# Crossover Study

## Roadshop Cosmetics VS Premium Cosmetics

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# Overview

1. Design
2. Crossover Study
3. Application
4. Limitation
5. Reference

# Motivation

- I am usually interested in skin and cosmetics.When I watch YouTube, I especially watch beauty YouTubers often.(ex.Director PI, Salary girl A and so on)
- When I watch YouTube, there are the videos the theme is what is effective through comparing cosmetics.
- However, there are no exact comparisons at the same time, and there are many things that are used and tested one by one.
- Therefore, I decided to experiment with using two cosmetics and comparing their efficacy.

# Design

## Unit

Me of the Day

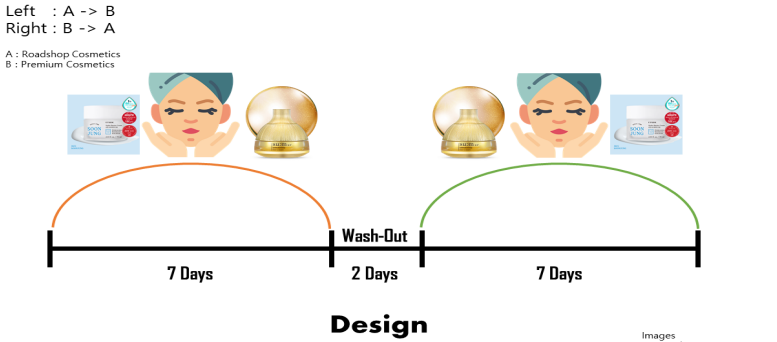
## Outcome

Moisture Change (After Measurement - Before Measurement)

## Treatment

- Treatment :Sum LosecSumma Elixir Cream
- Control : EtudeHouse SoonJung Hydro Barrier Cream

# Design




1. In the first week, apply A to the left face and B to the right.
2. It has a two-day wash-out period[1] to eliminate previous effects.
3. After wash out period, apply B to the left and A to the right.

[1] Wash-Out : a period between active drug periods, during which units receive no study medication.

# Experiment

1. Before going to bed, wash your face with a foam cleanser.
2. Measure skin moisture with the measuring device before applying cream
3. After 15 minutes of creaming, measure skin moisture.

Figure: Measuring Device

# Matching Pair

## Why did I experiment alone?

- Allergic reactions and skin troubles can occur.
- All cannot be tested under the same conditions.
- The cost is high.

## Solution

Considering my condition on that day, let's match each other in a similar condition!

- Skin is very affected by body condition.(ex. sleep time, steps, makeup, etc)

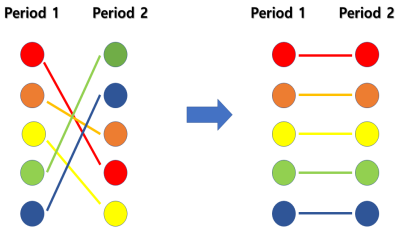



Figure: Solution

# Crossover Study

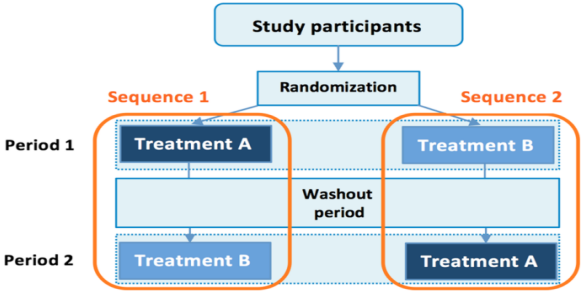



Figure: $2 \times 2$ Crossover Design

- Crossover study is a type of randomized clinical trial. Each unit participates in all treatments.
- In $2 \times 2$ crossover study, if Sequence 1 received treatment A for Period 1, It received treatment B for Period 2 after a certain washout period.
- Conversely,if Sequence 2 received treatment B for Period 1, It received treatment A for Period 2 after a certain washout period.

Source : Zeng, L., Qureshi, R., Viswanathan, S. et al. Registration of phase 3 crossover trials on ClinicalTrials.gov. Trials 21, 613 (2020).

