

Visualizing Ranges Over Time on Mobile Phones

A Task-Based Crowdsourced Evaluation

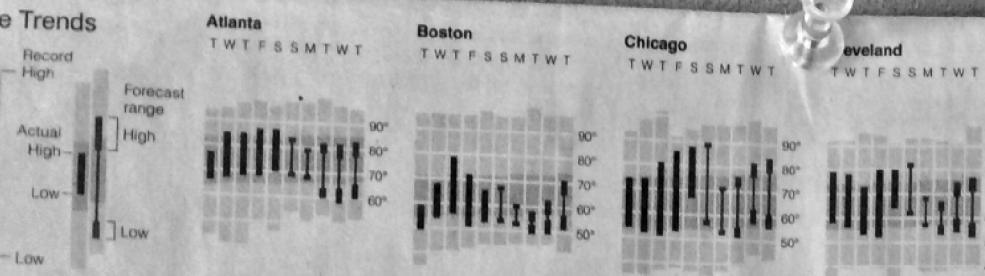
Matthew Brehmer · Microsoft Research · [@mattbrehmer](https://twitter.com/mattbrehmer)

In collaboration with Bongshin Lee, Petra Isenberg, & Eun Kyoung Choe



0-Day Temperature Trends

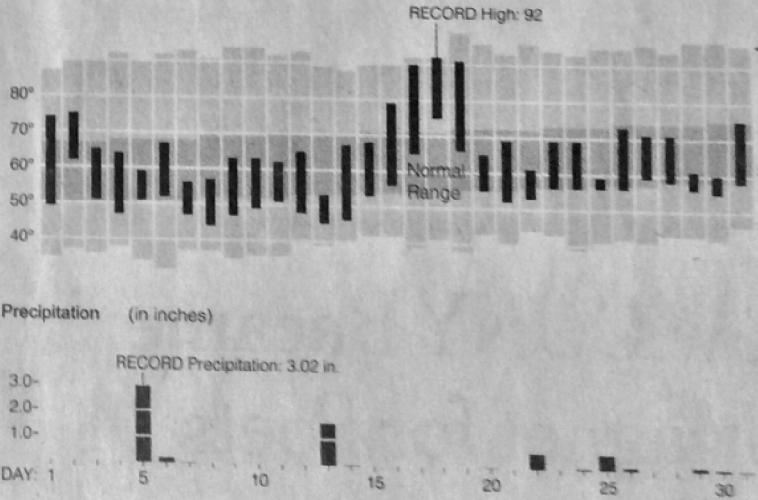
High and low temperatures for the past five days and forecasts for the next five. Yesterday's highs and lows are biased preliminary data.



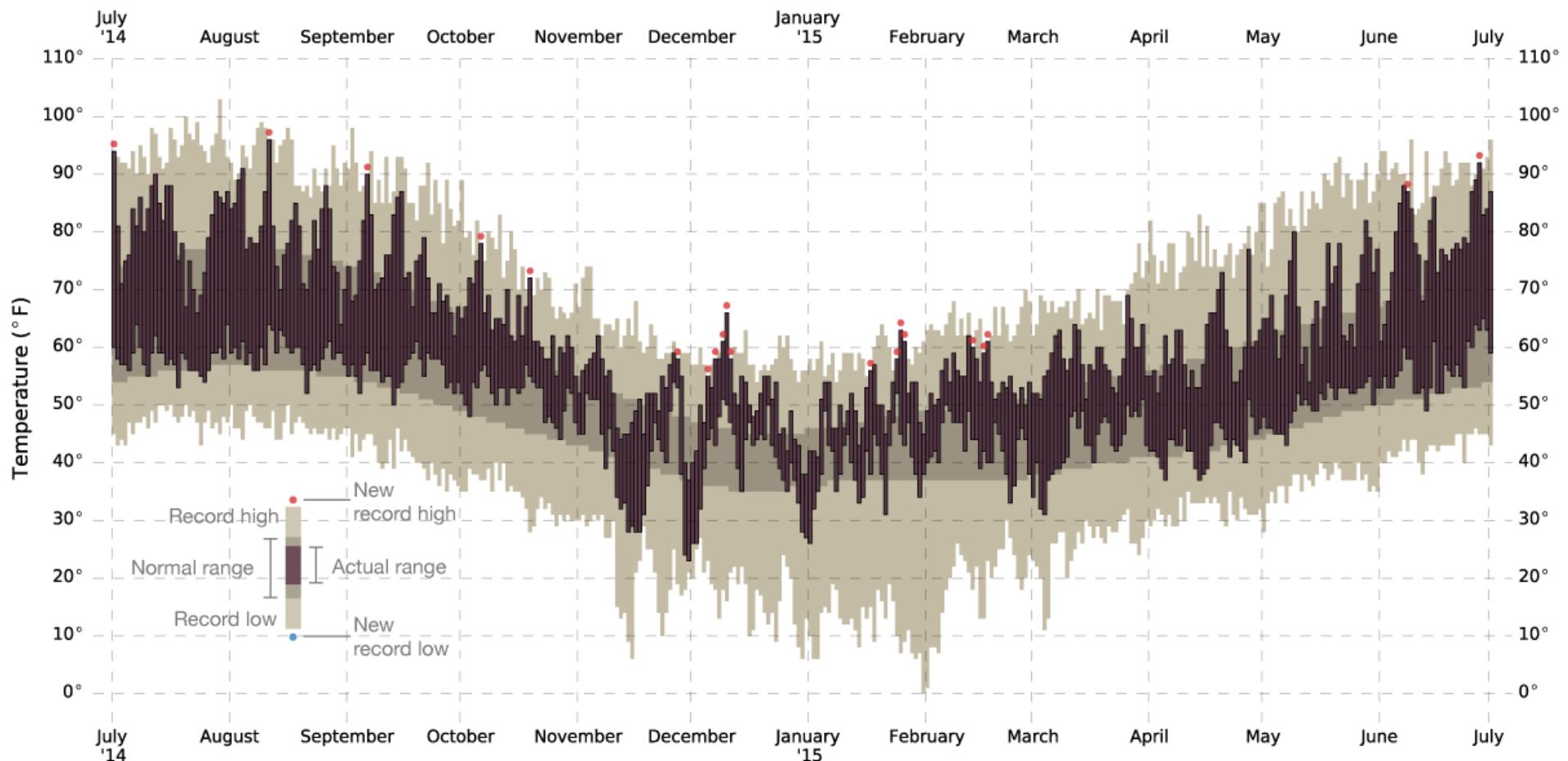
	Key West	88/ 80 0.03	87/ 80 Sh	89/ 81 C	London	68/ 49 0	65/ 52 PC
Knoxville	87/ 63 0	82/ 66 T	76/ 63 T	Madrid	87/ 61 0.16	79/ 50 T	81/ 52 PC
Boston	85/ 64 0	85/ 56 PC	73/ 53 PC	Moscow	50/ 38 0.08	56/ 43 C	51/ 52 PC
Las Vegas	104/ 80 0	104/ 79 S	104/ 77 PC	Nice	76/ 67 0.10	78/ 68 T	77/ 70 PC
Lexington	86/ 62 0	86/ 66 S	80/ 56 R	Oslo	59/ 48 0.08	60/ 50 R	60/ 52 PC
Little Rock	83/ 69 0.13	83/ 69 T	81/ 67 PC	Paris	71/ 48 0.06	70/ 53 PC	72/ 54 PC
Los Angeles	80/ 61 0	80/ 61 PC	81/ 61 PC	Prague	82/ 60 0	68/ 50 T	70/ 52 PC
Louisville	90/ 65 0	87/ 69 PC	86/ 60 R	Rome	77/ 60 0	80/ 63 PC	79/ 62 PC
Lubbock	81/ 60 0.10	84/ 59 PC	88/ 60 PC	S. Petersburg	48/ 35 0.02	55/ 39 S	56/ 40 PC
Madison	85/ 65 0.60	85/ 56 S	73/ 51 S	Stockholm	60/ 46 0.02	60/ 48 R	61/ 50 PC
Memphis	85/ 72 0.17	82/ 72 T	84/ 68 PC	Vienna	83/ 62 0	80/ 58 T	82/ 54 PC
Miami	85/ 77 0.29	85/ 78 Sh	90/ 80 Sh	Warsaw	71/ 51 0	82/ 54 R	83/ 55 PC
Milwaukee	84/ 68 0.45	86/ 57 PC	67/ 54 S	North America	Yesterday	Today	
Mpls. St. Paul	88/ 65 0.60	87/ 59 S	79/ 56 S	Acapulco	87/ 77 0.04	88/ 77 PC	
Mobile	80/ 70 0.40	83/ 71 T	81/ 70 T	Bermuda	77/ 72 0.08	78/ 70 S	
Monterey, Calif.	63/ 52 0	62/ 49 PC	64/ 50 PC	Calgary	78/ 55 0	70/ 50 T	
Nashville	90/ 68 0	83/ 69 T	83/ 63 T	Edmonton	78/ 49 0	72/ 50 C	
New Orleans	82/ 72 0.25	83/ 72 T	82/ 72 T	Guadalajara	93/ 58 0	93/ 59 PC	
Norfolk	86/ 65 0	85/ 71 S	82/ 65 T	Havana	86/ 72 0.13	88/ 72 PC	
Oklahoma City	76/ 64 0.45	76/ 65 T	84/ 63 PC	Kingston	90/ 79 0.01	90/ 80 PC	
Omaha	92/ 66 0	92/ 63 S	92/ 60 S	Martinique	87/ 78 0.23	86/ 73 Sh	
Orlando	83/ 70 0.55	82/ 69 T	84/ 71 T	Mexico City	81/ 53 0.04	82/ 60 PC	
Philadelphia	77/ 56 0.01	82/ 66 PC	78/ 61 T	Monterrey	92/ 63 0	91/ 72 PC	
Phoenix	108/ 80 0	108/ 82 S	109/ 83 S	Montreal	64/ 48 0	67/ 53 C	
Pittsburgh	79/ 59 0	84/ 62 T	73/ 54 Sh	Nassau	93/ 77 0.02	92/ 77 Sh	
Portland, Me.	63/ 47 0.02	66/ 50 PC	56/ 48 R	Panama City	88/ 77 0.15	87/ 77 T	
Portland, Ore.	68/ 51 0	67/ 45 PC	74/ 51 C	Quebec City	62/ 47 0	68/ 48 C	
Providence	69/ 52 0.13	70/ 56 R	66/ 54 R	Santo Domingo	90/ 75 0.15	89/ 76 PC	
Raleigh	88/ 63 0	89/ 65 T	81/ 66 T	Toronto	72/ 53 0	75/ 53 R	
Reno	86/ 57 0	82/ 58 PC	85/ 54 S	Vancouver	64/ 46 0	64/ 45 C	
Richmond	86/ 59 0	89/ 69 S	78/ 62 T	Winnipeg	82/ 58 0.04	78/ 55 PC	
Rochester	71/ 51 0	74/ 59 R	68/ 53 Sh	South America	Yesterday	Today	
Sacramento	85/ 53 0	86/ 53 S	90/ 55 S	Bogota	69/ 50 0.02	66/ 50 R	
Salt Lake City	92/ 68 0	96/ 66 S	86/ 64 S	Buenos Aires	62/ 40 0.01	61/ 38 PC	
San Antonio	88/ 70 0.11	86/ 70 T	87/ 70 T	Caracas	90/ 81 0.08	91/ 81 PC	
San Diego	72/ 62 0	72/ 62 PC	71/ 62 PC	Lima	72/ 63 0	72/ 63 S	
San Francisco	66/ 53 0	66/ 52 PC	70/ 52 PC	Quito	72/ 52 0.10	74/ 51 Sh	
San Jose	75/ 54 0	75/ 52 PC	79/ 55 PC	Recife	86/ 76 0.08	85/ 75 Sh	
San Juan	90/ 77 0.02	89/ 78 PC	89/ 79 PC	Rio de Janeiro	78/ 67 0.02	82/ 70 S	
Savannah	88/ 70 0.04	87/ 72 T	87/ 72 T	Santiago	58/ 34 0	58/ 34 S	
Seattle	66/ 50 0	66/ 48 PC	69/ 51 C	Sao Paulo	70/ 58 0	80/ 66 S	
Shreveport	86/ 70 0.10	83/ 69 T	81/ 68 T				

