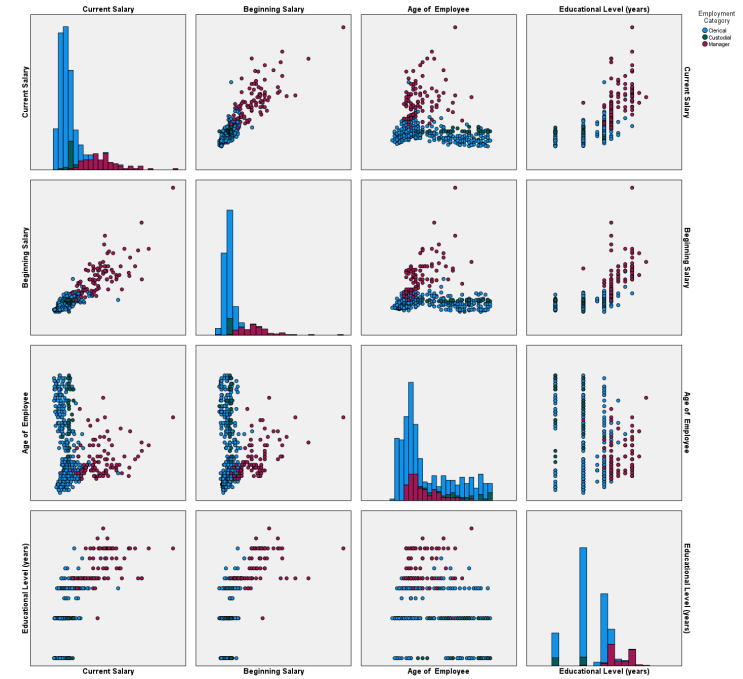


# Correlation analysis with SPSS Statistics

Jarlath Quinn – Analytics Consultant



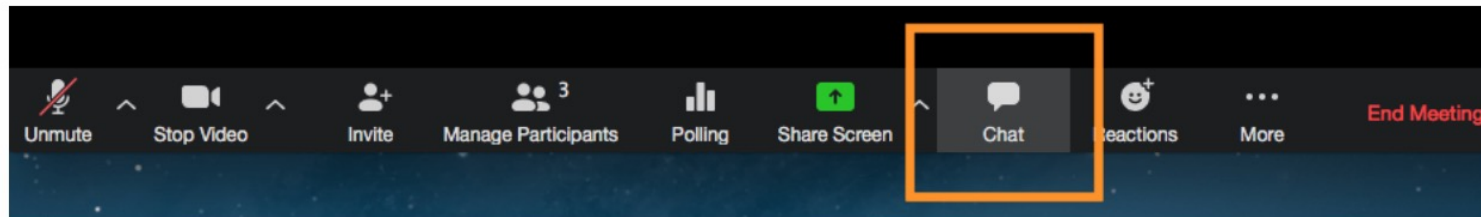
# Correlation analysis with SPSS Statistics

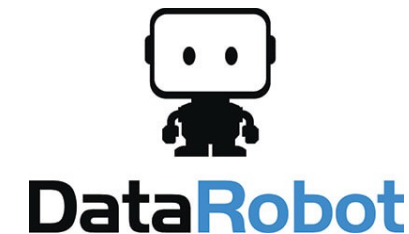
Just waiting for all attendees to join...

Jarlath Quinn – Analytics Consultant

# FAQ's

- Is this session being recorded? Yes
- Can I get a copy of the slides? Yes, we'll email links to download materials after the session has ended.
- Can we arrange a re-run for colleagues? Yes, just ask us.
- How can I ask questions? All lines are muted so please use the chat panel – if we run out of time, we will follow up with you.





- Gold accredited partner to IBM, Predictive Solutions and DataRobot specialising in advanced analytics & big data technologies
- Work with open source technologies (R, Python, Spark etc.)
- Team each has 15 to 30 years of experience working in the advanced and predictive analytics industry

- Deep experience of applied advanced analytics applications across sectors
  - Retail
  - Gaming
  - Utilities
  - Insurance
  - Telecommunications
  - Media
  - FMCG



# Agenda

- Why are correlation values useful?
- Interpreting correlation coefficients
- Estimating correlation values with bootstrapping techniques
- Automatically highlighting strong correlations
- How correlations are calculated
- Non-parametric correlations
- The limitations of correlations



**Correlations**

|                           |                     | Current Salary |
|---------------------------|---------------------|----------------|
| Educational Level (years) | Pearson Correlation | .661**         |
|                           | Sig. (2-tailed)     | <.001          |
|                           | N                   | 474            |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

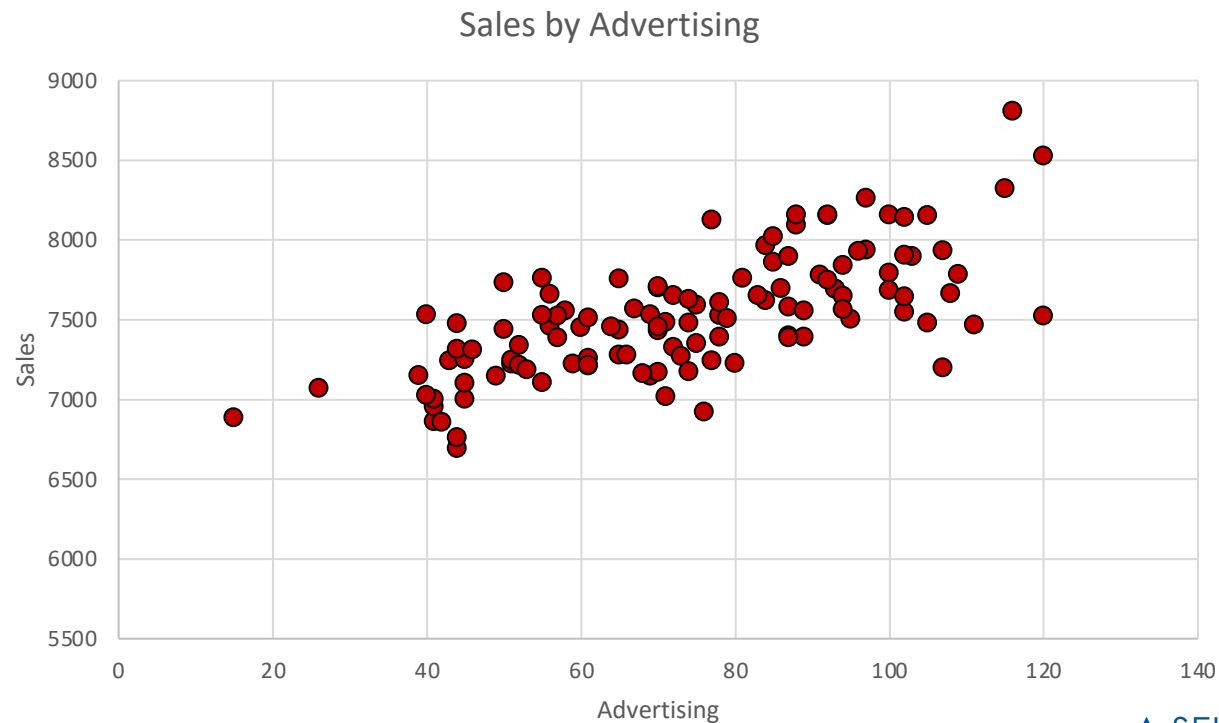
# Why are correlations useful?

# Why use correlations?

- Correlation is a term that we employ in everyday speech to denote things that *appear* to have some kind of relationship
- In analytics, correlations are specific values that are calculated in order to quantify the relationships between variables
- This kind of analysis is powerful because, it allows us to detect and measure the strength of linear associations between an near infinite range of factors, such as:
  - Advertising spend and website hits
  - Product sales and competitor pricing
  - Vibration and component part failure
  - Rainfall and pollution
  - Study time and examination grade
  - Exercise and weight loss
  - Government spending and population health outcomes

# The gateway to prediction

- Not only can we measure a linear relationship with correlation, but we can also use one variable to predict the other
- For example, if we know how much we're planning to increase our spend on advertising then we can use correlation to accurately predict what the increase in visitors to the website is likely to be.







