

# Analyzing the Ringelmann Effect with the Repeated Measures ANOVA

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## The Ringelmann Effect

- Maximilian Ringelmann (1861-1931):
  - ▶ French professor of agricultural engineering
- Work performance depends of number of group size
- Decreasing individual performance with increasing group size
- Example: Pulling weights with different sized groups




# Overview

- The Ringelmann Effect can be investigated with an experimental design
  - ▶ Dependent Variable: Individual performance
  - ▶ Independent Variable / Factor: Group size
  - ▶ Realization of different factor levels
- For our purpose: Data simulation  Quantlet Data Simulation



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# Code

Analyzing the Ringelmann Effect with the Repeated Measures ANOVA



# The Ringelmann Effect

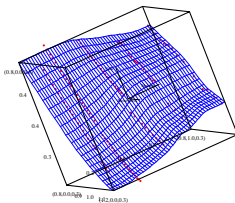


Figure 1: Include a short, but meaningful caption.



## The Repeated Measures ANOVA: The ANOVA model

- ANOVA: Analysis of Variance
- Comparison of the  $k$  factor level means

$$H_0 : \mu_1 = \mu_2 = \dots = \mu_k$$

$$H_1 : \exists i \neq j : \mu_i \neq \mu_j$$

- Test is accomplished by decomposition of variance components



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## The Repeated Measures ANOVA: An Advantageous Model

- Problem: In case of large variance between different subjects  
⇒ High error variance ⇒ Loss of power in F-Test
  - Repeated Measures ANOVA considers the between subject variance separately  
⇒ Relatively low error variance ⇒ Gain of power in F-Test
- 🔍 Reduction of error variance



# The Repeated Measures ANOVA: An Advantageous Model

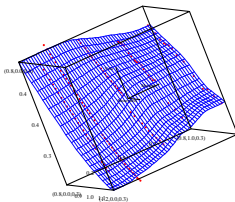


Figure 2: Include a short, but meaningful caption.



## The Repeated Measures ANOVA: An Advantageous Model

- Design Requirement: Each subject has to be measured under all factor levels

Title	Title
2.13	1.45
3.14	6.85

Table 1: Example Data Matrix



# Code

Analyzing the Ringelmann Effect with the Repeated Measures ANOVA



# Table



## The Repeated Measures ANOVA: Confidence Intervals

- The computation of the confidence intervals has to be adjusted in the Repeated Measures ANOVA



Confidence Intervals



# Code

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## The Repeated Measures ANOVA: Confidence Intervals

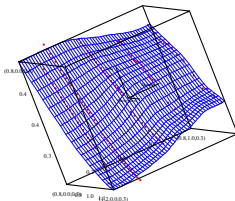


Figure 3: Include a short, but meaningful caption.





## The Repeated Measures ANOVA: Effect Size Measures

□ Two measures of effect size:

▶  $\eta^2$

▶  $\eta_p^2$



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## An Important Requirement

- Sphericity: The variance of differences are equal for each pair of factor levels
- Test for sphericity: Mauchly test
- Measurement of sphericity ( $\epsilon \in [0, 1]$ ):
  - ▶ Greenhouse & Geisser:  $\epsilon_{GG}$
  - ▶ Box:  $\epsilon_B$
  - ▶ Huynh & Feldt:  $\epsilon_{HF}$
- These can be used to correct the degrees of freedom and therefore adjust the p-values if sphericity is violated

