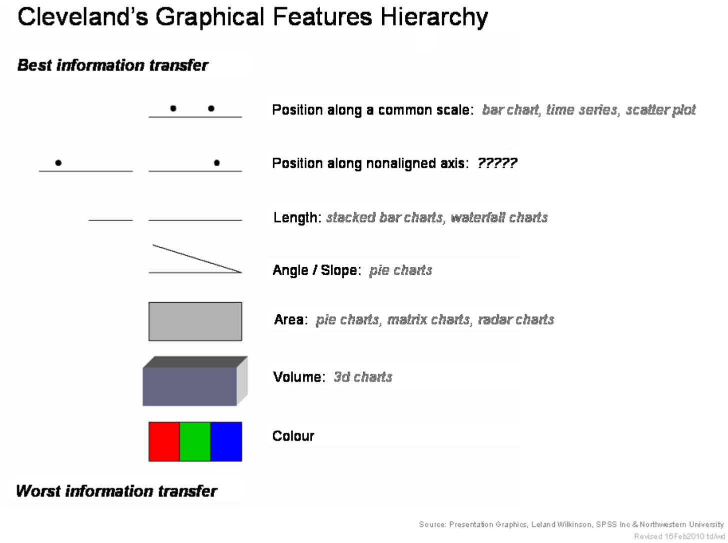
Cleveland’s hierarchy



Cleveland’s Graphical Features Hierarchy

Best information transfer

Position along a common scale: *bar chart, time series, scatter plot*

Position along nonaligned axis: *?????*

Length: *stacked bar charts, waterfall charts*

Angle / Slope: *pie charts*

Area: *pie charts, matrix charts, radar charts*

Volume: *3d charts*

Colour

Worst information transfer

Source: Presentation Graphics, Leland Wilkinson, SPSS Inc & Northwestern University
Revised 16Feb2010 td/wd

http://sfew.websitetoolbox.com/post/clevelands-graphical-features-hierarchy-4598555

Outline

Scales

- Anchors
- Transformations

Exploring data

Bivariate data

Scales

- The top of the hierarchy involves putting things on scales

Scales

- The top of the hierarchy involves putting things on scales
- But what scale do we use?

Scales

- The top of the hierarchy involves putting things on scales
- But what scale do we use?
  - Are our data anchored to zero?

Scales

- The top of the hierarchy involves putting things on scales
- But what scale do we use?
    - Are our data anchored to zero?
        - If so, are we interested in differences or ratios?

Scales

- The top of the hierarchy involves putting things on scales
- But what scale do we use?
  - Are our data anchored to zero?
    - If so, are we interested in differences or ratios?
  - Are they anchored somewhere else?

Scales

- The top of the hierarchy involves putting things on scales
- But what scale do we use?
  - Are our data anchored to zero?
    - If so, are we interested in differences or ratios?
  - Are they anchored somewhere else?

