Value-Suppressing Uncertainty Palettes

Michael Correll
Dominik Moritz
Jeffrey Heer

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Outline

What We Did

Why We Did It

Why We Think It Works

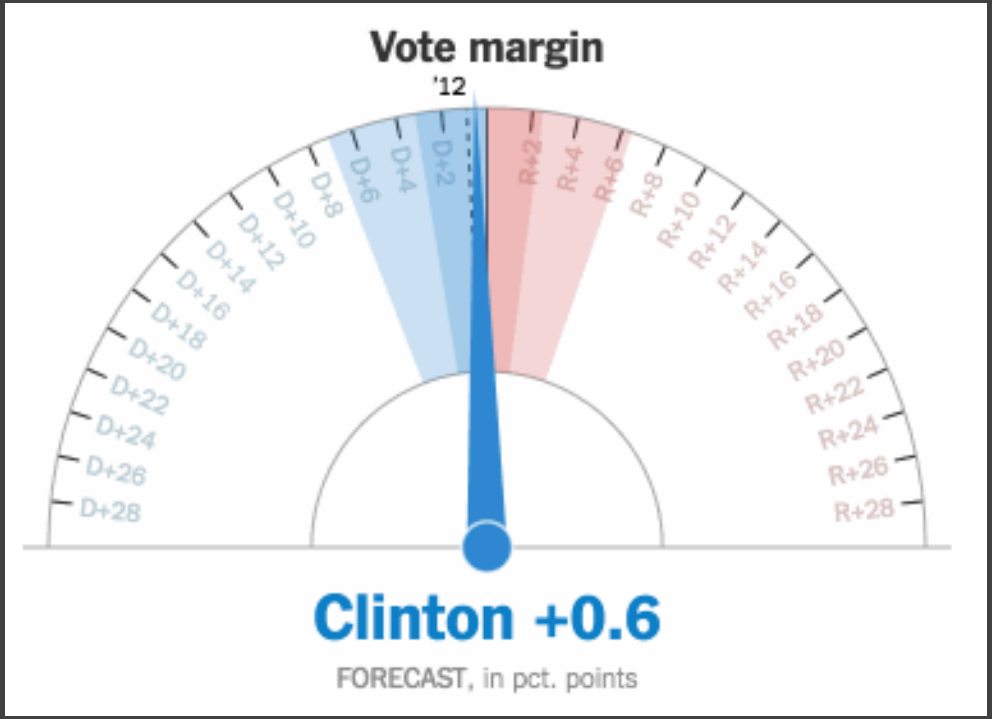
Outline

What We Did

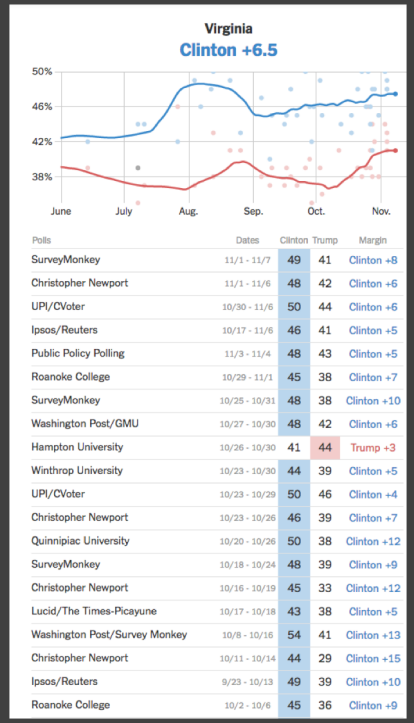
Why We Did It

Why We Think It Works

2016 Election



2016 U.S. Election

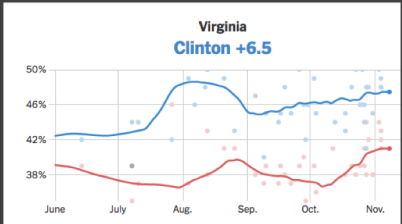


Virginia

Clinton +6.5

Polls	Dates	Clinton	Trump	Margin
SurveyMonkey	11/1 - 11/7	49	41	Clinton +8
Christopher Newport	11/1 - 11/6	48	42	Clinton +6
UPI/CVoter	10/30 - 11/6	50	44	Clinton +6
Ipsos/Reuters	10/17 - 11/6	46	41	Clinton +5
Public Policy Polling	11/3 - 11/4	48	43	Clinton +5
Roanoke College	10/29 - 11/1	45	38	Clinton +7
SurveyMonkey	10/25 - 10/31	48	38	Clinton +10
Washington Post/GMU	10/27 - 10/30	48	42	Clinton +6
Hampton University	10/26 - 10/30	41	44	Trump +3
Winthrop University	10/23 - 10/30	44	39	Clinton +5
UPI/CVoter	10/23 - 10/29	50	46	Clinton +4
Christopher Newport	10/23 - 10/26	46	39	Clinton +7
Quinnipiac University	10/20 - 10/26	50	38	Clinton +12
SurveyMonkey	10/18 - 10/24	48	39	Clinton +9
Christopher Newport	10/16 - 10/19	45	33	Clinton +12
Lucid/The Times-Picayune	10/17 - 10/18	43	38	Clinton +5
Washington Post/Survey Monkey	10/8 - 10/16	54	41	Clinton +13
Christopher Newport	10/11 - 10/14	44	29	Clinton +15
Ipsos/Reuters	9/23 - 10/13	49	39	Clinton +10
Roanoke College	10/2 - 10/6	45	36	Clinton +9

2016 U.S. Election



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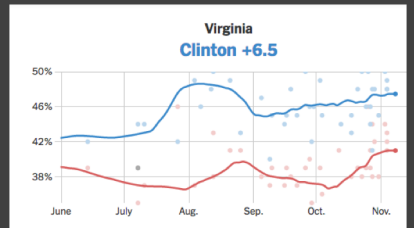
Clinton is only 1.6 margins of error away! ($p>0.05$)

2016 U.S. Election



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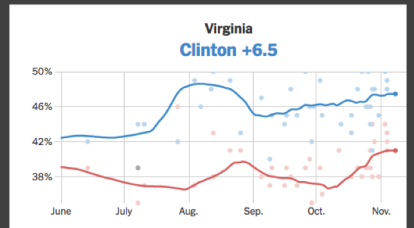
How to convey uncertainty?

2016 U.S. Election



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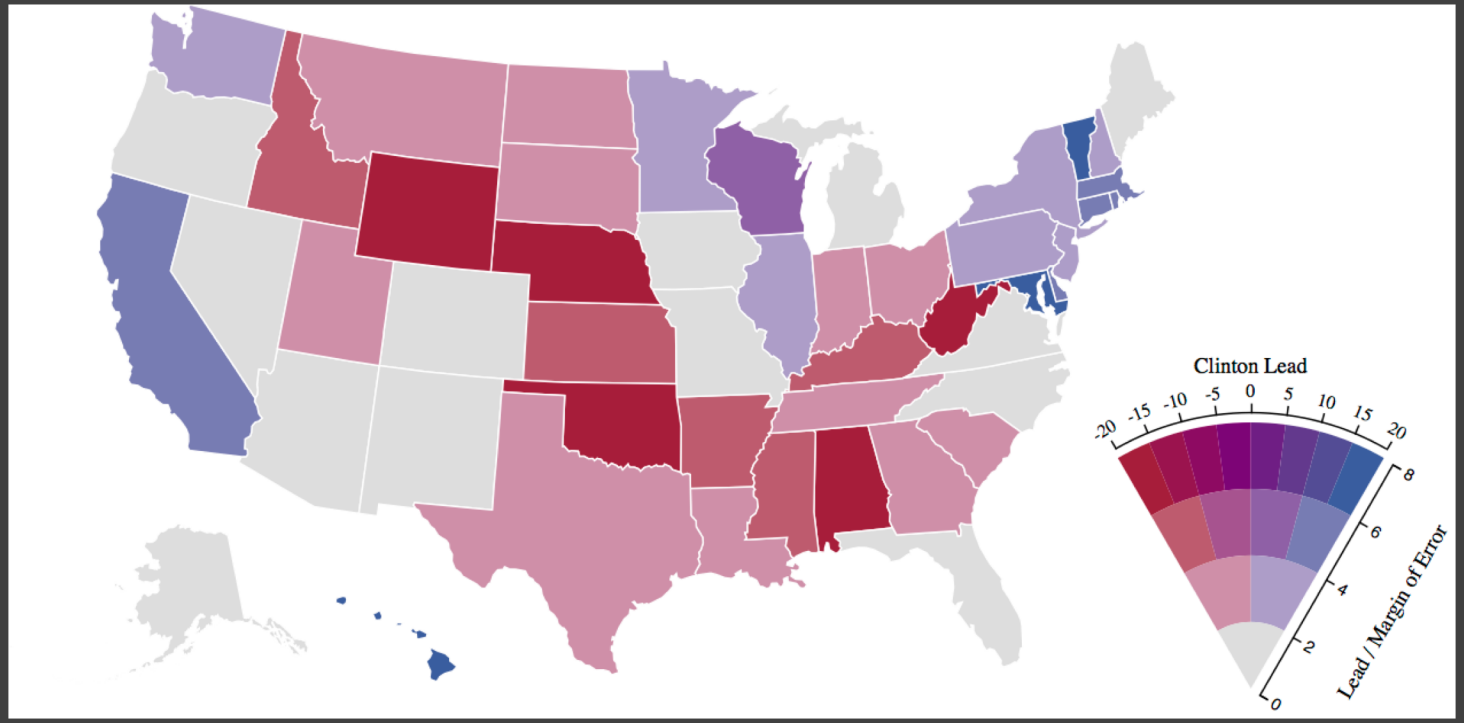
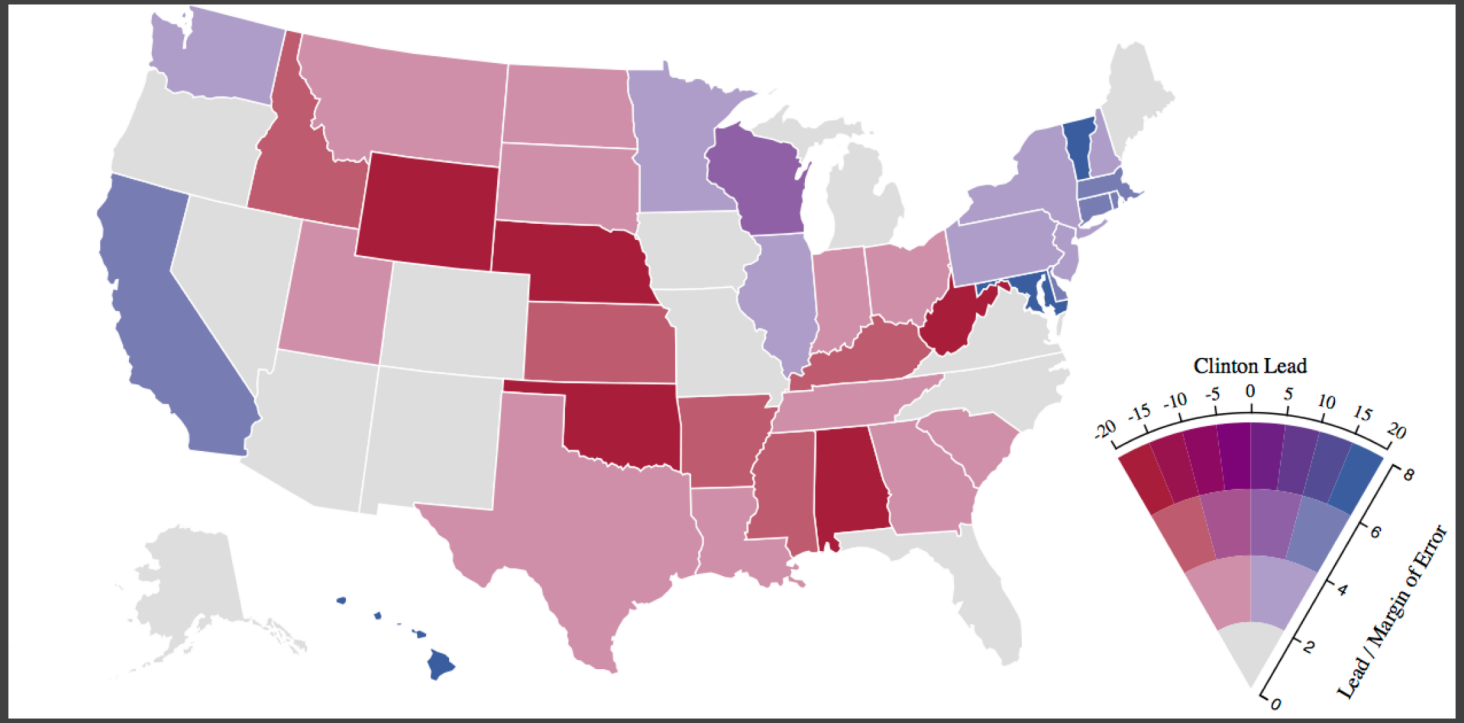
How to convey uncertainty?

How to encourage people from refraining from deciding?

Value-Suppressing Uncertainty Palette



Value-Suppressing **Uncertainty Palette**



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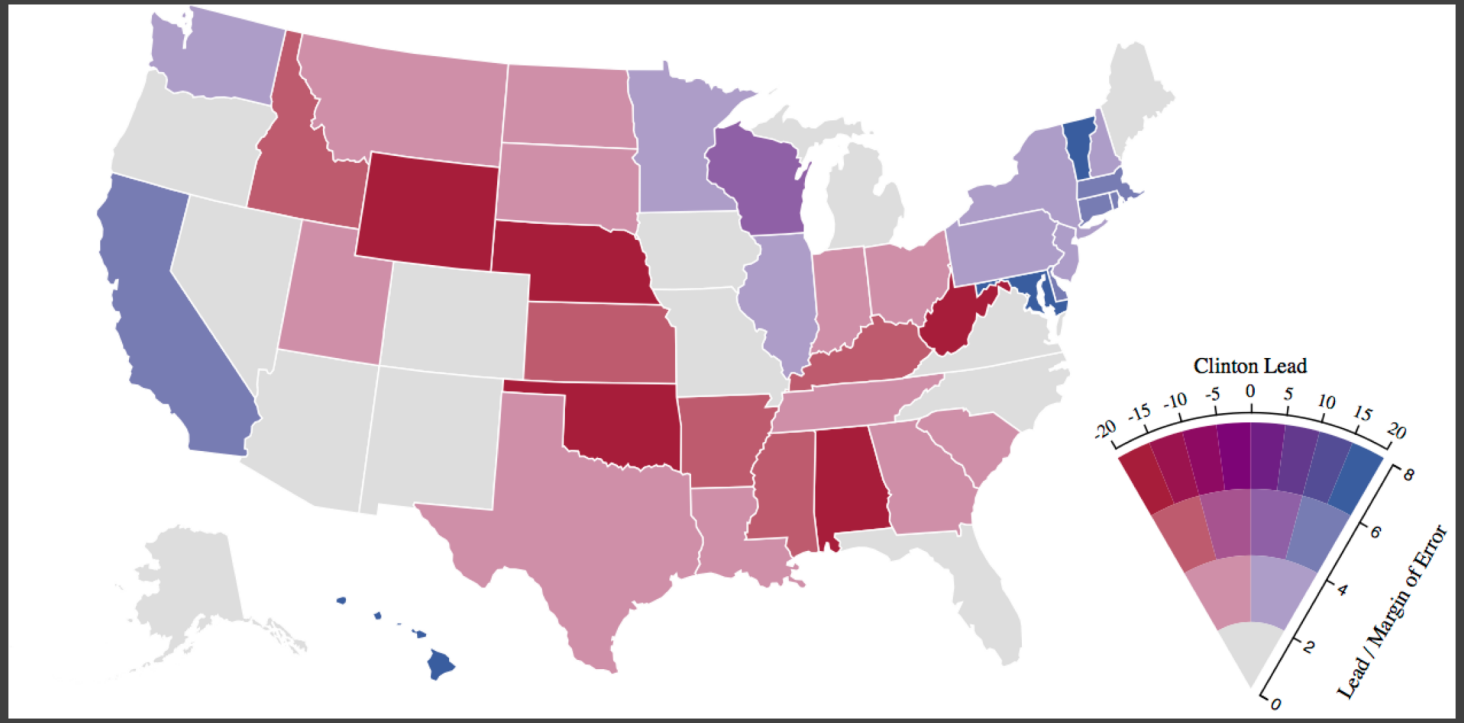
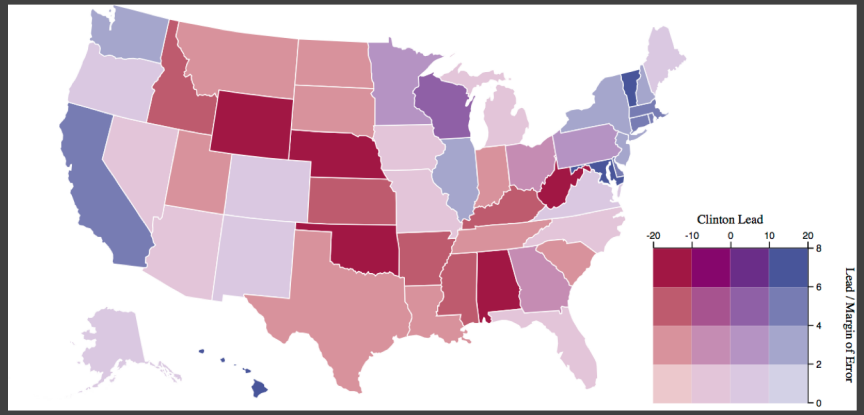


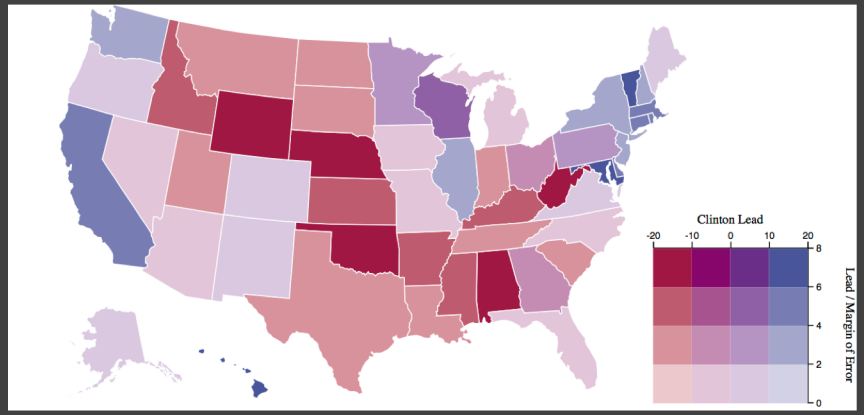
Value-Suppressing Uncertainty Palettes

Traditional Bivariate Map

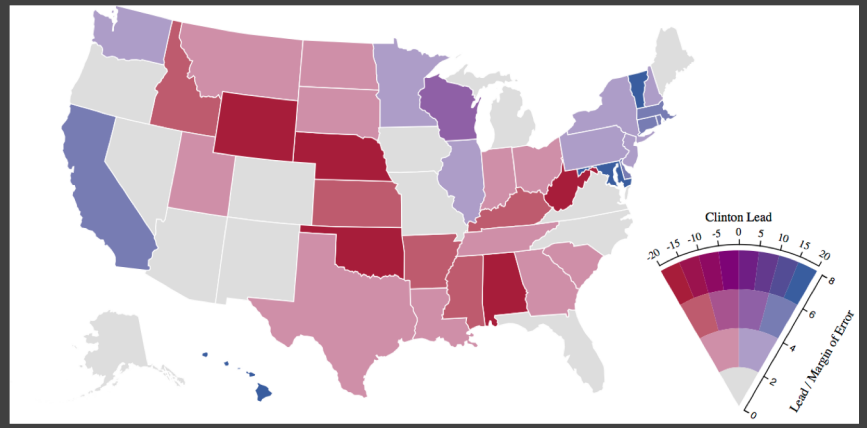


Value-Suppressing Uncertainty Palettes

Traditional Bivariate Map



VSUP



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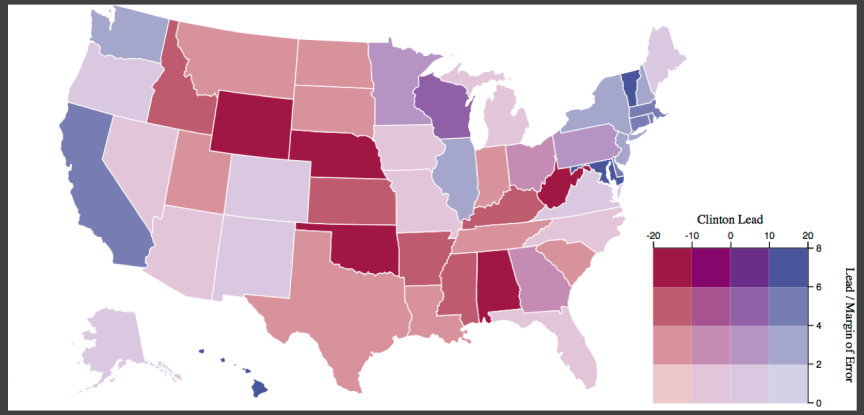

