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PSYC214: Statistics
Lecture 2 – One factor between-participants ANOVA – Part I

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One factor between-participants ANOVA

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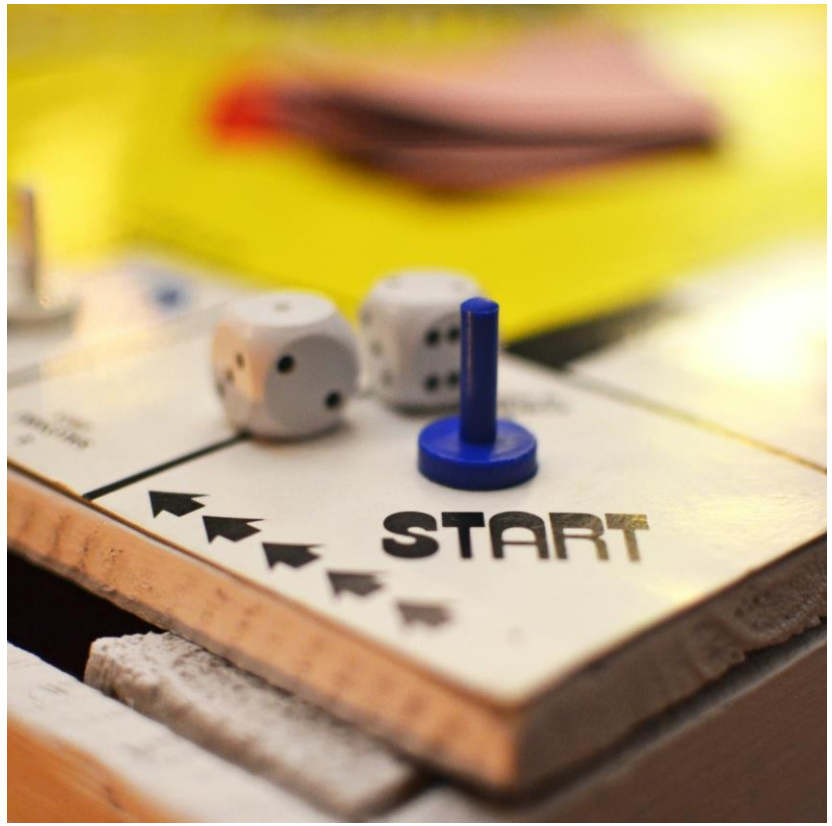
Agenda/Content for Lecture 2

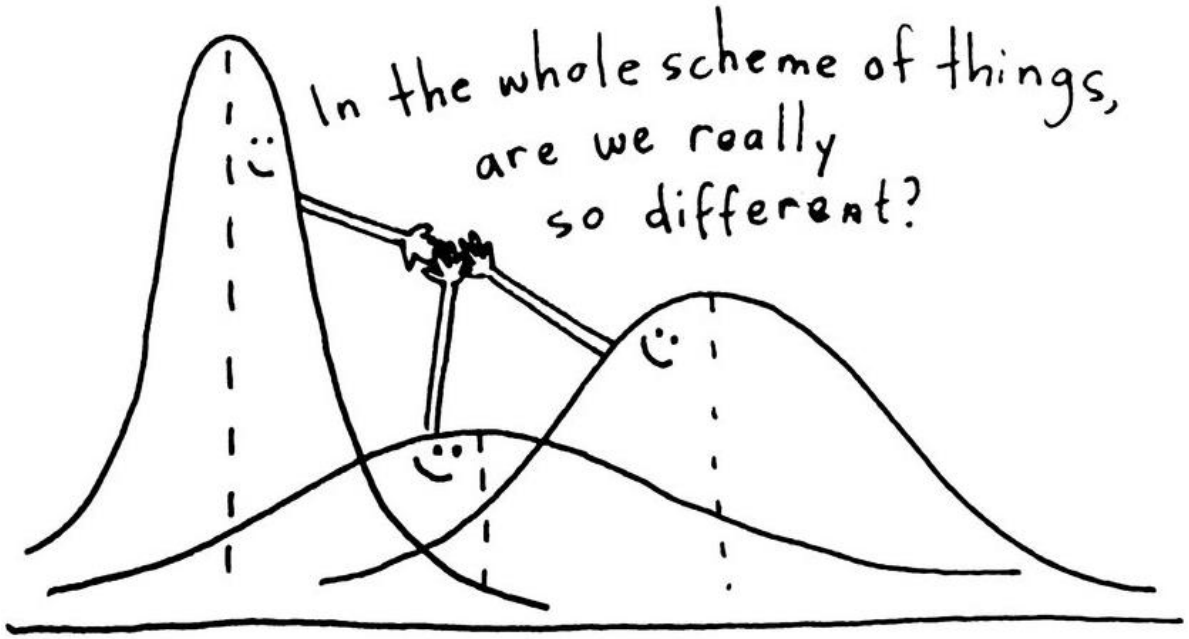
- Introduction to analysis of variance (ANOVA)
- Introduction to one factor between-participants design
- Sources of variability in data
- Calculating within-group and between-group variances
- Degrees of Freedom
- Producing the F-statistic



Introduction to analysis of variance

Why conduct an analysis of variance?

- Compares means and variance
- Allows analysis of group differences for more than two groups
- Several means without inflating Type I error rate

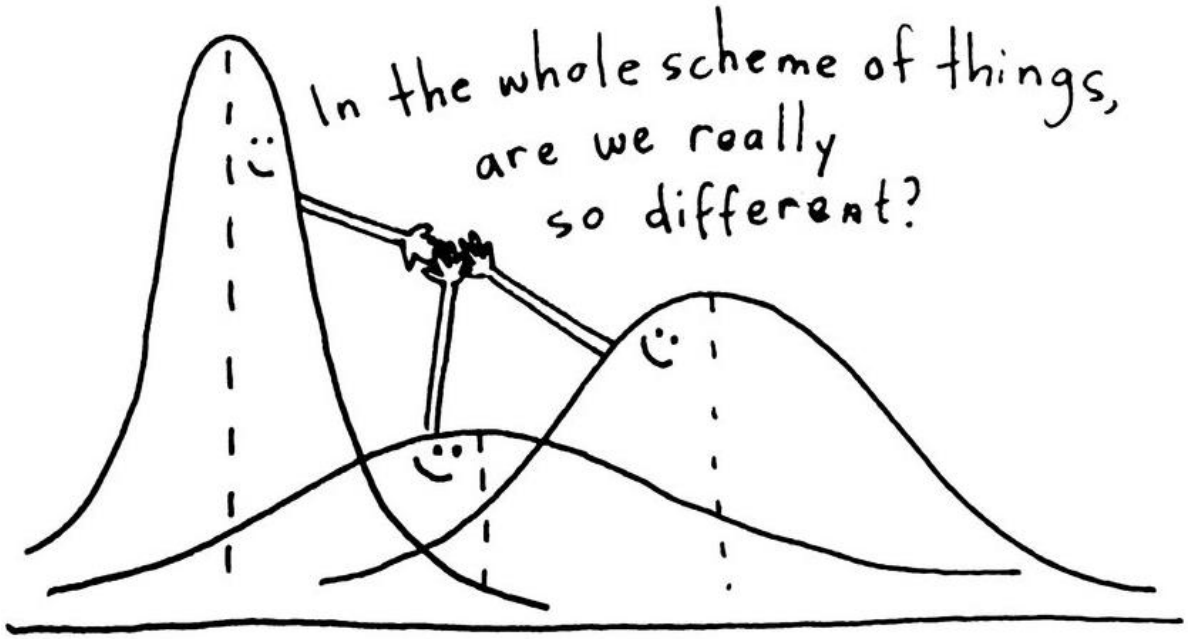


Source: Questionpro

Introduction to analysis of variance

What do you need for a one factor between participants ANOVA?

