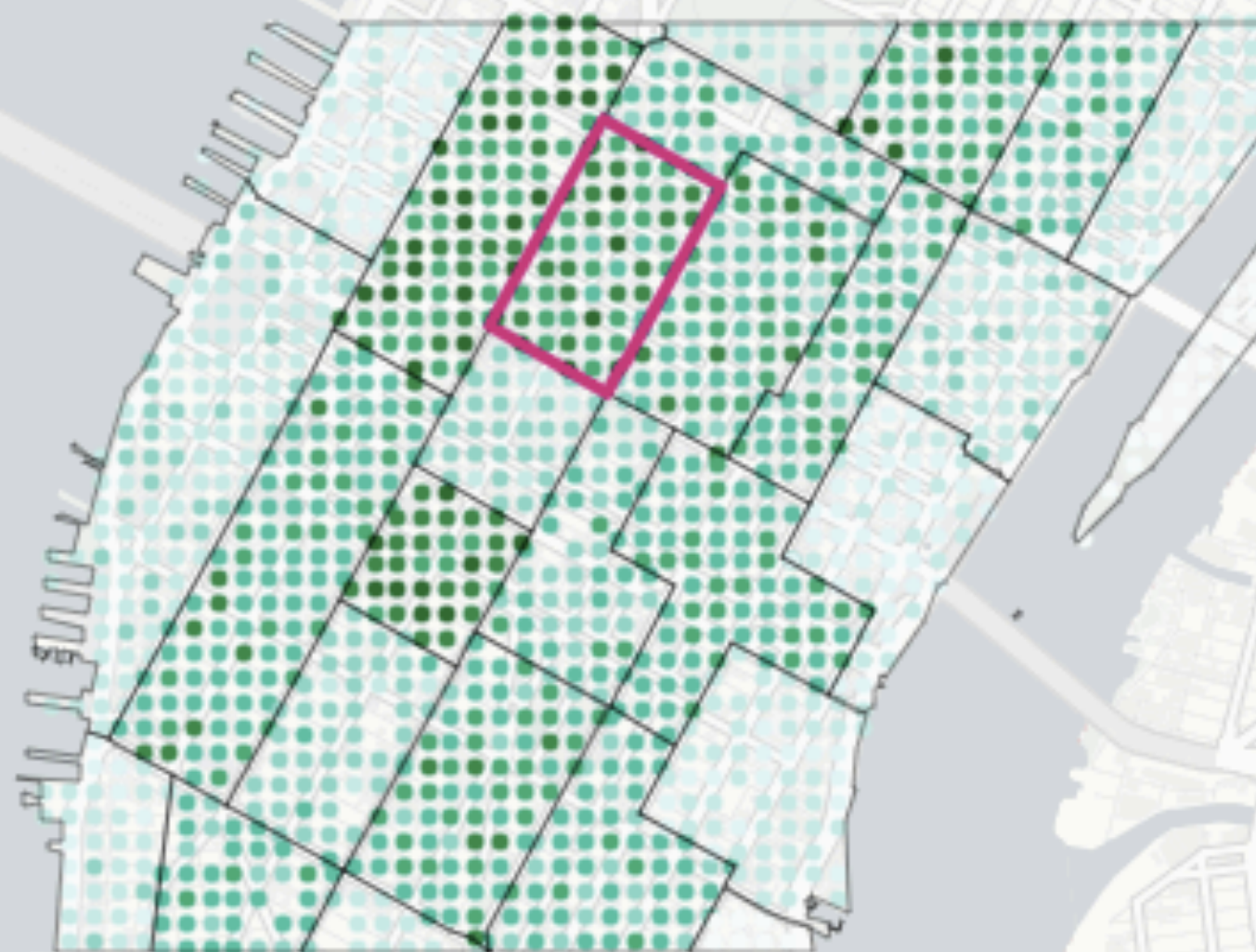
Dot Maps

Pontos de Densidade

Confirmação



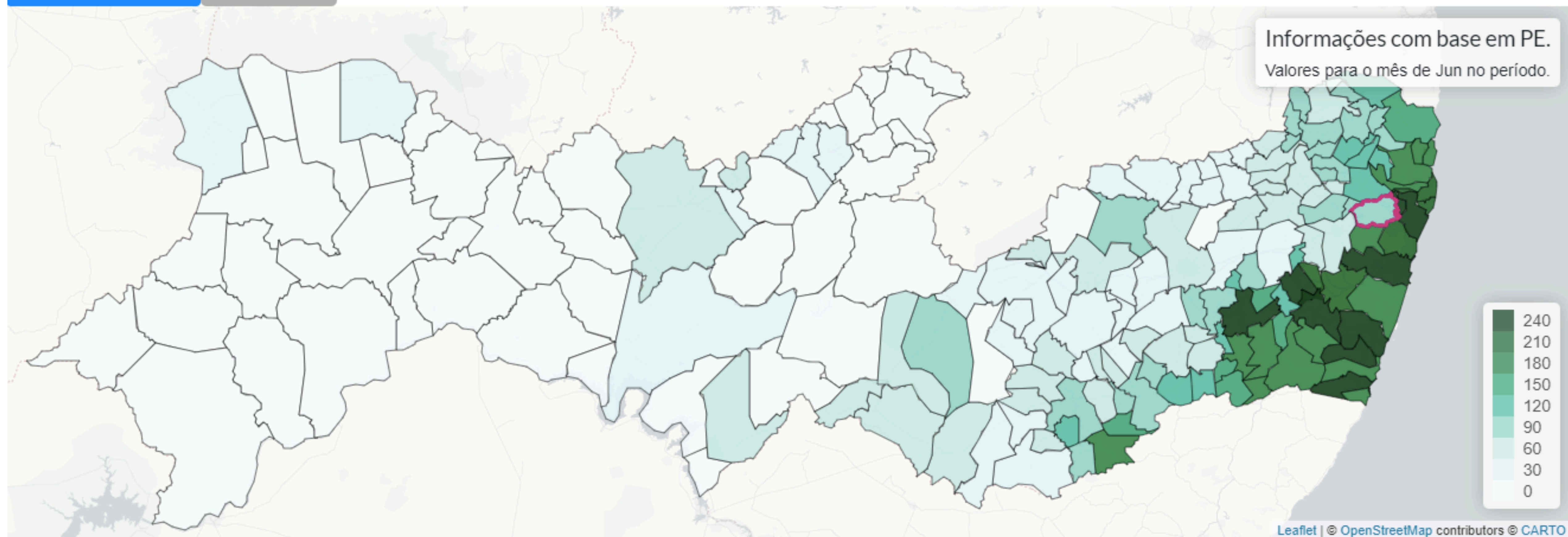
Informações baseadas na ilha de Manhattan - Nova York / EUA.
Valores para todo o período.



Hypothetical Outcome Maps

Gráficos Hipotéticos

Confirmação



Animar

Parar

Interactive CDF Maps

Interação

Confirmação

Informações baseadas na ilha de Manhattan - Nova York / EUA.
Valores para todo o período.

100%

0%

Leaflet | © OpenStreetMap contributors © CARTO

22 000

36 000

54 470

13 618

27 235

40 853

54 470

Posicione o ponteiro para escolher um valor.