Outline

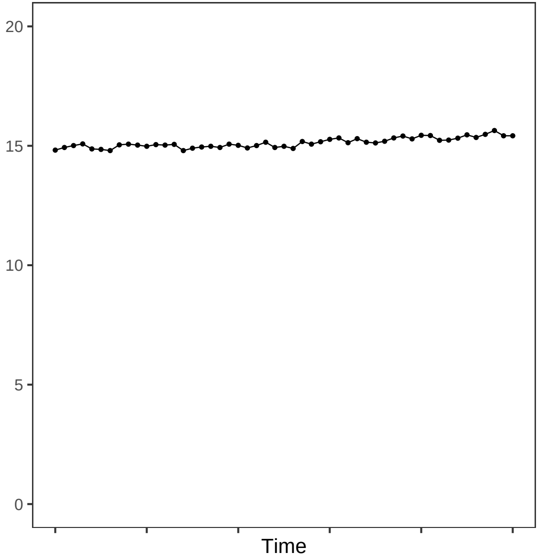
Scales

- Anchors
- Transformations

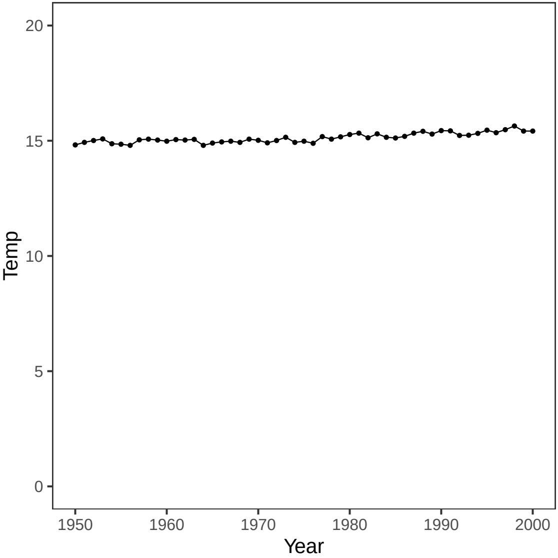
Exploring data

Bivariate data

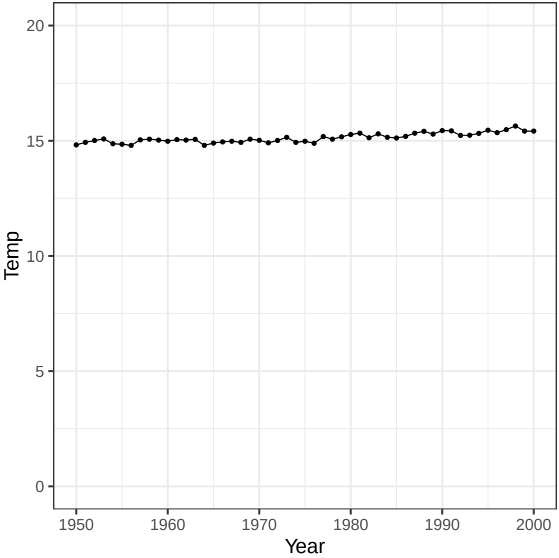
Golem bait call



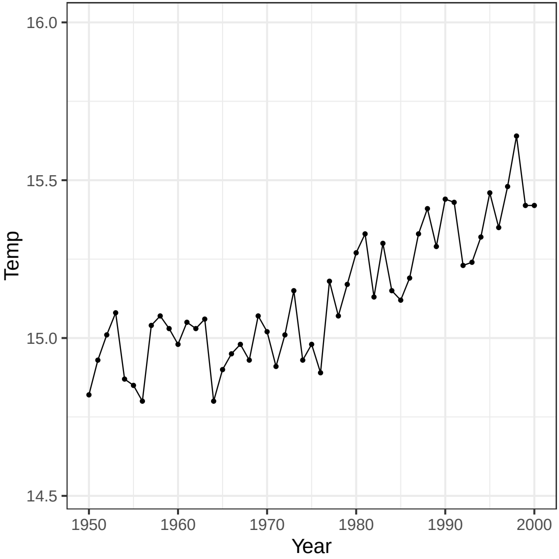
Global climate



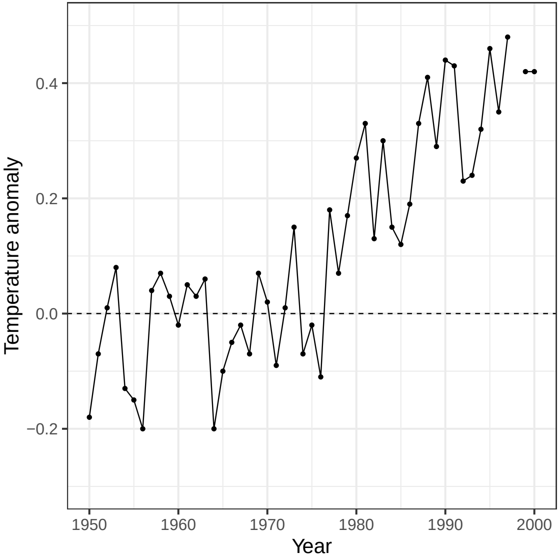
Global climate



Global climate



Global climate



Climate lessons

- Choosing an anchor is a scientific decision

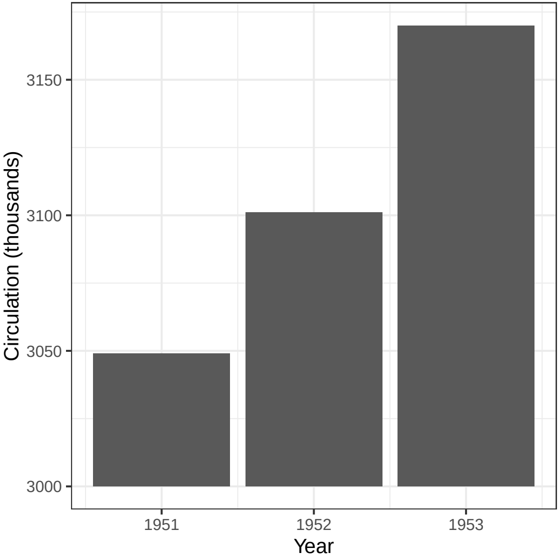
Climate lessons

- Choosing an anchor is a scientific decision
- Remember: graphic design is communication

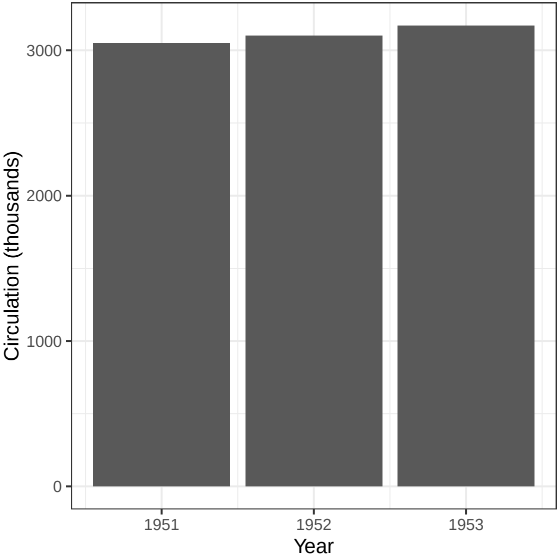
Climate lessons

- Choosing an anchor is a scientific decision
- Remember: graphic design is communication

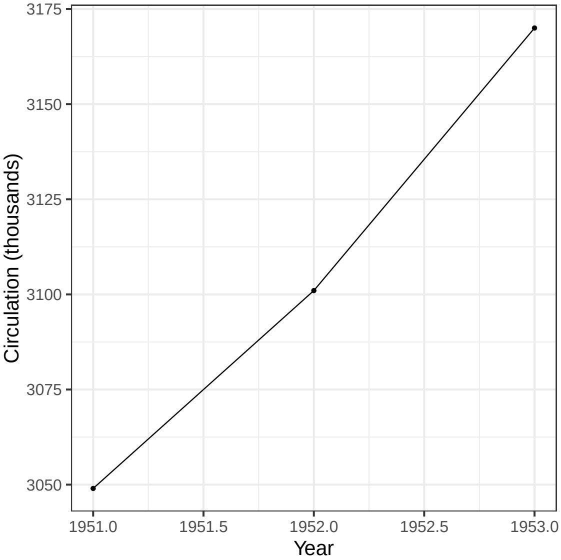
Magazine circulation (advertisement)



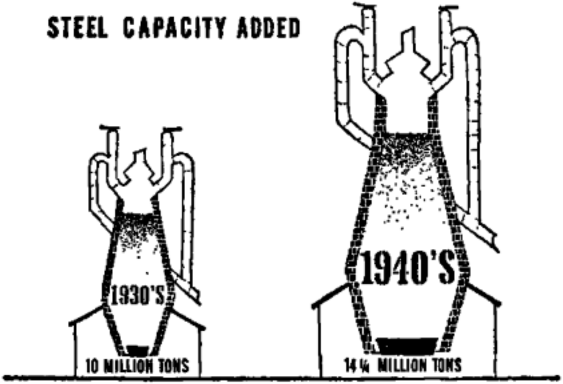
Magazine circulation (absolute amount)



Magazine circulation (trend)



Area and volume



Adapted by courtesy of STEELWAYS.

How to Lie with Statistics

Advertisement lessons

- Use area to indicate fair comparisons

Advertisement lessons

- Use area to indicate fair comparisons
  - On a physical scale

Advertisement lessons

- Use area to indicate fair comparisons
  - On a physical scale
- Areas that can be compared linearly should be preferred

Advertisement lessons

- Use area to indicate fair comparisons
  - On a physical scale
- Areas that can be compared linearly should be preferred
  - Depends on importance of feature

Advertisement lessons

- Use area to indicate fair comparisons
  - On a physical scale
- Areas that can be compared linearly should be preferred
  - Depends on importance of feature
- Avoid using (or hinting at) volume

Advertisement lessons

- Use area to indicate fair comparisons
  - On a physical scale
- Areas that can be compared linearly should be preferred
  - Depends on importance of feature
- Avoid using (or hinting at) volume

Outline

Scales

- Anchors
- Transformations

Exploring data

Bivariate data

Physical quantities

- 1 is to 10 as 10 is to what?