**Correlations**

|                           |                     | Current Salary |
|---------------------------|---------------------|----------------|
| Educational Level (years) | Pearson Correlation | .661**         |
|                           | Sig. (2-tailed)     | <.001          |
|                           | N                   | 474            |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

# Interpreting correlations

# Linear Correlation Scale

+1

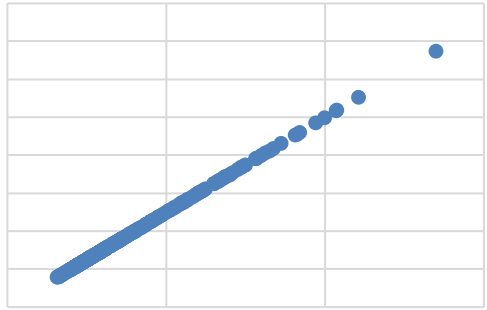
+0.5

0

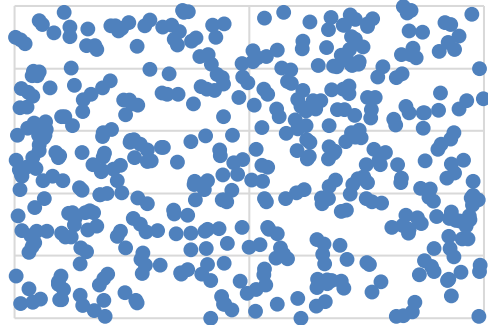
-0.5

-1

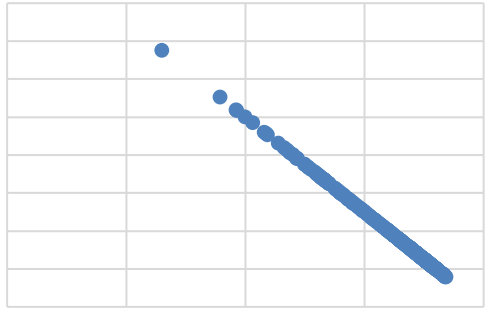
Perfect Positive Linear Relationship



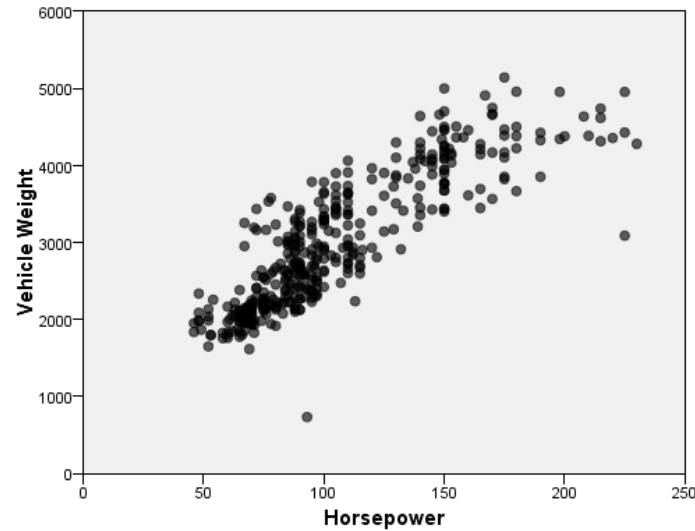
No Linear Relationship



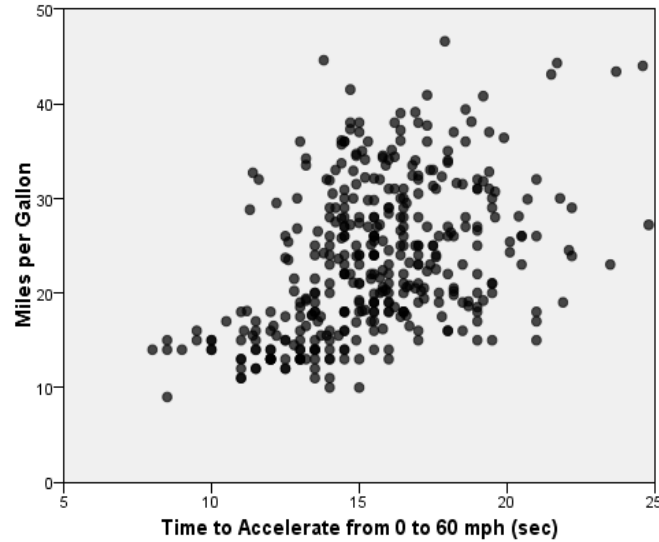
Perfect Negative Linear Relationship



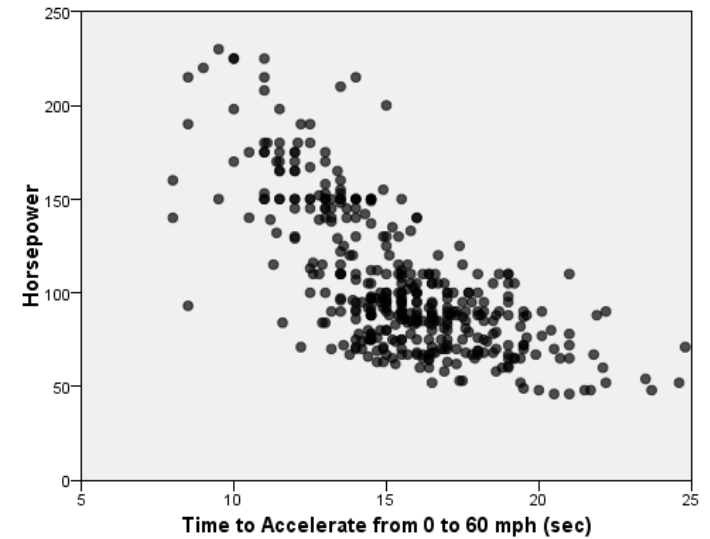
# Pearson's $r$ correlations



0.859



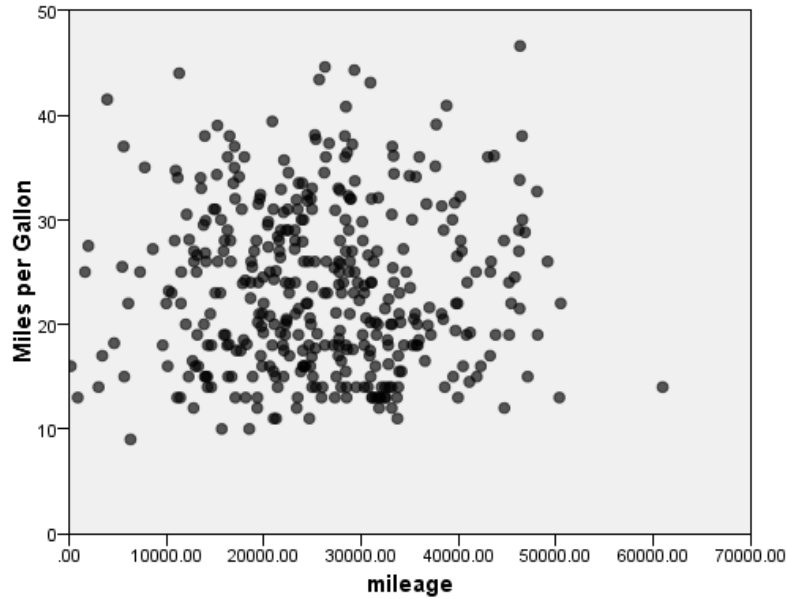
0.434



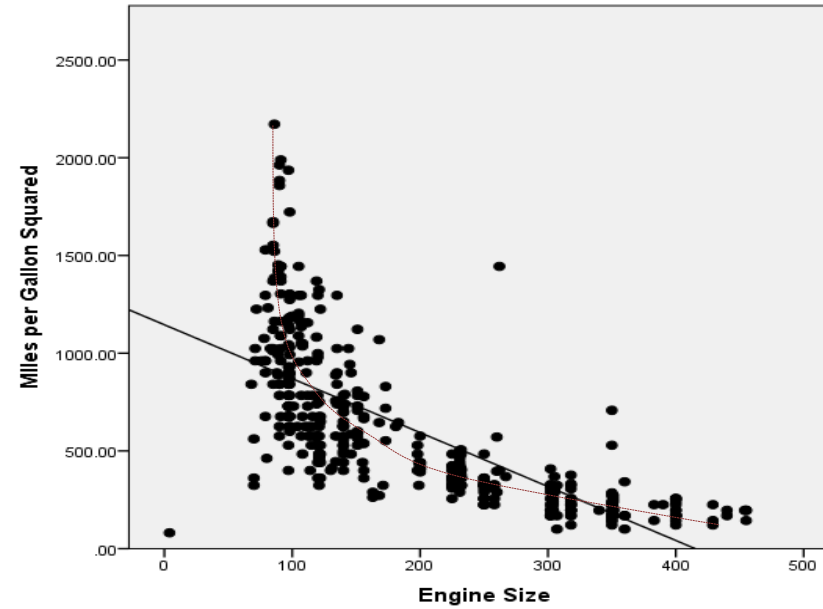
-.701

Pearson's  $r$  correlation coefficients

# Non-Linear Relationships



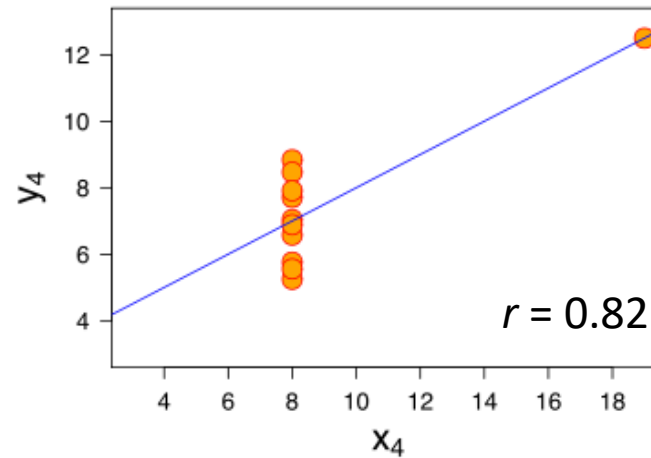
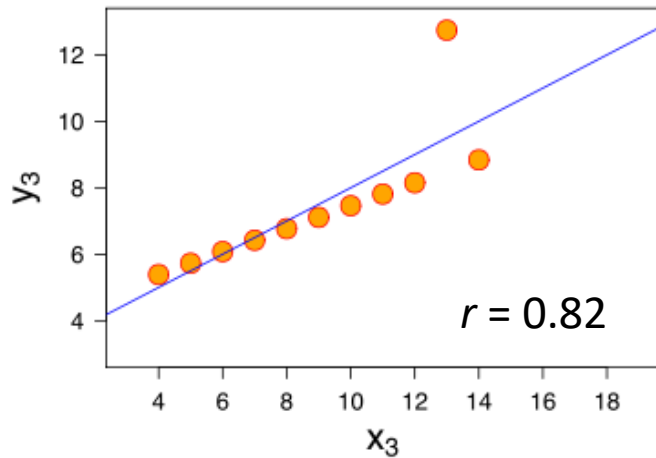
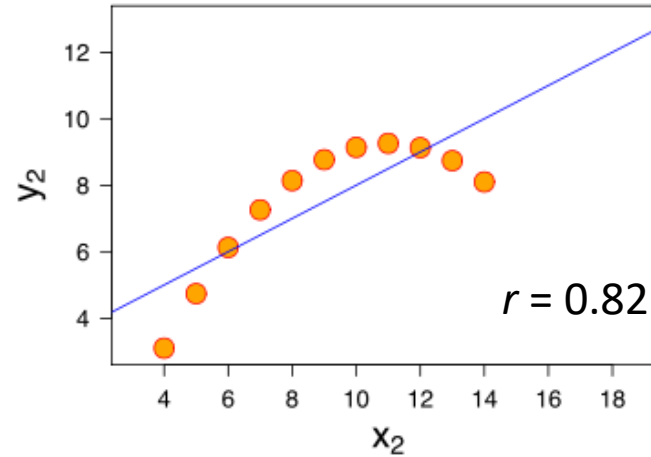
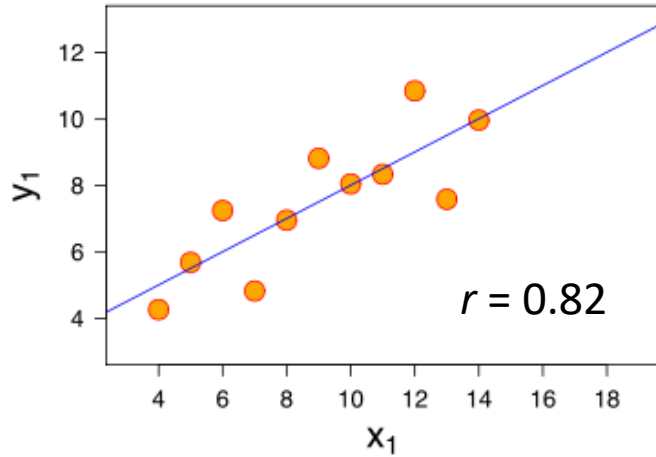
-0.005



-.671

Pearson's  $r$  Correlations

# A word of warning: always investigate the relationship



# Example SPSS Correlations

- Analyze
  - Correlate
    - Bivariate

The screenshot shows the IBM SPSS Statistics Data Editor interface. The 'Analyze' menu is open, and the 'Correlate' option is selected. The 'Bivariate' option is also highlighted. The data table below shows the following columns: id, gender, educ, jobcat, salary, and salbegin.

|    | id  | gender | educ | jobcat   | salary   | salbegin |          |         |
|----|-----|--------|------|----------|----------|----------|----------|---------|
| 1  | 434 | Male   | 16   | Clerical | \$34,950 | \$20,25  |          |         |
| 2  | 2   | Male   | 16   | Clerical | \$40,200 | \$18,75  |          |         |
| 3  | 6   | Male   | 15   | Clerical | \$32,100 | \$13,50  |          |         |
| 4  | 8   | Female | 12   | Clerical | \$21,900 | \$9,75   |          |         |
| 5  | 12  | Male   |      |          | \$28,350 | \$12,00  |          |         |
| 6  | 13  | Male   |      |          | \$27,750 | \$14,25  |          |         |
| 7  | 15  | Male   |      |          | \$27,300 | \$13,50  |          |         |
| 8  | 16  | Male   |      |          | \$40,800 | \$15,00  |          |         |
| 9  | 17  | Male   | 15   | Clerical | \$46,000 | \$14,25  |          |         |
| 10 | 19  | Male   | 12   | Clerical | \$42,300 | \$14,25  |          |         |