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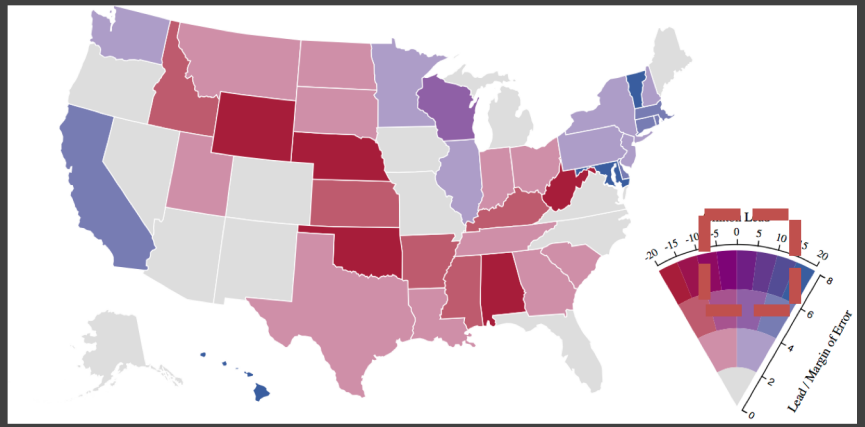

Value-Suppressing Uncertainty Palettes

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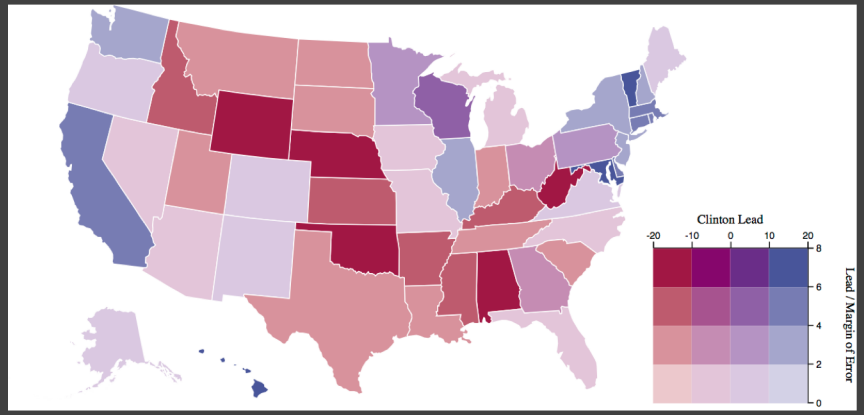

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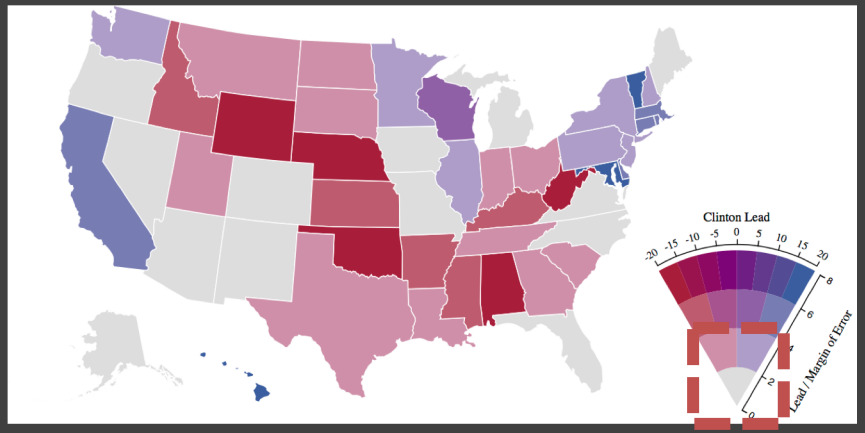

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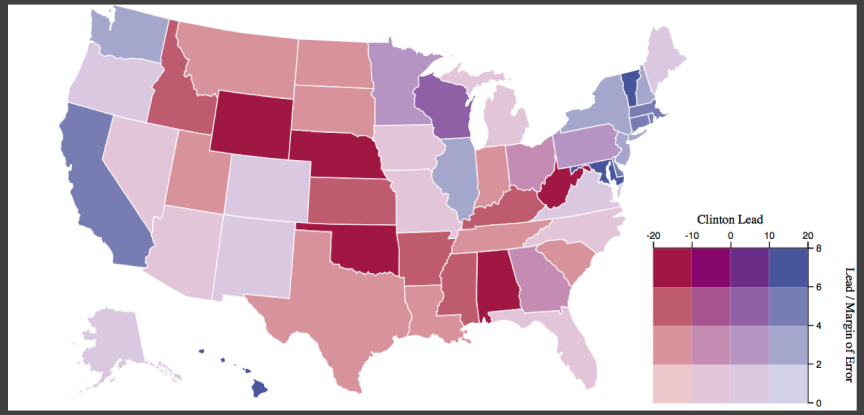

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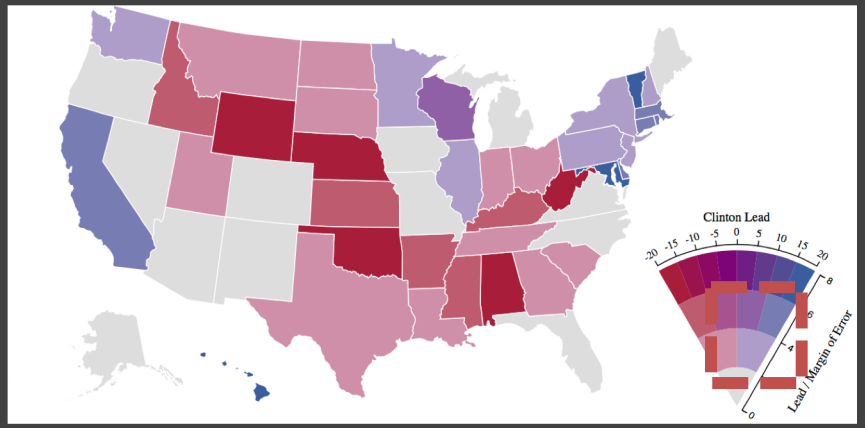

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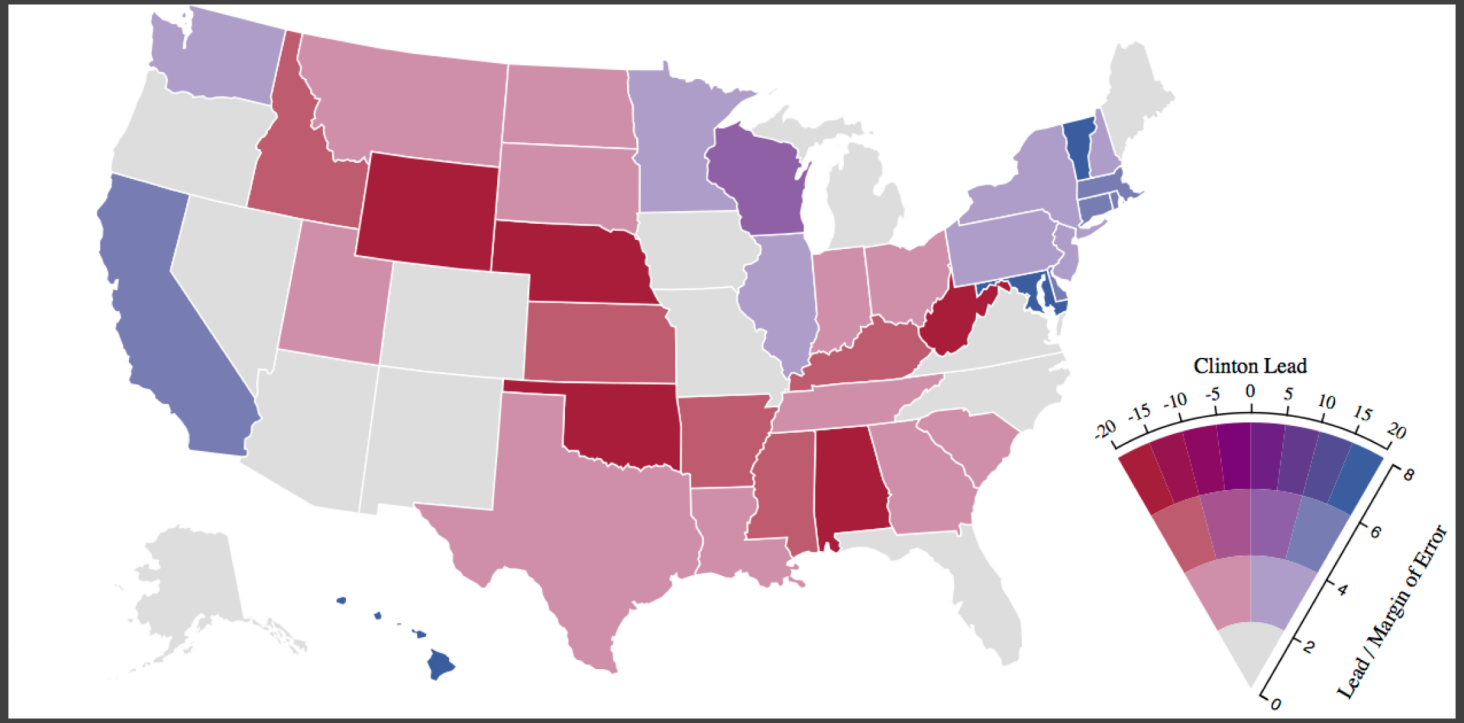
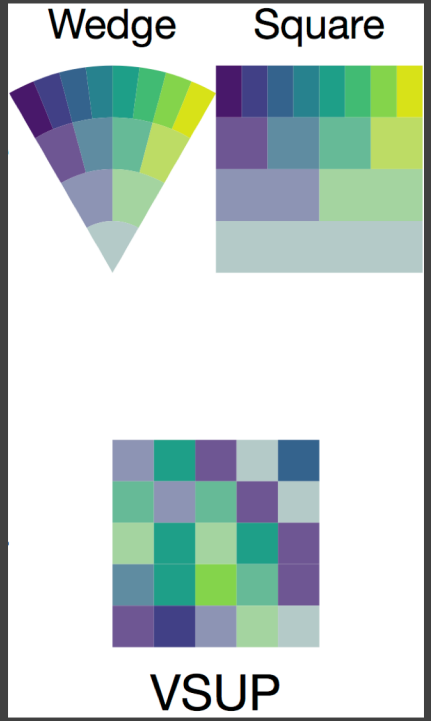


Tree-Quantization



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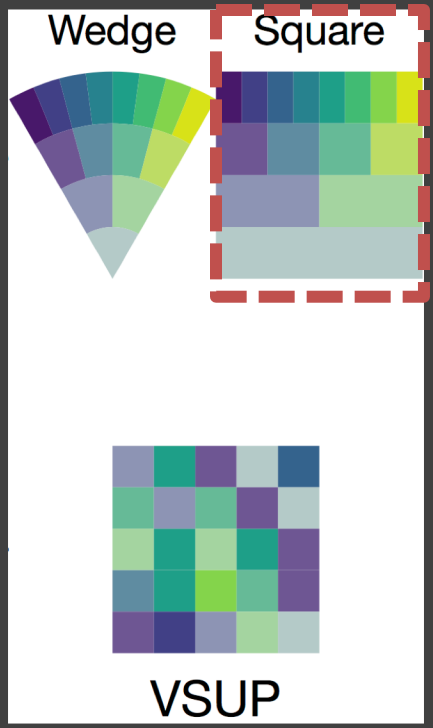

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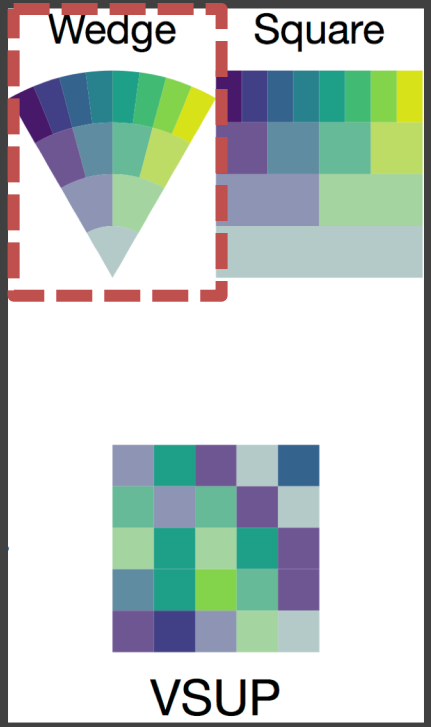
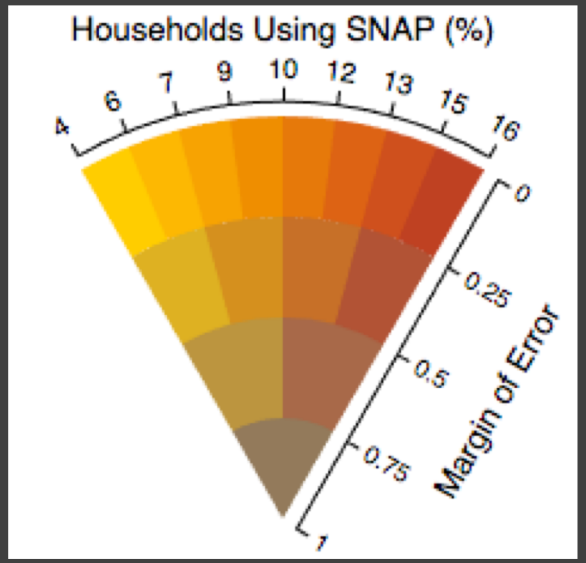
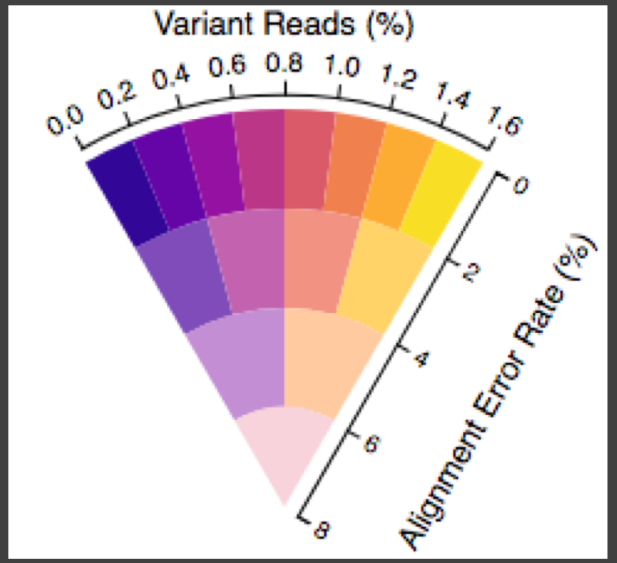
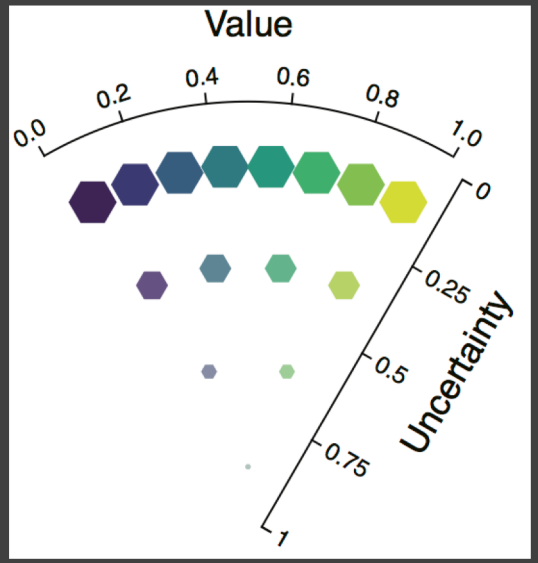



Households Using SNAP (%)
4
6
7
9
10
12
13
15
16
0
0.25
0.5
0.75
1
Margin of Error


Variant Reads (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
2
4
6
8
Alignment Error Rate (%)


Value
0.0
0.2
0.4
0.6
0.8
1.0
0
0.25
0.5
0.75
1
Uncertainty

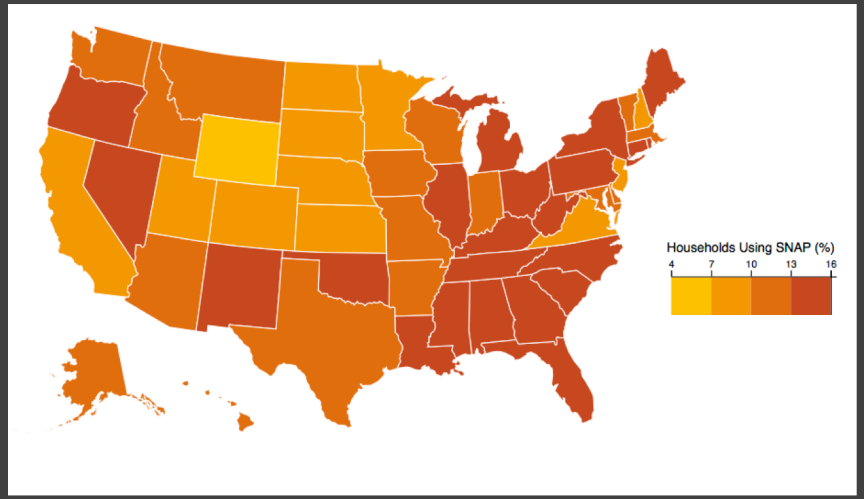
Outline

What We Did

Why We Did It

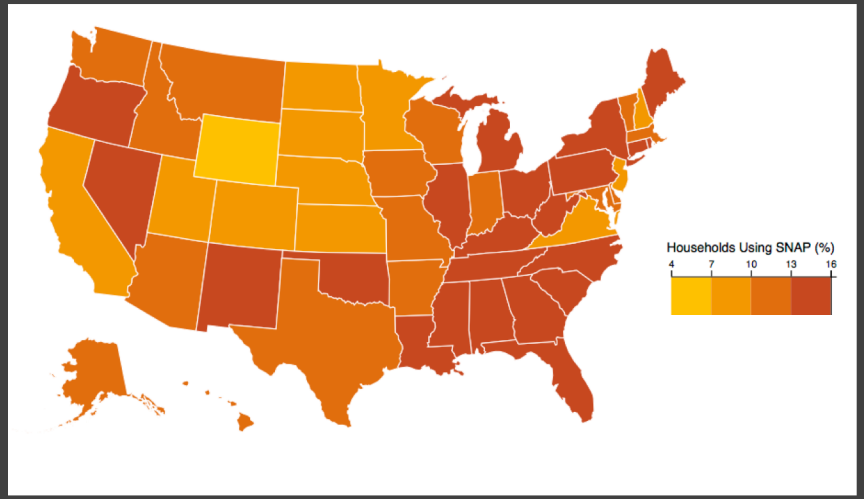
Why We Think It Works

Uncertainty In Maps



Uncertainty In Maps

Data Map



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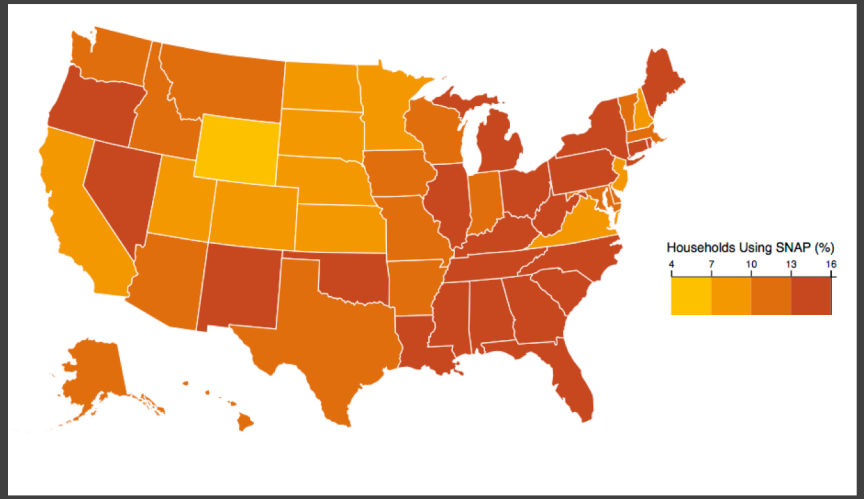

