Visual Encodings of Temporal Uncertainty: A Comparative User Study

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CSPSC 547

What: Data

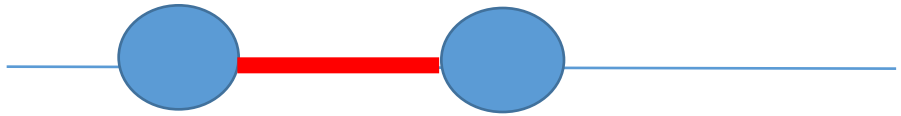
- What is the best way to represent an interval of time, with uncertainty?
- Times are often imprecise
  - Activity A started on June 14, 2009
    - Did the activity start at 12 a.m. on June?
- Times are often uncertain
  - Radiocarbon dating says this plant died 1000 +/- 10 years ago
  - Maybe you have a prior on how long a walk in clinic visit will take
    - If I leave the house now, I'll make it to the doctor's in 20 minutes to an hour, according to traffic
    - My doctor will spend between 10 and 20 minutes with me
    - What's the earliest time I can be done with the doctor?

What: Data

Time Primitives

- Instants
  - A single point in time
  - a UNIX timestamp

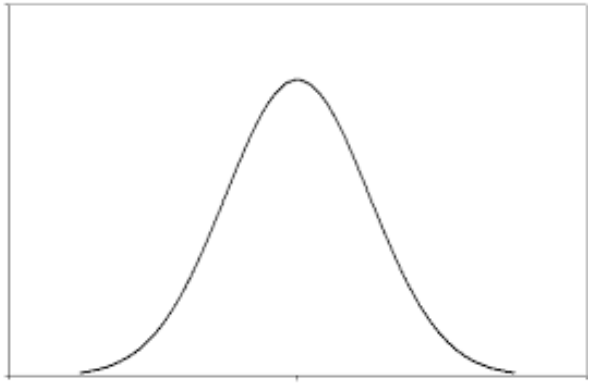
- Intervals
  - Duration between two instants
  - 2 – 3:30 p.m.



- Spans
  - A fixed amount of time, but not anchored to two specific instants
  - 3 hours, 5 minutes, etc.

Types of Uncertainty

- Statistical uncertainty
  - The probability follows a statistical distribution



- Bounded uncertainty
  - All values are equally probable (uniform)

Why: Tasks

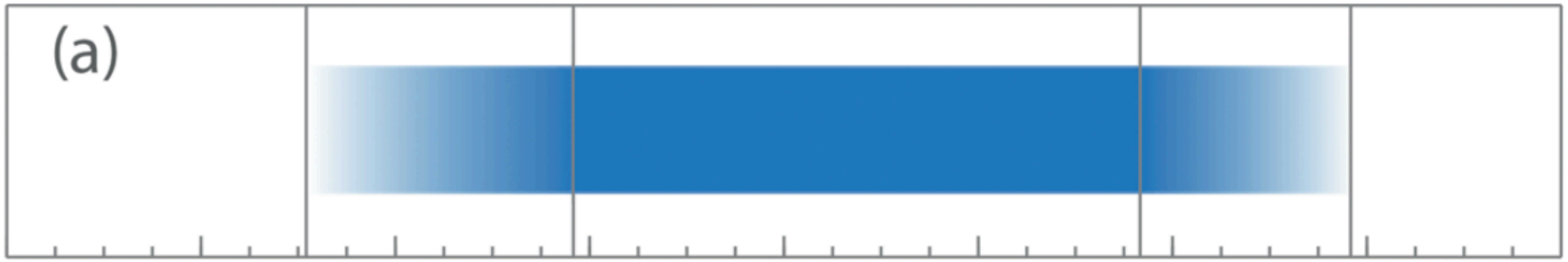
- Min (max) (average) amount of time an interval can take?
- How likely is a particular point in time to be part of an interval?
- What is the latest possible start time for an interval?
- Evaluation:
  - Speed
  - Accuracy

Goals

- Certain part of of the interval should be clearly represented
- Encoding should be compatible with the familiar idea of time as a line
- Statistical uncertainty representations should explictily map the probability distribution to a continuous variable
- Bounded uncertainty representations should not convey varying probabilities

