

# Results

## Two-ways subject design

		Reality	
		No difference $H_0$ is true	Difference $H_1$ is true
Your decision	Difference	Type I Error: <b>Liberal</b>	No error
	No difference	No error	Type II error: <b>Conservative</b>

*Population*

*Sample*

# Null hypotheses

Main effects (as many as # of IV):

1. There is no difference in the DV between the levels of the IV: A
2. There is no difference in the DV between the levels of the IV: B

# Null hypothesis

Interaction: There is no interaction

For IV A, level 1,

IV B: level 1 vs. level 2



Similar tendency: no difference

For IV A, level 2,

IV B: level 1 vs. level 2

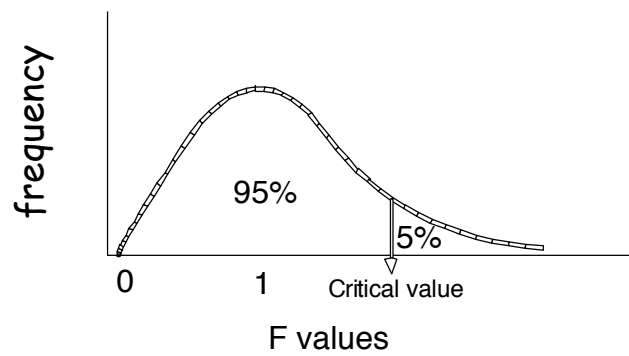
## F test: a ratio of variance

$$F = \frac{s_1^2}{s_2^2}$$

Variance between groups (conditions)  $\nearrow$

$\searrow$  Variance within groups (conditions)

## F values from sampling distribution



# Analysis of Variance

Equivalent to *t* test ( $t^2 = F$ )

## Assumptions underlying the use of *t* test & F test

- Errors are independent
- Errors are identically distributed (homogeneity of variance)
- Errors are normally distributed

## Two-ways between subjects ANOVA

Individual Data

Group 1 (Group)	Group 2 (Group)	
	Control	Alcohol
Control	█ █	█ █
Alcohol	█ █	█ █

Mean scores

Group 1 (Group)	Group 2 (Group)		Mean
	Control	Alcohol	
Control	█ █ ███ 1.0	█ █ ███ 0.5	█ 0.5 ███ 0.5
Alcohol	█ █ ███ 1.0	█ █ ███ 0.5	█ 0.5 ███ 0.5
Mean	█ 0.5 ███ 0.5	█ 0.5 ███ 0.5	Mean total: 0.5

## Two-ways between subjects ANOVA

### Manipulations

#### Means of responses

$$\text{Total SS} = \sum (X - \bar{X}_{total})^2$$

where  $N$  = single score

#### Degrees of freedom

$$N \text{ of scores} - 1$$

### Overall

$$\text{Between-subject Means SS} = \sum (n_j \bar{X}_j - \bar{X}_{total})^2$$

where  $n_j$  is one condition  
and  $\bar{X}_j$  is the  $M$  of subjects in a given condition

$$N \text{ of conditions} - 1$$

$$\text{Ways of Strategy SS} = \sum (n_{way} \bar{X}_{way} - \bar{X}_{total})^2$$

where  $n$  is the  $N$  of subjects in Way of Strategy

$$N \text{ of Ways of Strategy} - 1$$

$$\text{Regarded Strategy SS} = \sum (n_{regarded} \bar{X}_{regarded} - \bar{X}_{total})^2$$

where  $n$  is the  $N$  of subjects in Regarded Strategy

$$N \text{ of Regarded Strategy} - 1$$

$$\text{Interaction SS} =$$

$$[N \text{ of Ways of Strategy} - 1] [N \text{ of Regarded Strategy} - 1]$$

$$\text{Residual SS} = \text{Ways of Strategy SS} - \text{Regarded Strategy SS}$$

$$[N \text{ of Regarded Strategy} - 1]$$

$$\text{Within-subject Means SS} = \sum (X - \bar{X}_j)^2$$

where  $N$  is one condition

$$N(r-1)$$

## Two-ways between subjects ANOVA

### Means of responses

Source	SS	df	MS	F	p
Between subjects	200	8	25.0		
Ways of Strategy	100	1	100.0	10.000	0.0011
Regarded Strategy	100	1	100.0	10.000	0.0011
Interaction	0	1	0.0	0.000	0.9999
Within subjects	200	8	25.0		
Total	400	16			