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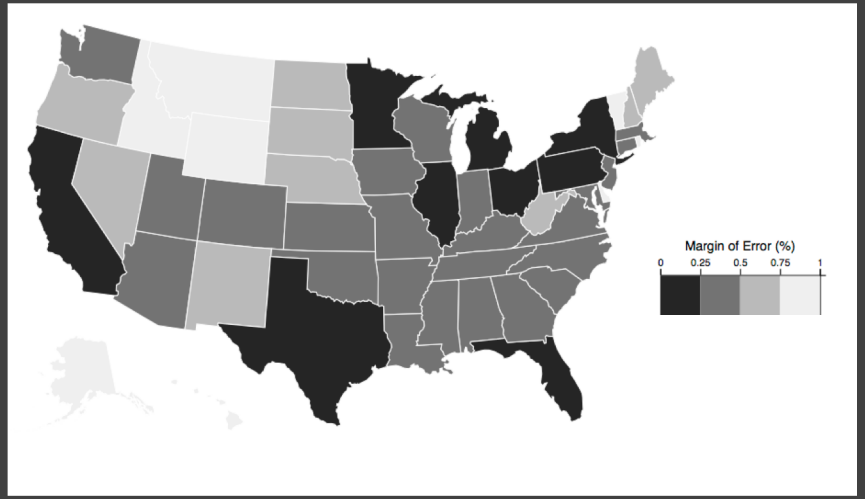

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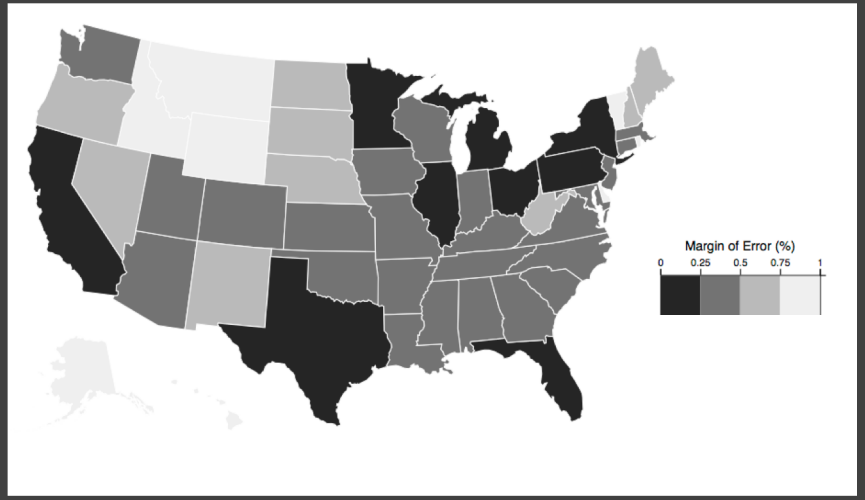

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Uncertainty Map

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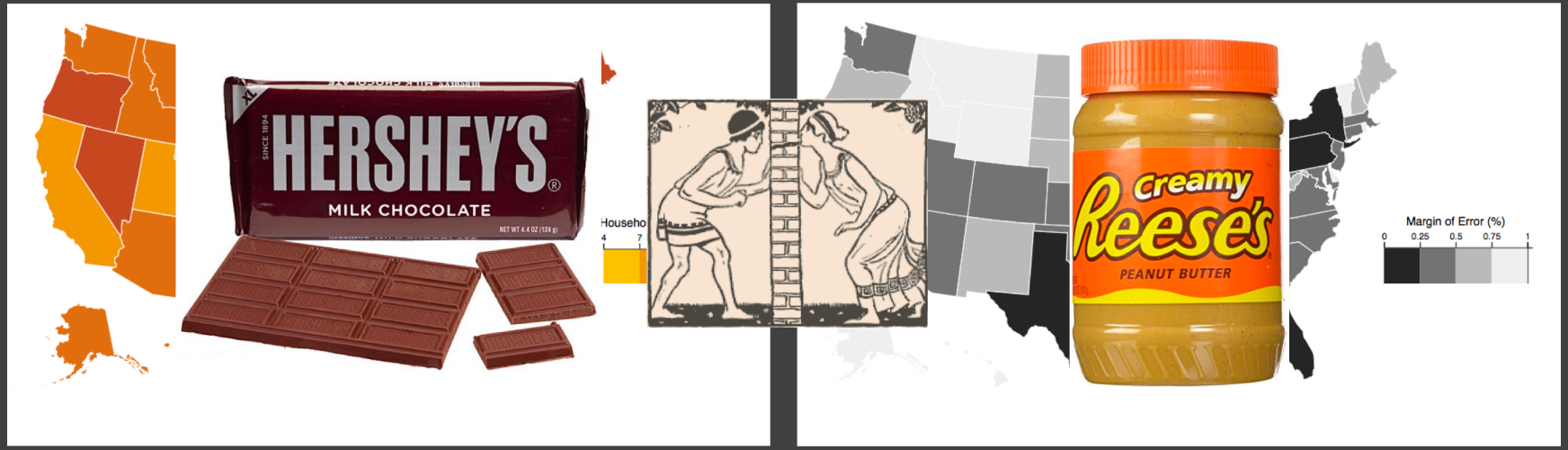
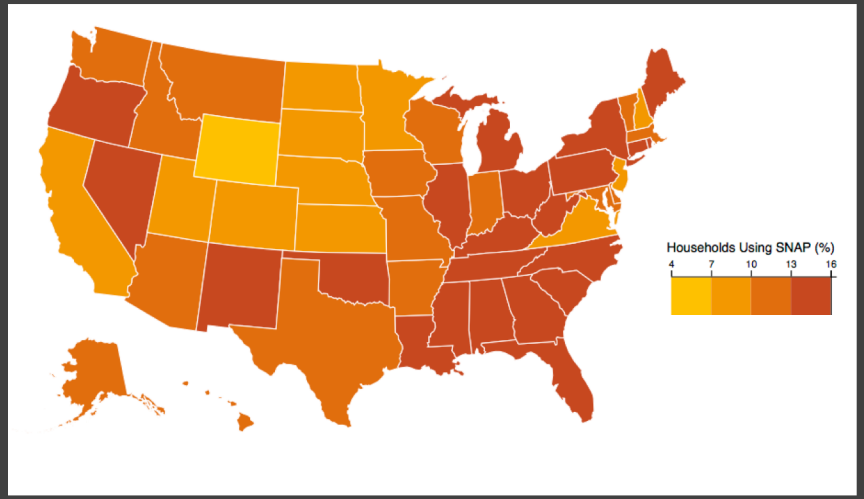


Juxtaposition

Data Map



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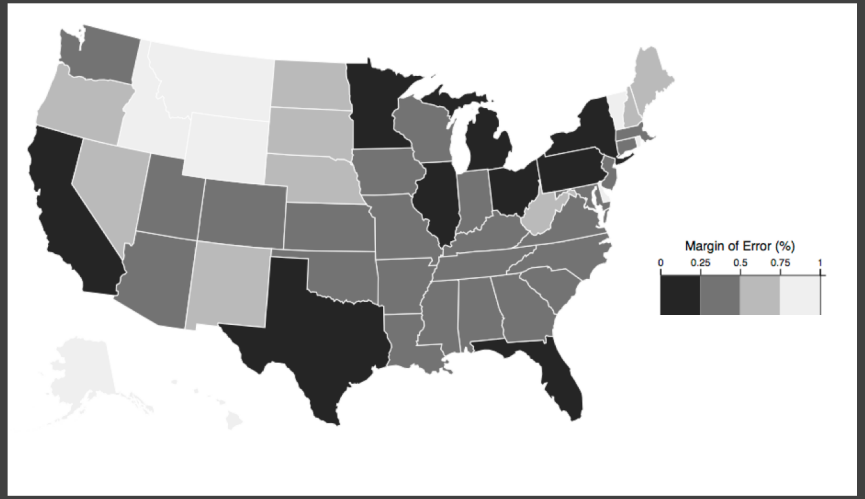

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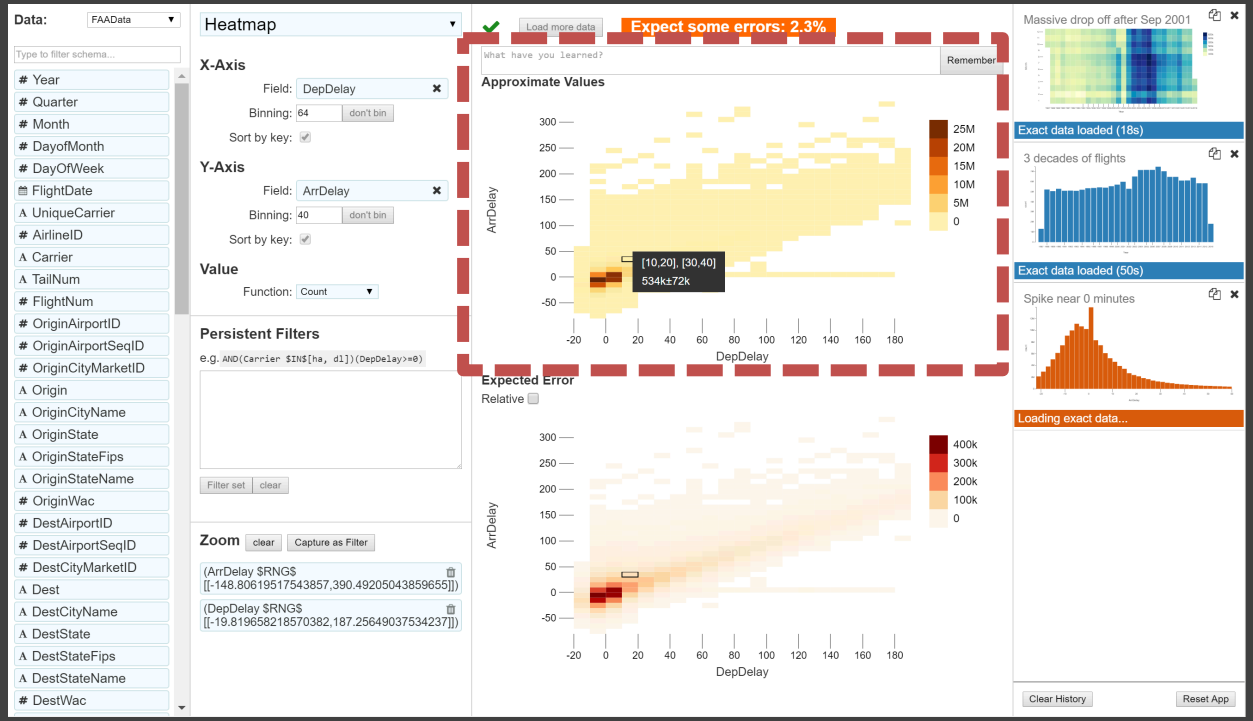
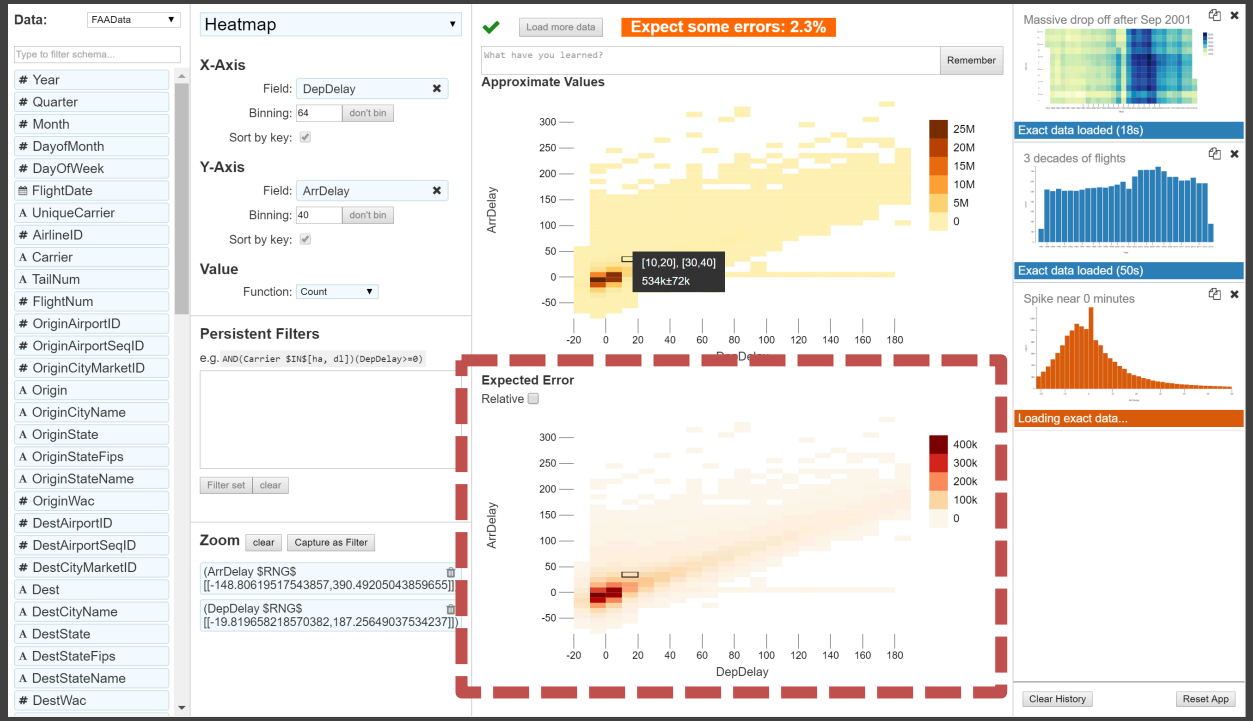
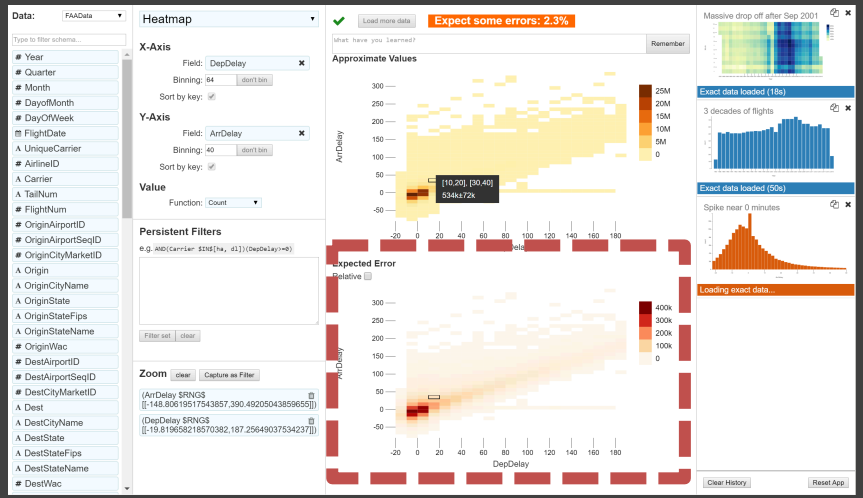

Data:
FAAData
Type to filter schema...
Year
Quarter
Month
DayofMonth
DayOfWeek
FlightDate
UniqueCarrier
AirlineID
Carrier
TailNum
FlightNum
OriginAirportID
OriginAirportSeqID
OriginCityMarketID
Origin
OriginCityName
OriginState
OriginStateFips
OriginStateName
OriginWac
DestAirportID
DestAirportSeqID
DestCityMarketID
Dest
DestCityName
DestState
DestStateFips
DestStateName
DestWac
Heatmap
X-Axis
Field: DepDelay
Binning: 64 don't bin
Sort by key:
Y-Axis
Field: ArrDelay
Binning: 40 don't bin
Sort by key:
Value
Function: Count
Persistent Filters
e.g. AND(Carrier IN[ha, dl])(DepDelay>=0)
Filter set clear
Zoom clear Capture as Filter
(ArrDelay RNG [[-148.80619517543857,390.49205043859655]])
(DepDelay RNG [[-19.819658218570382,187.25649037534237]])
Load more data
Expect some errors: 2.3%
What have you learned?
Remember
Approximate Values
ArrDelay
DepDelay
[10,20], [30,40]
534k±72k
25M
20M
15M
10M
5M
0
Expected Error
Relative
400k
300k
200k
100k
0
Massive drop off after Sep 2001
Exact data loaded (18s)
3 decades of flights
Exact data loaded (50s)
Spike near 0 minutes
Loading exact data...
Clear History
Reset App

Juxtaposed Uncertainty



Why This Is Bad

2x Space Requirements



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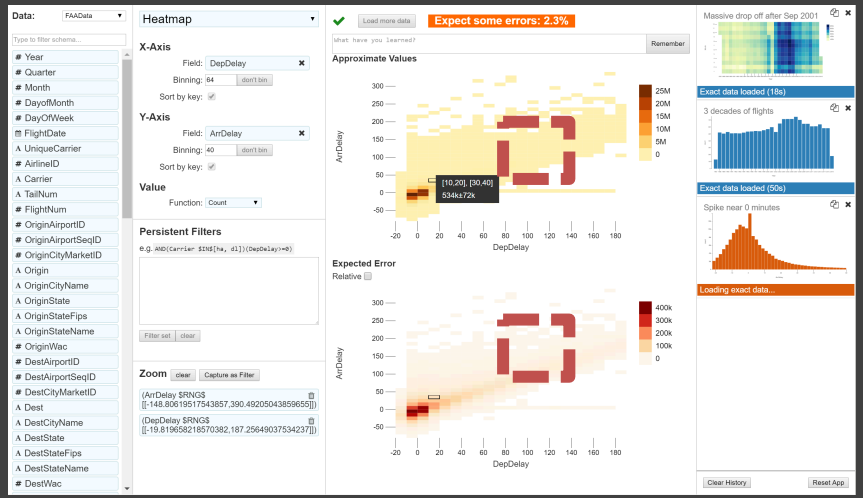
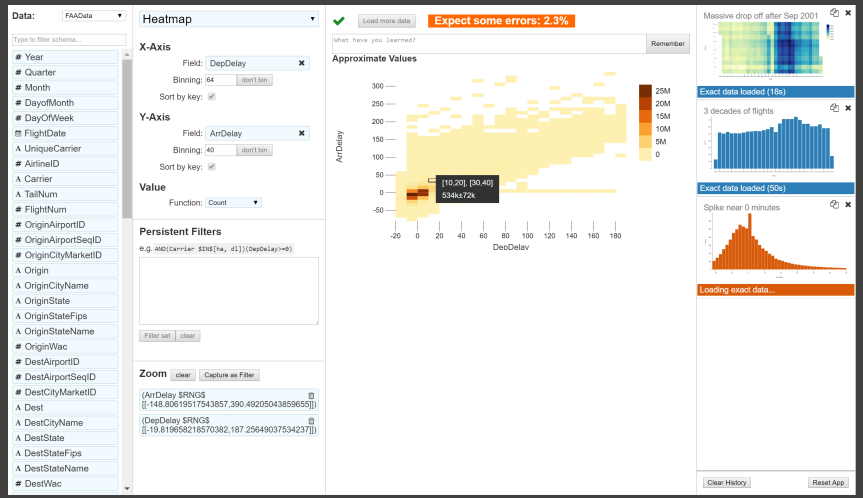


