*see bottom of page for 1 tailed

#	1-Tailed Hyp	2-Tailed Hyp	Assumptions	Formulas	Decision (2-tailed)	CI (2-Sided)	CI (1-Sided Upper)	CI (1-Sided Lower)
1	**1 Sample Z-Test** Ho: $\mu = 5$ Ha: $\mu > 5$	 Ho: $\mu = 5$ Ha: $\mu \neq 5$	- Random sample - Sample mean is normally distributed	$Z_{stat} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$	Reject Ho if $\lvert Z_{stat}\rvert > \lvert Z_{crit}\rvert$ or $p < \alpha$	$\bar{x} \pm Z_{\alpha/2}\sigma/\sqrt{n}$	if ">" in Ha UB = ∞ LB = $\bar{x} - Z_\alpha \sigma/\sqrt{n}$	if "<" in Ha UB = $\bar{x} + Z_\alpha \sigma/\sqrt{n}$ LB = $-\infty$ or 0
2	**1 Sample T-Test** Ho: $\mu = 6$ Ha: $\mu > 6$	 Ho: $\mu = 8$ Ha: $\mu \neq 8$	- Random sample - Sample mean is normally distributed	$T_{stat} = \frac{\bar{x} - \mu}{s/\sqrt{n}}$ $df = n - 1$	Reject Ho if $\lvert T_{stat}\rvert > \lvert T_{crit}\rvert$ or $p < \alpha$	$\bar{x} \pm T_{\alpha/2} s/\sqrt{n}$	if ">" in Ha UB = ∞ LB = $\bar{x} - T_\alpha s/\sqrt{n}$	if "<" in Ha UB = $\bar{x} + T_\alpha s/\sqrt{n}$ LB = $-\infty$ or 0
3	**Paired T-Test** Ho: $\mu d = 0$ Ha: $\mu d < 0$	 Ho: $\mu d = 0$ Ha: $\mu d \neq 0$	- Dependent sample - Sample mean of differences is normally distributed	$T_{stat} = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}}$ $df = n - 1$	Reject Ho if $\lvert T_{stat}\rvert > \lvert T_{crit}\rvert$ or $p < \alpha$	$\bar{d} \pm T_{\alpha/2} s_d/\sqrt{n}$	if ">" in Ha UB = ∞ LB = $\bar{d} - T_\alpha s_d/\sqrt{n}$	if "<" in Ha UB = $\bar{d} + T_\alpha s_d/\sqrt{n}$ LB = $-\infty$
4	**2 Sample T-Test** Ho: $\mu 1 - \mu 2 = 0$ Ha: $\mu 1 - \mu 2 < 0$	 Ho: $\mu 1 - \mu 2 = 0$ Ha: $\mu 1 - \mu 2 \neq 0$	- Independent samples - Population variences are equal - Sample means are both normally distributed	$T_{stat} = \frac{(\bar{x}_1 - \bar{x}_1) - (\mu_1 - \mu_2)}{s_p/\sqrt{(1/n_1 + 1/n_2)}}$ $s_p = \sqrt{\frac{(n_1 - 1)s_1^2 - (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$ $df = n_1 + n_2 - 2$	Reject Ho if $\lvert T_{stat}\rvert > \lvert T_{crit}\rvert$ or $p < \alpha$	$(\bar{x}_1 - \bar{x}_2) \pm T_{\alpha/2} *$ $s_p/\sqrt{1/n_1 + 1/n_2}$	if ">" in Ha UB = ∞ LB = $(\bar{x}_1 - \bar{x}_2) - T_\alpha *$ $\sqrt{1/n_1 + 1/n_2}$	if "<" in Ha UB = $(\bar{x}_1 - \bar{x}_2) + T_\alpha *$ $\sqrt{1/n_1 + 1/n_2}$ LB = $-\infty$
5	**2 Sample T-Test** Ho: $\mu 1 - \mu 2 = 0$ Ha: $\mu 1 - \mu 2 < 0$	 Ho: $\mu 1 - \mu 2 = 0$ Ha: $\mu 1 - \mu 2 \neq 0$	- Independent samples - Population variences are NOT equal - Sample means are both normally distributed	$T_{stat} = \frac{(\bar{x}_1 - \bar{x}_1) - (\mu_1 - \mu_2)}{\sqrt{s_1^2/n_1 + s_2^2/n_2}}$ $df = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{\left(\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}\right)}$	Reject Ho if $\lvert T_{stat}\rvert > \lvert T_{crit}\rvert$ or $p < \alpha$	$(\bar{x}_1 - \bar{x}_2) \pm T_{\alpha/2} *$ $\sqrt{s_1^2/n_1 + s_2^2/n_2}$	if ">" in Ha UB = ∞ LB = $(\bar{x}_1 - \bar{x}_2) - T_\alpha *$ $\sqrt{s_1^2/n_1 + s_2^2/n_2}$	if "<" in Ha UB = $(\bar{x}_1 - \bar{x}_2) + T_\alpha *$ $\sqrt{s_1^2/n_1 + s_2^2/n_2}$ LB = $-\infty$
