4.4 Chi-Square Example

MBC 638

Data Analysis and Decision Making

Example: Product Feature vs. Age Group

Example: Product Feature vs. Age Group

- Use results of survey on preferred product feature (A, B, or C).

Example: Product Feature vs. Age Group

- Use results of survey on preferred product feature (A, B, or C).
- Determine if you should market your product differently to the younger versus older generation.

Example: Product Feature vs. Age Group

- Use results of survey on preferred product feature (A, B, or C).
- Determine if you should market your product differently to the younger versus older generation.
    - Young: under 30 years old

Example: Product Feature vs. Age Group

- Use results of survey on preferred product feature (A, B, or C).
- Determine if you should market your product differently to the younger versus older generation.
    - Young: under 30 years old
    - Old: over 30 years old

Example: Product Feature vs. Age Group

- Use results of survey on preferred product feature (A, B, or C).
- Determine if you should market your product differently to the younger versus older generation.
    - Young: under 30 years old
    - Old: over 30 years old
- Assume $\alpha = 0.05$.

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).

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- Two-way table:

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

Young	
Old	

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**
Young			
Old			

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	Feature B	Feature C
Young	200	38	20
Old	157	45	5

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
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	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	
Old	157	45	5	
Totals				

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	258
Old	157	45	5	
Totals				

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals				

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357			

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83		

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	

Steps 1 and 2: Hypothesis and Two-Way Table

- Hypothesis statement:
  - H_0: Age and feature preference are independent (no relationship).
  - H_a: Age and feature preference are not independent (relationship).
- Two-way table:

	Feature A	**Feature B**	**Feature C**	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

Step 3: Reorganize Table

Step 3: Reorganize Table

Category
Young A
Young B
Young C
Old A
Old B
Old C

Step 3: Reorganize Table

Category	f(Observed)
Young A	200
Young B	38
Young C	20
Old A	157
Old B	45
Old C	5

Step 3: Reorganize Table

Category	f(Observed)
Young A	200
Young B	38
Young C	20
Old A	157
Old B	45
Old C	5

Step 3: Reorganize Table

Category	f(Observed)	F(Expected)
Young A	200	
Young B	38	
Young C	20	
Old A	157	
Old B	45	
Old C	5	

Step 4: Calculate *F(Expected)*

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$$F(Expected) = \frac{fr \times fc}{N}$$

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	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

Step 4: Calculate *F(Expected)*

$$F(Expected) = \frac{fr \times fc}{N}$$

	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A =

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	Feature A	Feature B	Feature C	Totals
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	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A = $\frac{258 \times 357}{465}$ = 198.1

Step 4: Calculate *F(Expected)*

$$F(Expected) = \frac{fr \times fc}{N}$$

	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A = $\frac{258 \times 357}{465}$ = 198.1
- Young B =

Step 4: Calculate *F(Expected)*

$$F(Expected) = \frac{fr \times fc}{N}$$

	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A = $\frac{258 \times 357}{465}$ = 198.1
- Young B =

Step 4: Calculate *F(Expected)*

$$F(Expected) = \frac{fr \times fc}{N}$$

	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A = $\frac{258 \times 357}{465}$ = 198.1
- Young B =

Step 4: Calculate *F(Expected)*

$$F(Expected) = \frac{fr \times fc}{N}$$

	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A = $\frac{258 \times 357}{465}$ = 198.1
- Young B =

Step 4: Calculate *F(Expected)*

$$F(Expected) = \frac{fr \times fc}{N}$$

	Feature A	Feature B	Feature C	Totals
Young	200	38	20	258
Old	157	45	5	207
Totals	357	83	25	465

r = row
c = column
N = total surveyed

- Young A = $\frac{258 \times 357}{465}$ = 198.1
- Young B = $\frac{258 \times 83}{465}$ = 46.1

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)
Young A	200	198.1
Young B	38	46.1
Young C	20	13.9
Old A	157	158.9
Old B	45	36.9
Old C	5	11.1
Totals	465	

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)
Young A	200	198.1
Young B	38	46.1
Young C	20	13.9
Old A	157	158.9
Old B	45	36.9
Old C	5	11.1
Totals	465	

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)
Young A	200	198.1
Young B	38	46.1
Young C	20	13.9
Old A	157	158.9
Old B	45	36.9
Old C	5	11.1
Totals	465	

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)
Young A	200	198.1
Young B	38	46.1
Young C	20	13.9
Old A	157	158.9
Old B	45	36.9
Old C	5	11.1
Totals	465	

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
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Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C =

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
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Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	
Young C	20	13.9	
Old A	157	158.9	
Old B	45	36.9	
Old C	5	11.1	
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$ = 3.38

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	1.41
Young C	20	13.9	2.71
Old A	157	158.9	0.02
Old B	45	36.9	1.75
Old C	5	11.1	3.38
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$ = 3.38

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
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Old A	157	158.9	0.02
Old B	45	36.9	1.75
Old C	5	11.1	3.38
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$ = 3.38

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	1.41
Young C	20	13.9	2.71
Old A	157	158.9	0.02
Old B	45	36.9	1.75
Old C	5	11.1	3.38
Totals	465		

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$ = 3.38

Step 5: Calculate Test Statistic

Category	f(Observed)	F(Expected)	$\frac{(f-F)^2}{F}$
Young A	200	198.1	0.02
Young B	38	46.1	1.41
Young C	20	13.9	2.71
Old A	157	158.9	0.02
Old B	45	36.9	1.75
Old C	5	11.1	3.38
Totals	465		**9.288**

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

- Young A = $\frac{(200-198.1)^2}{198.1}$ = 0.02
- Old C = $\frac{(5-11.1)^2}{11.1}$ = 3.38

Step 5: Calculate Test Statistic (cont.)

Step 5: Calculate Test Statistic (cont.)

- Using your test statistic (χ^2 = 9.288), find *p* in the distribution table.

Step 5: Calculate Test Statistic (cont.)

- Using your test statistic (χ^2 = 9.288), find *p* in the distribution table.
- Remember: If *p* is low, H_0 must go.

Chi-Square Distribution Table

Table E: Chi-Square (χ^2) Distribution

Degrees of freedom	Area to the right of critical value									
	0.995	**0.99**	**0.975**	**0.95**	**0.90**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**
1	—	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.071	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.299
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

Chi-Square Distribution Table

Table E: Chi-Square (χ^2) Distribution

Degrees of freedom	Area to the right of critical value									
	0.995	**0.99**	**0.975**	**0.95**	**0.90**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**
1	—	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.071	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.299
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

Chi-Square Distribution Table

Table E: Chi-Square (χ^2) Distribution

Degrees of freedom	Area to the right of critical value									
	0.995	**0.99**	**0.975**	**0.95**	**0.90**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**
1	—	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.071	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
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14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

Chi-Square Distribution Table

Table E: Chi-Square (χ^2) Distribution

Degrees of freedom	Area to the right of critical value									
	0.995	**0.99**	**0.975**	**0.95**	**0.90**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**
1	—	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.071	12.833	15.086	16.750
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Step 6: Calculate *df*

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$$df = (r-1)$$

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$$df = (r-1)(c-1)$$

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- Gives which row to reference in χ^2 distribution table
- Gives a sense of how many variables and how much information you have

Step 7: Find *p*-Value

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  - Consider separate marketing strategies for younger and older customers.