

Gaussian distributions

QQ plots

t-tests

Comparing two datasets

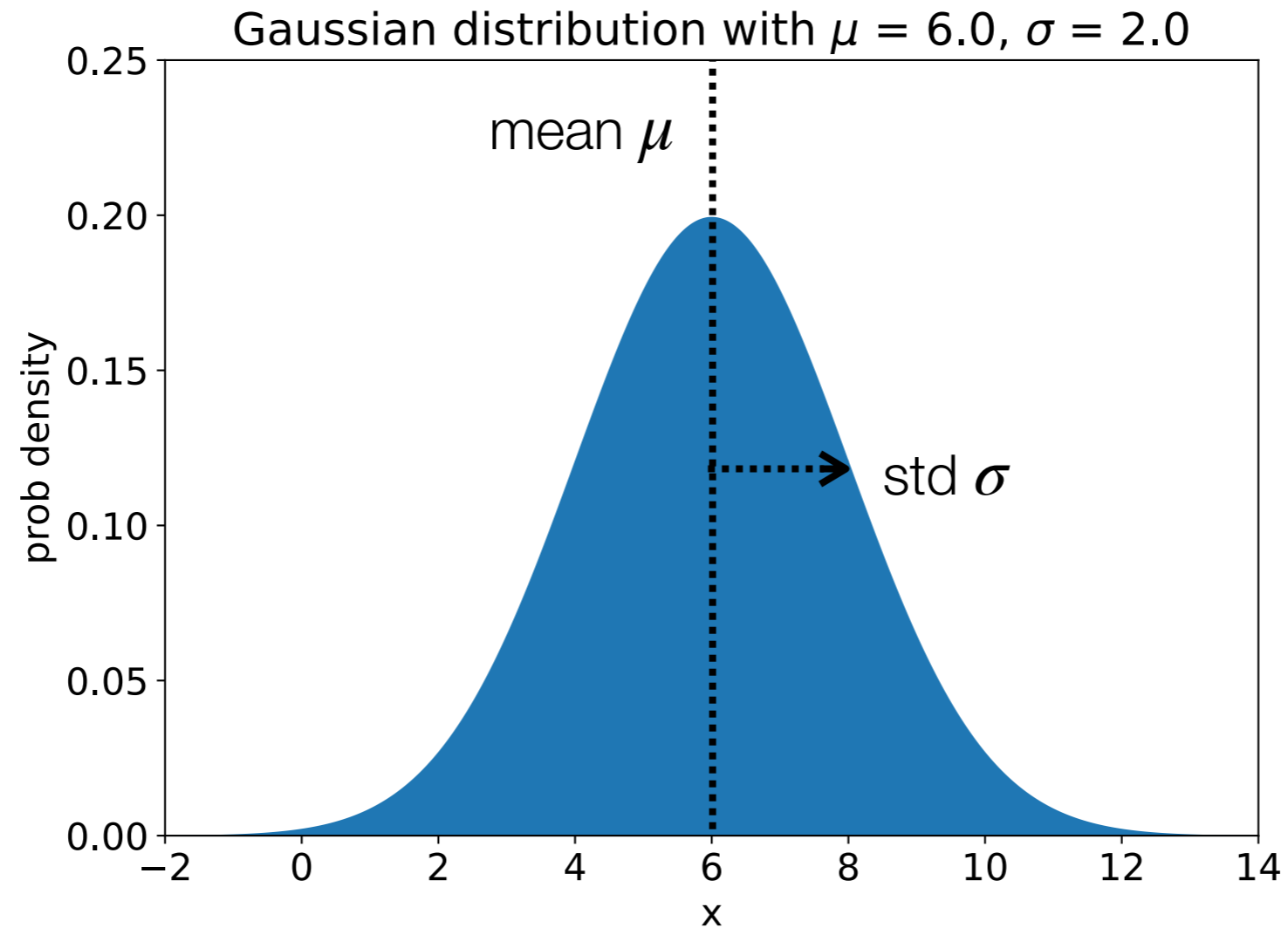


Biostatistics Course 2024
Lecture 3
Wednesday, 10 July 2024
10:00am - 12:00pm

Gaussian distributions

The normal distribution is ubiquitous in statistics

“Gaussian distribution” = “normal distribution”



$x \sim \text{Normal}(\mu, \sigma^2)$

drawn from mean variance

Mean and variance

Let $X \sim N(\mu, \sigma^2)$

- Mean: $E[X] = \mu$
- Variance: $Var[X] = \sigma^2$
- Standard Deviation: $SD_X = \sigma$

Mean of standardized random variable

Let

$$Z = (Y - \mu)/\sigma$$

$$\begin{aligned} E[Z] &= E\left[\frac{Y - \mu}{\sigma}\right] = \frac{1}{\sigma} E[Y - \mu] \\ &= \frac{1}{\sigma} (E[Y] - \mu) \\ &= \frac{1}{\sigma} (\mu - \mu) \\ &= 0 \end{aligned}$$

Variance of standardized random variable

$$\begin{aligned}\text{Var}[Z] &= \text{Var}\left[\frac{Y - \mu}{\sigma}\right] \\ &= \frac{1}{\sigma^2} \text{Var}[Y - \mu] \\ &= \frac{1}{\sigma^2} \text{Var}[Y] \\ &= \frac{1}{\sigma} \sigma^2 \\ &= 1\end{aligned}$$

NOTE: $\mu = 0$ and $\sigma^2 = 1$ for **any** standardized random variable

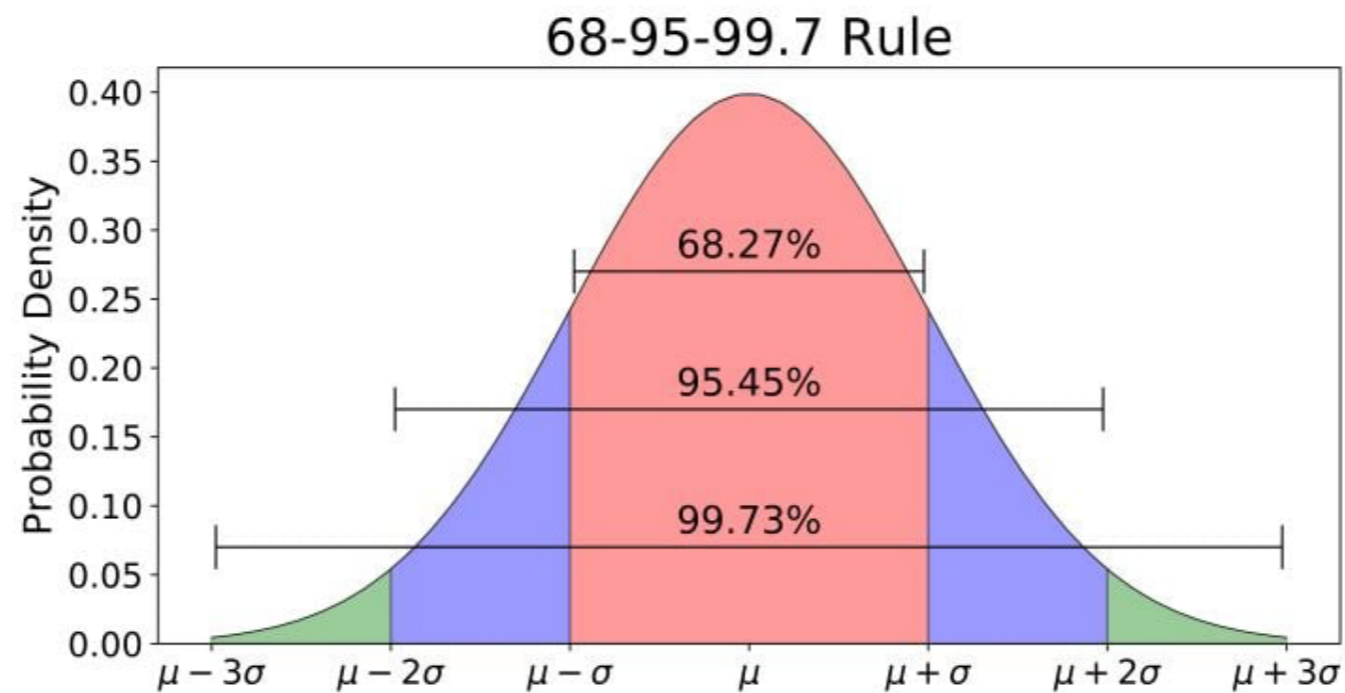
68-95-99.7 Rule

Recall the 68-95-99.7 rule Note for a standard normal random variable,
 $Z \sim N(0, 1)$

$$Pr(-1 < Z < 1) \approx 0.68$$

$$Pr(-2 < Z < 2) \approx 0.95$$

$$Pr(-3 < Z < 3) \approx 0.997$$



The central limit theorem makes the normal distribution extremely relevant

If a random variable X has population mean μ and population variance σ^2 , the sample mean \bar{X} , based on n observations, is approximately normally distributed with mean μ and variance σ^2 , for sufficiently large n .

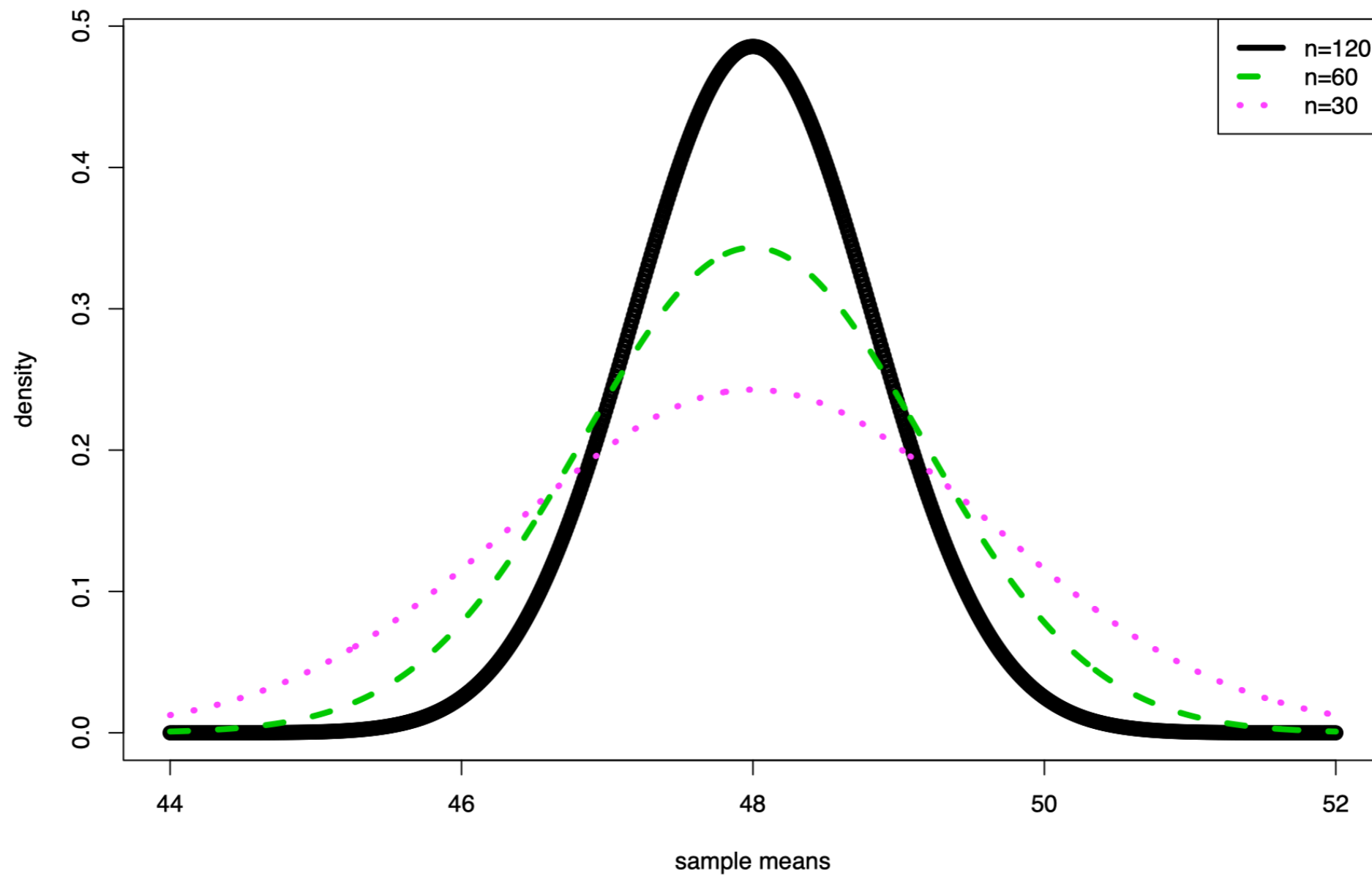
$$\begin{array}{l} x_1 \sim p_1(x) \\ x_2 \sim p_2(x) \\ \dots \\ x_N \sim p_N(x) \end{array} \quad \bar{x} = \frac{x_1 + x_2 + \dots + x_N}{N} \quad \Rightarrow \quad \bar{x} \sim \text{Normal}(\mu, \sigma^2)$$

This means that, if many sources additively contribute to an experimental measurement, independent measurements will be approximately normally distributed.

This is why statisticians so often assume that experimental measurements follow normal distributions.

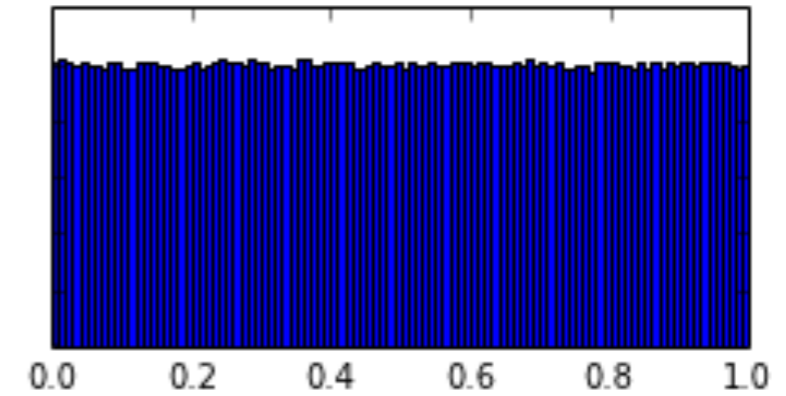
Impact of sample size on sampling distribution

Sample 1 (n=30); sample 2 (n=60); sample 3 (n=120)

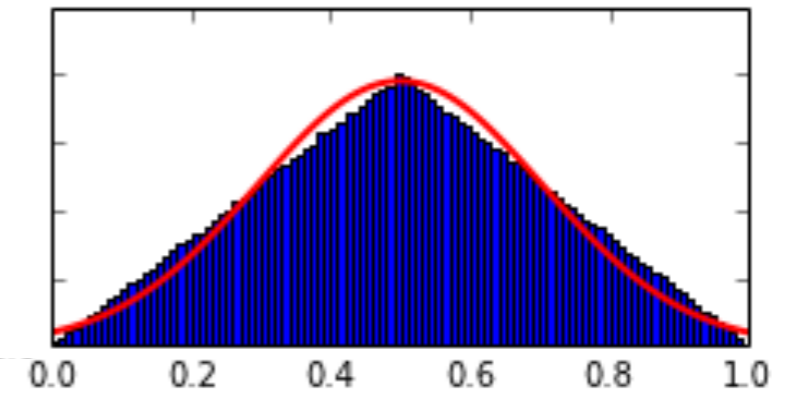


Suppose x_1, x_2, \dots, x_N are drawn from a uniform (i.e. flat) probability distribution that stands from 0 and 1

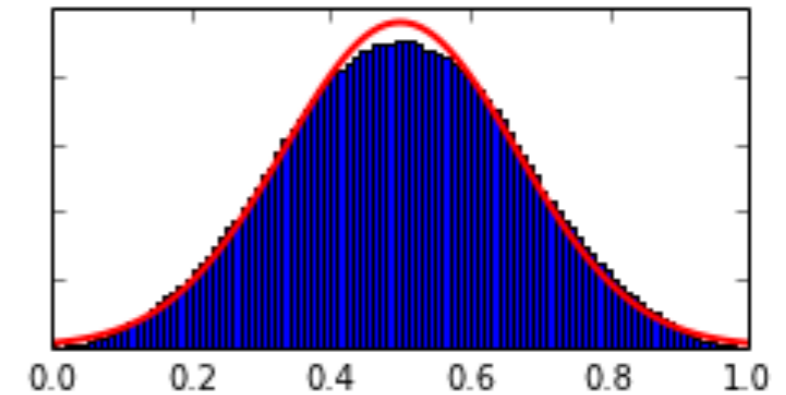
$$x_1$$



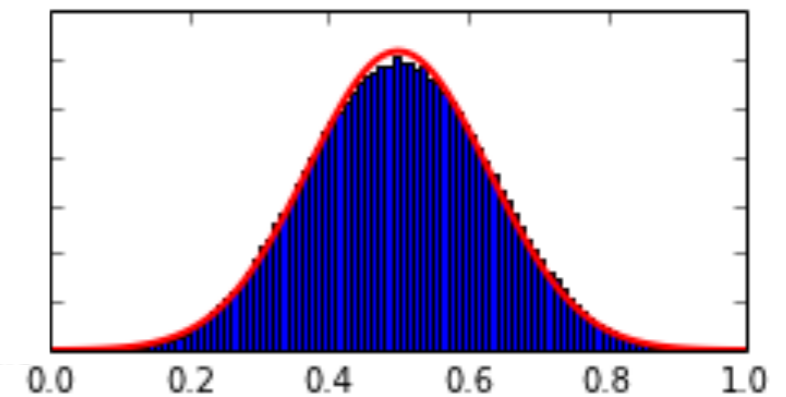
$$\frac{x_1 + x_2}{2}$$



$$\frac{x_1 + x_2 + x_3}{3}$$



$$\frac{x_1 + x_2 + x_3 + x_4 + x_5}{5}$$



Example 1: Human Sex Ratio

The human sex ratio at birth is slightly skewed towards boys rather than girls.

	count
male	484382
female	453841
total	938223



probability of male birth

estimate: 51.63%

95% CI: [51.53%, 51.73%]

Arbuthnot J (1711). An Argument for Divine Providence, taken from the Constant Regularity observed in the Births of both Sexes.