Highlight: New York's Weather in May

Temperature Central Park



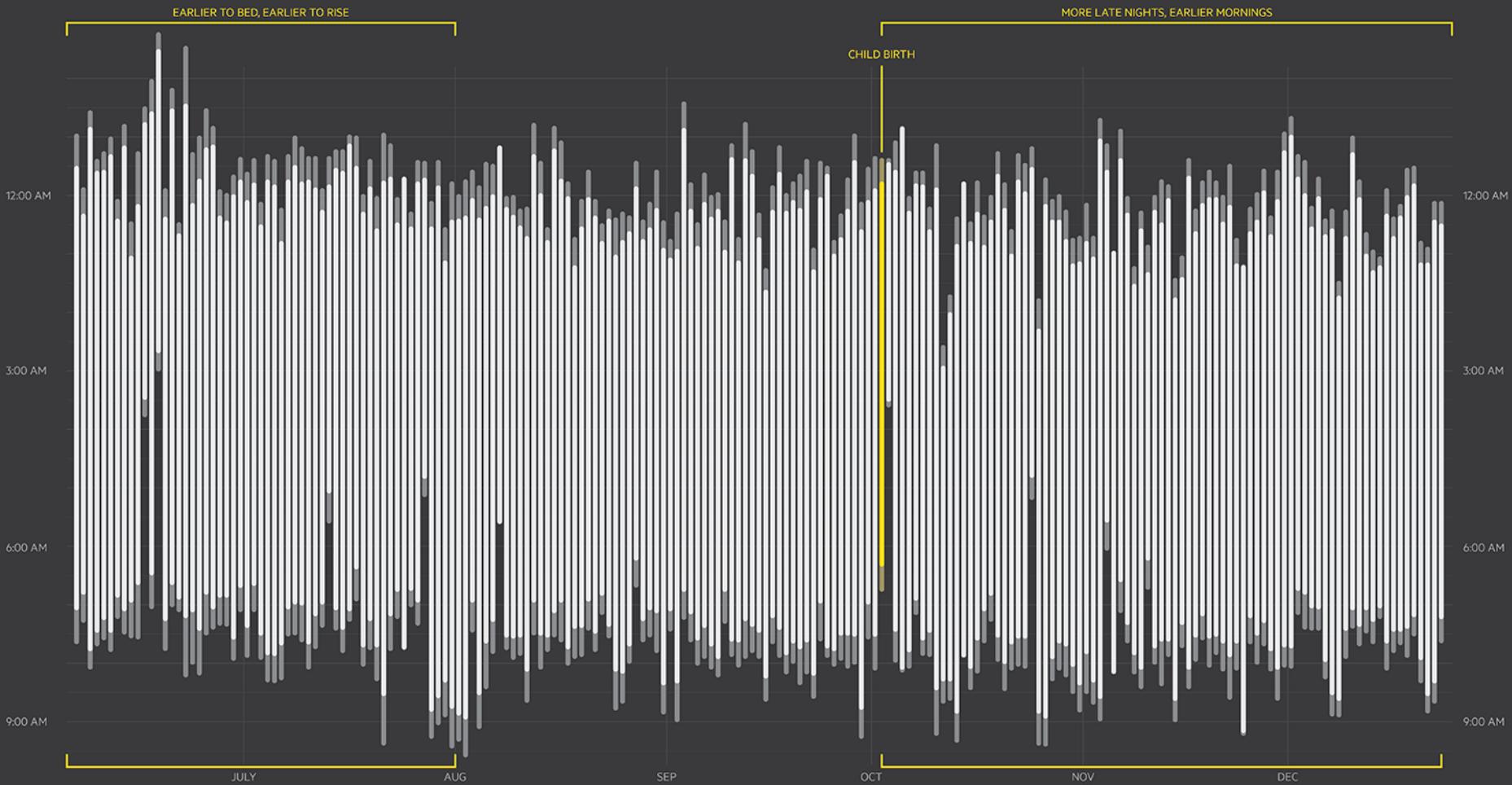
Seattle



Data source: wunderground.com
Author: Randy Olson (randalolson.com / [@randal_olson](https://twitter.com/randal_olson))

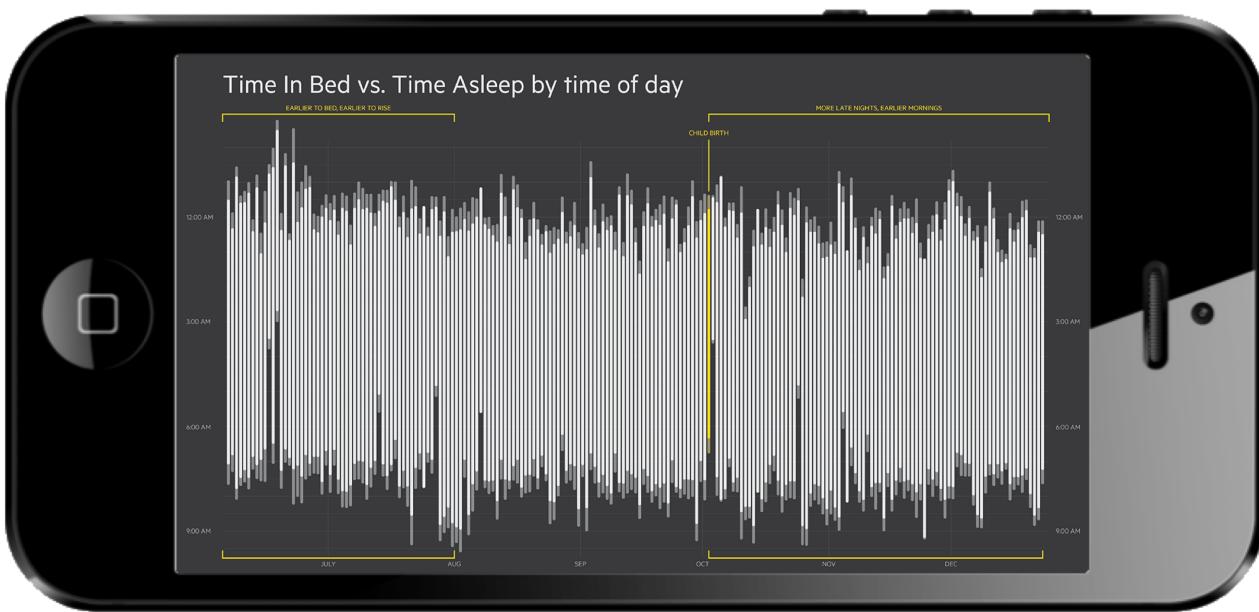
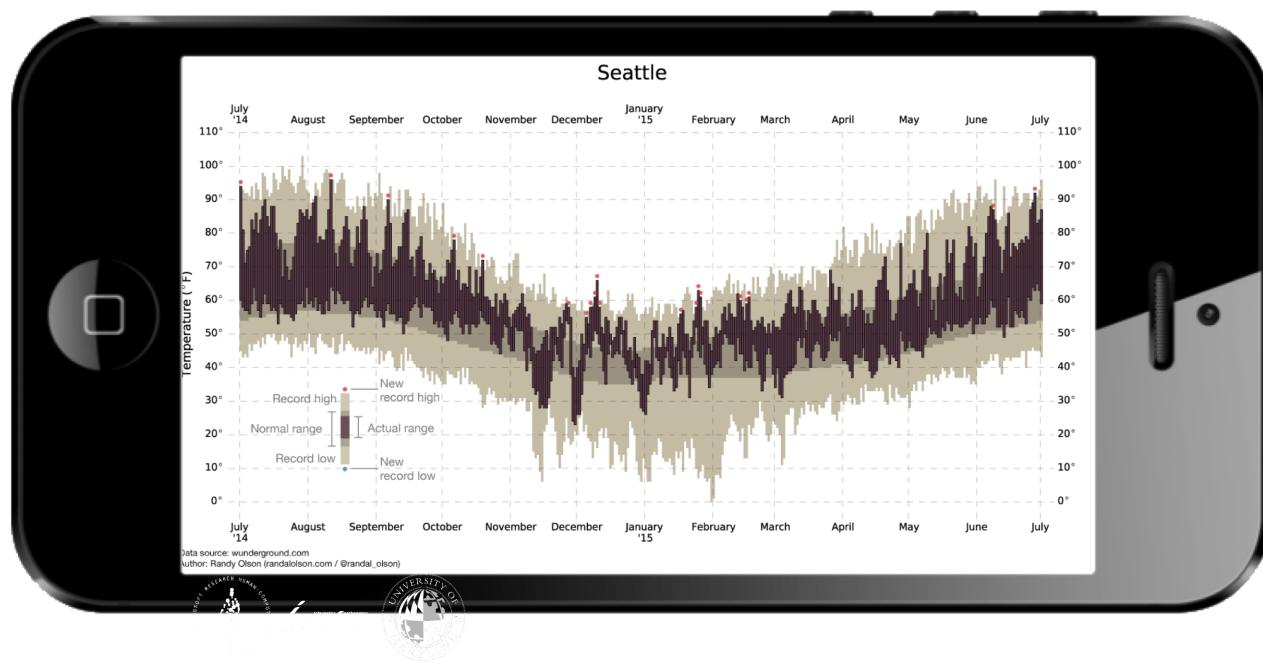
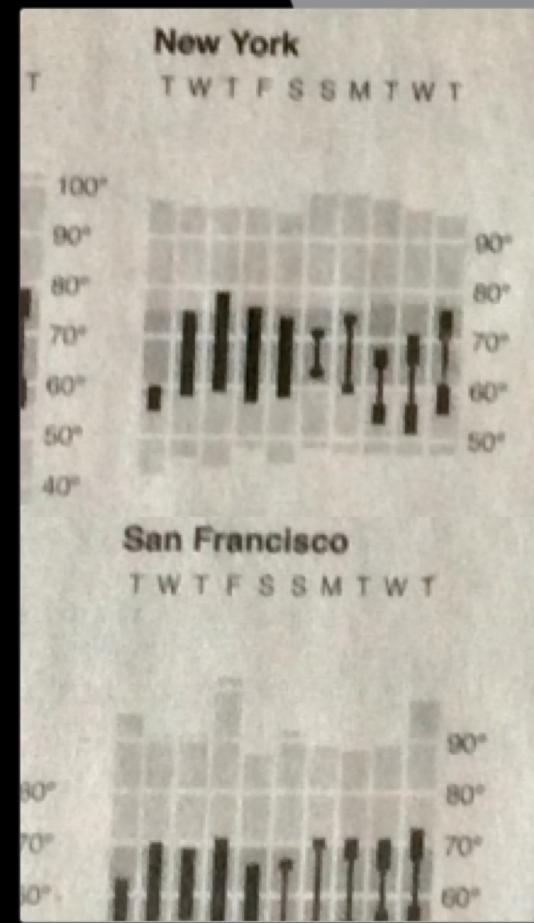


Time In Bed vs. Time Asleep by time of day



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Ranges in Weather Apps



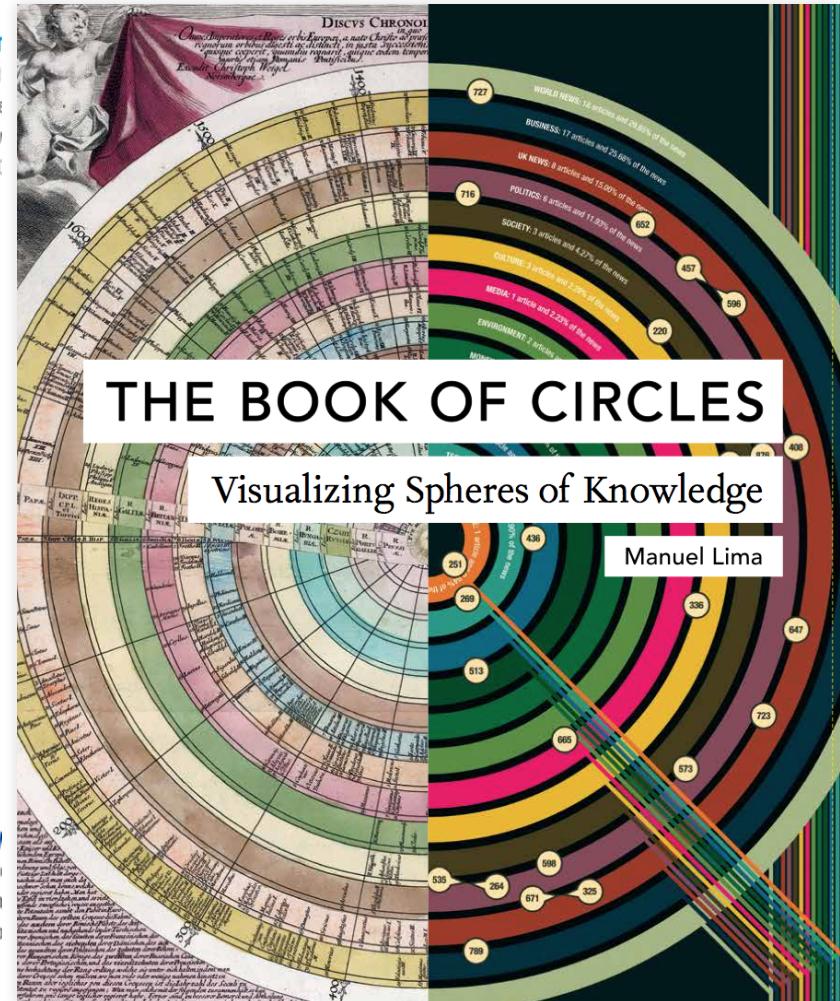
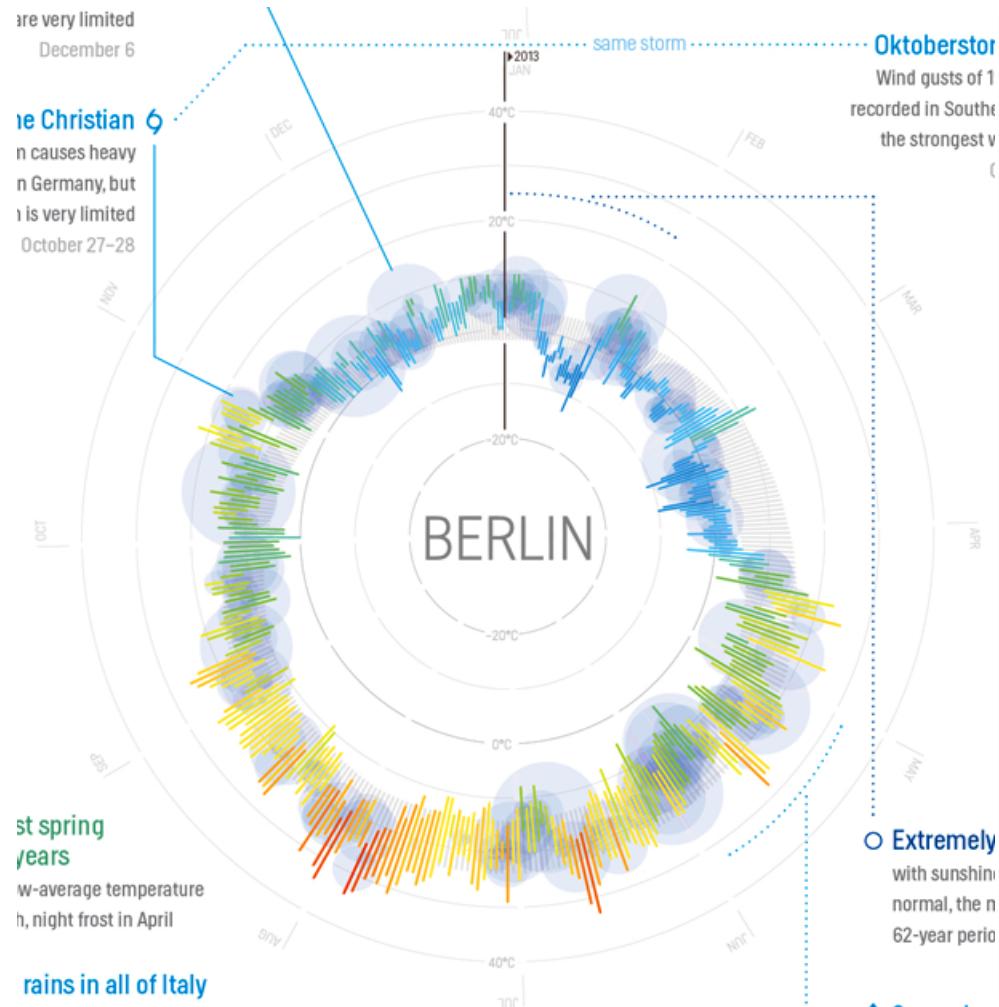
Ranges in Sleep Tracking Apps