# Crossover Study

$$Y_{ijkl} = \mu_k + \pi_l + \lambda_{k'_{l-1}} + \epsilon_{ijkl}{}^{1}$$

| | Period 1 | Period 2 |
|---|---|---|
| Sequence AB | $\mu_A + \pi_1$ | $\mu_B + \pi_2 + \lambda_{A_1}$ |
| Sequence BA | $\mu_B + \pi_1$ | $\mu_A + \pi_2 + \lambda_{B_1}$ |

Table: $2 \times 2$ crossover study

- Treatment Effect($\mu_k$) : $\frac{1}{2}(\bar{d_1} + \bar{d_2}) = \mu_B - \mu_A - \frac{1}{2}(\lambda_A - \lambda_B)$
- Carryover Effect($\lambda_{k'_{l-1}}$) : The effect of the treatment from the previous time period on the response at the current time period.
- Period Effect($\pi_l$) : The effect of each period on outcome.
- Crossover design is mainly tested using a Two sample T-test or Wilcoxon Rank Sum test.

[1] $\lambda_{k'_0} = 0$

# Crossover Study

## Advantage

- A comparison of treatments on the same subject is expected to be more precise. The increased precision often translates into a smaller sample size.

## Disadvantage

- The statistical analysis of a cross-over experiment is more complex than a parallel-group experiment and requires additional assumptions.
- .The design cannot be used when the treatment (or the measurement of the response) alters the subject permanently

## Why isn't the Potential Outcome Framework established?

- It is often difficult to manipulate the mediator perfectly.
- Even if such a manipulation is possible, the use of these designs requires the consistency assumption that the manipulation of the mediator should not affect the outcome through any pathway other than the mediator.

# Descriptive Statistics

$$Y(outcome) = Moisture_{post} - Moisture_{past}{}^{1}$$

| | Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Left(AB) | | | | Right(BA) | | | |
| | Roadshop | Premium | Difference[2] | Overall[3] | Roadshop | Premium | Difference | Overall |
| Mean | 0.070 | 0.034 | -0.036 | 0.052 | 0.073 | 0.047 | -0.027 | 0.060 |
| sd | 0.039 | 0.014 | 0.032 | 0.034 | 0.037 | 0.049 | 0.055 | 0.044 |
| n | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

Table: Descriptive Statistics

- Tests were conducted through the Two-sample T-test and the Wilcoxon Rank Sum Test.

[1] The measurement is a percentage.

[2] The moisture value on Premium - The moisture value on Roadshop

[3] All values in the group

# Two Sample T-test

| Effect | Hypothesis | T-stat | df | p-value |
|---|---|---|---|---|
| Treatment | $H_0 : \mu_A = \mu_B$ | -2.168 | 0.12 | 0.022 |
| Carry-over | $H_0 : \lambda_{A_1} = \lambda_{B_1}$ | -0.492 | 0.12 | 0.632 |
| Period | $H_0 : \pi_1 = \pi_2$ | -0.382 | 0.12 | 0.709 |

Table: Result for T-test

| Effect | Estimate | CI.lower | CI.upper |
|---|---|---|---|
| Treatment | -0.031 | -0.083 | 0.021 |

Table: Treatment Effect

- I created a function that performs $2 \times 2$ crossover tests.
- All tests in this study are two-sided tests.
- In the test, there is a treatment effect. However, there is no carryover and Period effect.
- Roadshop Cream Moisture Change is about 3.1% greater than Premium Cream Moisture Change.

# Wilcoxon Rank Sum Test

| Effect | Hypothesis | $Chi^2$ | df | p-value |
|---|---|---|---|---|
| Period1 | $H_0 : \mu_A = \mu_B$ in Period1 | 0.4821 | 1 | 0.4821 |
| Period2 | $H_0 : \mu_A = \mu_B$ in Period2 | 12.1 | 1 | 0.0005 |
| Treatment*Period | | 1.45 | 1 | 0.23 |

Table: Result for Wilcoxon Rank Sum test

- The test was conducted using the library ("sanon").
- There is no difference in Period 1.However, in Period 2, the difference between Roadshop and Premium creams was very significant.
- Given the interaction between Treatment and Period effect, there is no interaction effect. Therefore, it seems to have resulted from the presence of carry over effect in Period 2.

# Limitation

- The measuring machine has a large error.(the moisture value that varies every time)
- Since the unit is alone, the value may vary when applied to other units.(Low external validity)
- When the unit is matched, the condition is not exactly the same. Therefore, it would be good to consider the stratification of covariate.
    - The library ("sanon") can be stratified using a nonparametric method.

# Reference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- Kawaguchi, Atsushi, and Gary G. Koch. "Sanon: an R package for stratified analysis with nonparametric covariable adjustment." Journal of Statistical Software 67.9 (2015).
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