- At least one categorical independent variable (i.e., one factor)
- One continuous dependent variable (outcome measure)



Source: Questionpro

Sources of variability in data

1. Treatment effects
2. Individual differences
3. Random (residual) errors

Within-group variability?

Between-group variability?

Sources of variability in data

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1. Treatment effects
2. Individual differences
3. Random (residual) errors

Treatment effects

- The effects of the independent variable
- This is what we want!
- We want people who are treated differently because of our intervention to behave differently

Sources of variability in data

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1. Treatment effects
2. Individual differences
3. Random (residual) errors

Individual differences

- Some individuals may be more proficient in memory recall
- Maybe some individuals have experience of similar tasks
- Some may have ignored instructions or had lower attention spans / motivation
- A control group can employ their own strategy, increasing the variability

Sources of variability in data

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1. Treatment effects
2. Individual differences
3. Random (residual) errors

Random (residual) errors

- Ideally a participant would have a ‘true level’ at which they perform, which can always be measured accurately

1. Varying external conditions – e.g., temperature, time of day
2. State of participant (e.g. tired?)
3. Experimenter’s ability to measure accurately…

…Experimenter effects

- Experimenters need to minimise these, so not to obscure the treatment effect
- Spread data away from the true means – i.e., increase variability and standard errors
- Reduce confidence in our estimates and a randomly plucked sample

Within- and between- group variability

- Within-group variability
  - The extent to which participants within a single group or population differ, despite receiving the same treatment

- Between-group variability
  - The extent to which overall groups differ from one another (hopefully because of our treatment)

Within-group variability?

Between-group variability?

Within- and between- group variability

High between-group variability - no within group-variability

	Group A	Group B	Group C
	10	20	30
	10	20	30
	10	20	30
	10	20	30
	10	20	30
Mean	10	20	30
S	0	0	0

No between-group variability - high within-group variability

	Group A	Group B	Group C
	10	15	5
	25	20	25
	30	30	25
	35	40	45
	50	45	50
Mean	30	30	30
S	14.6	12.8	18.0

Moderate between-group variability - moderate within-group variability

	Group A	Group B	Group C
	10	10	20
	10	20	20
	10	20	30
	20	20	30
	20	30	30
Mean	14	20	26
S	5.5	7.1	5.5

Tables adapted from Roberts and Russo (1999)

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Lecture 2 – One factor between-participants ANOVA – Part II

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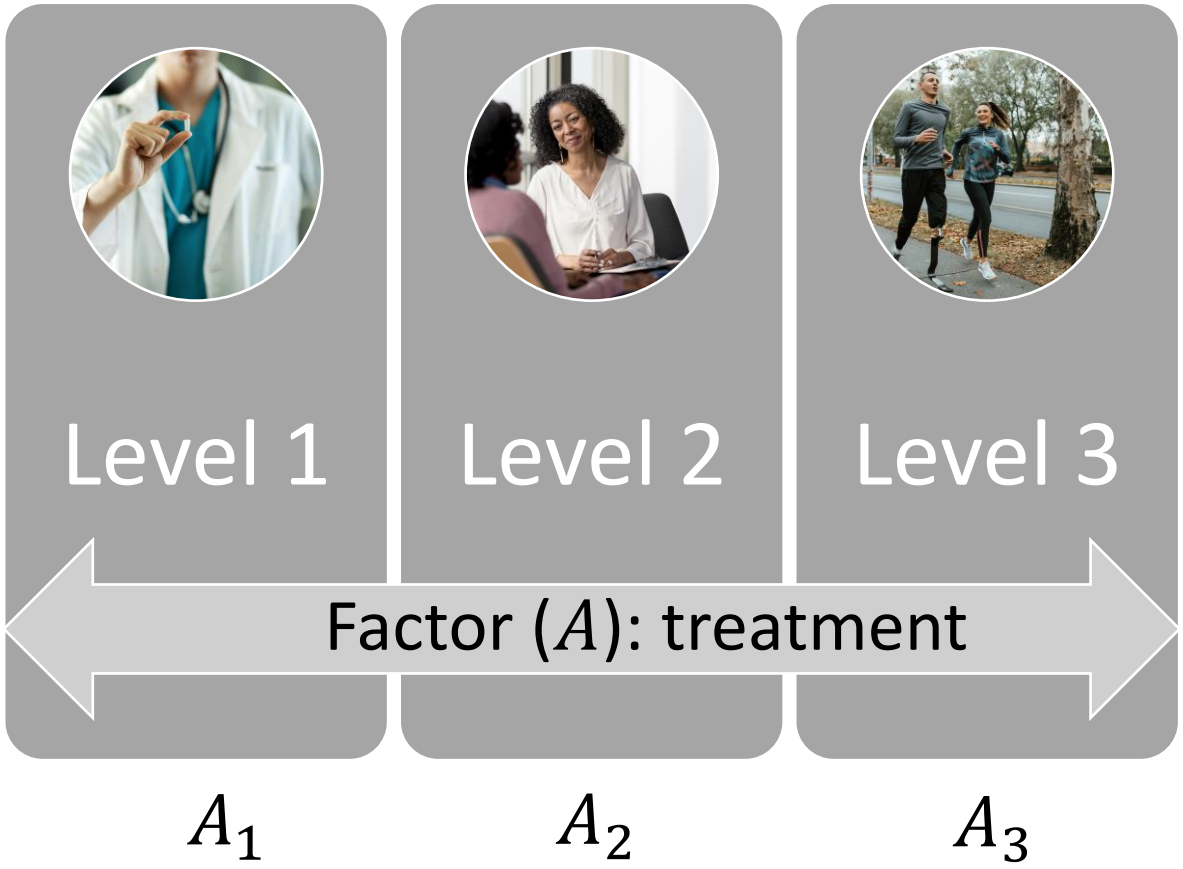
Introduction to analysis of variance