Study Design

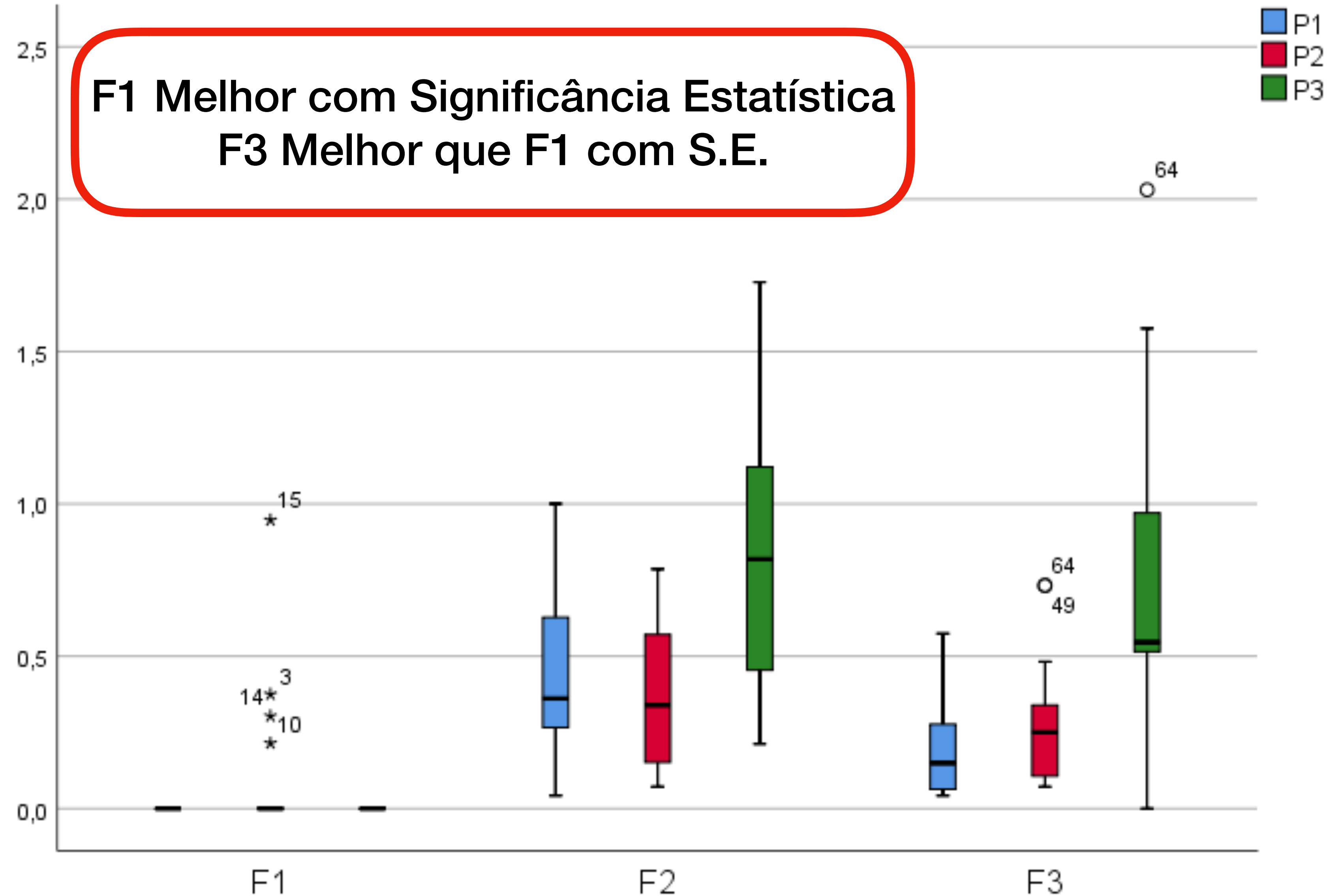
- Question of the type
 - What is the probability of area X have value larger than the constant c ?
 - What is the probability of area X have value larger than area Y?
 - What is the area most likely to be larger than constant c ?
 - What is the average of area X?
- Data collected
 - Answer (From 0 to 100)
 - Time
 - Confidence Report (1 – Completely Uncertain to 5 – Completely Certain)

Study Design

- Initial User Study
- 60 Participants (each participant only tests one scenario)
- Goal: Compares 3 data exploration scenarios
 - Dot Maps
 - Hypothetical Outcome Maps
 - Interactive CDF Maps
- Using two real datasets
 - Taxis in NYC
 - Rainfall in Pernambuco (Brazil)