Requires Searching

Why This Is Bad

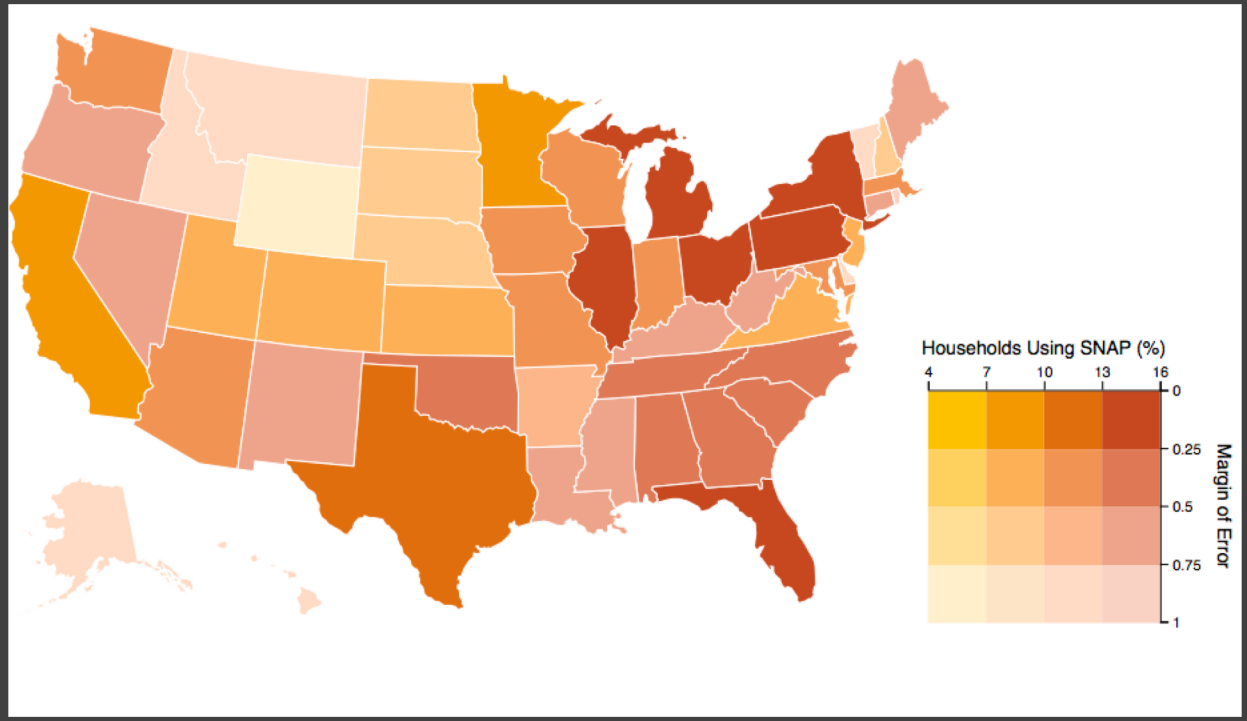


2x Space Requirements

Requires Searching

Ignorable

Superposition



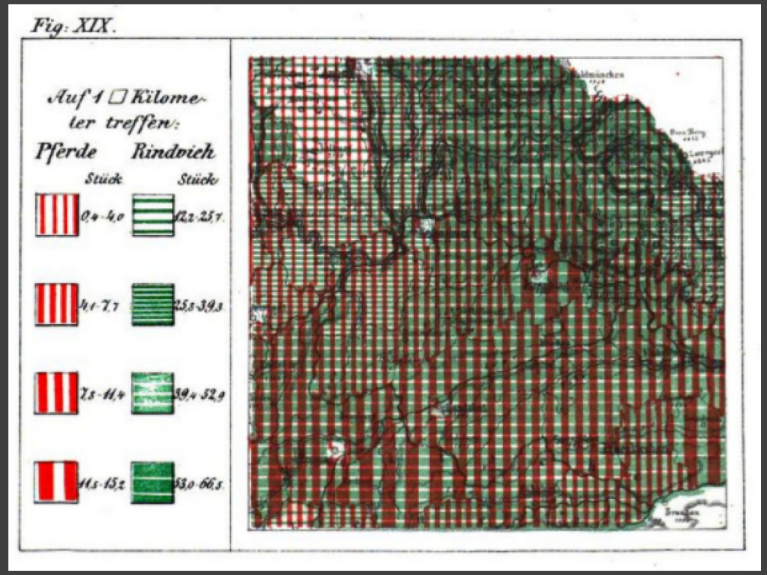
Bivariate Map

1928

Bivariate Map

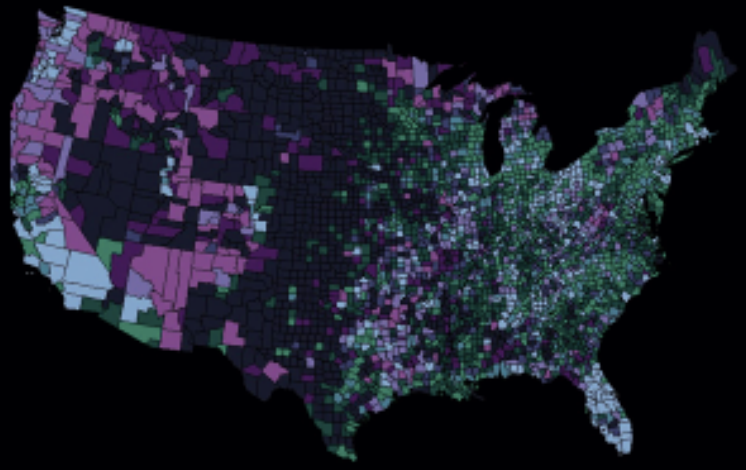
1928

1874



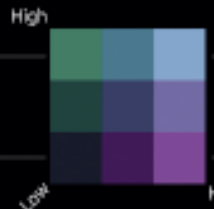
Big*foot* or Big *Population Effect*?

Are reported sasquatch sightings simply following population trends? This map shows the relationship between reported sightings and population density within each US county.



Sightings proportionally rare

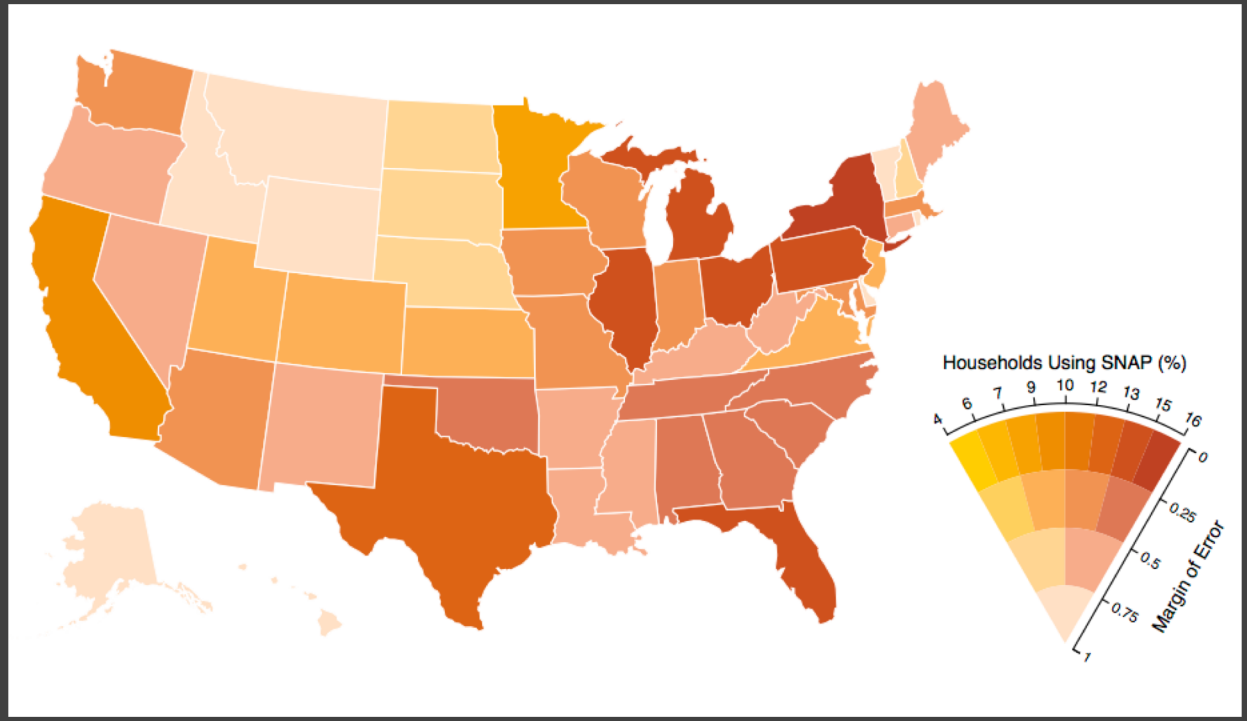
Sightings follow population



Population and reports sparse

'Squatches Galore

VSUP


Households Using SNAP (%)
4
6
7
9
10
12
13
15
16
Margin of Error
0
0.25
0.5
0.75
1

VSUP

VSUPs are a *bivariate* mapping of data and uncertainty that allow *fine-grain comparisons* when data are more certain, and *coarser comparisons* when data are less certain.

Outline

What We Did

Why We Did It

Why We Think It Works

Will This Work?

Will This Work?

Bivariate Maps Are Hard!

"[R]eading Two-Variable Color Maps at the elementary, intermediate, or superior level is at the very least difficult, and may be impossible."

-Wainer & Francolini, 1980

Discrete Color Maps Are Inaccurate!

"[W]ith possible rare exceptions, continuous color scales represent the data more effectively than binned color scales, so we should stick with them."

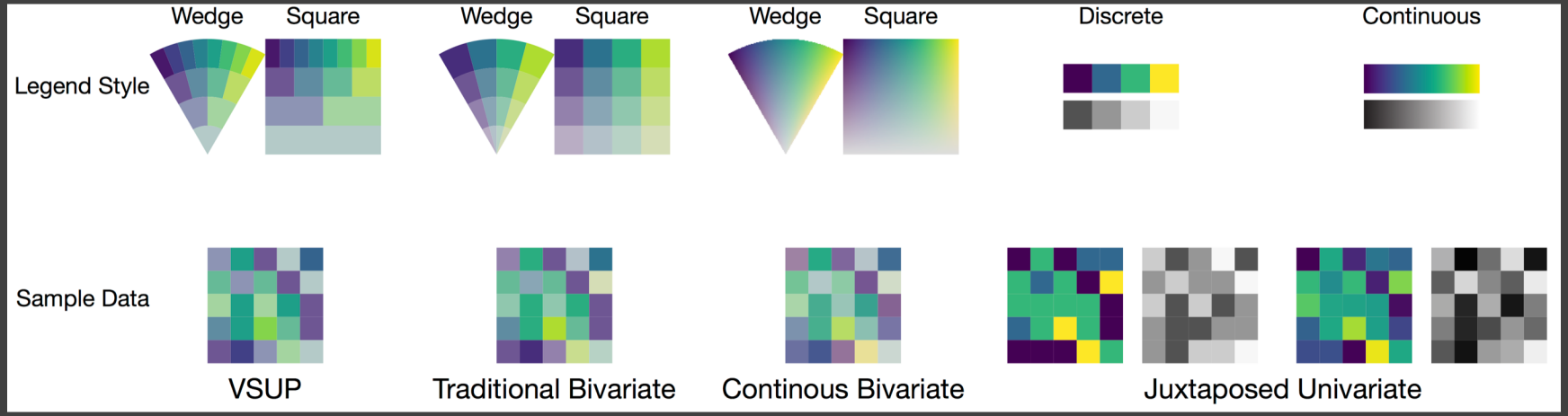
-Few, 2017

Evaluating VSUPs

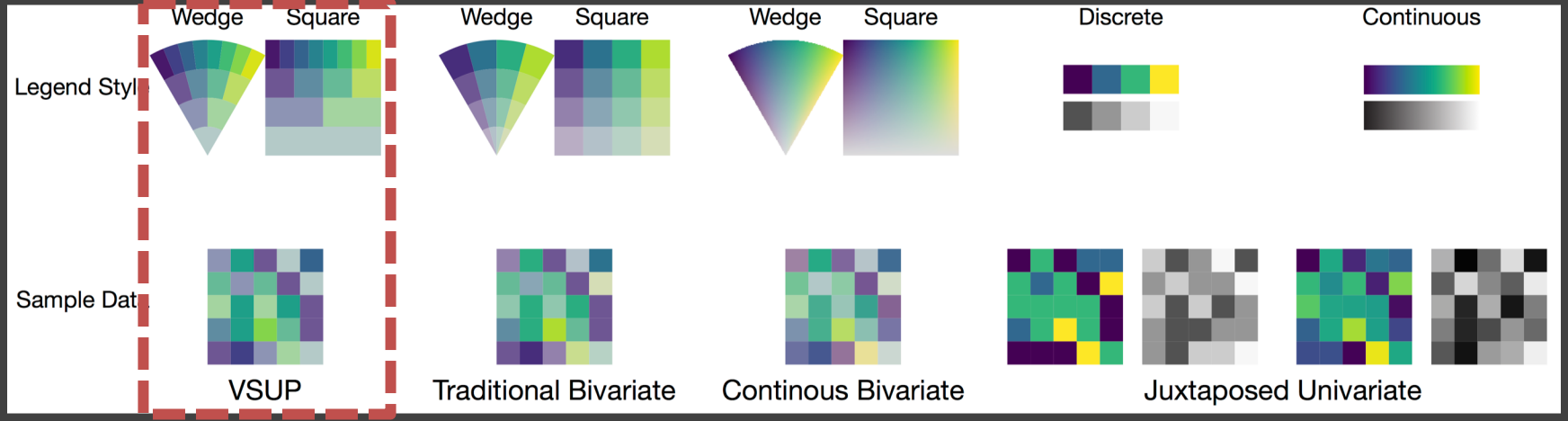
Evaluating VSUPs

Evaluating VSUPs

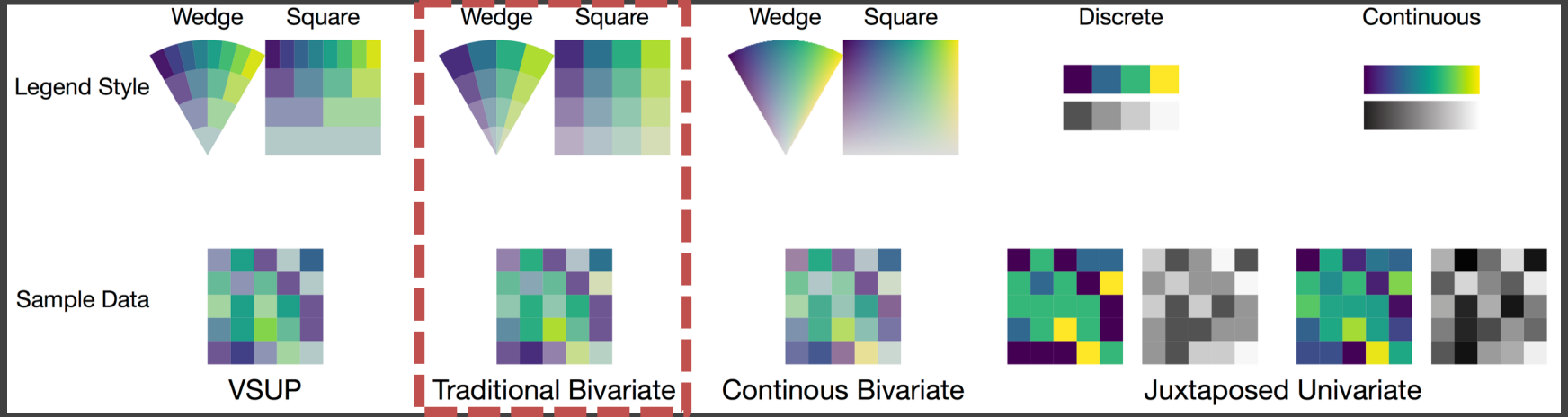
Alternative Designs



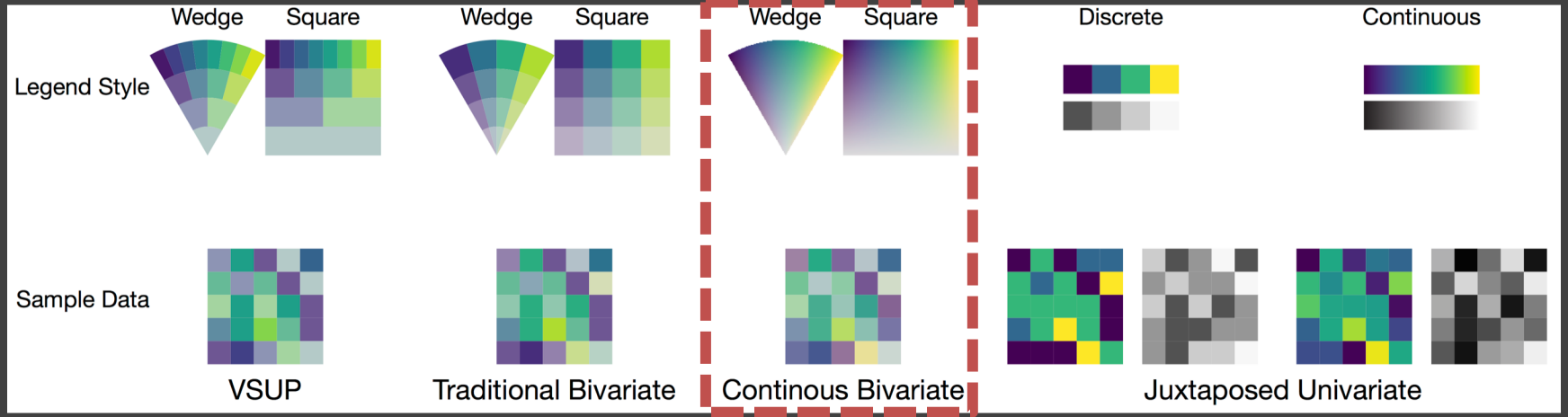
Alternative Designs



Alternative Designs



Alternative Designs



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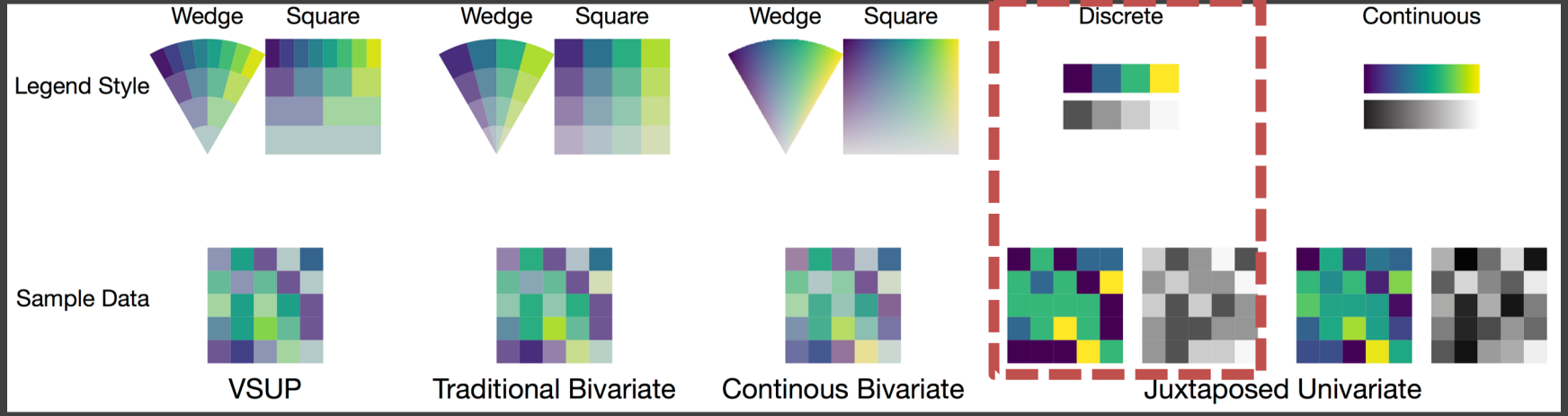
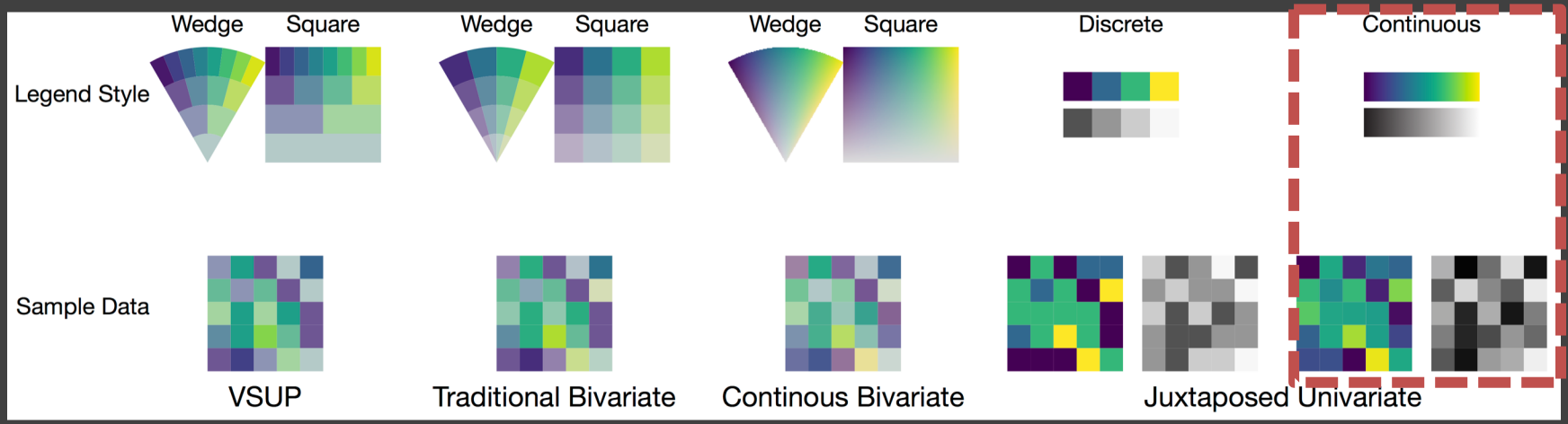


