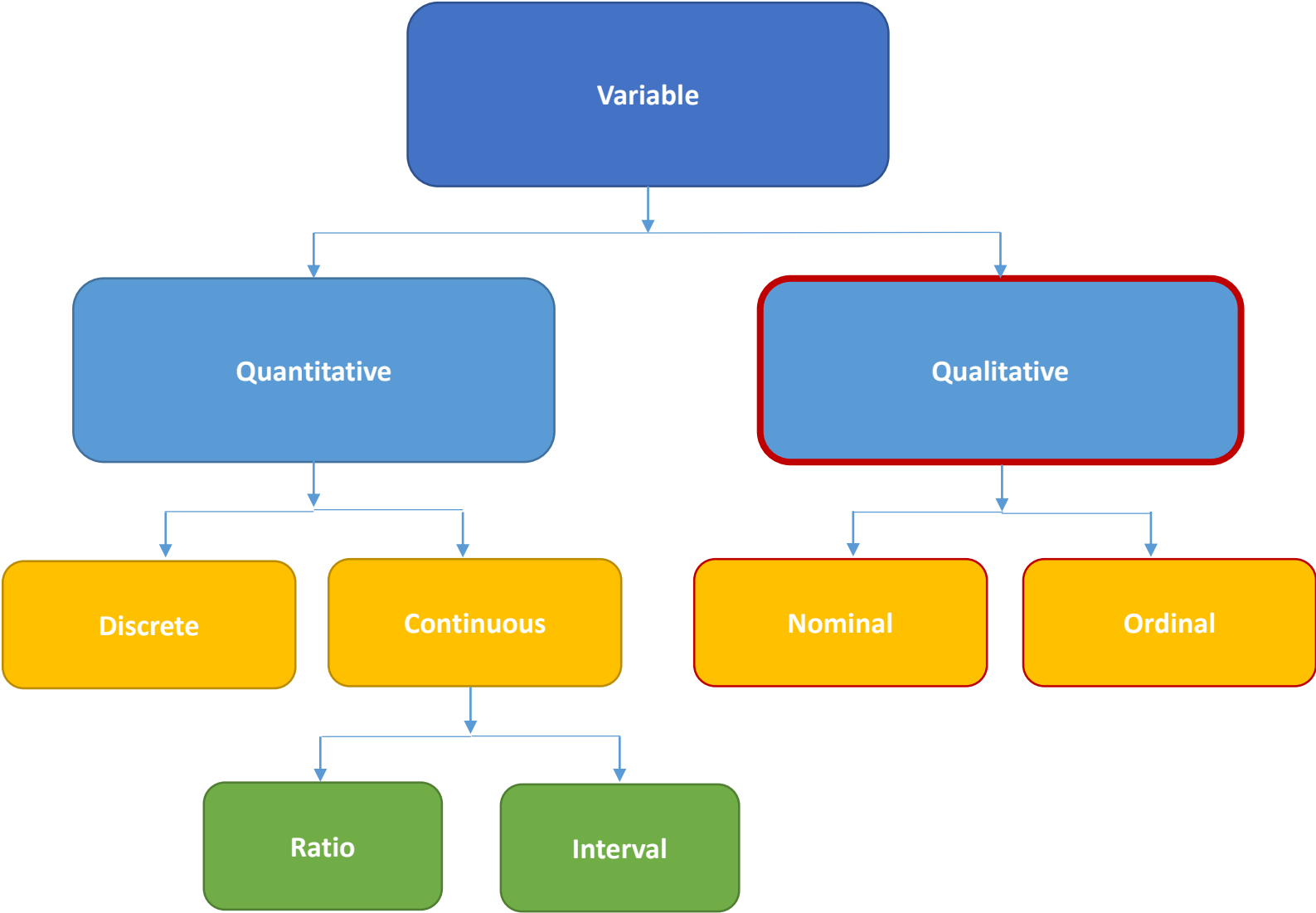


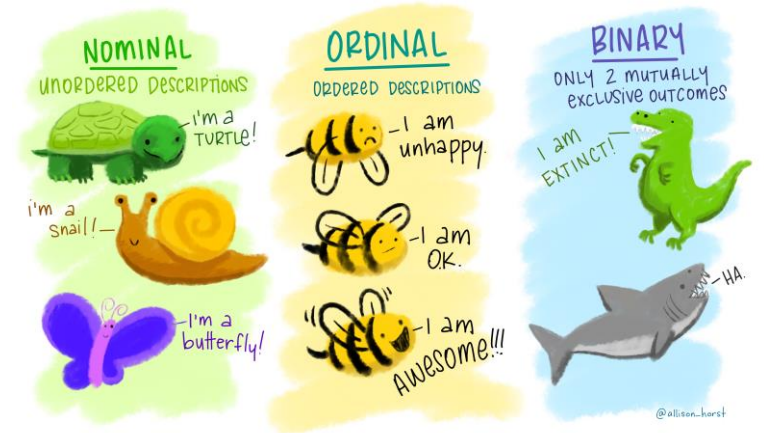
# Analysis of Qualitative data

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v2020-08



# Qualitative data

- = **not numerical**
- = values taken = usually names (also *nominal*)
  - e.g. genotypes
- Values can be numbers but not numerical
  - e.g. group number = numerical label but not unit of measurement
- Qualitative variable with intrinsic order in their categories = *ordinal*
- Particular case: qualitative variable with 2 categories: **binary** or *dichotomous*
  - e.g. alive/dead or presence/absence



<https://github.com/allisonhorst/stats-illustrations#other-stats-artwork>

# Fisher's exact and Chi<sup>2</sup>

## Example: cats and dogs.xlsx

- Cats and dogs trained to line dance
- 2 different rewards: food or affection
- **Question:** Is there a difference between the rewards?
  
- **Is there a significant relationship between the 2 variables?**
  - does the reward significantly affect the likelihood of dancing?
  
- To answer this type of question:
  - **Contingency table**
  - **Fisher's exact or Chi<sup>2</sup> tests**



	Food	Affection
Dance	?	?
No dance	?	?

But first: **how many animals** do we need?

## Exercise: Power calculation

- Preliminary results from a pilot study: **25%** line-danced after having received affection as a reward vs. **70%** after having received food.
  - **How many cats** do we need?

# Exercise: Power calculation

## Output:

If the values from the pilot study are good predictors and if we use a sample of **n=23 for each group**, we will achieve a power of 83%.