How: Encode

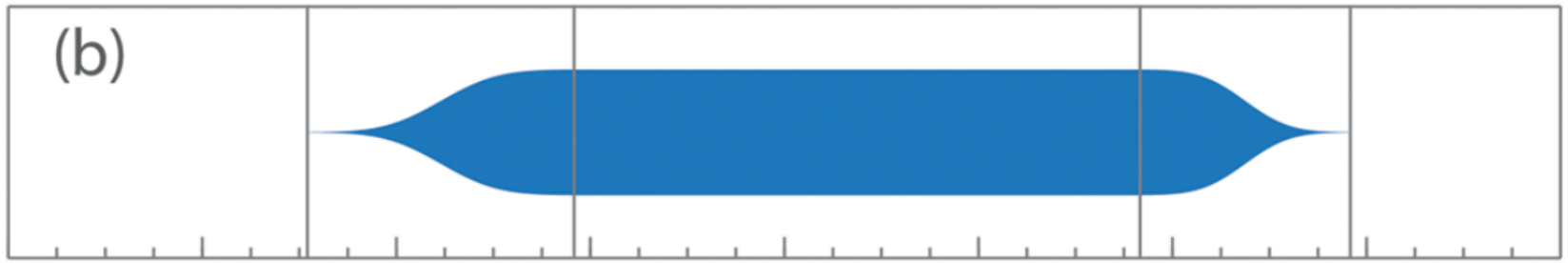
Gradient Plot



Statistical uncertainty

How: Encode

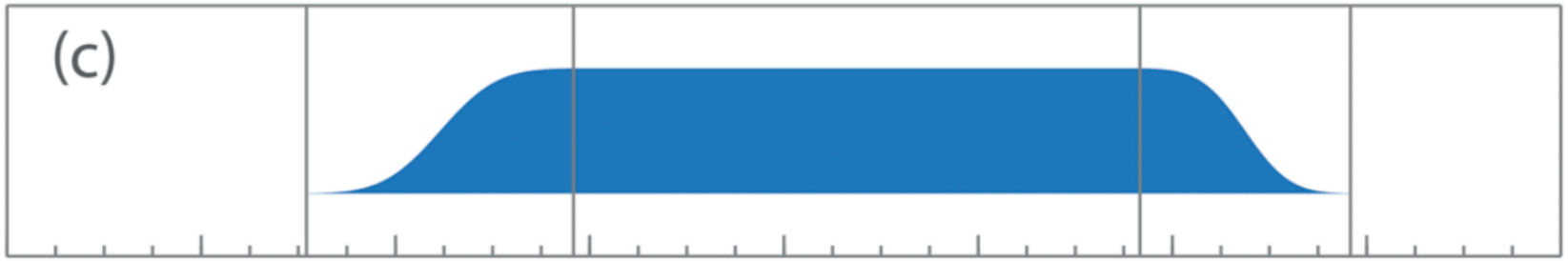
Violin Plot



Statistical uncertainty

How: Encode

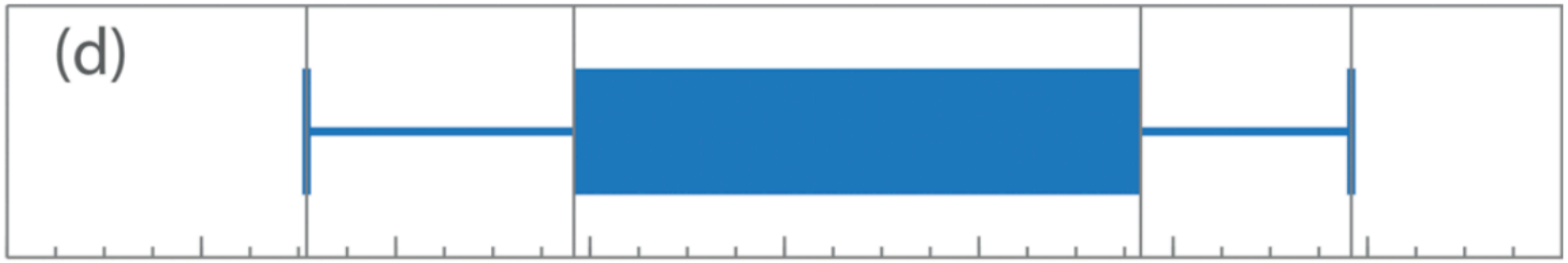
Accumulated Probability Plot



Statistical uncertainty

How: Encode

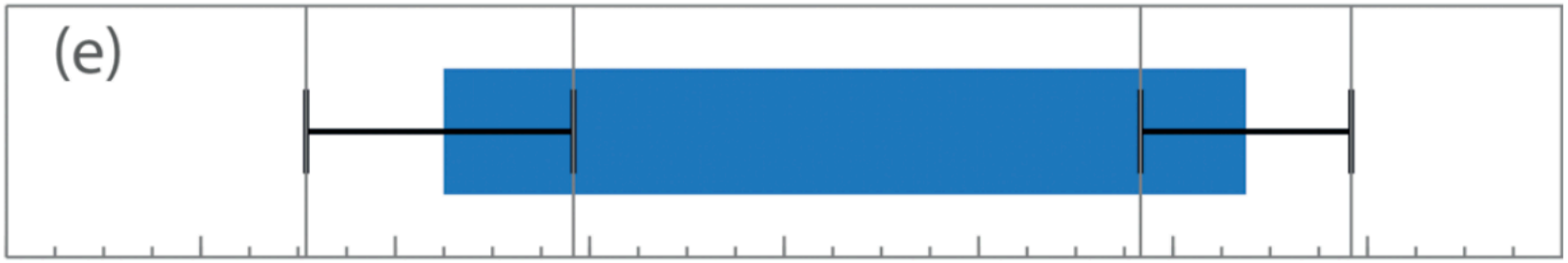
Error Bars



Bounded uncertainty

How: Encode

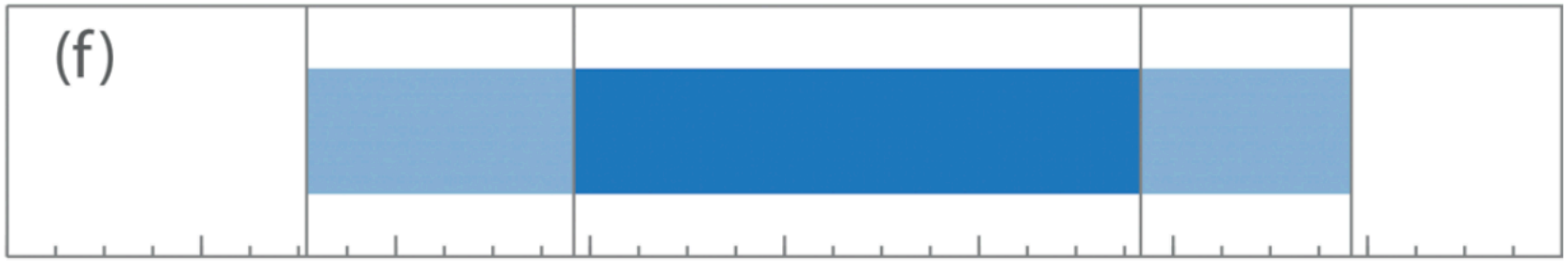
Centered Error Bars



Bounded uncertainty

How: Encode

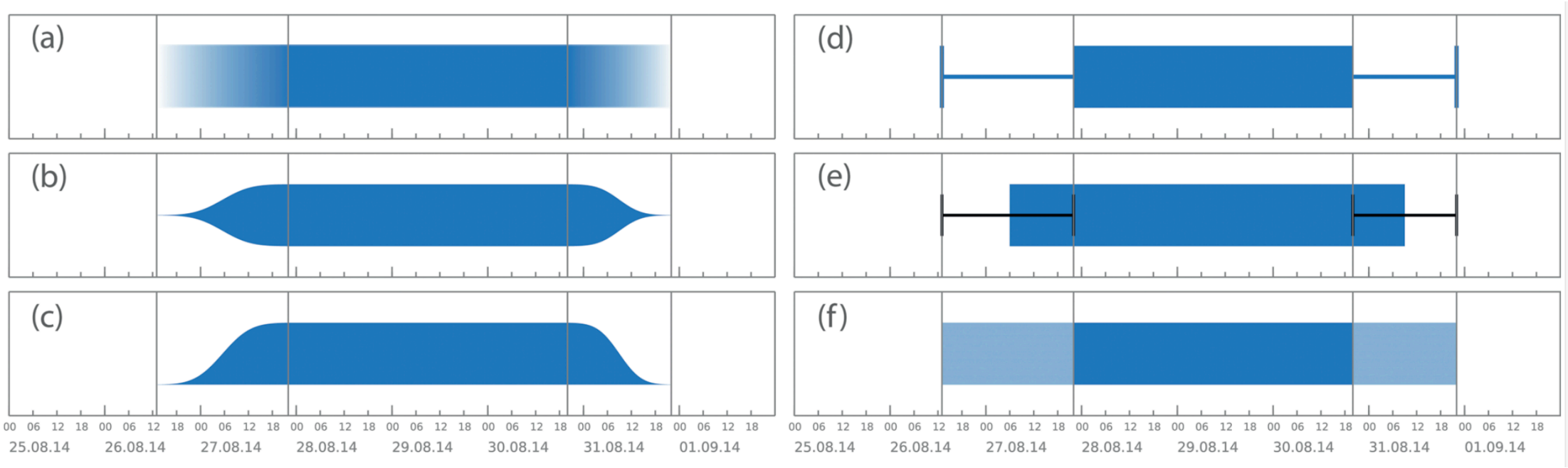
Ambiguation



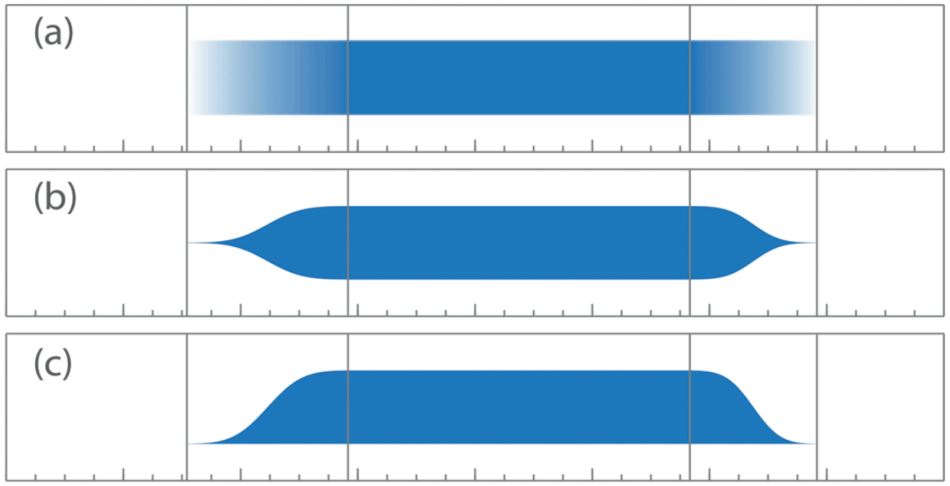
Bounded uncertainty

How: Encode

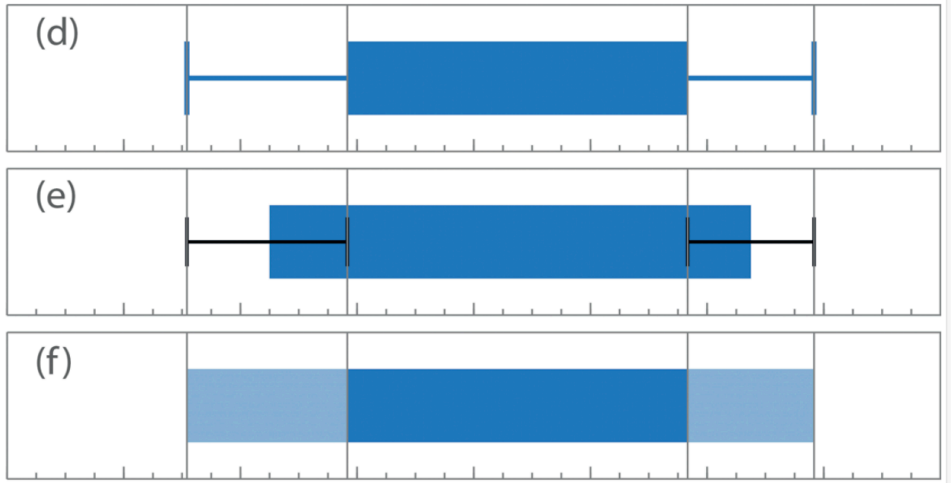
All together



Hypotheses

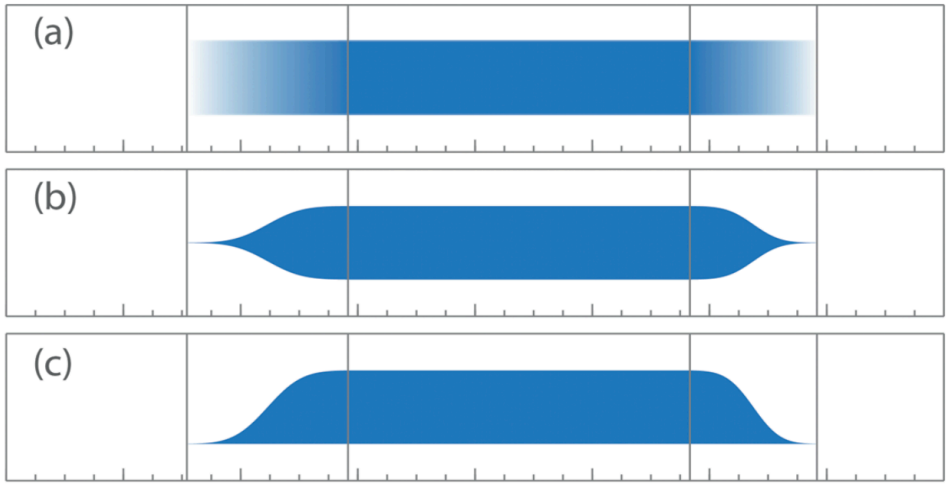


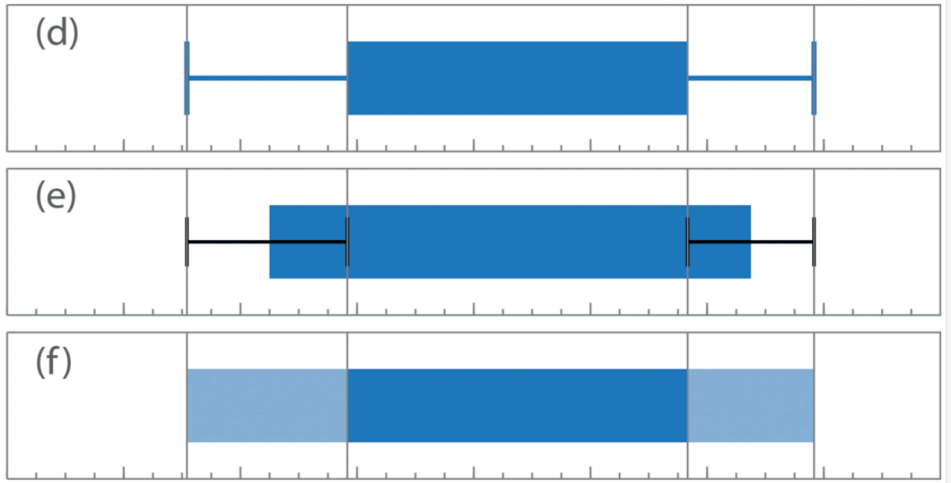
Users will understand these to represent statistical uncertainty