| 11 | 21  | Female | 16   | Clerical | \$38,850 | \$15,00  |          |         |
| 12 | 23  | Female | 15   | Clerical | \$24,000 | \$11,10  |          |         |
| 13 | 26  | Male   | 15   | Clerical | \$31,050 | \$12,60  |          |         |
| 14 | 28  | Male   | 15   | Clerical | \$32,550 | \$14,25  |          |         |
| 15 | 30  | Male   | 15   | Clerical | \$31,200 | \$14,25  |          |         |
| 16 | 31  | Male   | 12   | Clerical | \$36,150 | \$14,25  |          |         |
| 17 | 33  | Male   | 15   | Clerical | \$42,000 | \$15,00  |          |         |
| 18 | 35  | Male   |      | 08/22/61 | 17       | Manager  | \$81,250 | \$30,00 |
| 19 | 36  | Female |      | 08/27/62 | 9        | Clerical | \$34,350 | \$14,25 |

# Example SPSS Correlations

- Three variables chosen – so three pairs of correlations
  1. Current Salary x Beginning Salary
  2. Current Salary x Education Level
  3. Beginning Salary x Education Level

Bivariate Correlations

Variables:

- Current Salary [salary]
- Beginning Salary [salbegin]
- Educational Level (years) [educ]

Correlation Coefficients

Pearson  Kendall's tau-b  Spearman

Test of Significance

Two-tailed  One-tailed

Flag significant correlations  Show only the lower triangle  Show diagonal

OK Paste Reset Cancel Help

Options...  
Style...  
Bootstrap...  
Confidence interval...

# Example SPSS Correlations

**Correlations**

|                           |                     | Current Salary | Beginning Salary | Educational Level (years) |
|---------------------------|---------------------|----------------|------------------|---------------------------|
| Current Salary            | Pearson Correlation | 1              | .880**           | .661**                    |
|                           | Sig. (2-tailed)     |                | <.001            | <.001                     |
|                           | N                   | 474            | 474              | 474                       |
| Beginning Salary          | Pearson Correlation | .880**         | 1                | .633**                    |
|                           | Sig. (2-tailed)     | <.001          |                  | <.001                     |
|                           | N                   | 474            | 474              | 474                       |
| Educational Level (years) | Pearson Correlation | .661**         | .633**           | 1                         |
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|                           | N                   | 474            | 474              | 474                       |

\*\* . Correlation is significant at the 0.01 level (2-tailed).