The screenshot shows the G\*Power 3.1.9.2 software interface. The window title is "G\*Power 3.1.9.2". The menu bar includes "File", "Edit", "View", "Tests", "Calculator", and "Help". The main window has two tabs: "Central and noncentral distributions" and "Protocol of power analyses".

The "Test family" is set to "Exact". The "Statistical test" is "Proportions: Inequality, two independent groups (Fisher's exact test)". The "Type of power analysis" is "A priori: Compute required sample size - given  $\alpha$ , power, and effect size".

**Input Parameters:**

Determine =>	Tail(s)	Two
	Proportion p1	0.25
	Proportion p2	0.7
	$\alpha$ err prob	0.05
	Power (1- $\beta$ err prob)	0.80
	Allocation ratio N2/N1	1

**Output Parameters:**

Sample size group 1	23
Sample size group 2	23
Total sample size	46
Actual power	0.8284631
Actual $\alpha$	0.0248526

Buttons at the bottom: "Options", "X-Y plot for a range of values", and "Calculate".

# Chi-square and Fisher's tests

- Chi<sup>2</sup> test very easy to calculate by hand but Fisher's very hard
- Many software will not perform a Fisher's test on tables > 2x2
- **Fisher's test more accurate** than Chi<sup>2</sup> test on **small samples**
- **Chi<sup>2</sup> test more accurate** than Fisher's test on **large samples**
- **Chi<sup>2</sup> test assumptions:**
  - 2x2 table: no expected count < 5
  - Bigger tables: all expected > 1 and no more than 20% < 5

# Chi-square test

- In a chi-square test, **the observed frequencies** for two or more groups are compared with **expected frequencies** by chance.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

- O = Observed frequencies
- E = Expected frequencies

- **Example with 'cats and dogs'**



# How are the expected frequencies calculated?

Example: expected frequency of cats line dancing after having received food as a reward.