How many ranges can you show in a mobile display?



Ranges and Radial Layouts





SMARTPHONE

TABLET

ALL

CIRCLE 28

BAR 20

LINE 14

MAP 11

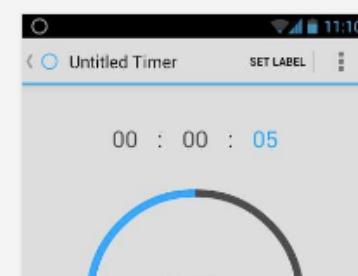
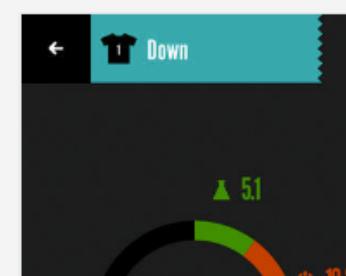
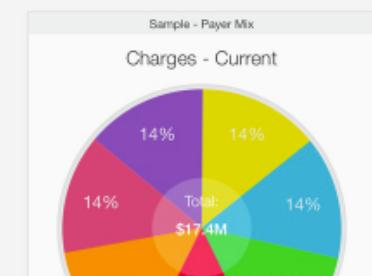
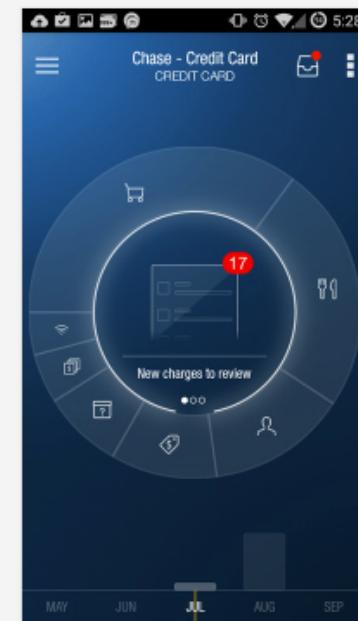
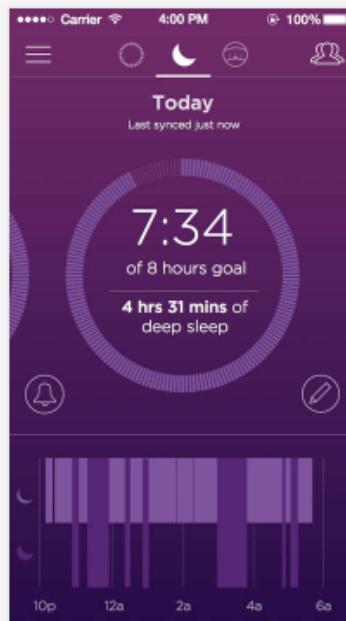
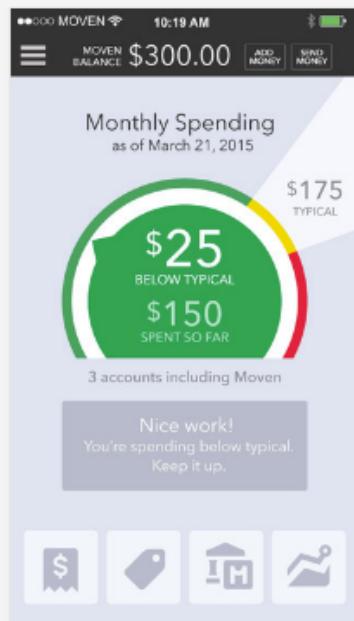
AREA 9

POINT 6

TEXT 4

TABLE 1

NETWORK 1



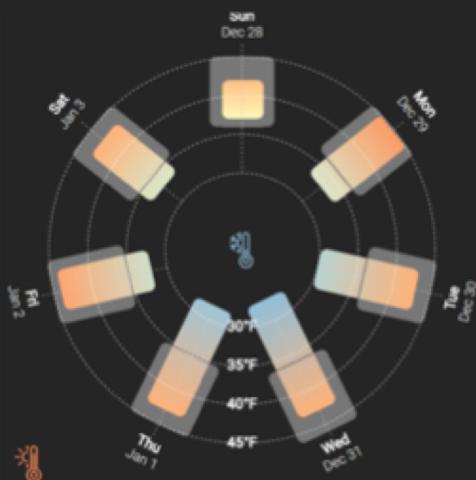
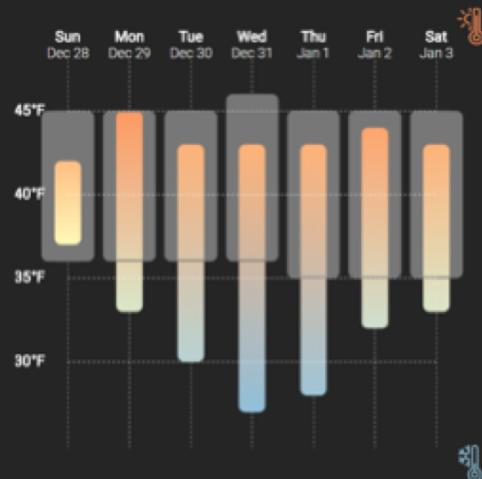
A Crowd sourced Experiment on Mobile Phones



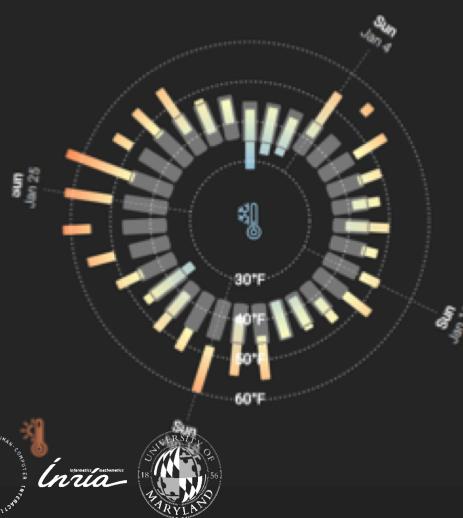
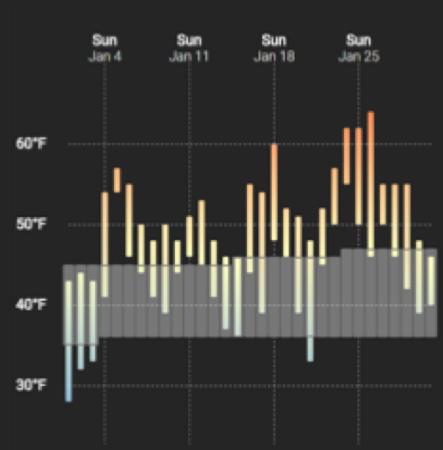
1024x600 pixels (16:9 aspect ratio) (1024x576 pixels and 12.5% margins)

Linear

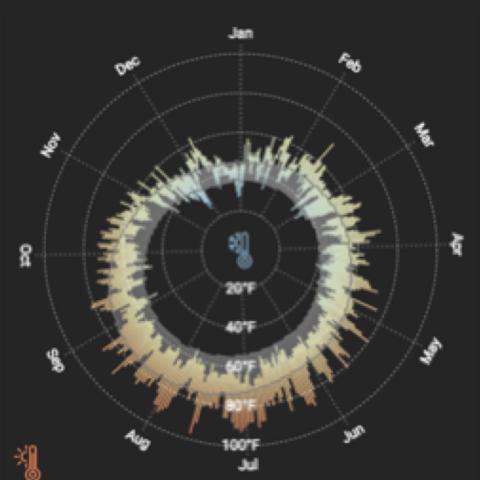
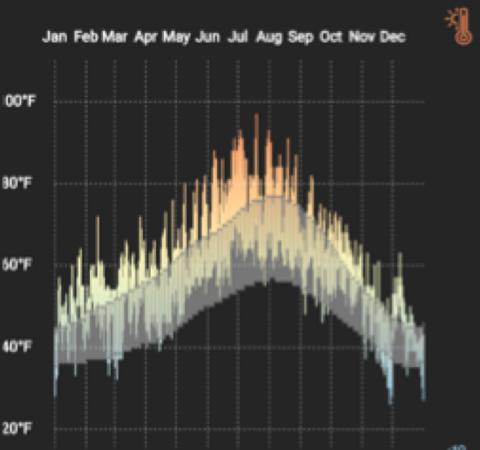
Week