Physical quantities

- 1 is to 10 as 10 is to what?
  - *

Physical quantities

- 1 is to 10 as 10 is to what?
    - * If you said 19, you are thinking on a linear scale

Physical quantities

- 1 is to 10 as 10 is to what?
  - * If you said 19, you are thinking on a linear scale
  - *

Physical quantities

- 1 is to 10 as 10 is to what?
  - * If you said 19, you are thinking on a linear scale
  - * If you said 100, you are thinking on a log scale

Physical quantities

- 1 is to 10 as 10 is to what?
  - * If you said 19, you are thinking on a linear scale
  - * If you said 100, you are thinking on a log scale
- The log scale is often good for physical quantities:

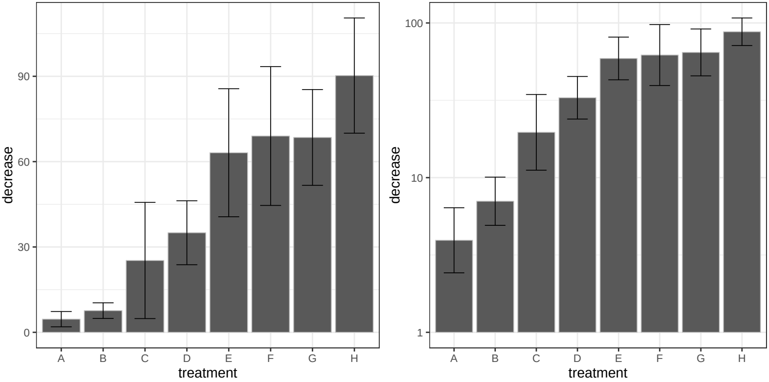
Physical quantities

- 1 is to 10 as 10 is to what?
  - * If you said 19, you are thinking on a linear scale
  - * If you said 100, you are thinking on a log scale
- The log scale is often good for physical quantities:
  - When zero means zero

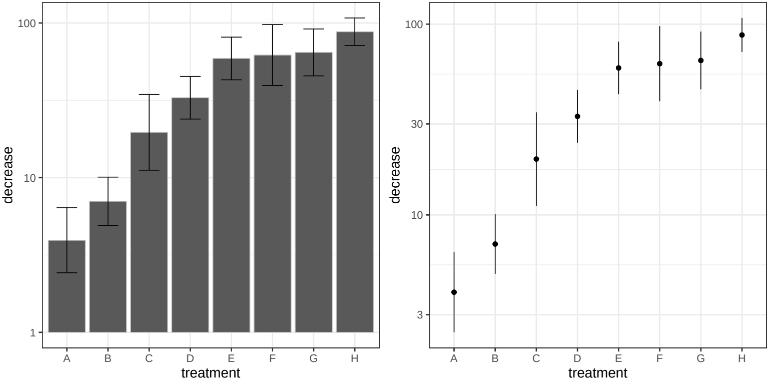
Physical quantities

- 1 is to 10 as 10 is to what?
  - * If you said 19, you are thinking on a linear scale
  - * If you said 100, you are thinking on a log scale
- The log scale is often good for physical quantities:
  - When zero means zero

Log vs. linear



Making room



100
10
1
decrease
A
B
C
D
E
F
G
H
treatment
100
30
10
3
decrease
A
B
C
D
E
F
G
H
treatment

Data shape

- There are a lot of different ways to show data shape

Data shape

- There are a lot of different ways to show data shape
- Choices will depend on your data set:

Data shape

- There are a lot of different ways to show data shape
- Choices will depend on your data set:
  - Overall size

Data shape

- There are a lot of different ways to show data shape
- Choices will depend on your data set:
  - Overall size
  - Number of replicates

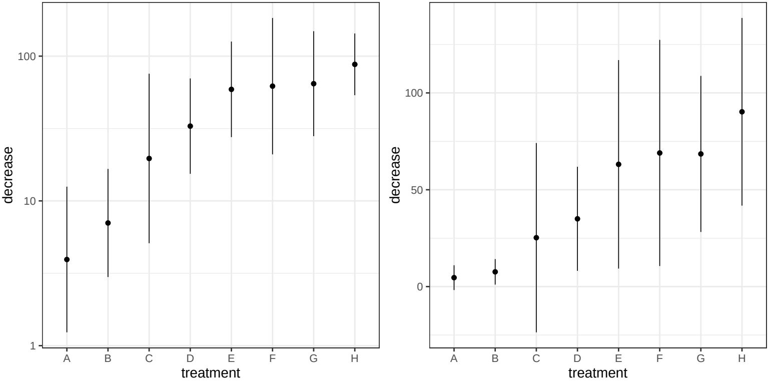
Data shape

- There are a lot of different ways to show data shape
- Choices will depend on your data set:
  - Overall size
  - Number of replicates
  - Number of levels, predictor variables, etc.

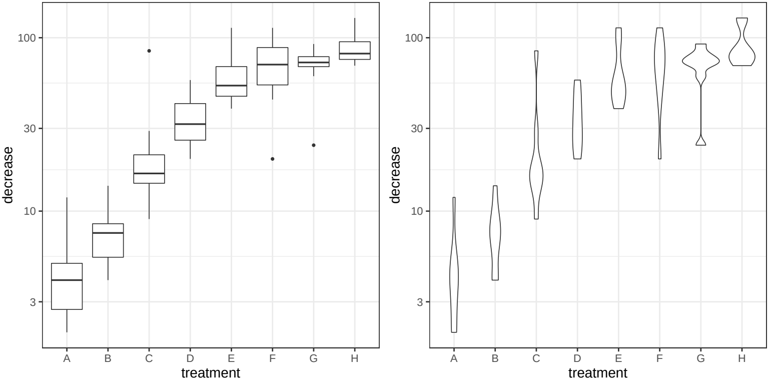
Data shape

- There are a lot of different ways to show data shape
- Choices will depend on your data set:
  - Overall size
  - Number of replicates
  - Number of levels, predictor variables, etc.

Different scales



More detail


100
30
10
3
decrease
A
B
C
D
E
F
G
H
treatment
100
30
10
3
decrease
A
B
C
D
E
F
G
H
treatment

Orchard lessons

- Choices about log vs. linear scale are scientific choices

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data
- You can also make choices about

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data
- You can also make choices about
  - sending a simple message

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data
- You can also make choices about
  - sending a simple message
  - providing more information about shape

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data
- You can also make choices about
  - sending a simple message
  - providing more information about shape
- Log scales are almost never physical

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data
- You can also make choices about
  - sending a simple message
  - providing more information about shape
- Log scales are almost never physical
  - Don't mislead with area information on a log scale

Orchard lessons

- Choices about log vs. linear scale are scientific choices
  - Neither is more valid, or closer to the data
- You can also make choices about
  - sending a simple message
  - providing more information about shape
- Log scales are almost never physical
  - Don't mislead with area information on a log scale

Probabilities

- 1% is to 2% as 50% is to what?