## Two-ways between subjects ANOVA

Results of ANOVA					
Source	SS	df	MS	F	p
Between subjects	20	8	2.5		
Drug X dosage	16	1	16.0	16.00	0.0011
Drug Y dosage	16	1	16.0	16.00	0.0011
Interaction	0	1	0.0	0.00	0.9589
Within subjects	20	8	2.5		
Total	40	16			

## Two-ways within subjects ANOVA

Individual Data						
	Condition				T <sub>total</sub>	SS <sub>total</sub>
	Drug X		Drug Y			
	Low	High	Low	High		
Subject 1	0	0	0	0	0.00	0.0
Subject 2	0	0	0	0	0.00	0.0
Subject 3	0	0	0	0	0.00	0.0
T <sub>total</sub>	0.00	0.00	0.00	0.00		
SS	0.0	0.0	0.0	0.0	T <sub>total</sub>	0.00

Male effect: 0.00

	Sex of Mother					
	Female		Female		Male	
	Mean	SD	Mean	SD	Mean	SD
Method 1	0.00	1.00	0.00	1.00	0.00	1.00
Method 2	0.00	1.00	0.00	1.00	0.00	1.00
Method 3	0.00	1.00	0.00	1.00	0.00	1.00
	N = 0.00		N = 0.00		N = 0.00	
	SD = 0.00		SD = 0.00		SD = 0.00	

Male effect: 0.000000

	Condition					
	Stage		Stage		Stage	
	Mean	SD	Mean	SD	Mean	SD
Method 1	0.00	1.00	0.00	1.00	0.00	1.00
Method 2	0.00	1.00	0.00	1.00	0.00	1.00
Method 3	0.00	1.00	0.00	1.00	0.00	1.00
	N = 0.00		N = 0.00		N = 0.00	
	SD = 0.00		SD = 0.00		SD = 0.00	

## Two-ways within subjects ANOVA

Male of Mother: Two-Way Repeated Measures (2x2) = Subject Design

Source	SS	df	MS	F	p
Subjects	10.0	0	0.00		
Sex	00.0	1	00.0	10.0	0.000
Sex of Mother	0.0	0	0.00		
Condition	00.0	1	00.0	100.0	0.000
Condition of Mother	0.0	0	0.00		
Sex of Condition	0.0	1	0.0	10.0	0.000
Sex of Condition of Mother	0.0	0	0.00		

# Two-ways within subjects ANOVA

**Notations**

Name of squares	Degrees of freedom
$\text{Total SS} = \sum (X - \bar{X}_{total})^2$ <p style="text-align: center; font-size: small;">where N : single score</p>	N of scores - 1
$\text{Subject SS} = \sum (X_{subject} - \bar{X}_{subject})^2$ <p style="text-align: center; font-size: small;">where N : N of scores for 1 subject</p>	N of subjects - 1
$\text{Main SS} = \sum (N) (\bar{X}_{main} - \bar{X}_{total})^2$ <p style="text-align: center; font-size: small;">where N : N of scores for each Main</p>	N of Main - 1
$\text{Interaction (Main X Subject) SS} = \sum (N) (\bar{X}_{main-sub} - \bar{X}_{subject})^2 - \text{Subject SS} - \text{Main SS}$ <p style="text-align: center; font-size: small;">where N : N of scores for 1 subject of each Main</p>	(N of Main - 1) (N of subjects - 1)
$\text{Residual SS} = \sum (N) (\bar{X}_{subject} - \bar{X}_{total})^2$ <p style="text-align: center; font-size: small;">where N : N of scores for each Residual</p>	N of Residuals - 1

$\text{Interaction (Residual X Subject) SS} = \sum (N) (\bar{X}_{res-sub} - \bar{X}_{subject})^2 - \text{Subject SS} - \text{Residual SS}$ <p style="text-align: center; font-size: small;">where N : N of scores for 1 subject of each Residual</p>	(N of Residuals - 1) (N of subjects - 1)
$\text{Interaction (Residual X Main) SS} = \sum (N) (\bar{X}_{res-main} - \bar{X}_{main})^2 - \text{Main SS} - \text{Residual SS}$ <p style="text-align: center; font-size: small;">where N : N of scores for each Residual-Main</p>	(N of Residuals - 1) (N of Main - 1)
$\text{Interaction (Residual X Main X Subject) SS} = \text{Total SS} - \text{Subject SS} - \text{Main SS} - \text{Residual SS} - \text{Main X Subject SS} - \text{Residual X Subject SS} - \text{Residual X Main SS}$	(N of Main - 1) (N of Residuals - 1) (N of subjects - 1)



