# Tips for Forming Conclusions & Analyzing Limitations:

***After having processed your data,*** follow through the steps of this document to help you form a conclusion based on data analysis and then evaluate your experiment and design by considering limitations, their impact on results and possible improvements.

## Document Overview:

Part A: Forming Conclusions

1. Data analysis
2. Conclusion/ claim
3. Reasoning
4. Format & writing the CER.

Part B: Evaluation & limitation writing

1. Obvious errors
2. Non-obvious errors
3. Writing the evaluation

## A. Forming Conclusions:

**Step 1: Begin with data analysis** [this will later serve as evidence in the CER]
Data analysis has several components to it and all should be completed before you attempt to form a conclusion/ claim.

A. **Analyze trends:** *As (IV) increases, the (DV)* _____.
   **You CANNOT do a trend analysis if you have a qualitative IV, skip to comparisons**
   a. Use the format: *As (IV) increases, the (DV)* _____.
   b. Remember you can include specific IV data points in this, as your trend might both increases and decrease.
   c. If you complete a trend analysis (R2 value) you can comment on how well-correlated the data is for this trend. For example—"Shows a strong/weak positive linear correlation with an R2 value of ___"

**B. Comparisons:**
   a. Compare IV treatment groups: Highest, lowest, same?
   b. You can take it a step further and calculate: "Group X is 2 times greater than Group y"

C. **Error Bar analysis:** Do error bars of data points overlap?
    a. While it's possible you could have ALL error bars or NO error bars overlap and that would make a simple conclusion for significance, it is more likely you might just have one or two that overlap. If this is the case, BE SPECIFIC, for example: "The error bars of Treatment X & Y overlap, while there is no overlap between any other treatment groups".

**D. Qualitative Data:**
    a. Is there a qualitative trend? For example, with the most intense exercise, there is always more sweating or shortness of breath? This is great evidence to include.
    b. You might also note that qualitative data shows a lot of inconsistencies. This is good observational data to support error bar overlaps or uncertainty in the data.

**<u>Step 2:</u> Form a Claim**

Revisit your research question and hypothesis. Evaluate your hypothesis against all of the evidence provided in order to form a claim.

**A. Hypothesis is supported:**
    a. Trend analysis, comparisons and qualitative data support
    b. No error bar overlaps

→ *Your hypothesis can be restated as the claim.*

**B. Hypothesis is NOT supported:**
    a. Trends, comparisons or qualitative data does not match what was predicted.
    b. Error bar overlaps

There are two options if your hypothesis is not supported:

1. You can simply state a claim that the hypothesis is not supported/ rejected.
2. You can say it isn't supported and restate a new claim (if the new claim would be supported by the criteria in "A" above.
    a. For example: *"The hypothesis that pea plants grow with increasing fertilizer concentration is not supported by this data, but a new conclusion is formed that: pea plants grow more with concentrations of fertilizers up to 0.5M and then experience no additional growth".*

**<u>Step 3:</u> Connecting your evidence and claim with scientific reasoning.**

**Reasoning must:**

- Make connections back to scientific explanations of homeostasis/ feedback loops.
- If exercise related, make connections back to energy & cell respiration.
- Include a citation.

A. When the hypothesis is supported, or you have written a new/revised claim that can be supported by scientific reasoning.
    a. Explain the trends and/or comparisons—why does it increase, decrease? Why is certain data the highest/lowest?
    b. Explain qualitative observations: "Why is their more sweating, pain, etc?"

B. If your data is inconclusive / overlapping error bars, but you know (based on background research) that your hypothesis should be supported—you will still take a similar process as outlined for explaining homeostasis/feedback loops, but you are tying it back to a different claim, and trying to show why YOUR DATA doesn't fit the hypothesis.
    a. For example: *"According to _____, when exercise increases, heart rate should also increase…..(include more and more reasoning here)" but this is not the trend shown above, thus this data does not support the hypothesis and must be the result of experimental errors.*

**<u>Step 4:</u> Writing the Conclusion: CER Format**

You should complete all of the above thinking before formatting your CER. It is important to fully analyze the data before forming a claim.

<u>Remember to format as:</u>
Claim:
Evidence:
Reasoning:

- For evidence, you might choose to write all of your evidence together or separate it out into separate sections of
    - Evidence 1:
    - Reasoning 1:
    - Evidence 2:
    - Reasoning 2:
- Only separate it out, if you have different reasoning to provide. Do not separate the evidence and write the same, repetitive explanation for both.

**Part B. Evaluation and Limitations:**

Here are a few tips to help you determine and format writing for your evaluation and limitations.

**A. Obvious Errors & Uncertainties:**

1. Effects/ Results:
   a) Analyze the spread of quantitative data: SEM, error bar overlaps; trend analysis, etc.
   b) Look at qualitative data & Observations for inconsistencies—sometimes sweating, but other times not?

2. Consider Causes:
   a) You may have taken good qualitative notes that can help you understand inconsistencies. If so, use these.
   b) You may have experiences frustrations you didn't write down, but you remember—"difficulty in finding pulse; uncontrolled variables—temperature, tiredness, food eaten, increasing strength & conditioning, etc.

**B. Non-obvious errors: Consider how your design limits (the range of) your conclusion.** The cause of these limitation is something about your research question or design.
   a) Only 3 IV treatment groups—is this enough to really know the full trend for a quantitative IV? 3 data points might show a linear correlation, but with more data points this could change.
   b) Only 1 test subject—could this be extrapolated to all humans—age group, gender, athletic ability, genetics, etc?
   c) Timing of data recordings—Do you truly know when data returned to baseline, or is it an estimate (change after 1 minute)? Would a different or additional timing be better?

**Writing the Evaluation:**

- There are three components you need to have for a minimum of 3 limitations you will write about.
  - CAUSE: A description of the limitation.
  - Effect: How the limitation/ cause impacted your data/ results/ conclusion.
  - Suggested Improvement: For whatever limitations you include, you should suggest a realistic and relevant improvement for if you were to do this investigation again in the future.
- You may write these as full sentences or format into a data table, as shown below.

*Table 1:* Example Data table of evaluation

| Description of Limitation | Impact on Results | Suggested Improvement |
|---|---|---|
| *The fertilizer treatments were applied before the pea plants had germinated.*<br><br>*[This outlines a design issue in methodology]* | *At high concentrations, none of the pea plants germinated, and this is likely because the concentration of fertilizer was too high.*<br>*[This identifies an observation from the data]* | *If I were to redo this, I would first let the pea plants germinate before applying fertilizer, so I am able to analyze how fertilizer impacts "growth" instead of "germination" of the plant.*<br>*[This suggests an alteration of the methodology/ design].* |
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