Alternative Designs



Methods

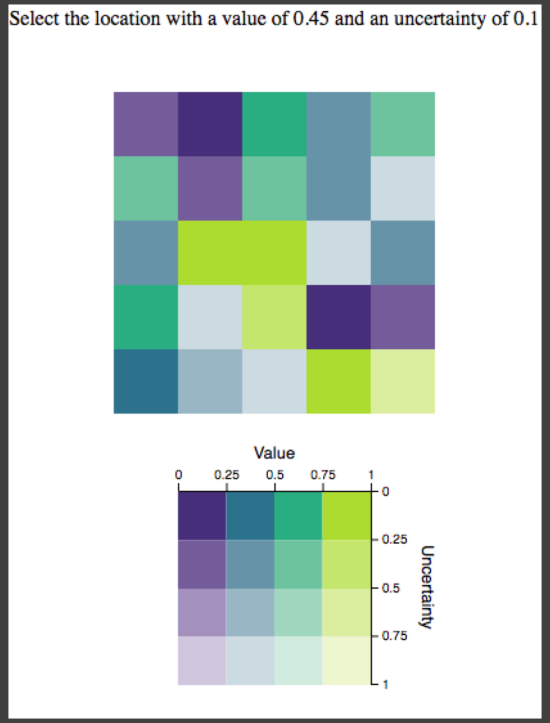
2 MTurk Experiments:

- Identification Task
- Prediction Task

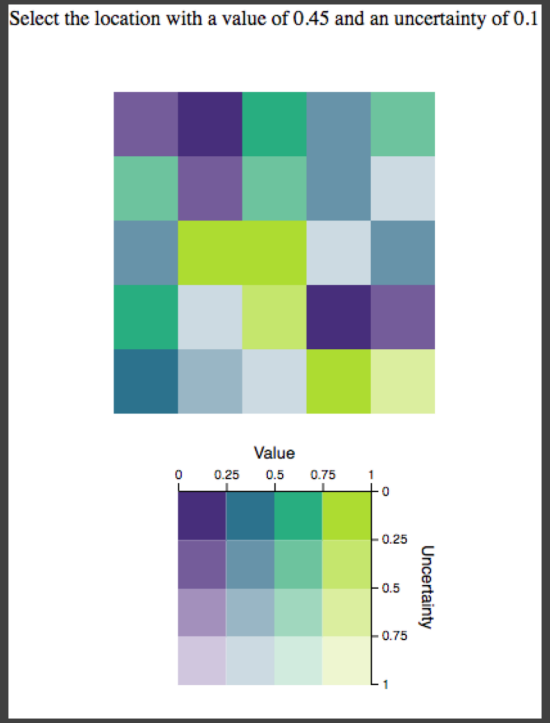
48 Participants (w/o CVD)

2112 Trials

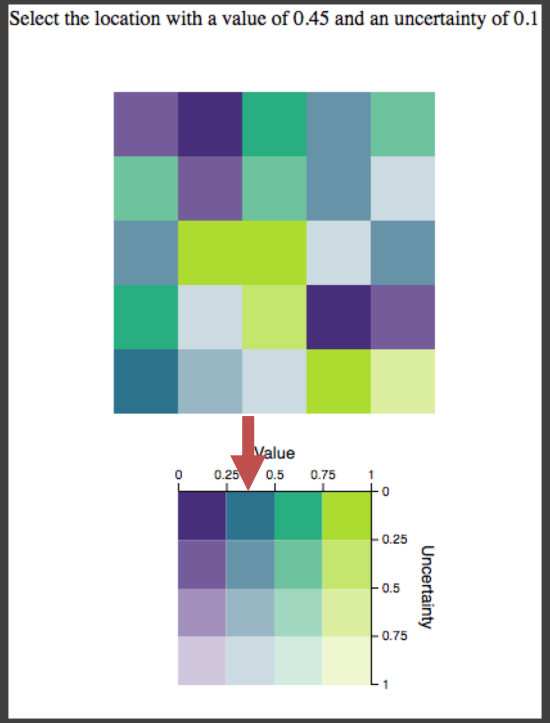
Identification Task



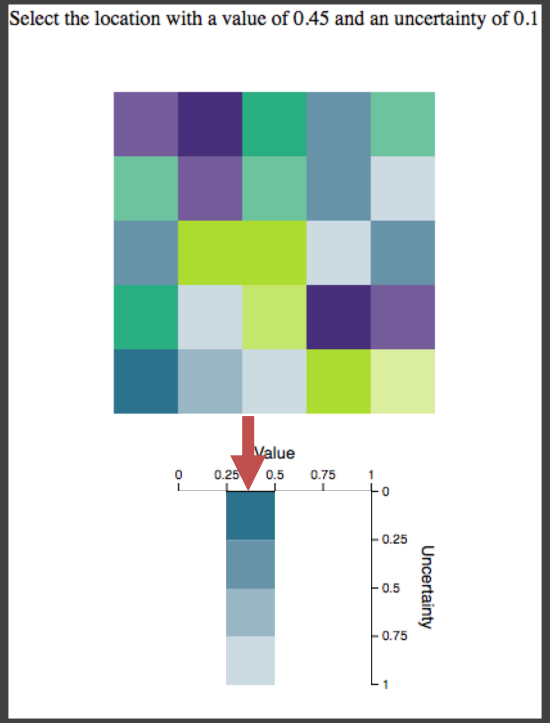
Value of 0.45, Uncertainty of 0.1



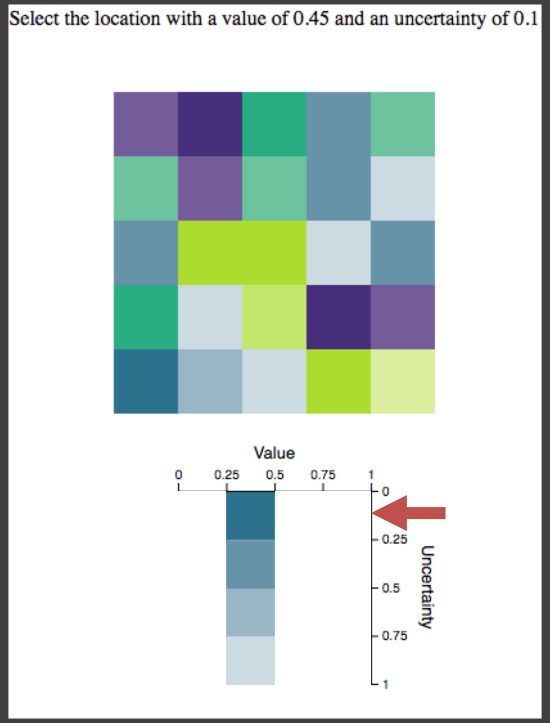
Value of 0.45


Select the location with a value of 0.45 and an uncertainty of 0.1
Value
0
0.25
0.5
0.75
1
Uncertainty
0
0.25
0.5
0.75
1

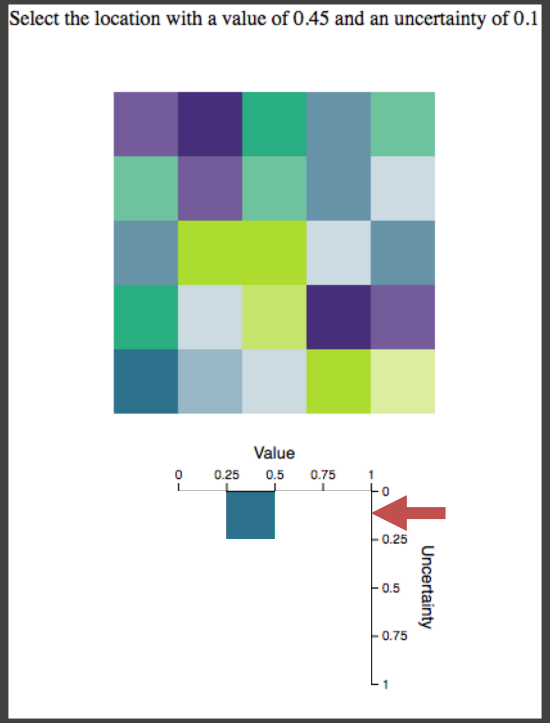
Value of 0.45


Select the location with a value of 0.45 and an uncertainty of 0.1
Value
0
0.25
0.5
0.75
1
Uncertainty
0
0.25
0.5
0.75
1

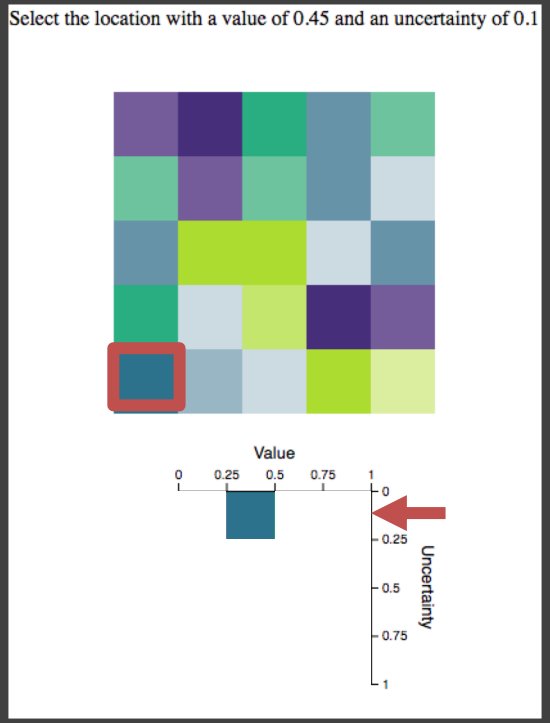
Uncertainty of 0.1



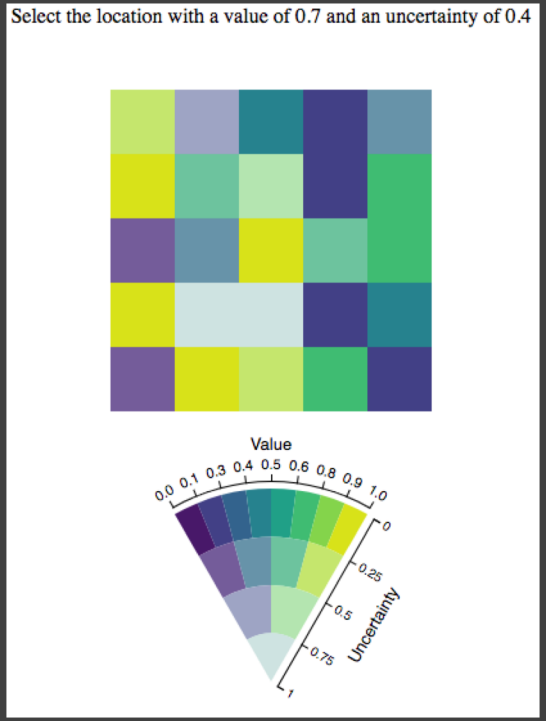
Uncertainty of 0.1



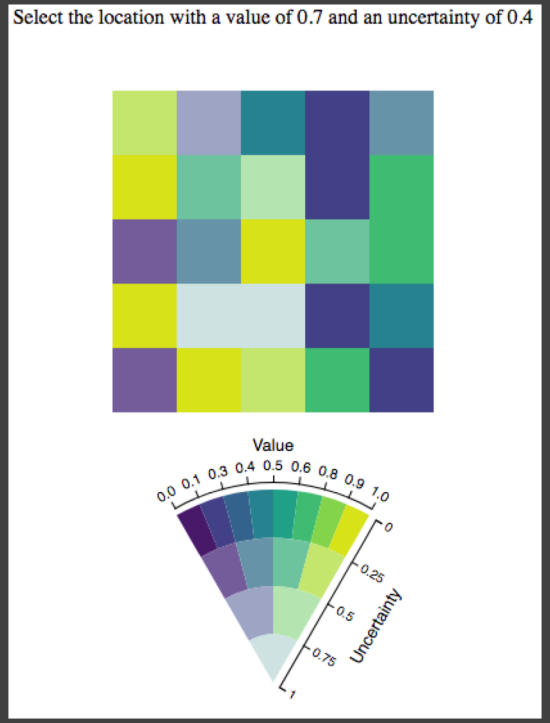
Uncertainty of 0.1



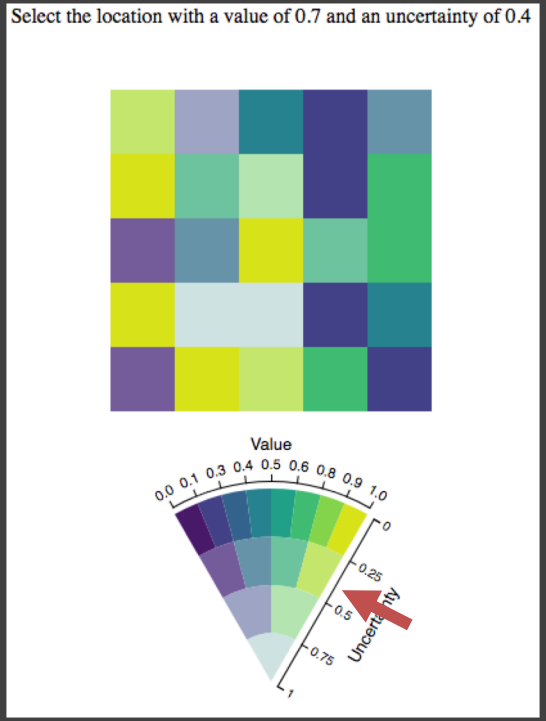
Identification Task



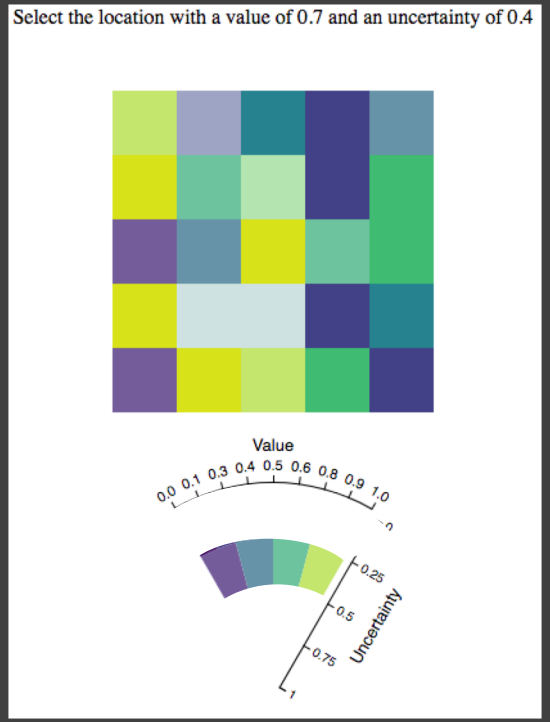
Value of 0.7, Uncertainty of 0.4



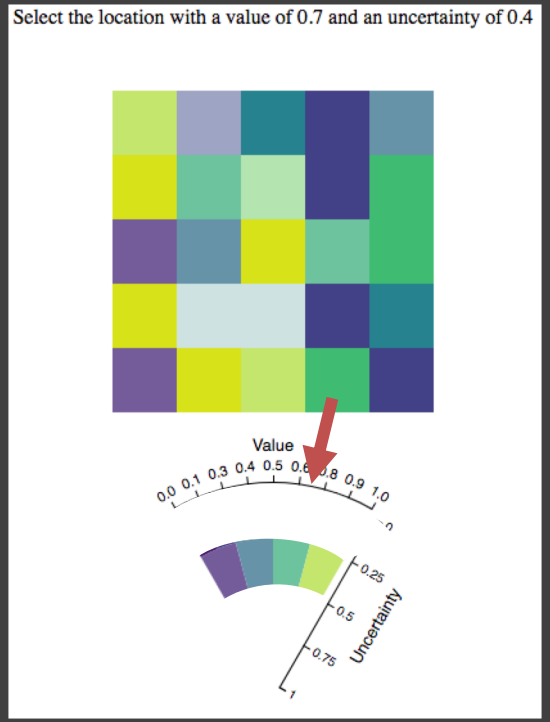
Uncertainty of 0.4



Uncertainty of 0.4



Value of 0.7


Select the location with a value of 0.7 and an uncertainty of 0.4
Value
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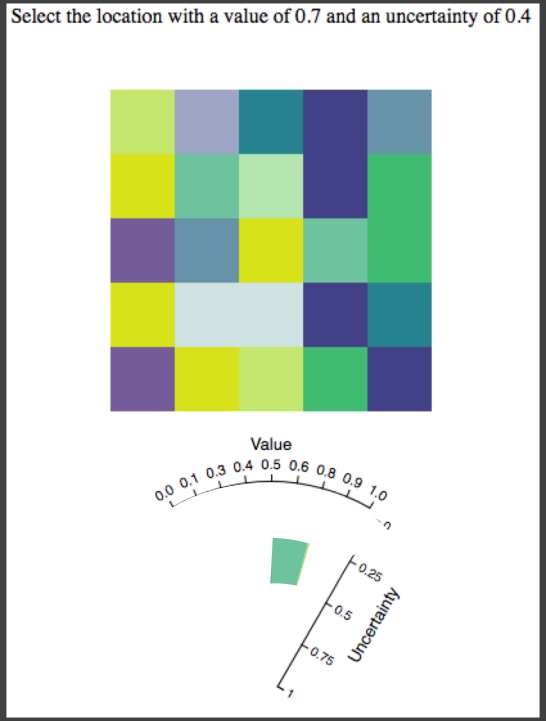
0.25
0.5
0.75
1
Uncertainty

