PSYC214: Statistics
Lecture 4 – One-factor within-participants ANOVA – Part I

Michaelmas Term
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One factor within-participants ANOVA

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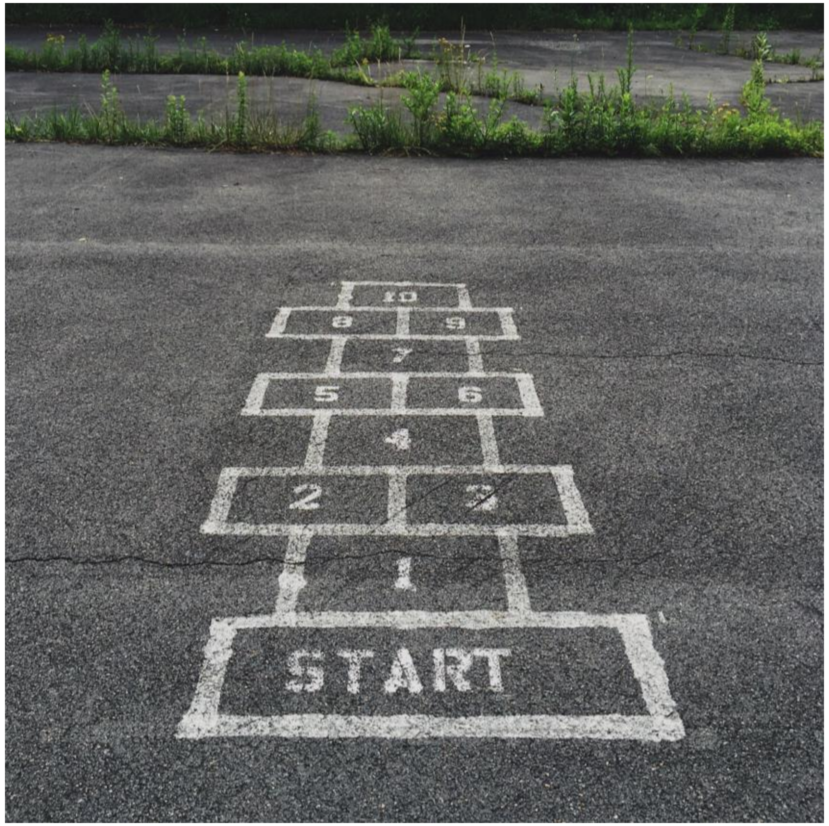
Agenda/Content for Lecture 4

- Introduction to one factor within-participants ANOVA and its limitations
- Between-participant variability and residual variance
- Calculating within-group and between group variances
- Producing the within-participants F-statistic



Between-participants

Within-participants

Within-participants design - limitations

Type	Definition	An example…
Practice effects	The experience/performance on a task at a given point in time, may influence your performance of that task at a subsequent time.	

Within-participants design - limitations

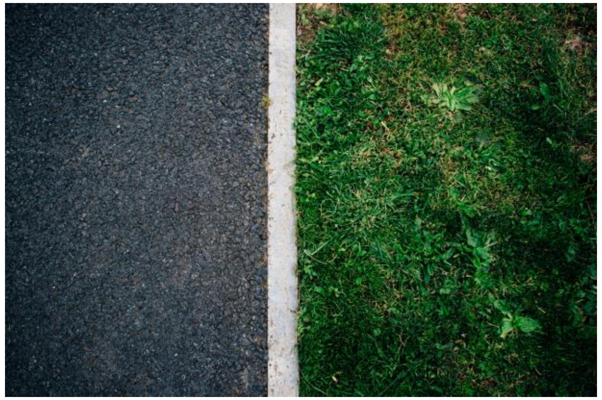
	Type	Definition	An example…
Order effects	Practice effects	The experience/performance on a task at a given point in time, may influence your performance of that task at a subsequent time.	
	Fatigue effects	Fatigue or boredom with a task may influence your performance of that task at a subsequent time.	

Within-participants design - limitations

	Type	Definition	An example…
Order effects	Practice effects	The experience/performance on a task at a given point in time, may influence your performance of that task at a subsequent time.	
	Fatigue effects	Fatigue or boredom with a task may influence your performance of that task at a subsequent time.	
	Demand characteristic	Participants form an idea of the experiment's purpose and (sub)consciously change their behaviour to comply	

