ENV 710

power and t-tests continued…

roadmap

- labs
  - look at sample labs
  - no screenshots!
  - can't knit – see me
- next week: no quiz
- open book exam on Sept. 30
  - 24 hours to take exam
  - type answers into Sakai

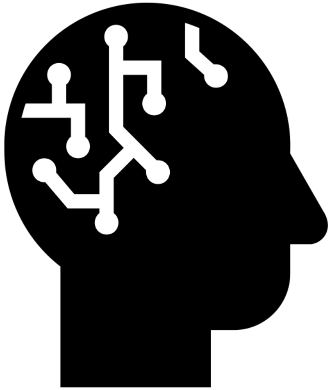
descriptive statistics
discrete probability/distributions
continuous probability/distributions
inference

one- and two-sample tests
z-test, t-tests, etc., more on hypothesis testing and statistical power

study design
data transformation

type I and type II errors

decision	true state: H_0	true state: H_A
do not reject H_0	correct decision $p = 1-\alpha$	**type II error** $p = \beta$ wrongly retain H_0
reject H_0	**type I error** $p = \alpha$ wrongly reject H_0	correct decision $p = 1-\beta$

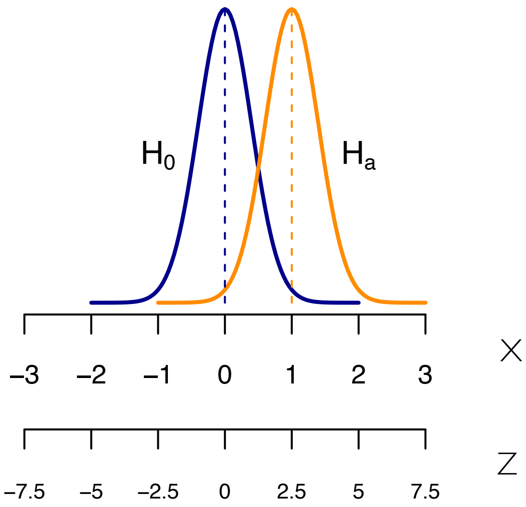


1 – power

Can a 6-month exercise program increase the total body bone mineral content (TBBMC) of young women? A team of researchers is planning a study to examine this question. Based on a previous study, they are willing to assume **σ** = 2 for the percent change in TBBMC over the 6-month period. A **change in TBBMC of 1%** would be considered important, and the researchers would like to have a reasonable chance of detecting a change this large or larger. Is **25 subjects** large enough to sample for this project for a power of 80% or more?

$$H_0 : \mu_0 = 0$$

$$H_a : \mu_0 > 0$$



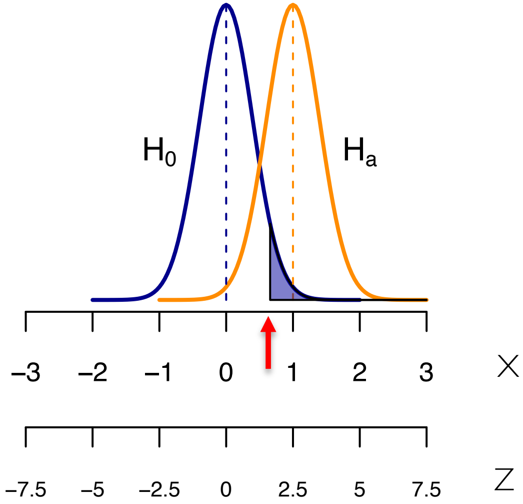
Step 1: state the hypotheses

Step 2: specify the alternative hypothesis

I – power

Can a 6-month exercise program increase the total body bone mineral content (TBBMC) of young women? A team of researchers is planning a study to examine this question. Based on a previous study, they are willing to assume **σ** = 2 for the percent change in TBBMC over the 6-month period. A **change in TBBMC of 1%** would be considered important, and the researchers would like to have a reasonable chance of detecting a change this large or larger. Is **25 subjects** large enough to sample for this project for a power of 80% or more?

```
Zc <- qnorm(p = 0.95, mean=0, sd=1)
[1] 1.644854
Xc <- qnorm(p = 0.95, mean=0, sd=2/sqrt(25))
[1] 0.6579415
```