Value of 0.7


Select the location with a value of 0.7 and an uncertainty of 0.4
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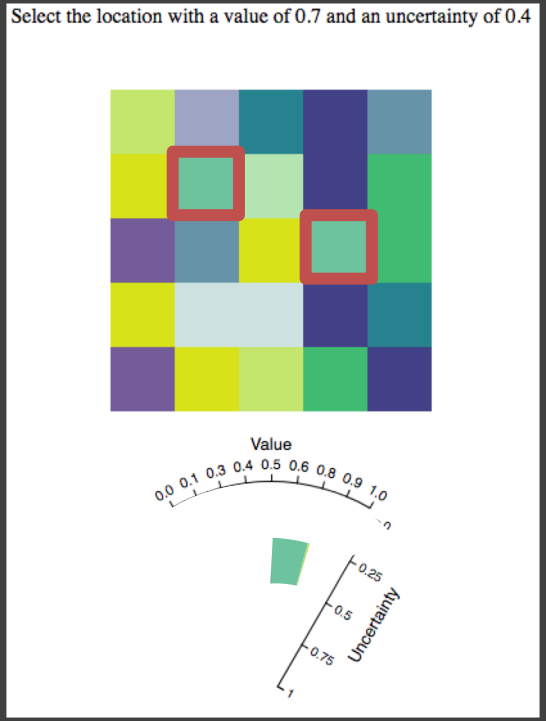
0.25
0.5
0.75
1
Uncertainty

Value of 0.7


Select the location with a value of 0.7 and an uncertainty of 0.4
Value
0.0 0.1 0.3 0.4 0.5 0.6 0.8 0.9 1.0
0.25
0.5
0.75
1
Uncertainty

Results

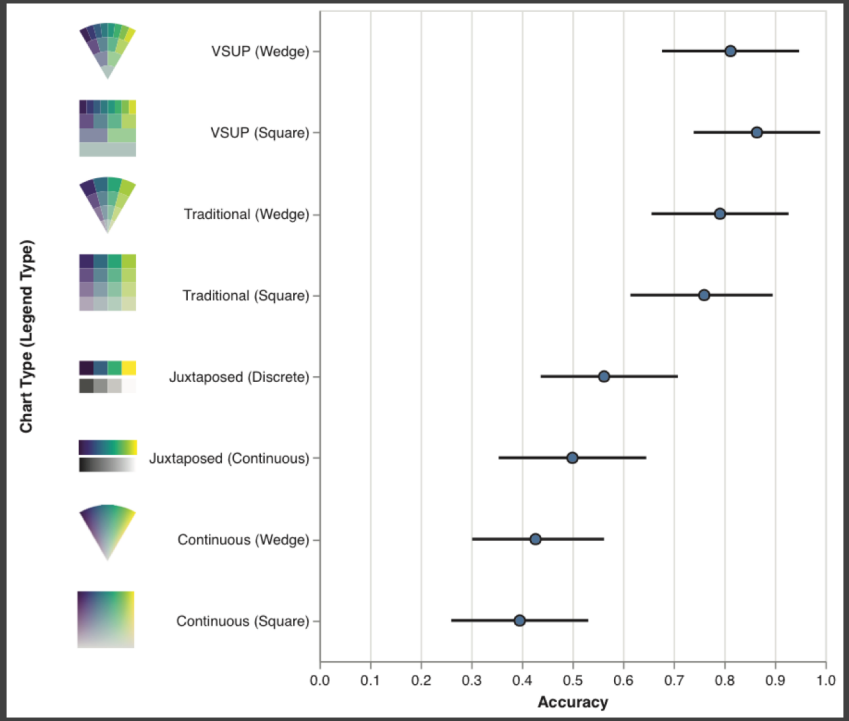


Chart Type (Legend Type)
VSUP (Wedge)
VSUP (Square)
Traditional (Wedge)
Traditional (Square)
Juxtaposed (Discrete)
Juxtaposed (Continuous)
Continuous (Wedge)
Continuous (Square)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Accuracy

Results

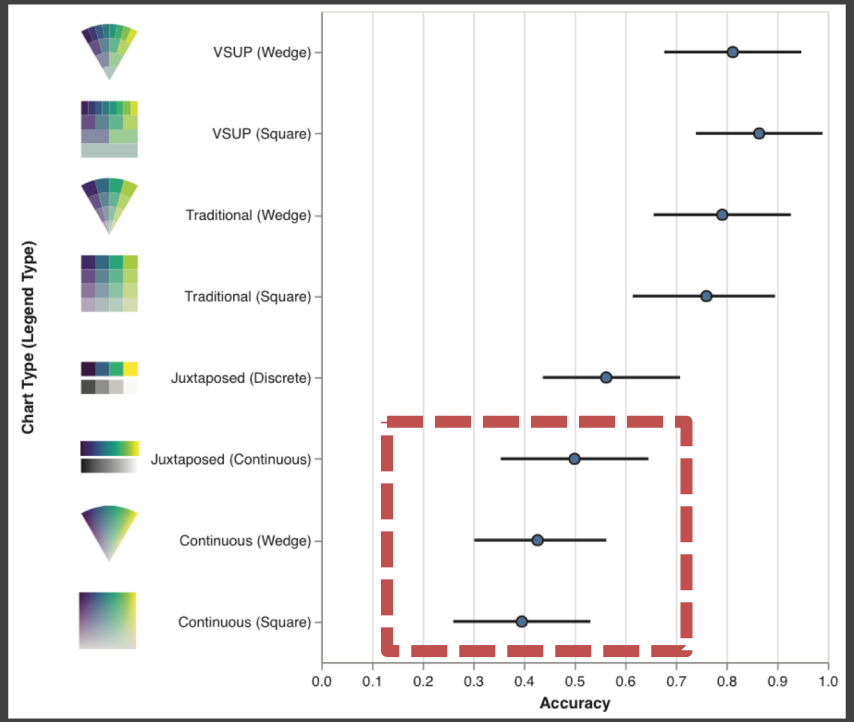
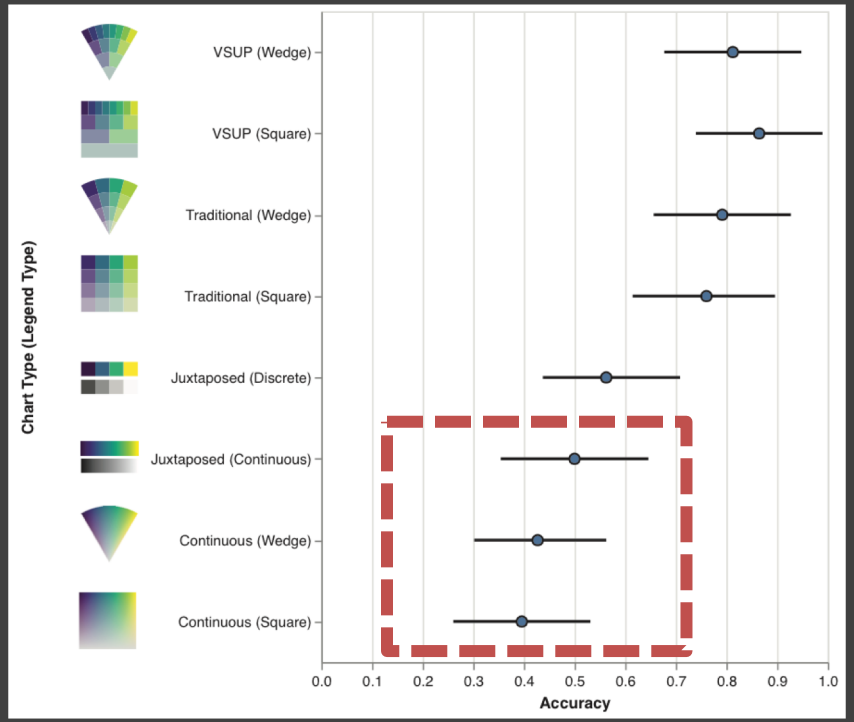
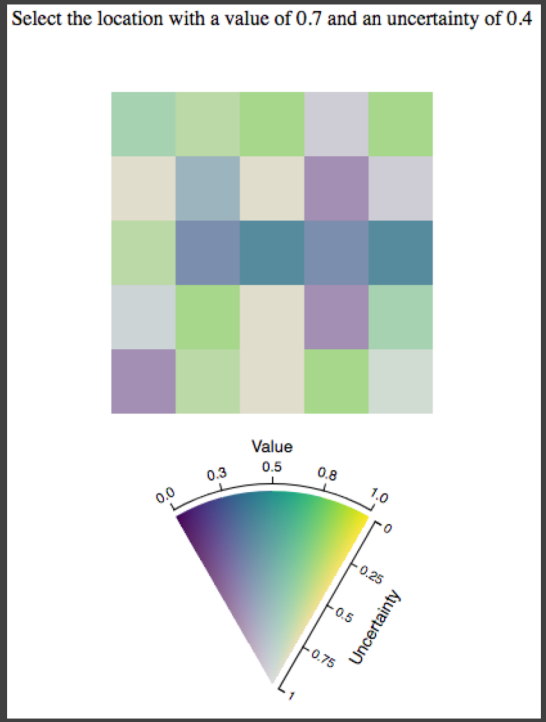


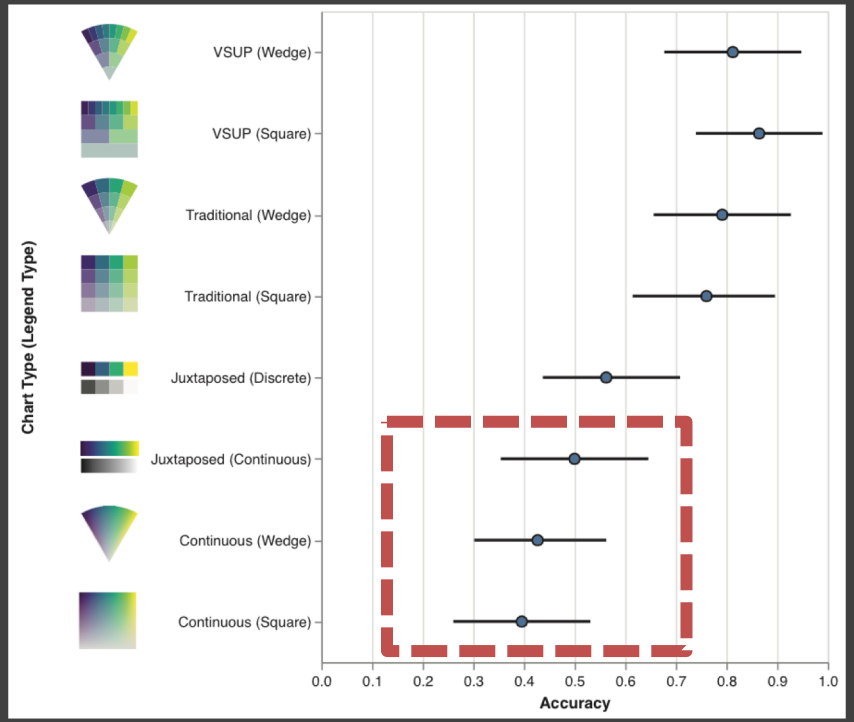
Chart Type (Legend Type)
VSUP (Wedge)
VSUP (Square)
Traditional (Wedge)
Traditional (Square)
Juxtaposed (Discrete)
Juxtaposed (Continuous)
Continuous (Wedge)
Continuous (Square)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Accuracy

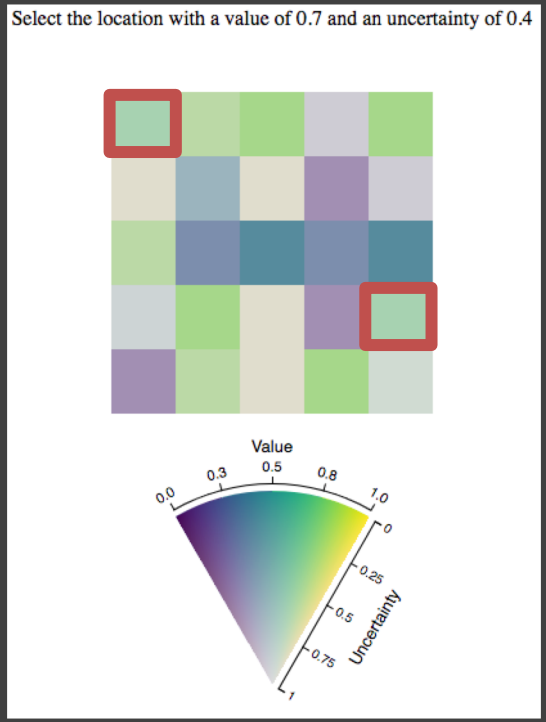
Value of 0.7, Uncertainty of 0.4



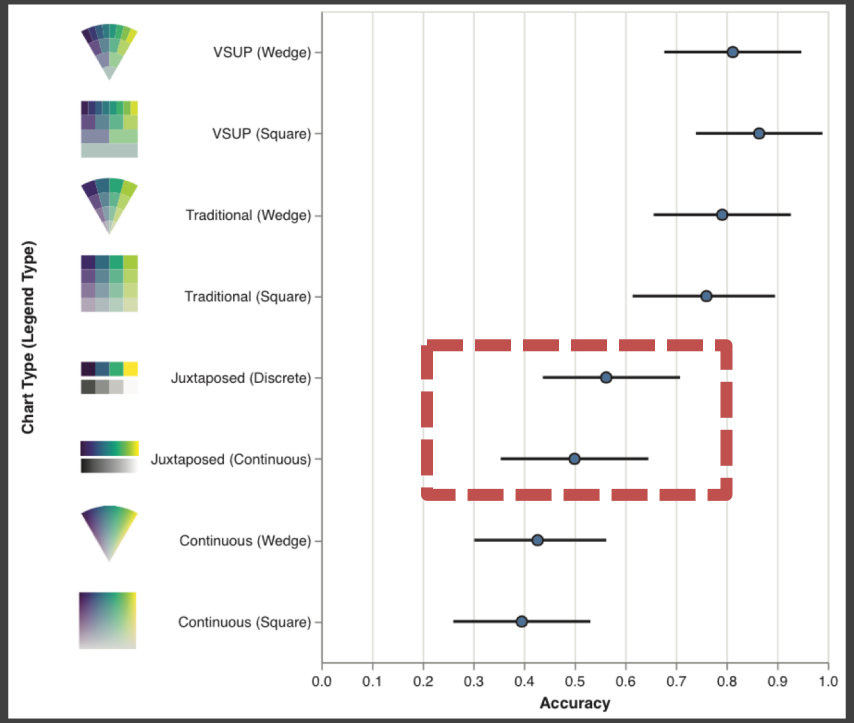


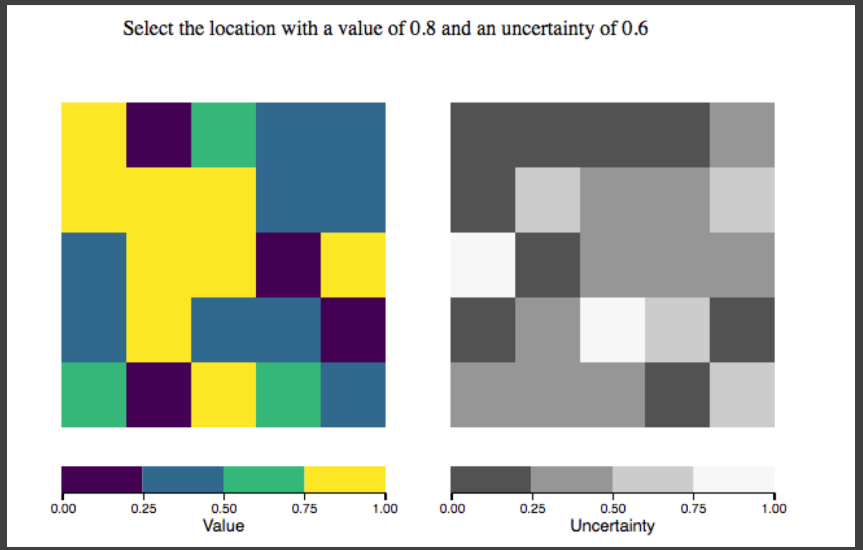
Value of 0.7, Uncertainty of 0.4





Results


VSUP (Wedge)
VSUP (Square)
Traditional (Wedge)
Traditional (Square)
Juxtaposed (Discrete)
Juxtaposed (Continuous)
Continuous (Wedge)
Continuous (Square)
Chart Type (Legend Type)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Accuracy


Select the location with a value of 0.8 and an uncertainty of 0.6
0.00 0.25 0.50 0.75 1.00
Value
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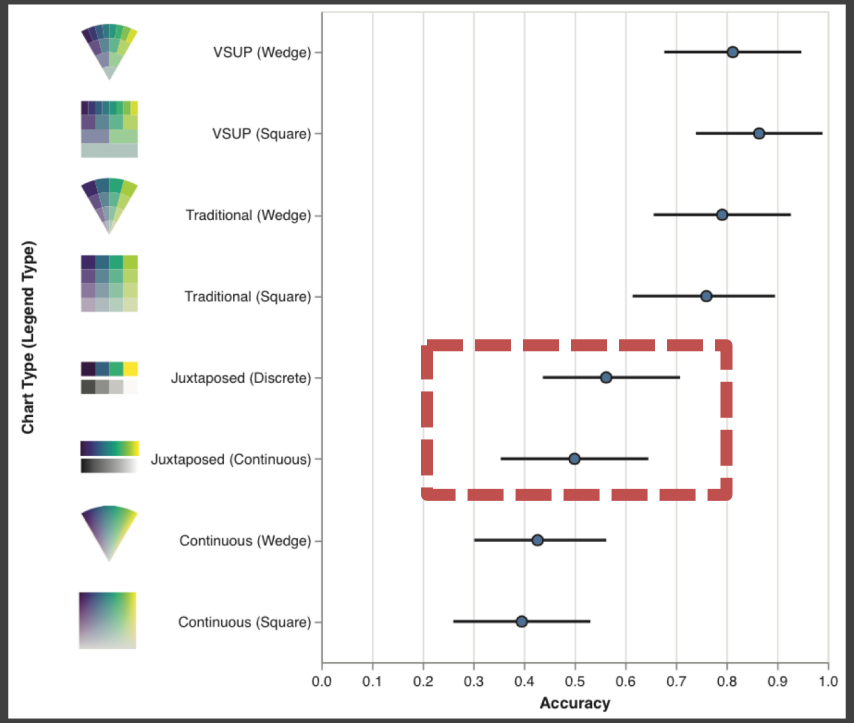
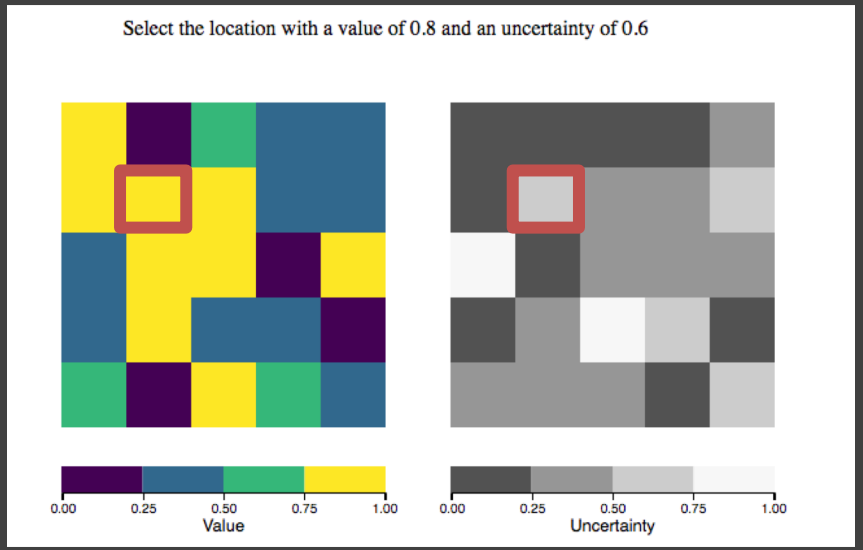
Uncertainty