Assumptions underlying the W-P ANOVA

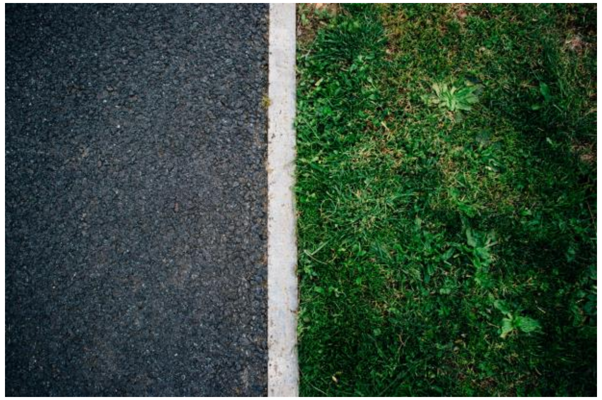
1. Assumption of **independence**



Independence

Assumptions underlying the W-P ANOVA

1. Assumption of independence
2. Assumption of **normality**



Independence

Normality

Assumptions underlying the W-P ANOVA

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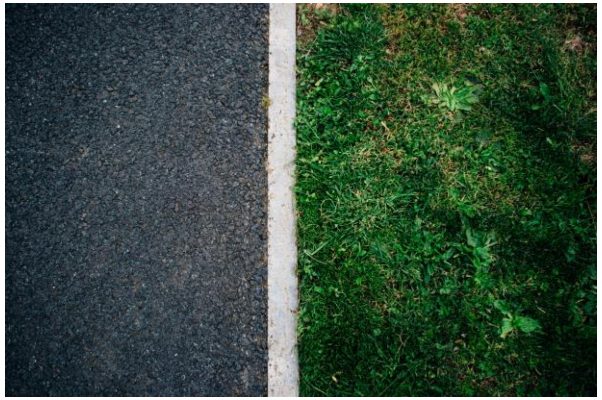
1. Assumption of independence
2. Assumption of normality
3. Assumption of **sphericity**

The variances of the differences between all combinations of related groups are equal



Independence

Normality

Sphericity

Between-participants F ratio

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

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

experimental error → individual differences + random (residual) errors

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

Within-participants F ratio

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

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

The F ratio

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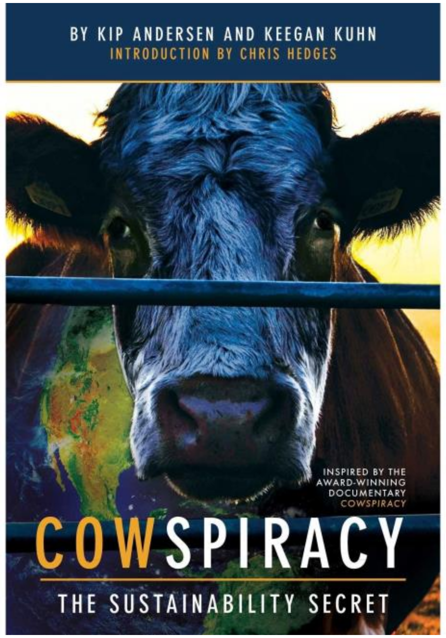
$$F = \frac{\text{Signal}}{\text{Noise}}$$

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

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.

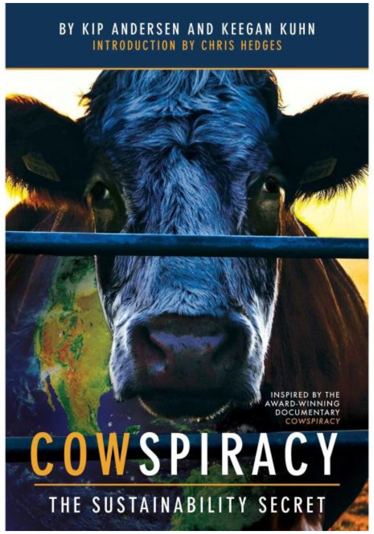
A within-participants example



A within-participants example

Table 1. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	*ΔA*	*P Mean*
P_1	3	1	-2	*2*
P_2	5	3	-2	*4*
P_3	4	2	-2	*3*
P_4	5	3	-2	*4*
P_5	5	3	-2	*4*
A Mean	4.4	2.4	-2	



A within-participants example

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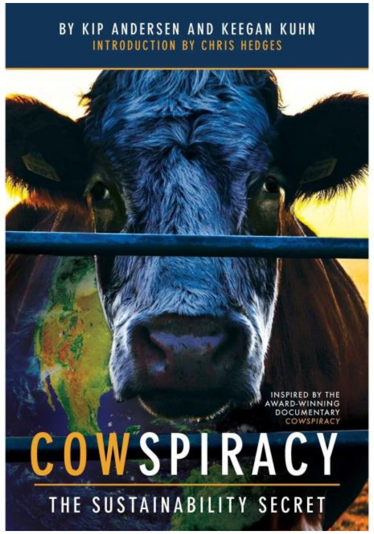
Table 2. Burgers consumed before (A_1) and after (A_2) Cowspiracy

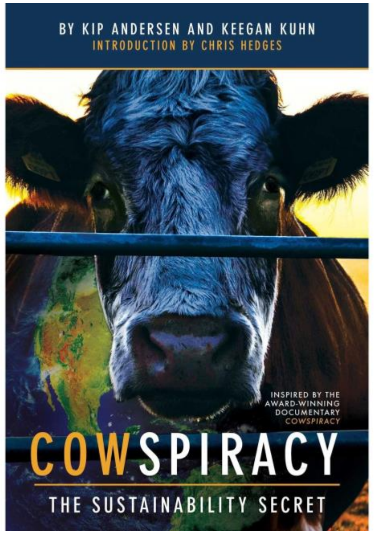
	A_1	A_2	ΔA	*P Mean*
P_1	1	3	2	*2*
P_2	3	5	2	*4*
P_3	2	4	2	*3*
P_4	3	5	2	*4*
P_5	3	5	2	*4*
A Mean	2.4	4.4	2	