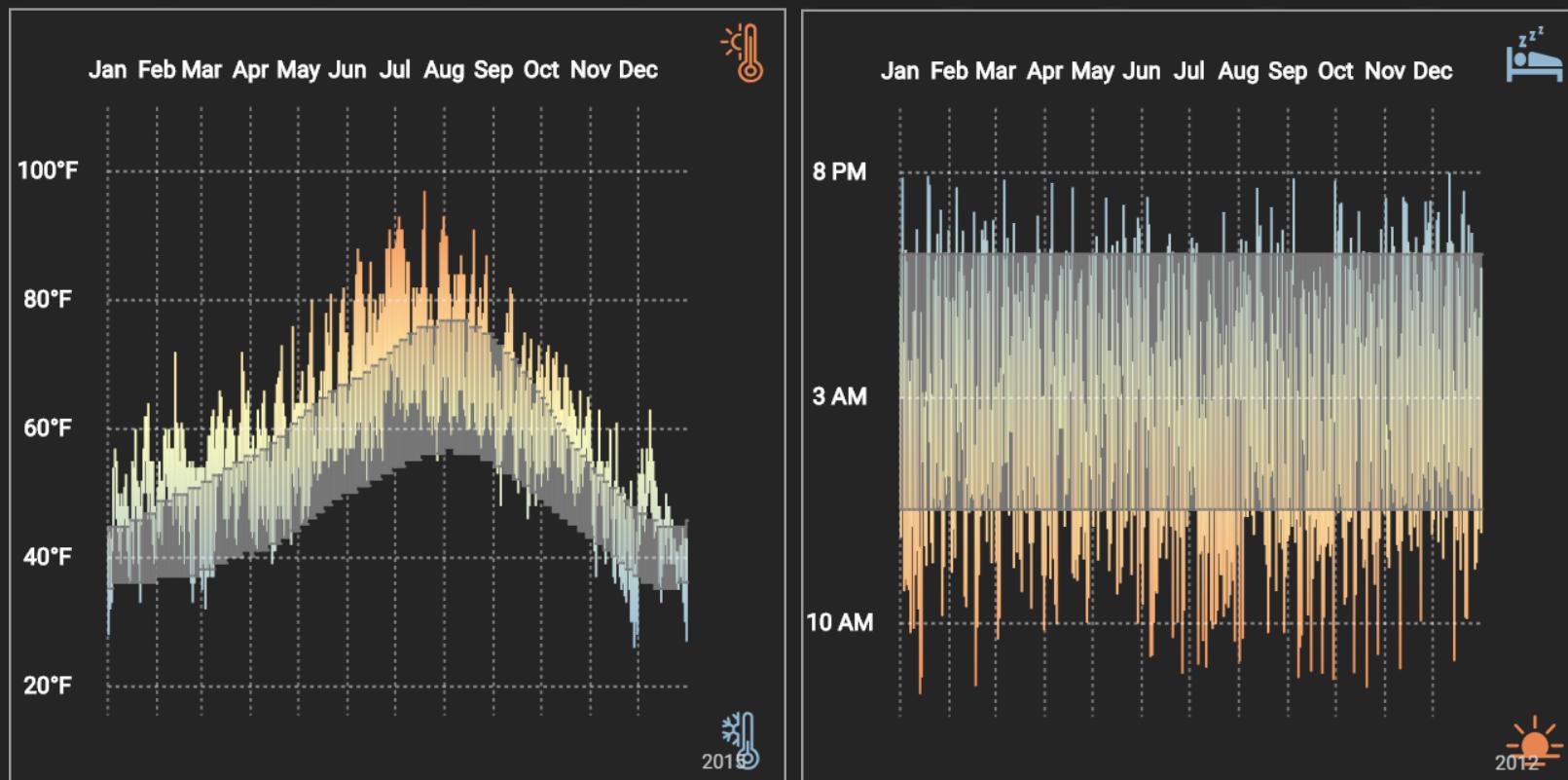
Month



Year

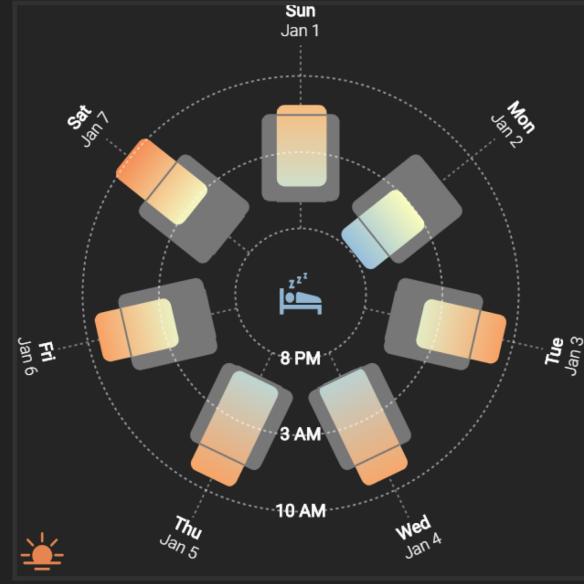
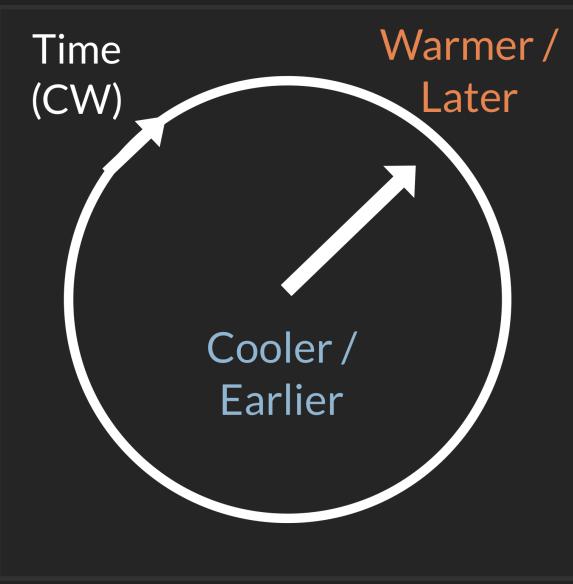
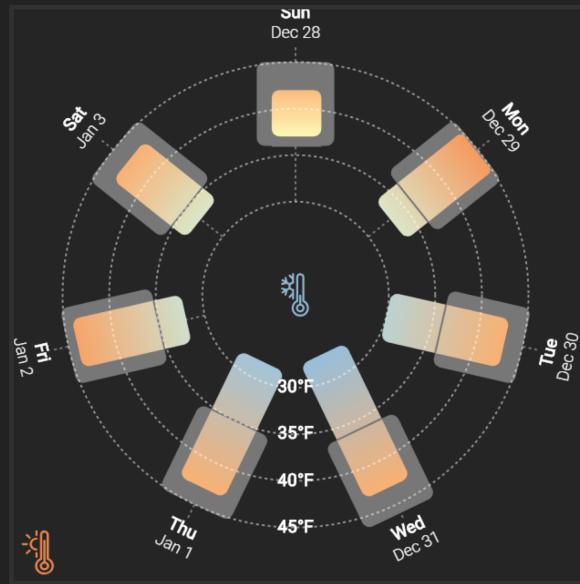
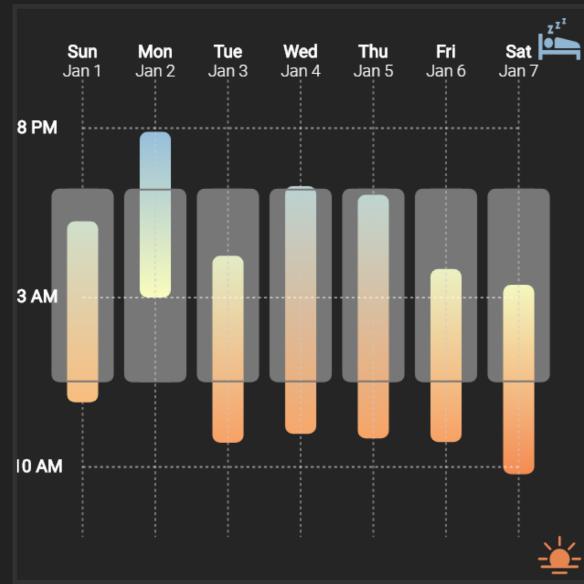
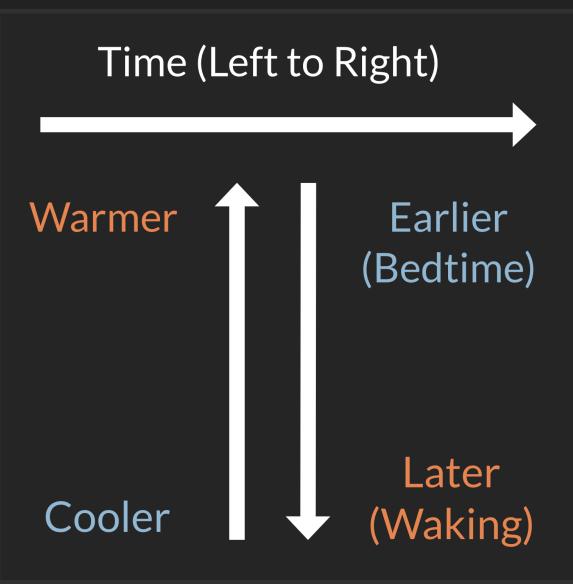
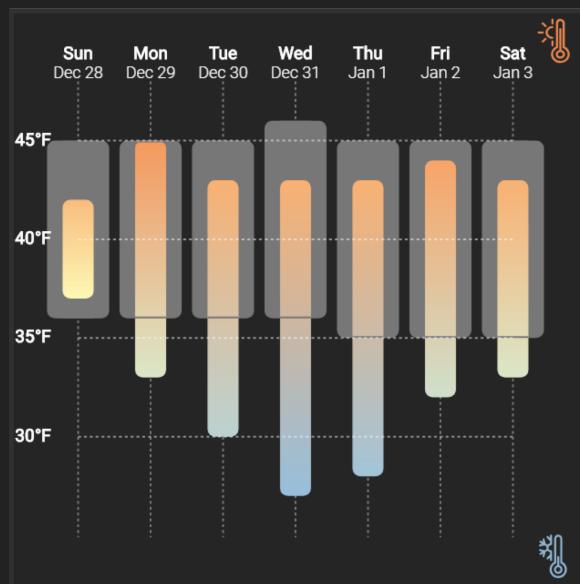


Data: Temperature (Left) and Sleep (Right) Ranges



Temperature (L) and Sleep (R) Range Encoding, Explained





5 Experimental Tasks

Locate Dates

Read Values (on an indicated day)

Locate Min / Max Values

Compare Values (on an indicated day)

Compare Ranges (between two indicated date spans)



Locating Dates

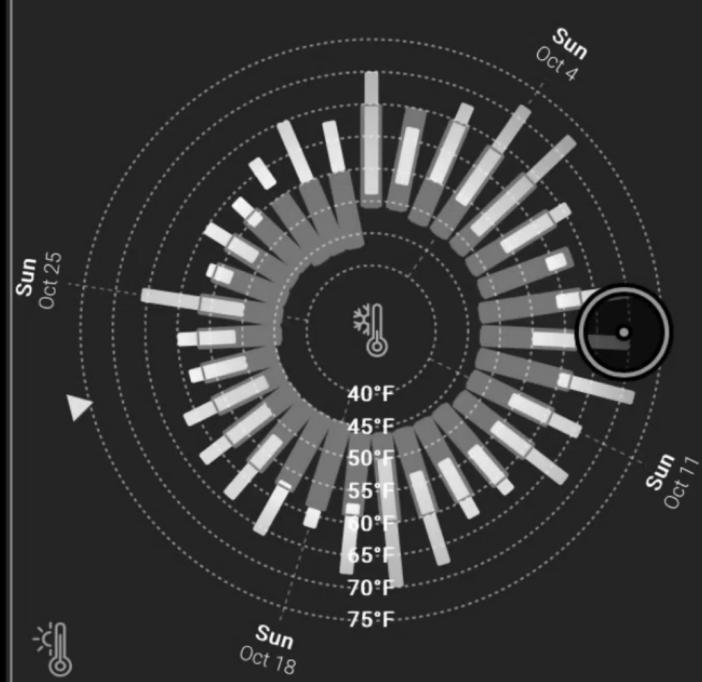


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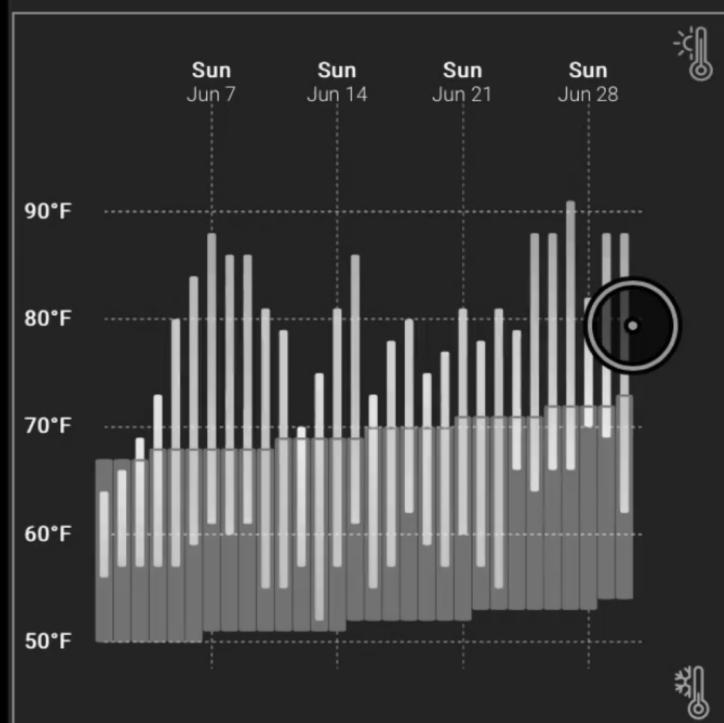
Reading Values

Contain the Daily High Temperature for Friday, October 23rd.



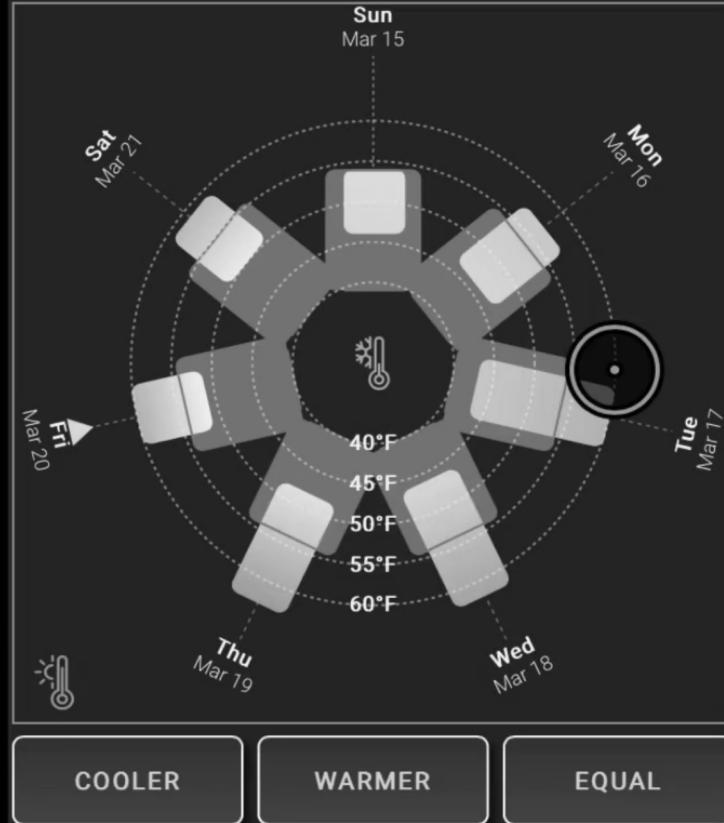
Locating Min / Max

On which day did the Warmest Daily High Temperature occur?