We assume the number of male babies (versus female babies) is drawn from a binomial distribution

data

$n = 484,382$: number of male births

$N = 938,223$: total number of births

model

$$n \sim \text{Binom}(q, N)$$

q : probability of a male birth

The assumed probability distribution is called the sampling distribution

goals

1. Compute a best estimate \hat{q} for q
2. Compute a confidence interval for q

The standard estimate of probability is just the ratio of counts

$n = 484,382$: number of male births

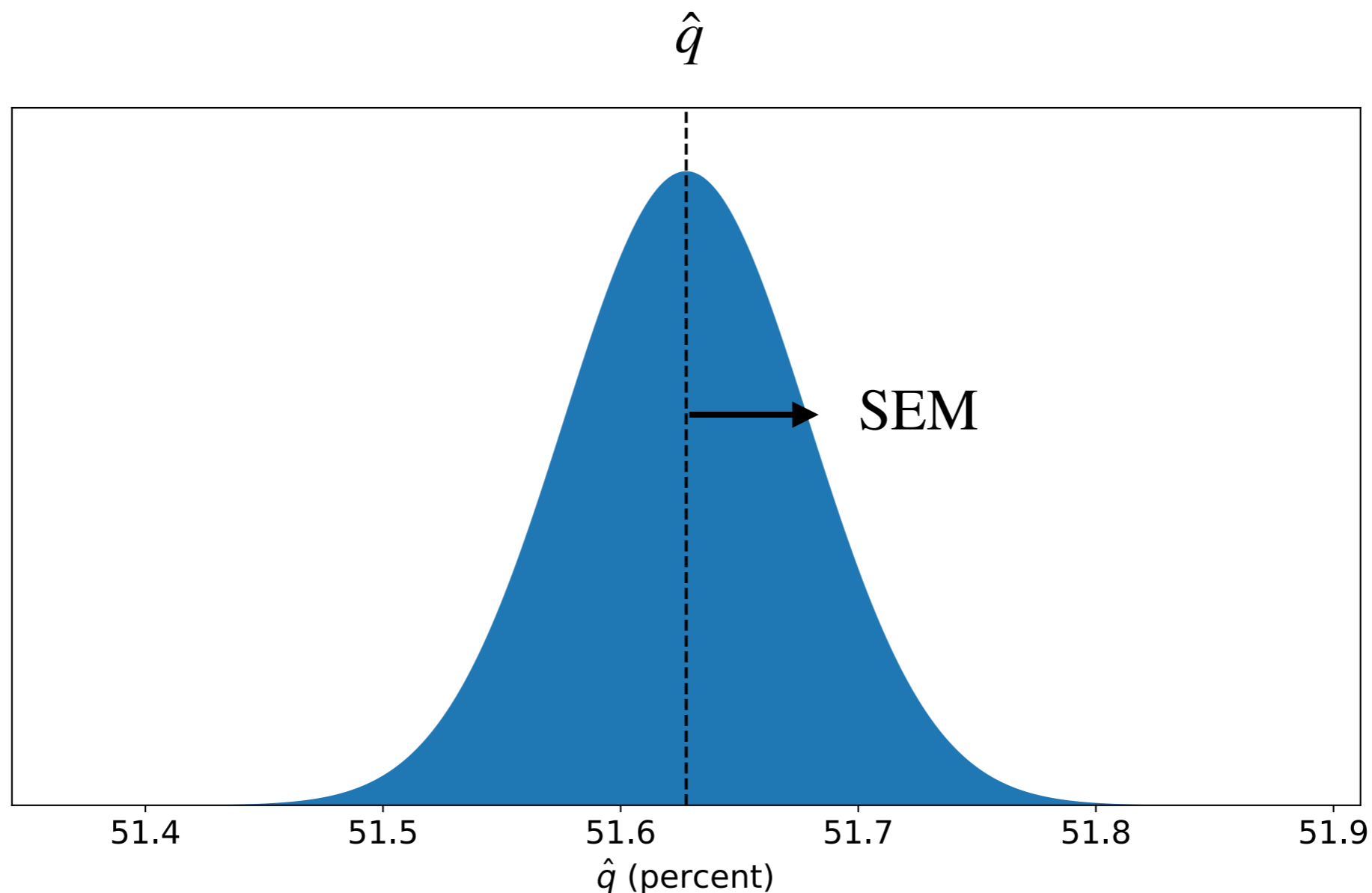
$N = 938,223$: total number of male births

$\hat{q} = \frac{n}{N} = 51.63\%$: estimated probability of a newborn being male

The lingering uncertainty in q is (verly nearly) described by a normal distribution centered on the estimate \hat{q} .

The standard deviation of this distribution is called the standard error of the mean (SEM).

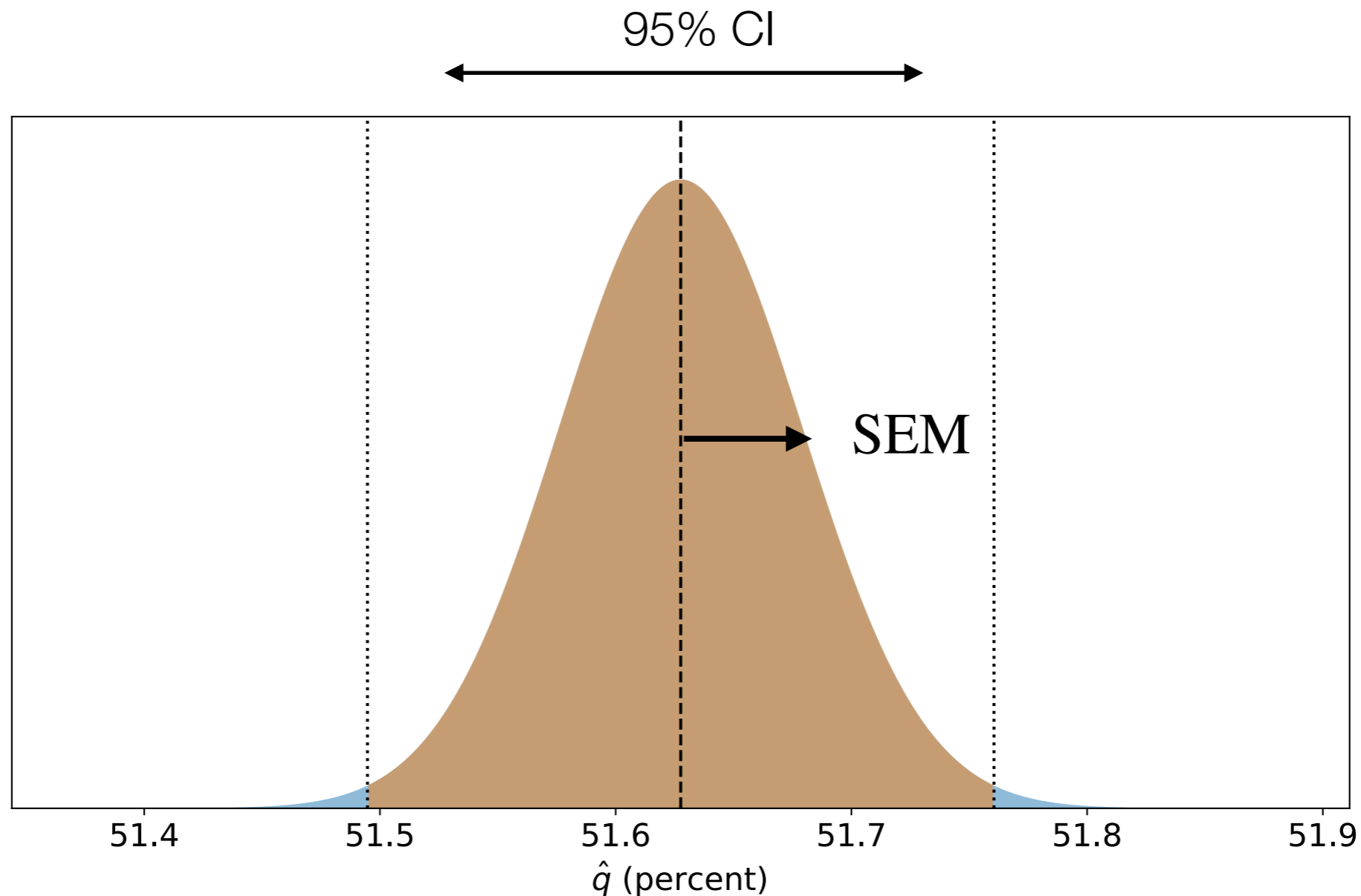
$$\text{SEM} = \sqrt{\hat{q}(1 - \hat{q})/N}$$



The 95% confidence interval, describing plausible values of q , is computed using both \hat{q} and SEM.

The corresponding 95% confidence interval (CI) is

$$[\hat{q} - W, \hat{q} + W] \quad \text{where} \quad W = 1.96 \times \text{SEM}$$



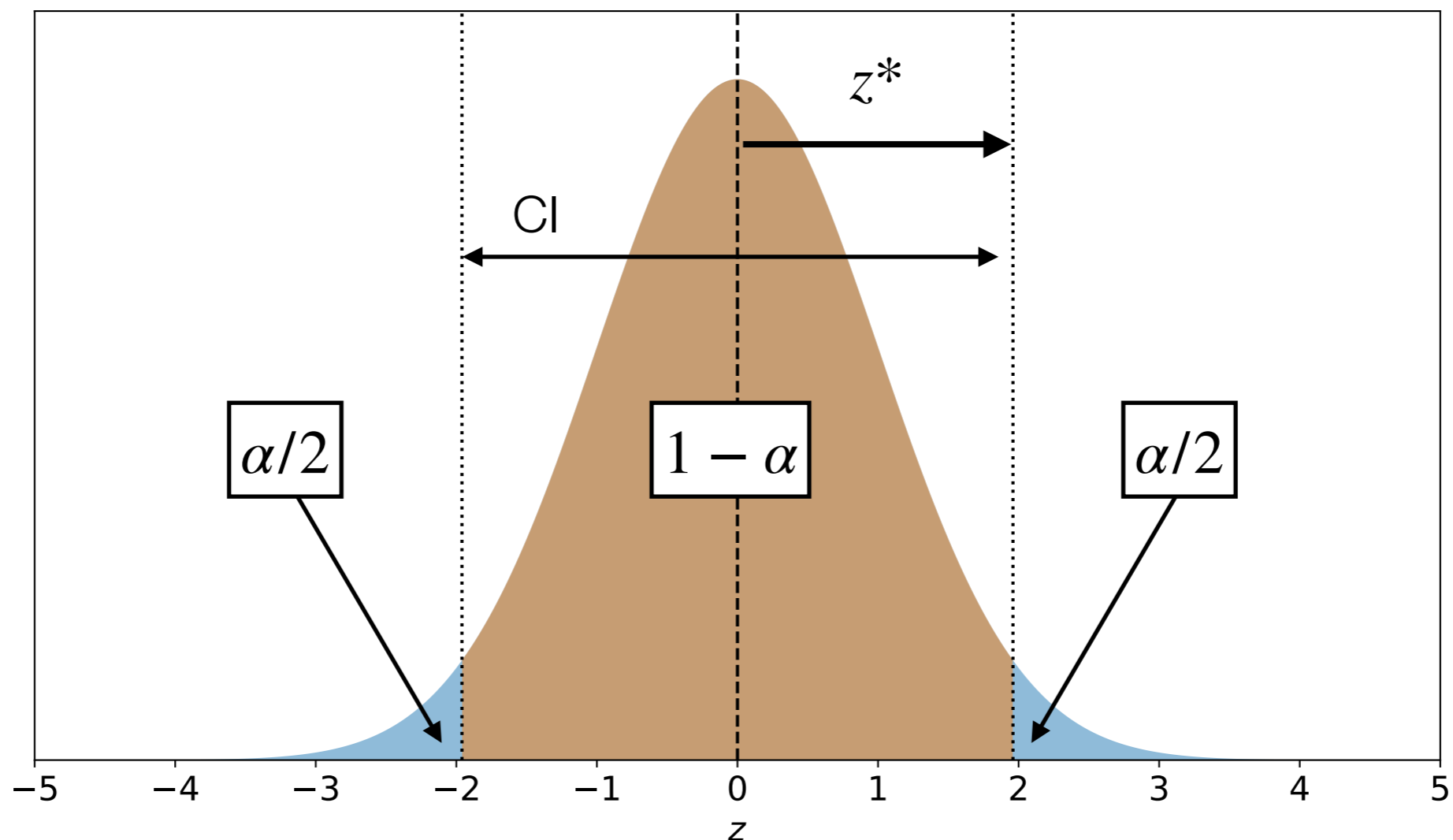
Uncertainty in q is summarized by a z -statistic

The z -statistic is defined by:
$$z = \frac{q - \hat{q}}{\text{SEM}}$$

Because of the central limit theorem, $z \sim \text{Normal}(0, 1)$.

The user chooses a value for α , the probability that q is not within the confidence interval.