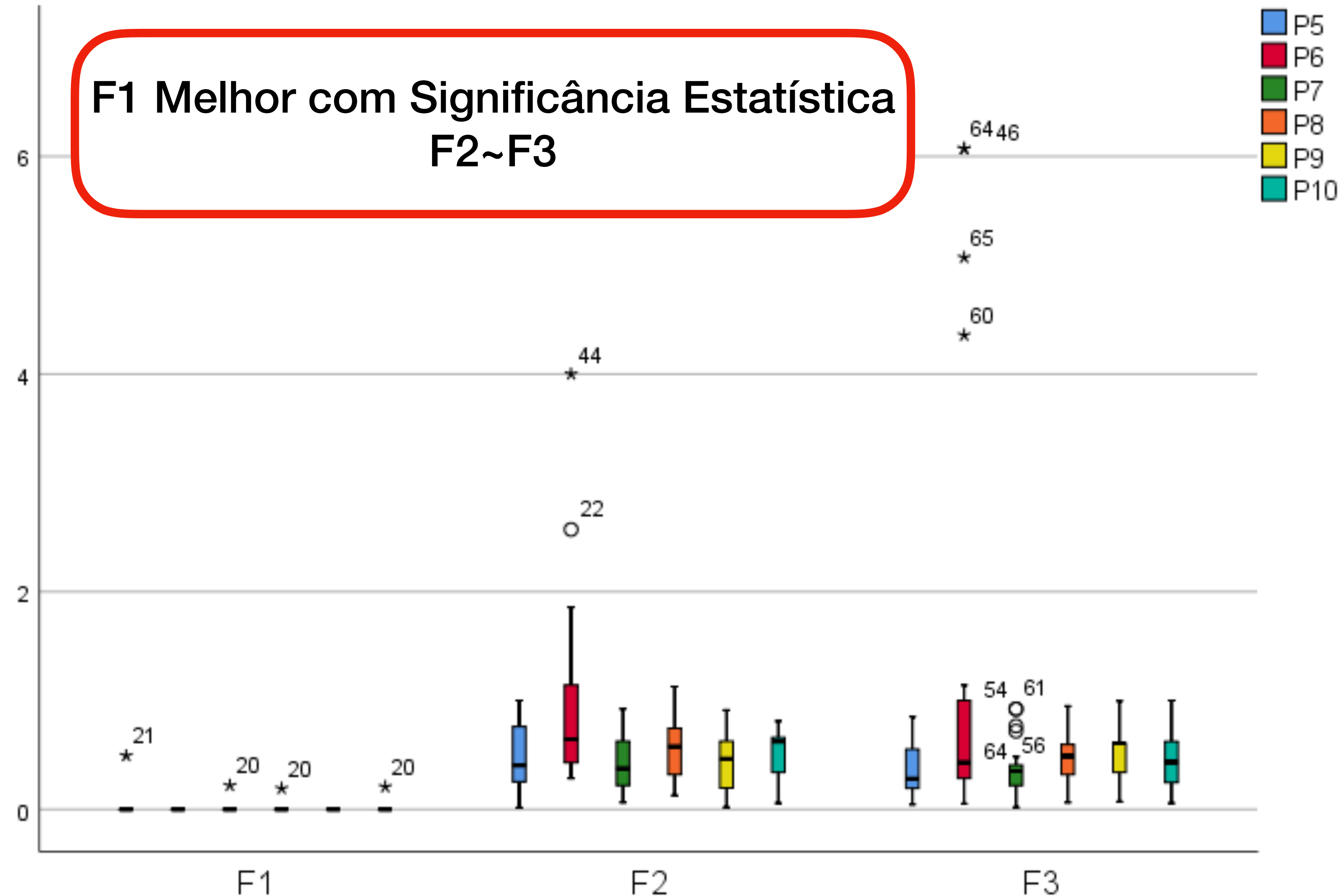
Relative Error - $\Pr(X < a)$, $\Pr(X > a)$, $\Pr(a < X < b)$