Users will understand these to represent bounded uncertainty

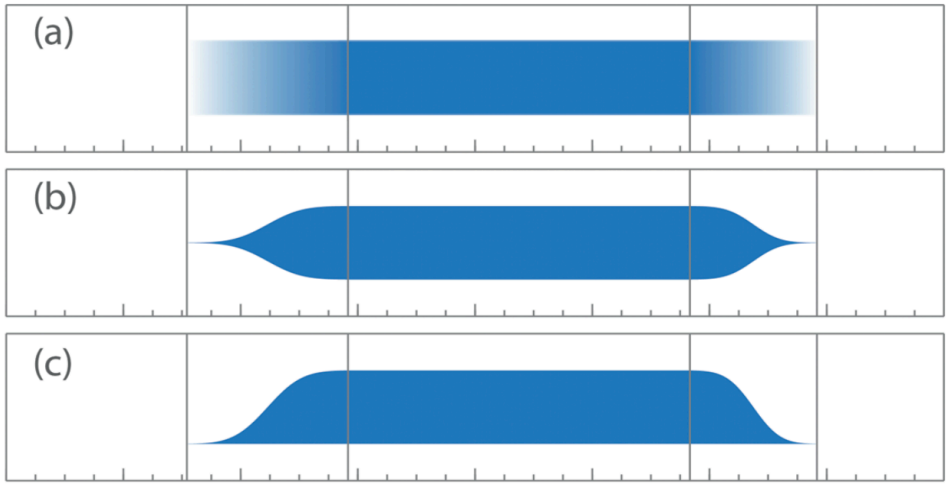
Hypotheses

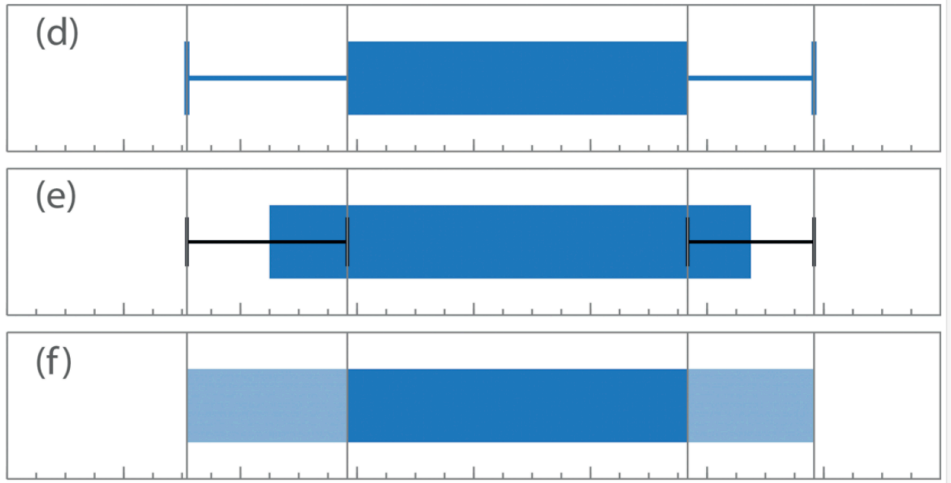




Superior for identifying earliest start, latest start, earliest end, latest end

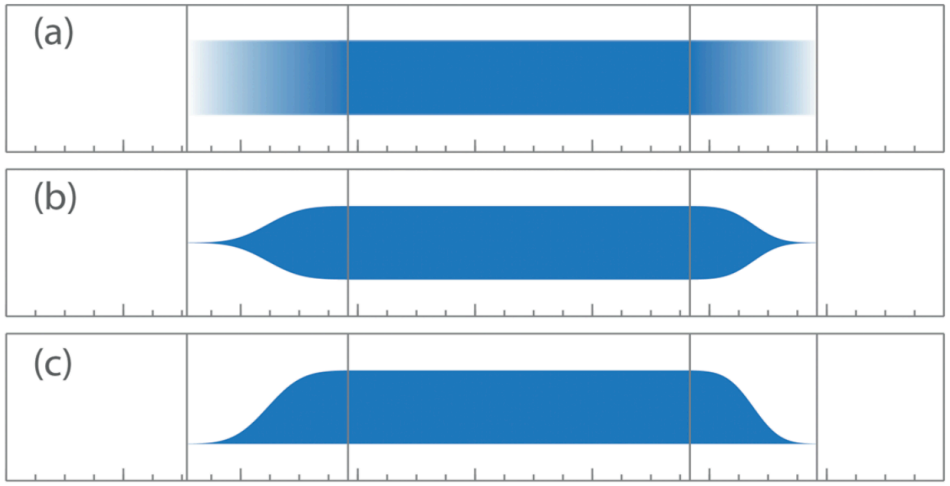
Hypotheses



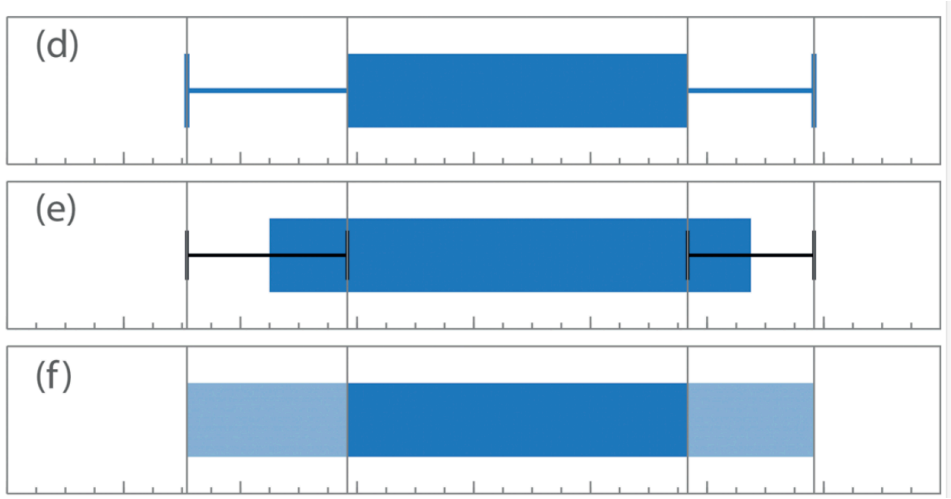


Superior for judging min and max duration

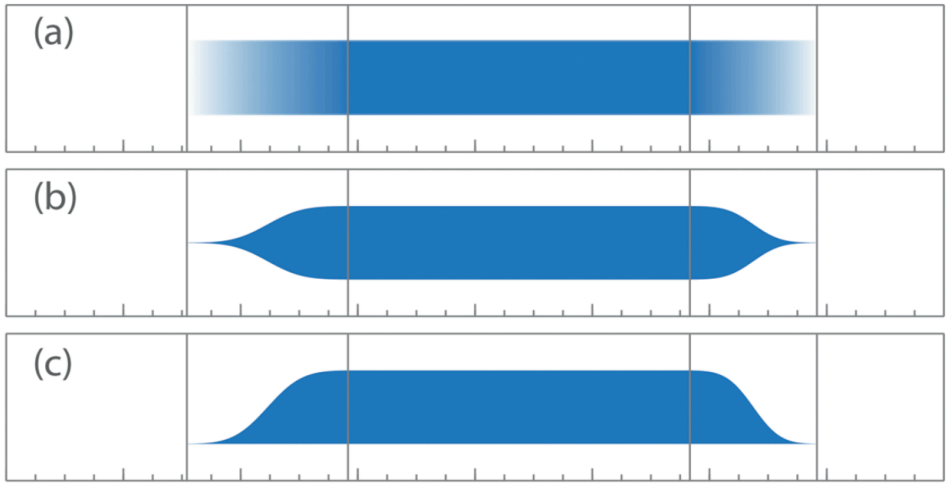
Hypotheses



Superior for judging average duration of interval



Hypotheses



Equal for judging probability that a point falls in interval

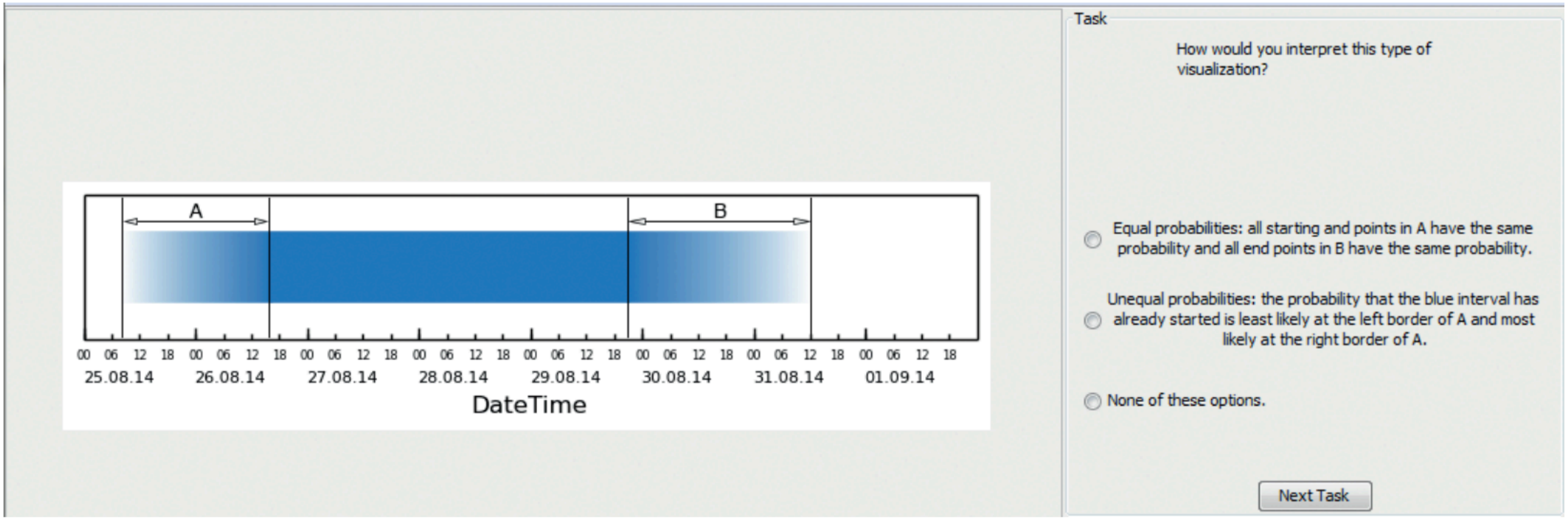
Data

- Generated a uniform day, month in 2014
- Randomly add / subtract hours to get start times, end times
- Fixed time scale for all visualizations
- Normal CDF for statistical uncertainty

Participants

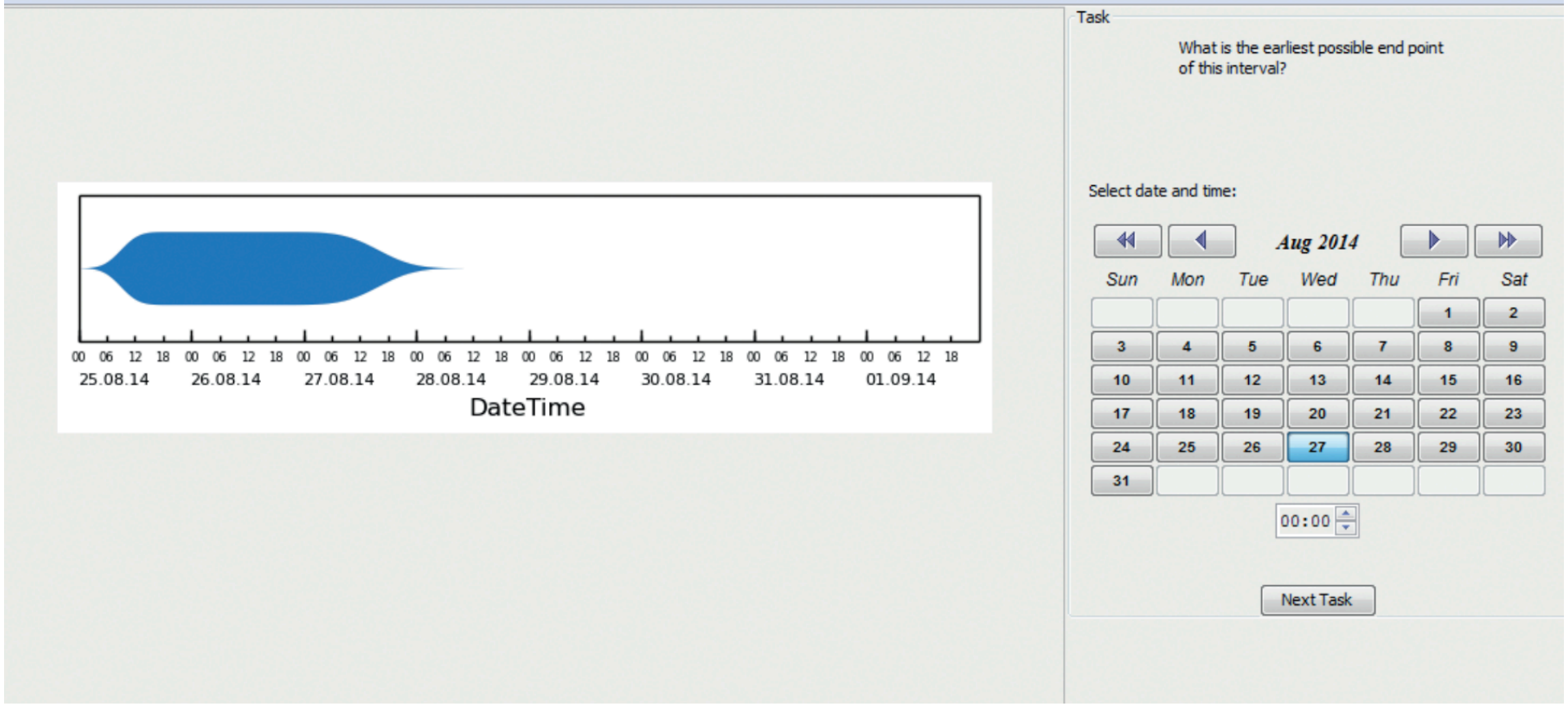
- 73 Computer Science students, taking a viz course
- 14 female

Tasks



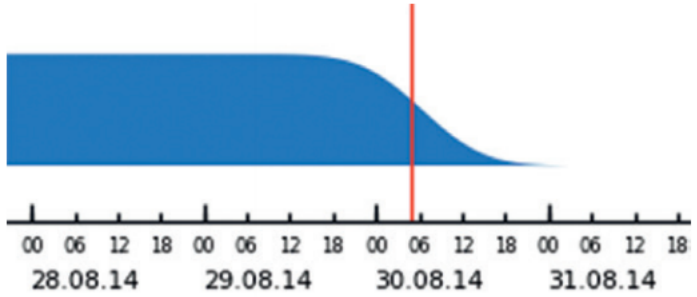
Does this represent statistical or bounded uncertainty?
(Repeated for each of the 6)

Tasks



Earliest (Latest) possible start (end)? Min (max) (average) duration?
(Repeated for each of the 6)

Tasks



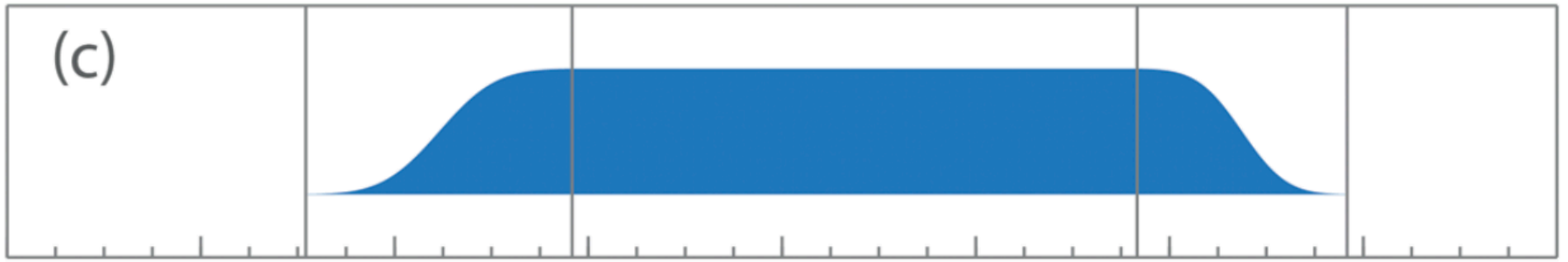
P(already_started) = ?
P(already_ended) = ?
(Repeated for each of the 3 statistical visualizations)

