# Module 6: Hypothesis Testing with Sample Means

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Introduction to Statistics for the Social Sciences

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# Outline

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# From a score to a distribution of scores

- Moving toward more realistic research applications an examples.

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- From a sample of one to a sample of many...

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  - Now we ask, does this sample of 3 cartoon dogs (Scooby, Pluto, & Goofy) differ from a particular population?
    - Now, we are given $\mu$ and $\sigma$, and must compare a sample mean to the **Distribution of Means**.

# Distribution of Means

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http://onlinestatbook.com/stat_sim/sampling_dist/index.html

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   - So, we correct for this bias.
3. The shape of the distribution of means is approximately normal if (a) each sample is of 30 or greater individuals, or (b) the distribution of the population is normal.

# More on Rule 1

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  - Central Limit Theorem

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  - Even with large numbers of large samples, we may not have any single sample mean which is exactly equal to the population mean.
  - Larger sample sizes are always better than smaller sample sizes.

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# Central Limit Theorem

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  - Mathematical proof showing that no matter the shape of a population distribution, with an infinite number of random samples (with replacement), the distribution of sample means will be normally distributed around a mean which is equal to the population mean.

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# More on Rule 2 (Part A)

- **Rule 2a:** The variance of a distribution of means is the variance of the population of individuals divided by the number of individuals in each sample.

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- This corrects for the known bias of the distribution of means' variability.
  - The variability of the distribution of means is always less than the population's variability.

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# More on Rule 2 (Part B)

- **Rule 2b:** The standard deviation of a distribution of means is the square root of the variance of the distribution of means.

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- **Rule 2b:** The standard deviation of a distribution of means is the square root of the variance of the distribution of means.

$$\sigma_M = \sqrt{\sigma_M^2} = \sqrt{\frac{\sigma^2}{n}}$$

- The standard deviation of a distribution of means is called the **Standard Error of the Mean (*SEM*)** or just the **Standard Error (*SE*)**.

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# More on Rule 3

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- Therefore, we can use what we know about the standard normal curve.
  - Percentage of scores, probabilities, and *p* values of Z-scores.

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- Essentially, we're doing the same **Z-test** we were doing in the previous module, just modified slightly.

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We found that Scooby's Z-score was not more extreme than 1.64. Meaning, Scooby's IQ was not significantly greater than dogs not in cartoons.
Now, we have a sample of 3 cartoon dogs (Scooby, Pluto, & Goofy). We are expanding our research to include a sample greater than one individual, but we are pursuing the same research question. Do cartoon dogs have significantly higher IQ than other dogs (i.e., those not on cartoons)?

# The Sample Data

Table 1: Raw Data

| X | Dog | IQ |
|---|---|---|
| 1 | Scooby | 123 |
| 2 | Pluto | 145 |
| 3 | Goofy | 133 |

$$\frac{\sum X}{n} = \frac{401}{3} = 133.67$$

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Null Hypothesis: $H_0 : \mu_1 = \mu_2$
Alternative Hypothesis: $H_0 : \mu_1 > \mu_2$

# Step 2

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Standard deviation of the distribution of means:

$$\sigma_M = \sqrt{\sigma_M^2} = \sqrt{75} = 8.67$$

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- Given: $H_0 : \mu_1 > \mu_2$ (one-tailed test)

We know from previous experience our cutoff score or critical value is a Z-score of 1.64

http://www.sjsu.edu/faculty/gerstman/EpiInfo/z-table.htm

# Step 4

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$$Z = \frac{\overline{X} - \mu_M}{\sigma_M} = \frac{133.67 - 100}{8.67} = \frac{33.67}{8.67} = 3.88$$

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Clearly 3.88 is a very extreme Z-score.

# Step 5

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- Our sample's mean IQ is higher than 95% of the population of dogs not in cartoons.
- Reject the null hypothesis.

We have demonstrated that our sample is more extreme than our cutoff of 5% ($p = .05$) and conclude that; based on our (very small) sample, dogs on cartoons have a higher avergae IQ than dogs not on cartoons.

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- Interval estimates have gained popularity, in part because they tend to give us a better *idea* of where the population value is located.
  - Using a range of possible values that likely include the *unknown* population parameter.

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  - Standard deviation of a distribution of means is the **Standard Error** (*SE*): $\sigma_M$
- Confidence Interval (CI).
  - Using the *SE*, we can calculate the range above and below the mean on a distribution of means that reflects the uncertainty associated with our sample.

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    - Typically 95% confidence interval.
    - 95% translates to +1.96 and -1.96 Z-scores above and below the mean on the standard normal curve.

# Calculating the Limits

- If our sample yields a mean of 133.67 with a *SE* of 8.67, then we can use a simple conversion to find the upper and lower limits of our interval estimate (i.e., confidence interval).

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  $$(+1.96)(8.67) + 133.67 = 150.6632$$

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- Lower Limit

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  $(-1.96)(8.67) + 133.67 = 116.6768$
- So, the 95% confidence interval from our sample is 150.66 to 116.68.

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# Interpretation of Confidence Intervals

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  - If we were to take an infinite number of samples of dogs on cartoons, 95% of those samples' means would be between 150.66 and 116.68.
- Remember, the population mean is fixed (but unknown); while each sample has its own mean (sample means fluctuate).

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http://onlinestatbook.com/stat_sim/conf_interval/index.html

# Controversy of Confidence Intervals

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# Controversy of Confidence Intervals

- What we really want to know is the range that includes the population mean with $p = .95$ or we wish we could get a 95% chance that the interval includes the population mean.
  - Because we are dealing with a sample and a distribution of samples; we do not really know what the population value is and therefore, can not know what that interval would be.

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# Summary of Module 6

Module 6 covered the following topics:

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Many of these topics will be revisited consistently in future modules.

# This concludes Module 6

Next time Module 7.

- Next time we'll begin covering Additions to Statistical Significance.
- Until next time; have a nice day.

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