- Relative error
- F1: Interaction
- F2: Dot Maps
- F3 Hypothetical Maps



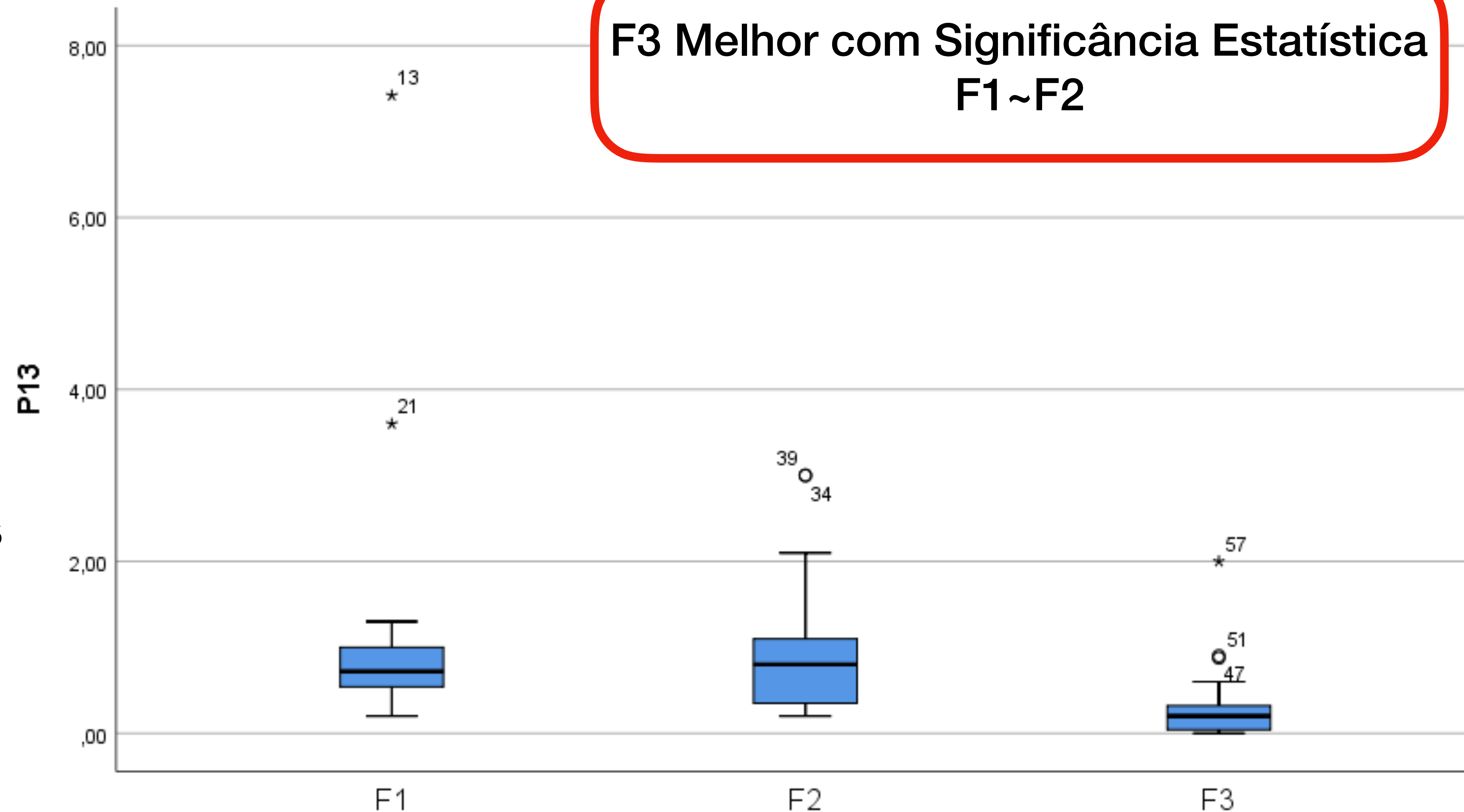
Relative Error - $\Pr(X < Y)$

- Relative error
- F1: Interaction
- F2: Dot Maps
- F3 Hypothetical Maps



Mean Estimation

- Relative error
- F1: Interaction
- F2: Dot Maps
- F3 Hypothetical Maps



Discussion

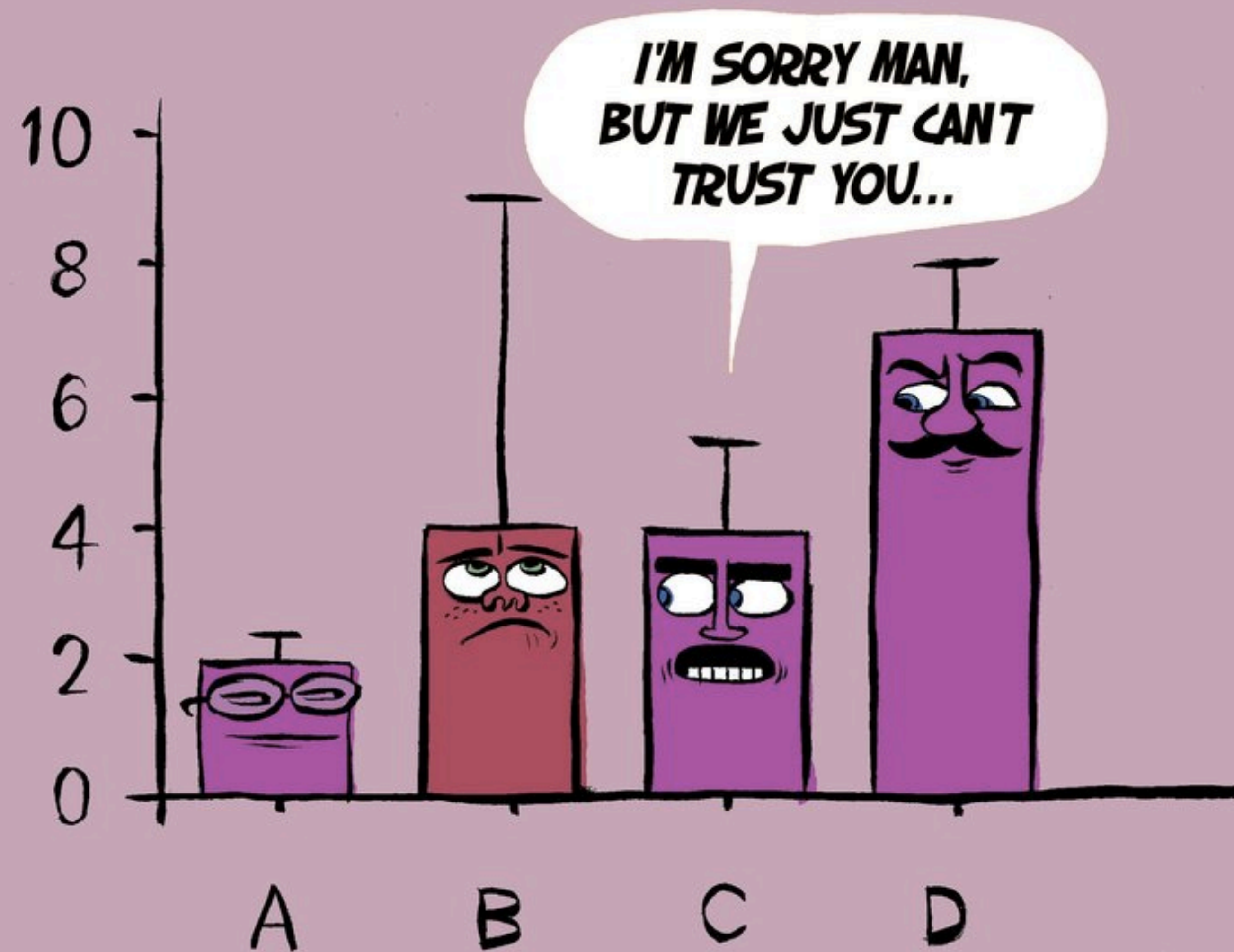
- Interaction showed to be a promising approach, but more work needs to be done on other tasks
- Hypothetical outcome maps are very influenced by factors such as spatial distance and area size
- Dot maps were surprisingly not accurate as accurate and users spent too much time on it. We want to explore different dot sizes and spatial arrangement

Comments

- Interaction: "Easy to use and helpful. However, I tried to always double check, since I have to trust that the system is doing the right thing."
- Hypothetical outcome maps: "Almost impossible to keep up with all the changing areas. It is very hard to compare areas that are far apart. After the fourth question I got tired and started guessing."
- Dot maps: "The process of counting requires a lot of effort and time consuming. A lot of extra interaction with zooming and panning are needed."

Future Work

- How can we get the unique features of the different approaches in a single system?
- Is it possible/worth it to generalize the ordering in quantile dot plots to the geographical scenario?
- Other types of data: Trajectory Simulations



19/2011

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