Probabilities

- 1% is to 2% as 50% is to what?
    - *

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - *

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large
- The natural distance to use on a probability scale is log odds

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large
- The natural distance to use on a probability scale is log odds
  - *

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large
- The natural distance to use on a probability scale is log odds
  - * 1% is to 2% as 50% is to 67%

Probabilities

- 1% is to 2% as 50% is to what?
    - * 51% is way too small
    - * 100% is way too large
- The natural distance to use on a probability scale is log odds
    - * 1% is to 2% as 50% is to 67%
    - *

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large
- The natural distance to use on a probability scale is log odds
  - * 1% is to 2% as 50% is to 67%
  - * . . . as 2% is to 4%

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large
- The natural distance to use on a probability scale is log odds
  - * 1% is to 2% as 50% is to 67%
  - * . . . as 2% is to 4%
  - *

Probabilities

- 1% is to 2% as 50% is to what?
  - * 51% is way too small
  - * 100% is way too large
- The natural distance to use on a probability scale is log odds
  - * 1% is to 2% as 50% is to 67%
  - * . . . as 2% is to 4%
  - * . . . as 98% is to 99%

Probabilities

- 1% is to 2% as 50% is to what?
    - * 51% is way too small
    - * 100% is way too large
- The natural distance to use on a probability scale is log odds
    - * 1% is to 2% as 50% is to 67%
    - * . . . as 2% is to 4%
    - * . . . as 98% is to 99%

Odds

- Odds are a ratio between the probability of something and the probability of its opposite:

Odds

- Odds are a ratio between the probability of something and the probability of its opposite:
  - $o = p/(1 - p)$

Odds

- Odds are a ratio between the probability of something and the probability of its opposite:
  - $o = p/(1-p)$
- Log odds give a natural distance on probability space

Odds

- Odds are a ratio between the probability of something and the probability of its opposite:
  - $o = p/(1-p)$
- Log odds give a natural distance on probability space

Extreme values

- Our transformations take extreme values to infinity.

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
    - this is like using estimated values instead of observed

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
  - this is like using estimated values instead of observed
    - rarely infinite

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
  - this is like using estimated values instead of observed
    - rarely infinite
    - matches analysis

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
    - this is like using estimated values instead of observed
        - rarely infinite
        - matches analysis
- Extend the scale (e.g., use $\log(1+x)$ instead of $\log(x)$)

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
  - this is like using estimated values instead of observed
    - rarely infinite
    - matches analysis
- Extend the scale (e.g., use $\log(1 + x)$ instead of $\log(x)$)
  - This usually involves arbitrary choices

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
  - this is like using estimated values instead of observed
    - rarely infinite
    - matches analysis
- Extend the scale (e.g., use $\log(1+x)$ instead of $\log(x)$)
  - This usually involves arbitrary choices
  - Should often be *avoided* for analysis

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
  - this is like using estimated values instead of observed
    - rarely infinite
    - matches analysis
- Extend the scale (e.g., use $\log(1+x)$ instead of $\log(x)$)
  - This usually involves arbitrary choices
  - Should often be *avoided* for analysis
  - But can be good for visualization

Extreme values

- Our transformations take extreme values to infinity.
- Use link functions
  - this is like using estimated values instead of observed
    - rarely infinite
    - matches analysis
- Extend the scale (e.g., use $\log(1+x)$ instead of $\log(x)$)
  - This usually involves arbitrary choices
  - Should often be *avoided* for analysis
  - But can be good for visualization

Outline

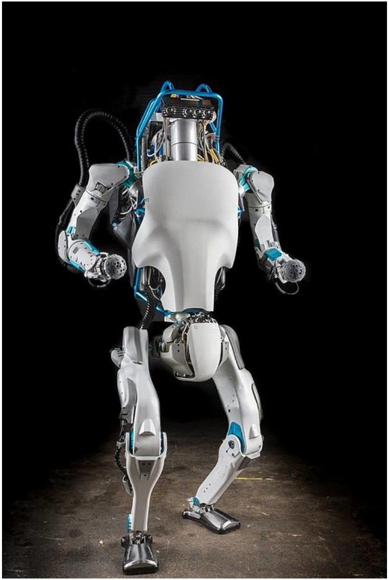
Scales

- Anchors
- Transformations

Exploring data

Bivariate data

Rote analysis vs. snooping



Spurious correlations

There's a whole website about this

What can you do?

The best you can

- Identify scientific questions

What can you do?

The best you can

- Identify scientific questions
- Distinguish between exploratory and confirmatory analysis

What can you do?

The best you can

- Identify scientific questions
- Distinguish between exploratory and confirmatory analysis
- Pre-register studies when possible

What can you do?

The best you can

- Identify scientific questions
- Distinguish between exploratory and confirmatory analysis
- Pre-register studies when possible
- Keep an exploration and analysis journal

What can you do?

The best you can

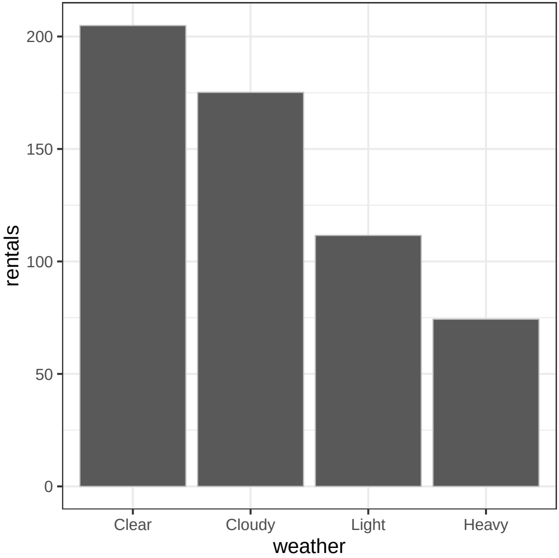
- Identify scientific questions
- Distinguish between exploratory and confirmatory analysis
- Pre-register studies when possible
- Keep an exploration and analysis journal
- Explore predictors and responses separately at first

What can you do?

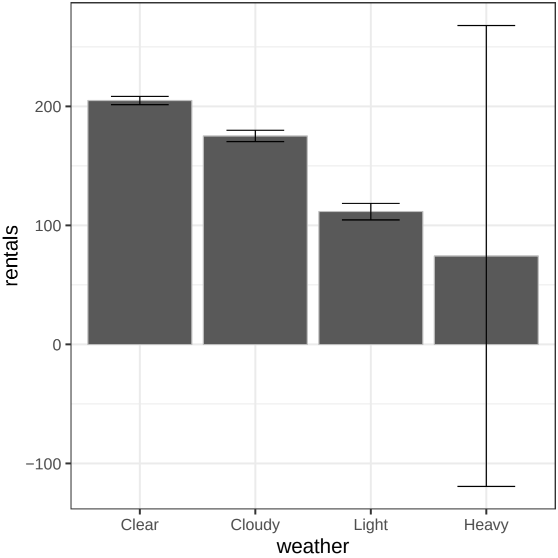
The best you can

- Identify scientific questions
- Distinguish between exploratory and confirmatory analysis
- Pre-register studies when possible
- Keep an exploration and analysis journal
- Explore predictors and responses separately at first