**Direct counts approach:**

Expected frequency = (row total)\*(column total)/grand total

$$= 32 * 32 / 68 = 15.1$$

**Probability approach:** The Multiplicative Rule

Probability of line dancing:  $32/68$

Probability of receiving food:  $32/68$

Expected frequency:  $(32/68) * (32/68) = 0.22$ : 22% of 68 = 15.1

Observed frequencies

	Food	Affection	Total
Dance	26	6	32
No dance	6	30	36
Total	32	36	68

Expected frequencies

	Food	Affection
Dance	15.1	16.9
No dance	16.9	19.1





# Chi<sup>2</sup> test

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Observed frequencies

	Food	Affection
Dance	26	6
No dance	6	30

Expected frequencies

	Food	Affection
Dance	15.1	16.9
No dance	16.9	19.1

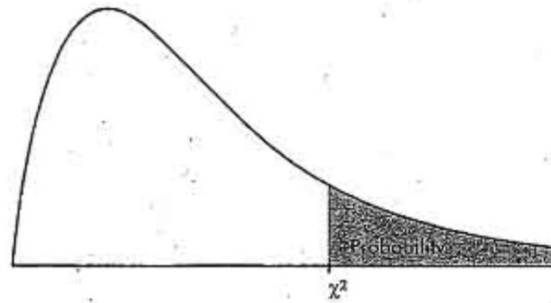
$$\text{Chi}^2 = (26-15.1)^2/15.1 + (6-16.9)^2/16.9 + (6-16.9)^2 /16.9 + (30-19.1)^2/19.1 = 28.4$$

Is 28.4 big enough for the test to be significant?

# Is 28.4 big enough for the test to be significant?

*The old fashion way*

Degree of freedom: df  
 $df = (row-1)(col-1)=1$



Critical value

TABLE C:  $\chi^2$  CRITICAL VALUES

	Food	Affection
Dance	26	6
No dance	6	30

df	Tail probability $p$								
	.25	.20	.15	.10	.05	.025	.02	.01	.005
1	1.32	1.64	2.07	2.71	3.84	5.02	5.41	6.63	7.88
2	2.77	3.22	3.79	4.61	5.99	7.38	7.82	9.21	10.60
3	4.11	4.64	5.32	6.25	7.81	9.35	9.84	11.34	12.84
4	5.39	5.99	6.74	7.78	9.49	11.14	11.67	13.28	14.86
5	6.63	7.29	8.12	9.24	11.07	12.83	13.39	15.09	16.75
6	7.84	8.56	9.45	10.64	12.59	14.45	15.03	16.81	18.55
7	9.04	9.80	10.75	12.02	14.07	16.01	16.62	18.48	20.28
8	10.22	11.03	12.03	13.36	15.51	17.53	18.17	20.09	21.95
9	11.39	12.24	13.29	14.68	16.92	19.02	19.68	21.67	23.59
10	12.55	13.44	14.53	15.99	18.31	20.48	21.16	23.21	25.19

$\chi^2 = 28.4 > 3.84$  so Yes!

# Fisher's exact and Chi<sup>2</sup> tests with Prism 8

The image shows the Prism 8 interface with a contingency table and two dialog boxes. The table has columns for 'Outcome A' (Dance Yes) and 'Outcome B' (Dance No), and rows for 'Food' and 'Affection'. The 'Analyze Data' dialog shows 'Chi-square (and Fisher's exact) test' selected. The 'Parameters' dialog shows 'Odds ratio' checked under 'Effect sizes to report' and 'Fisher's exact test' selected under 'Method to compute the P value'. Annotations include 'Classic effect size' pointing to 'Odds ratio' and '2x2 tables' and 'bigger tables' pointing to 'Fisher's exact test' and 'Chi-square test' respectively. A yellow box at the bottom provides a note about the z test.