# Example SPSS Correlations

**Correlations**

The table is a mirror image

|                           |                     | Current Salary | Beginning Salary | Educational Level (years) |
|---------------------------|---------------------|----------------|------------------|---------------------------|
| Current Salary            | Pearson Correlation | 1              | .880**           | .661**                    |
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|                           | N                   | 474            | 474              | 474                       |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

# Example SPSS Correlations

The diagonal values are all equal to one as they are the variables correlated against themselves

**Correlations**

|                           |                     | Current Salary | Beginning Salary | Educational Level (years) |
|---------------------------|---------------------|----------------|------------------|---------------------------|
| Current Salary            | Pearson Correlation | 1              | .880**           | .661**                    |
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|                           | Sig. (2-tailed)     | <.001          | <.001            |                           |
|                           | N                   | 474            | 474              | 474                       |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

# Example SPSS Correlations

The Significance values show how likely one is to get a correlation like that assuming there's no relationship between the variables

**Correlations**

|                           |                     | Current Salary | Beginning Salary | Educational Level (years) |
|---------------------------|---------------------|----------------|------------------|---------------------------|
| Current Salary            | Pearson Correlation | 1              | .880**           | .661**                    |
|                           | Sig. (2-tailed)     |                | <.001            | <.001                     |
|                           | N                   | 474            | 474              | 474                       |
| Beginning Salary          | Pearson Correlation | .880**         | 1                | .633**                    |
|                           | Sig. (2-tailed)     | <.001          |                  | <.001                     |
|                           | N                   | 474            | 474              | 474                       |
| Educational Level (years) | Pearson Correlation | .661**         | .633**           | 1                         |
|                           | Sig. (2-tailed)     | <.001          | <.001            |                           |
|                           | N                   | 474            | 474              | 474                       |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

# Example SPSS Correlations

The N values show how many cases the correlation was based on

**Correlations**

|                           |                     | Current Salary | Beginning Salary | Educational Level (years) |
|---------------------------|---------------------|----------------|------------------|---------------------------|
| Current Salary            | Pearson Correlation | 1              | .880**           | .661**                    |
|                           | Sig. (2-tailed)     |                | <.001            | <.001                     |
|                           | N                   | 474            | 474              | 474                       |
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|                           | Sig. (2-tailed)     | <.001          | <.001            |                           |
|                           | N                   | 474            | 474              | 474                       |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

# Example SPSS Correlations

- We can re-run the analysis, but this time....
  - Show only the bottom half of the matrix
  - Don't show the correlations of each variable against itself

Bivariate Correlations

Employee Code [id]  
Date of Birth [bdate]  
Employment Category [jobcat]  
Months since Hire [jobtime]  
Previous Experience (months) [prevexp]  
Minority Classification [minority]  
Age of Employee [age]

Variables:  
Current Salary [salary]  
Beginning Salary [salbegin]  
Educational Level (years) [educ]

Correlation Coefficients  
 Pearson  Kendall's tau-b  Spearman

Test of Significance  
 Two-tailed  One-tailed

Flag significant correlations  Show only the lower triangle  Show diagonal

Options...  
Style...  
Bootstrap...  
Confidence interval...  
OK Paste Reset Cancel Help

# Example SPSS Correlations

**Correlations**

|                           |                     | Current Salary     | Beginning Salary   |
|---------------------------|---------------------|--------------------|--------------------|
| Beginning Salary          | Pearson Correlation | .880 <sup>**</sup> |                    |
|                           | Sig. (2-tailed)     | <.001              |                    |
|                           | N                   | 474                |                    |
| Educational Level (years) | Pearson Correlation | .661 <sup>**</sup> | .633 <sup>**</sup> |
|                           | Sig. (2-tailed)     | <.001              | <.001              |
|                           | N                   | 474                | 474                |

<sup>\*\*</sup>. Correlation is significant at the 0.01 level (2-tailed).

# Let's explore Pearson's correlations in SPSS Statistics



$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

How is a Pearson's correlation calculated?



# Pearson's $r$ (the most well known correlation measure)

- In statistics, the **Pearson correlation coefficient** is also known as **Pearson's  $r$**  or the **Pearson product-moment** correlation coefficient
- Correlations describe data moving together
- This is a **parametric** procedure. That means it makes assumptions about the data. Strictly speaking Pearson's  $r$  assumes the following:
  - The level of measurement of the variables are continuous/scale (i.e. interval or ratio)
  - There should be no extreme outliers in the correlated variables
  - The data are normally distributed - this is not needed for a reasonable sample size

# Formula for Pearson's $r$

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

$r$  = correlation coefficient

$x_i$  = values of the x-variable in a sample

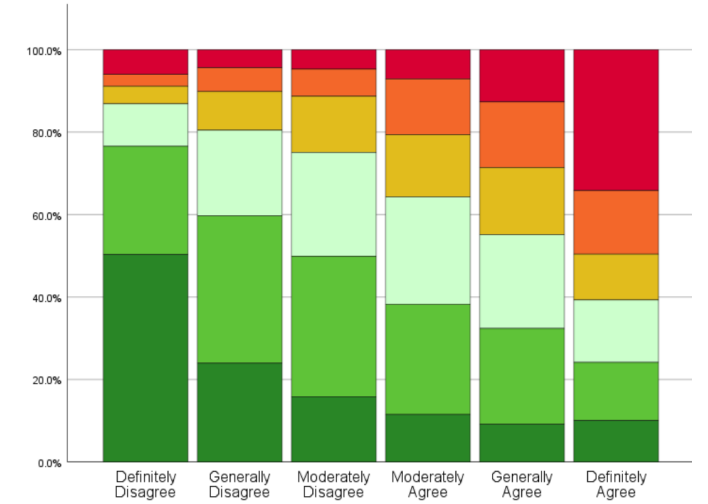
$\bar{x}$  = mean of the values of the x-variable

$y_i$  = values of the y-variable in a sample

$\bar{y}$  = mean of the values of the y-variable



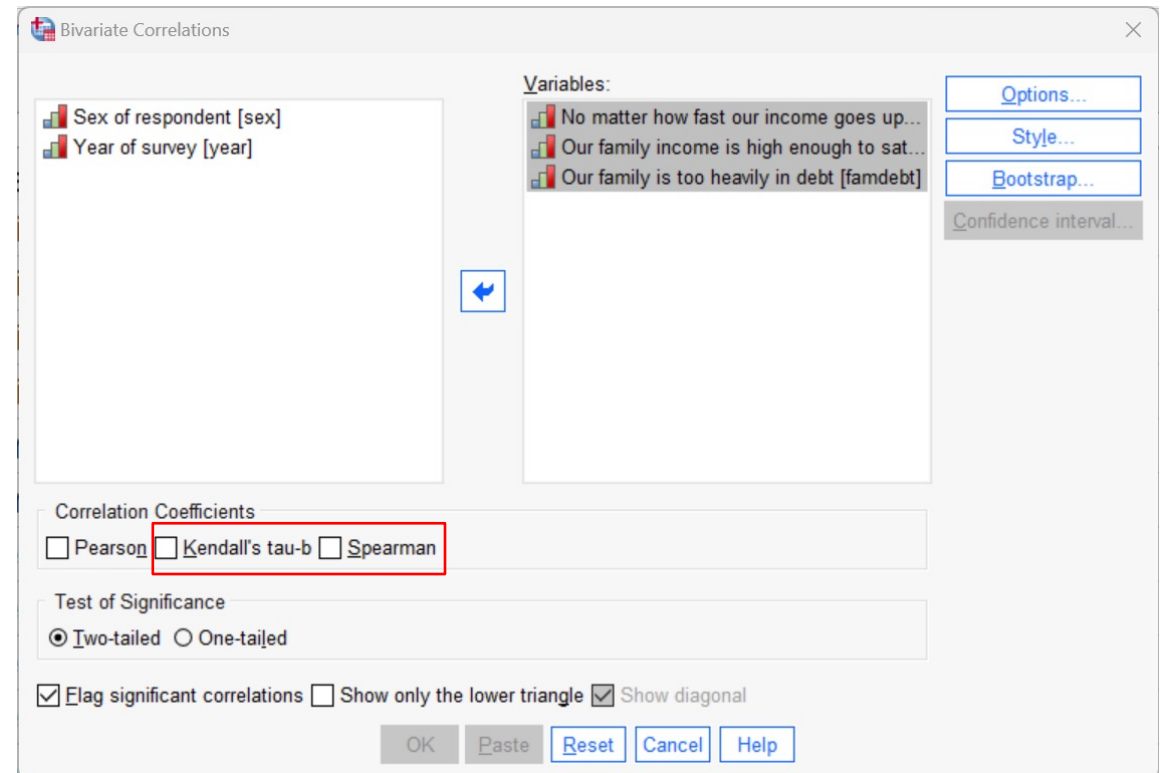
**Let's see an example of calculating  
Pearson's R**



# Correlations with rank order variables

# Correlations for Ordinal Variables

- Rank order or 'ordinal' variables refer to variables such as rating scales
- These are not true numbers, but rather ranked 'numerals'
- Two techniques exist in SPSS that deal with these kind of data
  - Spearman's Rho
  - Kendall's Tau-b
- Both are non-parametric methods