A within-participants example

Table 3. Burgers consumed before (A_1) and after (A_2) Cowspiracy

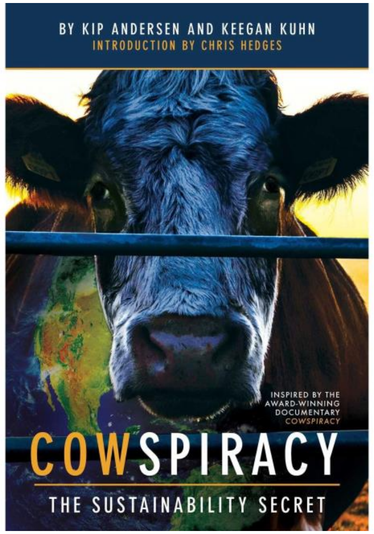
	A_1	A_2	ΔA	*P Mean*
P_1	3	1	-2	*2*
P_2	5	4	-1	*4.5*
P_3	4	1	-3	*2.5*
P_4	5	1	-4	*3*
P_5	5	3	-2	*4*
A Mean	4.4	2	-2.4	



A within-participants example

Table 4. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	*ΔA*	*P Mean*
P_1	3	5	2	*4*
P_2	5	4	-1	*4.5*
P_3	4	5	1	*4.5*
P_4	5	1	-4	*3*
P_5	5	5	0	*5*
A Mean	4.4	4	-0.4	



Between-participant variability

Table 5. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P_1	5	3	-2	*4*
P_2	9	7	-2	*8*
P_3	3	1	-2	*2*
P_4	7	5	-2	*6*
P_5	4	6	2	*5*
A Mean	5.6	4.4		*5*

High between-participant variability

The extent to which participants, on average, differ from another regardless of their stage of the experiment

- In this example, there is high variability between participant means.

Between-participant variability

The extent to which participants, on average, differ from another regardless of their stage of the experiment

- In this example, there is zero variability between participant means.
- Zero differences = zero variance.

Low between-participant variability

Table 6. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P_1	9	1	-8	*5*
P_2	5	5	0	*5*
P_3	4	6	2	*5*
P_4	6	4	-2	*5*
P_5	4	6	2	*5*
A Mean	5.6	4.4		*5*

Between-participant variability

Table 5. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P_1	5	3	-2	*4*
P_2	9	7	-2	*8*
P_3	3	1	-2	*2*
P_4	7	5	-2	*6*
P_5	4	6	2	*5*
A Mean	5.6	4.4		*5*

High between-participant variability

Table 6. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P_1	9	1	-8	*5*
P_2	5	5	0	*5*
P_3	4	6	2	*5*
P_4	6	4	-2	*5*
P_5	4	6	2	*5*
A Mean	5.6	4.4		*5*

Low between-participant variability

Residual variance

Table 5. Burgers consumed before (A_1) and after (A_2) Cowspiracy

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A Mean	5.6	4.4		*5*

High between-participant variability / **Low** residual variance

Residual variance

Table 5. Burgers consumed before (A_1) and after (A_2) Cowspiracy

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P_5	4	6	2	*5*
A Mean	5.6	4.4		*5*

High between-participant variability / **Low** residual variance

The variability in the consistency of trends

- In this example, these trends overall are pretty consistent.
- [-2, -2, -2, -2, 2].
- Most are same direction and -2 in difference.
- As such, the residual variance is said to be low

Residual variance

The variability in the consistency of trends

- In this example, there trends are very inconsistent.
- [-8, 0, 2, -2, 2] = widespread.
- As such, the residual variance is said to be high.

Low between-participant variability / **High** residual variance

Table 6. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P_1	9	1	-8	*5*
P_2	5	5	0	*5*
P_3	4	6	2	*5*
P_4	6	4	-2	*5*
P_5	4	6	2	*5*
A Mean	5.6	4.4		*5*

Summary

Table 5. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P1	5	3	-2	*4*
P2	9	7	-2	*8*
P3	3	1	-2	*2*
P4	7	5	-2	*6*
P5	4	6	2	*5*
A Mean	5.6	4.4		5

High between-participant variability / **Low** residual variance

Table 6. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P1	9	1	-8	*5*
P2	5	5	0	*5*
P3	4	6	2	*5*
P4	6	4	-2	*5*
P5	4	6	2	*5*
A Mean	5.6	4.4		5

Low between-participant variability / **High** residual variance

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Lecture 4 – One-factor within-participants ANOVA – Part II

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Summary

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Table 5. Burgers consumed before (A_1) and after (A_2) Cowspiracy

	A_1	A_2	ΔA	*P Mean*
P_1	5	3	-2	*4*
P_2	9	7	-2	*8*
P_3	3	1	-2	*2*
P_4	7	5	-2	*6*
P_5	4	6	2	*5*
A Mean	5.6	4.4		5