Tasks

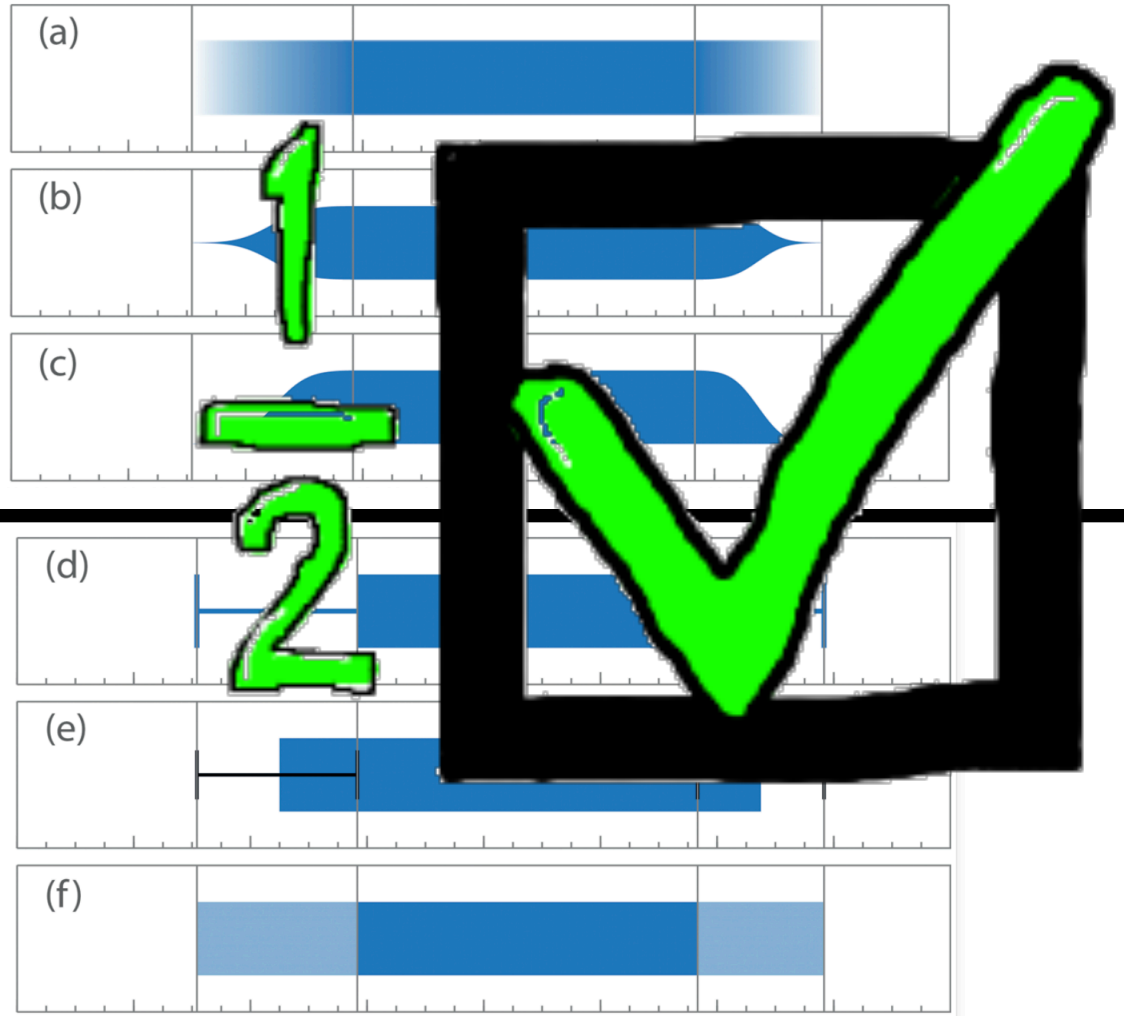
Preferences (5 point scale) for each viz

Experimental Design Flaws

- Earliest start, latest start, earliest end, latest end are confusing terms that are easy to mix up
- “The probability the interval has already ended” is 1 – “The probability the interval is ongoing”