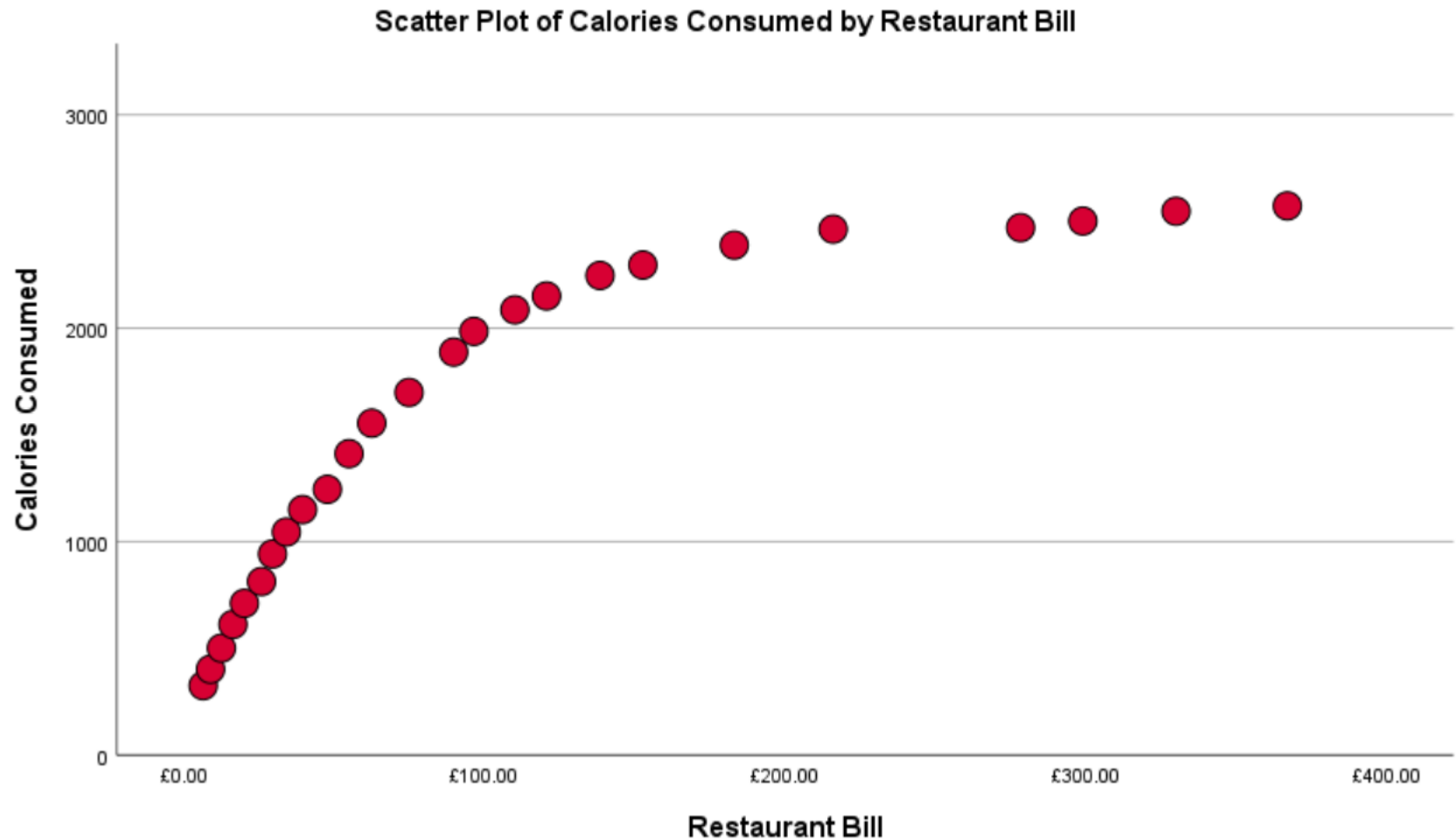


# Spearman's Rho

- **Spearman's Rho** works by ranking the original values from the lowest number to the highest
- For this reason, it's sometimes referred to as Spearman's Rank Correlation
- Unlike Pearson's Correlation here we don't know if the variables are linearly related as ranking the values hides this relationship
- Spearman's correlation detects *monotonic* relationships. A monotonic relationship is one in which, as the size of one variable increases, the other variables also increases, or where the as the size of one variable increases, as the other variable decreases.
- Spearman correlations are not affected by outliers but analysts should still consider whether extreme outliers are valid reflections of the population under consideration

# Spearman's Rho

- Consider this non-linear relationship....



**Let's explore how Spearman's  
correlations work**



# **An alternative to Spearman's Correlation: Kendall's Tau b**

# Kendall's Tau

- **Kendall's Tau b** also works by ranking the original values from the lowest number to the highest
- However, this time the analysis focuses on *the degree of concordance and discordance* between two ranked columns of data

|    | 🎬 Movie_Title                      | 📊 IMDb | 🍅 Rotten_Tomatoes |
|----|------------------------------------|--------|-------------------|
| 1  | Uncorked                           | 1      | 6                 |
| 2  | Spenser Confidential               | 2      | 1                 |
| 3  | The Willoughbys                    | 3      | 5                 |
| 4  | Tigertail                          | 4      | 3                 |
| 5  | Extraction                         | 5      | 2                 |
| 6  | The Half of It                     | 6      | 8                 |
| 7  | To All the Boys I've Loved Before  | 7      | 9                 |
| 8  | LA Originals                       | 8      | 4                 |
| 9  | Miss Americana                     | 9      | 7                 |
| 10 | Crip Camp: A Disability Revolution | 10     | 10                |

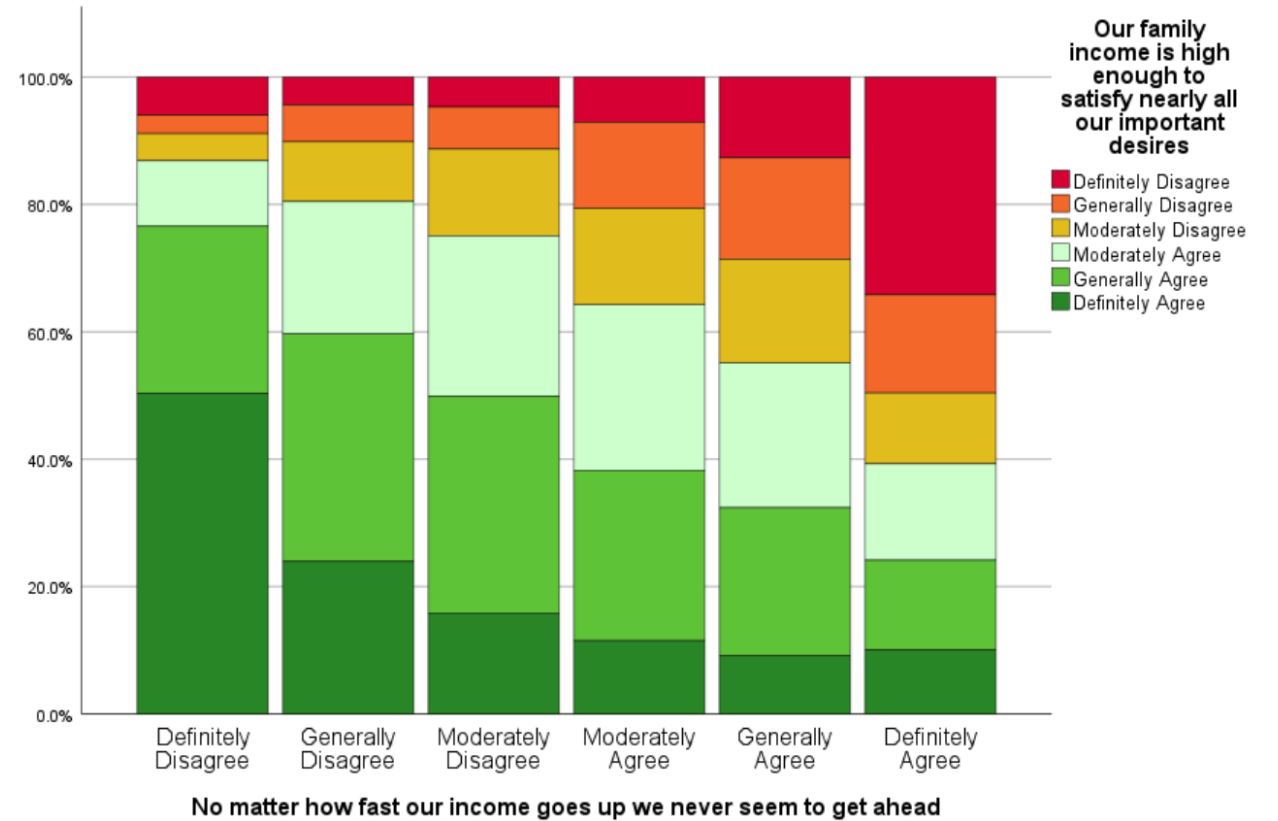
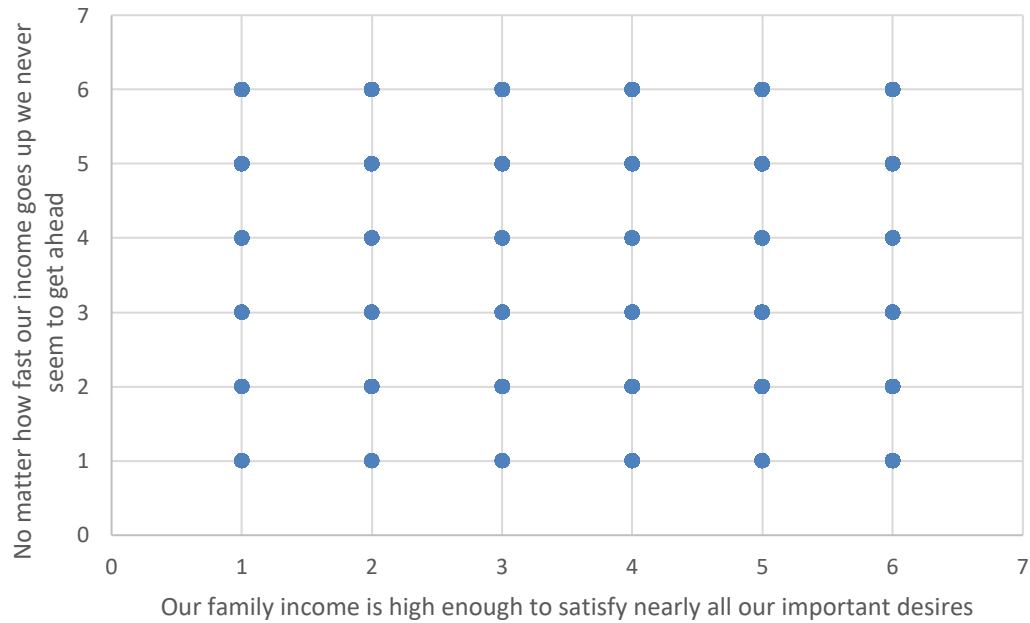
# Kendall's Tau