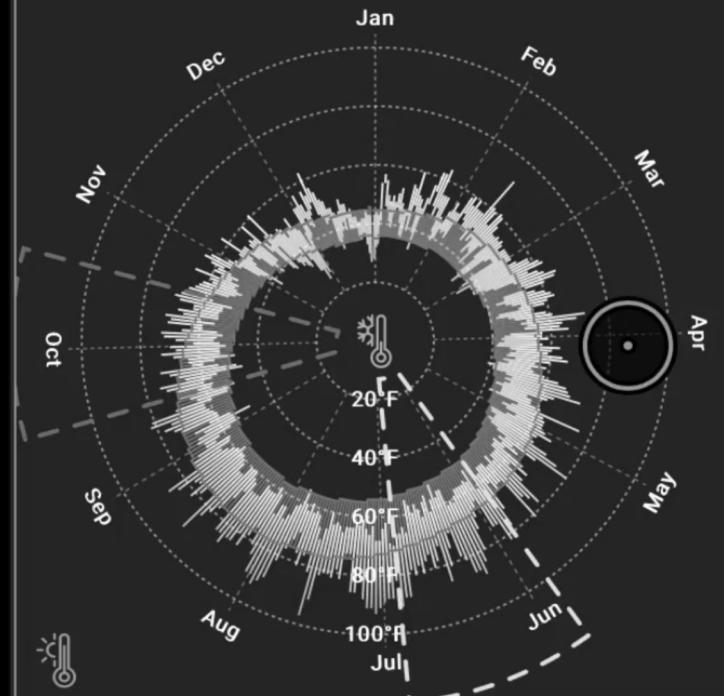
Comparing Values

Is the Daily Low Cooler, Warmer, or Equal to the
Expected Daily Low on Fri, Mar 20th?



Comparing Ranges

Which span of temperature ranges is more closely aligned with the expected temperature range?



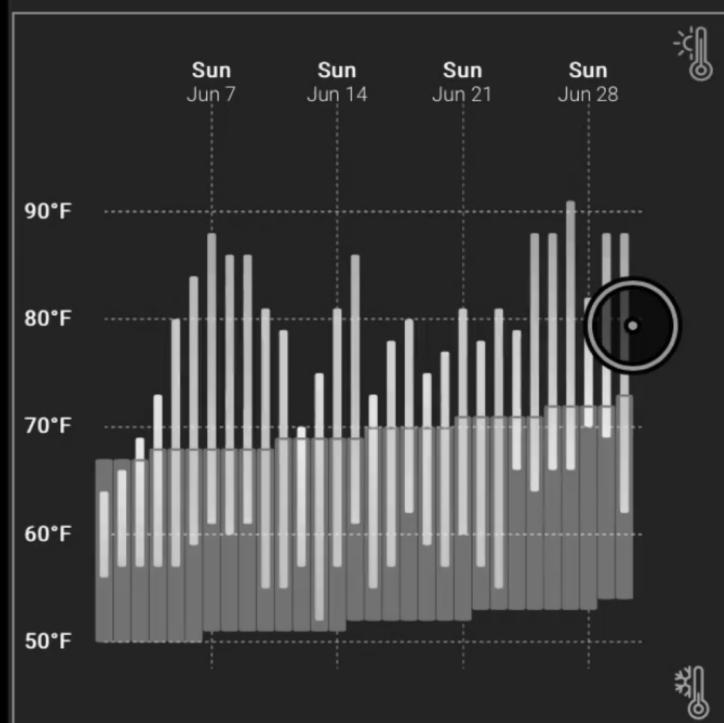
EQUALLY ALIGNED

DONE



Locating Min / Max

On which day did the Warmest Daily High Temperature occur?



Data We Collected:

For each trial:

- ⌚ Trial completion time
 - ✓ Response accuracy

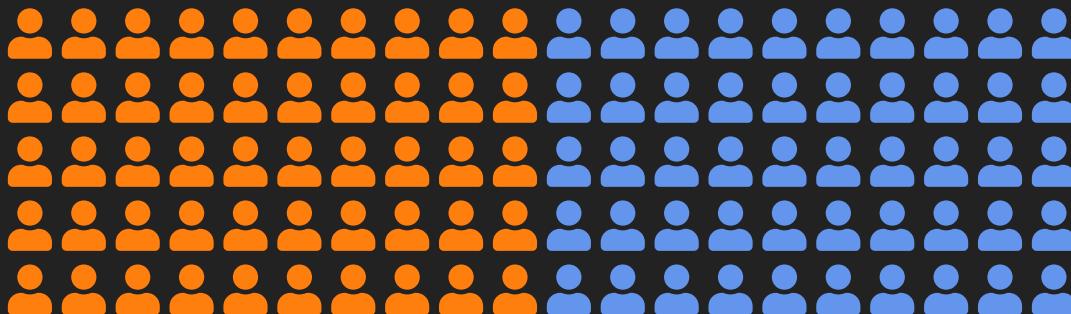
At each level of granularity:

- Preference: Linear or Radial
Confidence: Low (1) to High (5)



100 Participants

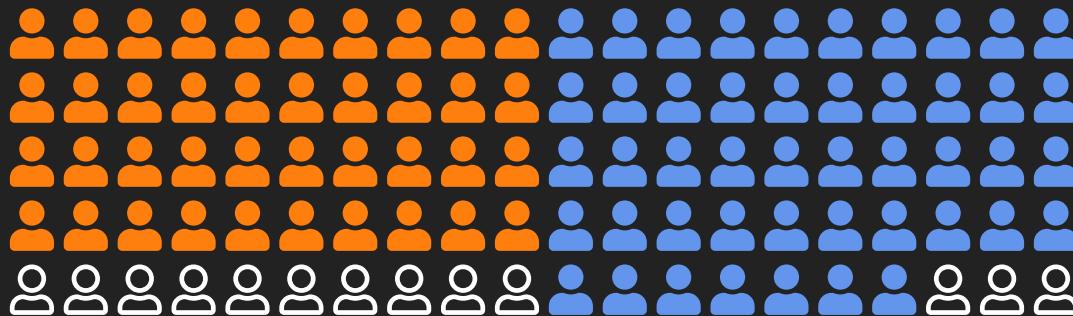
Temperature (N = 50), Sleep (N = 50)



84 trials per participant, 20 - 25 minutes to complete full experiment

Results from 87 Participants

Temperature (N = 40), Sleep (N = 47)



3,337 Temperature group trials; 3,926 Sleep group trials



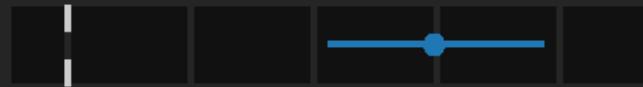
Sleep

Temperature

Locate Date



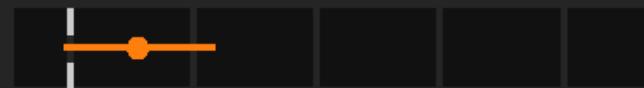
Read Value



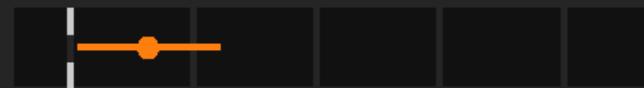
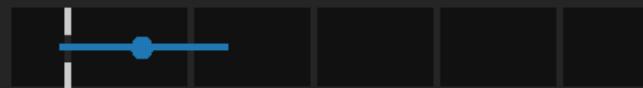
Locate Min / Max



Compare Values



Compare Ranges



Radial / Linear completion time ratios



Sleep

Temperature

Locate Date



Read Value



Locate Min / Max



Compare Values



Compare Ranges



Radial / Linear completion time ratios



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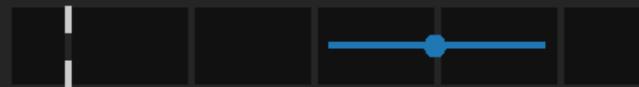


Sleep

Temperature

Locate Date

Read Value



Locate Min / Max

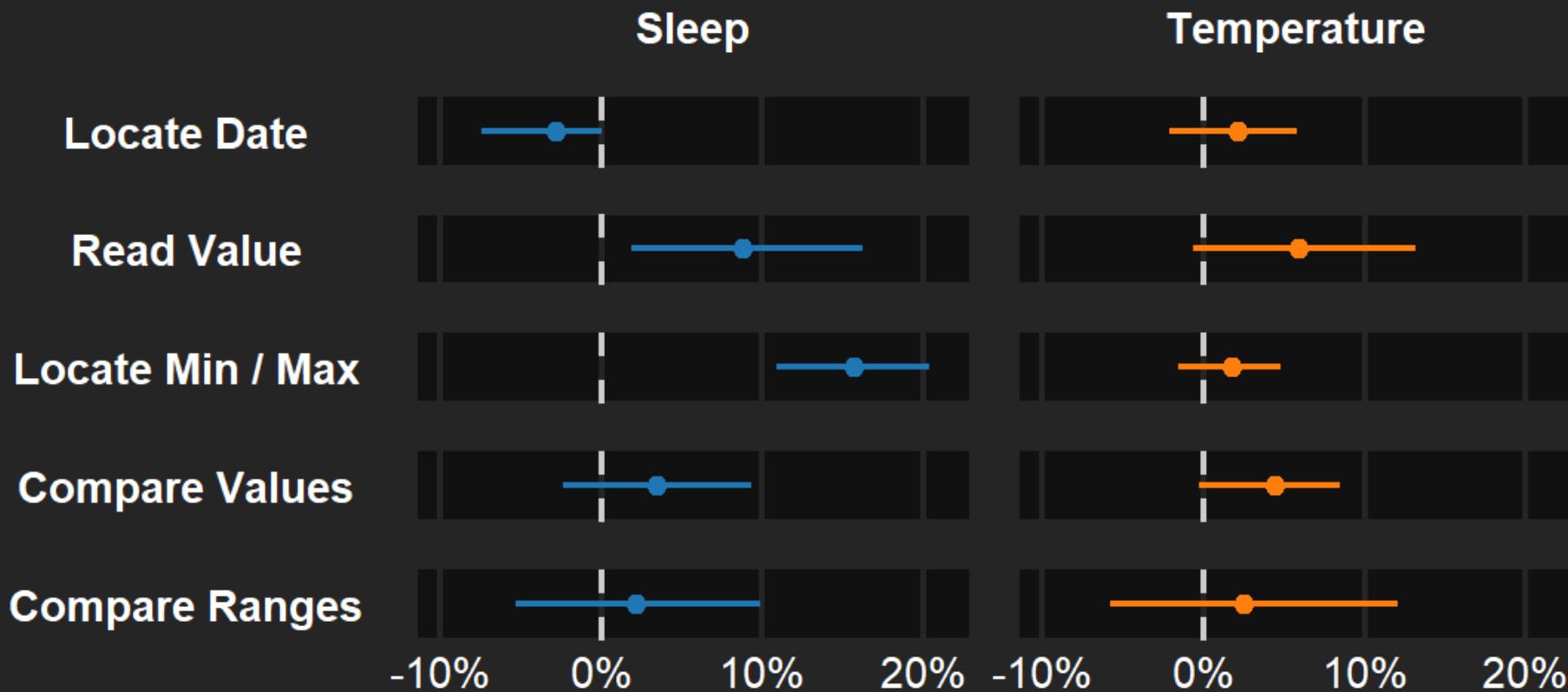


Compare Values

Compare Ranges

Radial / Linear completion time ratios



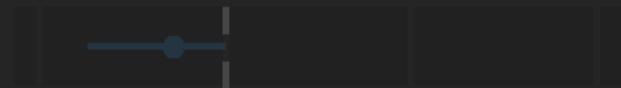


Radial - Linear error rate differences



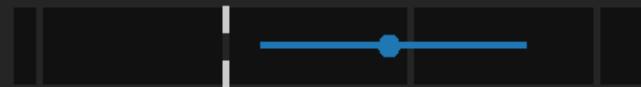
Sleep

Locate Date

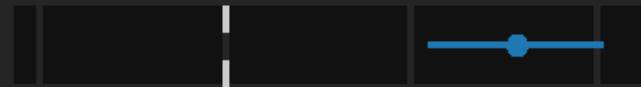


Temperature

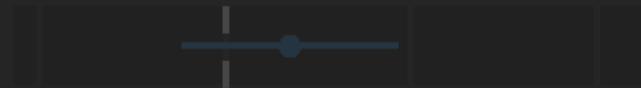
Read Value



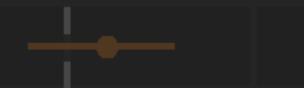
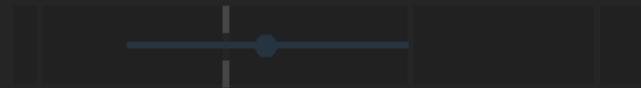
Locate Min / Max