	Outcome A Dance Yes	Outcome B Dance No	Outcome C Title	Outcome D Title	Outcome E Title	Outcome F Title	Outcome G Title	Outcome H Title	Outcor Title
1	Food	26	6						
2	Affection	6	30						
3	Title								
4	Title								
5	Title								
6	Title								
7	Title								
8	Title								
9	Title								
10	Title								
11	Title								
12	Title								
13	Title								
14	Title								
15	Title								
16	Title								
17	Title								
18	Title								
19	Title								
20	Title								
21	Title								
22	Title								
23	Title								
24	Title								
25	Title								
26	Title								

**Analyze Data**

Which analysis?

- Transform, Normalize...
- XY analyses
- Column analyses
- Grouped analyses
- Contingency table analyses
  - Chi-square (and Fisher's exact) test
  - Row means with SD or SEM
  - Fraction of total
- Survival analyses
- Parts of whole analyses
- Multiple variable analyses
- Nested analyses
- Generate curve
- Simulate data
- Recently used

Analyze which data sets?

- A:Dance Yes
- B:Dance No

**Parameters: Chi-square (and Fisher's exact) test**

**Main Calculations** Options

**Effect sizes to report**

- Relative Risk  
Used for prospective and experimental studies
- Difference between proportions (attributable risk) and NNT  
Used for prospective and experimental studies
- Odds ratio  
Used for retrospective case-control studies
- Sensitivity, specificity and predictive values  
Used for diagnostic tests

**Method to compute the P value**

- Fisher's exact test
- Yates' continuity corrected chi-square test
- Chi-square test
- Chi-square test for trend

Looking for the z test to compare proportions? Choose the chi-square test (with or without the Yates' correction). The chi-square and z tests are equivalent.

# Fisher's exact and Chi<sup>2</sup> tests Results

Contingency		A	B
1	Table Analyzed	Cats	
2			
3	P value and statistical significance		
4	Test	Fisher's exact test	
5	P value	<0.0001	
6	P value summary	****	
7	One- or two-sided	Two-sided	
8	Statistically significant (P < 0.05)?	Yes	
9			
10	Effect size	Value	95% CI
11	Odds ratio	21.67	6.431 to 68.72
12	Reciprocal of odds ratio	0.04615	0.01455 to 0.1555

Contingency		A	B
1	Table Analyzed	Cats	
2			
3	P value and statistical significance		
4	Test	Chi-square	
5	Chi-square, df	28.36, 1	
6	z	5.326	
7	P value	<0.0001	
8	P value summary	****	
9	One- or two-sided	Two-sided	
10	Statistically significant (P < 0.05)?	Yes	
11			
12	Effect size	Value	95% CI
13	Odds ratio	21.67	6.431 to 68.72
14	Reciprocal of odds ratio	0.04615	0.01455 to 0.1555