- Some argue that the significance estimates and confidence intervals for Kendall's Tau tend to be more reliable than for Spearman correlations.
- Kendall's Tau tend to give smaller correlation values than Spearman's and can also take much longer to calculate

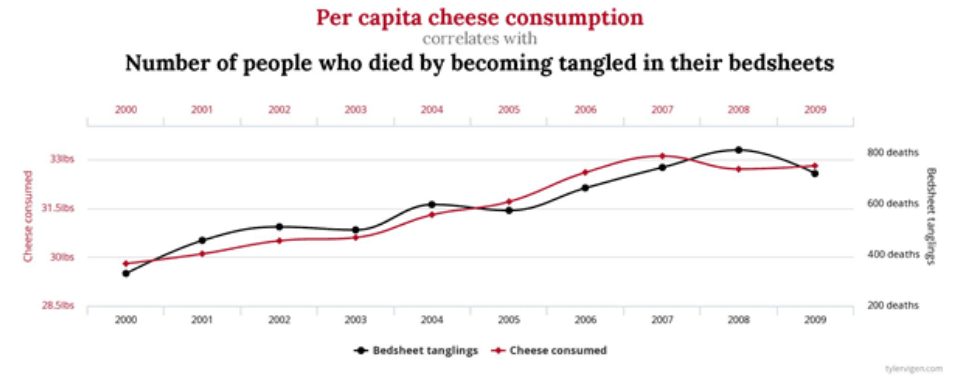
|    | 🎬 Movie_Title                      | 📊 IMDb | 🍅 Rotten_Tomatoes |
|----|------------------------------------|--------|-------------------|
| 1  | Uncorked                           | 1      | 6                 |
| 2  | Spenser Confidential               | 2      | 1                 |
| 3  | The Willoughbys                    | 3      | 5                 |
| 4  | Tigertail                          | 4      | 3                 |
| 5  | Extraction                         | 5      | 2                 |
| 6  | The Half of It                     | 6      | 8                 |
| 7  | To All the Boys I've Loved Before  | 7      | 9                 |
| 8  | LA Originals                       | 8      | 4                 |
| 9  | Miss Americana                     | 9      | 7                 |
| 10 | Crip Camp: A Disability Revolution | 10     | 10                |