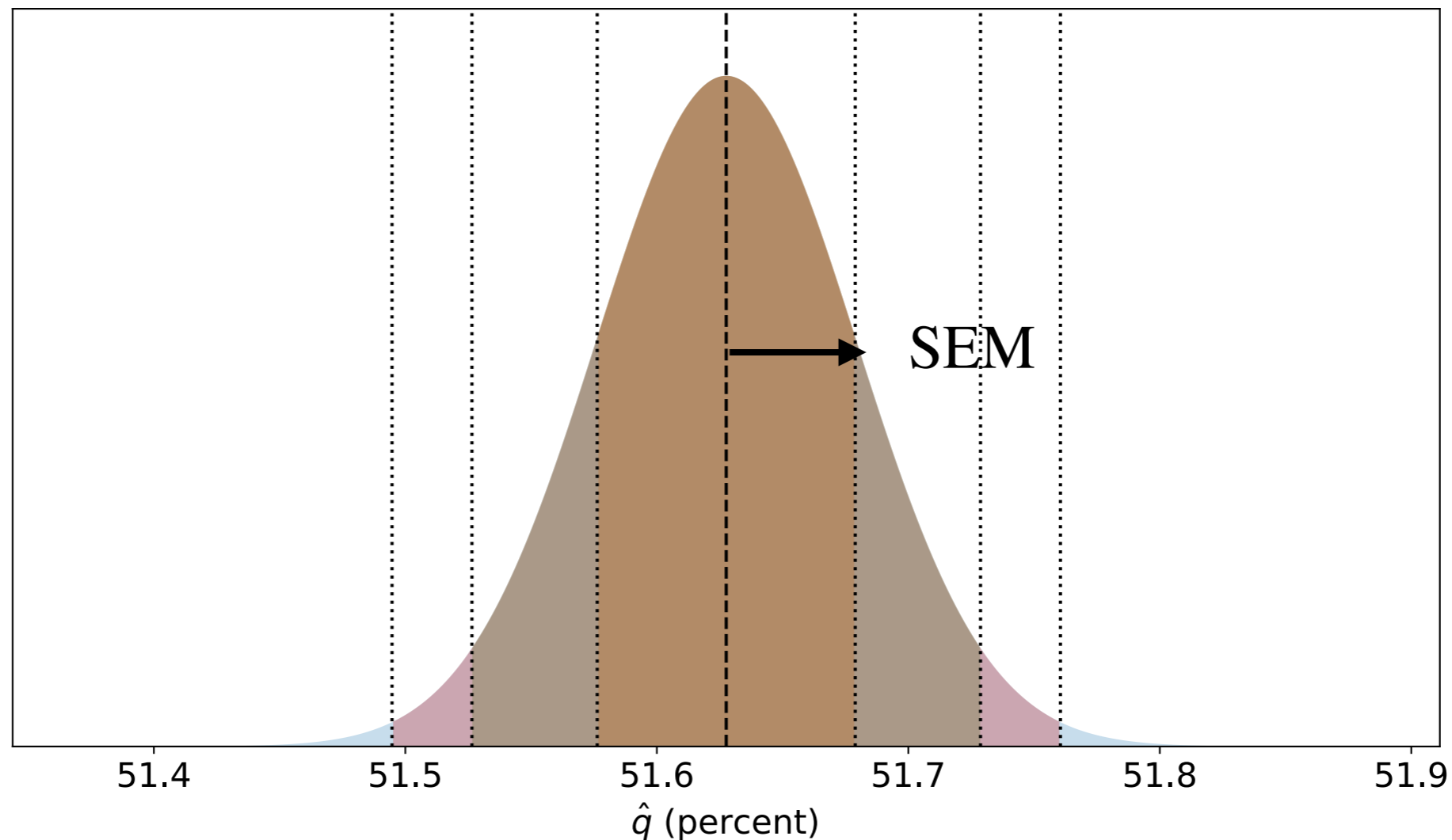
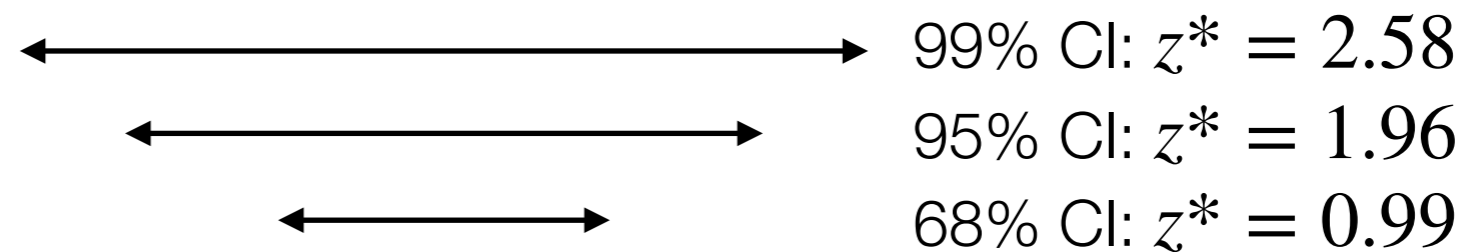
Choosing α fixes the value of z^* . Using $\alpha = 5\%$ gives $z^* = 1.96$.



Confidence intervals of different stringency can be computed using different z-statistic thresholds

Other confidence intervals are given by $[\hat{q} - W, \hat{q} + W]$ where

margin of error: $W = z^* \times \text{SEM}$



Example 2: Healthy Human Body Temperature

Example 2: Human body temperature

Body Temp	Sex	Heart Rate
96.3	2	70
96.7	2	71
96.9	2	74
97.0	2	80
97.1	2	73
97.1	2	75
97.1	2	82
97.2	2	64
97.3	2	69
97.4	2	70

⋮

Mackowiak PA, Wasserman SS, Levine MM. (1992) A Critical Appraisal of 98.6°F, the Upper Limit of the Normal Body Temperature, and Other Legacies of Carl Reinhold August Wunderlich. *JAMA*. 268(12):1578–1580.

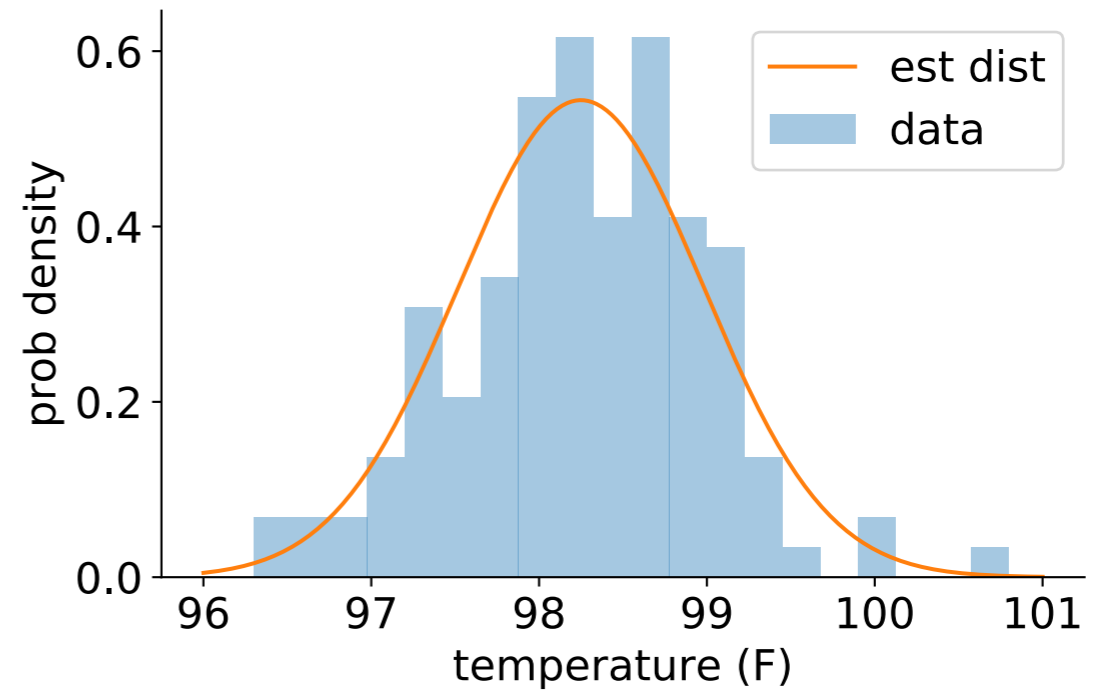
(Sex: 1 = female, 2 = male)

Example 2: Human Body Temperature

We model temperature using a normal distribution

Body Temp
96.3
96.7
96.9
97.0
97.1
97.1
97.1
97.2
97.3
97.4

⋮



temperature mean μ

estimate: 98.25 F

95% CI: [98.12 F, 98.38 F]

temperature standard deviation σ

estimate: 0.73 F

95% CI: [0.65 F, 0.83 F]

How to do this in PRISM

Welcome to GraphPad Prism

Column tables have one grouping variable, with each group defined by a column

	A	B
	Control	Treated
1	Y	Y
2		

Control Treated

? [Learn more](#)

Data table:

- Enter or import data into a new table
- Start with sample data to follow a tutorial

Options:

- Enter replicate values, stacked into columns
- Enter paired or repeated measures data - each subject on a separate row
- Enter and plot error values already calculated elsewhere

Enter:

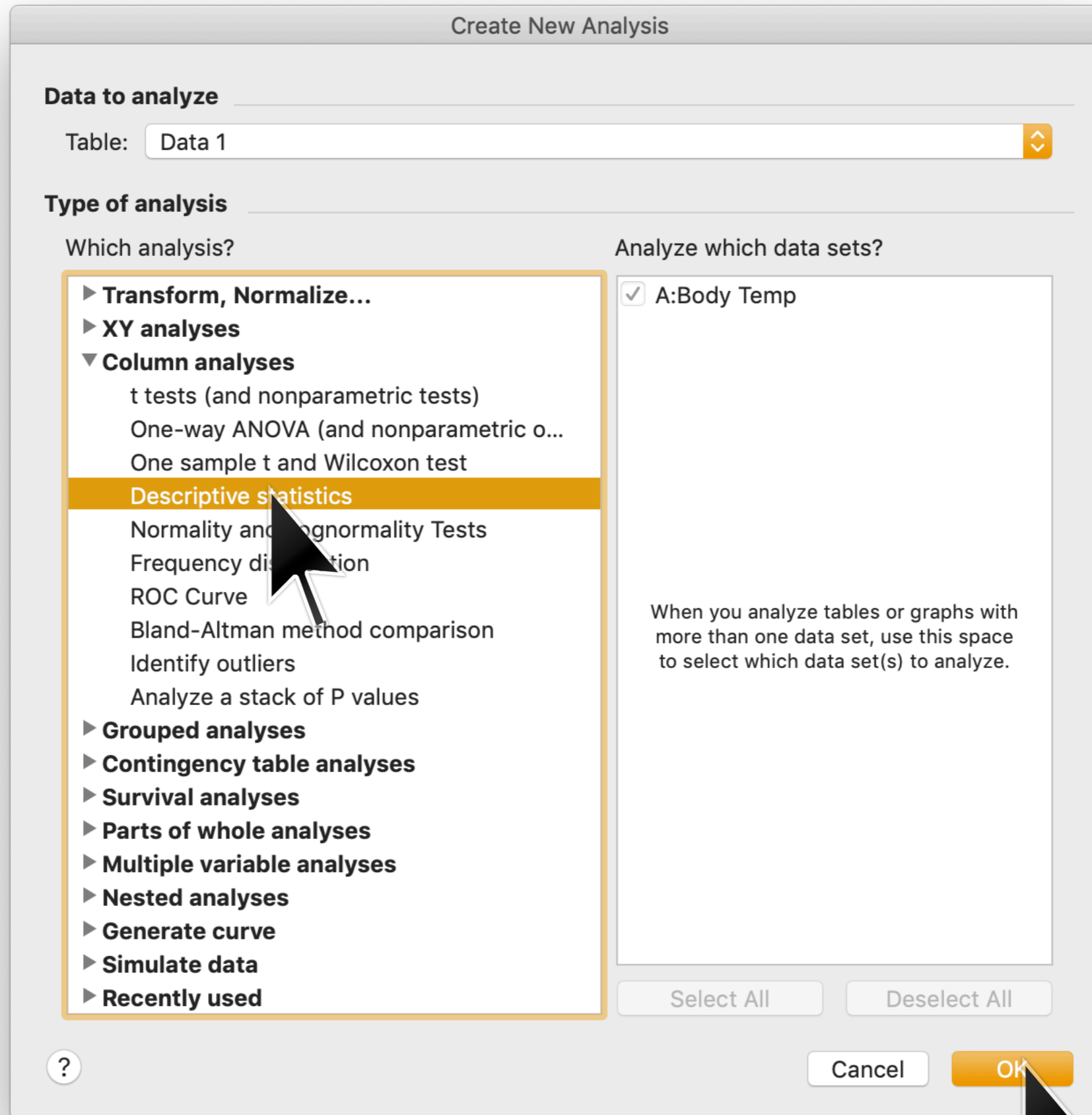
Prism Tips Cancel Create

How to do this in PRISM

The screenshot shows the PRISM software interface with a data table. The table has columns for Group A, Group B, and Group C, and rows for Body Temp and numerical values. A mouse cursor is pointing to the 'Data 1' icon in the bottom toolbar.

	Group A	Group B	Group C	Group D
Body Temp	Y	Y	Y	Y
1	96.3			
2	96.7			
3	96.9			
4	97.0			
5	97.1			
6	97.1			
7	97.1			
8	97.2			
9	97.3			
10	97.4			
11	97.4			
12	97.4			
13	97.4			
14	97.5			

How to do this in PRISM



How to do this in PRISM

Parameters: Descriptive Statistics

Basics

Mean, SD, SEM Minimum and maximum, range
 Column sum Quartiles (Median, 25th and 75th percentile)

Advanced

Coefficient of variation Geometric mean
 Skewness and kurtosis Harmonic mean
 Percentile
 Quadratic mean

Confidence intervals

CI of the mean CI of harmonic mean
 CI of geometric mean CI of quadratic mean
 CI of median
Confidence level

Subcolumns

Average the replicates in each row, and then perform the calculation for each column
 Perform the calculation for each subcolumn separately
 Treat all the values in all subcolumns as one set of data

Output

Show this many significant digits:

Make these choices the default for future analyses.

How to do this in PRISM

Descriptive statistics		A	B
		Body Temp	Title
		Y	Y
1	Number of values	130	
2			
3	Mean	98.25	
4	Std. Deviation	0.7332	
5	Std. Error of Mean	0.06430	
6			
7	Lower 95% CI of mean	98.12	
8	Upper 95% CI of mean	98.38	
9			
10			
11			
12			
13			
14			

We assume the temperature of a healthy person is drawn from a normal distribution

data

$$x_1, x_2, \dots, x_N$$

x_i : temperature of individual i in Fahrenheit

model

$$x \sim \text{Normal}(\mu, \sigma^2)$$

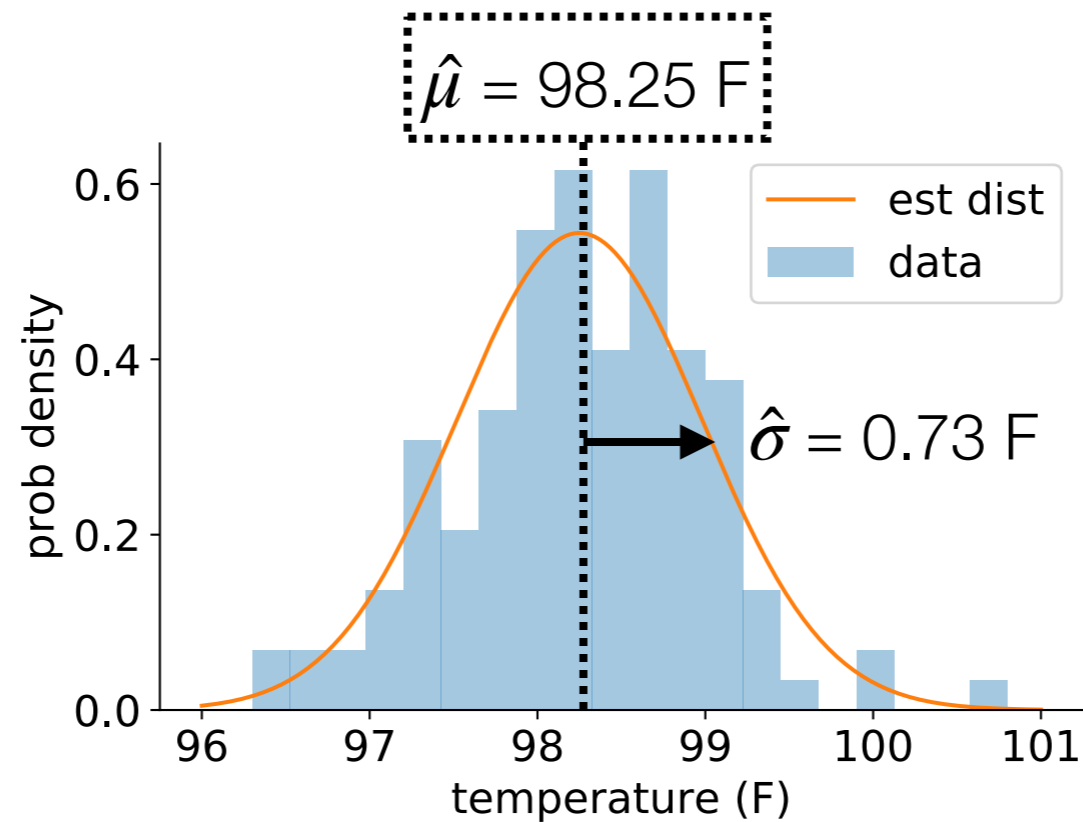
μ : average body temperature

σ : standard deviation of temperatures

goals

1. Compute best estimates for both μ, σ
2. Compute confidence intervals for both μ, σ

We want to infer two parameters from our data



Here there are two parameters that need to be estimated, μ and σ

This is unlike with the binomial distribution, where there was only one parameter q .