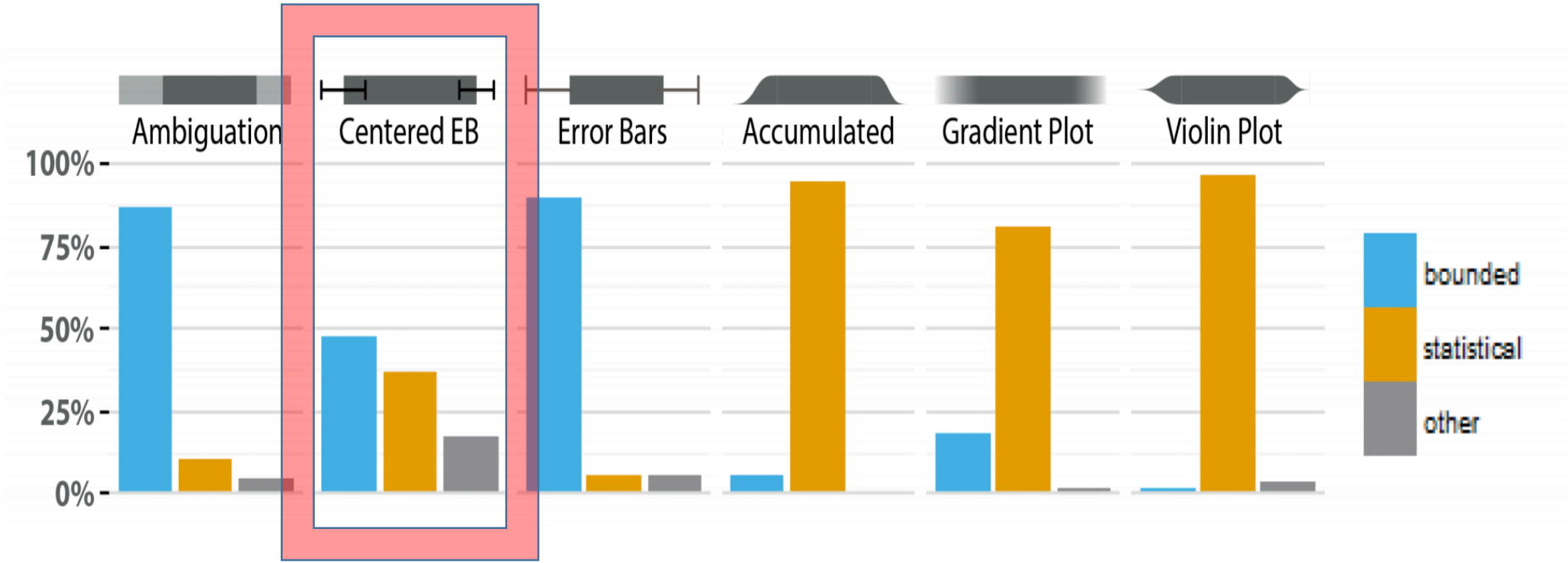


Hypotheses

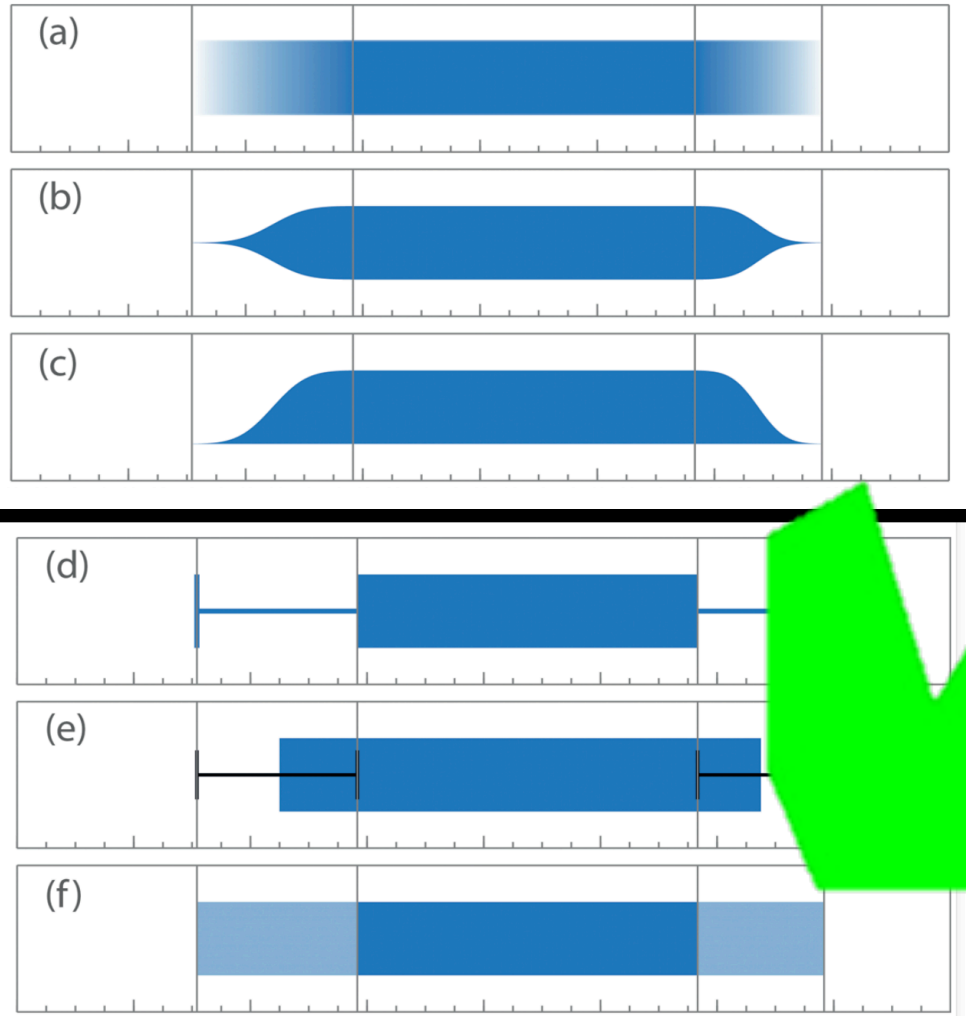


Users will understand these to represent statistical uncertainty

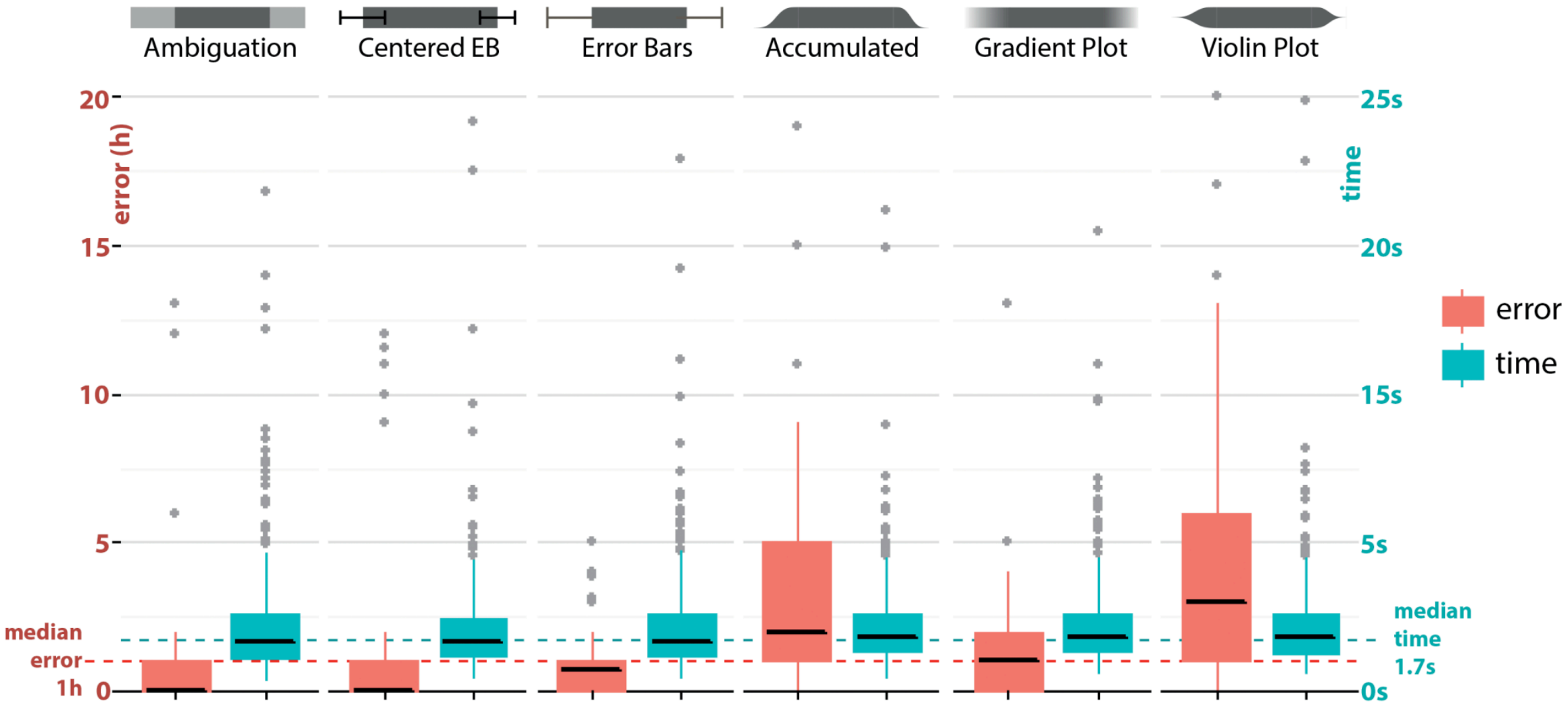
Users will understand these to represent bounded uncertainty


Ambiguation
Centered EB
Error Bars
Accumulated
Gradient Plot
Violin Plot
100%
75%
50%
25%
0%
bounded
statistical
other