7	**Wilcoxon** Ho: Md = 0 Ha: Md < 0	 Ho: Md = 0 Ha: Md $\neq$ 0	- Dependent samples - Sample of Diff is NOT normally distributed	p-value = from Minitab output	Reject Ho if $p < \alpha$	Minitab	Minitab	Minitab
8	**Mann-Whitney** Ho: M1-M2 = 0 Ha: M1-M2 < 0	 Ho: M1-M2 = 5 Ha: M1-M2 $\neq$ 5	- Independent samples - One or both of the samples is NOT normally distributed	p-value = from Minitab output	Reject Ho if $p < \alpha$	Minitab	Minitab	Minitab
9	**1 Proportion** Ho: p = 0.3 Ha: p < 0.3	 Ho: p = 0.4 Ha: p $\neq$ 0.4	- $np \geq 10$ - $nq \geq 10$ - Sample proportion normally distributed	$Z_{stat} = \frac{\hat{p} - p}{\sqrt{(pq/n)}}$ $\hat{p} = x/n$ $\hat{q} = 1 - \hat{p}$	Reject Ho if $\lvert Z_{stat}\rvert > \lvert Z_{crit}\rvert$ or $p < \alpha$	$\hat{p} \pm Z_{\alpha/2}\sqrt{\hat{p}\hat{q}/n}$	if ">" in Ha UB = 1 LB = $\hat{p} - Z_\alpha\sqrt{\hat{p}\hat{q}/n}$	if "<" in Ha UB = $\hat{p} + Z_\alpha\sqrt{\hat{p}\hat{q}/n}$ LB = -1
10	**2 Proportions** Ho: p1-p2 = 0.0 Ha: p1-p2 < 0.0 (Independent	 Ho: p1-p2 = 0.0 Ha: p1-p2 $\neq$ 0.0 Pooled)	- Sample proportions nomally distributed	$Z_{stat} = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\bar{p}(1 - \bar{p})(1/n_1 + 1/n_2)}}$ $\bar{p} = (n_1\hat{p}_1 - n_2\hat{p}_2)/(n_1 + n_2)$ $\hat{p}_1 = x_1/n_1$ $\hat{p}_2 = x_2/n_2$	Reject Ho if $\lvert Z_{stat}\rvert > \lvert Z_{crit}\rvert$ or $p < \alpha$	$(\hat{p}_1 - \hat{p}_2) \pm Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2}$	if ">" in Ha UB = 1 LB = $(\hat{p}_1 - \hat{p}_2) - Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2}$	if "<" in Ha UB = $(\hat{p}_1 - \hat{p}_2) + Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2}$ LB = -1
11	**2 Proportions** Ho: p1-p2 = 0.1 Ha: p1-p2 < 0.1 (Independent)	 Ho: p1-p2 = 0.1 Ha: p1-p2 $\neq$ 0.1	- Sample proportions nomally distributed	$Z_{stat} = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{(\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2)}}$ $\hat{p}_1 = x_1/n_1$ $\hat{p}_2 = x_2/n_2$	Reject Ho if $\lvert Z_{stat}\rvert > \lvert Z_{crit}\rvert$ or $p < \alpha$	$(\hat{p}_1 - \hat{p}_2) \pm Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2}$	if ">" in Ha UB = 1 LB = $(\hat{p}_1 - \hat{p}_2) - Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2}$	if "<" in Ha UB = $(\hat{p}_1 - \hat{p}_2) + Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_2\hat{q}_2/n_2}$ LB = -1
12	**2 Proportions** Ho: p1-p2 = 0.1 Ha: p1-p2 < 0.1 (Dependent, ˆp1	 Ho: p1-p2 = 0.1 Ha: p1-p2 $\neq$ 0.1 and ˆp2 from same	- Sample proportions nomally distributed sample)	$Z_{stat} = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{(\hat{p}_1\hat{q}_1/n + \hat{p}_2\hat{q}_2/n + 2\hat{p}_1\hat{p}_2/n)}}$ $\hat{p}_1 = x_1/n$ $\hat{p}_2 = x_2/n$	Reject Ho if $\lvert Z_{stat}\rvert > \lvert Z_{crit}\rvert$ or $p < \alpha$	$(\hat{p}_1 - \hat{p}_2) \pm Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n + \hat{p}_2\hat{q}_2/n + 1\hat{p}_1\hat{p}_2/n}$	if ">" in Ha UB = 1 LB = $(\hat{p}_1 - \hat{p}_2) - Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n + \hat{p}_2\hat{q}_2/n + 1\hat{p}_1\hat{p}_2/n}$	if "<" in Ha UB = $(\hat{p}_1 - \hat{p}_2) + Z_{\alpha/2} *$ $\sqrt{\hat{p}_1\hat{q}_1/n + \hat{p}_2\hat{q}_2/n + 1\hat{p}_1\hat{p}_2/n}$ LB = -1