	Food	Affection
Dance	26	6
No dance	6	30

Odds of dancing on Food group = 26/6

Odds of dancing on Affection group = 6/30

O.R. = ratio of the odds = 26/6 / 6/30 = 21.7

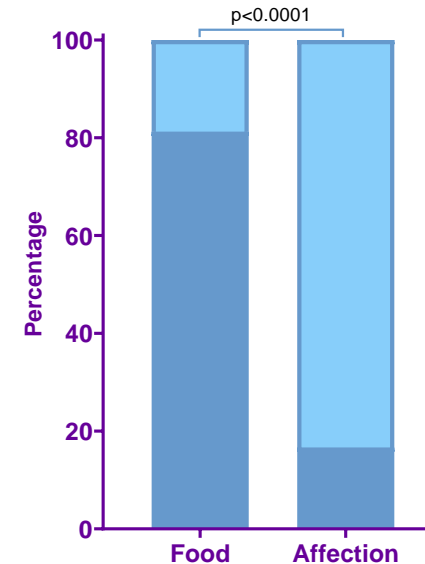
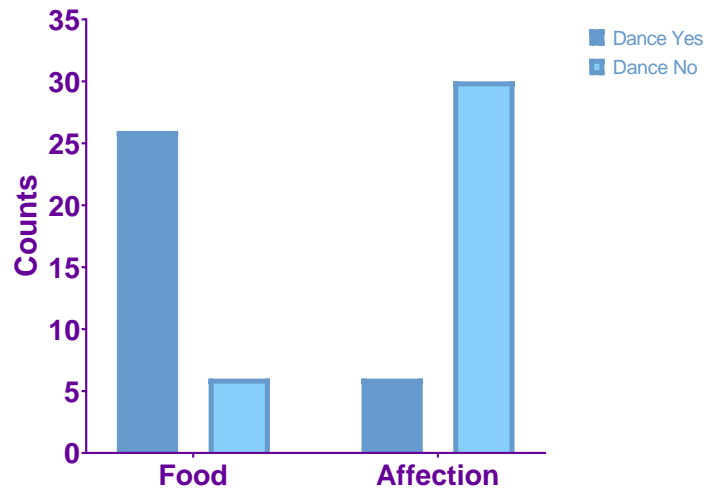
**Odds Ratio = 21.7**

If you are a dancing cat, you are almost 22 times more likely to have received food than affection as a reward (p<0.0001).

# Fisher's exact and Chi<sup>2</sup> tests with Prism 8

## Beyond significance

- Two super important things to keep in mind:
  - ❖ Qualitative data can be presented as percentages but the **tests should always be run on actual counts.**
    - ❖ Power!
  - ❖ A **p-value should always be interpreted in the context of the experiment.**
    - ❖ Power!



**Let's do it with the dogs**

# Results for cats and dogs

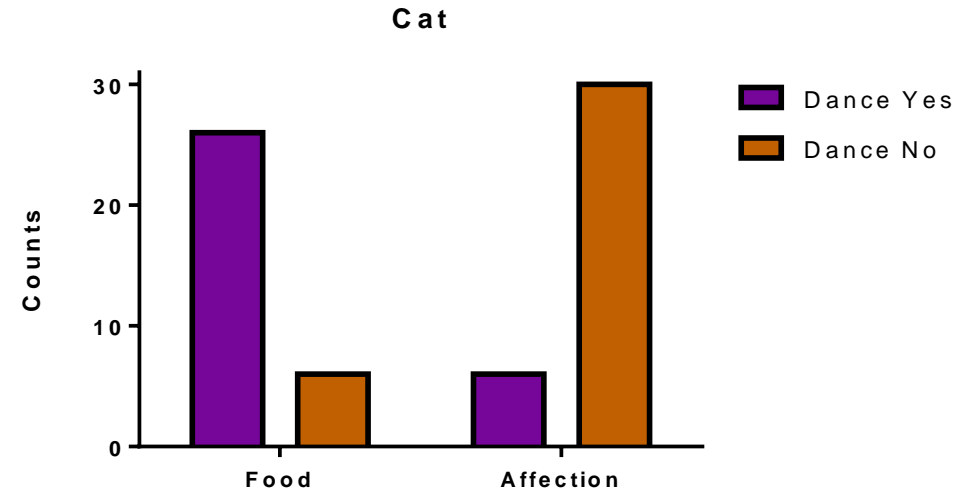
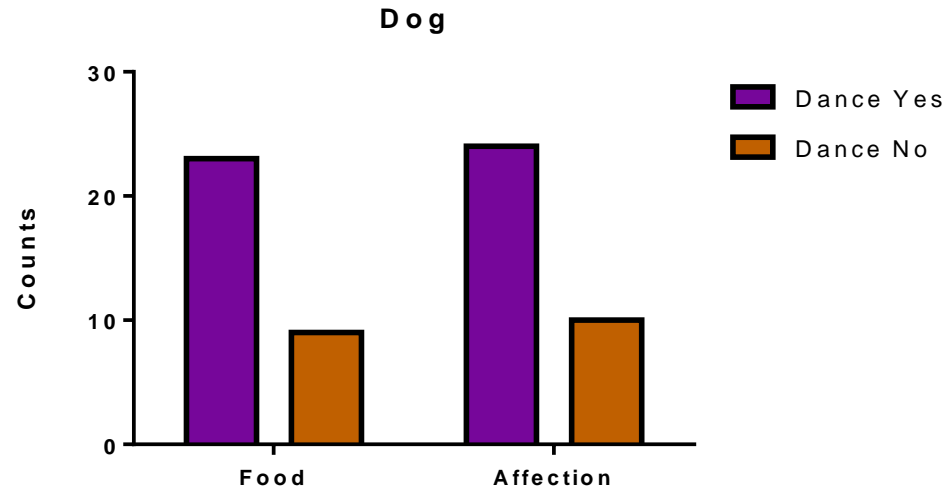
Table Analyzed	Cat
P value and statistical significance	
Test	Chi-square
Chi-square, df	28.36, 1
z	5.326
P value	<0.0001
P value summary	****
One- or two-sided	Two-sided
Statistically significant (P < 0.05)?	Yes