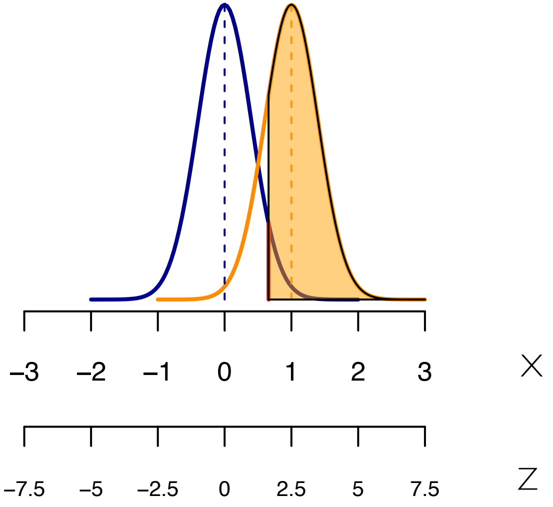


Step 3: Find the critical statistic that defines the rejection region and Type I error

1 – power

Can a 6-month exercise program increase the total body bone mineral content (TBBMC) of young women? A team of researchers is planning a study to examine this question. Based on a previous study, they are willing to assume **σ = 2** for the percent change in TBBMC over the 6-month period. A **change in TBBMC of 1%** would be considered important, and the researchers would like to have a reasonable chance of detecting a change this large or larger. Is **25 subjects** large enough to sample for this project for a power of 80% or more?

```
Zpow <- 1-pnorm(q=Zc, mean = (1-0)/(2/sqrt(25)), 1)
[1] 0.8037649
Xpow <- 1-pnorm(q=Xc, mean=1, sd=2/sqrt(25))
[1] 0.8037649
```

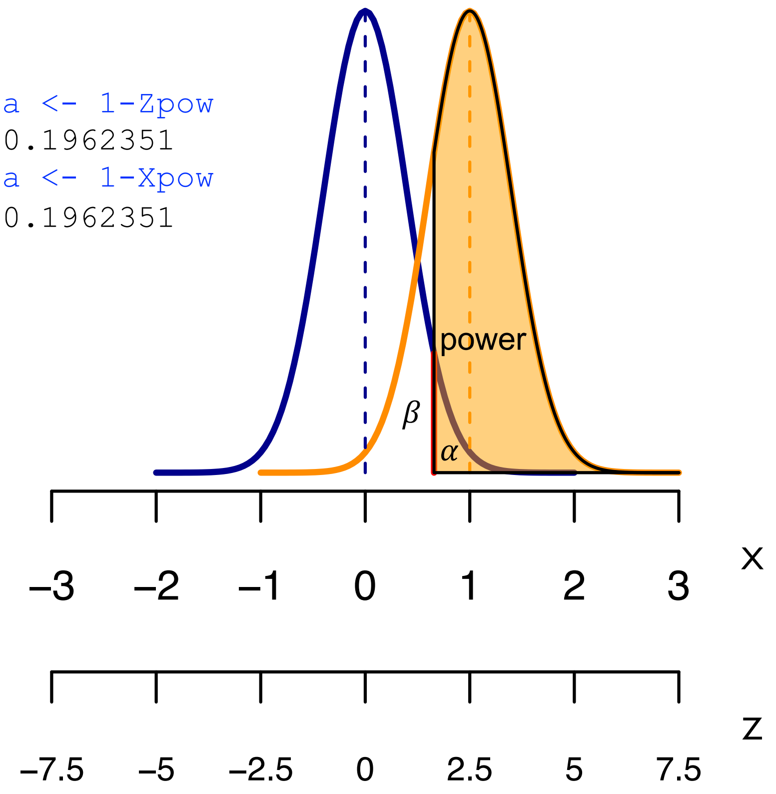


Step 4: To determine power, find the area to the right of the critical statistic on the alternative distribution