High between-participant variability / **Low** residual variance

Table 6. Burgers consumed before (A_1) and after (A_2) Cowspiracy

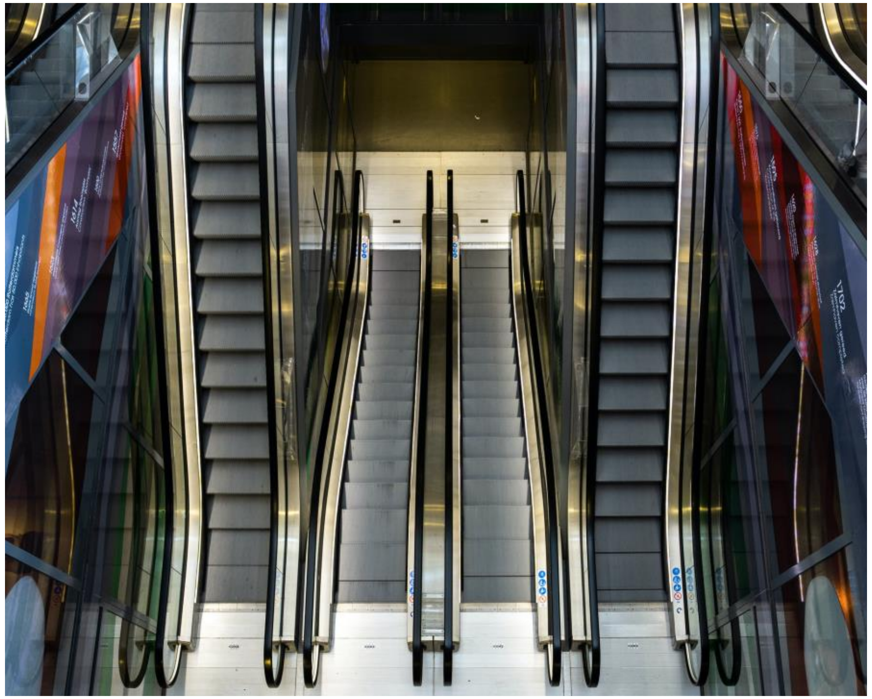
	A_1	A_2	ΔA	*P Mean*
P_1	9	1	-8	*5*
P_2	5	5	0	*5*
P_3	4	6	2	*5*
P_4	6	4	-2	*5*
P_5	4	6	2	*5*
A Mean	5.6	4.4		5

Low between-participant variability / **High** residual variance

Within-participants F ratio

Ways in which people can differ:

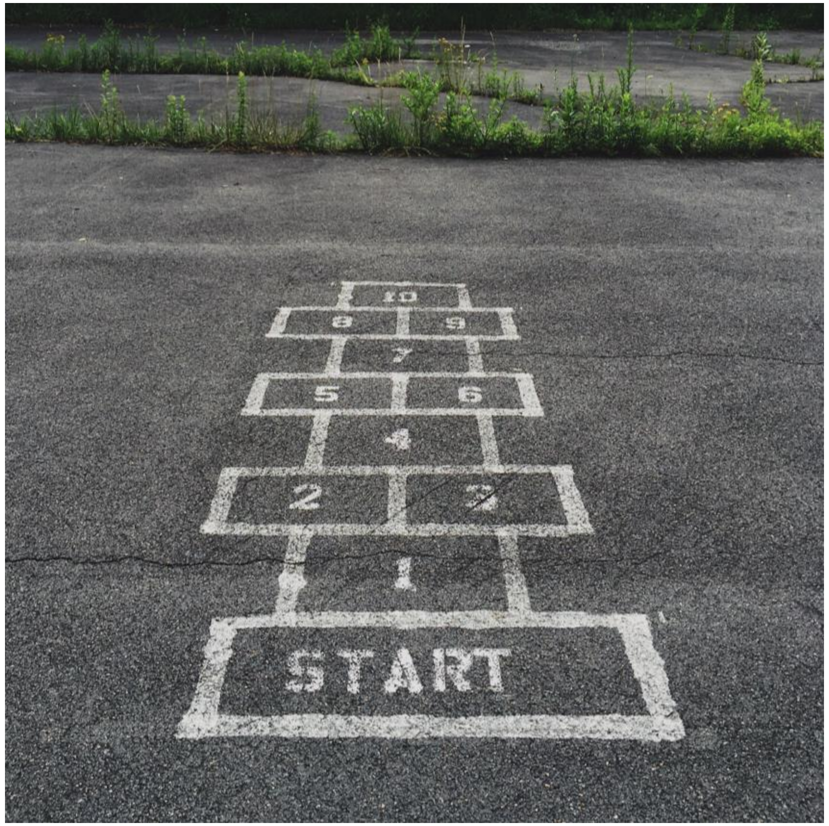
- Overall level of performance/score
- Trends in their scores (↗ ↘ →)
- Both!



One factor within-participants ANOVA

Between-participant variability vs Residual variance

- In virtually all within-participant studies, we hypothesise that a score at one time would significantly differ from at another time.
- Less interested in the actual change in scores and not interested in between participant differences.
- As such, we are more interested in the residual variance than the between participant variability.



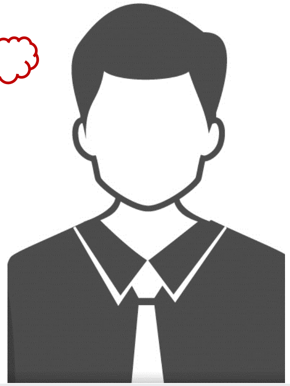
Within-participants F ratio

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

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

We calculate the F ratio in a similar way as for the between participants design, with the exception that we are not interested in how participants vary from one another!

We therefore include an additional step to remove the between-participant variability (we spoke of before) from the error term.