1	Table Analyzed	Cat
2		
3	Fisher's exact test	
4		
5	P value	< 0.0001
6	P value summary	****
7	One- or two-sided	Two-sided
8	Statistically significant? (alpha<0.05)	Yes
9		

Table Analyzed	Dog
P value and statistical significance	
Test	Chi-square
Chi-square, df	0.01331, 1
z	0.1154
P value	0.9081
P value summary	ns
One- or two-sided	Two-sided
Statistically significant (P < 0.05)?	No

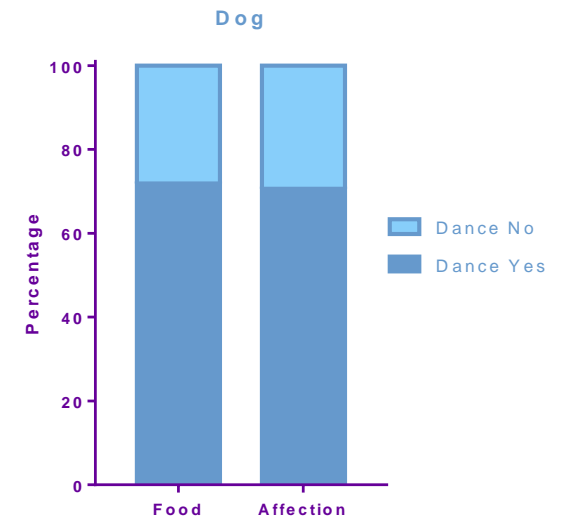
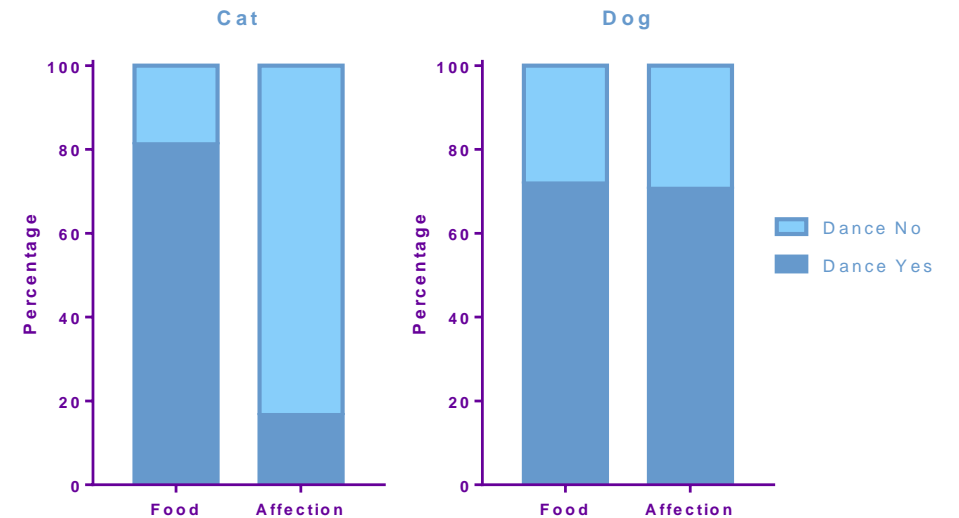
Table Analyzed	Dog
P value and statistical significance	
Test	Fisher's exact test
P value	>0.9999
P value summary	ns
One- or two-sided	Two-sided
Statistically significant (P < 0.05)?	No