Variables:
E = margin of error
μ = pop. mean
$\bar{x}$ = sample mean
σ = pop. SD
s = sample SD
σ^2 = pop. variance
s^2 = sample variance

μ_d = pop. mean of differences
$\bar{d}$ = pop. mean of differences
s_d = sample SD of differences
s_p = pooled SD
n = sample size

M_d = pop. median of differences
M = pop. median
p = pop. proportion
$\hat{p}$ = sample proportion
$\bar{p}$ = pooled proportion

Testing Steps
1) State assumptions
2) Write hypothesis
3) Calculate STAT value
4) Calculate CRIT value
5) Make decision
6) Write conclusion

1-Tailed Decision Rules
*** If 1 tailed and you have a "<" sign in Ha, reject Ho if $Z_{stat} < Z_{crit}$ or $T_{stat} < T_{crit}$,**
*** If 1 tailed and you have a ">" sign in Ha, reject Ho if $Z_{stat} > Z_{crit}$ or $T_{stat} > T_{crit}$,**
*** ALWAYS reject Ho if $p < \alpha$.**
Writing your conclusion
If you accept Ho → "There is not sufficient evidence that ... (describe what Ha means)
If you reject Ho → "There is sufficient evidence that ... (describe what Ha means)

Confidence Intervals
* Never input a negative $Z_\alpha(Z_{\alpha/2})$ or $T_\alpha(T_{\alpha/2})$ in your interval formulas.
* Decision Rule: Reject Ho if the CI does not contain the value (#) in your hypothesis

emily de witte | 8661174

13

1-WAY ANOVA
Assumptions
-Samples normal
-Equal variances
-Observations Ind
(see graphs below)

Ho: $\mu_1 = \mu_2 = \mu_3 = \ldots \mu_n$
Ha: not all means equal
***Review 1 WAY ANOVA table in book for detailed calculations.

$F_{stat} = MS_{fac}/MS_{err}$
Reject Ho if $\lvert F_{stat}\rvert > \lvert F_{crit}\rvert$ or $p < \alpha$.
Both F_{stat} and p come from minitab.

$df_f = k-1$
$df_e = N-k$
$df_t = N-1$
k = # of rows

17

2-WAY ANOVA
**Review 2 WAY ANOVA table in the book for detailed calculations.
3 Possible Tests

Test #1-Interaction
Ho: Factors A and B do not interact
Ha: Factors A and B interact
$F_{stat} = MS_{int}/MS_{err}$

Test #2-Factor A Means
Ho: $\mu_{1a} = \mu_{2a} = \ldots \mu_{na}$
Ha: not all means equal
$F_{stat} = MS_{facA}/MS_{err}$

Test #3-Factor B Means
Ho: $\mu_{1b} = \mu_{2b} = \ldots \mu_{nb}$
Ha: not all means equal
$F_{stat} = MS_{facB}/MS_{err}$

For all 3 tests reject Ho if $\lvert F_{stat}\rvert > \lvert F_{crit}\rvert$ or $p < \alpha$.
There will be 3 F-values and/or p-values in minitab.

