Introducing ANOVA

Sometimes we want to know whether the mean level on one variable (such as pain), differs between three or more groups (e.g. Treatment A, Treatment B, and Placebo Treatment).

**ANalysis Of Variance (ANOVA):** the statistical procedure for testing variation among the means of three or more groups.

We could use multiple independent t-tests, however, conducting all of these tests would increase the likelihood we would observe significant results by chance. For example, if we work on an alpha level of 5%, and conduct enough t-tests to cover all possible combinations of the three treatment groups (3 possible comparisons), there would be a 15% chance of at least one of the comparisons being incorrectly significant. When working with more than three groups this probability would be even greater.

Using ANOVA protects the researcher against error inflation by first asking if there are differences at all among means of the groups.
Introducing ANOVA

The main statistical question is: Do the means of the dependent variables depend on which group the individual is in?

If categorical variable has only 2 values, you would use an independent means t-test

ANOVA allows for 3 or more groups.

One-way ANOVA:

involves analysing only one dimension over three or more groups.

The null and research hypothesis

$H_0$: The null hypothesis in ANOVA is that the three or more populations being compared all have the same mean.

$H_1$: The research hypothesis is that the means of the three or more groups differ.

Basic question: do the means of the samples differ more than you would expect if the null hypothesis were true.

The $F$ ratio

Analysis of Variance measures the different types of variance (variability in scores) that appear in the data and then explains the source of each variance.

Two types of variance:

1. Between-treatments variance - Variance due to differences between the group means.
2. Within-treatment variance - Variance due to differences within the groups (i.e., between the individuals).

Three types: (cont.)

3. Treatment effect: What was manipulated between the groups.
   - Always different between groups.
   - Cannot influence within-treatment variance since all the subjects in a group are given the same treatment. This is a between treatment variance.

So, the treatment effect is the only source of variance that can influence between-treatment variance that doesn’t influence within-treatment variance.

Sources of Variance:

Three types:

1. Individual differences: Variability between all participants (gender, age, education level, mood). People bring different experiences to your study.

2. Experimental error: Inaccurate measurement of the DV, poor planning of the study. Maybe measured weight w/ a broken scale, or I measured intelligence poorly.

The $F$ ratio

Three types: (cont.)

2. Within-treatment variance - Variance due to differences within the groups (i.e., between the individuals).
The F ratio

ANOVA measures two sources of variation in the data and compares their relative sizes.

variation between groups
for each data value look at the difference between its group mean and the overall mean.

variation within groups
for each data value we look at the difference between that value and the mean of its group.

\[ F = \frac{\text{Between-subjects variability}}{\text{Within-subjects variability}} \]

\[ F = \frac{\text{Treatment effect + Indiv. Diff. + Exper. Error}}{\text{Indiv. Diff. + Exper. Error}} \]

The F ratio

The ANOVA F-ratio is a ratio of the Between Group Variation divided by the Within Group Variation.

A large F is evidence against \( H_0 \), since it indicates that there is more difference between groups than within groups.

From a practical point of view the bigger the F value, the larger the chance of significance, the bigger the difference in the groups.

\[ \boxed{F \text{ ratio}}: \text{the crucial ratio of the between-group to the within-group variance estimate.} \]

\[ \boxed{F \text{ distribution}}: \text{a distribution of F ratios.} \]

Essentially, ANOVA uses your sample to tell you whether, in the population, you have overlapping group distributions (no significant difference between groups) or fairly distinct group distributions (significant differences between groups).
Assumptions of ANOVA

Assumptions: randomness, an interval/ratio scale of measurement and normality.

Normality: Use Levene's test of variance. If significance value is less than .05 then there is a significant difference in the variance of the groups. Also called homogeneity of variance. If significant, lower the alpha level.

Post Hoc Tests

Overall, any type of ANOVA will simply tell you if at least one of the groups is different from the rest.

So after every significant ANOVA, you need to run post hoc tests to tell you which of the groups are significantly different.

Post Hoc Tests

Post Hoc Tests

- Because of the likelihood of multiple comparison errors, statisticians have created ways to reduce the multiple comparison error rate.
- They are similar to running a bunch of T-tests (i.e. group 1 vs 2, 1 vs 3 and 2 vs 3). In this way they tell you specifically which group is different, whilst keeping the alpha level low.
- SPSS has many types of post hoc tests which are calculated in different ways, you only need to pick one.