**Let's compare Kendall's Tau to  
Spearman's correlations**

# Visualising Correlations for Ordinal Variables

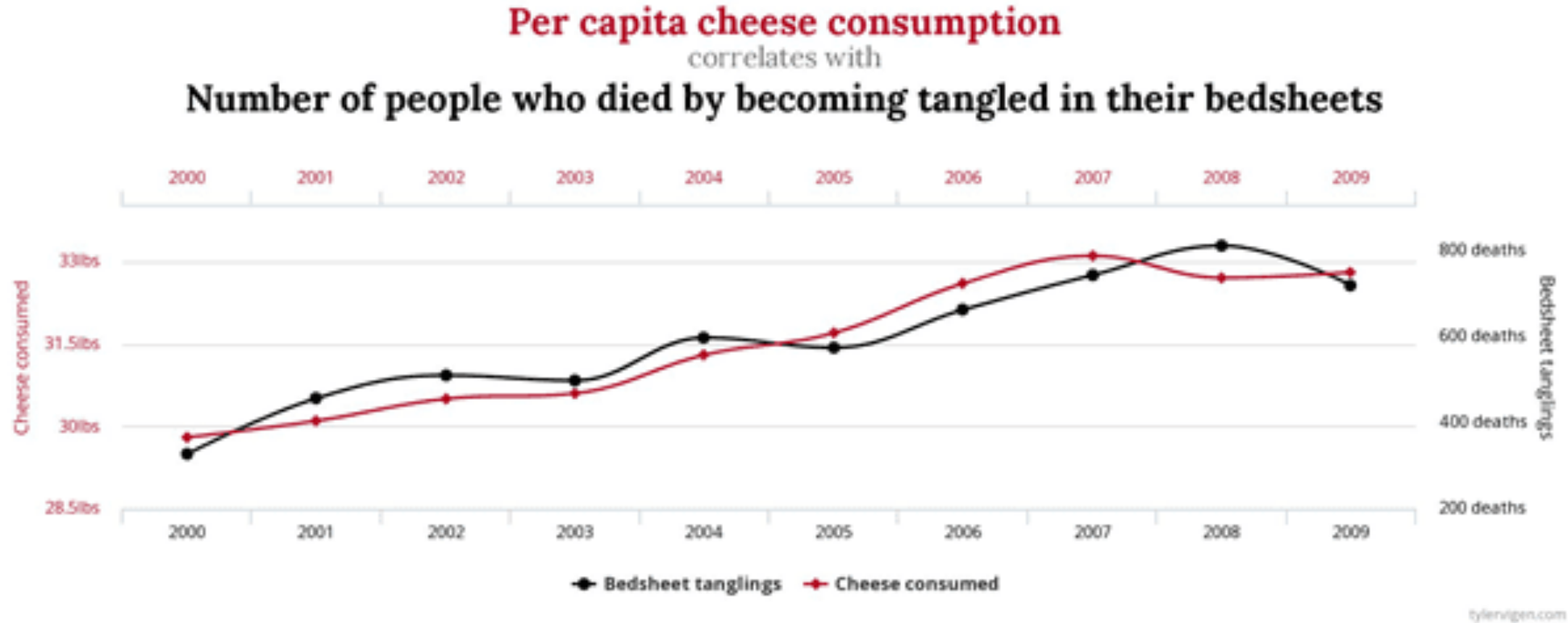


May require a different approach than scatterplots



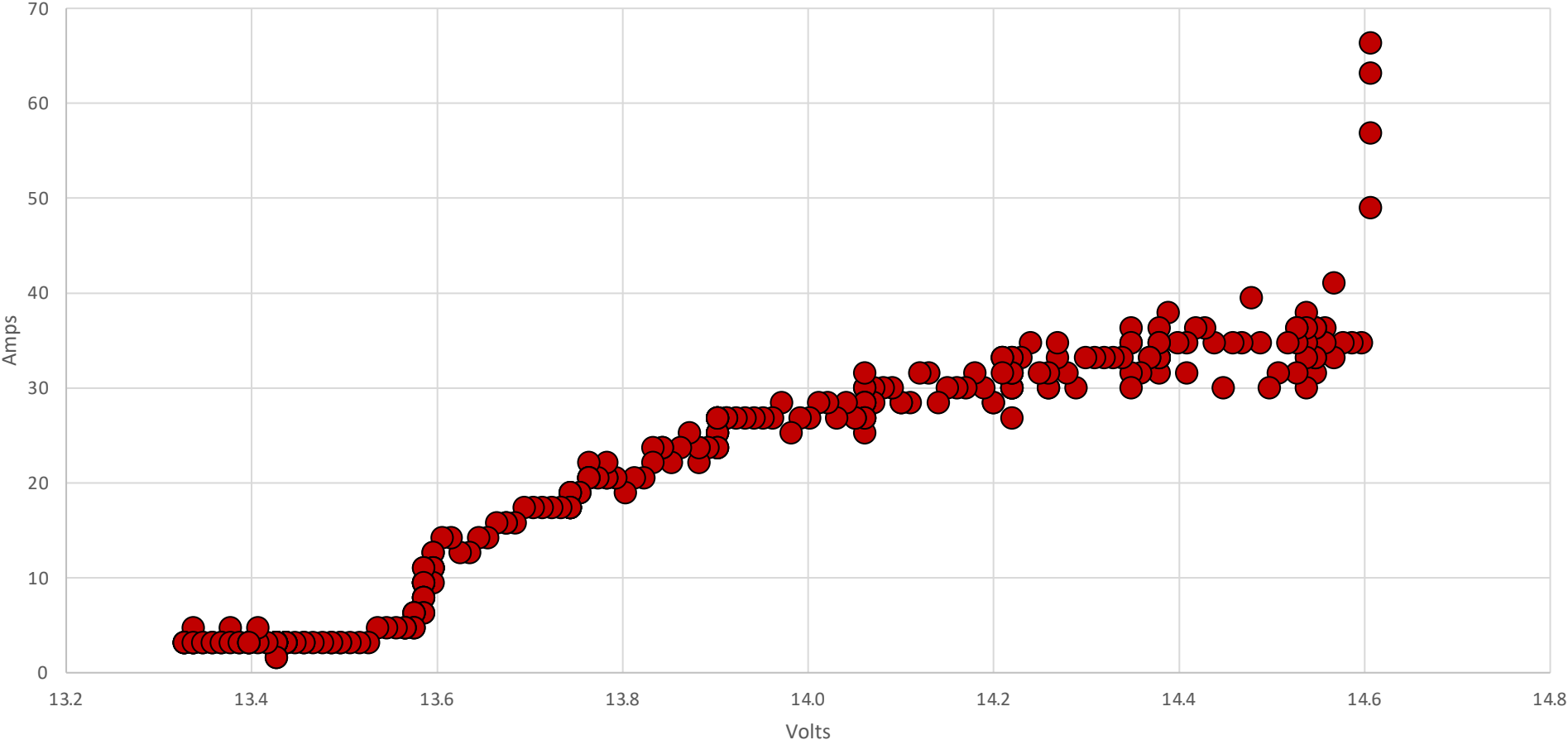
# The Limitations of Correlations

# Correlation does not indicate causation



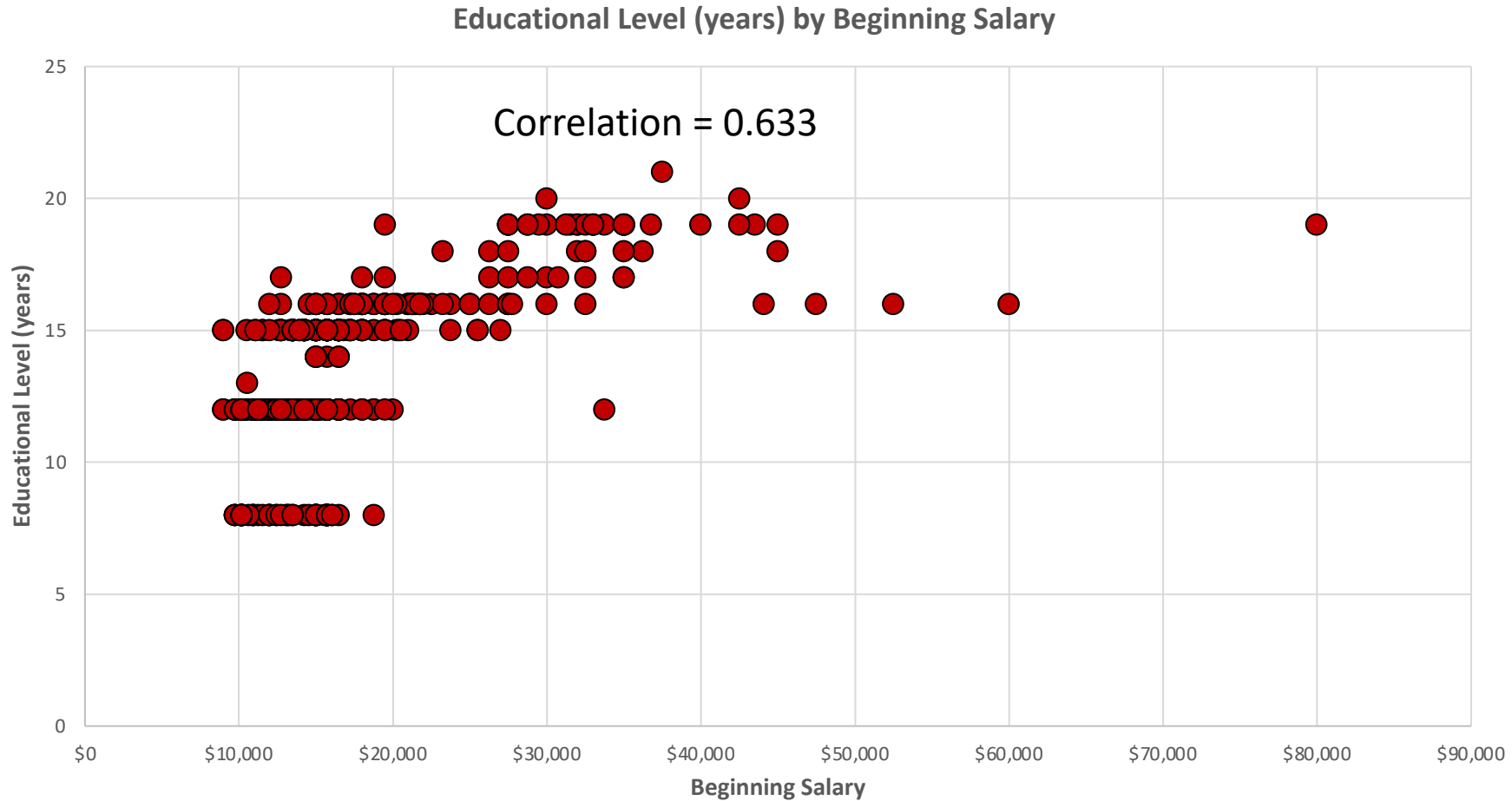
<https://www.productleadership.com/does-causation-imply-correlation/>