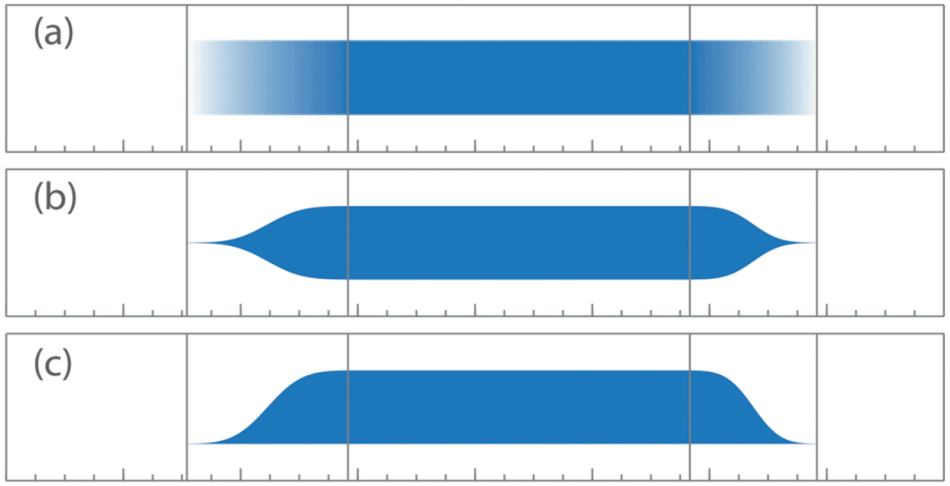
Hypotheses

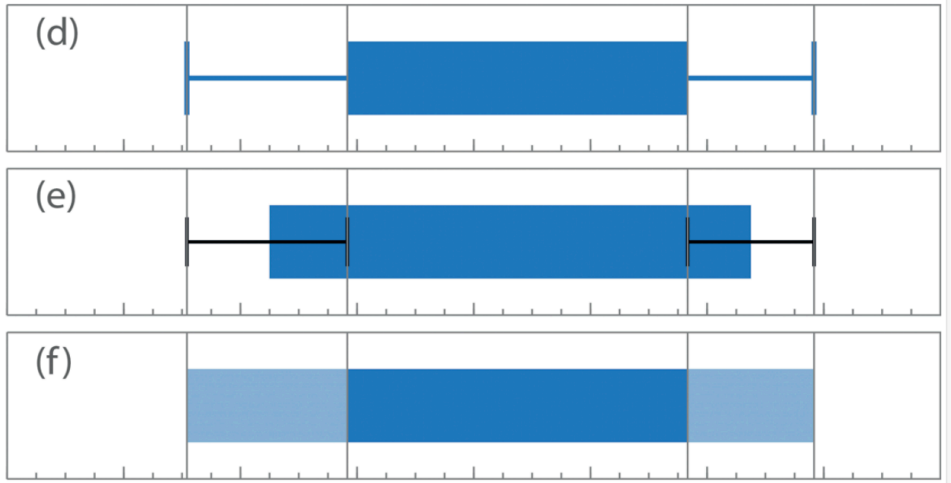


Superior for identifying earliest start, latest start, earliest end, latest end

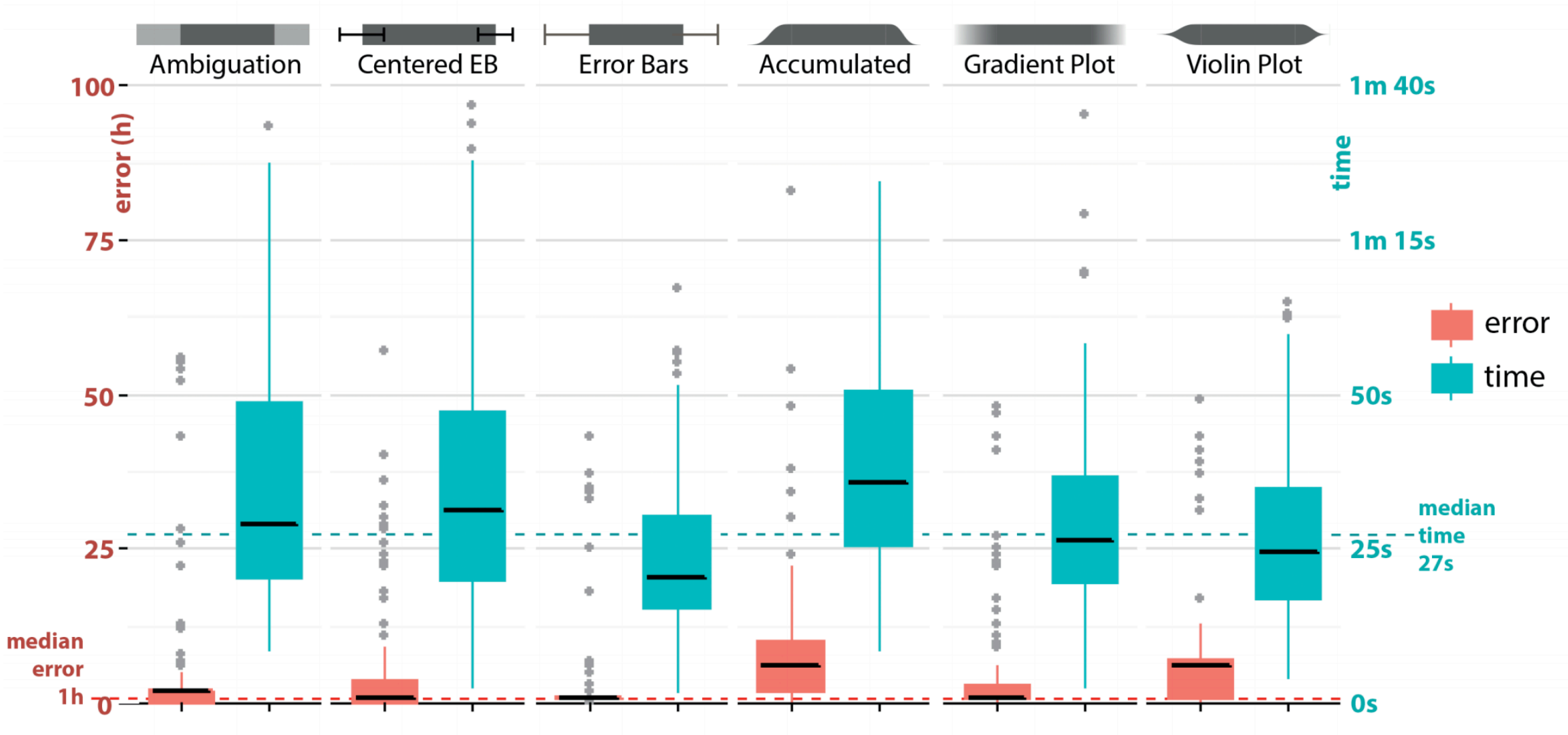

Ambiguation
Centered EB
Error Bars
Accumulated
Gradient Plot
Violin Plot
20
15
10
5
0
error (h)
25s
20s
15s
5s
0s
time
error
time
median
error
1h
median
time
1.7s