The lingering uncertainty in μ is described by a t-distribution

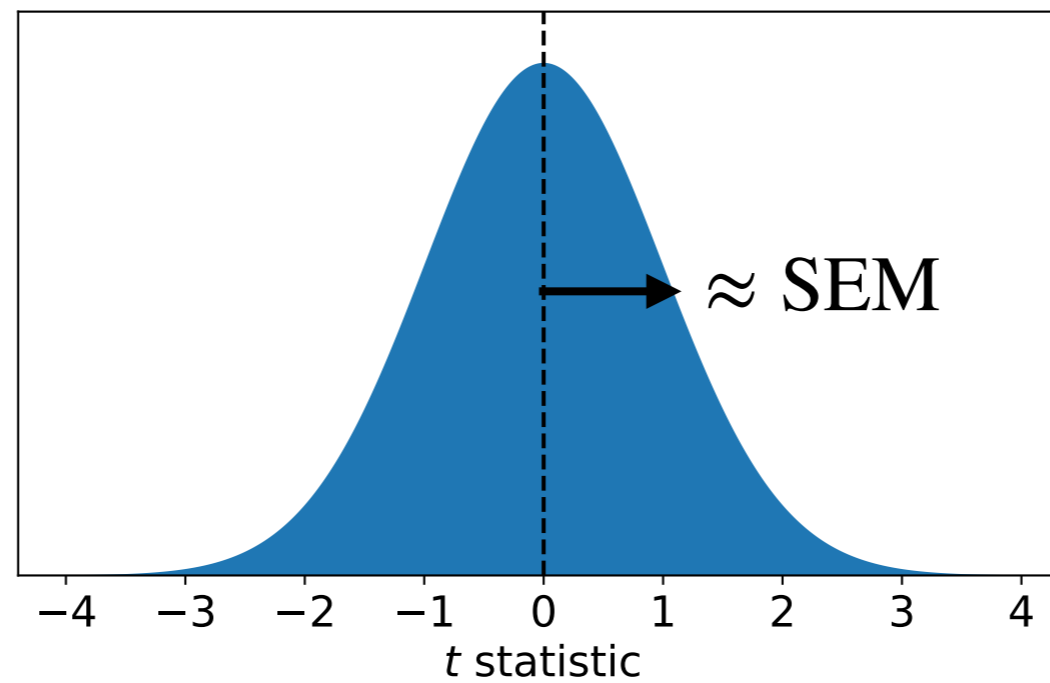
The standard error of the mean (SEM) is given by

$$\text{SEM} = \frac{\hat{\sigma}}{\sqrt{N}}$$

A t-statistic is then used to indicate how strongly μ deviates from $\hat{\mu}$:

$$t = \frac{\mu - \hat{\mu}}{\text{SEM}}$$

The t-statistic follows a t-distribution
(almost a normal distribution, but not quite)

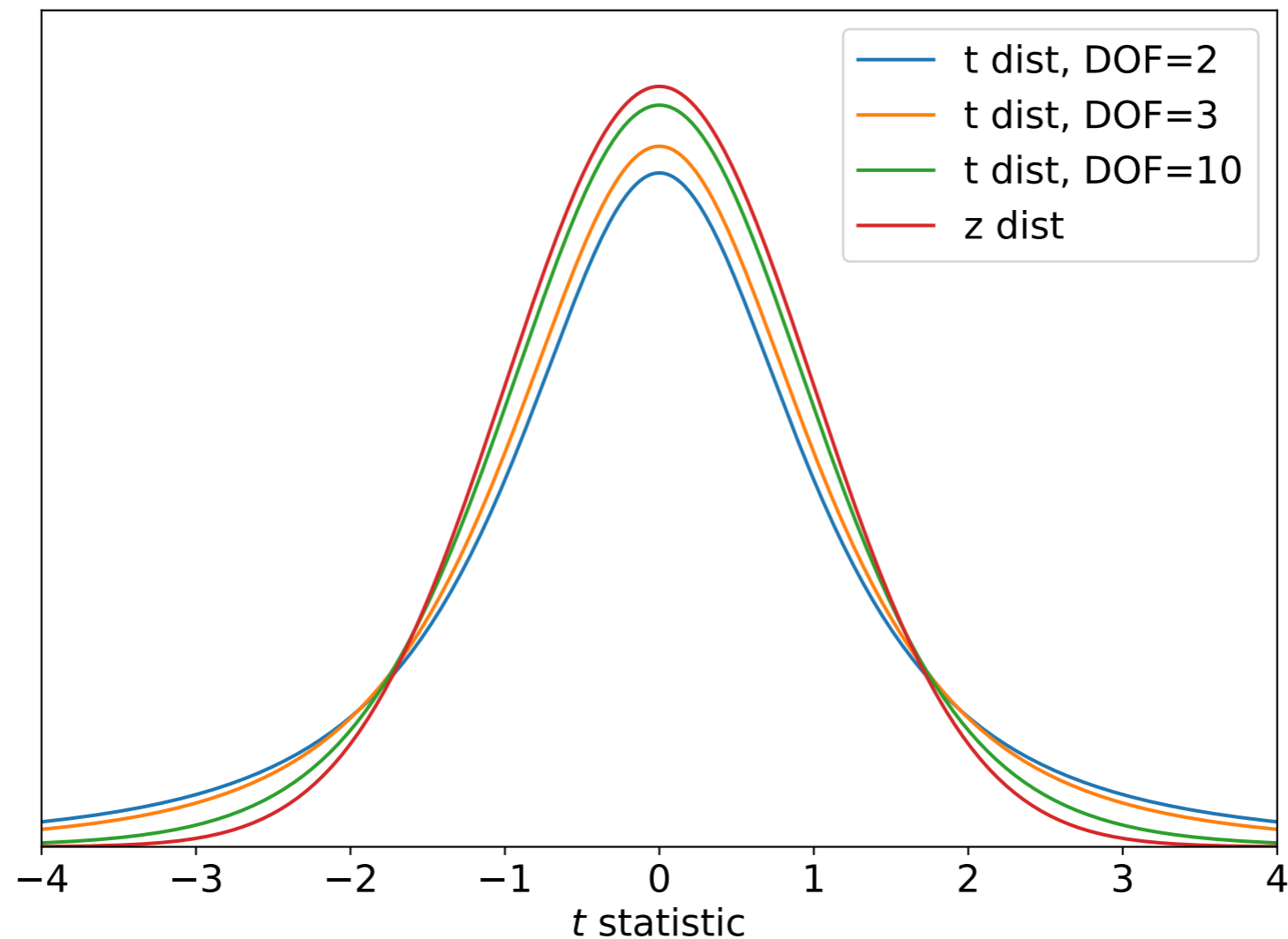


The shape of the t-distribution is affected by the number of degrees of freedom (DOF)

In this case, we use a t-distribution with DOF given by

$$\text{DOF} = N - 1$$

This is almost indistinguishable from a normal (z) distribution when $\text{DOF} \gtrsim 10$.

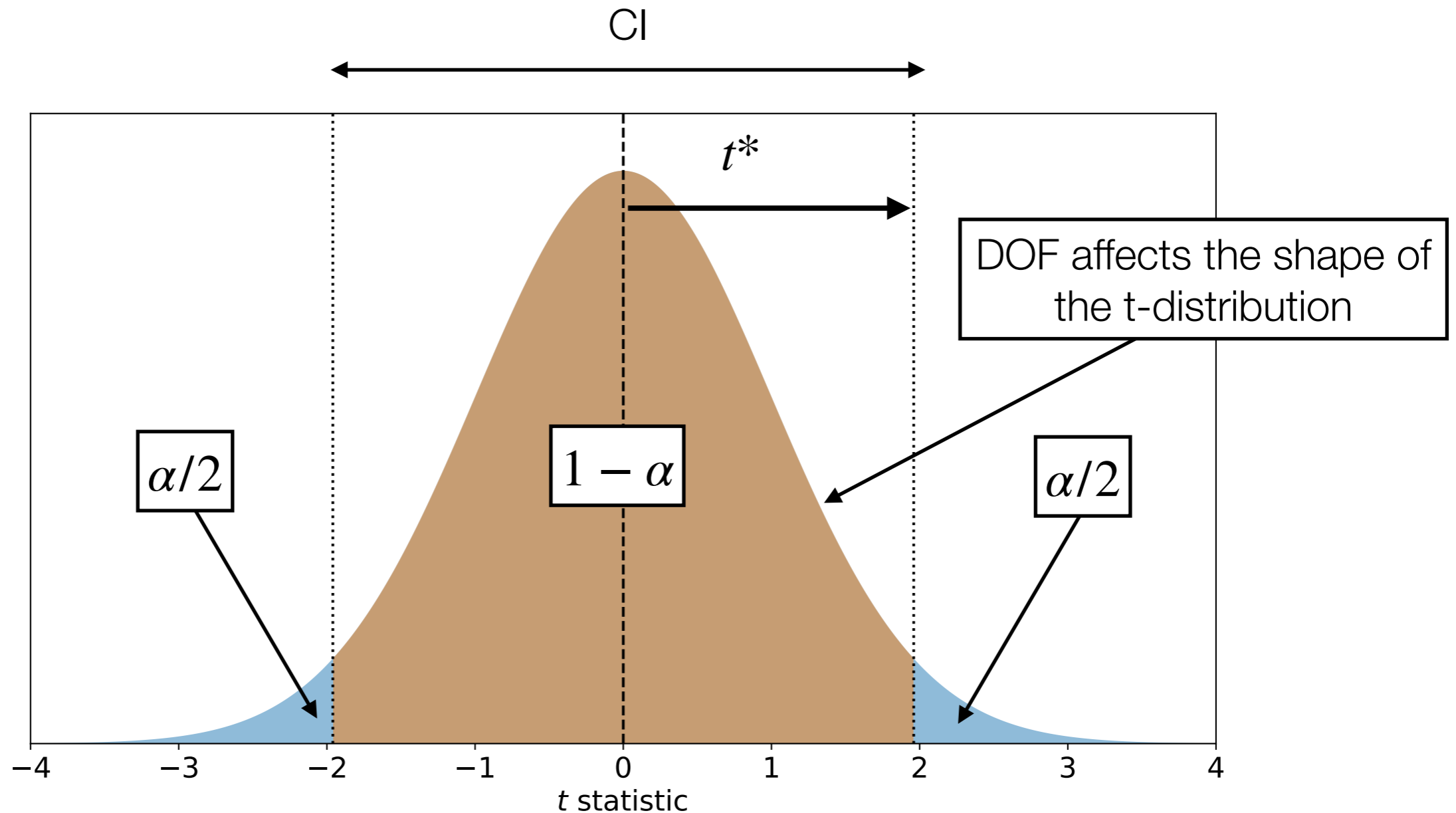


The t-distribution is used to compute a t-statistic cutoff, which determines the confidence interval

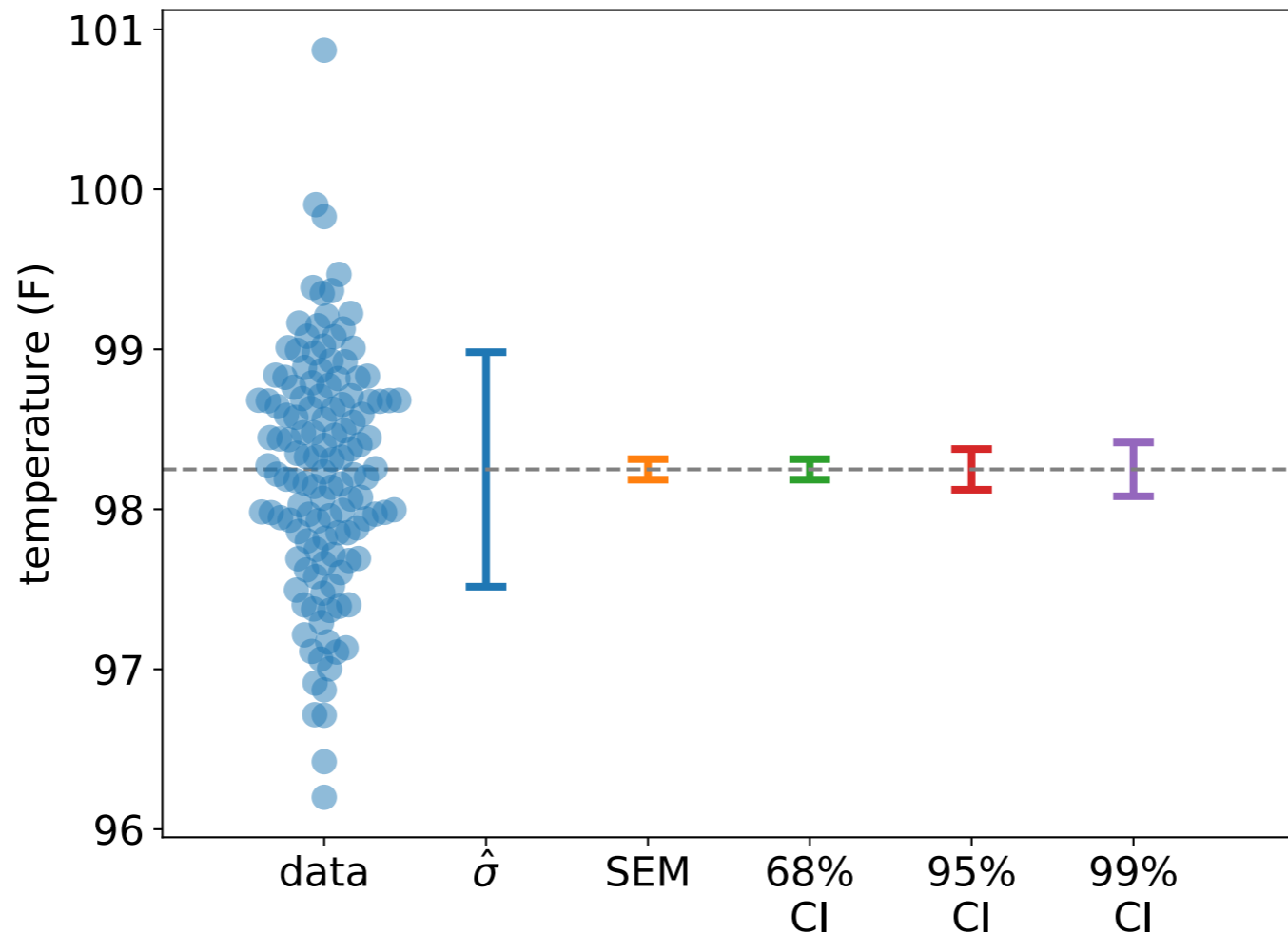
The t-statistic cutoff, t^* , is determined by both α and the DOF.

$$\text{margin of error: } W = t^* \cdot \text{SEM}$$

$$\text{confidence interval: } \hat{\mu} \pm W$$



Confidence intervals (CIs) and standard errors of the mean (SEMs) quantify how uncertain a parameter



SEMs and CIs of the mean quantify the uncertainty in μ ,
not the width of the sampling distribution ($\hat{\sigma}$).

SEMs and CIs decrease in size as the amount of data increases.

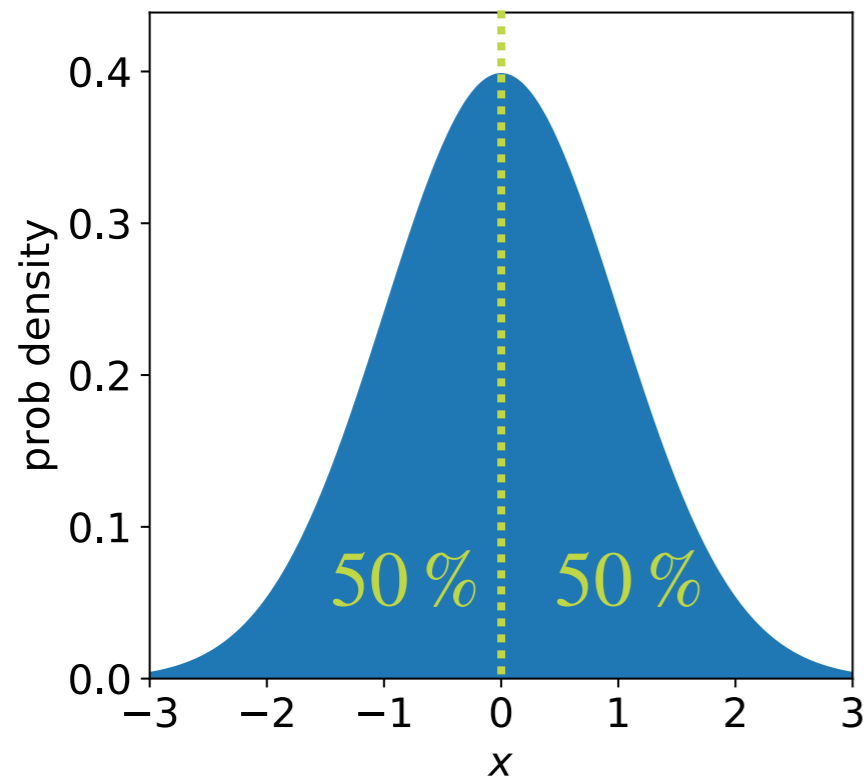
CIs increase in size if the required confidence level increases (i.e., α decreases)

The median is the standard nonparametric estimate of a distribution's center

For data: sort the data $x_1, x_2, x_3, \dots, x_N$ in ascending order. The median is then defined as:

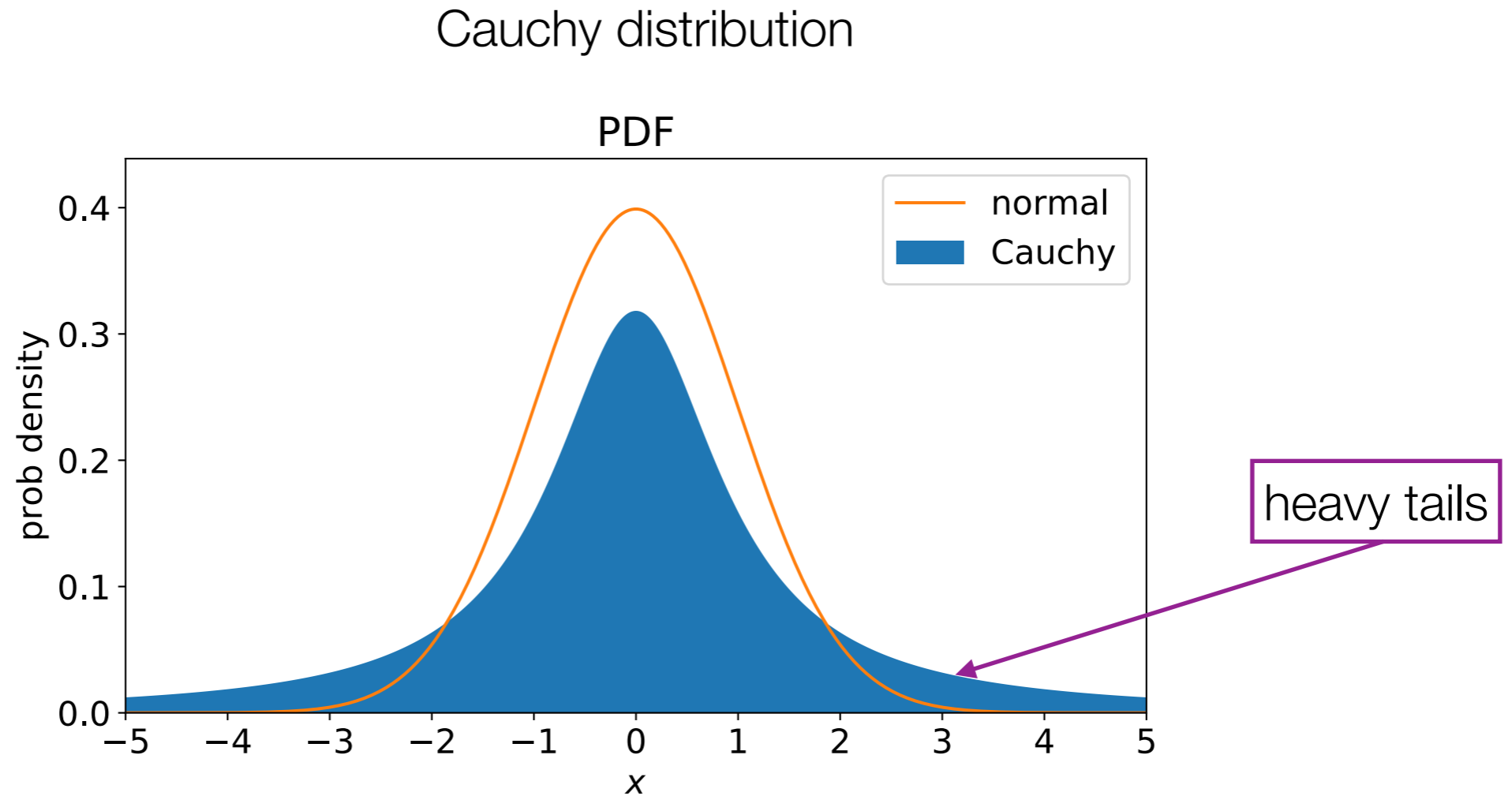
$$\text{median} = q_{50} = \begin{cases} x_{\frac{N+1}{2}} & \text{if } N \text{ odd} \\ \frac{1}{2} \left(x_{\frac{N}{2}} + x_{\frac{N+2}{2}} \right) & \text{if } N \text{ even} \end{cases}$$

For a distribution: the median is the value of x that separates half the distribution's mass from the other.



The median of a symmetric distribution is equal to its mean

The median is less sensitive to outliers than the mean



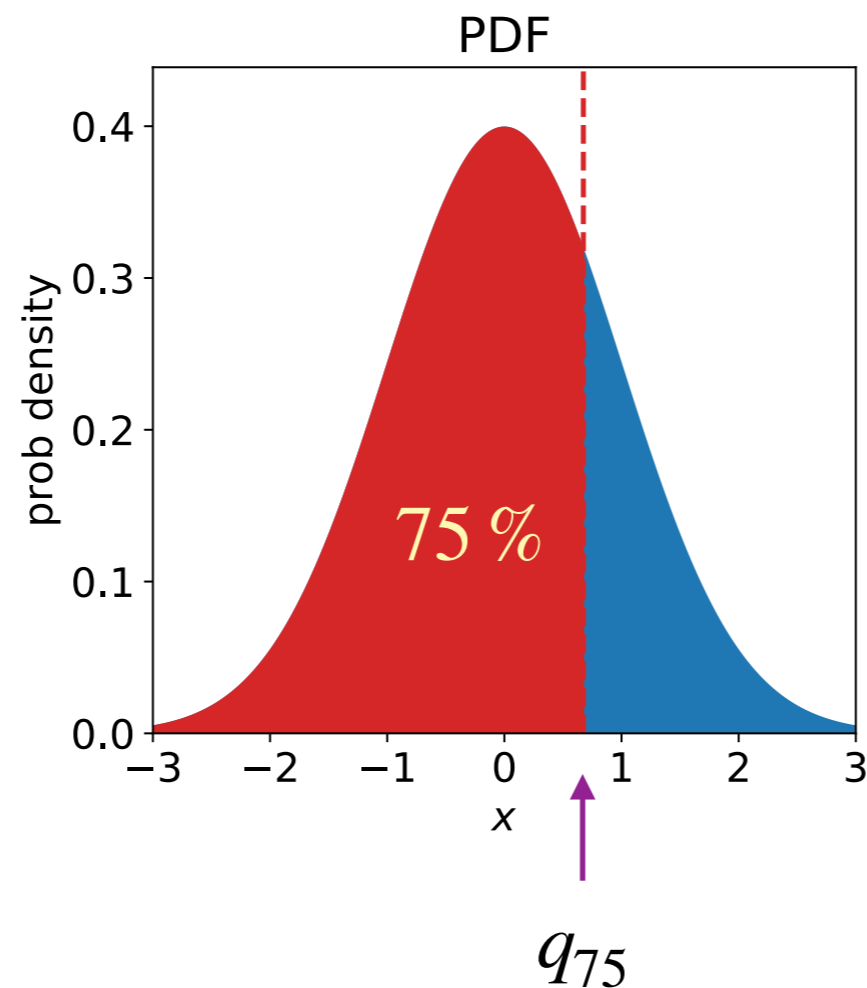
The standard estimate of the mean $\hat{\mu}$ will not converge as N becomes large!

The median q_{50} does converge, just as quickly as for any distribution.

Quantiles of a distribution

More generally, the quantile q_K of a distribution is the value of x that bounds $K\%$ of the distribution's mass.

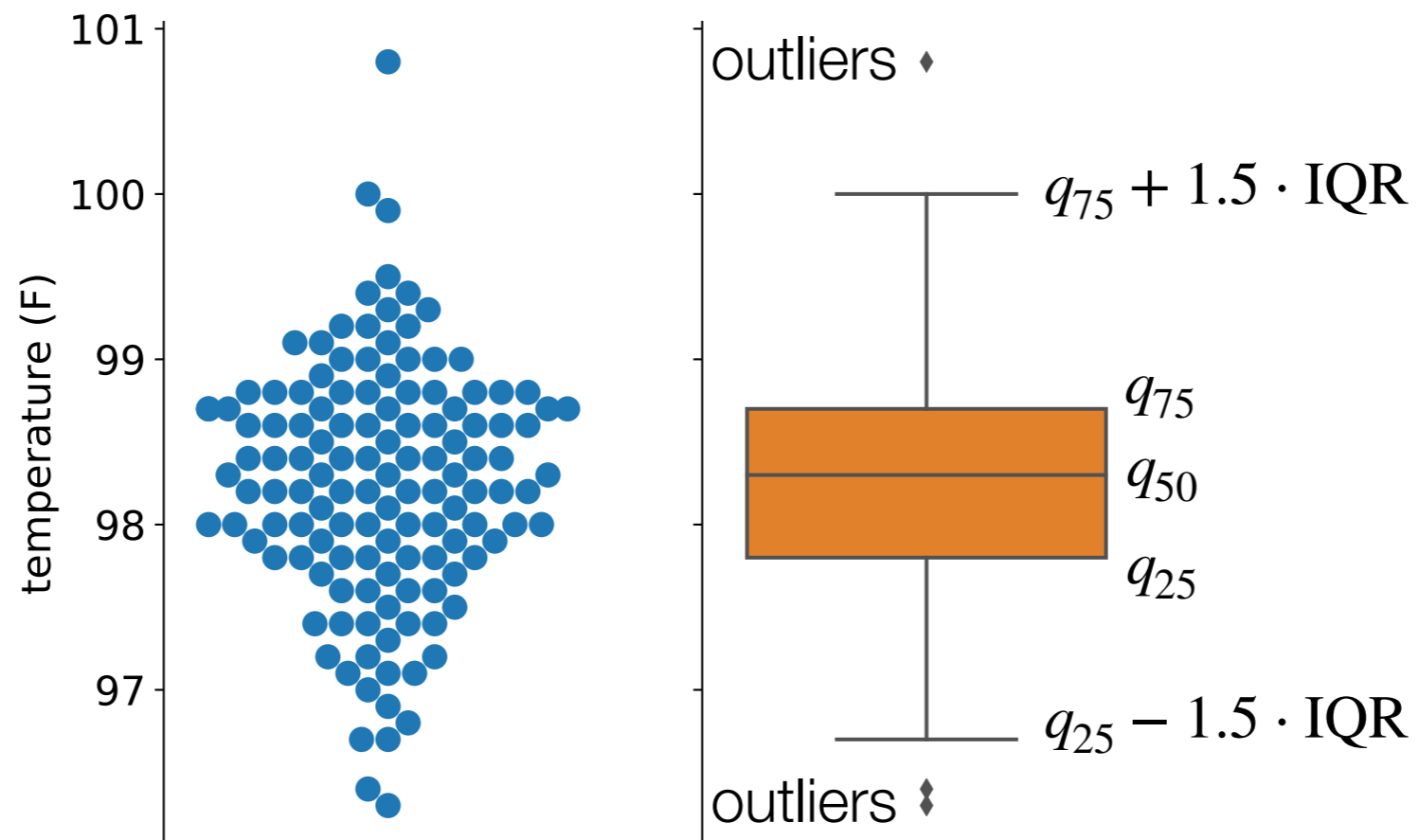
E.g., the median in the quantile q_{50}



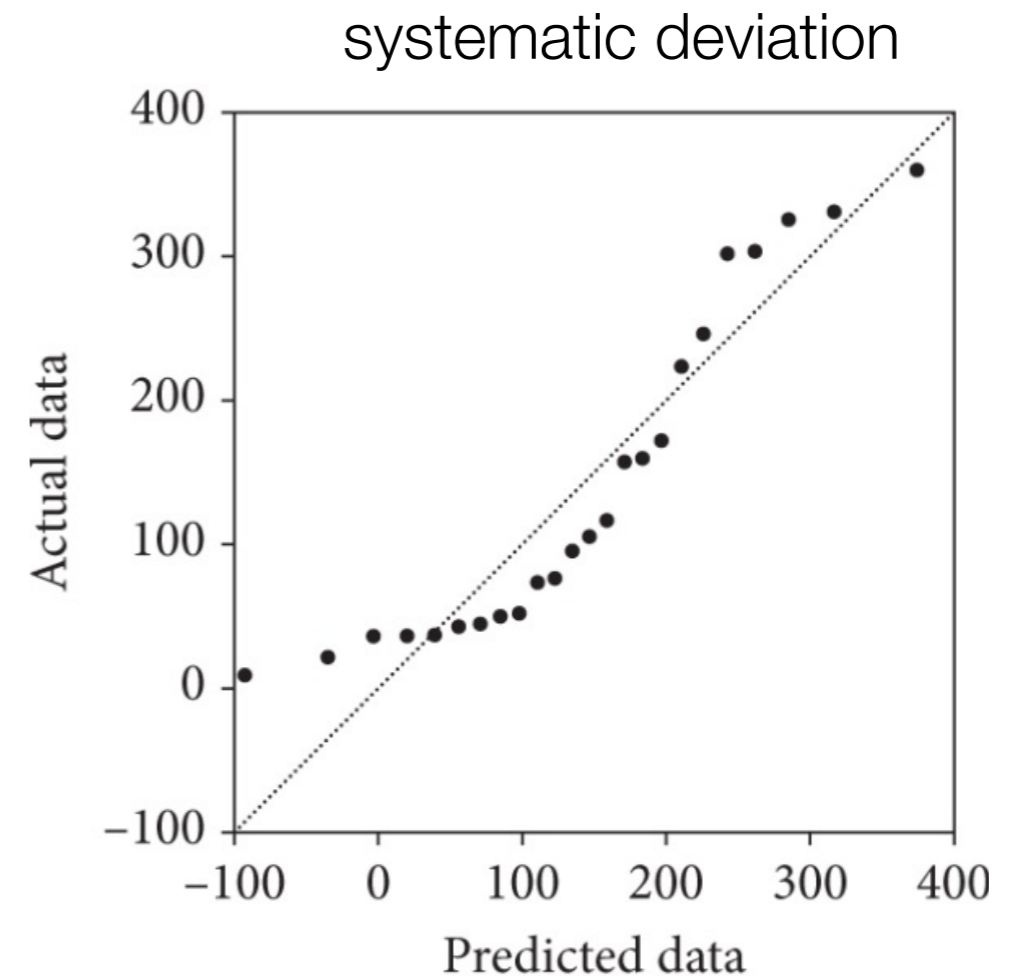
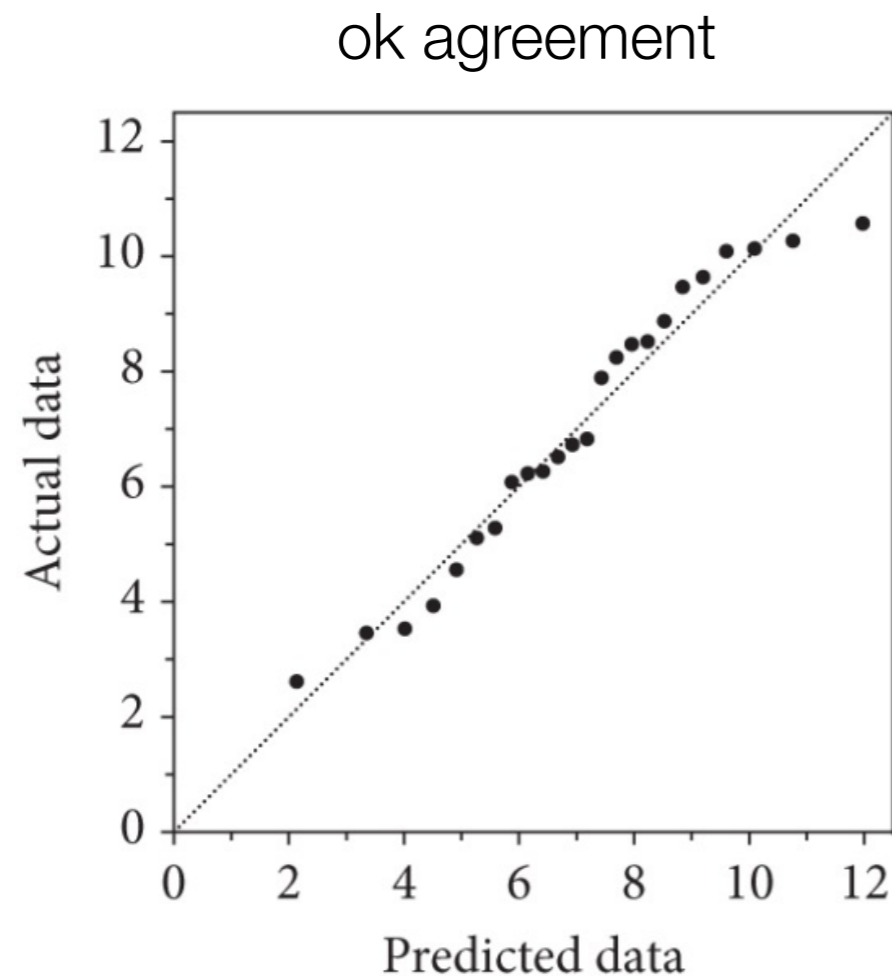
Box and whisker plots indicate quantiles

Interquartile range is defined by

$$\text{IQR} = q_{75} - q_{25}$$



QQ plots are used to visually test whether data follows an expected distribution.