Compare Values



Compare Ranges



-10% 0% 10% 20% -10% 0% 10% 20%

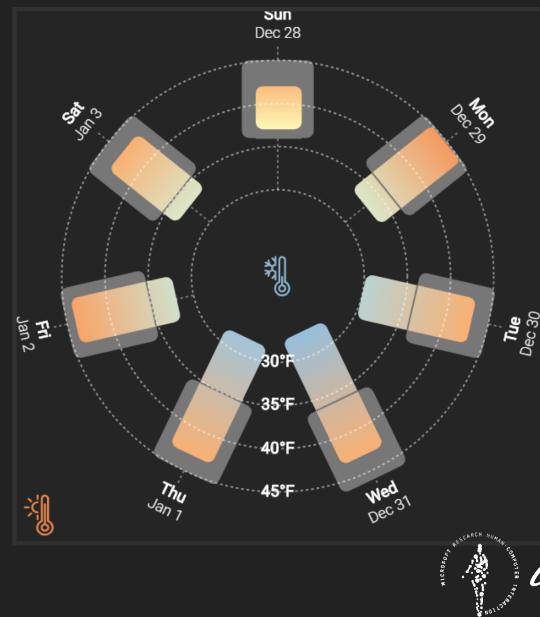
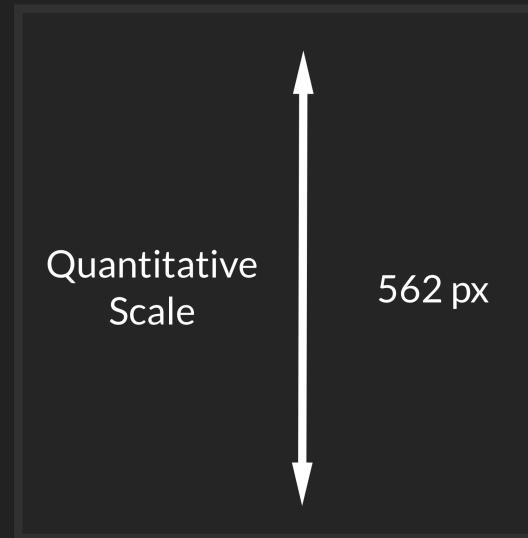
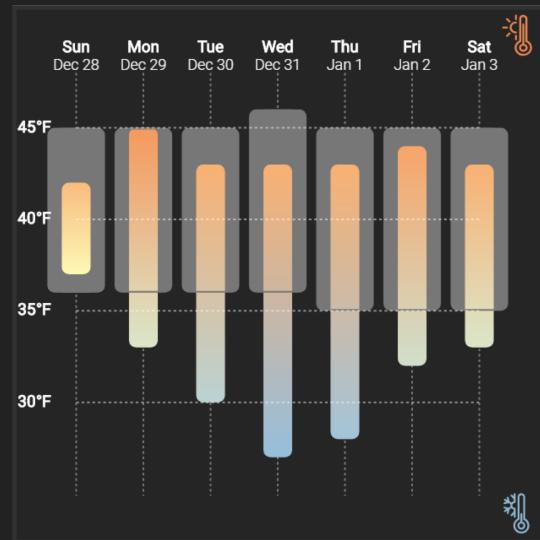
Radial - Linear error rate differences



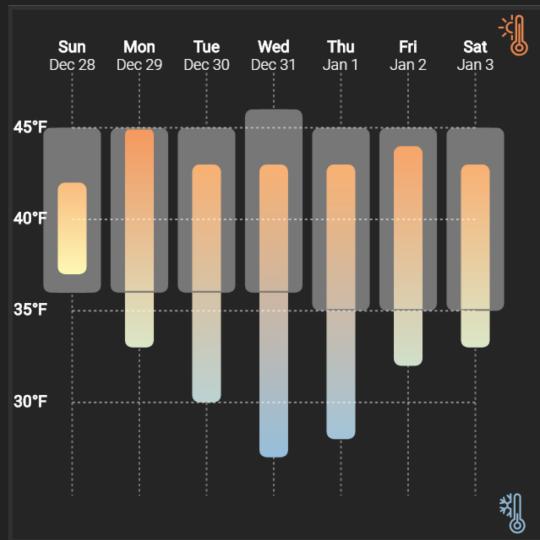
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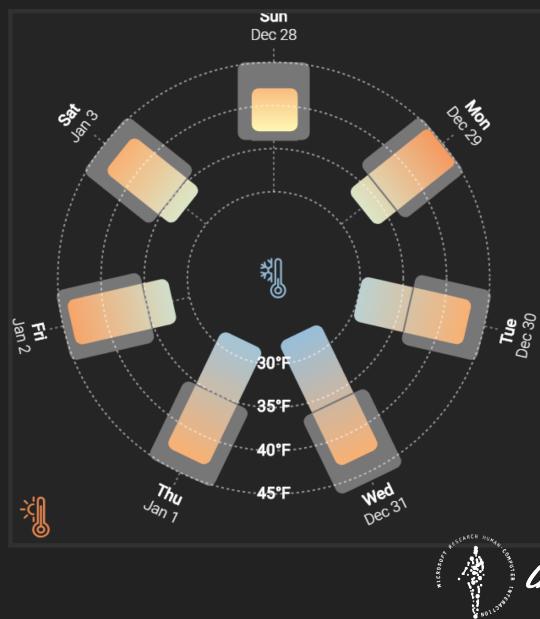
Interpreting Radial vs. Linear performance differences



