Unit 5: Inference for categorical data

1. Single sample proportion

Sta 104 - Summer 2015

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June 8, 2015

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Slides posted at http://bit.ly/sta104su15

- No OH tomorrow (Tuesday) but I will be answering questions on Piazza throughout the day + can stay for a bit after class for quick questions

- parameter of interest, p: Proportion of "success" in the population (unknown)
- point estimate, $\hat{p}$: Proportion of "success" in the sample

Central limit theorem for proportions: Sample proportions will be nearly normally distributed with mean equal to the population mean, p, and standard error equal to $\sqrt{\frac{p\,(1-p)}{n}}$.

$$\hat{p} \sim N\left(mean = p, SE = \sqrt{\frac{p\,(1-p)}{n}}\right)$$

Conditions:

- Independence: Random sample/assignment + 10% rule
- At least 10 successes and failures

Clicker question

Suppose $p = 0.93$. What shape does the distribution of $\hat{p}$ have in random samples of $n = 100$.

(a) unimodal and symmetric (nearly normal)
(b) bimodal and symmetric
(c) right skewed
(d) left skewed

Clicker question

Suppose $p = 0.05$. What shape does the distribution of $\hat{p}$ have in random samples of $n = 100$.

(a) unimodal and symmetric (nearly normal)
(b) bimodal and symmetric
(c) right skewed
(d) left skewed

Clicker question

Suppose $p = 0.5$. What shape does the distribution of $\hat{p}$ have in random samples of $n = 100$.

(a) unimodal and symmetric (nearly normal)
(b) bimodal and symmetric
(c) right skewed
(d) left skewed

CI vs. HT determines observed vs. expected counts / proportions

Remember, when doing a HT always assume H_0 is true!

- **S-F:** Number of successes and failures for checking the success-failure condition for the nearly normal distribution of $\hat{p}$:
  - CI: use observed proportion $\rightarrow n\hat{p} \geq 10$ and $n(1-\hat{p}) \geq 10$
  - HT: use null value of the proportion $\rightarrow np_0 \geq 10$ and $n(1-p_0) \geq 10$
- **SE:** Proportion of success for calculating the standard error of $\hat{p}$:

$$SE = \sqrt{\frac{p(1-p)}{n}}$$

  - CI: use observed proportion $\rightarrow SE = \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$
  - HT: use null value of the proportion $\rightarrow SE = \sqrt{\frac{p_0(1-p_0)}{n}}$

Simulation vs. theoretical inference

- If the S-F condition is met, can do theoretical inference: Z test, Z interval
- If the S-F condition is not met, must use simulation based methods: randomization test, bootstrap interval

Activity: π

Write out the digits of π from memory in the chat box. No cheating!

Application exercise: App Ex 5.1

See course website for details.

Clicker question

Are you vegetarian?

(a) Yes
(b) No

Clicker question

A variety of studies suggest that 8% of college students are vegetarians. Assuming that this class is a representative sample of Duke students, which of the following are the correct set of hypotheses for testing if the proportion of Duke students who are vegetarian is different than the proportion of vegetarian college students at large.

(a) $H_0 : p = 0.08$; $H_A : p \neq 0.08$
(b) $H_0 : p = 0.08$; $H_A : p < 0.08$
(c) $H_0 : \hat{p} = 0.08$; $H_A : \hat{p} \neq 0.08$
(d) $H_0 : \hat{p}_{Duke} = \hat{p}_{all\ college}$; $H_A : \hat{p}_{Duke} \neq \hat{p}_{all\ college}$
(e) $H_0 : p_{Duke} = p_{all\ college}$; $H_A : p_{Duke} \neq p_{all\ college}$

Simulate by hand

Describe a simulation scheme for this hypothesis test.

- 100 chips in a bag: 8 green (vegetarian), 92 white (non vegetarian).
- Sample randomly n times from the bag, with replacement (n = observed sample size)
- Calculate $\hat{p}$, the proportion of greens (successes) in the random sample of size n, record this value.
- Repeat many times.
- Calculate the proportion of simulations where $\hat{p}$ is at least as different from 0.08 as the observed sample proportion.

Simulate in R

```
download("https://stat.duke.edu/~mc301/R/inference.RData",
         destfile = "inference.RData")
load("inference.RData")

n_veg = [fill in based on class data]
n_nonveg = [fill in based on class data]

class_veg = c(rep("veg", n_veg), rep("non vegetarian", n_nonveg))

inference(class_veg, success = "veg", est = "proportion",
          type = "ht", null = 0.08, alternative = "twosided",
          method = "simulation")
```


Bootstrap interval for a single proportion

How would the simulation scheme change for a bootstrap interval for the proportion of Duke students who are vegetarians?

Recap on CLT based methods

- Calculating the necessary sample size for a CI with a given margin of error:
  - If there is a previous study, use $\hat{p}$ from that study
  - If not, use $\hat{p} = 0.5$:
    - if you don't know any better, 50-50 is a good guess
    - $\hat{p} = 0.5$ gives the most conservative estimate – highest possible sample size
- HT vs. CI for a proportion
  - Success-failure condition:
    - CI: At least 10 *observed* successes and failures
    - HT: At least 10 *expected* successes and failures, calculated using the null value
  - Standard error:
    - CI: calculate using observed sample proportion: $SE = \sqrt{\frac{p(1-p)}{n}}$
    - HT: calculate using the null value: $SE = \sqrt{\frac{p_0(1-p_0)}{n}}$

Recap on simulation methods

If the S-F condition is not met

- HT: Randomization test – simulate under the assumption that H_0 is true, then find the p-value as proportion of simulations where the simulated $\hat{p}$ is at least as extreme as the one observed.
- CI: Bootstrap interval – resample with replacement from the original sample, and construct interval using percentile or standard error method.

Summary of main ideas

1. For inference on a single proportion: parameter is p and point estimate is $\hat{p}$
2. The CLT also describes the distribution of $\hat{p}$
3. CI vs. HT determines observed vs. expected counts / proportions
4. Only used CLT based methods if the sample size is large enough for a nearly normal sampling distribution