Factors and levels

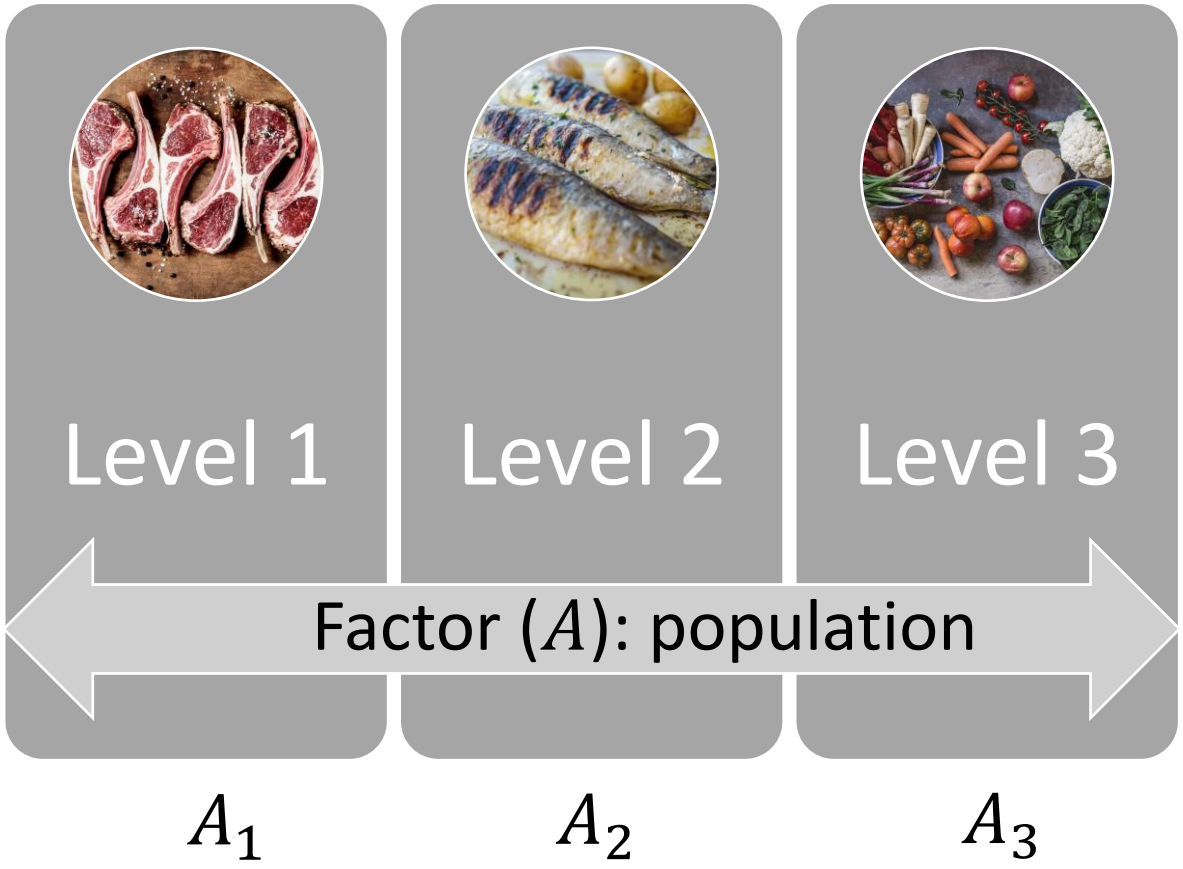
- Factor: treatment
- 3 levels
  - Medication
  - Counselling
  - Exercise



Introduction to analysis of variance

Factors and levels

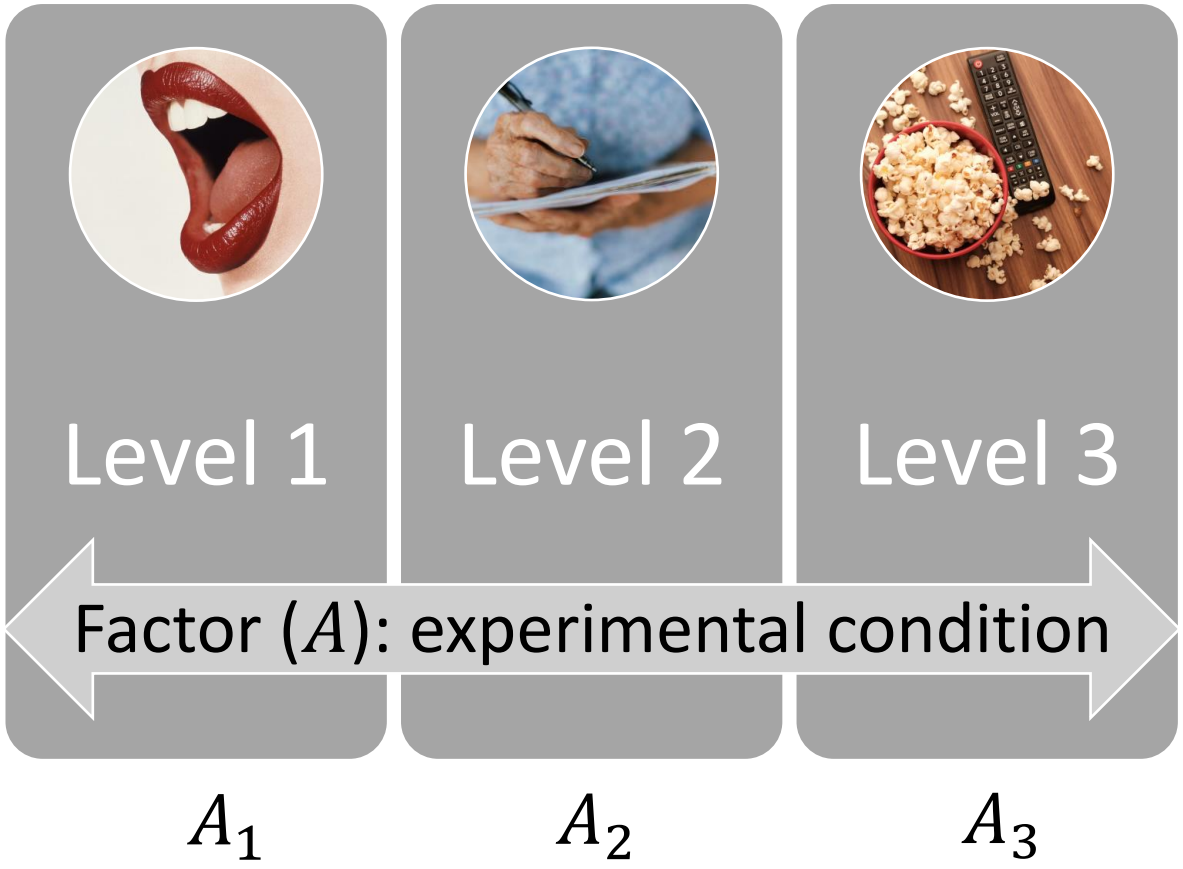
- Factor: population
- 3 levels:
  - A_1 Meat eater
  - A_2 Pescatarian
  - A_3 Vegetarian