We remove the between-participant variability from the within-group variability – leaving only random errors behind – a.k.a., the residual variability

Ingredients of within-participants ANOVA

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Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
$Total$	20	41	48

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

Ingredients of within-participants ANOVA



Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$$SS_{BETWEEN} = \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A} - \frac{(\Sigma Y)^2}{N}$$

$$SS_{WITHIN} = \Sigma Y^2 - \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A}$$

$$SS_{TOTAL} = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

SS-Between groups

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$$SS_{BETWEEN} = \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A} - \frac{(\Sigma Y)^2}{N}$$

Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

SS-Between groups

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Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$$SS_{BETWEEN} = \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A} - \frac{(\Sigma Y)^2}{N}$$

$$SS_{BETWEEN} = \frac{(20)^2 + (41)^2 + (48)^2}{9} - \frac{(109)^2}{27}$$

$$SS_{BETWEEN} = \frac{400 + 1681 + 2304}{9} - \frac{11881}{27}$$

$$SS_{BETWEEN} = 44.44 + 186.77 + 256.00 - 440.03$$

$$SS_{BETWEEN} = 487.21 - 440.03$$

$$SS_{BETWEEN} = 47.18$$

Ingredients of within-participants ANOVA



Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$$SS_{BETWEEN} = 47.18$$

$$SS_{WITHIN} = \Sigma Y^2 - \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A}$$

$$SS_{TOTAL} = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

Ingredients of within-participants ANOVA



Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$$SS_{BETWEEN} = \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A} - \frac{(\Sigma Y)^2}{N}$$

$$SS_{WITHIN} = \Sigma Y^2 - \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A}$$

SS-Within group



Participant	$A_1{}^2$ scores	$A_2{}^2$ scores	$A_3{}^2$ scores
1	$2^2 = 4$	$3^2 = 9$	$5^2 = 25$
2	$1^2 = 1$	$4^2 = 16$	$4^2 = 16$
3	$3^2 = 9$	$5^2 = 25$	$6^2 = 36$
4	$2^2 = 4$	$6^2 = 36$	$5^2 = 25$
5	$2^2 = 4$	$3^2 = 9$	$3^2 = 9$
6	$1^2 = 1$	$5^2 = 25$	$6^2 = 36$
7	$4^2 = 16$	$7^2 = 49$	$7^2 = 49$
8	$3^2 = 9$	$3^2 = 9$	$6^2 = 36$
9	$2^2 = 4$	$5^2 = 25$	$6^2 = 36$
Total	20	41	48

$$SS_{WITHIN} = \Sigma Y^2 - \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A}$$

$$SS_{WITHIN} = 523 - \frac{(20)^2 + (41)^2 + (48)^2}{9}$$

$$SS_{WITHIN} = 523 - \frac{400 + 1681 + 2304}{9}$$

$$SS_{WITHIN} = 523 - 487.21$$

$$SS_{WITHIN} = 35.79$$

Ingredients of within-participants ANOVA

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Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$$SS_{BETWEEN} = 47.18$$

$$SS_{WITHIN} = 35.79$$

$$SS_{TOTAL} = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

Ingredients of within-participants ANOVA

Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$$SS_{BETWEEN} = \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A} - \frac{(\Sigma Y)^2}{N}$$

$$SS_{WITHIN} = \Sigma Y^2 - \frac{(\Sigma A_1)^2 + (\Sigma A_2)^2 + (\Sigma A_3)^2}{N_A}$$

$$SS_{TOTAL} = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

SS-Total



Participant	$A_1{}^2$ scores	$A_2{}^2$ scores	$A_3{}^2$ scores
1	$2^2 = 4$	$3^2 = 9$	$5^2 = 25$
2	$1^2 = 1$	$4^2 = 16$	$4^2 = 16$
3	$3^2 = 9$	$5^2 = 25$	$6^2 = 36$
4	$2^2 = 4$	$6^2 = 36$	$5^2 = 25$
5	$2^2 = 4$	$3^2 = 9$	$3^2 = 9$
6	$1^2 = 1$	$5^2 = 25$	$6^2 = 36$
7	$4^2 = 16$	$7^2 = 49$	$7^2 = 49$
8	$3^2 = 9$	$3^2 = 9$	$6^2 = 36$
9	$2^2 = 4$	$5^2 = 25$	$6^2 = 36$
Total	20	41	48