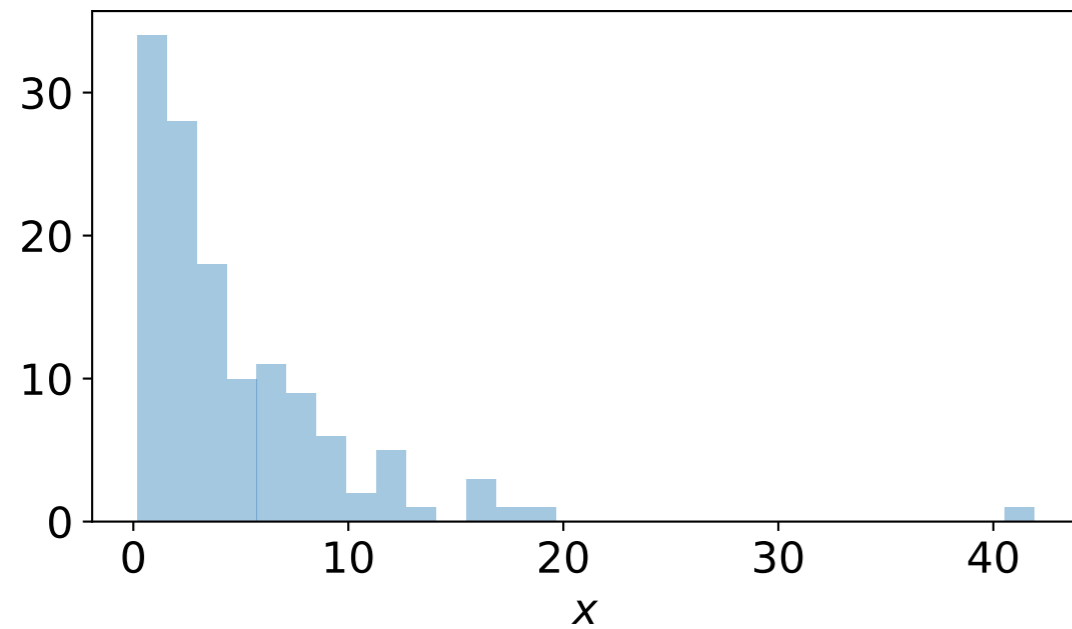
y axis: sorted data values x_1, x_2, \dots, N .

x axis: corresponding quantiles q_X of the inferred distribution, using the percentile values X_1, X_2, \dots, X_N computed for each data point.

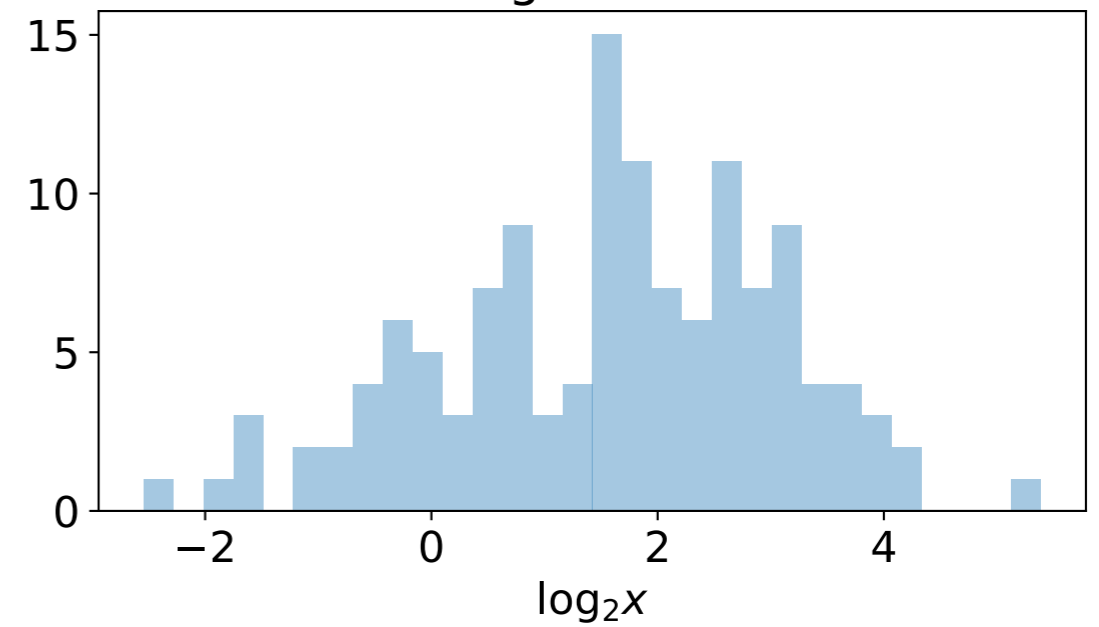
The analysis of a QQ plot is done by eye and making a judgement call.

QQ plot example: simulated lognormal data

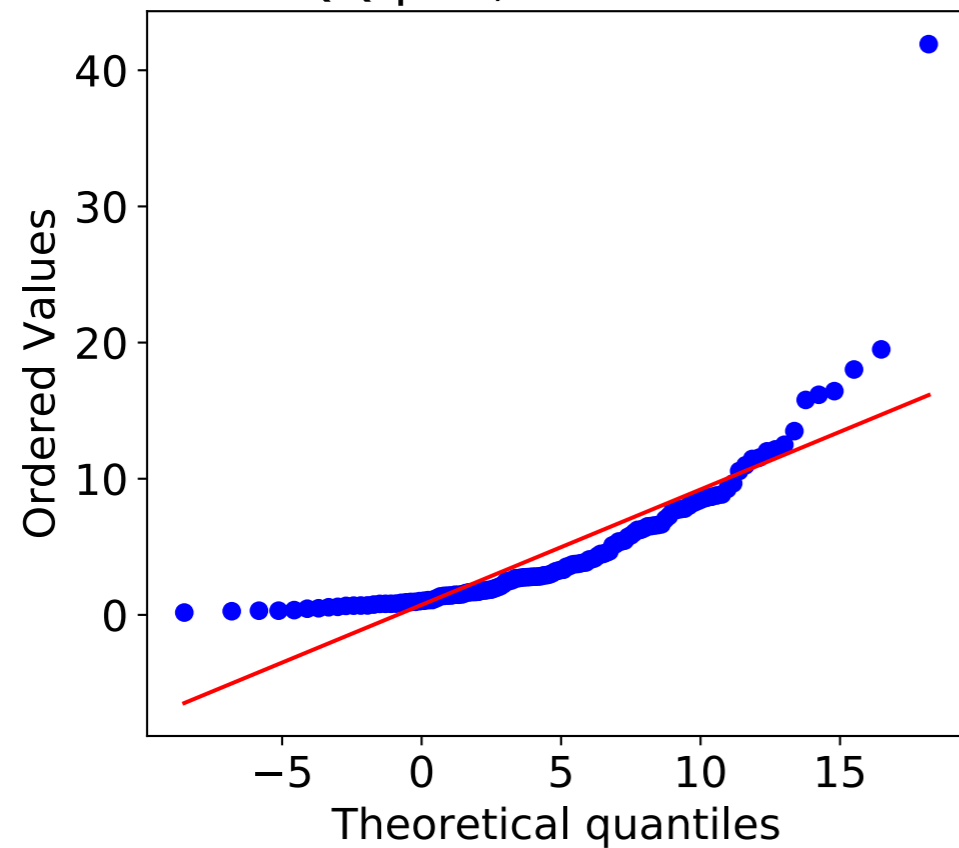
linear scale



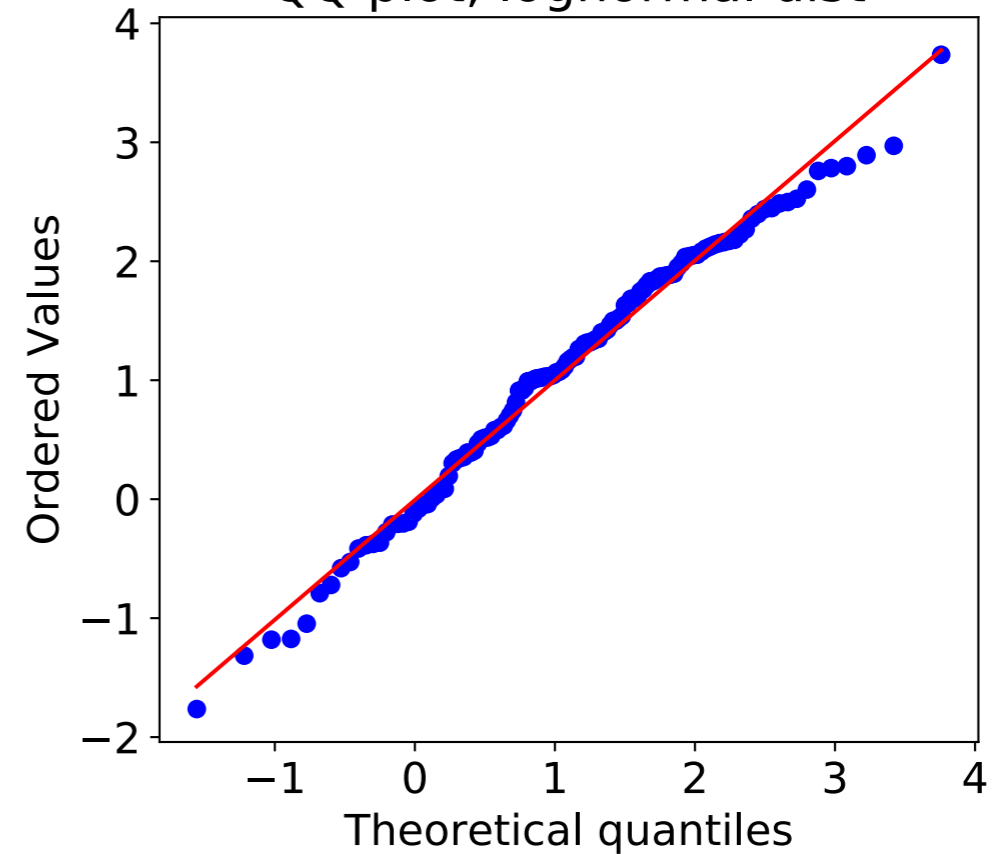
log2 scale



QQ plot, normal dist



QQ plot, lognormal dist

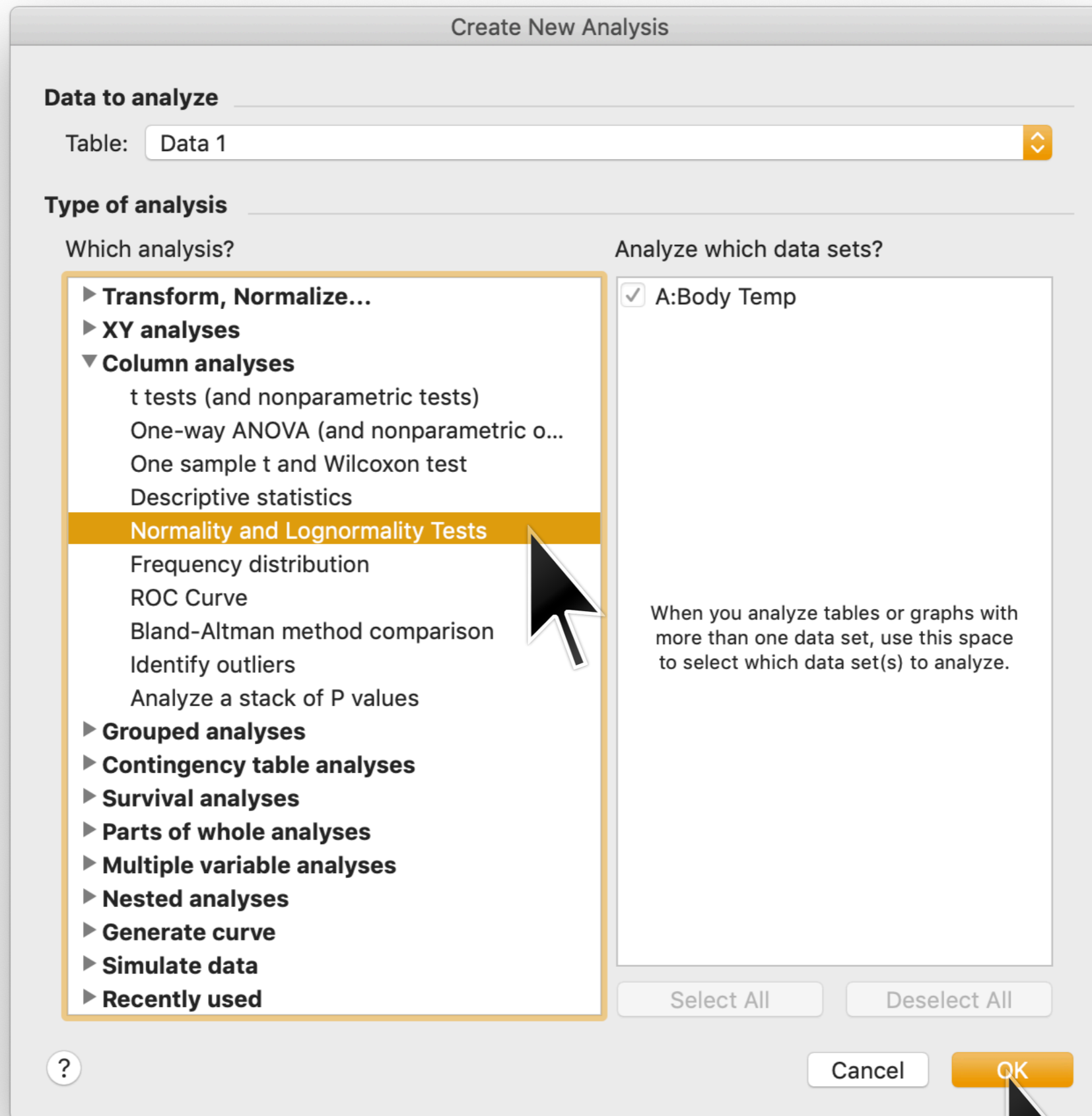


How to do this in Prism

The screenshot shows the Prism software interface with a data table titled "bodytemp.pzfx — Edited". The table has four columns: "Group A", "Group B", "Group C", and "Group D". The "Group A" column contains a "Body Temp" header and a "Y" indicator. The "Group B" and "Group C" columns contain "Title" headers and "Y" indicators. The data rows show a sequence of body temperature values from 96.3 to 97.5. A mouse cursor is pointing at the "Data 1" icon in the bottom toolbar.

	Group A	Group B	Group C	Group D
	Body Temp	Title	Title	Title
	Y	Y	Y	Y
1	96.3			
2	96.7			
3	96.9			
4	97.0			
5	97.1			
6	97.1			
7	97.1			
8	97.2			
9	97.3			
10	97.4			
11	97.4			
12	97.4			
13	97.4			
14	97.5			

How to do this in Prism



How to do this in Prism

Parameters: Normality and Lognormality Tests

Which distribution(s) to test?

- Normal (Gaussian) distribution
- Lognormal distribution
- Compute the relative likelihood of sampling from a Gaussian (normal) vs. a lognormal distribution (assuming no other possibilities)

Methods to test distribution(s)

- Anderson-Darling test
- D'Agostino-Pearson omnibus normality test
- Shapiro-Wilk normality test
- Kolmogorov-Smirnov normality test with Dallal-Wilkinson-Lilliefors P value

Graphing options

- Create a QQ plot

Subcolumns

- Average the replicates in each row, and then perform the calculation for each column
- Perform calculations on each subcolumn separately
- Treat all the values in all subcolumns as single set of data

Calculations

Significance level (alpha)

Output

Show this many significant digits (for everything except P values):

P value style: N =

Make these choices the default for future analyses

? Cancel OK

How to do this in Prism

bodytemp.pzfx — Edited

Restrict: Sheet is Any

▼ Data Tables

- Data 1
- New Data Table...

▼ Info

- Project info 1
- New Info...

▼ Results

- Normality and Lognormality Tests**
- New Analysis...

▼ Graphs

- Data 1
- Normal QQ plot: Normality and Lognormality Tests
- New Graph...