No advantage at the periphery relative to the center



Chronological Scale
562 px



Chronological Scale
at Periphery
 $C = 1766$ px

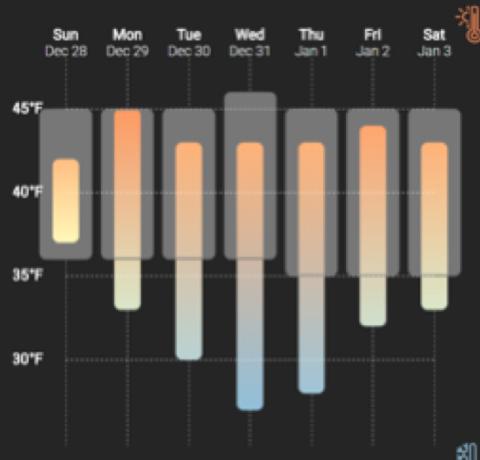




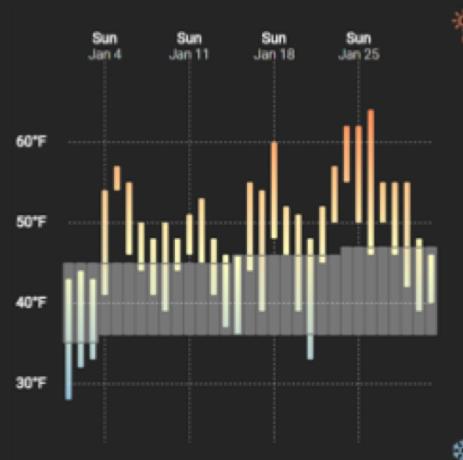


Linear

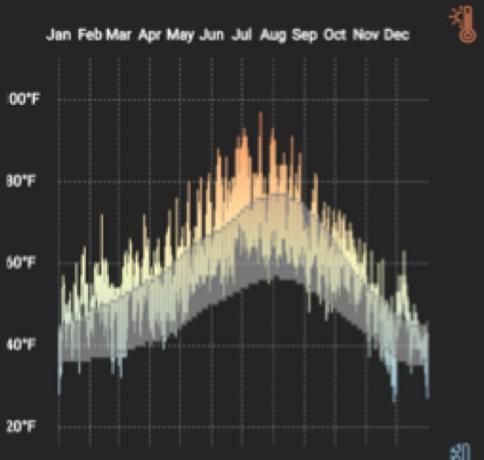
Week



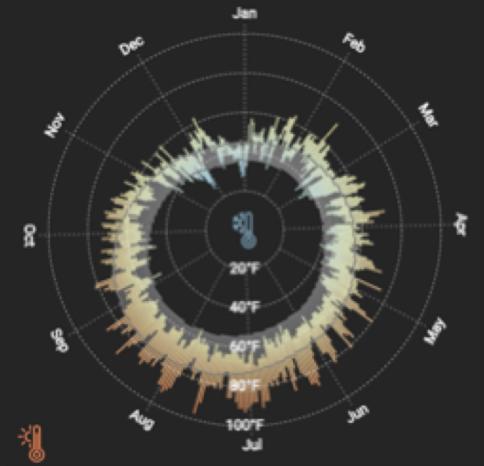
Month

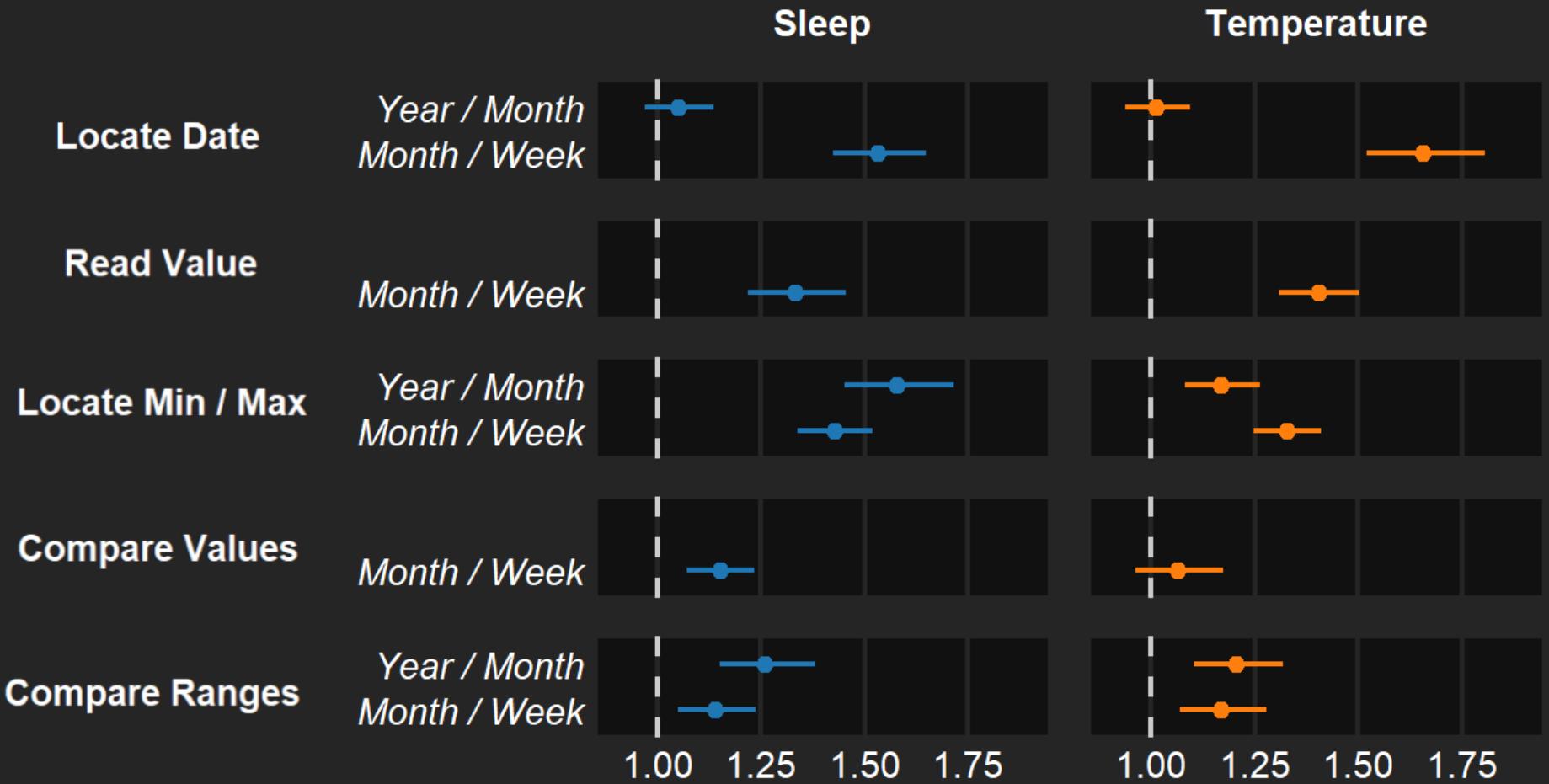


Year



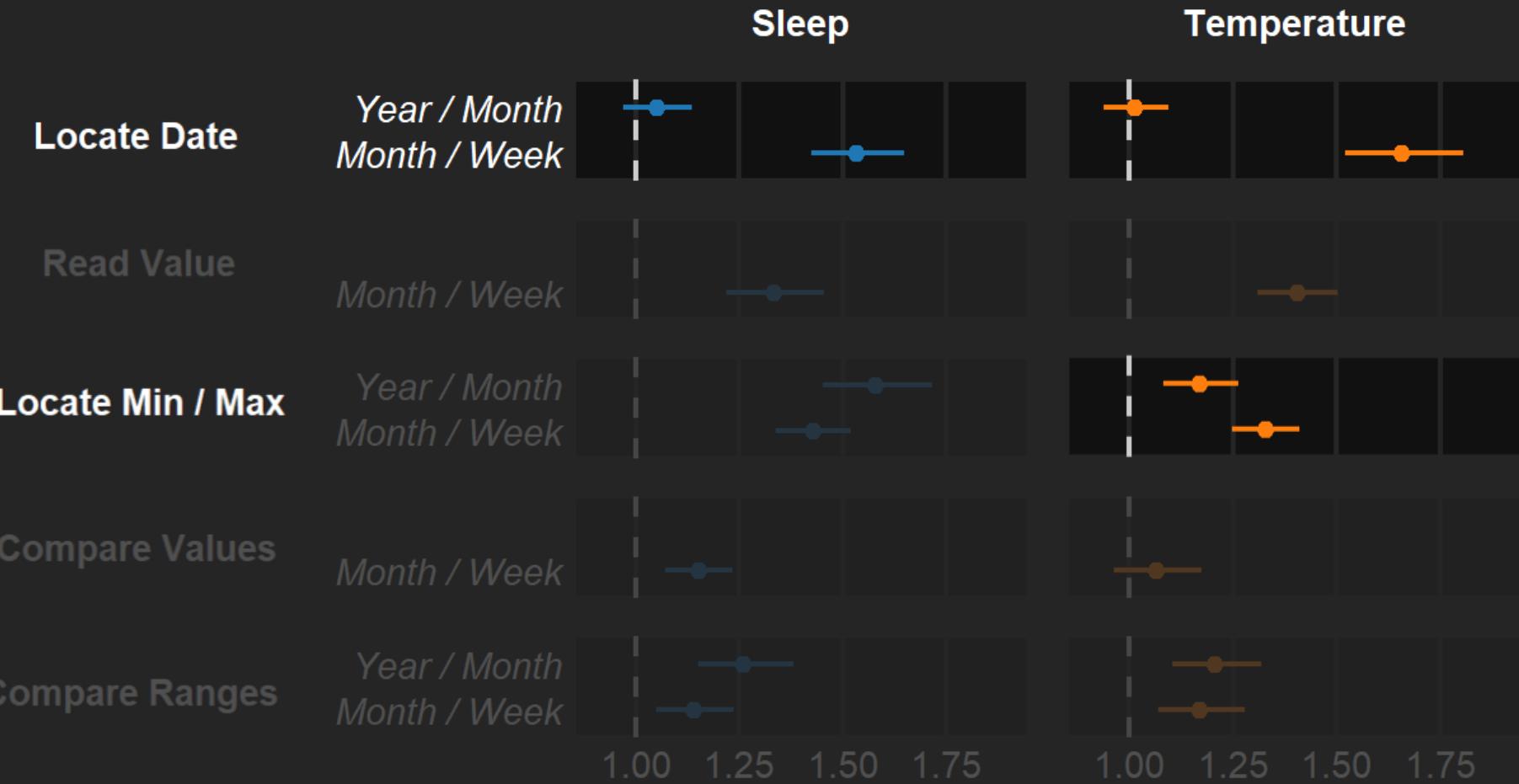
Radial





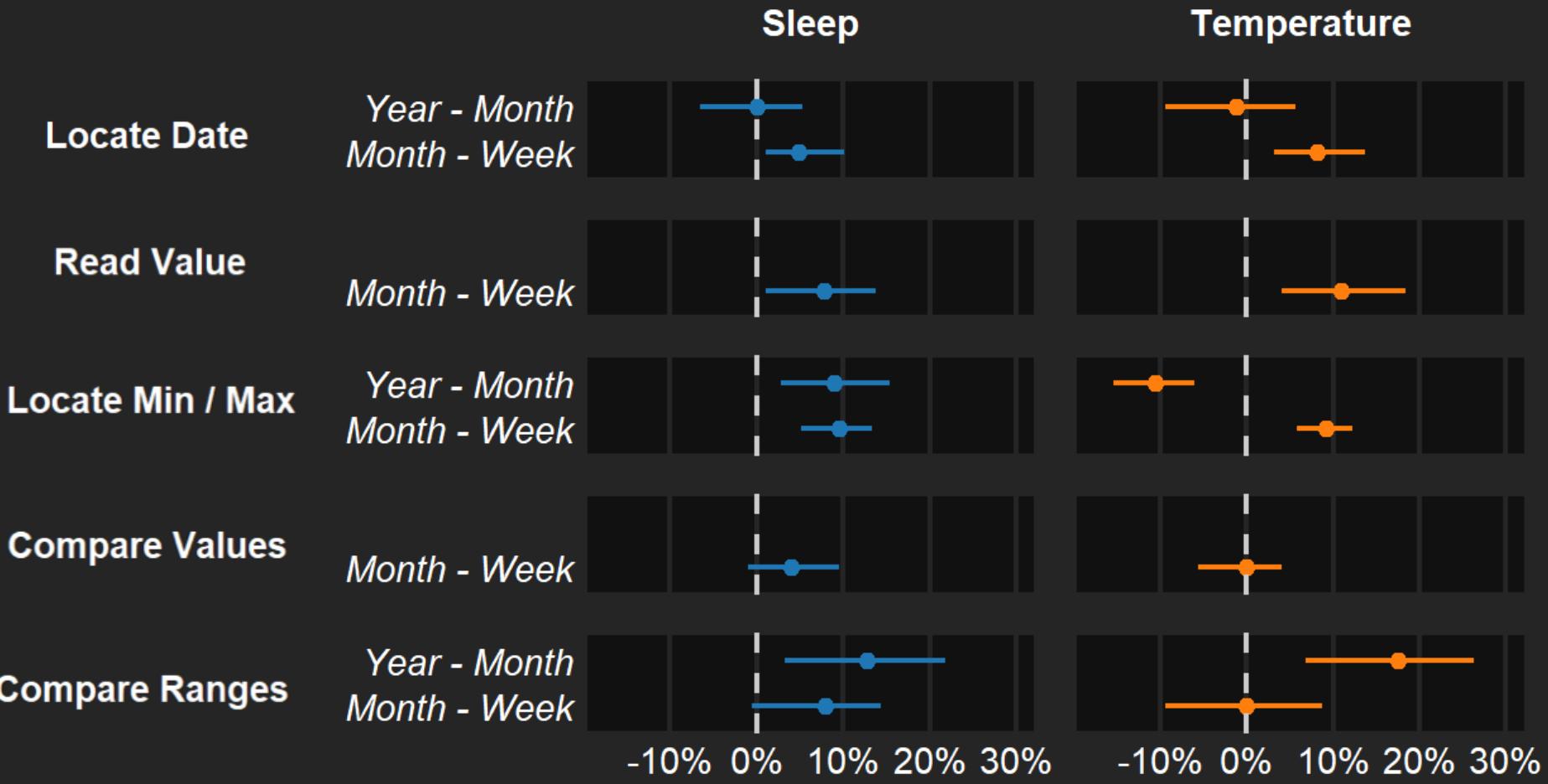
Completion time ratios between granularities