Results


VSUP (Wedge)
VSUP (Square)
Traditional (Wedge)
Traditional (Square)
Juxtaposed (Discrete)
Juxtaposed (Continuous)
Continuous (Wedge)
Continuous (Square)
Chart Type (Legend Type)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Accuracy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Value
0.00 0.25 0.50 0.75 1.00
Uncertainty

Results

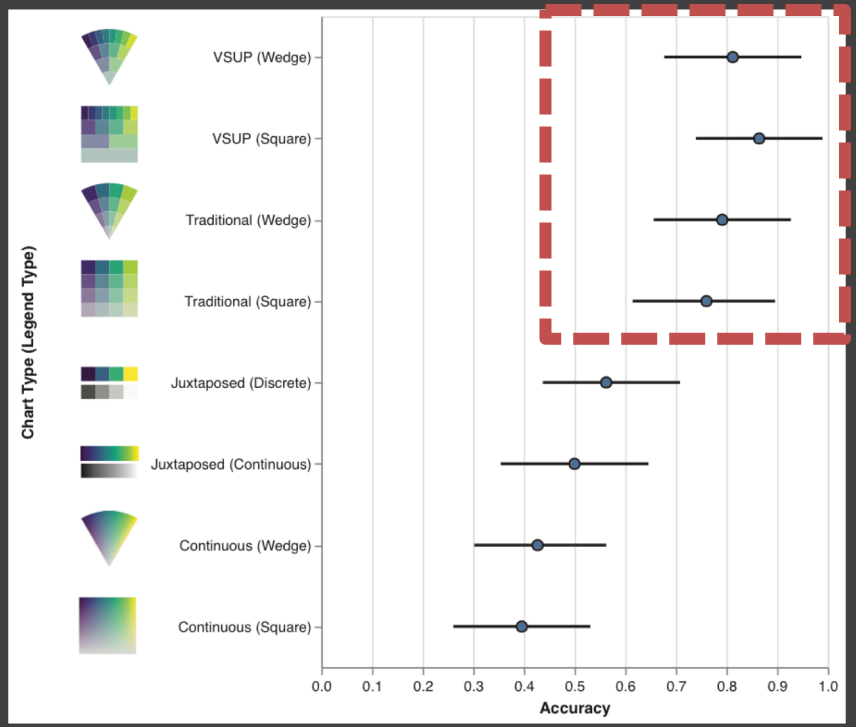
Chart Type (Legend Type)
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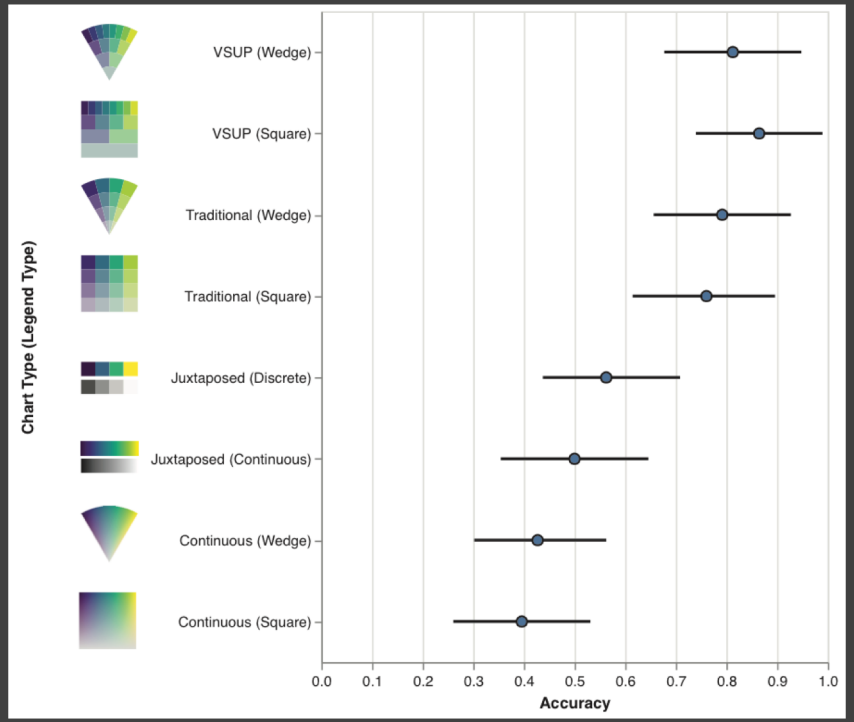
VSUP (Square)
Traditional (Wedge)
Traditional (Square)
Juxtaposed (Discrete)
Juxtaposed (Continuous)
Continuous (Wedge)
Continuous (Square)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Accuracy

Results



Interference disrupts Continuous Maps

Search disrupts Juxtaposed Maps

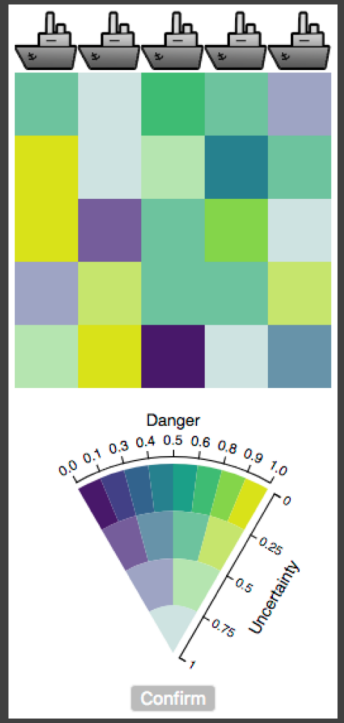
Prediction Task

How can we induce and compare *risk-averse* behavior in heatmaps?

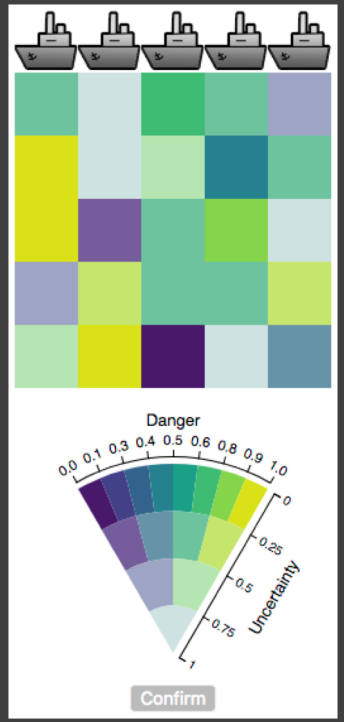
Prediction Task

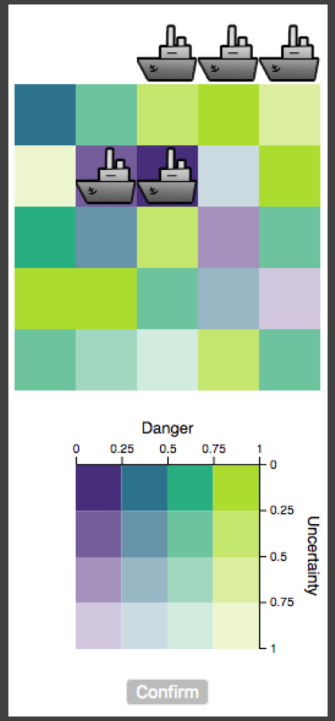
Prediction Task

Prediction Task

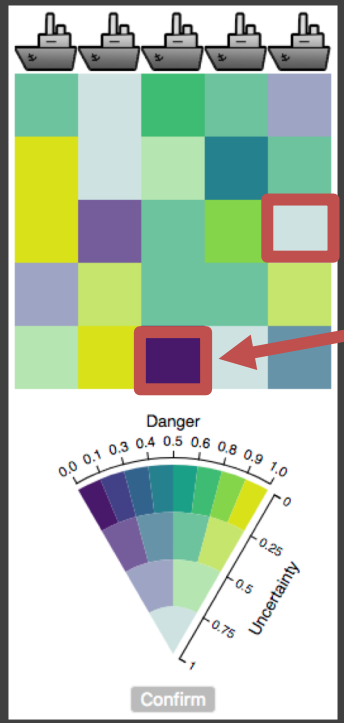


Prediction Task





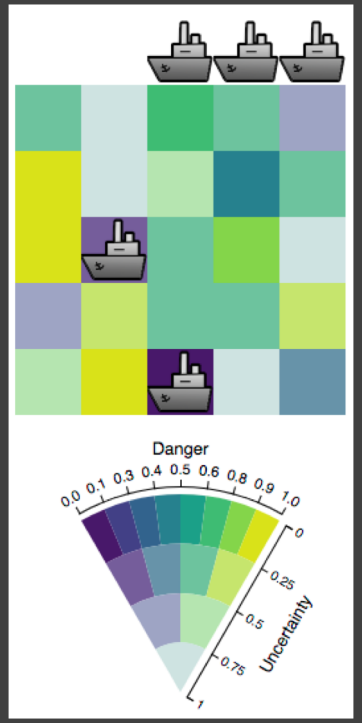
Prediction Task

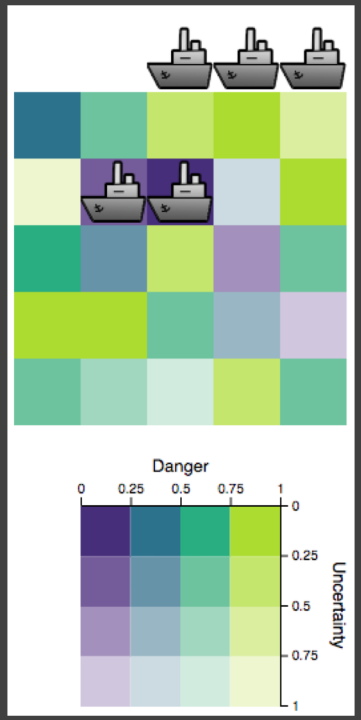


Could be Dangerous!

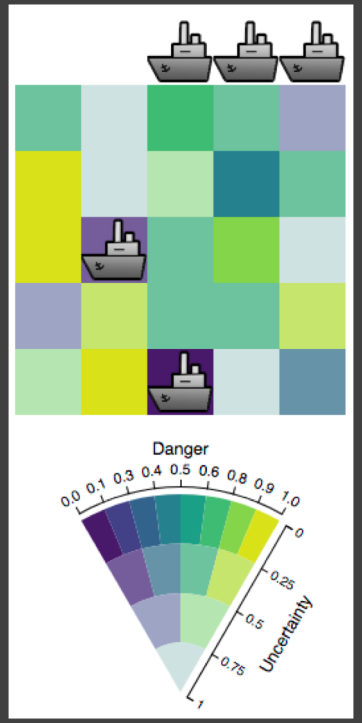
Definitely Safe.

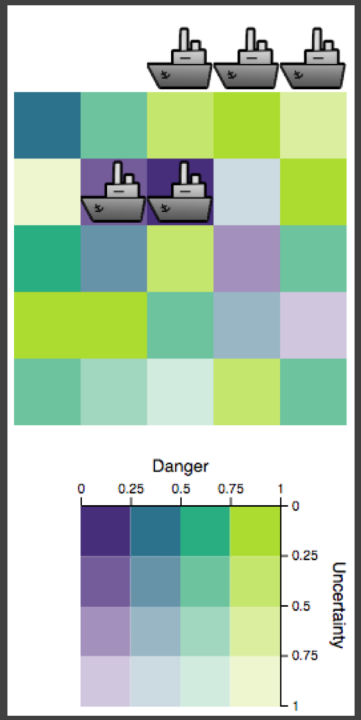
Placing Ships



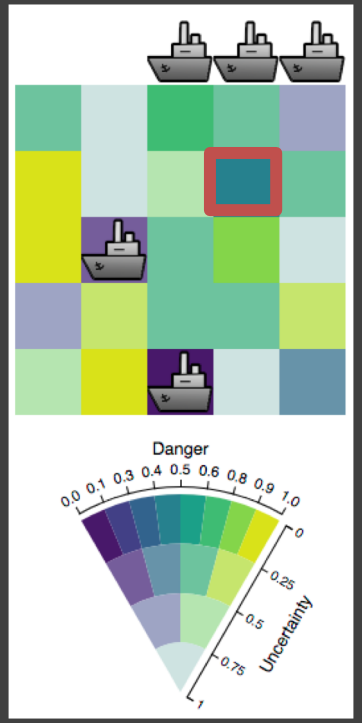


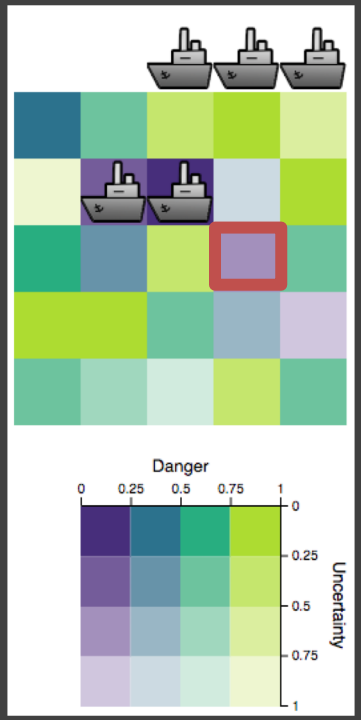
Where To Put The Last Ships?



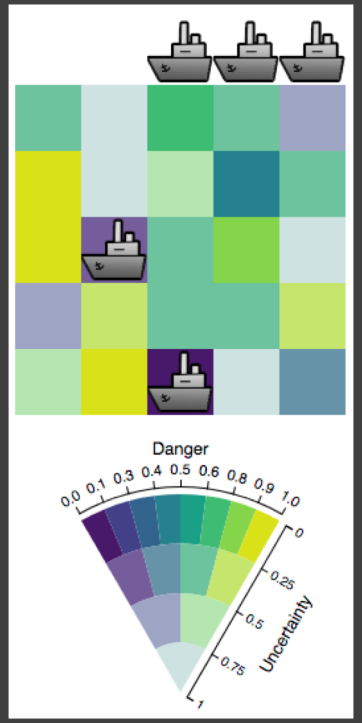


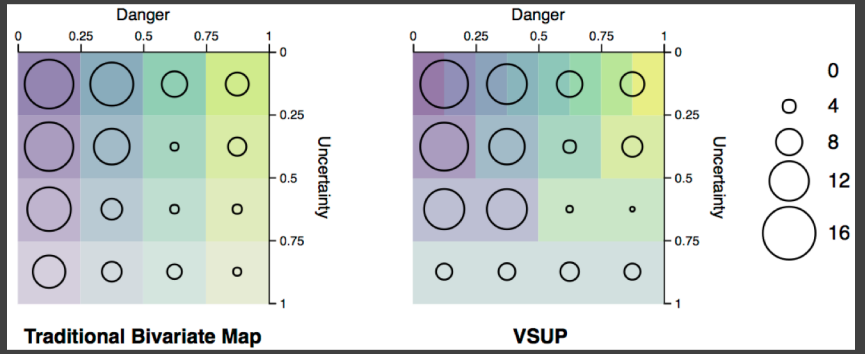
Where To Put The Last Ships?



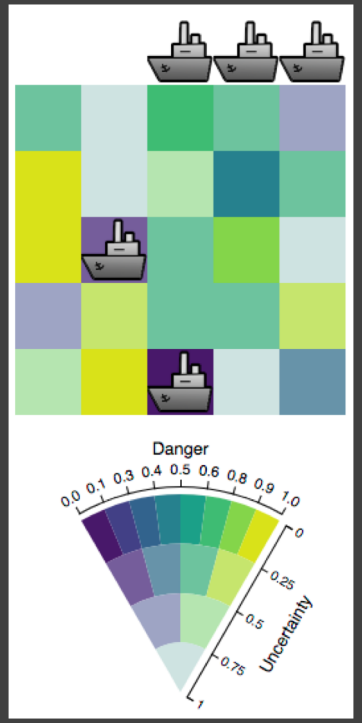


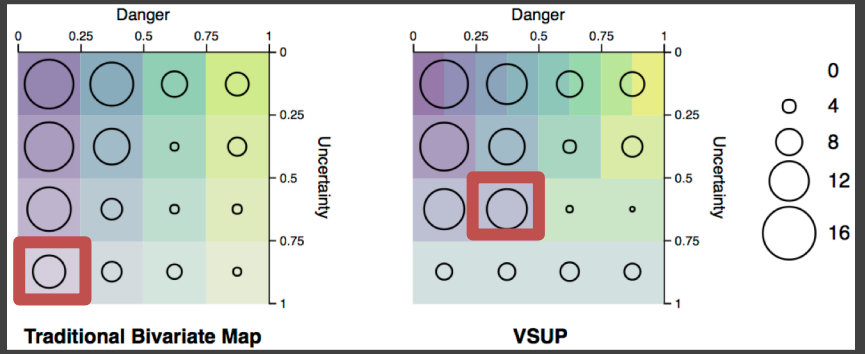
Where To Put The Last Ship?



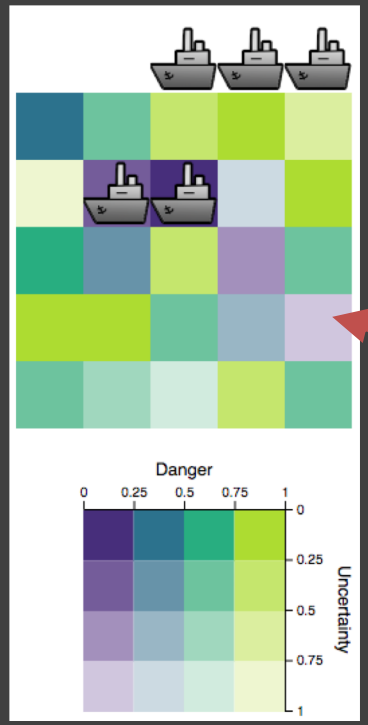


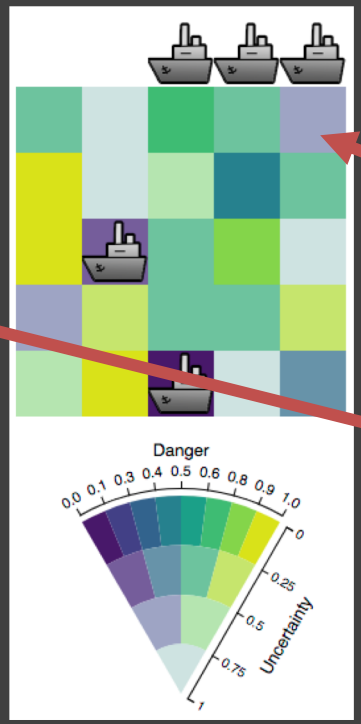
Where To Put The Last Ships?

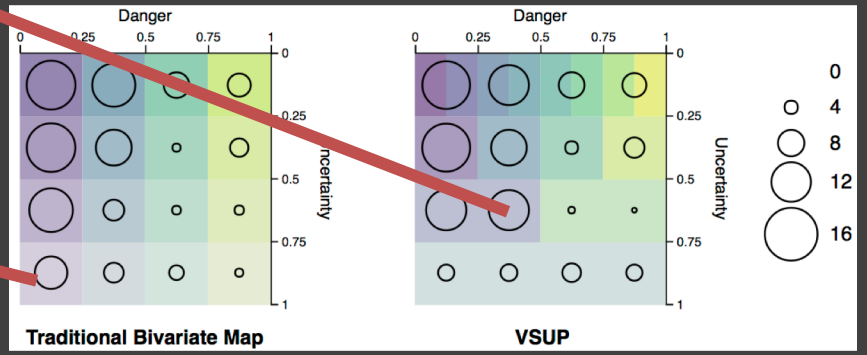




Where To Put The Last Ships?