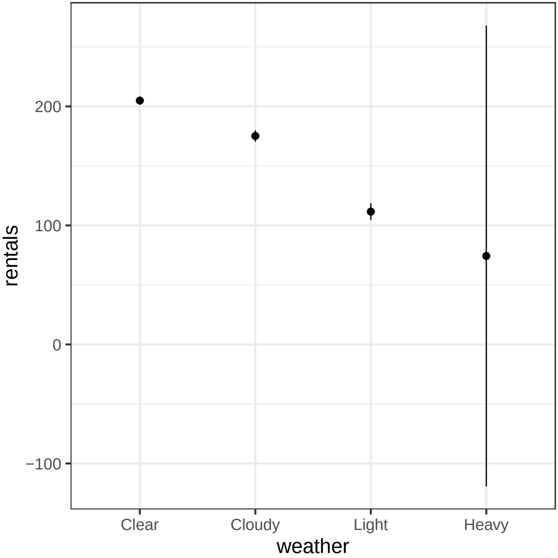
Bike example



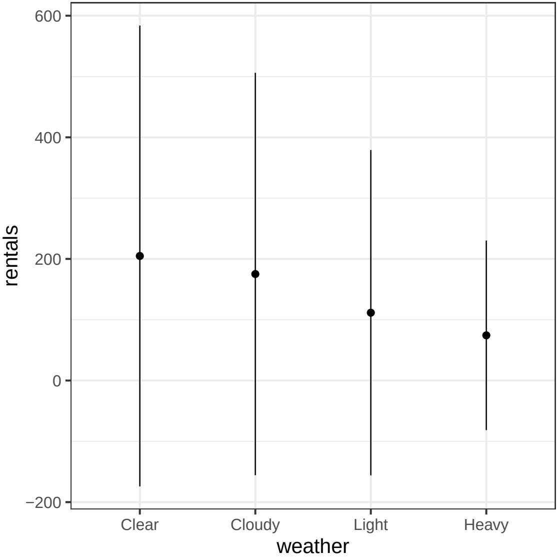
Standard errors



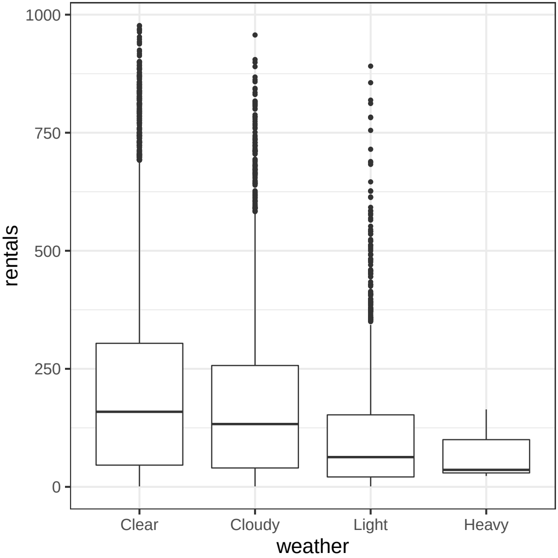
Standard errors



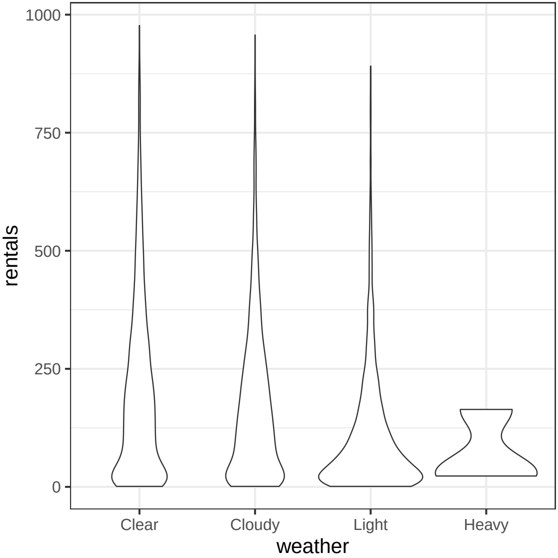
Standard deviations



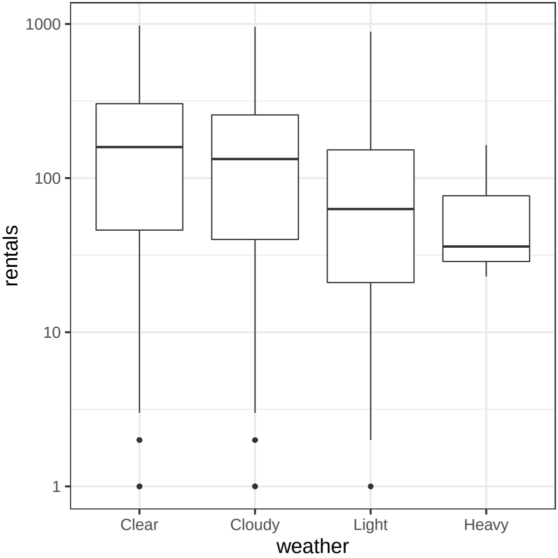
Data shape



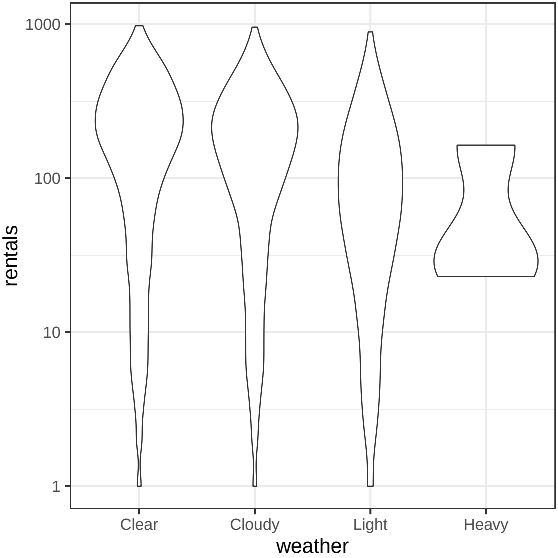
Data shape



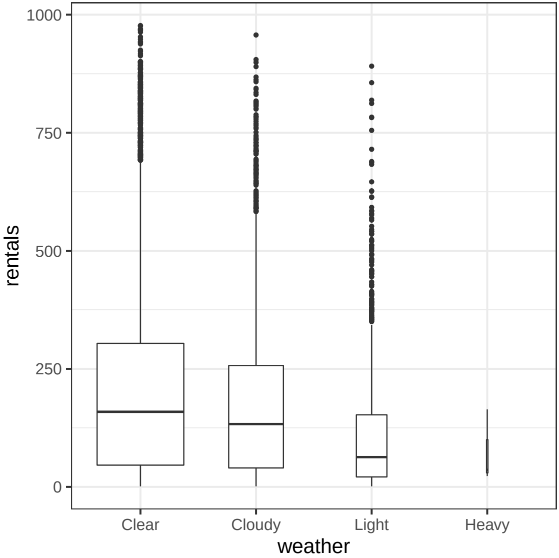
Data shape



Data shape



Data shape and weight



Log scales

- In general:

Log scales

- In general:
  - If your logged data span $<$ 3 decades, use human-readable numbers (e.g., 10-5000 kilotons per hectare)

Log scales

- In general:
  - If your logged data span $<$ 3 decades, use human-readable numbers (e.g., 10-5000 kilotons per hectare)
  - If not, just embrace "logs" (log10 particles per ul is from 3–8)

Log scales

- In general:
  - If your logged data span <3 decades, use human-readable numbers (e.g., 10-5000 kilotons per hectare)
  - If not, just embrace “logs” (log10 particles per ul is from 3–8)
    - But remember these are not physical values