# Can't accurately measure curvilinear relationships

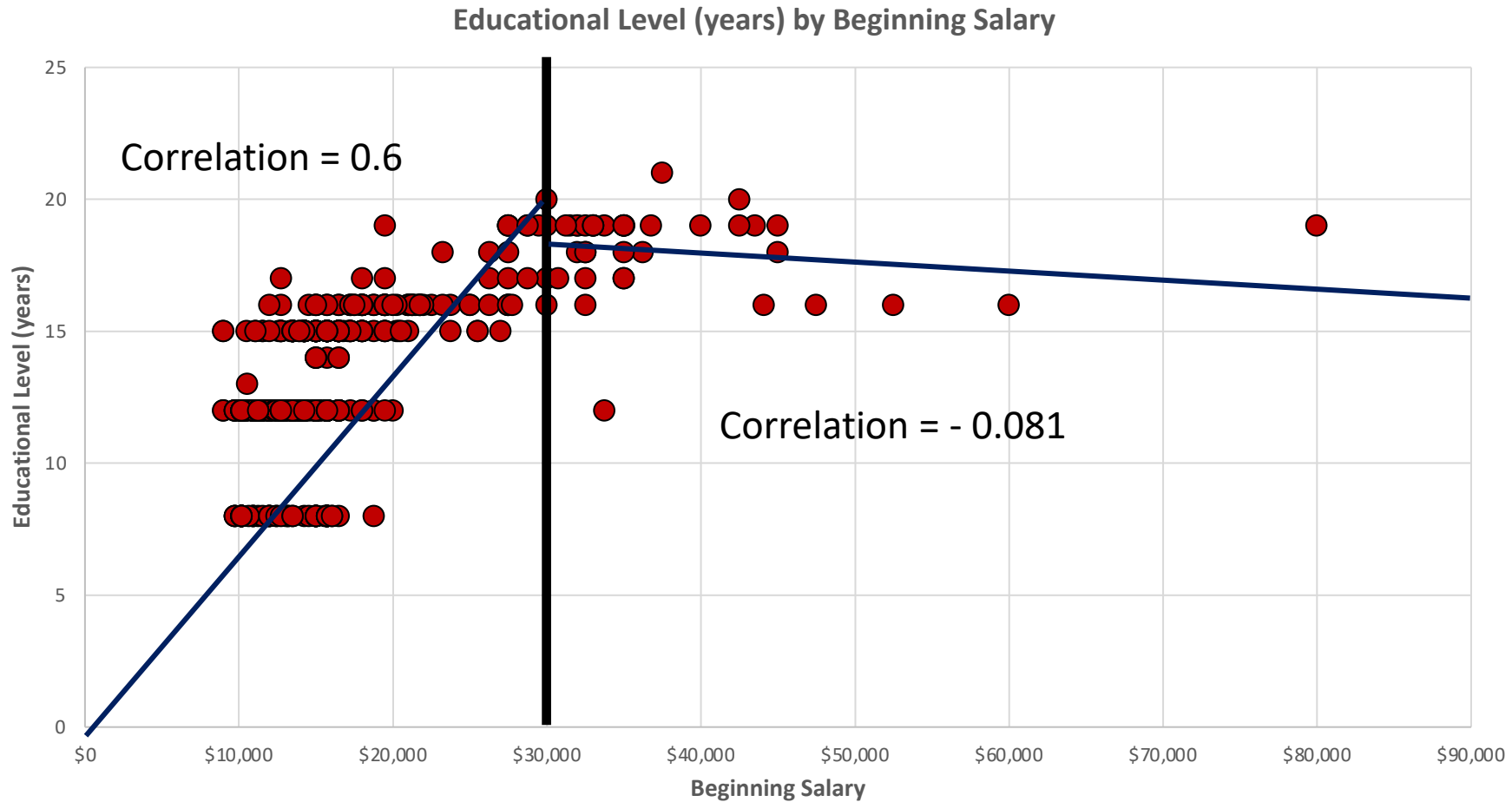




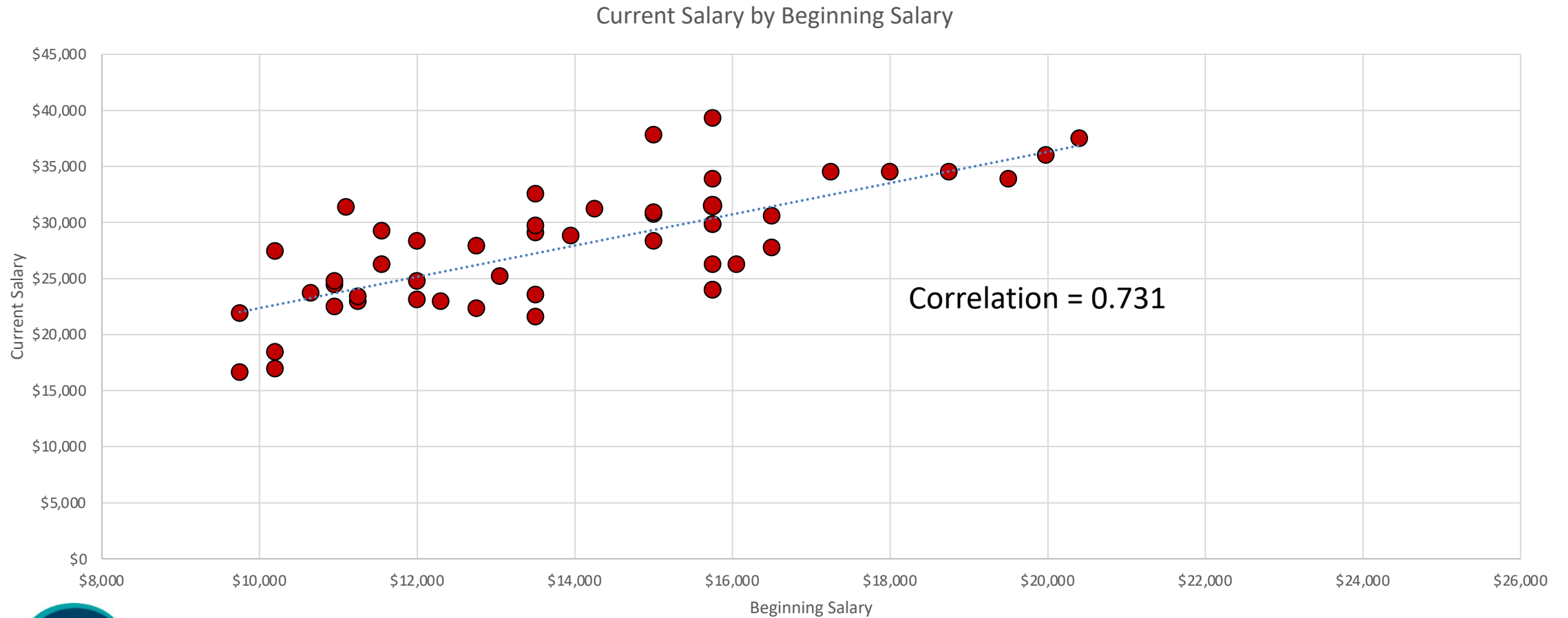
# Are influenced by the range of values in the sample



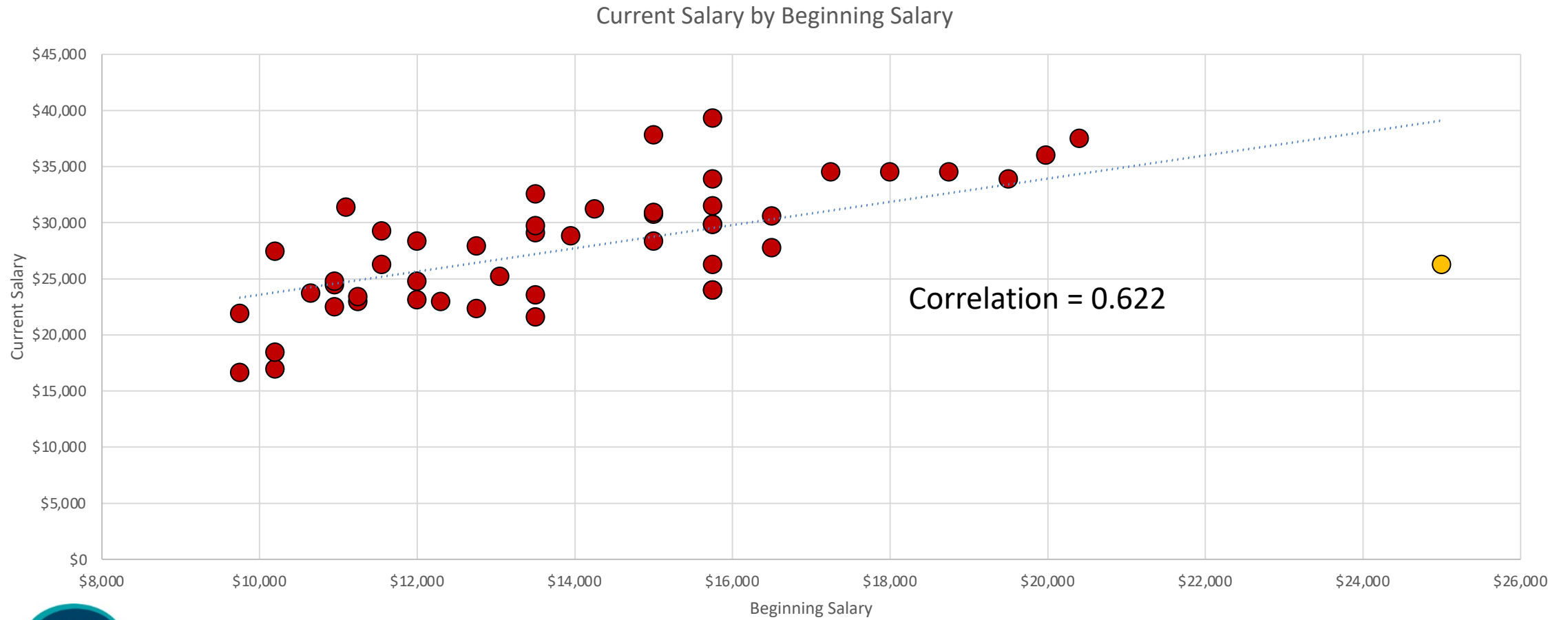
# Are influenced by the range of values in the sample



# Can be unduly affected by extreme/outlier values



# Can be unduly affected by extreme/outlier values



# Working with Smart Vision Europe

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Let us explore your data landscape to test hypotheses, identify problem areas, find key outcome drivers or develop new applications

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  - Assist with selection, pilot, implementation & support of analytical tools
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  - Guided consulting & training to develop in house skills
  - Delivery of classroom training courses / side by side training support
  - Identification & recruitment of analytical skills into your organisation
- **Advice and Support**
  - offer ‘no strings attached’ technical and business advice relating to analytical activities
  - Technical support services



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Thank you