$$SS_{TOTAL} = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

$$SS_{TOTAL} = 523 - \frac{(109)^2}{27}$$

$$SS_{TOTAL} = 523 - \frac{11881}{27}$$

$$SS_{TOTAL} = 523 - 440.03$$

$$SS_{TOTAL} = 82.97$$

Ingredients of within-participants ANOVA

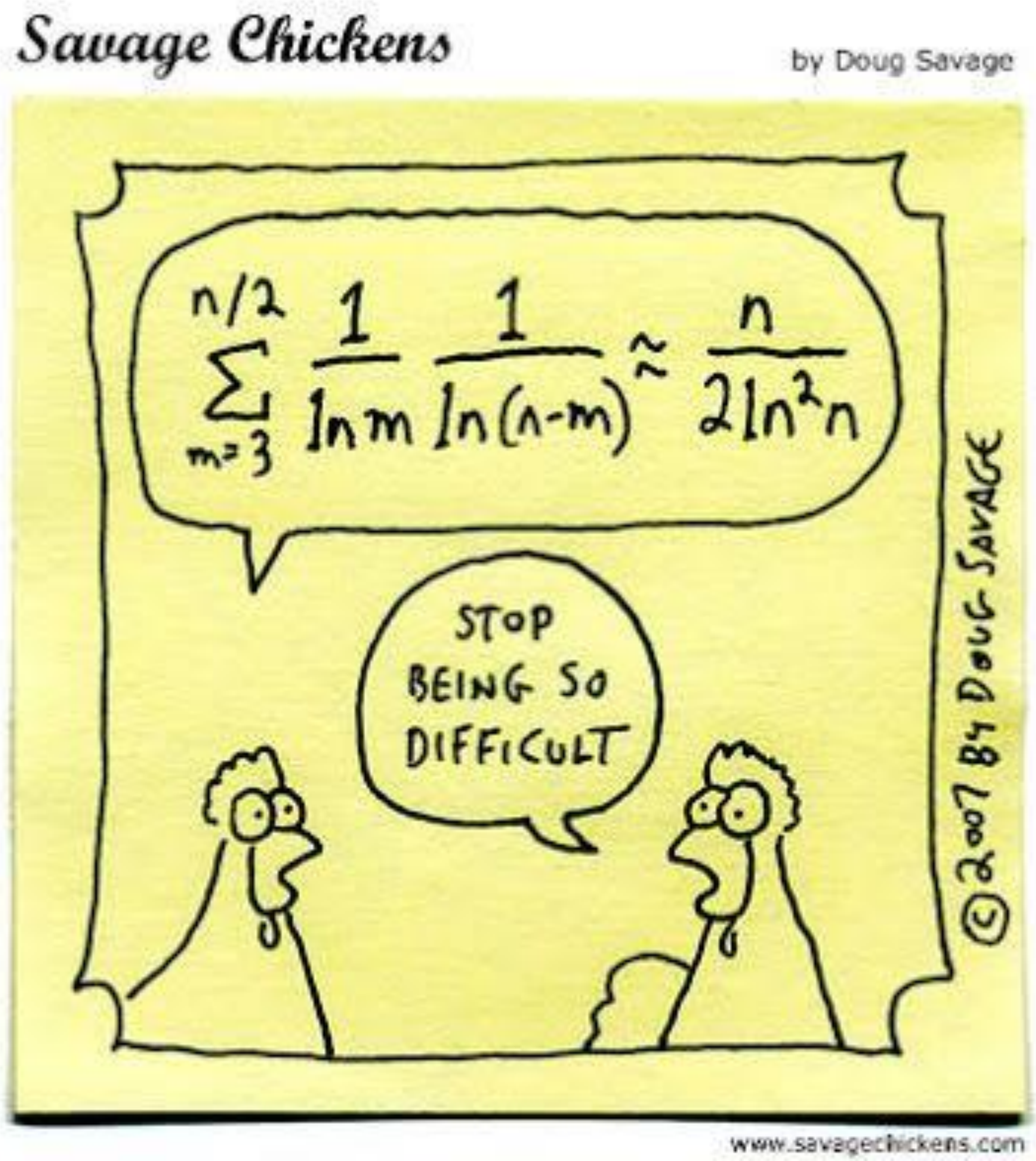


Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
$Total$	20	41	48

$SS_{BETWEEN} = 47.18$

$SS_{WITHIN} = 35.79$

$SS_{TOTAL} = 82.97$


Savage Chickens
by Doug Savage
$\sum_{m=3}^{n/2} \frac{1}{\ln m} \frac{1}{\ln(n-m)} \approx \frac{n}{2\ln^2 n}$
STOP BEING SO DIFFICULT
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Lecture 4 – One-factor within-participants ANOVA – Part III

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Ingredients of within-participants ANOVA

  

Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
Total	20	41	48

$SS_{BETWEEN} = 47.18$

$SS_{WITHIN} = 35.79$

$SS_{TOTAL} = 82.97$

$$SS_{between\ participants} = \frac{(\Sigma P_1)^2 + (\Sigma P_2)^2\ (and\ so\ on)}{N_P} - \frac{(\Sigma Y)^2}{N}$$

SS-between participants



$$SS_{between\ participants} = \frac{(\Sigma P_1)^2 + (\Sigma P_2)^2\ (and\ so\ on)}{N_P} - \frac{(\Sigma Y)^2}{N}$$

Participant	A_1 scores	A_2 scores	A_3 scores	P total	
1	2	3	5	10	
2	1	4	4	9	
3	3	5	6	14	
4	2	6	5	13	
5	2	3	3	8	
6	1	5	6	12	
7	4	7	7	18	
8	3	3	6	12	
9	2	5	6	13	
Total	20	41	48	109	

SS-between participants

Lancaster University

$$SS_{between\ participants} = \frac{(\Sigma P_1)^2 + (\Sigma P_2)^2\ (and\ so\ on)}{N_P} - \frac{(\Sigma Y)^2}{N}$$

Participant	A_1 scores	A_2 scores	A_3 scores	P total
1	2	3	5	10
2	1	4	4	9
3	3	5	6	14
4	2	6	5	13
5	2	3	3	8
6	1	5	6	12
7	4	7	7	18
8	3	3	6	12
9	2	5	6	13
Total	20	41	48	109

$$\left(\frac{10^2}{3} + \frac{9^2}{3} + \frac{14^2}{3} + \frac{13^2}{3} + \frac{8^2}{3} + \frac{12^2}{3} + \frac{18^2}{3} + \frac{12^2}{3} + \frac{13^2}{3}\right) - \frac{(109)^2}{27}$$

$$\left(\frac{100}{3} + \frac{81}{3} + \frac{196}{3} + \frac{169}{3} + \frac{64}{3} + \frac{144}{3} + \frac{324}{3} + \frac{144}{3} + \frac{169}{3}\right) - \frac{(109)^2}{27}$$

$$(33.33 + 27 + 65.33 + 56.33 + 21.33 + 48 + 108 + 48 + 56.33)$$

$$- 440.03$$

$$463.67 - 440.03$$

$$= 23.64$$

Ingredients of within-participants ANOVA

Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
$Total$	20	41	48

$SS_{BETWEEN} = 47.18$

$SS_{WITHIN} = 35.79$

$SS_{TOTAL} = 82.97$

$SS_{between\ participants} = 23.64$

$SS_{RESIDUAL}$ ….

