Repeated Measures ANOVA

BUS 735: Business Decision Making and Research

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Goals of this section

Specific goals

- Learn background and implementation of RANOVA: a method to detect the impact of categorical variables measured over the same subjects (dependent samples).
- Learn how to incorporate ideas we have already learned in RANOVA models.

Learning objectives

- LO3: Be able to construct and use analysis of variance and analysis of covariance models to construct and test hypotheses considering complex relationships among multiple variables.
- LO6: Be able to use standard computer packages such as R to conduct the quantitative analyses described in the learning objectives above.
- LO7: Have a sound familiarity of various statistical and quantitative methods in order to be able to approach a business decision problem and be able to select appropriate methods to answer the question.

Paired Samples T-Test

- Recall paired samples T-test:
  - Involved *repeated measures*: same sampling units were measured twice (eg: before/after treatment, two related variables on same scale)
  - Examined *within-subject variability*: examined differences in dependent variable *within each subject*.
- Repeated Measures ANOVA (RANOVA): extends the analysis of Paired Samples T-tests to two or more groups.
  - In much the same way One-Way ANOVA extended the Independent Samples T-test.
  - RANOVA measures **Within-Subjects Analysis of Variance**.

Alternative Within-Subjects Variation

- Paired samples T-Test and RANOVA have dependent samples as the same sampling units are in each group.
- **Across Time Variation**... aka **Occasions variation**.
  - Sales revenue before advertising campaign begins
  - Sales revenue one month into advertising campaign
  - Sales revenue one month after conclusion of advertising campaign
- **Different Conditions Variation**: measure the same dependent variable, among the same subject, but under different conditions:
  - Eg: Sales revenue under different marketing strategies
- **Related Topics Variation**: *Slightly different* dependent variables are measured for the same subjects:
  - GMAT score percentiles for quantitative, verbal, writing, and analytical reasoning

One-Way and Two-Way ANOVA

Recall One-Way ANOVA

- Involved *independent groups*: different individuals randomly fell or assigned to into different groups.
- Examined *between-subject variability*: examined differences in dependent variable *between different groups of subjects.*
- Example: Is there is difference in sales revenue between businesses that advertise primarily on television, radio, and outdoor advertising?

Recall Two-way ANOVA

- Jointly considered two categorical explanatory variables.
- Accounts for one variable while examining significance of the other.
- Can measure interaction effects.

Between-Within-Subjects ANOVA

- **Between-Within-Subjects ANOVA**: Also a type of RANOVA
- Extends the *repeated-measures within subjects ANOVA* to also account for categorical explanatory variables that put subjects into *independent groups*.
- Combines:
  1. *repeated-measures within-subjects ANOVA*, and
  2. *One-way ANOVA* (which measures between-effects).

Example: Between-Within-Subjects ANOVA

Example for sales revenue and advertising:

1. Is there a difference in sales revenue for businesses...
   - before advertising campaign begins,
   - one month into advertising campaign, and
   - one month after conclusion of advertising campaign...
2. while accounting for differences due to advertising on...
   - television,
   - radio, and
   - outdoor advertising?

Example continued...

Hypothesis Tests:

- (Accounting for...) are there differences in sales revenue depending on time into the advertising campaign?
- (Accounting for...) are there differences in sales revenue depending on the type of advertising?
- Is there an interaction effect between type of advertising and time into the advertising campaign?
  - In other words, "Does the effect advertising has on sales revenue across time depend on the type of advertising?"

Null and Alternative Hypotheses

- Null: Accounting for the other explanatory variables in the model, there is no difference in the mean outcome variable among the categories of the explanatory variable of interest.
- Alternative: Accounting for the other explanatory variables in the model, at least one of the categories of the explanatory variable leads to a different mean for the outcome than the other categories.

Hypothesis Example: Within-Subjects

- Dependent variable: Sales revenue.
- Within-subjects explanatory variable: time into advertising campaign (categorical).
- Null: There is no difference in mean sales revenue for business before an advertising campaign begins, one month into advertising, and one month after conclusion of advertising.
- Alternative: There is a difference in mean sales revenue for at least one of these time frames.

Hypothesis Example: Within-Between-Subjects

Variables

- Dependent variable: Sales revenue.
- Within-subjects explanatory variable: time into advertising campaign.
- Between-subjects explanatory variable: advertising medium (TV, radio, outdoor).

Null Hypotheses 1
Accounting for advertising medium, there is no difference in mean sales revenue for business before an advertising campaign begins, one week into advertising, one month into advertising, and one month after conclusion of advertising.

Null Hypotheses 2
Accounting for time into advertising campaign, there is no difference in mean sales revenue for businesses advertising on TV, radio, and outdoor.

Null Hypotheses 3
There is no interaction effect on mean sales revenue coming from advertising medium and time into advertising.

Advantages of RANOVA

- RANOVA is more **powerful** than ANOVA: accounting for within-subjects variation reduces unexplained variation.
- Capture interaction effects that Multi-Way ANOVA cannot.

Assumptions

- Sample size sufficiently large.
  - At least 30? subjects with repeated measures taken.
  - At least 30? subjects in each group for categorical explanatory variables.
- Dependent variable is interval data or above.

- Normally distributed dependent variable is helpful.
- Sphericity, aka constant of variance/covariance:
  - Homogeneity across categories for between-groups.
  - Sphericity: across all differences for within-groups categories.
  - Sphericity across categories for between-groups.