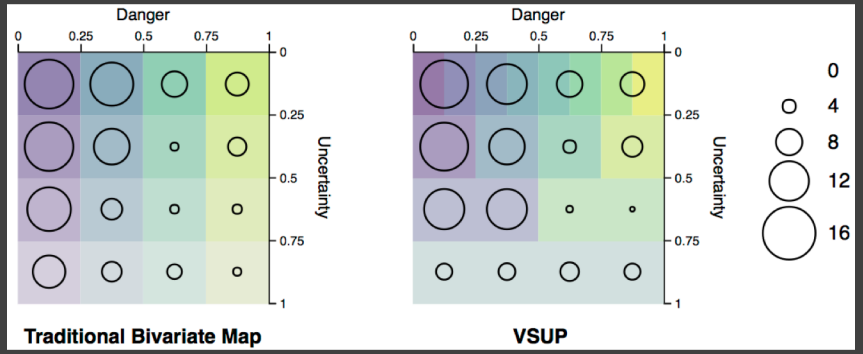


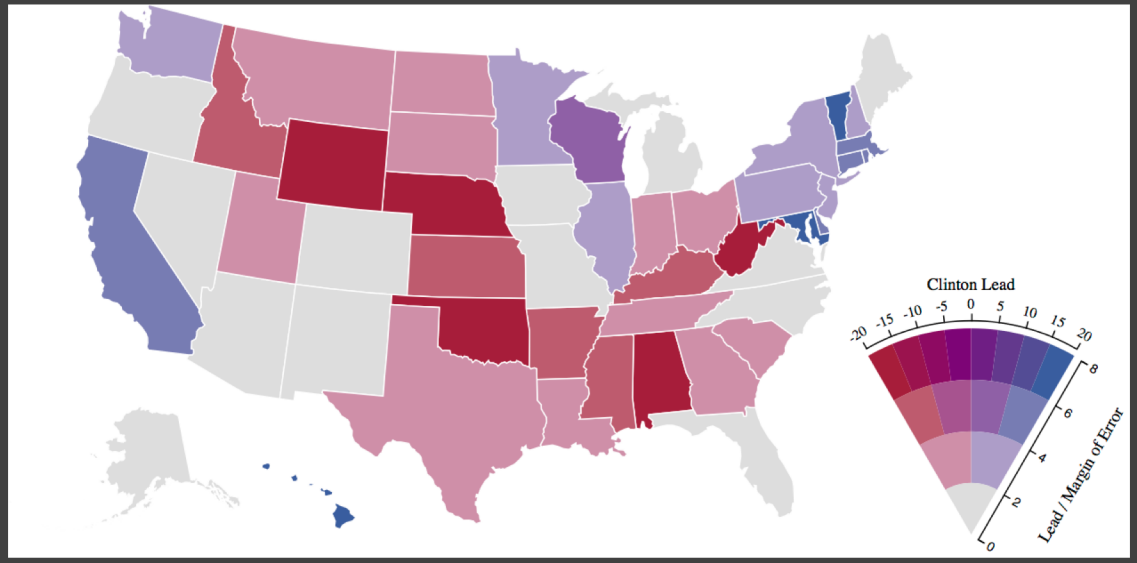


Results

Bivariate Maps
encourage *risk seeking*

VSUP Maps
encourage *risk aversion*





VSUPs are an *unignorable* way of *integrating* data and uncertainty.

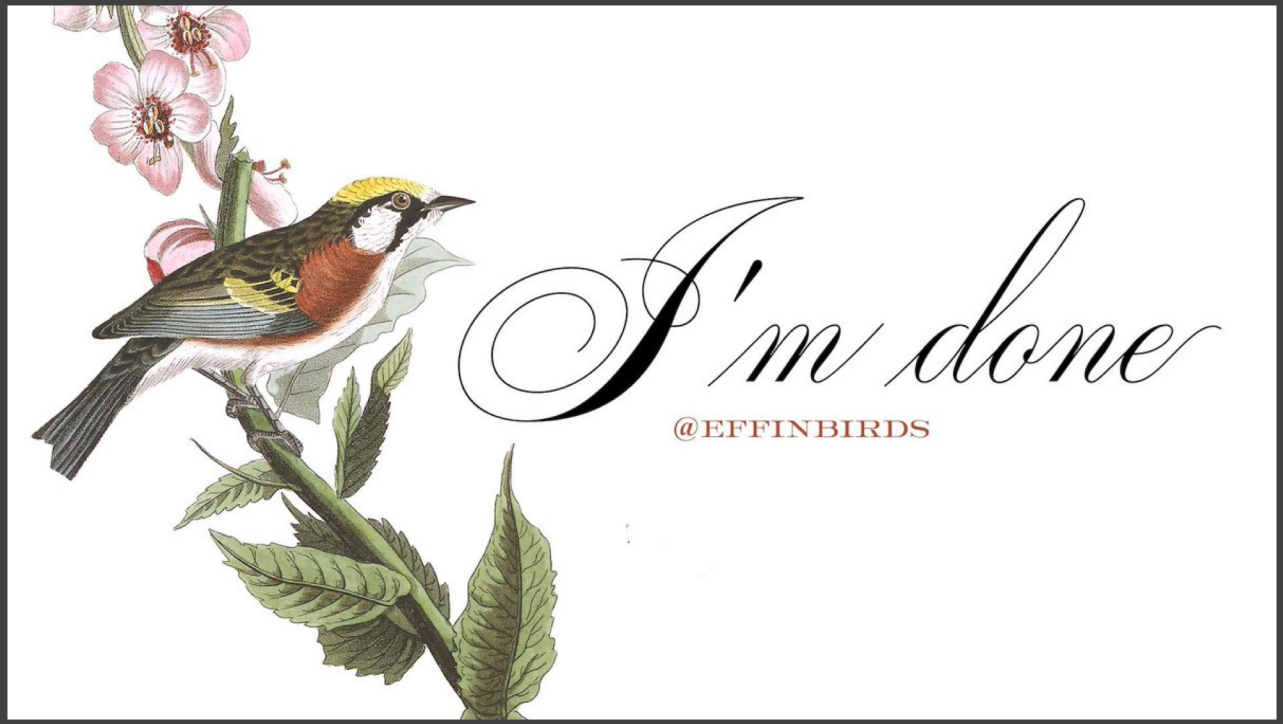
VSUPs make people more *cautious* in their decision-making.

Thanks!

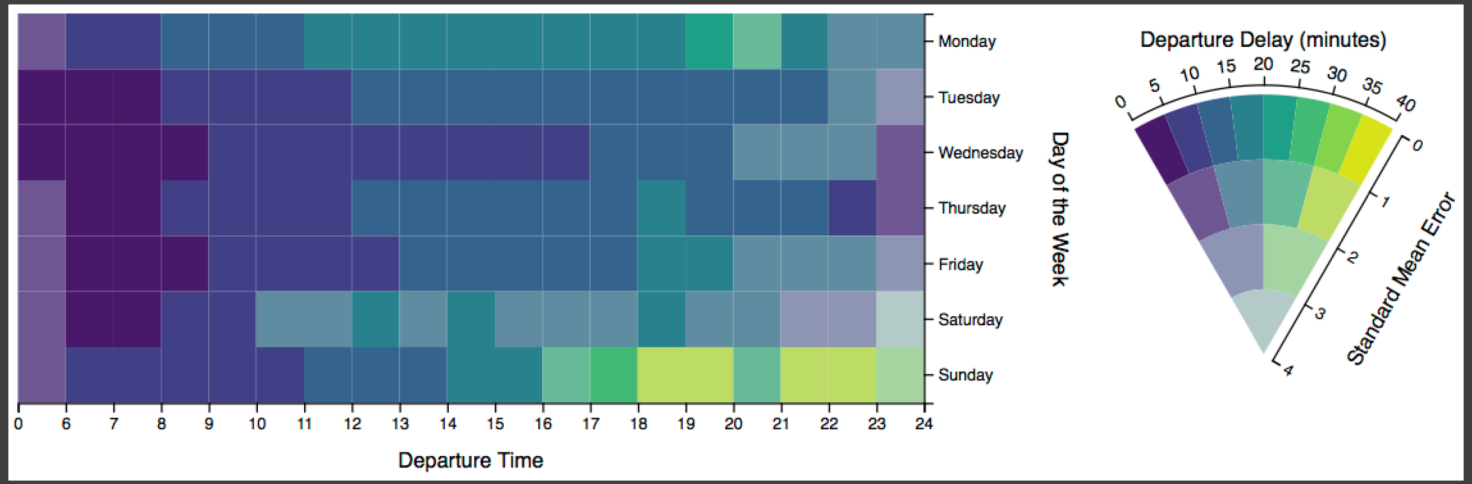
This work was supported by a Moore Foundation Data-Driven Discovery Investigator award.

Study materials available at:
https://github.com/uwdata/papers-vsup
Make your own VSUPs at:
https://github.com/uwdata/vsup

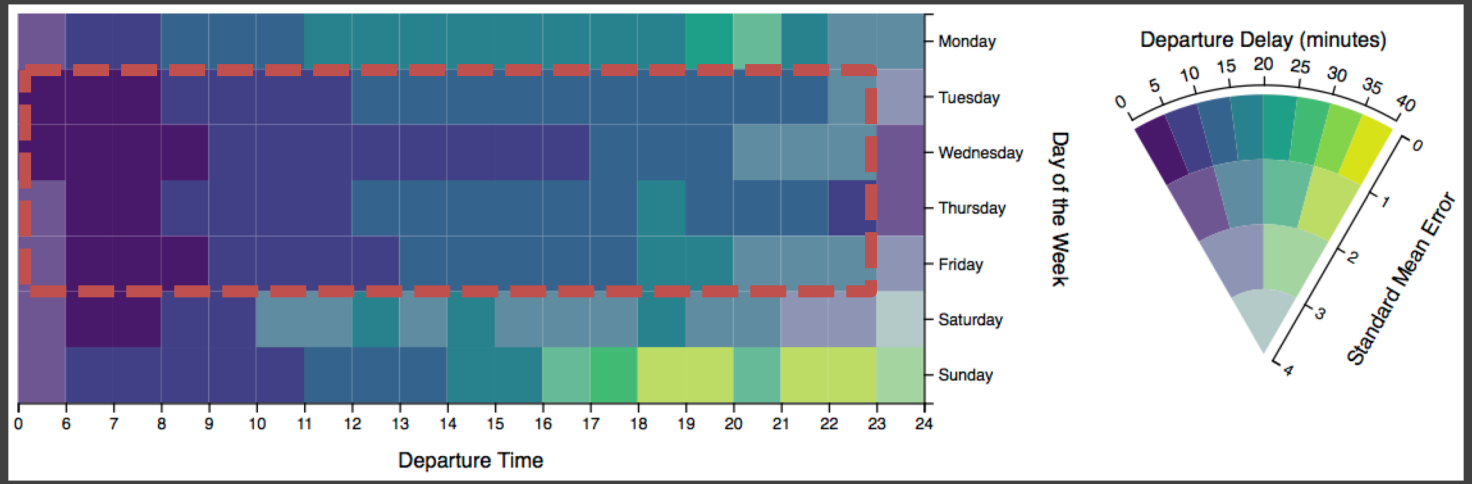
Extra Slides


I'm done
@EFFINBIRDS

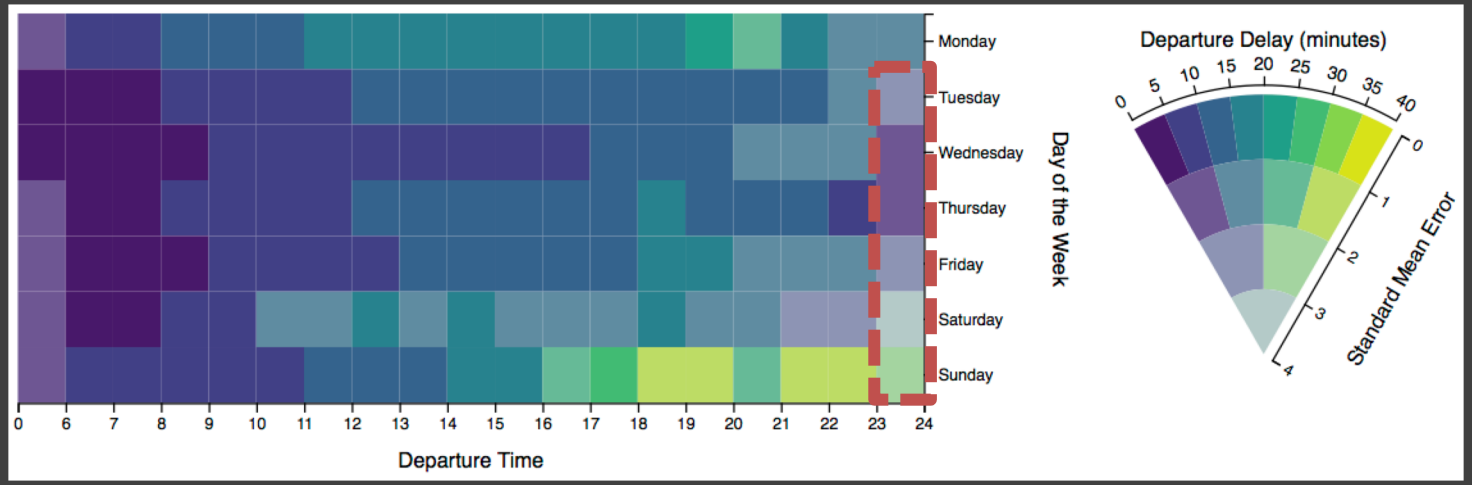
Flight Delay

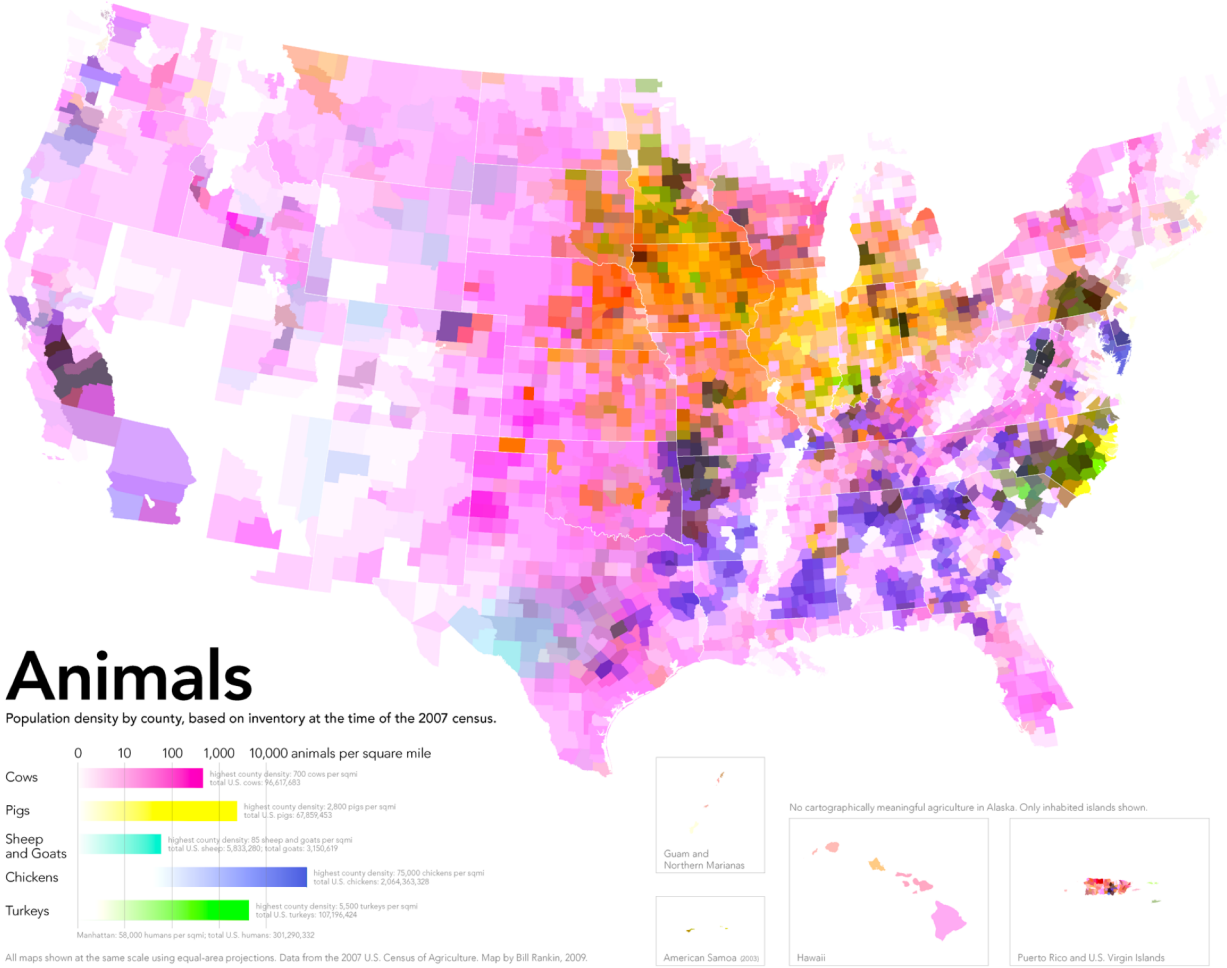


Flight Delay



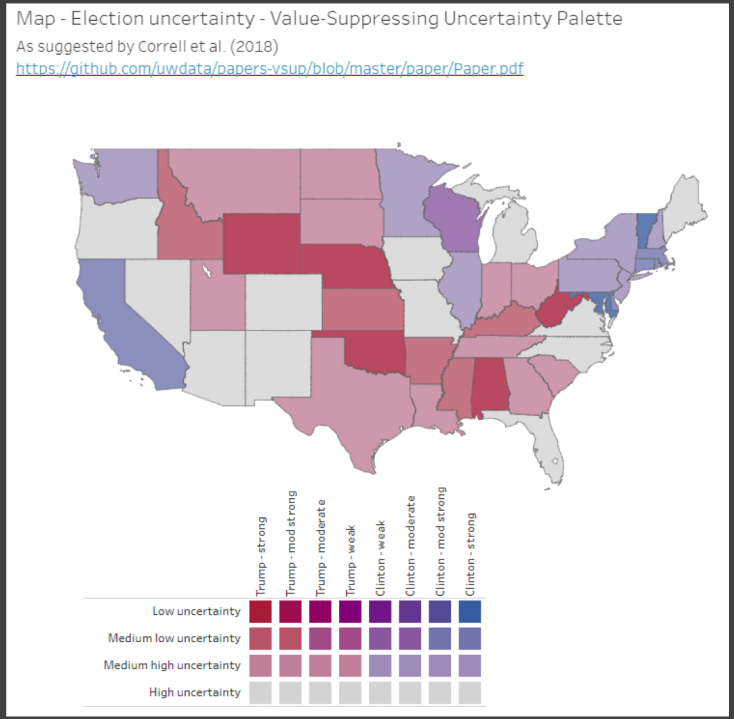
Flight Delay




Animals
Population density by county, based on inventory at the time of the 2007 census.
0 10 100 1,000 10,000 animals per square mile
Cows
highest county density: 700 cows per sqmi
total U.S. cows: 96,617,683
Pigs
highest county density: 2,800 pigs per sqmi
total U.S. pigs: 67,859,453
Sheep and Goats
highest county density: 85 sheep and goats per sqmi
total U.S. sheep: 5,833,280; total goats: 3,150,619
Chickens
highest county density: 75,000 chickens per sqmi
total U.S. chickens: 2,064,363,328
Turkeys
highest county density: 5,500 turkeys per sqmi
total U.S. turkeys: 107,196,424
Manhattan: 58,000 humans per sqmi; total U.S. humans: 301,290,332
All maps shown at the same scale using equal-area projections. Data from the 2007 U.S. Census of Agriculture. Map by Bill Rankin, 2009.
Guam and Northern Marianas
American Samoa (2003)
No cartographically meaningful agriculture in Alaska. Only inhabited islands shown.
Hawaii
Puerto Rico and U.S. Virgin Islands

Can you do this in Tableau?

"How to make effective bivariate choropleth maps with Tableau"
Sarah Battersby
https://www.tableau.com/about/blog/2018/2/how-make-effective-bivariate-choropleth-maps-tableau-83121



Have you Used this for Anything?