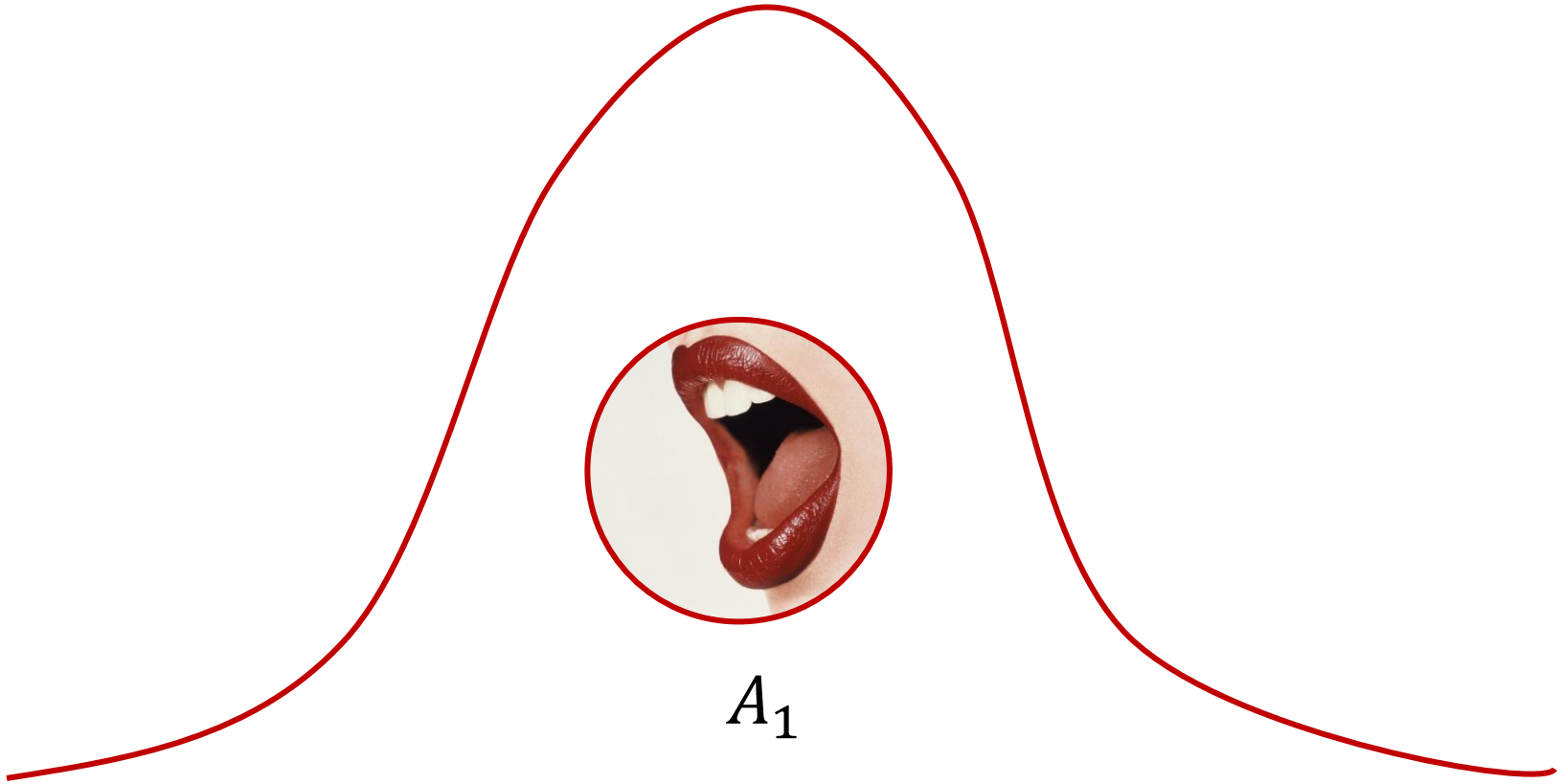
Introduction to analysis of variance

Factors and levels

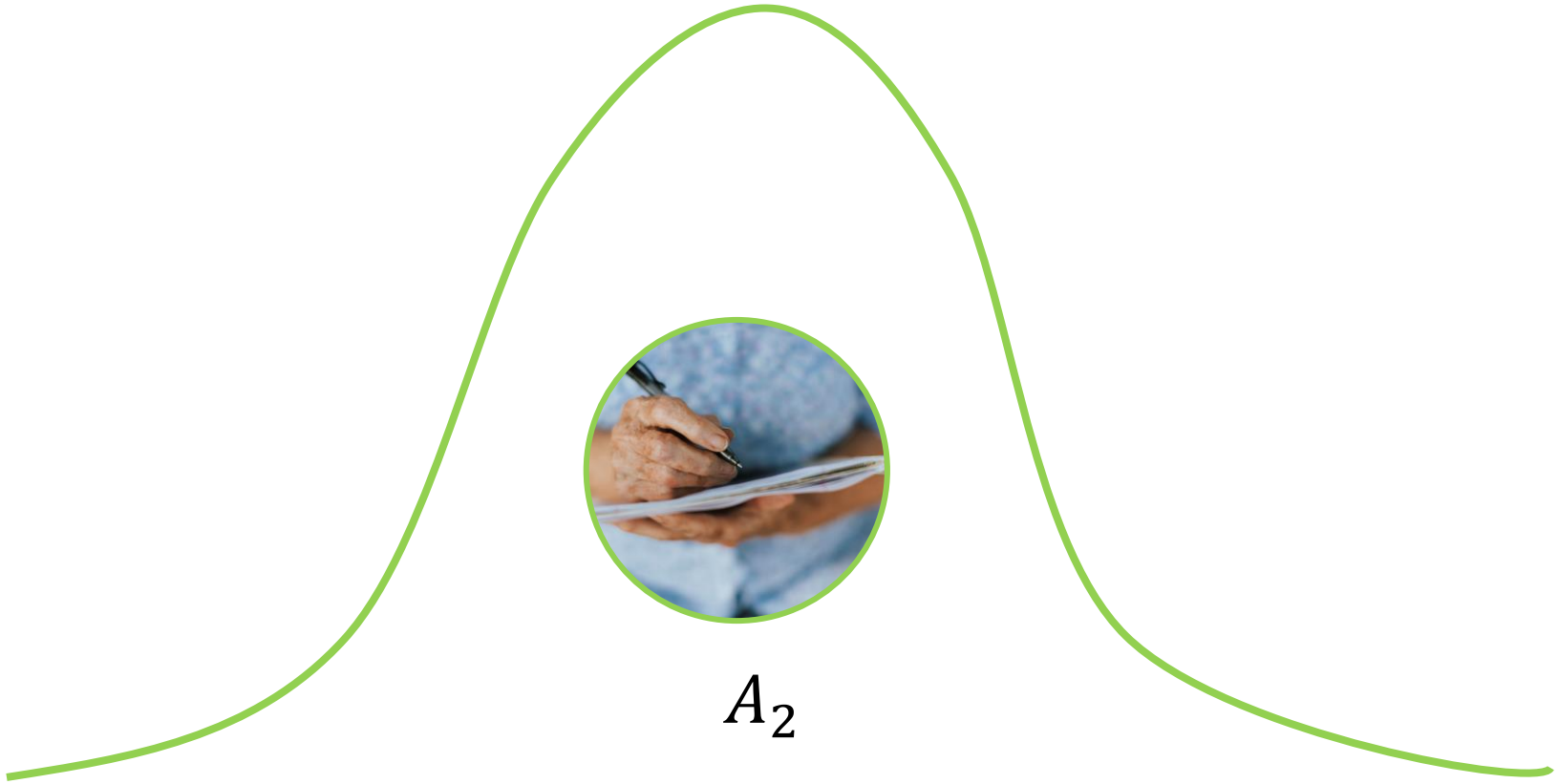
- Factor: experimental condition
- 3 levels:
  - A_1 Verbal negative feedback
  - A_2 Written negative feedback
  - A_3 Control (no feedback)