What we'll need for the ANOVA

$$SS_{RESIDUAL} = SS_{WITHIN} - SS_{between\ participants}$$

$$12.15 = 35.79 - 23.64$$

Ingredients of within-participants ANOVA

  

Participant	A_1 scores	A_2 scores	A_3 scores
1	2	3	5
2	1	4	4
3	3	5	6
4	2	6	5
5	2	3	3
6	1	5	6
7	4	7	7
8	3	3	6
9	2	5	6
$Total$	20	41	48

$SS_{BETWEEN} = 47.18$

$SS_{WITHIN} = 35.79$

$SS_{TOTAL} = 82.97$

$SS_{between\ participants} = 23.64$

$SS_{RESIDUAL}$ .... = 12.15

What we'll need for the ANOVA

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

$$\text{between-group variance} = \frac{SS_{BETWEEN}}{df_{BETWEEN}} = \frac{47.18}{2} = 23.59$$

a – 1 [i.e., number of levels – 1]

What we'll need for the ANOVA

$$F = \frac{23.59}{\text{residual variance}}$$

$$\text{between-group variance} = \frac{SS_{BETWEEN}}{df_{BETWEEN}} = \frac{47.18}{2} = 23.59$$

$$\text{residual variance} = \frac{SS_{RESIDUAL}}{df_{RESIDUAL}} = \frac{12.15}{16} = 0.76$$

(a – 1)*(p – 1)
[i.e., (no. of levels – 1) x (np. Participants – 1)]