## Two-ways within subjects ANOVA

**Table of Sources: Two-Way Repeated Measures (2000's Subject Design)**

Source	SS	df	MS	F	p
Subjects	10.0	9	1.11		
Year	20.0	1	20.0	10.0	0.000
Year X Subjects	0.0	9	0.00		
Gender	20.0	1	20.0	100.0	0.000
Gender X Subjects	0.0	9	0.00		
Year X Gender	0.0	1	0.0	0.0	0.999
Year X Gender X Subjects	0.0	9	0.00		

## Two-ways mixed subjects ANOVA

**Table of Sources: Two-Way Mixed: One 2000's Subject Variable, One Repeated Measures Variable**

Source	SS	df	MS	F	p
<u>Between Subjects</u>	100.00				
Signatures	20.00	1	20.00	0.200	0.656
Subjects with Signatures	80.00	10	8.00		
<u>2000's Subjects</u>					
Year	0.00	1	0.00	0.000	0.999
Year X Signatures	0.00	1	0.00	0.000	0.999
Year X Subjects	200.00	10	20.00		
Year X Subjects X Signatures					
Total	300.00	20			

## Two-ways mixed subjects ANOVA

		Mixed Nuts			
		Walrus Nuts	Alleged	$\bar{X}_{total}$ SS	
Squirrel	Mixed 1	0	10	10.0 0.0	
	Mixed 2	10	0	0.0 0.0	
	Mixed 3	0	0	0.0 1.0	
	Mixed 4	0	10	0.0 0.0	
	Mixed 5	0	0	0.0 0.0	
	Mixed 6	10	0	0.0 0.0	
		$\bar{X}_{Squirrel}$ 0.00	$\bar{X}_{Mixed Nuts}$ 0.00	$\bar{X}_{total}$ 0.00	
		SS 0.00	SS 0.00	SS 0.00	
Raccoon		Mixed 7	0	11	0.0 0.0
		Mixed 8	0	0	0.0 0.0
		Mixed 9	0	0	0.0 0.0
		Mixed 10	0	0	0.0 1.0
		Mixed 11	0	0	0.0 0.0
		Mixed 12	0	0	0.0 0.0
		$\bar{X}_{Raccoon}$ 0.00	$\bar{X}_{Mixed Nuts}$ 0.00	$\bar{X}_{total}$ 0.00	
		SS 0.00	SS 0.00	SS 0.00	
		$\bar{X}_{total}$ 0.00	$\bar{X}_{total}$ 0.00	$\bar{X}_{total}$ 0.0	
		SS 0.00	SS 0.00		

### Formulas

Source of variation	Degrees of freedom
Total SS = $\sum (X_{ij} - \bar{X}_{total})^2$ where N : # of subjects	N of scores - 1
Subjects SS = $\sum [k(\bar{X}_{sub} - \bar{X}_{total})^2]$ where k : # of scores for each subject	N of subjects - 1
Significance SS = $\sum [N(\bar{X}_{sig} - \bar{X}_{total})^2]$ where N : N of scores for each level of Significance	N of Significance - 1
N of subjects within Significance SS = $\text{Subjects SS} - \text{Significance SS}$	N of subjects within Significance - 1
Mixed Nuts SS = $\sum [N(\bar{X}_{MN} - \bar{X}_{total})^2]$ where N : N of scores for each level of Mixed Nuts	N of Mixed Nuts - 1
Interaction (Significance X Mixed Nuts) SS = $\sum [N(\bar{X}_{sig-MN} - \bar{X}_{total})^2] - \text{Significance SS} - \text{Mixed Nuts SS}$ where N : N of scores for each cell (sig-MN)	(N of Significance - 1)(N of Mixed Nuts - 1)
Interaction (total gain N subjects within Significance) SS = $\text{Total SS} - \text{Mixed Nuts SS} - \text{Subjects SS} - \text{Interaction (Significance X Mixed Nuts) SS}$	(N of Mixed Nuts - 1)(N of subjects within Significance - 1)

## Two-ways mixed subjects ANOVA

**Table of Sources: Two-Way Mixed: One Within Subject Variable, One Between Subjects Variable**

Source	SS	df	MS	F	p
<b>Between Subjects</b>					
Subjects	100.00	1	100.00	0.000	0.999
Subjects within Subjects	100.00	10	10.00		
<b>Within Subjects</b>					
Word Size	0.00	1	0.00	0.000	0.999
Word Size X Signatures	0.00	1	0.00	0.000	0.999
Word Size X Subjects within Subjects	100.00	10	10.00		
Total	200.00	20			