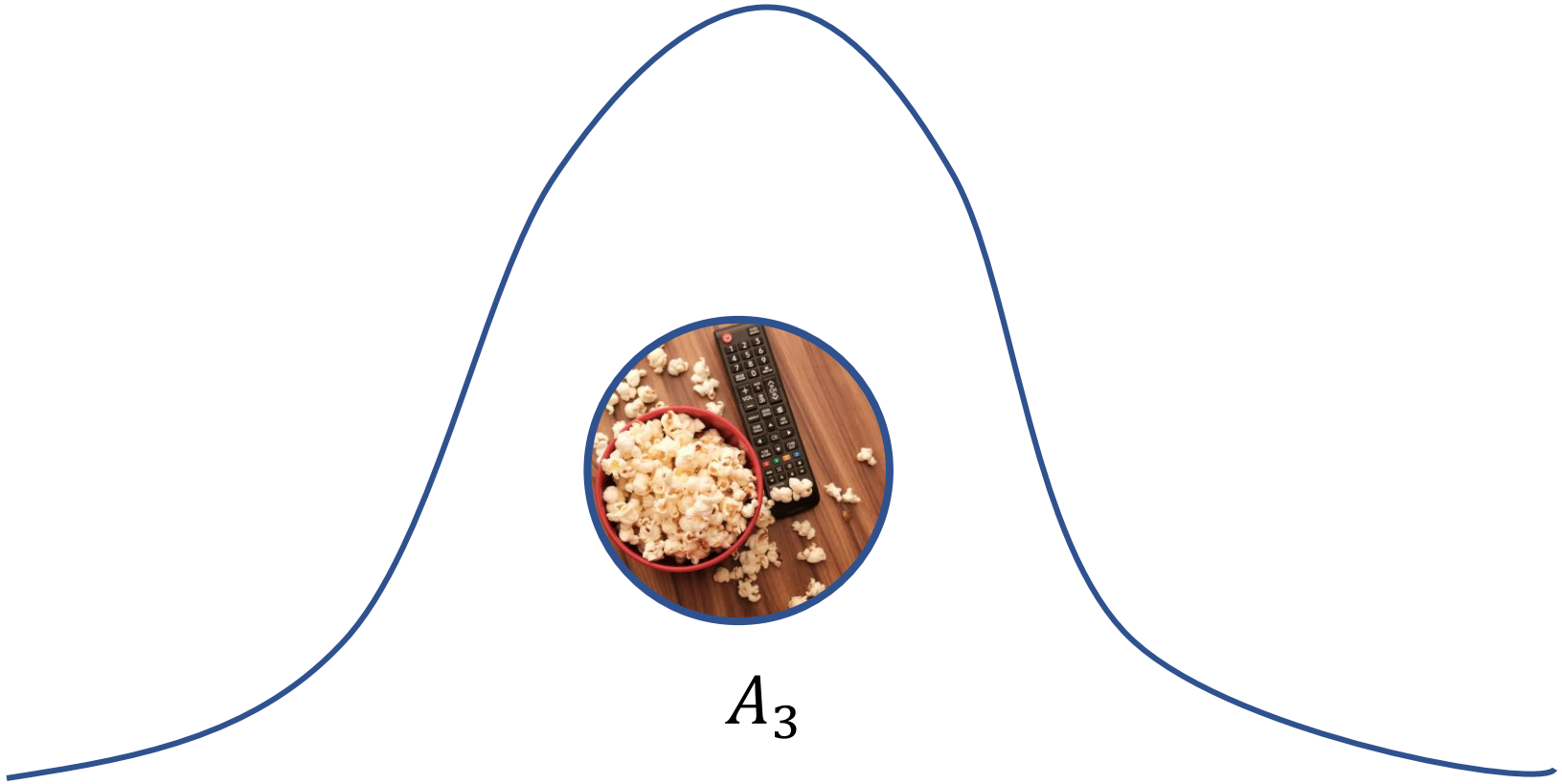
Introduction to analysis of variance



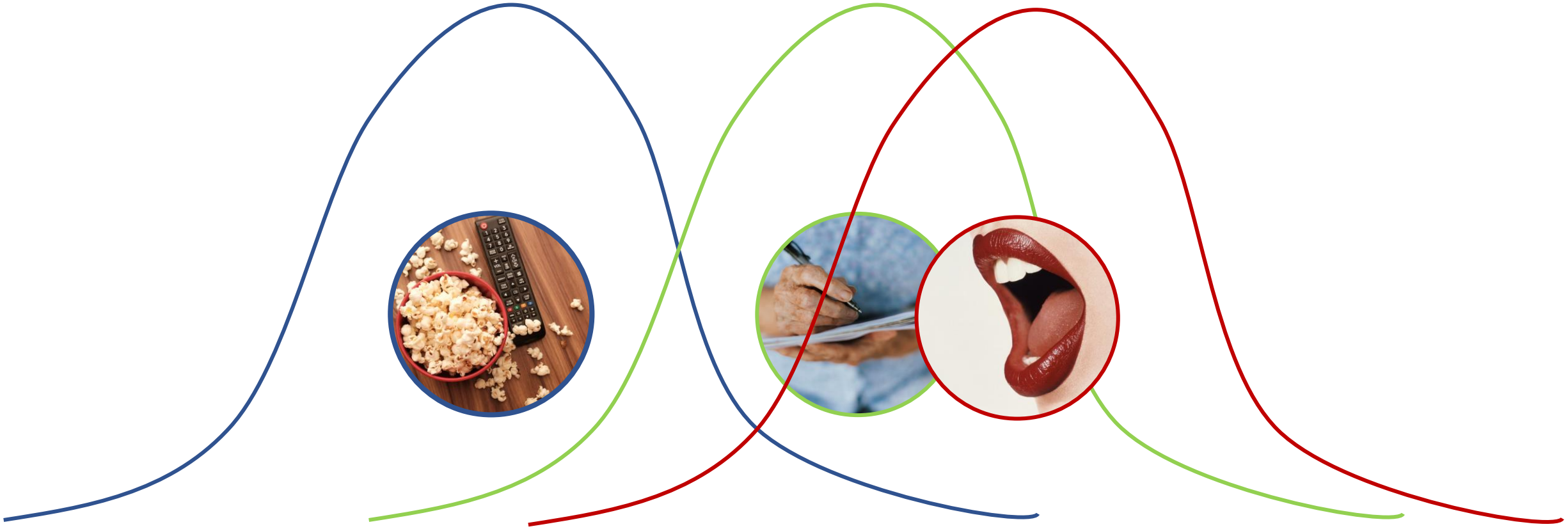
Introduction to analysis of variance



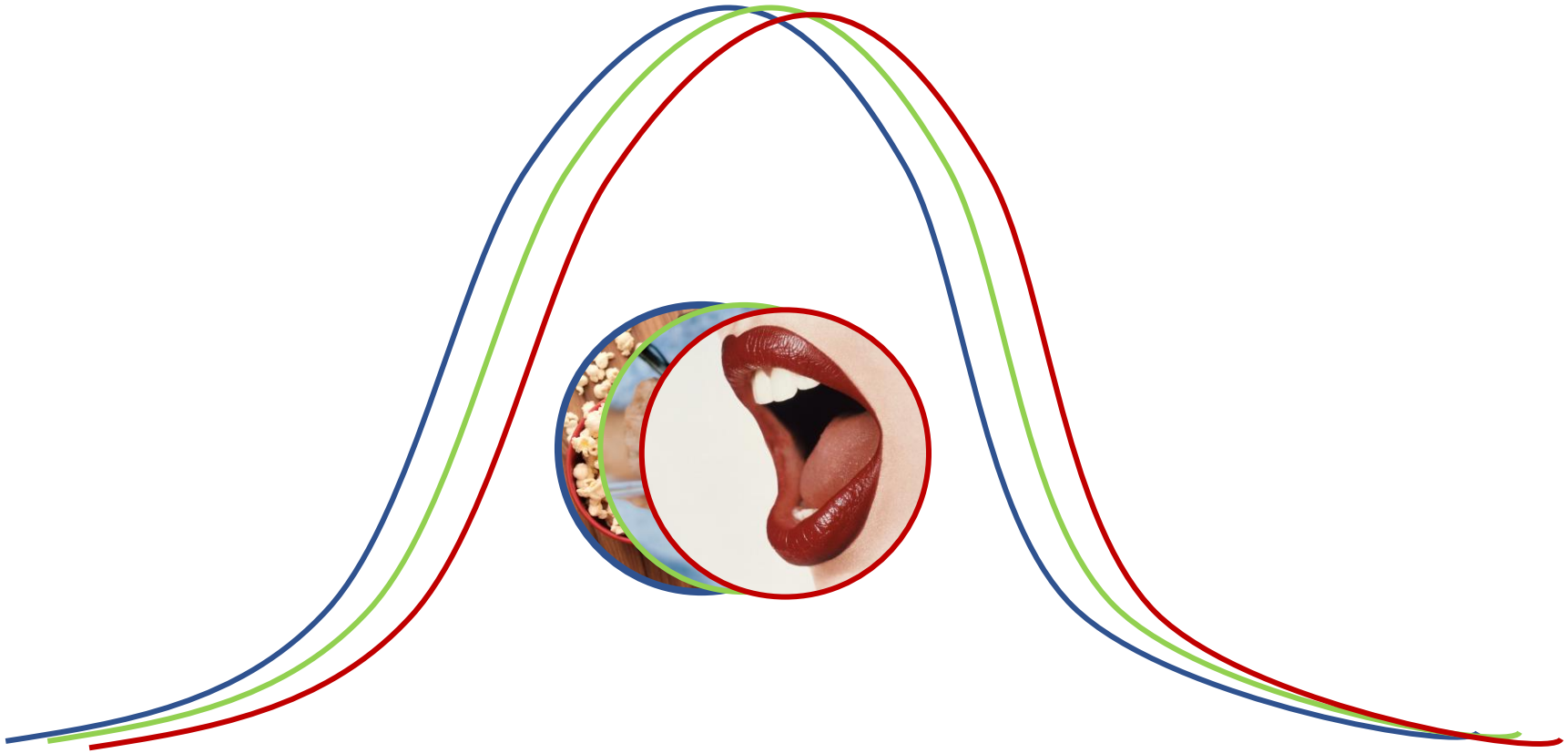
Introduction to analysis of variance



Introduction to analysis of variance



Introduction to analysis of variance



Testing for differences

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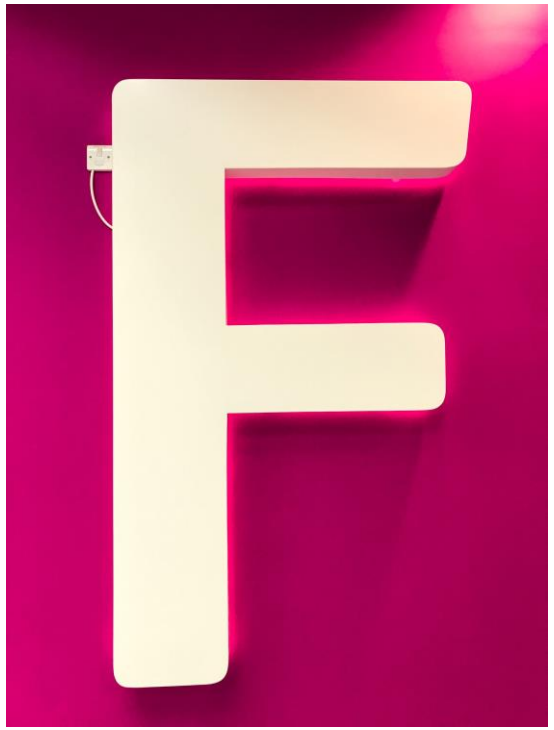
- H_0 the Null Hypothesis
- Under H0, the samples come from the same population
- $\mu_1 = \mu_2 = \mu_3$ [No difference in the population means]
- Experimental effect = 0
- All differences are due to individual differences + random (residual) errors

- H_1 the Experimental Hypothesis
- Under H1, the samples come from the different populations.
- $\mu_1 \neq \mu_2 \neq \mu_3$ [Population means are different]
- Experimental effect ≠ 0
- All differences are due to individual differences, random (residual) errors AND the experimental effect

Introduction to analysis of variance



$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{\text{Signal}}{\text{Noise}}$$

$$F = \frac{\text{Signal}}{\text{Noise}}$$

The F ratio

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

The F ratio