# Fisher's exact test: results



- **In our example:**

cats are more likely to line dance if they are given food as reward than affection ( $p < 0.0001$ ) whereas dogs don't mind ( $p > 0.99$ ).





## Exercise: Cane toads

	Infected	Uninfected
Rockhampton	12	8
Bowen	4	16
Mackay	15	5



- A researcher decided to check the hypothesis that the proportion of cane toads with intestinal parasites was the same in 3 different areas of Queensland.

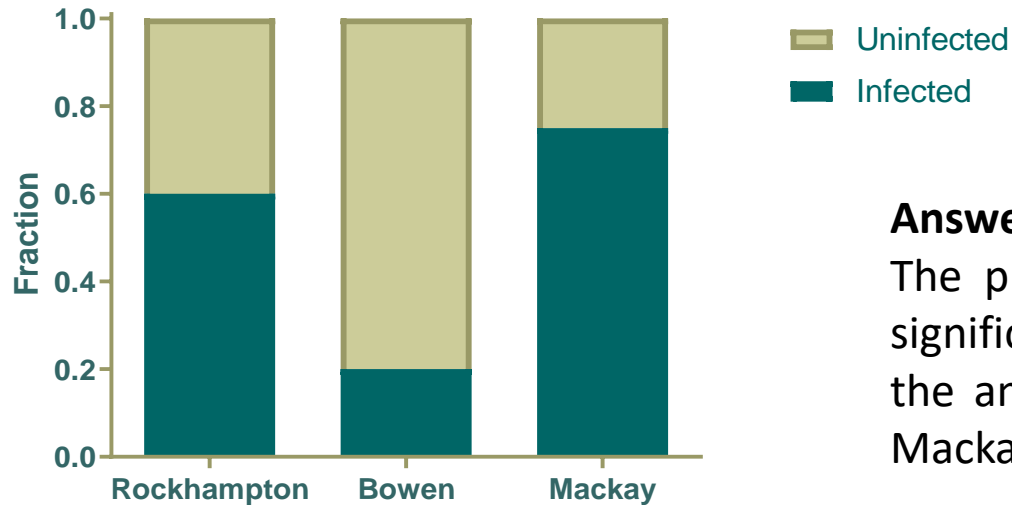
*From Statistics Explained by Steve McKillup*

- **Question:** Is the proportion of cane toads infected by intestinal parasites the same in 3 different areas of Queensland?

# Exercise: Cane toads



Table Analyzed	Cane toad
Chi-square	
Chi-square, df	12.95, 2
P value	0.0015
P value summary	**
One- or two-tailed	NA
Statistically significant? (alpha<0.05)	Yes
Data analyzed	
Number of rows	3
Number of columns	2