Hypotheses

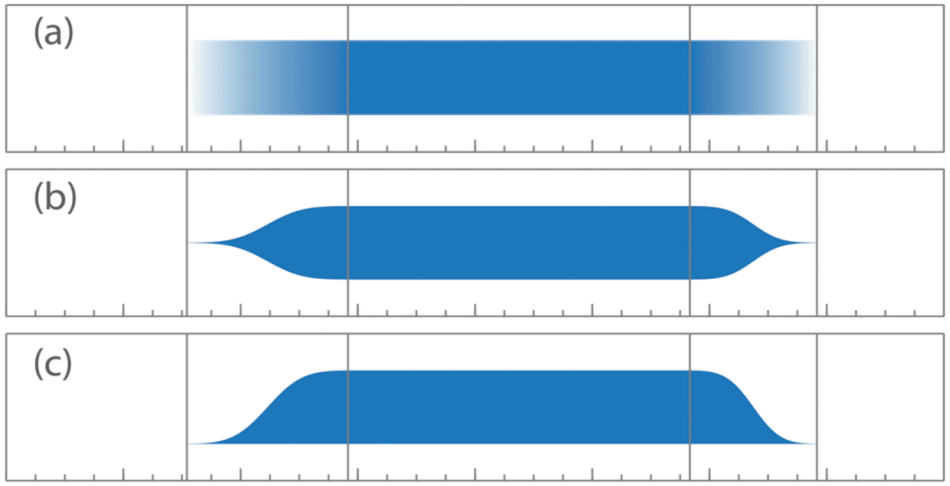


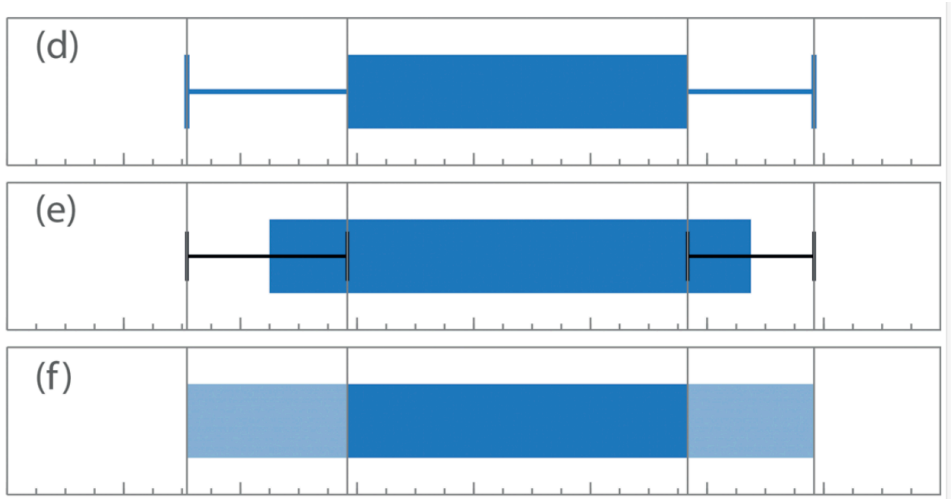


Superior for judging min and max duration

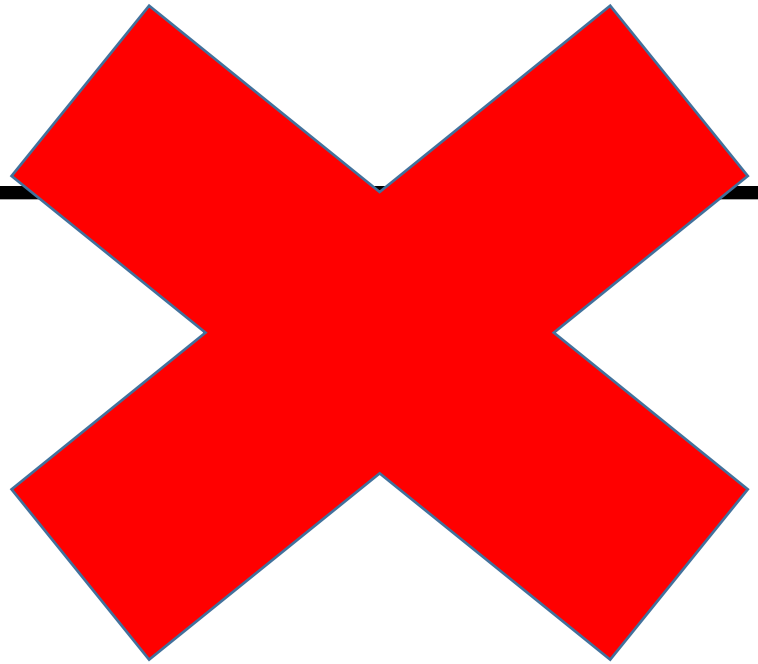

Ambiguation
Centered EB
Error Bars
Accumulated
Gradient Plot
Violin Plot
100
75
50
25
0
error (h)
median
error
1h
1m 40s
1m 15s
50s
25s
0s
time
median
time
27s
error
time