$df_{facA} = r-1$ $df_{facB} = c-1$ $df_{int} = (r-1)*(c-1)$ $df_{err} = r*c*(n-1)$ $df_{tot} = N-1$

Assumptions – Residual vs FIT graph
1) Normality – no pts outside 2SD 2) Equal Variances 3) Independence

No outliers (good) Equal Spread (good) No patter (good)

Important Formulas
$R^2 = 1-(SS_{err}/SS_{tot})$
$R^2_{adj} = 1 - \frac{MS_{err}}{(SS_{tot}/df_{tot})}$
$s = \sqrt{(MSE)}$
$SS_e = \sum[(n_i-1)*s_i^2]$
MS = SS/df

Outliers (bad) Cone shape – unequal spread (bad) Pattern in graph (bad)

Interaction Plot -Parallel lines suggest that there is not interaction present between the two factors
-Crossing/non-parallel lines suggest there is interaction between the two factors

Bonferroni used to identify where the actual differences between means are.
Step 1 – Determine number of observations in each sample being compared (n)
Step 2 – Calculate "J" (the number of possible comparisons) J = [(rc)*(rc-1)]/2 s = SQRT(MSE)
Step 3 – Calculate α/2(J) and the df = df_e
Step 4 – Get T-value from table at 1-tailed significance level of α/2(J) and df_e (pick closest value)
Step 5 – Interval = $(\bar{x}_1 - \bar{x}_2) \pm t_{\alpha/2J} * s * \sqrt{1/n_1 + 1/n_2}$
critical difference = margin of error = $t_{\alpha/2J} * s * \sqrt{1/n_1 + 1/n_2}$
Rule – if the interval contains "0", there is no difference between the means being compared
OR – if |actual diff| < |critical diff|, there is no difference between the means

- Used for 1-WAY ANOVA and 2-WAY ANOVA, do not use for BLOCKED ANOVA
- For 2-WAY ANOVA there are 3 types of possible comparisons, row comparisons, column comparisons and cell comparisons, all steps will be exactly the same except step 1. The values of "r", "c" "n" are determined based on type of comparison.

19

ANOVA-BLOCKED
Assumptions
- See 1-Way ANOVA
**Review BLOCKED ANOVA table in the book for detailed calculations.
2 Possible Tests

Test #1-Was Blocking Needed?
Ho: $\mu_{bl1} = \mu_{bl2} \ldots \mu_{bln}$
Ha: not all blocked means equal
$F_{stat} = MS_{block}/MS_{err}$

Test #2-Factor Means
Ho: $\mu_{s1} = \mu_{s2} \ldots \mu_{sn}$
Ha: not all factor means equal
$F_{stat} = MS_{facA}/MS_{err}$

***If in test #1 we DO NOT reject Ho we must run a 1-WAY ANOVA to complete test #2, otherwise, you can proceed with test #2 using the output.

For both tests Reject Ho if $\lvert F_{stat}\rvert > \lvert F_{crit}\rvert$ or $p < \alpha$.
There will be 2 F-values and/or p-values in minitab.

$df_{block} = b-1$ $df_{fac} = c-1$ $df_{err} = (b-1)*(c-1)$ $df_{tot} = N-1$ b = # of rows

18

Kruskal-Wallace
Ho: $M_1 = M_2 \ldots M$
Ha: not all M equal
-Get p-value from minitab and compare to alpha.
Reject Ho $p < \alpha$

16

Binomial
Ho: p = 3 Ho: p = 0.4
Ha: p < 0.3 Ha: p $\neq$ 0.4
$P(X=x) = nCx*p^x q^{n-x}$
n = # of trials (sample size)
p = probability of a success
q = probability of a failure
q = 1 – p
x = # of successes in "n" trials
Reject Ho $p < \alpha$

Required Sample Size (always round up)
- proportion
$n = \frac{Z_{\alpha/2}{}^2 \hat{p}\hat{q}}{E^2}$
*$\hat{p}$, $\hat{q}$ and E are always entered as decimals
*if $\hat{p}$ and $\hat{q}$ are not given use values of 0.5
- means
(σ known)
$n = \frac{Z_{\alpha/2}{}^2 \sigma^2}{E^2}$