Log scales

- In general:
  - If your logged data span <3 decades, use human-readable numbers (e.g., 10-5000 kilotons per hectare)
  - If not, just embrace “logs” (log10 particles per ul is from 3–8)
    - But remember these are not physical values
- I love natural logs, but not as axis values

Log scales

- In general:
    - If your logged data span $<$ 3 decades, use human-readable numbers (e.g., 10-5000 kilotons per hectare)
    - If not, just embrace “logs” (log10 particles per ul is from 3–8)
        - But remember these are not physical values
- I love natural logs, but not as axis values

Outline

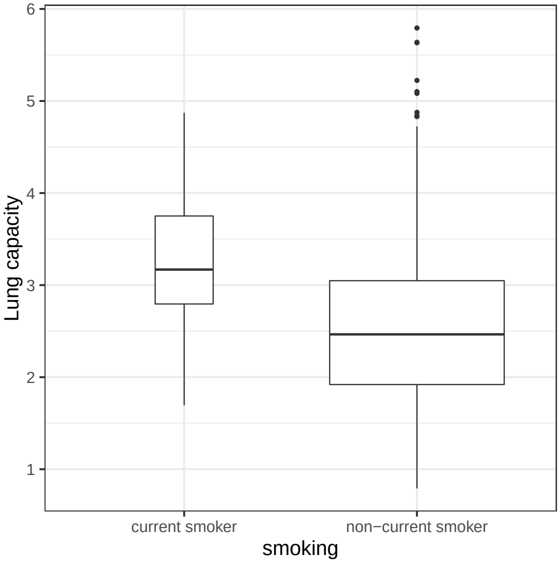
Scales

- Anchors
- Transformations

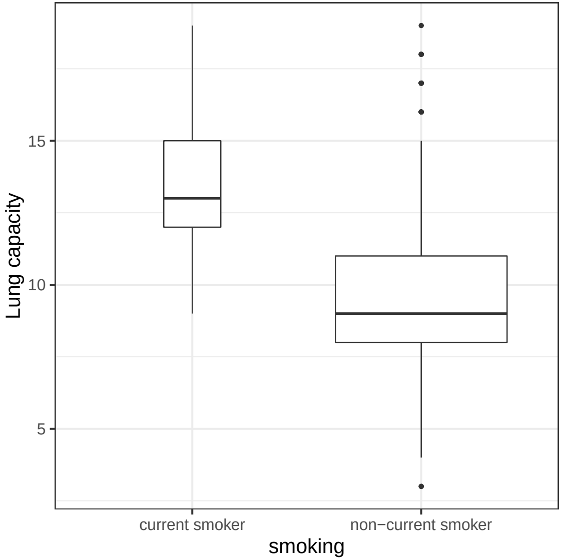
Exploring data

Bivariate data

Smoking data



Smoking data



Scatter plots

- Depending on how many data points you have, scatter plots may indicate relationships clearly

Scatter plots

- Depending on how many data points you have, scatter plots may indicate relationships clearly
- They can often be improved with trend interpolations

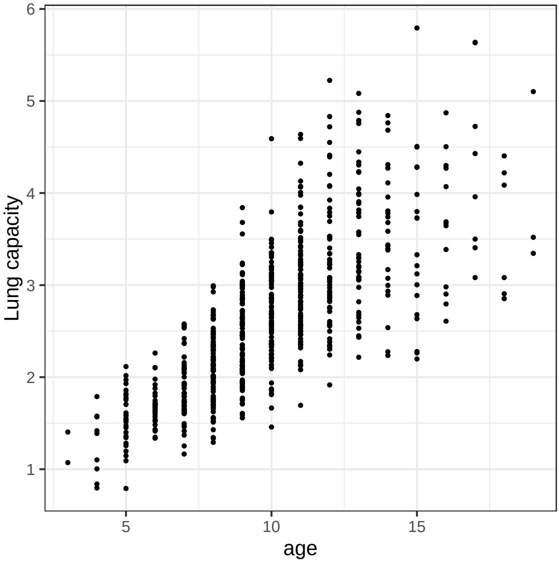
Scatter plots

- Depending on how many data points you have, scatter plots may indicate relationships clearly
- They can often be improved with trend interpolations
  - Interpolations may be particularly good for discrete responses (count or true-false)

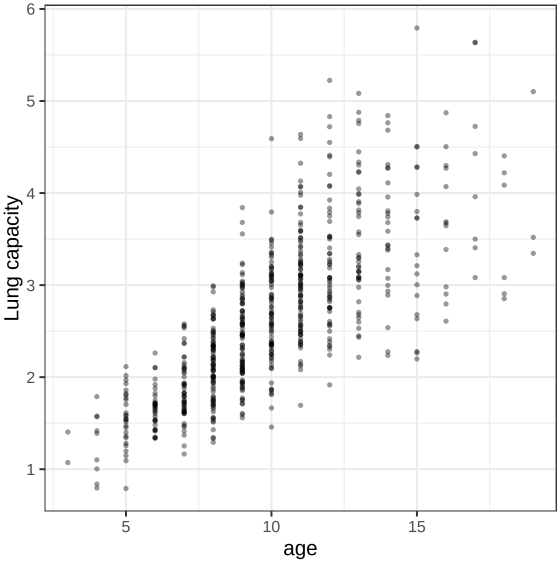
Scatter plots

- Depending on how many data points you have, scatter plots may indicate relationships clearly
- They can often be improved with trend interpolations
  - Interpolations may be particularly good for discrete responses (count or true-false)