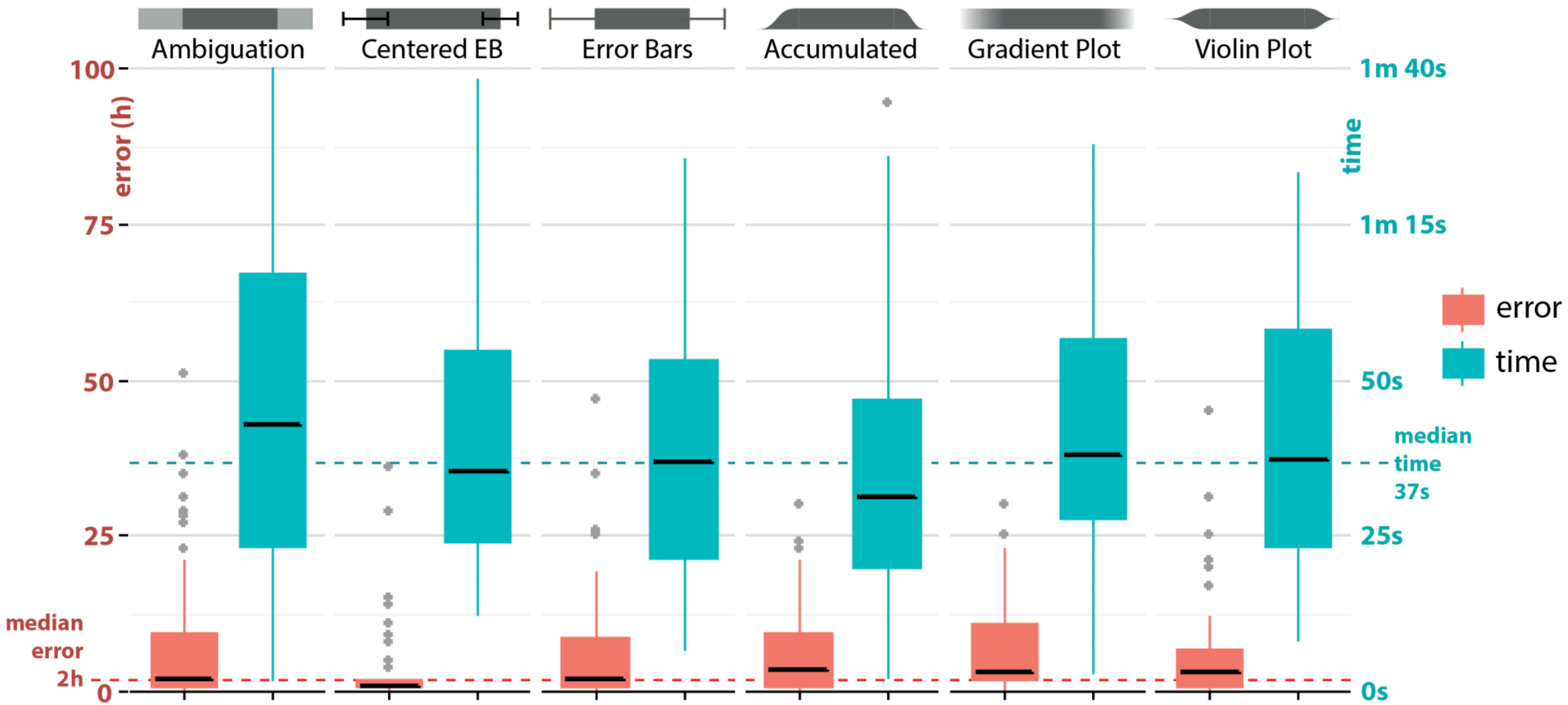
Hypotheses



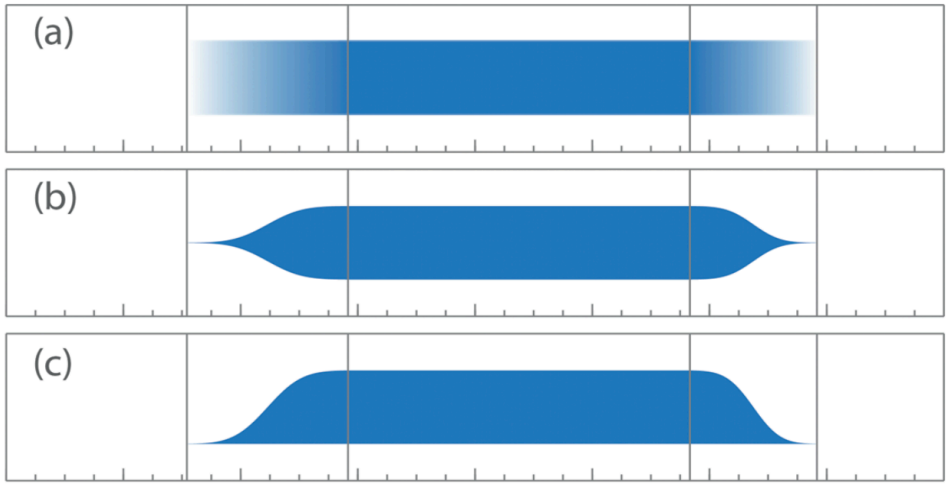


Superior (faster, more accurate) for judging average duration of interval

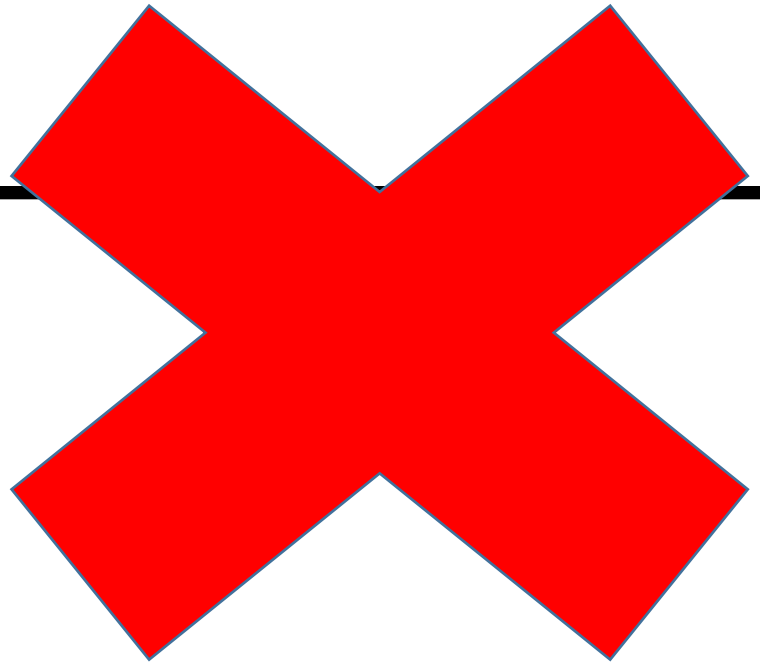


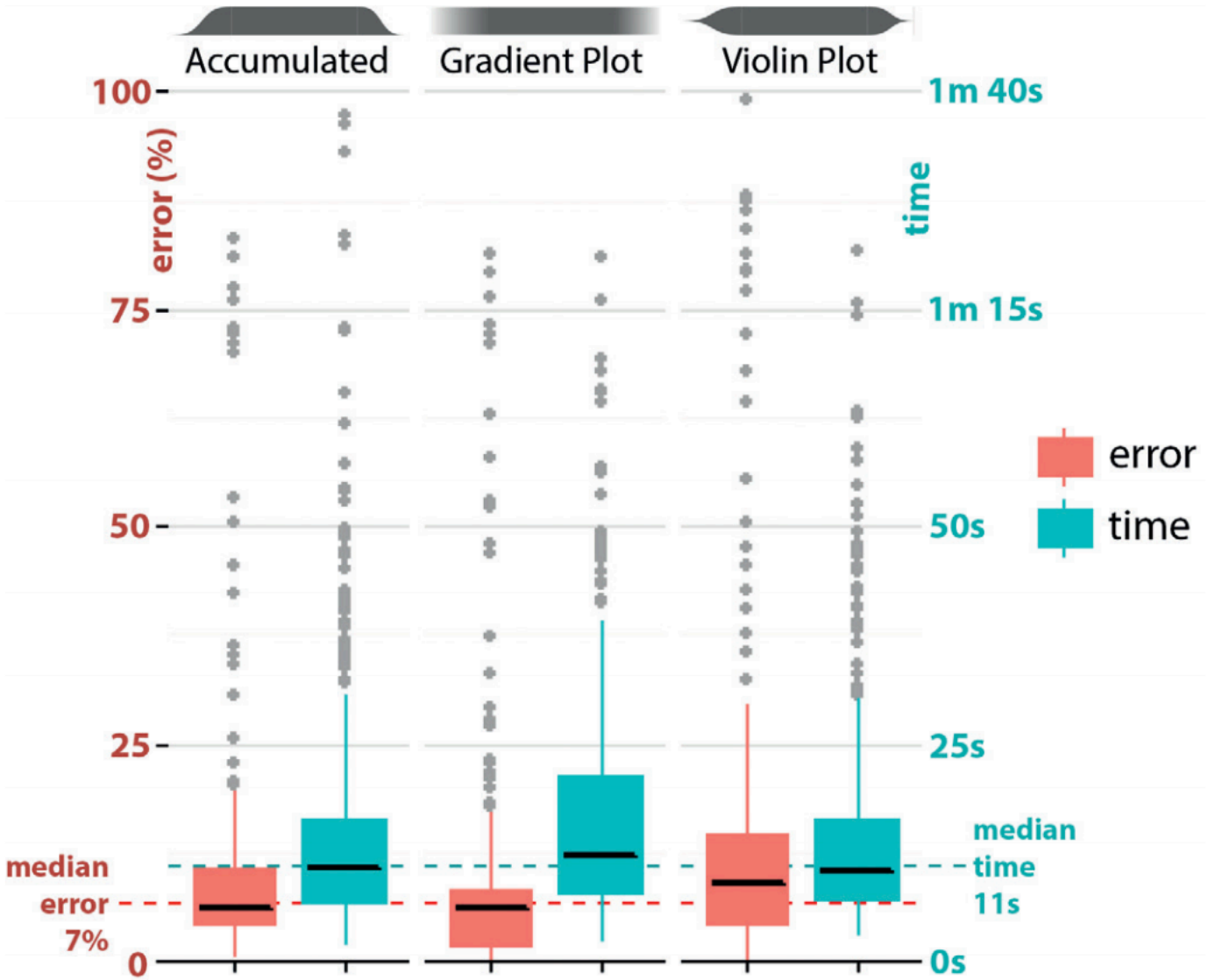

Ambiguation
Centered EB
Error Bars
Accumulated
Gradient Plot
Violin Plot
100
75
50
25
0
error (h)
median
error
2h
1m 40s
1m 15s
50s
25s
0s
time
median
time
37s
error
time

Hypotheses

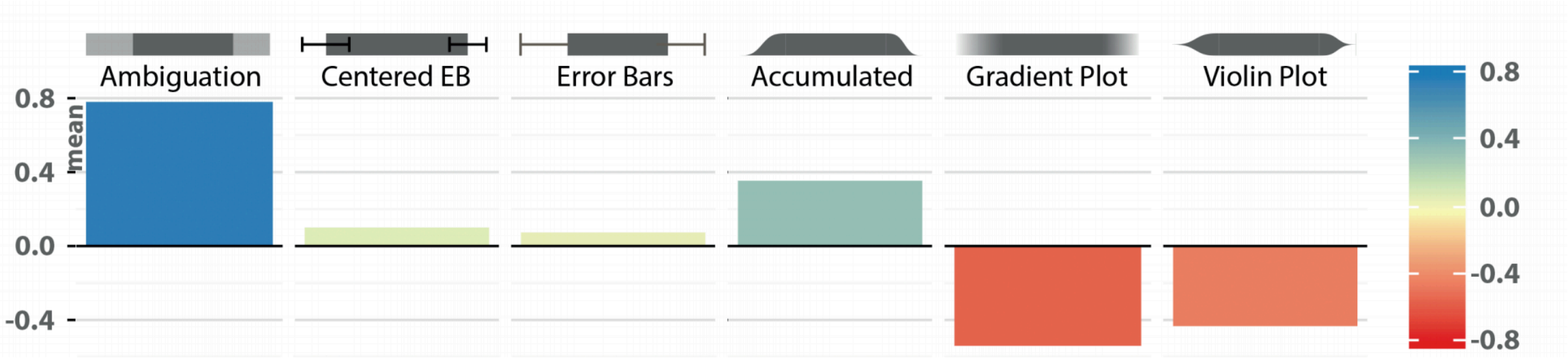


Equal (speed, accuracy) for judging probability that a point falls in interval




Accumulated
Gradient Plot
Violin Plot
100
75
50
25
0
error (%)
1m 40s
1m 15s
50s
25s
0s
time
error
time
median
error
7%
median
time
11s

Preferences



Criticisms

- Does it make sense to compare statistical and bounded distributions in the same visualizations?
- Limited scope of what was tested: normal distribution, no cases where the certain part of the interval is shorter than it’s starting uncertainty
- Dependencies between intervals were not explored

Conclusions

- Compared six ways of encoding temporal uncertainty
- If you don’t need statistical uncertainty, any of the three bounded encodings are good
- Gradient plots are best for statistical uncertainty