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{\text{treatment effects} + \text{individual differences} + \text{random (residual) errors}}{\text{individual differences} + \text{random (residual) errors}}$$

experimental error

experimental error

The F ratio

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{\text{treatment effects + individual differences + random (residual) errors}}{\text{individual differences + random (residual) errors}}$$

$$F = \frac{\text{treatment effects + experimental error}}{\text{experimental error}}$$

Introduction to analysis of variance

$$F = \frac{\text{Signal}}{\text{Noise}}$$

$$F = \frac{\text{Signal}}{\text{Noise}}$$

The larger in magnitude the F value, the more treatment effects are standing out away from experimental error – i.e., the larger the signal is from the noise. The larger the F, the less likely that differences in scores are caused by chance.

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Calculating between-group variance

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

Mean ($\bar{A}$)



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6

$$\bar{X} = \frac{\sum X}{N}$$

Total set of scores

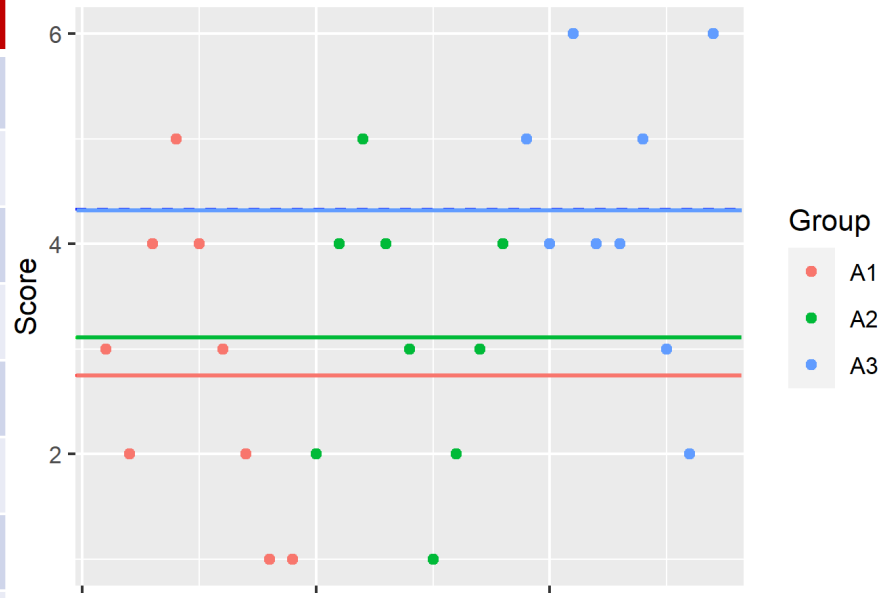
Mean

Number of scores

Mean ($\bar{A}$)



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33



Grand Mean ($\bar{Y}$)