One-Way ANOVA Example

Blister Treatment Study

Participants: 25 patients with skin grazes.
Treatments: Treatment A (wound bandaged 1 hour a day), Treatment B (wound elevated 1 hour a day), Placebo (participant listens to music 1 hour a day).
Measurement: number of days until skin graze heals.

Data [and means]:
A: 5,6,6,7,7,8,9,10 [7.25]
B: 7,7,8,9,10,10,11 [8.875]
P: 7,9,9,10,10,11,12,13 [10.11]

Are these differences significant?
One-Way ANOVA Example

Whether the differences between the groups are significant depends on:
- the difference in the means
- the standard deviations of each group
- the sample sizes

All of these potential sources of difference are included in an ANOVA.

One-Way ANOVA Example

Descriptive statistics:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>24</td>
<td>8.7500</td>
<td>2.0054</td>
<td>0.4094</td>
<td>7.9032 to 9.5968</td>
<td>5.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Treatment A</td>
<td>8</td>
<td>7.2500</td>
<td>1.6690</td>
<td>0.5901</td>
<td>5.8546 to 8.6454</td>
<td>5.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Treatment B</td>
<td>8</td>
<td>10.1250</td>
<td>1.8851</td>
<td>0.6665</td>
<td>8.5490 to 11.7010</td>
<td>7.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Treatment C</td>
<td>8</td>
<td>10.0937</td>
<td>1.4577</td>
<td>0.5154</td>
<td>8.6563 to 11.5363</td>
<td>7.6563</td>
<td>10.0937</td>
</tr>
</tbody>
</table>

One-Way ANOVA Example

Test of homogeneity (for assumptions):

<table>
<thead>
<tr>
<th></th>
<th>Days Healing</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levene Test of Homogeneity of Variances</td>
<td>Days Healing</td>
<td>2</td>
<td>21</td>
<td>.141</td>
</tr>
</tbody>
</table>

One-Way ANOVA Example

ANOVA Table

<table>
<thead>
<tr>
<th></th>
<th>Days Healing</th>
<th>df1</th>
<th>df2</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>33.250</td>
<td>2</td>
<td>16.625</td>
<td>5.892</td>
<td>.009</td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>59.250</td>
<td>21</td>
<td>2.821</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>92.500</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One-Way ANOVA Example

Post Hoc comparisons

<table>
<thead>
<tr>
<th></th>
<th>Mean Difference</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment A - Treatment B</td>
<td>1.6250</td>
<td>.8399</td>
<td>.154</td>
<td>-3.3669</td>
<td>3.3669</td>
</tr>
<tr>
<td>Treatment A - Treatment C</td>
<td>1.2500</td>
<td>.8399</td>
<td>.316</td>
<td>-2.8669</td>
<td>2.8669</td>
</tr>
<tr>
<td>Treatment B - Treatment C</td>
<td>-2.8750</td>
<td>.8399</td>
<td>.007</td>
<td>-4.9919</td>
<td>-0.7581</td>
</tr>
</tbody>
</table>

One-Way ANOVA Example

Experimental Outcome:

The wounds of participants in Treatment Group B (elevation) healed significantly faster than Treatment Group A (bandaging), when compared to the control group.
Introduction to APA Style

APA style: the literary style used in most scientific writing. It embodies:
- How to effectively organise information,
- Acknowledge sources,
- Structure an argument,
- Deal with data honestly and economically,
- Communicate persuasively, and . . .
- Write clearly.

APA Report Structure

The Title Page:
- Full Title of the Study Here
- A Research and Investigation Assignment
- Student Name
- Student ID
- Date due
- Subject

The Abstract:
- Abstract
- Self-contained summary of the report. Approximately 200 words. One non-indented paragraph only. Usually written last.

The Literature Review:
- Full Title of the Study Here
- Introduce the general area and review literature relevant to the topic in a logical and coherent way, gradually becoming more and more specific.
- Try to cite as often as possible, however only quote when absolutely necessary. This section may amount to approximately 1000 words.