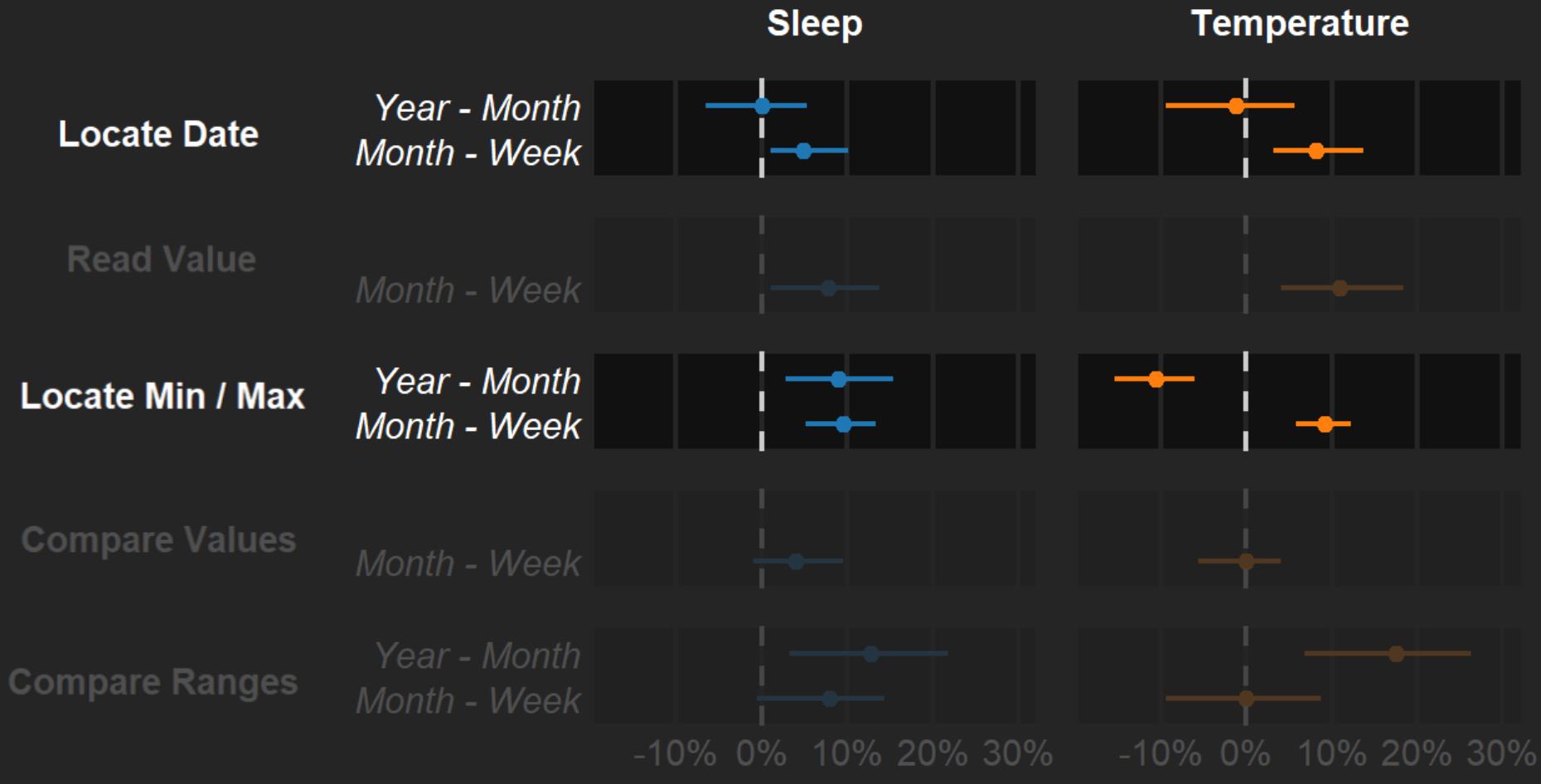


Completion time ratios between granularities





Accuracy differences between granularities



Accuracy differences between granularities

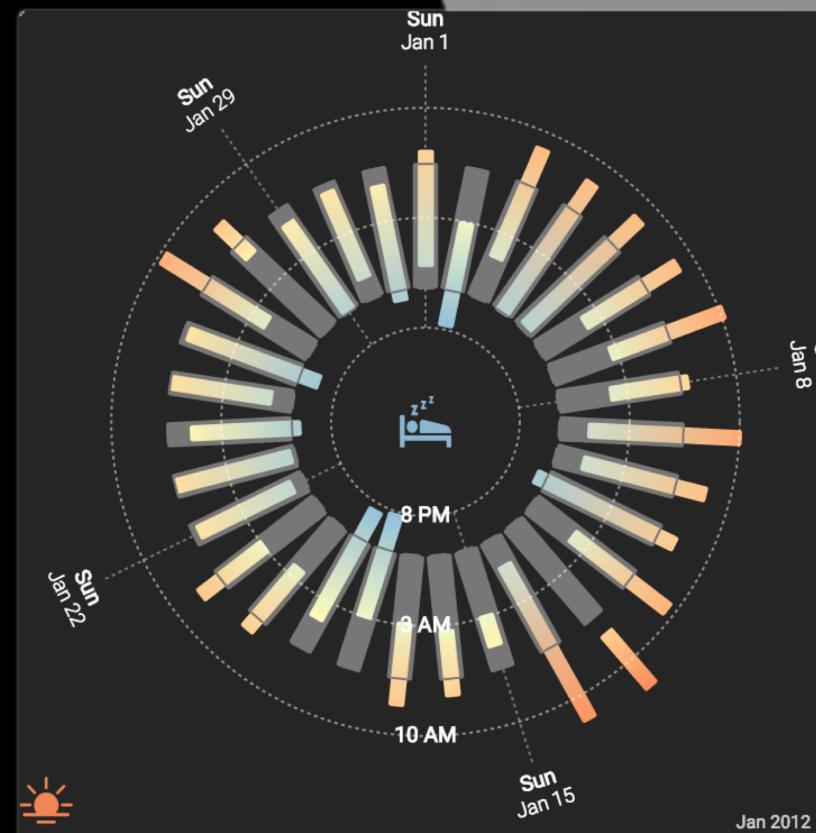
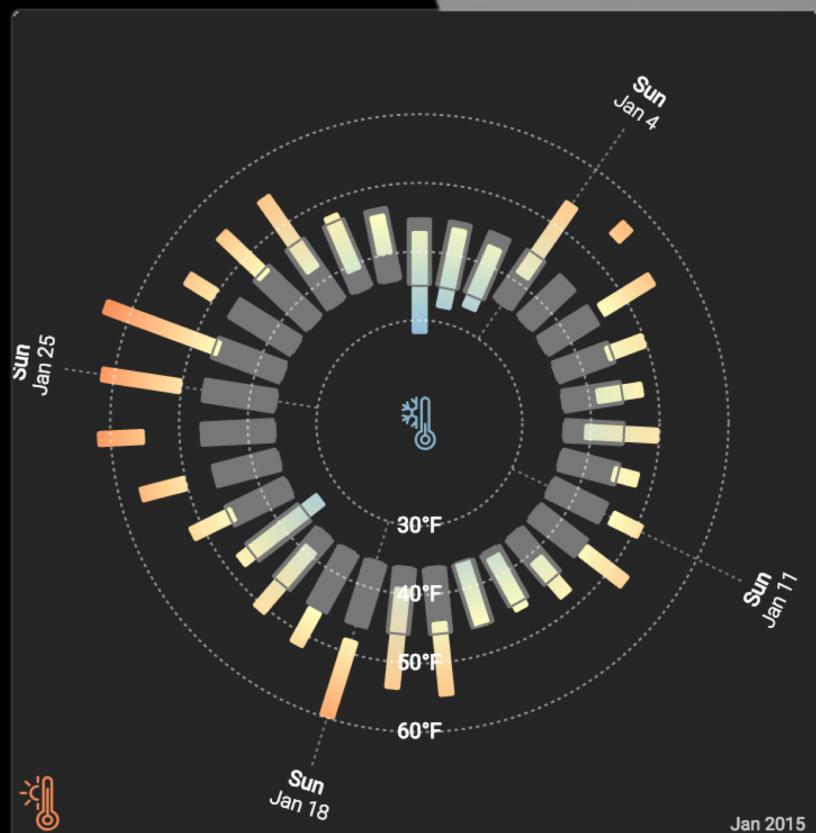


Temperature and Sleep don't follow Monthly cycles



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Selecting an appropriate layout and granularity

Is a cycle meaningful in the context of the data?

Is the task involve locating values? Or comparing them?

Is efficiency the primary consideration?

Locating values (quickly)? → Linear

Comparing values (unconcerned with efficiency)? → Radial or Linear



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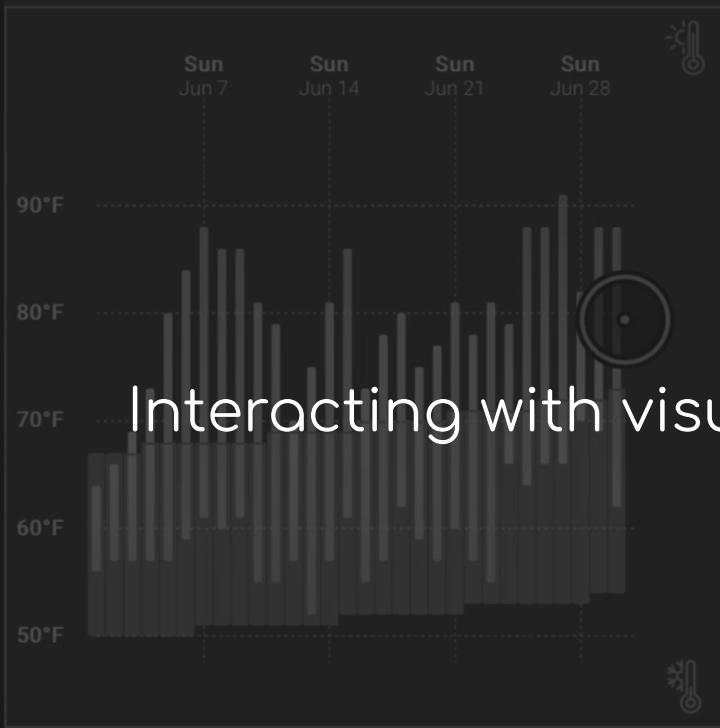
Our findings only apply to mobile contexts



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On which day did the
Warmest Daily High Temperature occur?



Interacting with visualization on mobile devices

Is the Daily Low Cooler, Warmer, or Equal to the
Expected Daily Low on Fri, Mar 20th?



DONE



Visualizing Ranges Over Time on Mobile Phones

Matthew Brehmer · Microsoft Research · [@mattbrehmer](https://twitter.com/mattbrehmer)

In collaboration with Bongshin Lee, Petra Isenberg, & Eun Kyoung Choe

(mobile only) experimental app: aka.ms/ranges
code: github.com/microsoft/RangesOnMobile
slides: aka.ms/ranges-vis



Supplemental

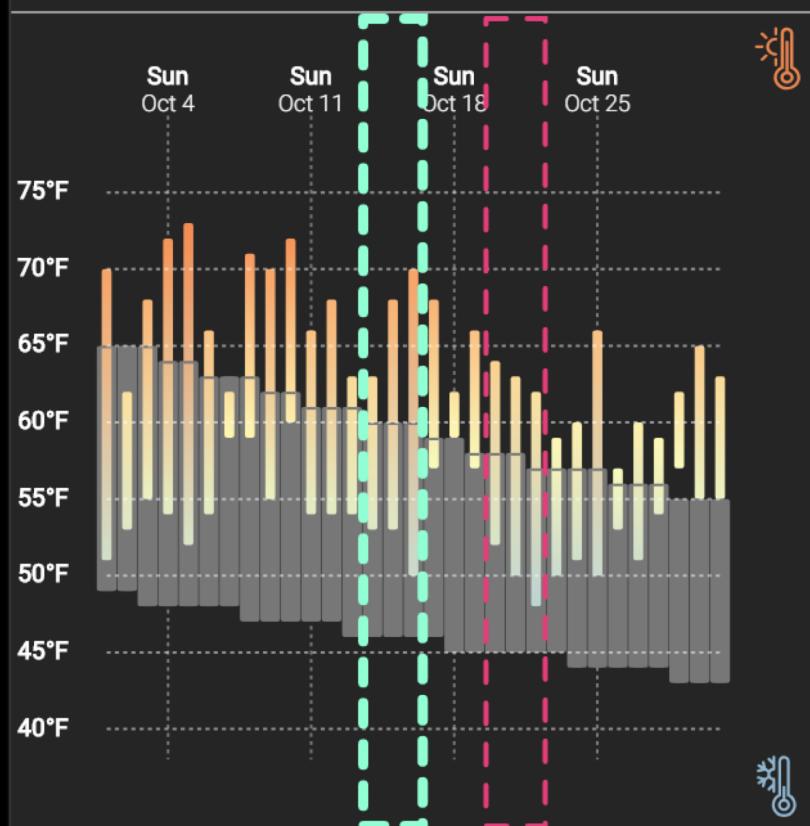


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Layout does not appear to affect comparison performance

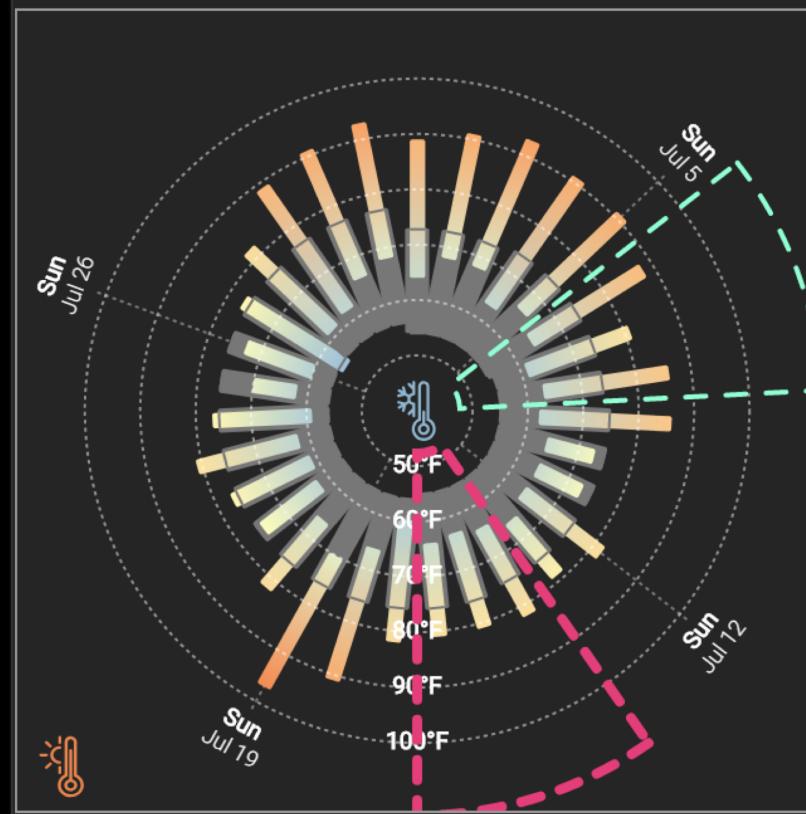
Which span of temperature ranges is more closely aligned with the expected temperature range?



EQUALLY ALIGNED

DONE

Which span of temperature ranges is more closely aligned with the expected temperature range?

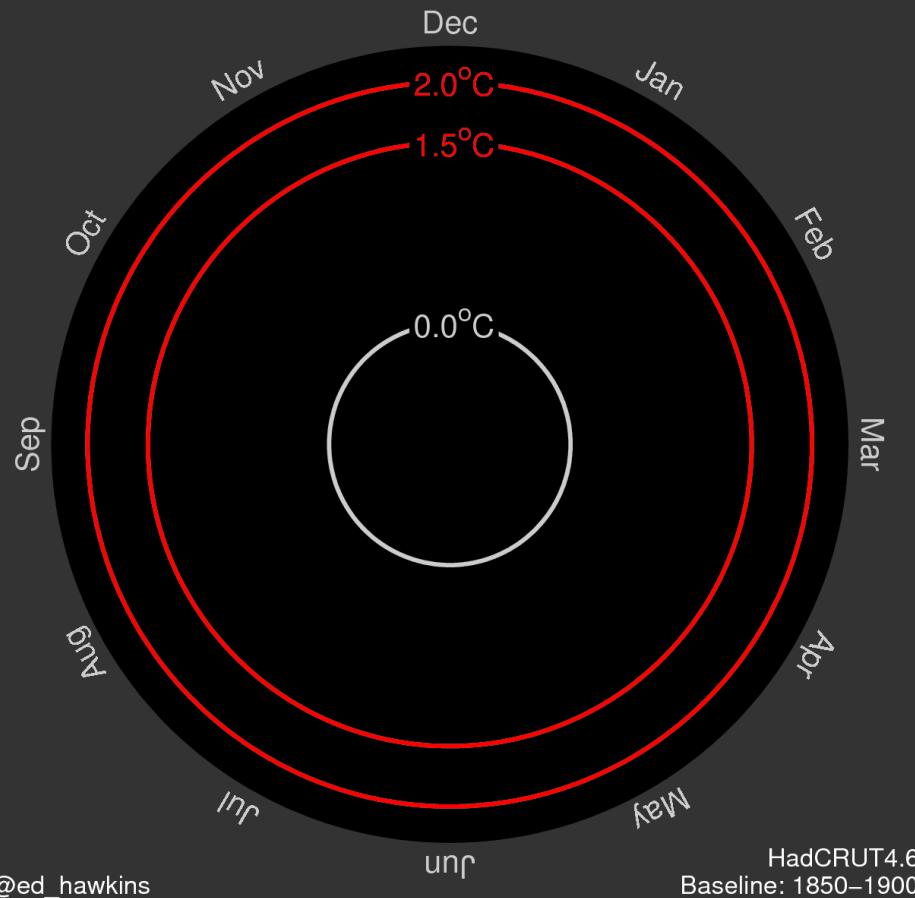


EQUALLY ALIGNED

DONE

Radial layouts for other tasks?

Global temperature change (1850–2017)



Beyond temperature and sleep range data



Note: HRV is measured using the SD1 and SD2 measures. The chart is 100% accurate (100% HRV) and 12.5% margins.

Time In Bed vs. Time Asleep by time of day

EARLIER TO BED, EARLIER TO RISE

MORE LATE NIGHTS, EARLIER MORNINGS

CHILD BIRTH

The role of personal data and lived experience

JULY

AUG

SEP

OCT

NOV

DEC



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