What we'll need for the ANOVA

$$F = \frac{23.59}{0.76} = 31.04$$

	DF1	α = 0.05																	
DF2	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	Inf
1	161.45	199.5	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88	243.91	245.95	248.01	249.05	250.1	251.14	252.2	253.25	254.31
2	18.513	19	19.164	19.247	19.296	19.33	19.353	19.371	19.385	19.396	19.413	19.429	19.446	19.454	19.462	19.471	19.479	19.487	19.496
3	10.128	9.5521	9.2766	9.1172	9.0135	8.9406	8.8867	8.8452	8.8123	8.7855	8.7446	8.7029	8.6602	8.6385	8.6166	8.5944	8.572	8.5494	8.5264
4	7.7086	6.9443	6.5914	6.3882	6.2561	6.1631	6.0942	6.041	5.9988	5.9644	5.9117	5.8578	5.8025	5.7744	5.7459	5.717	5.6877	5.6581	5.6281
5	6.6079	5.7861	5.4095	5.1922	5.0503	4.9503	4.8759	4.8183	4.7725	4.7351	4.6777	4.6188	4.5581	4.5272	4.4957	4.4638	4.4314	4.3985	4.365
6	5.9874	5.1433	4.7571	4.5337	4.3874	4.2839	4.2067	4.1468	4.099	4.06	3.9999	3.9381	3.8742	3.8415	3.8082	3.7743	3.7398	3.7047	3.6689
7	5.5914	4.7374	4.3468	4.1203	3.9715	3.866	3.787	3.7257	3.6767	3.6365	3.5747	3.5107	3.4445	3.4105	3.3758	3.3404	3.3043	3.2674	3.2298
8	5.3177	4.459	4.0662	3.8379	3.6875	3.5806	3.5005	3.4381	3.3881	3.3472	3.2839	3.2184	3.1503	3.1152	3.0794	3.0428	3.0053	2.9669	2.9276
9	5.1174	4.2565	3.8625	3.6331	3.4817	3.3738	3.2927	3.2296	3.1789	3.1373	3.0729	3.0061	2.9365	2.9005	2.8637	2.8259	2.7872	2.7475	2.7067
10	4.9646	4.1028	3.7083	3.478	3.3258	3.2172	3.1355	3.0717	3.0204	2.9782	2.913	2.845	2.774	2.7372	2.6996	2.6609	2.6211	2.5801	2.5379
11	4.8443	3.9823	3.5874	3.3567	3.2039	3.0946	3.0123	2.948	2.8962	2.8536	2.7876	2.7186	2.6464	2.609	2.5705	2.5309	2.4901	2.448	2.4045
12	4.7472	3.8853	3.4903	3.2592	3.1059	2.9961	2.9134	2.8486	2.7964	2.7534	2.6866	2.6169	2.5436	2.5055	2.4663	2.4259	2.3842	2.341	2.2962
13	4.6672	3.8056	3.4105	3.1791	3.0254	2.9153	2.8321	2.7669	2.7144	2.671	2.6037	2.5331	2.4589	2.4202	2.3803	2.3392	2.2966	2.2524	2.2064
14	4.6001	3.7389	3.3439	3.1122	2.9582	2.8477	2.7642	2.6987	2.6458	2.6022	2.5342	2.463	2.3879	2.3487	2.3082	2.2664	2.2229	2.1778	2.1307
15	4.5431	3.6823	3.2874	3.0556	2.9013	2.7905	2.7066	2.6408	2.5876	2.5437	2.4753	2.4034	2.3275	2.2878	2.2468	2.2043	2.1601	2.1141	2.0658
16	4.494	3.6337	3.2389	3.0069	2.8524	2.7413	2.6572	2.5911	2.5377	2.4935	2.4247	2.3522	2.2756	2.2354	2.1938	2.1507	2.1058	2.0589	2.0096
17	4.4513	3.5915	3.1968	2.9647	2.81	2.6987	2.6143	2.548	2.4943	2.4499	2.3807	2.3077	2.2304	2.1898	2.1477	2.104	2.0584	2.0107	1.9604
18	4.4139	3.5546	3.1599	2.9277	2.7729	2.6613	2.5767	2.5102	2.4563	2.4117	2.3421	2.2686	2.1906	2.1497	2.1071	2.0629	2.0166	1.9681	1.9168
19	4.3807	3.5219	3.1274	2.8951	2.7401	2.6283	2.5435	2.4768	2.4227	2.3779	2.308	2.2341	2.1555	2.1141	2.0712	2.0264	1.9795	1.9302	1.878
20	4.3512	3.4928	3.0984	2.8661	2.7109	2.599	2.514	2.4471	2.3928	2.3479	2.2776	2.2033	2.1242	2.0825	2.0391	1.9938	1.9464	1.8963	1.8432
21	4.3248	3.4668	3.0725	2.8401	2.6848	2.5727	2.4876	2.4205	2.366	2.321	2.2504	2.1757	2.096	2.054	2.0102	1.9645	1.9165	1.8657	1.8117
22	4.3009	3.4434	3.0491	2.8167	2.6613	2.5491	2.4638	2.3965	2.3419	2.2967	2.2258	2.1508	2.0707	2.0283	1.9842	1.938	1.8894	1.838	1.7831
23	4.2793	3.4221	3.028	2.7955	2.64	2.5277	2.4422	2.3748	2.3201	2.2747	2.2036	2.1282	2.0476	2.005	1.9605	1.9139	1.8648	1.8128	1.757
24	4.2597	3.4028	3.0088	2.7763	2.6207	2.5082	2.4226	2.3551	2.3002	2.2547	2.1834	2.1077	2.0267	1.9838	1.939	1.892	1.8424	1.7896	1.733
25	4.2417	3.3852	2.9912	2.7587	2.603	2.4904	2.4047	2.3371	2.2821	2.2365	2.1649	2.0889	2.0075	1.9643	1.9192	1.8718	1.8217	1.7684	1.711
26	4.2252	3.369	2.9752	2.7426	2.5868	2.4741	2.3883	2.3205	2.2655	2.2197	2.1479	2.0716	1.9898	1.9464	1.901	1.8533	1.8027	1.7488	1.6906
27	4.21	3.3541	2.9604	2.7278	2.5719	2.4591	2.3732	2.3053	2.2501	2.2043	2.1323	2.0558	1.9736	1.9299	1.8842	1.8361	1.7851	1.7306	1.6717
28	4.196	3.3404	2.9467	2.7141	2.5581	2.4453	2.3593	2.2913	2.236	2.19	2.1179	2.0411	1.9586	1.9147	1.8687	1.8203	1.7689	1.7138	1.6541
29	4.183	3.3277	2.934	2.7014	2.5454	2.4324	2.3463	2.2783	2.2229	2.1768	2.1045	2.0275	1.9446	1.9005	1.8543	1.8055	1.7537	1.6981	1.6376
30	4.1709	3.3158	2.9223	2.6896	2.5336	2.4205	2.3343	2.2662	2.2107	2.1646	2.0921	2.0148	1.9317	1.8874	1.8409	1.7918	1.7396	1.6835	1.6223
40	4.0847	3.2317	2.8387	2.606	2.4495	2.3359	2.249	2.1802	2.124	2.0772	2.0035	1.9245	1.8389	1.7929	1.7444	1.6928	1.6373	1.5766	1.5089
60	4.0012	3.1504	2.7581	2.5252	2.3683	2.2541	2.1665	2.097	2.0401	1.9926	1.9174	1.8364	1.748	1.7001	1.6491	1.5943	1.5343	1.4673	1.3893
120	3.9201	3.0718	2.6802	2.4472	2.2899	2.175	2.0868	2.0164	1.9588	1.9105	1.8337	1.7505	1.6587	1.6084	1.5543	1.4952	1.429	1.3519	1.2539
Inf	3.8415	2.9957	2.6049	2.3719	2.2141	2.0986	2.0096	1.9384	1.8799	1.8307	1.7522	1.6664	1.5705	1.5173	1.4591	1.394	1.318	1.2214	1

What we'll need for the ANOVA

$$F = \frac{23.59}{0.76} = 31.04$$ WAY BIGGER THAN 3.6337! ☺

Lecture 4 – One-factor within-participants ANOVA

Review of lecture 4

- Introduction to one factor within-participants ANOVA and its limitations
- Between-participant variability and residual variance
- Calculating within-group and between group variances
- Producing the within-participants F-statistic


Savage Chickens
by Doug Savage
I FEEL MY MIND SLIPPING SLOWLY INTO MADNESS
"SLOWLY"? MUST BE NICE.
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