The Method:
- Page numbering starts on the second page of the literature review as page 2. Conclude this section of the report with the general aim of the study, and any hypotheses/objectives you have formulated.
- Method
  - The method follows on directly from the literature review. It contains three areas:
  - Participants
    - Include numbers, sexes, ages, occupations and any other relevant details.

The Results:
- Materials
  - Include statistical properties pertaining to the measures used in the report.
- Procedure
  - A detailed chronological account of what happened to participants in the study.
- Results
  - The results follow on directly from the method. Results are presented in the order in which the hypotheses/objectives were stated in the literature review.
APA Report Structure

The Discussion:

For each hypothesis, restate the hypothesis/objective, provide an illustration that simplifies the findings, and then report any statistical analyses that quantify these findings.

Discussion

The discussion follows directly from the results. Again, discuss the results in the order in which the hypotheses/objectives were stated in the literature review.

In this section review your findings as they relate to the literature cited in your literature review. Make suggestions for any observed differences, consider limitations of the study, and suggest avenues for future research. Make the discussion section interesting and end on a positive note.

Approximate length 1000 words.

APA Report Structure

The References:

References

Starts on a new page. Only list references cited in your text in alphabetical order.

APA Report Structure

The Appendices:

Appendix

Starts on a new page. Includes any additional important material that was not included in the body of the report, but was alluded to in the text. Here you might include blank copies of the questionnaires used in the study. Each separate Appendix begins on a new page and is titled Appendix A, Appendix B etc...

APA Report Structure

Tables

Introduce the Table here.

Table IV

Full Title of the Table Here in Title Case

<table>
<thead>
<tr>
<th>Scale</th>
<th>Scale M</th>
<th>Scale SD</th>
<th>Cronbach's Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDS</td>
<td>3.08</td>
<td>2.27</td>
<td>0.49</td>
</tr>
<tr>
<td>CTAI-2 (cognitive anxiety intensity)</td>
<td>27.08</td>
<td>5.16</td>
<td>0.89</td>
</tr>
<tr>
<td>CTAI-2 (somatic anxiety intensity)</td>
<td>21.98</td>
<td>5.6</td>
<td>0.87</td>
</tr>
<tr>
<td>CTAI-2-D (cognitive direction)</td>
<td>-15.67</td>
<td>6.03</td>
<td>0.87</td>
</tr>
<tr>
<td>CTAI-2-D (somatic direction)</td>
<td>-11.23</td>
<td>6.64</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Follow-up with a descriptive statement.

Figures

Introduce the Figure here.

Figure 1: Full Title of the Figure Here in Title Case. Follow-up with a descriptive statement.
**Citation**

**Citation:** rephrasing an author's original words into your own. Include the author(s) names and year of publication in the text. Report additional details in the reference section.

- **Single author:** Hewitt (1987) initiated these studies by . . .
- **Two to five authors:** Jones and Allen (1979) found . . . or . . . was found (Jones & Allen, 1979).
- **Multiple citations different authors:** Several studies (Jones, 1979; Lorenzo & Masters, 1981; Pope, 1965) have found . . .
- **Secondary sources:** Marx's (1945) study (cited in Johnston, 1956) suggests that . . .

**Quotation**

**Quotation:** the use of the original author's own words within the body of your report. Only quote if rephrasing leads to a loss of meaning.

Brown (1988) defined learning as "any relatively permanent change in behaviour which occurs as a result of experience or practise" (p. 85).

Learning has been defined as "any relatively permanent change in behaviour which occurs as a result of experience or practise" (Brown, 1988, p. 85).

**Referencing**

Provides the information necessary to retrieve a source.


**Evaluation Criteria**

- There is a clear discussion of the limitations and implications of the results.
- The hypothesis/es or objective/s evolve/s logically and clearly from the theoretical and empirical work you cite in the introduction.
- That you give precise specification of the results, including any details of statistical procedures employed.
- That the details of the experimental method are communicated unambiguously.
- That you reading be sufficient, cited effectively and precisely to support your hypothesis/es or objective/s and discussion.
- That you use clear and accurate expression.
- That you adhere to the rules and regulations set down for report writing.