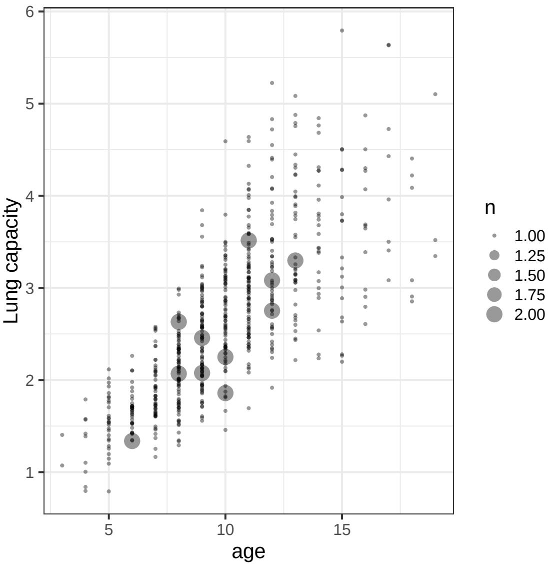
Scatter plot



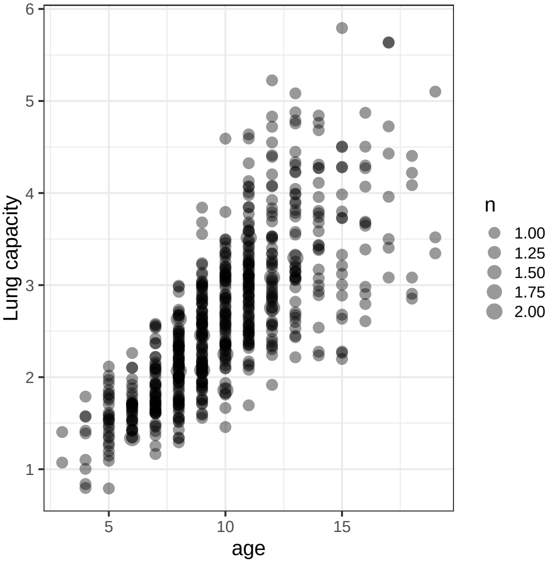
Seeing the density better



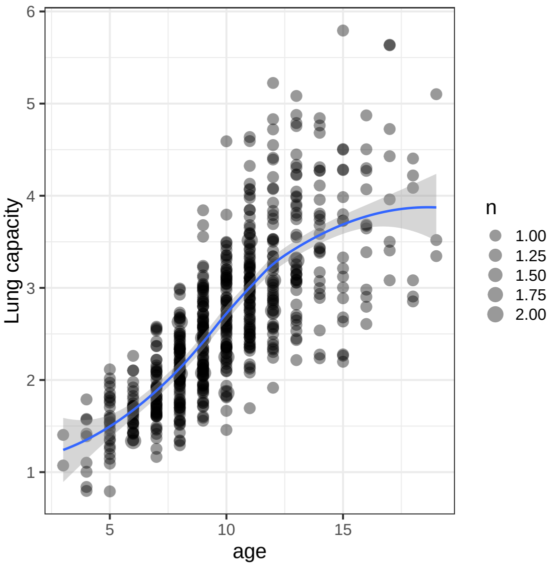
Seeing the density worse



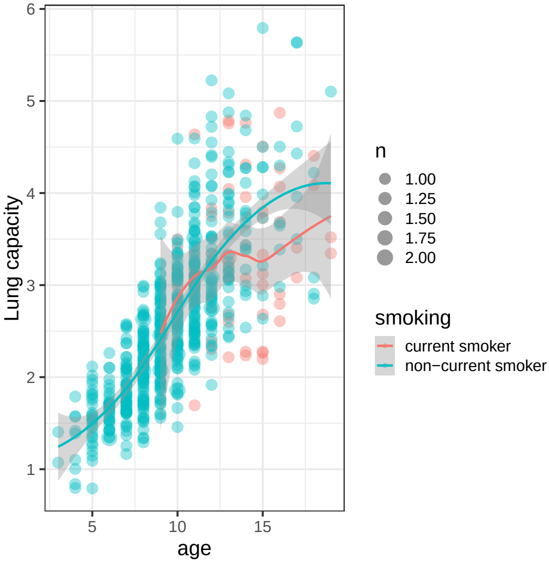
Use area in a principled way!



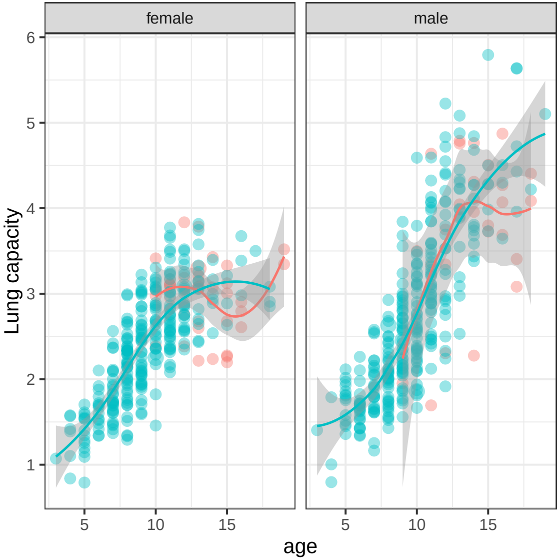
A loess trend line



Two loess trend lines



Many loess trend lines



Density plots

- Contours

Density plots

- Contours
  - use `_density_2d()` to fit a two-dimensional kernel to the density

Density plots

- Contours
  - use `_density_2d()` to fit a two-dimensional kernel to the density
- hexes

Density plots

- Contours
  - use `_density_2d()` to fit a two-dimensional kernel to the density
- hexes
  - use `geom_hex` to plot densities using hexes

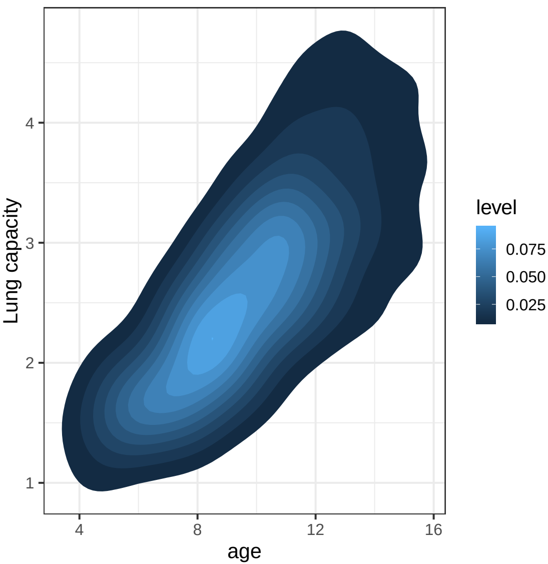
Density plots

- Contours
  - use `_density_2d()` to fit a two-dimensional kernel to the density
- hexes
  - use `geom_hex` to plot densities using hexes
  - this can also be done using rectangles for data with more discrete values

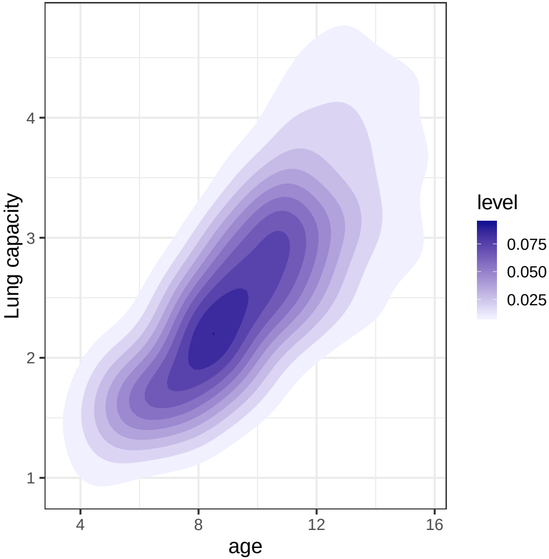
Density plots

- Contours
  - use `_density_2d()` to fit a two-dimensional kernel to the density
- hexes
  - use `geom_hex` to plot densities using hexes
  - this can also be done using rectangles for data with more discrete values