▼ Layouts

Family

- Data 1
- Normality and Lognormality Tests
- Normal QQ plot: Normality and Lognormality Tests

Tabular results

		A	B	C	D
	Normality and Lognormality Tests	Body Temp	Title	Title	Title
	Tabular results	Y	Y	Y	Y
1	Test for normal distribution				
2	Anderson-Darling test				
3	A2*	0.5201			
4	P value	0.1829			
5	Passed normality test (alpha=0.05)?	Yes			
6	P value summary	ns			
7					
8	D'Agostino & Pearson test				
9	K2	2.704			
10	P value	0.2587			
11	Passed normality test (alpha=0.05)?	Yes			
12	P value summary	ns			
13					
14	Shapiro-Wilk test				
15	W	0.9866			
16	P value	0.2332			
17	Passed normality test (alpha=0.05)?	Yes			
18	P value summary	ns			
19					
20	Kolmogorov-Smirnov test				
21	KS distance	0.06473			
22	P value	>0.1000			
23	Passed normality test (alpha=0.05)?	Yes			
24	P value summary	ns			
25					
26	Number of values	130			
27					

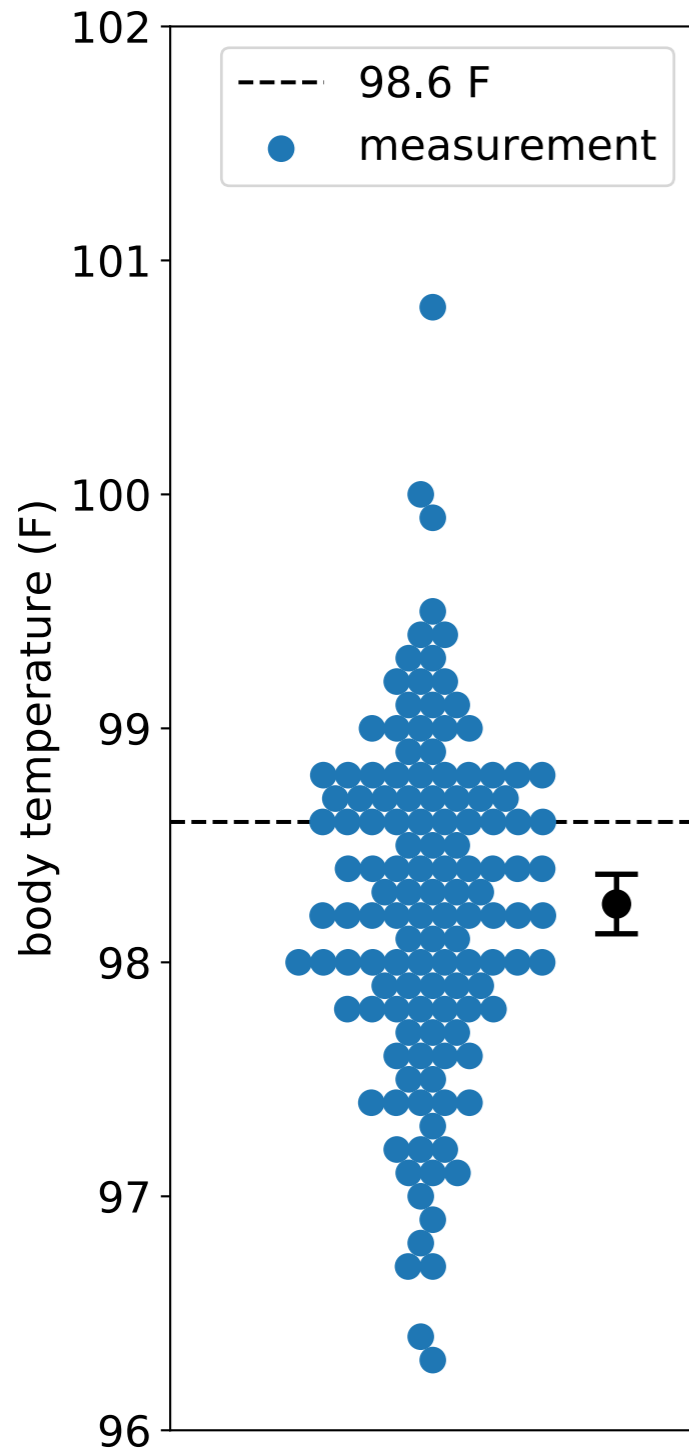
Normality and Lognormality

How to do this in PRISM

The screenshot displays the PRISM software interface. The window title is "bodytemp.pzfx — Edited". On the left, a navigation pane shows a tree view with categories: Data Tables (Data 1), Info (Project info 1), Results (Normality and Lognormality Tests), Graphs (Data 1, Normal QQ plot: Normality and Lognormality Tests), and Layouts. The "Normal QQ plot: Normality and Lognormality Tests" graph is selected and highlighted. The main workspace shows a "Normal QQ plot" with "Predicted" on the y-axis and "Actual" on the x-axis, both ranging from 96 to 101. A red diagonal line represents the identity function (y=x). The data points are black dots that closely follow this line, indicating a strong linear relationship between predicted and actual values.

Actual	Predicted
96.5	96.5
97.0	97.0
97.5	97.5
98.0	98.0
98.5	98.5
99.0	99.0
99.5	99.5
100.0	100.0
100.5	100.5
101.0	101.0

Student's t test (one sample)



Null Hypothesis:

a population is normally distributed with a known mean value of μ_{null}

Data:

measurements: x_1, x_2, \dots, x_N

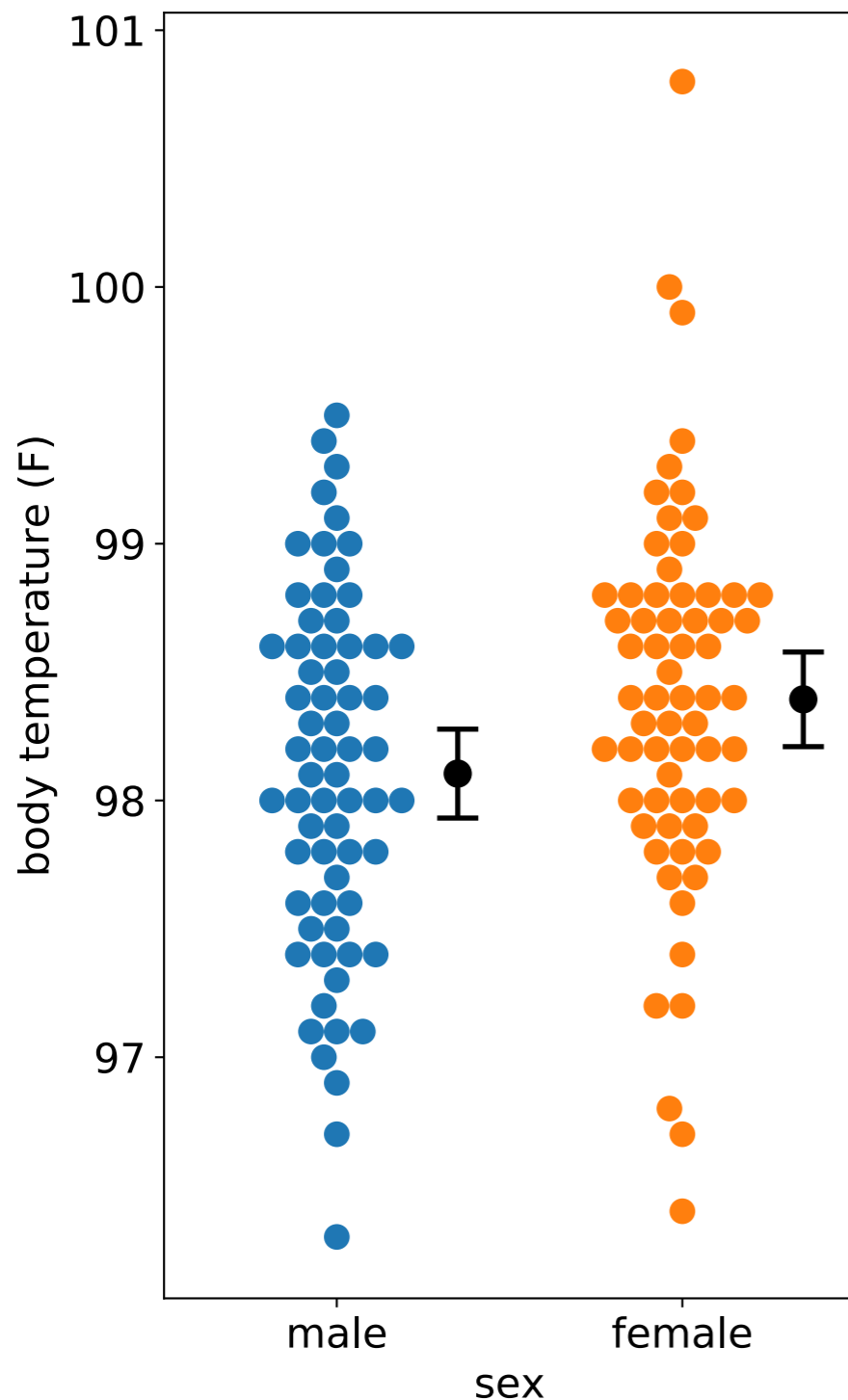
Test statistic:

$$t = \frac{\hat{\mu} - \mu_{\text{null}}}{\text{SEM}}$$

Null distribution:

t distribution with $\text{DOF} = N - 1$.

Student's t test (two sample, equal variance)



Null Hypothesis:

two populations have the same mean

Data:

x_1, x_2, \dots, x_m and y_1, y_2, \dots, y_n

Assumptions:

the two populations follow normal distributions and have equal variances

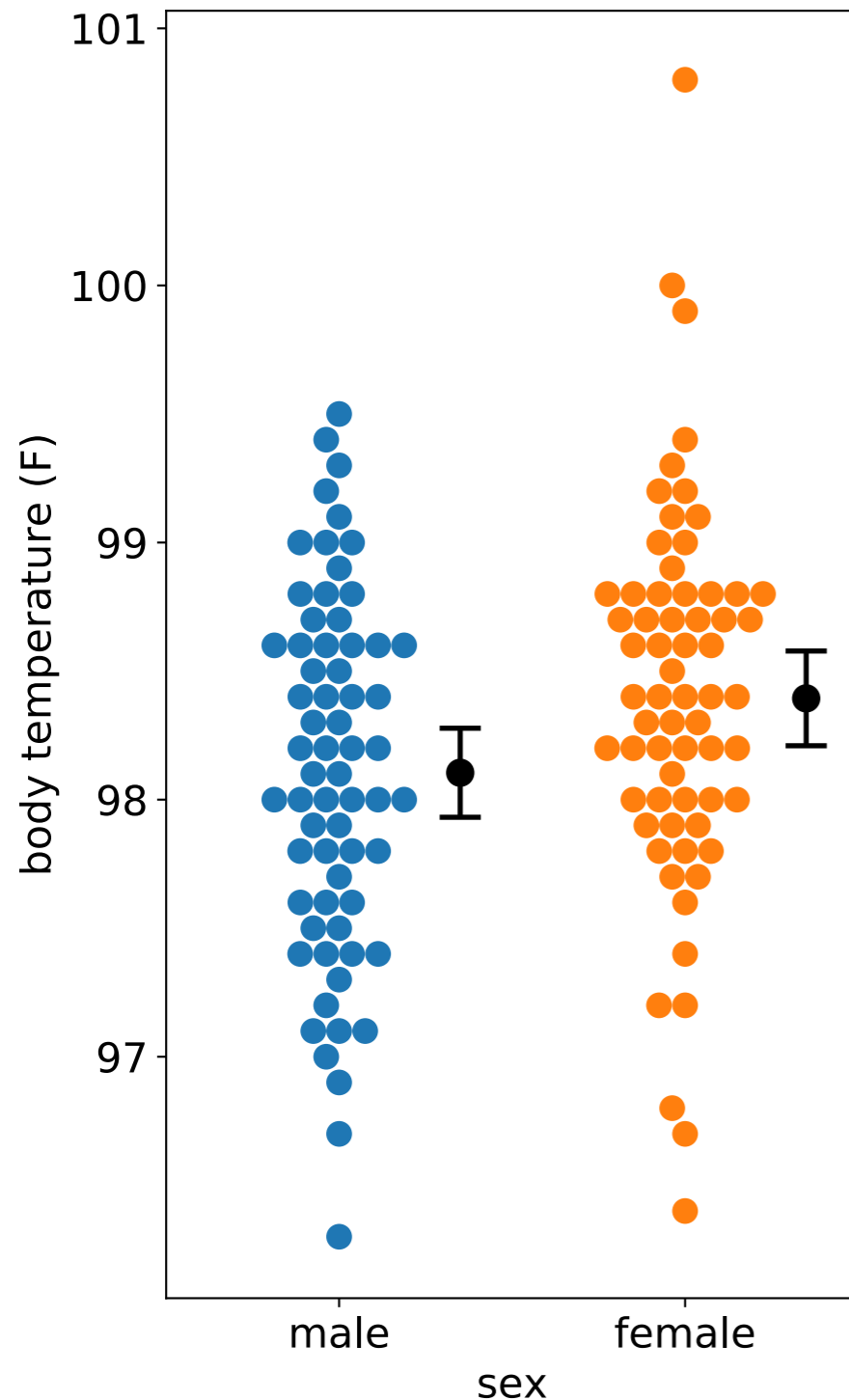
Test statistic:

$$t = \frac{\hat{\mu}_x - \hat{\mu}_y}{\hat{\sigma} \sqrt{\frac{1}{m} + \frac{1}{n}}}, \quad \hat{\sigma} = \sqrt{\frac{(m-1)\hat{\sigma}_x^2 + (n-1)\hat{\sigma}_y^2}{m+n-2}}$$

Null distribution:

t distribution with $\text{DOF} = m + n - 2$.

Welch's t test



Null Hypothesis:

two populations have the same mean but not necessarily the same standard deviation

Data:

x_1, x_2, \dots, x_m and y_1, y_2, \dots, y_n

Advantage:

Fewer assumptions than standard unpaired t test

Disadvantage:

Less power than standard unpaired t tests

Test statistic:

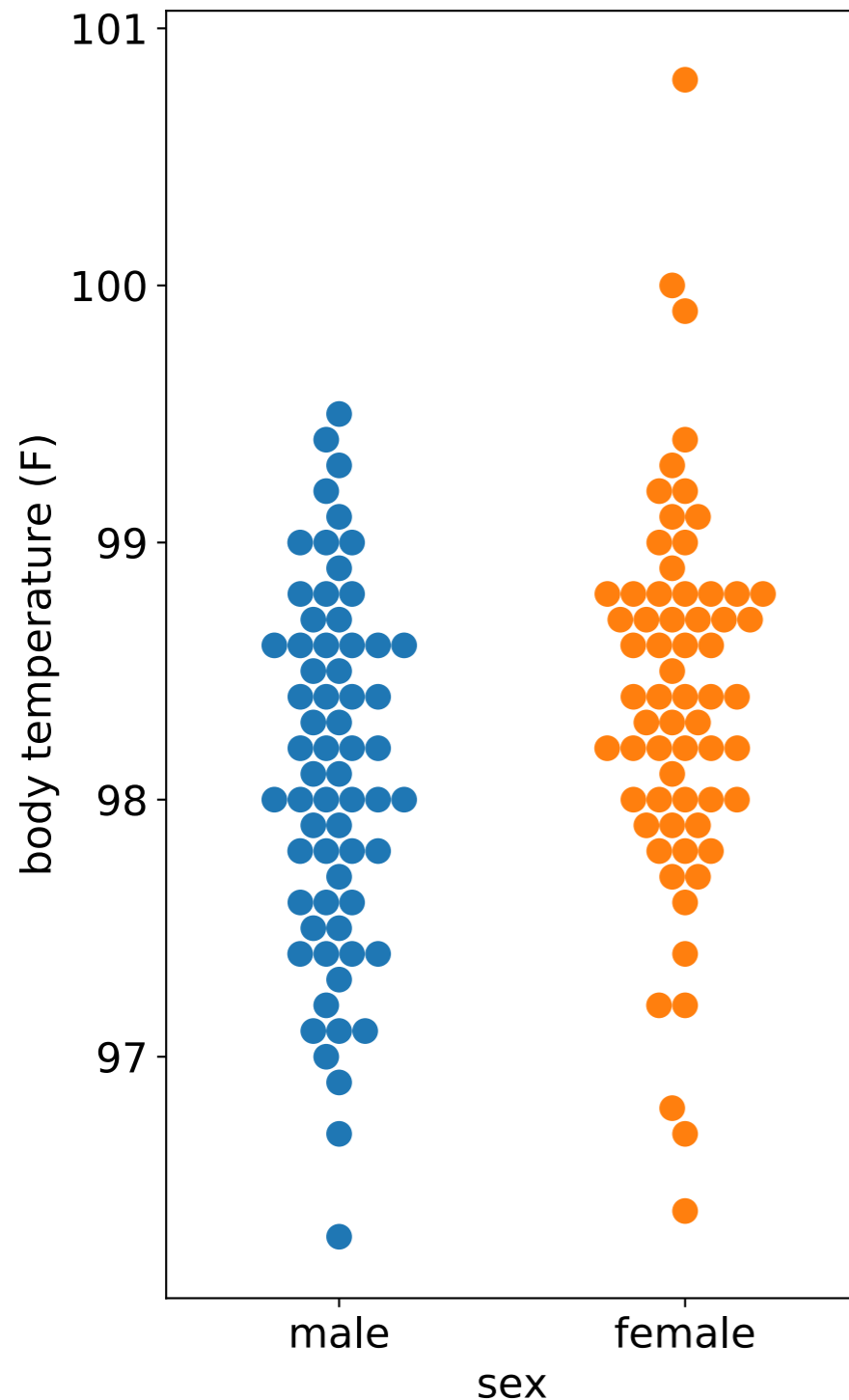
$$t = \frac{\hat{\mu}_x - \hat{\mu}_y}{\sqrt{\frac{\hat{\sigma}_x^2}{m} + \frac{\hat{\sigma}_y^2}{n}}}$$

Null distribution:

Student's t distribution with

$$\text{DOF} = \frac{\left(\frac{\hat{\sigma}_x^2}{m} + \frac{\hat{\sigma}_y^2}{n}\right)^2}{\frac{(\hat{\sigma}_x^2/m)^2}{m-1} + \frac{(\hat{\sigma}_y^2/n)^2}{n-1}}$$

Mann Whitney U test (Wilcoxon rank-sum test)



Null Hypothesis:

If x is sampled from population 1 and y is sampled from population 2,

$$p(x > y) = p(x < y)$$

Data:

x_1, x_2, \dots, x_m and y_1, y_2, \dots, y_n

Advantage:

No assumptions about the mathematical form of $p(x)$ and $p(y)$.

