**Standard Deviation**

$$\mathrm{SD} = \sqrt{\frac{\sum |x - \bar{x}|^2}{n}}$$

where $\sum$ means "sum of", $x$ is a value in the data set, $\bar{x}$ is the mean of the data set, and $n$ is the number of data points.

**Used for:** Looking for differences between mean values

**Interpretation:** The more spread out a data distribution is, the greater its standard deviation.

**Example:** Measuring the rate of photosynthesis at two different wavelengths of light

The rate of photosynthesis is measured by the number of oxygen bubbles released in an hour, by an aquatic plant, when exposed to green and white light. Calculate the Standard Deviation using the data below:

| Light source | Repeat 1 | Repeat 2 | Repeat 3 | Mean | S.D. |
|---|---|---|---|---|---|
| White | 10 | 11 | 13 | | |
| Green | 8 | 4 | 6 | | |

## Standard error and 95% confidence limits

Calculate the standard error of the mean, $SE$, for each sample from the following formula

$$SE = \frac{SD}{\sqrt{n}}$$

where $SD$ = the standard deviation
and $n$ = sample size

95% confidence limits = 2 × $SE$ above and below the mean

Using the data from the table above, calculate the Standard Error for each reading.

| Light source | Mean | S.D. | S.E. range |
|---|---|---|---|
| White | | | |
| Green | | | |

## Null Hypothesis

When we pose a research question, we want to know whether the outcome is due to the treatment (independent variable) or due to chance (in which case our treatment is probably not effective).

For example, we want to test the hypothesis 'Exposure to classical music improves IQ scores'

There are many factors that affect IQ score, apart from music. To prove that exposure to classical music has an impact on IQ, we must be able to show a significant correlation between exposure to music and change in IQ score.

We do this by setting out the null hypothesis, as follows,

***There is no correlation between exposure to classical music and IQ scores***

We then use SE to determine if there is any significant difference between the two factors.

| Group | Mean IQ score | SE | 2 x SE | 95% confidence range (2x SE above and below the mean) |
|---|---|---|---|---|
| Control (not exposed to music) | 108 | 1.23 | 2.46 | 105.5 - 110.5 |
| Test (exposed to classical music) | 121 | 0.95 | 1.9 | 119.1 - 122.9 |

Interpretation:

The standard error range for the two groups, control and test, do not overlap.

There is less than 5% probability that the results are due to chance, therefore the differences between the control and test groups are significant.

We reject the null hypothesis.

(If SE range overlap, accept the null hypothesis, as greater than 5% probability that results are due to chance)