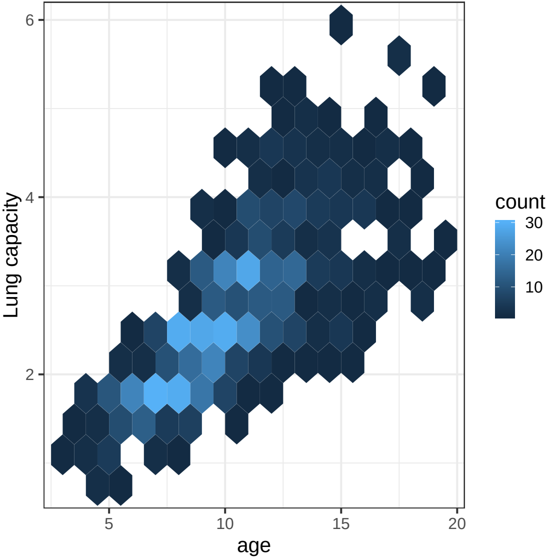
Contours



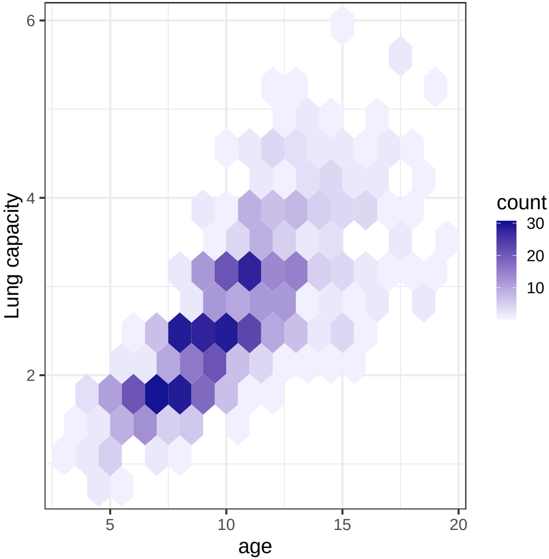
Contours



Hexes



Hexes



Color principles

- Use clear gradients

Color principles

- Use clear gradients
- If zero has a physical meaning (like density), go in just one direction

Color principles

- Use clear gradients
- If zero has a physical meaning (like density), go in just one direction
  - e.g., white to blue, white to red

Color principles

- Use clear gradients
- If zero has a physical meaning (like density), go in just one direction
  - e.g., white to blue, white to red
  - If the map contrasts with a background, zero should match the background

Color principles

- Use clear gradients
- If zero has a physical meaning (like density), go in just one direction
  - e.g., white to blue, white to red
  - If the map contrasts with a background, zero should match the background
- If there's a natural *middle*, you can use blue to white to red, or something similar

Color principles

- Use clear gradients
- If zero has a physical meaning (like density), go in just one direction
  - e.g., white to blue, white to red
  - If the map contrasts with a background, zero should match the background
- If there's a natural *middle*, you can use blue to white to red, or something similar

Principles

- Graphs tell stories better than tables do

Principles

- Graphs tell stories better than tables do
    - Use graphs to illustrate comparisons

Principles

- Graphs tell stories better than tables do
  - Use graphs to illustrate comparisons
  - Be careful about *units*

Principles

- Graphs tell stories better than tables do
  - Use graphs to illustrate comparisons
  - Be careful about *units*
- Distinguish between (scientific) variables and (statistical) parameters

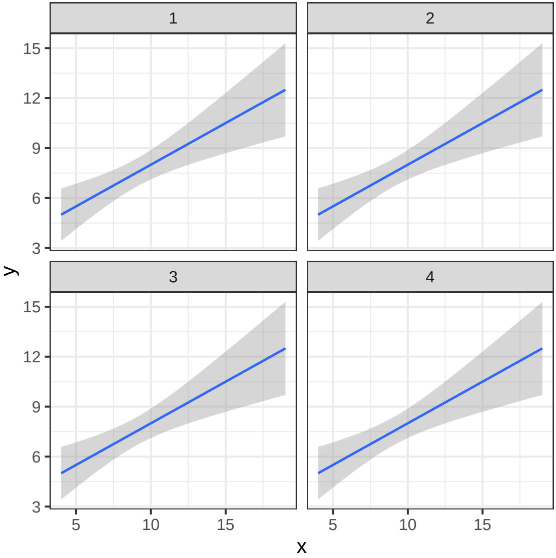
Principles

- Graphs tell stories better than tables do
  - Use graphs to illustrate comparisons
  - Be careful about *units*
- Distinguish between (scientific) variables and (statistical) parameters
- Show data when you can do it without obscuring the key patterns

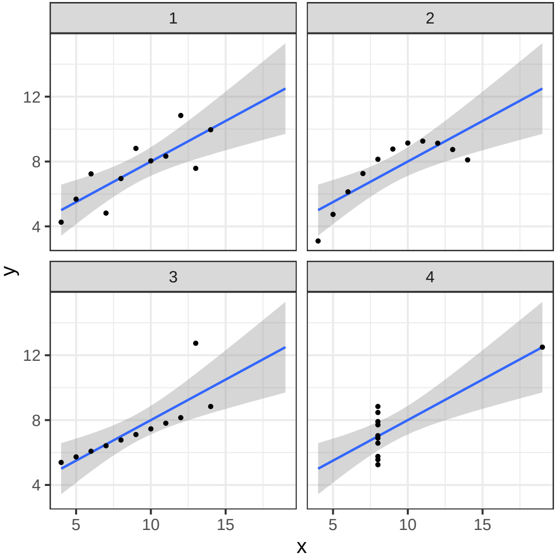
Principles

- Graphs tell stories better than tables do
  - Use graphs to illustrate comparisons
  - Be careful about *units*
- Distinguish between (scientific) variables and (statistical) parameters
- Show data when you can do it without obscuring the key patterns

Choosing what to show



Choosing what to show



Avoiding choices

- Provide users with alternatives

Avoiding choices

- Provide users with alternatives
  - Supplementary material for the curious

Avoiding choices

- Provide users with alternatives
  - Supplementary material for the curious
- Avoid choices by providing more information

Avoiding choices

- Provide users with alternatives
  - Supplementary material for the curious
- Avoid choices by providing more information
  - Use more than one figure

Avoiding choices

- Provide users with alternatives
  - Supplementary material for the curious
- Avoid choices by providing more information
  - Use more than one figure
  - Or dynamic features in figures

Avoiding choices

- Provide users with alternatives
  - Supplementary material for the curious
- Avoid choices by providing more information
  - Use more than one figure
  - Or dynamic features in figures

Conclusions

- Give thought to your goals

Conclusions

- Give thought to your goals
- Give thought to your decisions

Conclusions

- Give thought to your goals
- Give thought to your decisions
- Be conscious when you are withholding information

Conclusions

- Give thought to your goals
- Give thought to your decisions
- Be conscious when you are withholding information
  - Be willing to use more than one picture

Conclusions

- Give thought to your goals
- Give thought to your decisions
- Be conscious when you are withholding information
  - Be willing to use more than one picture
  - Use dynamic features to give access to detail

Conclusions

- Give thought to your goals
- Give thought to your decisions
- Be conscious when you are withholding information
    - Be willing to use more than one picture
    - Use dynamic features to give access to detail