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$ = 2.78	$\bar{A}_2$ = 3.11	$\bar{A}_3$ = 4.33

$$\bar{Y} = \frac{\bar{A}_1 + \bar{A}_2 + \bar{A}_3 + \ldots \bar{A}_k}{k}$$

$\bar{Y} = The\ grand\ mean\ of\ averages$

k = *number of levels*

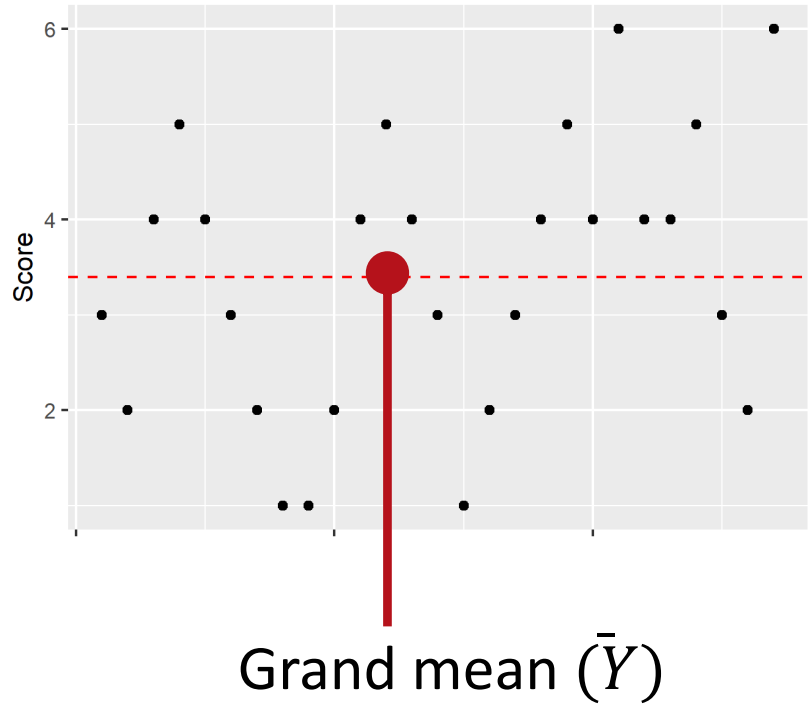
$$\bar{Y} = \frac{2.78 + 3.11 + 4.33}{3}$$

$\bar{Y}$ = 3.41

Grand Mean ($\bar{Y}$)



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41



Total between-group variance

$$total\ between\ group\ variance = \frac{N_{A1}\left(\bar{A}_1 - \bar{Y}\right)^2 + N_{A2}\left(\bar{A}_2 - \bar{Y}\right)^2 + N_{A3}\left(\bar{A}_3 - \bar{Y}\right)^2\ (and\ so\ on)}{total\ between\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
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Total between-group variance

$$total\ between\ group\ variance = \frac{N_{A1}(\bar{A}_1 - \bar{Y})^2 + N_{A2}(\bar{A}_2 - \bar{Y})^2 + N_{A3}(\bar{A}_3 - \bar{Y})^2\ (and\ so\ on)}{total\ between\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores
3	2	5
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2	2	3
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1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

Total between-group variance

$$total\ between\ group\ variance = \frac{N_{A1}(\bar{A}_1 - \bar{Y})^2 + N_{A2}(\bar{A}_2 - \bar{Y})^2 + N_{A3}(\bar{A}_3 - \bar{Y})^2\ (and\ so\ on)}{total\ between\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
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5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
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Total between-group variance

$$total\ between\ group\ variance = \frac{N_{A1}(\bar{A}_1 - \bar{Y})^2 + N_{A2}(\bar{A}_2 - \bar{Y})^2 + N_{A3}(\bar{A}_3 - \bar{Y})^2\ (and\ so\ on)}{total\ between\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

N_{A1} = Number of scores for A_1
= 9

N_{A2} = Number of scores for A_2
= 9

N_{A3} = Number of scores for A_3
= 9

Degrees of freedom

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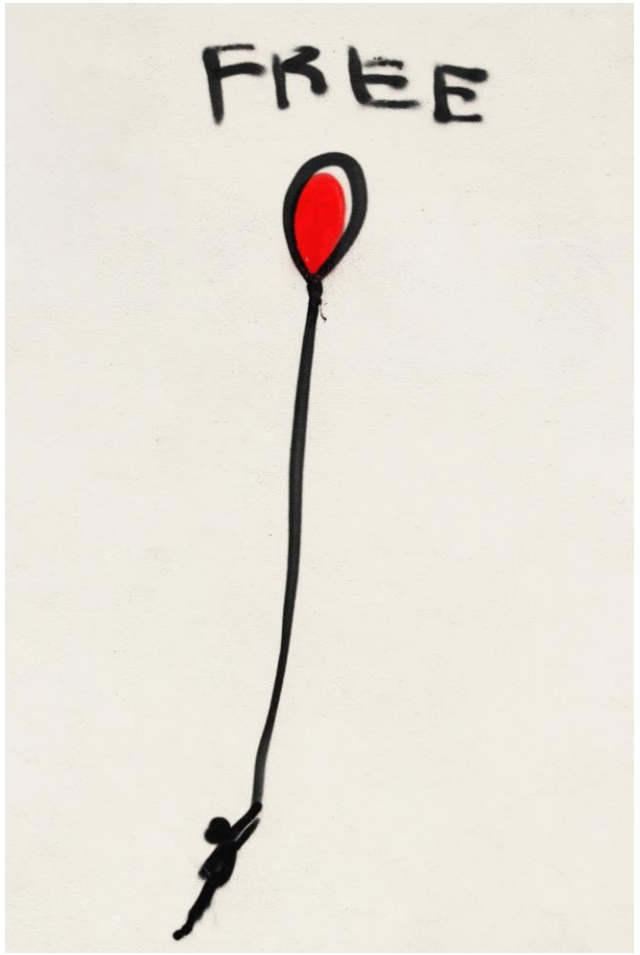
Between-groups degrees of freedom

- The total number of levels minus one
- For example, in our experiment we have three levels [verbal feedback, written feedback, control]
- The between-groups degree of freedom is there 3 levels – 1 = 2
- Between-groups df = 2



Total between-group variance

$$total\ between\ group\ variance = \frac{9(2.78-3.41)^2 + 9(3.11-3.41)^2 + 9(4.33-3.41)^2}{2}$$



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33

$\bar{Y}$ = 3.41

N_{A1} = Number of scores for A_1
= 9

N_{A2} = Number of scores for A_2
= 9

N_{A3} = Number of scores for A_3
= 9

Total between-group variance

$$total\ between\ group\ variance = \frac{9(-0.63)^2 + 9(-0.30)^2 + 9(0.92)^2}{2}$$



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

N_{A1} = Number of scores for A_1
= 9

N_{A2} = Number of scores for A_2
= 9

N_{A3} = Number of scores for A_3
= 9

Total between-group variance

$$total\ between\ group\ variance = \frac{9(0.40)\ + 9(0.09)\ + 9(0.85)}{2}$$



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33

$\bar{Y}$ = 3.41

N_{A1} = Number of scores for A_1
= 9

N_{A2} = Number of scores for A_2
= 9

N_{A3} = Number of scores for A_3
= 9

Total between-group variance

$$total\ between\ group\ variance = \frac{3.60 + 0.81\ + 7.65}{2} = 6.037 \text{ (with rounding)}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

Calculating between-group variance

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{6.037}{\text{within-group variance}}$$

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Lecture 2 – One factor between-participants
ANOVA – Part IV

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Up to now…

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{6.037}{\text{within-group variance}}$$