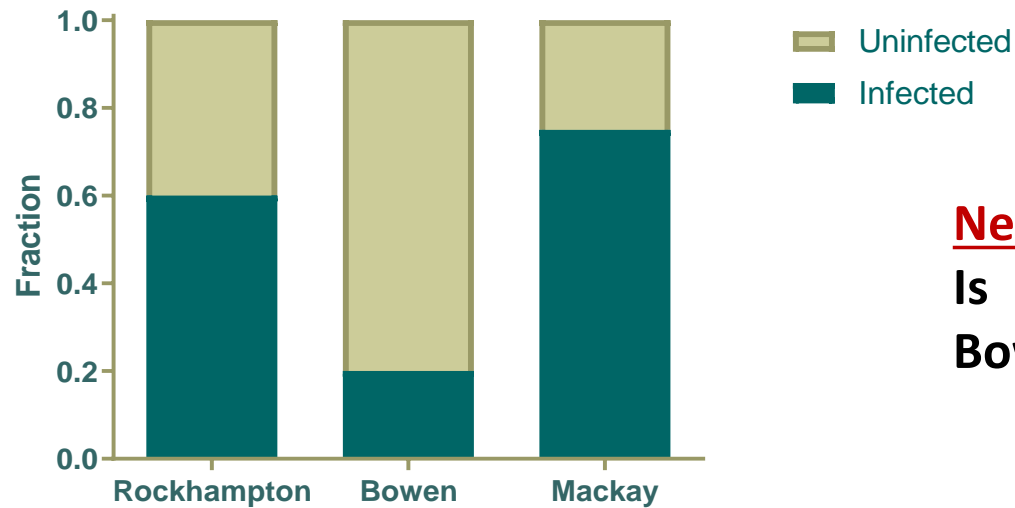
## Answer:

The proportion of cane toads infected by intestinal parasites varies significantly between the 3 different areas of Queensland ( $p=0.0015$ ), the animals being more likely to be parasitized in Rockhampton and Mackay than in Bowen.

# Exercise: Cane toads



Table Analyzed	Cane toad
Chi-square	
Chi-square, df	12.95, 2
P value	0.0015
P value summary	**
One- or two-tailed	NA
Statistically significant? (alpha<0.05)	Yes
Data analyzed	
Number of rows	3
Number of columns	2



## New question:

Is the proportion of infected cane toads different in Bowen than in the other 2 areas?

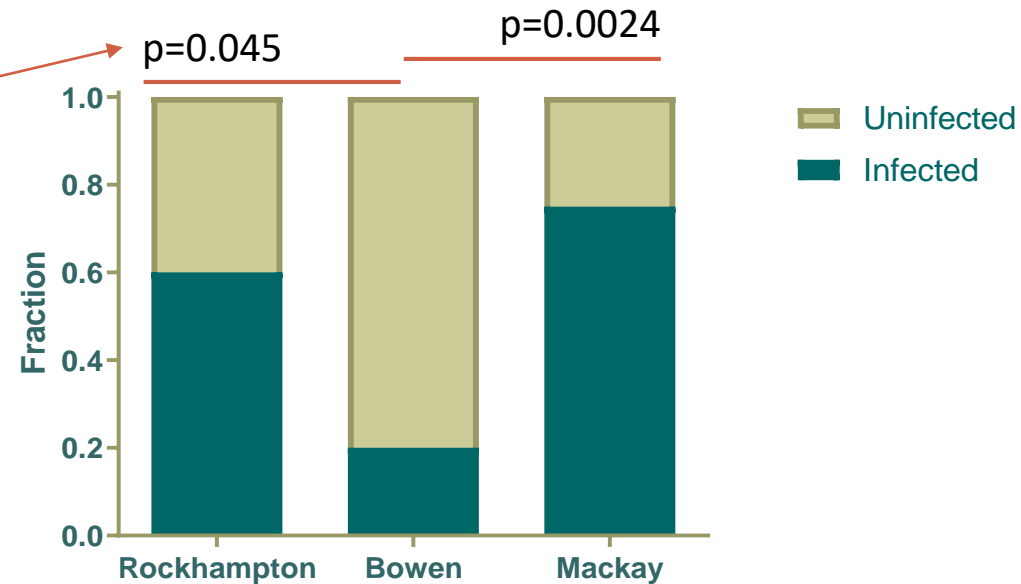
# Exercise: Cane toads



P value and statistical significance	
Test	Fisher's exact test
P value	0.0225

P value and statistical significance	
Test	Fisher's exact test
P value	0.0012

Bonferroni correction



Is the proportion of infected cane toads different in Bowen than in the other 2 areas? Yes, it is.