Disadvantage:

Somewhat less powerful than Student's t test

Test statistic:

U (based on rank-order of x s and y s)

temp_by_sex.pzfx

Search

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- + New Info...

▼ Results >>

- + New Analysis...

▼ Graphs >>

- Data 1

Family >>

- Data 1
- Data 1

	Group A	Group B	Group C	Group D
	male	female	Title	Title
	Y	Y	Y	Y
1	96.3	96.4		
2	96.7	96.7		
3	96.9	96.8		
4	97.0	97.2		
5	97.1	97.2		
6	97.1	97.4		
7	97.1	97.6		
8	97.2	97.7		
9	97.3	97.7		
10	97.4	97.8		
11	97.4	97.8		
12	97.4	97.8		
13	97.4	97.9		
14	97.5	97.9		

Navigation icons: Home, Back, Forward, Search, Print, Grid, Info, List, Graph, Table, Right Arrow

Create New Analysis

Data to analyze

Table: Data 1



Type of analysis

Which analysis?

- ▶ Transform, Normalize...
- ▶ XY analyses
- ▼ Column analyses
 - t tests (and nonparametric tests)**
 - One-way ANOVA (and nonparametric o...
 - One sample t and Wilcoxon test
 - Descriptive statistics
 - Normality and Lognormality Tests
 - Frequency distribution
 - ROC Curve
 - Bland-Altman method comparison
 - Identify outliers
 - Analyze a stack of P values
- ▶ Grouped analyses
- ▶ Contingency table analyses
- ▶ Survival analyses
- ▶ Parts of whole analyses
- ▶ Multiple variable analyses
- ▶ Nested analyses
- ▶ Generate curve
- ▶ Simulate data
- ▶ Recently used

Analyze which data sets?

- A: male
- B: female

Select All

Deselect All



Cancel

OK

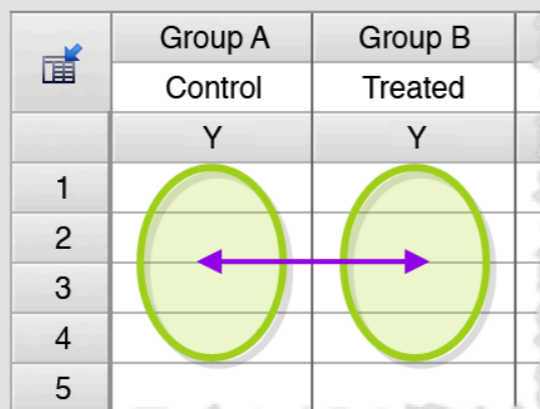
Parameters: t Tests (and Nonparametric Tests)

Experimental Design Residuals Options

Experimental design

- Unpaired
- Paired

	Group A	Group B	
	Control	Treated	
	Y	Y	
1			
2			
3			
4			
5			



Assume Gaussian distribution?

- Yes. Use parametric test.
- No. Use nonparametric test.

Choose test

- Unpaired t test. Assume both populations have the same SD
- Unpaired t test with Welch's correction. Do not assume equal SDs



Cancel

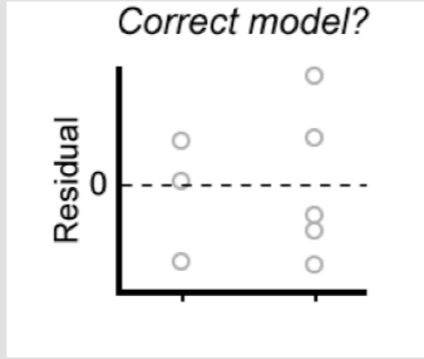
OK

Parameters: t Tests (and Nonparametric Tests)

Experimental Design **Residuals** Options

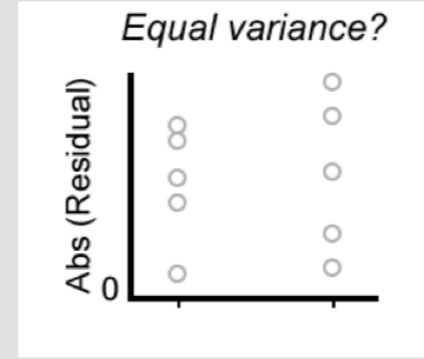
What graphs to create?

Correct model?



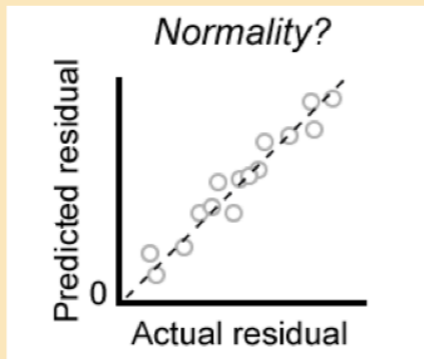
Residual plot

Equal variance?



Homoscedasticity plot

Normality?



QQ plot



Heatmap plot

Diagnostics for residuals

- Are the residuals Gaussian?
Normality tests of Anderson-Darling, D'Agostino, Shapiro-Wilk and Kolmogorov-Smirnov.

Make options on this tab be the default for future tests.



Cancel

OK

Parameters: t Tests (and Nonparametric Tests)

Experimental Design Residuals **Options**

Calculations

P value: One-tailed Two-tailed (recommended)

Report differences as: female - male

Confidence level: 95%

Definition of statistical significance: $P < 0.05$

Graphing options

- Graph differences (paired)
- Graph ranks (nonparametric)
- Graph correlation (paired)
- Graph CI of difference between means

Additional results

- Descriptive statistics for each dataset
- t Test: Also compare models using AICc
- Mann-Whitney: Also compute the CI of difference between medians
Assumes both distributions have the same shape.
- Wilcoxon: When both values on a row are identical, use method of Pratt
If this option is unchecked, those rows are ignored and the results will match prior version of Prism

Output

Show this many significant digits (for everything except P values): 4

P value style: GP: 0.1234 (ns), 0.0332 (*), 0.0021 (**), 0.0002 (***), <0.000... N= 6

Make options on this tab be the default for future tests.



Cancel

OK

temp_by_sex.pzfx — Edited

Search

Tabular results

Unpaired t test
Tabular results

1	Table Analyzed	Data 1		
2				
3	Column B	female		
4	vs.	vs.		
5	Column A	male		
6				
7	Unpaired t test			
8	P value	0.0239		
9	P value summary	*		
10	Significantly different (P < 0.05)?	Yes		
11	One- or two-tailed P value?	Two-tailed		
12	t, df	t=2.285, df=128		
13				
14	How big is the difference?			
15	Mean of column A	98.10		
16	Mean of column B	98.39		
17	Difference between means (B - A)	0.2892 ± 0.1266		
18	95% confidence interval	0.03882 to 0.5396		
19	R squared (eta squared)	0.03921		
20				
21	F test to compare variances			
22	F, DFn, Dfd	1.132, 64, 64		
23	P value	0.6211		

Family

Data 1

Unpaired t test

QQ plot: Unpaired t test of Data 1

Mean diff. CI plot: Unpaired t test

Unpaired t test of Data 1

Row 1, Column A

Search

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Data 1

QQ plot: Unpaired t test of Data 1

Mean diff. CI plot: Unpaired t test

Family >>

Data 1

Unpaired t test

QQ plot: Unpaired t test of Data 1

Mean diff. CI plot: Unpaired t test

Tabular results

Unpaired t test

Tabular results

20

21

F test to compare variances

22

F, DFn, Dfd

1.132, 64, 64

23

P value

0.6211

24

P value summary

ns

25

Significantly different (P < 0.05)?

No

26

27

Normality of Residuals

28

Test name**Statistics****P value****Passed normality test (alpha=0.05)?****P value summary**

29

Anderson-Darling (A2*)

0.3633

0.4359

Yes

ns

30

D'Agostino-Pearson omnibus (K2)

2.467

0.2913

Yes

ns

31

Shapiro-Wilk (W)

0.9906

0.5264

Yes

ns

32

Kolmogorov-Smirnov (distance)

0.05178

0.1000

Yes

ns

33

34

Data analyzed

35

Sample size, column A

65

36

Sample size, column B

65

37

38



Unpaired t test of Data 1



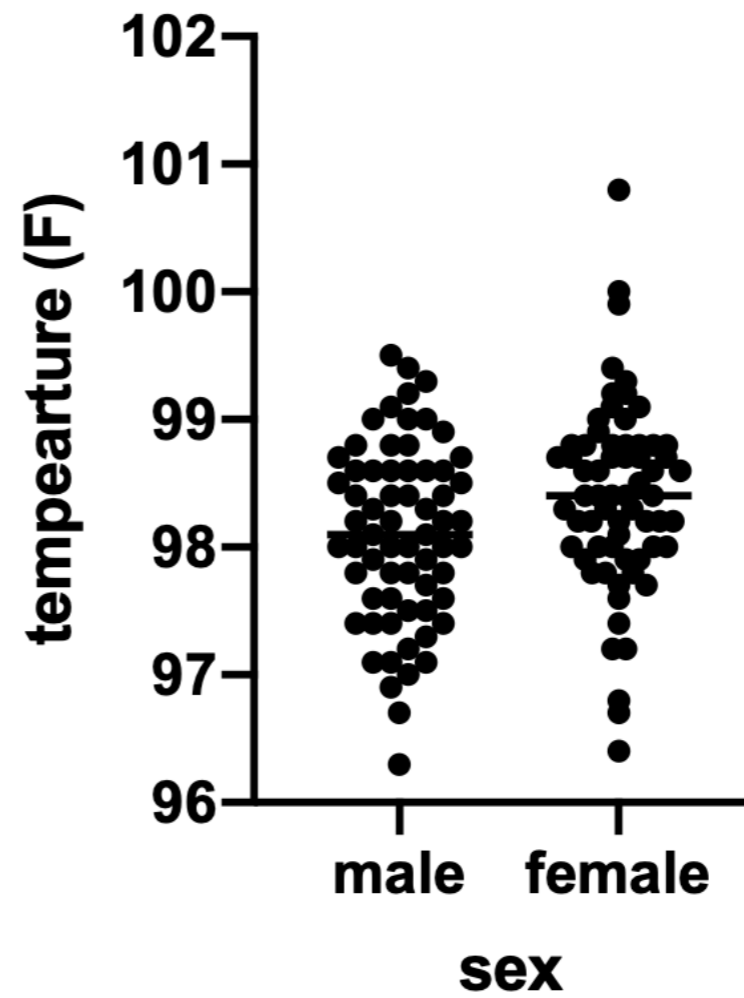
Row 1, Column A



- Search
- ▼ Data Tables >>
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- Family >>
 - Data 1
 - Data 1

Data 1



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Unpaired t test of Data 1

+ New Analysis...

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Data 1

QQ plot: Unpaired t test of Data 1

Mean diff. CI plot: Unpaired t test of

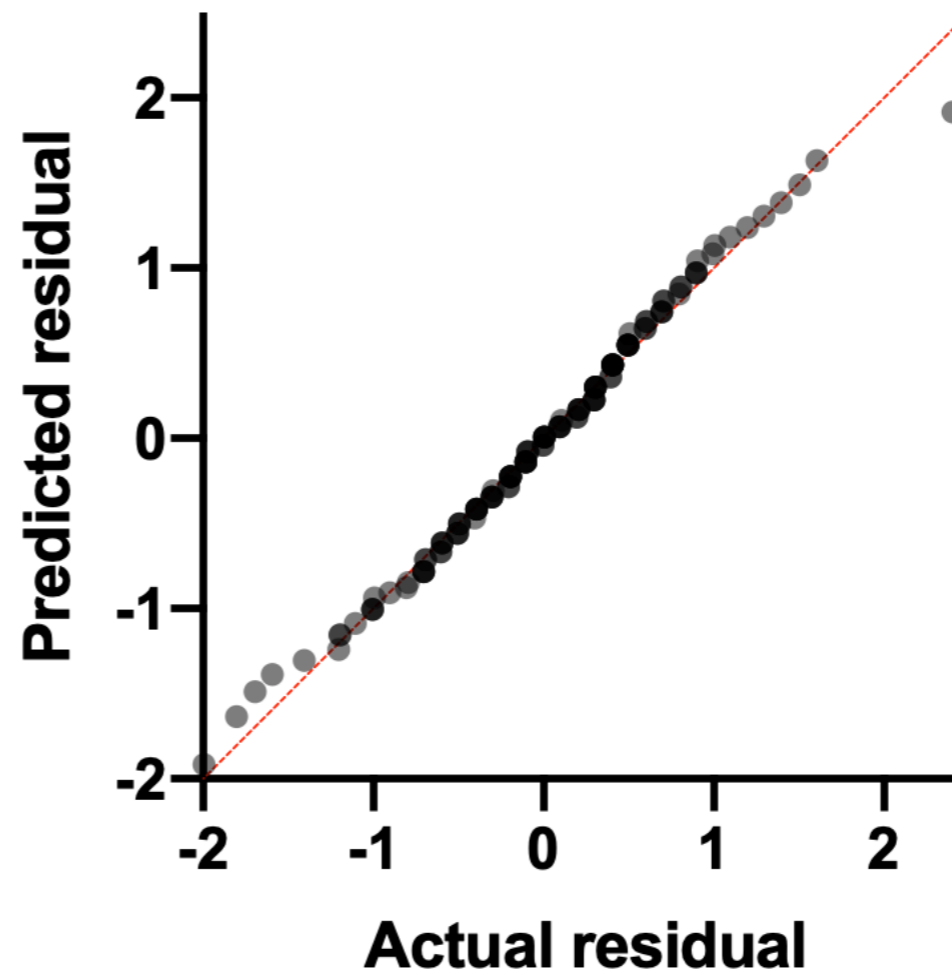
Family >>

Data 1

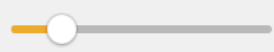
Unpaired t test

QQ plot: Unpaired t test of Data 1

QQ plot



QQ plot: Unpaired t test of D



Search

▼ Data Tables >>

Data 1

+ New Data Table...

▼ Info >>

Project info 1

+ New Info...

▼ Results >>

Unpaired t test of Data 1

+ New Analysis...

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Data 1

QQ plot: Unpaired t test of Data 1

Mean diff. CI plot: Unpaired t test

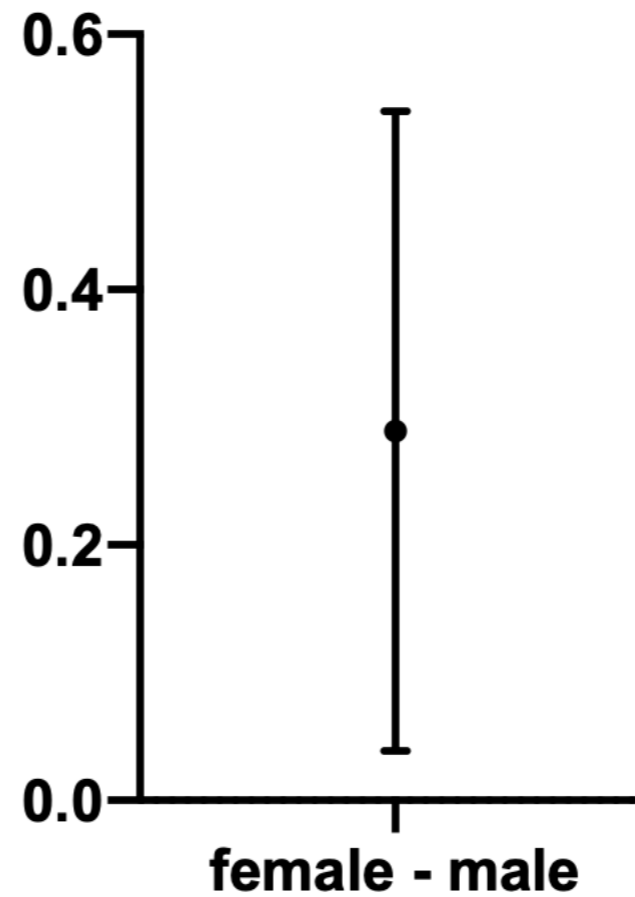
Family >>

Data 1

Unpaired t test

Mean diff. CI plot: Unpaired t test

Difference between means



Mean diff. CI plot: Unpaired t