Calculating within-group variance

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

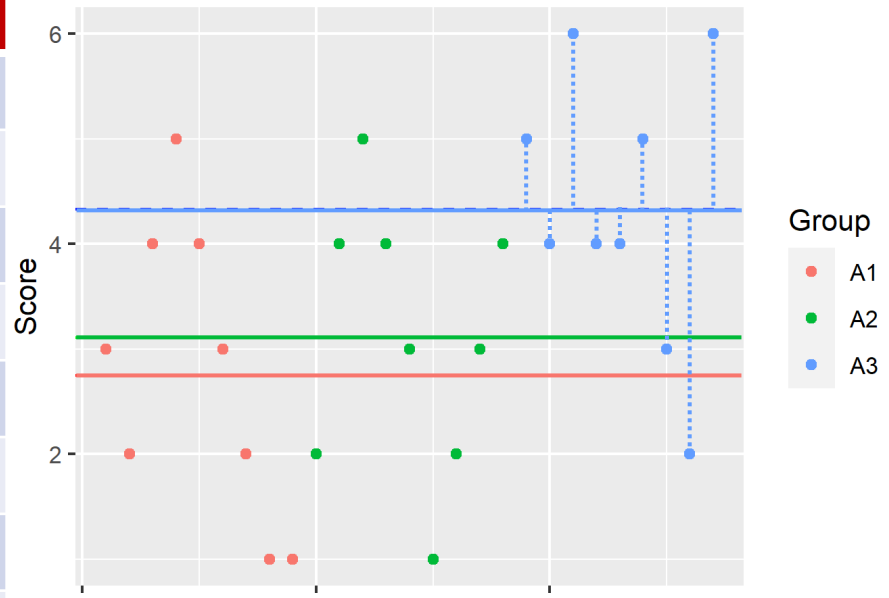
Total within-group variance

$$total\ within\ group\ variance = \frac{SS\ level\ A_1 + SS\ level\ A_2 + SS\ level\ A_3 (and\ so\ on)}{total\ within\ group\ degrees\ of\ freedom}$$

Mean



A_1 scores	A_2 scores	A_3 scores
3	2	5
2	4	4
4	5	6
5	4	4
4	3	4
3	1	5
2	2	3
1	3	2
1	4	6
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33



Total within-group variance

$$total\ within\ group\ variance = \frac{SS\ level\ A_1 + SS\ level\ A_2 + SS\ level\ A_3 (and\ so\ on)}{total\ within\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

$SS\ level\ A_1$
$= Sums\ of\ squares\ for\ level\ 1$

$SS\ level\ A_2$
$= Sums\ of\ squares\ for\ level\ 2$

$SS\ level\ A_3$
$= Sums\ of\ squares\ for\ level\ 3$

Total within-group variance

$$total\ within\ group\ variance = \frac{\sum(A_1 - \bar{A}_1)^2 + (A_2 - \bar{A}_2)^2 + (A_3 - \bar{A}_3)^2 + \ (and\ so\ on)}{total\ within\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

Total within-group variance

$$total\ within\ group\ variance = \frac{\sum(A_1 - 2.78)^2 + (A_2 - 3.11)^2 + (A_3 - 4.33)^2 + \ (and\ so\ on)}{total\ within\ group\ degrees\ of\ freedom}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

Degrees of freedom

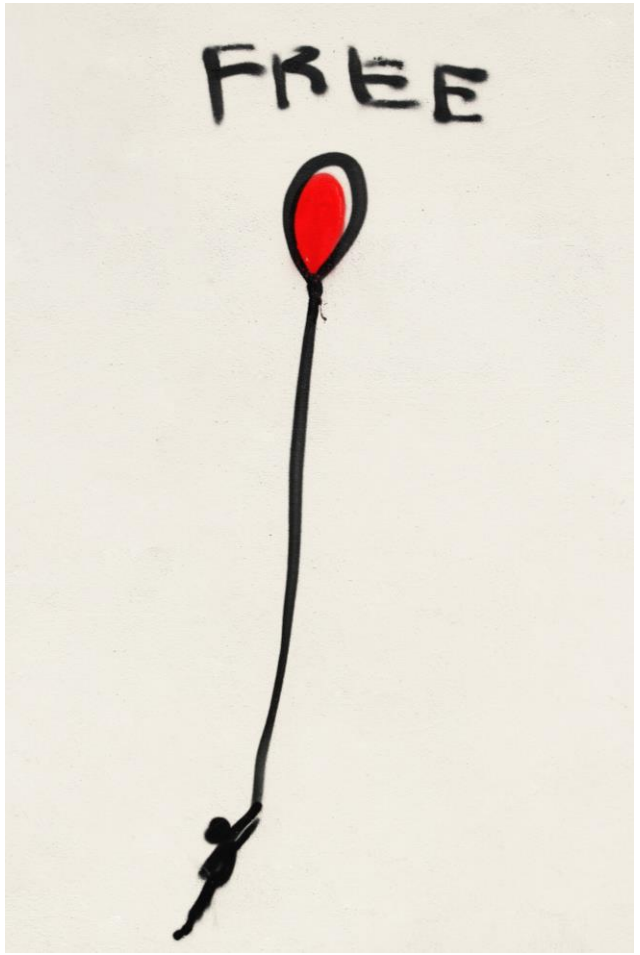
Within-groups degrees of freedom

- For within-groups degrees of freedom, we add up the number of participants for each level – 1
- Mathematically this is expressed as:

$$= (N_{A1} - 1) + (N_{A2} - 1) + (N_{A3} - 1)$$

$$= (9 - 1) + (9 - 1) + (9 - 1)$$

$$= 24$$



Total within-group variance

$$total\ within\ group\ variance = \frac{\sum(A_1 - 2.75)^2 + (A_2 - 3.11)^2 + (A_3 - 4.33)^2}{24}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

Total within-group variance

$$total\ within\ group\ variance = \frac{42.444}{24} = 1.769 \text{ (with rounding)}$$



A_1 scores	A_2 scores	A_3 scores	
3	2	5	
2	4	4	
4	5	6	
5	4	4	
4	3	4	
3	1	5	
2	2	3	
1	3	2	
1	4	6	
$\bar{A}_1$= 2.78	$\bar{A}_2$= 3.11	$\bar{A}_3$= 4.33	$\bar{Y}$ = 3.41

The F ratio

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{6.037}{1.769}$$

$F = 3.414$

ν_2 \ ν_1	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161	200	216	225	230	234	237	239	241	242	244	246	248	249	250	251	252	253	254
2	18.5	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.5	19.5	19.5	19.5	19.5	19.5
3	10.1	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.37
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.18	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

Source: E. S. Pearson and H. O. Hartley, *Biometrika Tables for Statisticians*, Vol. 2 (1972), Table 5, page 178, by permission.

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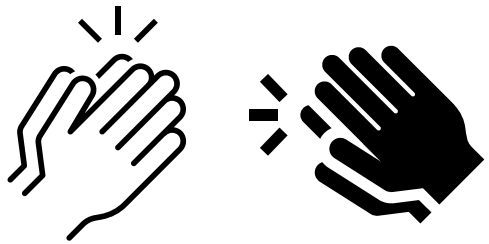
The F ratio

$$F = \frac{\text{between-group variance}}{\text{within-group variance}}$$

$$F = \frac{6.037}{1.769}$$

$F = 3.414$, $p = 0.05$, A statistically significant test result ($P \leq 0.05$)



Lecture 2 – One factor between-participants ANOVA

Lancaster University

Review of lecture 2

- What is Analysis of Variance
- What is a one-factor between-participants design
- Sources of variability in data
- Calculated within-group and between-group variances
- Degrees of Freedom
- Produced the F-statistic

Thank you for attention! Questions?