1 – power

Can a 6-month exercise program increase the total body bone mineral content (TBBMC) of young women? A team of researchers is planning a study to examine this question. Based on a previous study, they are willing to assume **σ** = 2 for the percent change in TBBMC over the 6-month period. A **change in TBBMC of 1%** would be considered important, and the researchers would like to have a reasonable chance of detecting a change this large or larger. Is **25 subjects** large enough to sample for this project for a power of 80% or more?

```
Zbeta <- 1-Zpow
[1] 0.1962351
Xbeta <- 1-Xpow
[1] 0.1962351
```



Step 5: Find the Type II error

Step 6: Make a conclusion

2 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

A. Do the two rivers have different pH levels given these samples?

(10 mins)

1. state the H_0 and H_a
2. what type of test should be used? (one- or two-sample, one- or two-sided, etc.) why?
3. assume the data for each sample are normally distributed, but check that sample variances are not significantly different
4. conduct your test and draw conclusions

```
ph <- read.csv("River_pH.csv", header = T)
```

2 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

A. Do the two rivers have different pH levels given these samples?

(10 mins)

1. state the H_0 and H_a

   H_0: River A pH = River B pH

   H_A: River A pH ≠ River B pH

2. what type of test should be used? (one- or two-sample, one- or two-sided, etc.) why?

   two-sample, two-sided, t-test

2 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

A. Do the two rivers have different pH levels given these samples?

(10 mins)

```
> with(ph, var.test(pH[River_name == "A"],
       pH[River_name == "B"]))

>  var.test(ph$pH ~ ph$River_name)

          F test to compare two variances

data:  ph$pH by ph$River_name
F = 1.6536, num df = 9, denom df = 9, p-
value = 0.4653
alternative hypothesis: true ratio of
variances is not equal to 1
95 percent confidence interval:
 0.4107238 6.6572692
sample estimates:
ratio of variances
          1.653572
```

2 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

A. Do the two rivers have different pH levels given these samples?

(10 mins)

```
> with(ph, t.test(x=pH[River_name == "A"],
                  y=pH[River_name == "B"],
        alternative = "two.sided",
         var.equal = T))

> t.test(ph$pH ~ ph$River_name, var.equal=T,
         alternative = ”two.sided”)

        Two Sample t-test

data:  ph$pH by ph$River_name
t = 6.9788, df = 18, p-value = 1.618e-06
alternative hypothesis: true difference in
means is not equal to 0
95 percent confidence interval:
 1.574706 2.931168
sample estimates:
mean in group A mean in group B
       8.661497        6.408560
```

3 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

B. Does river A have significantly greater pH levels than river B?

(5 mins)

1. state the H_0 and H_a
2. what type of test should be used? (one- or two-sample, one- or two-sided, etc.) why?
3. conduct your test and draw conclusions

3 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

B. Does river A have significantly greater pH levels than river B?

1. state the H_0 and H_a

   H_0: River A pH = River B pH

   H_A: River A pH **>** River B pH

2. what type of test should be used? (one- or two-sample, one- or two-sided, etc.) why?

   two-sample, one-sided t-test

3 – river pH

The file, "River_pH.csv", includes data on pH measurements from two rivers, A and B.

B. Does river A have significantly greater pH levels than river B?

```
> t.test(ph$pH~ph$River_name, var.equal=T,
         alternative="greater")

         Two Sample t-test

data:  phA and phB
t = 6.9788, df = 18, p-value = 8.089e-07
alternative hypothesis: true difference in
means is greater than 0
95 percent confidence interval:
 1.693137      Inf
sample estimates:
mean of x mean of y
 8.661497  6.408560
```

4 – river pH

The file, "River_pH.csv", includes data on pH measurements from one river in which **pH was sampled at 10 locations before and after a flood**.

C. Did the flood significantly decrease the pH of the river?

(5 mins)

1. state the H_0 and H_a
2. what type of test should be used? (one- or two-sample, one- or two-sided, etc.) why?
3. conduct your test and draw conclusions

4 – river pH

The file, "River_pH.csv", includes data on pH measurements from one river in which **pH was sampled at 10 locations before and after a flood**.

C. Did the flood significantly decrease the pH of the river?

1. state the H_0 and H_a

   H_0: $pH_{before} = pH_{after}$

   H_A: $pH_{after} < pH_{before}$

2. what type of test should be used? (one-sample, two-sample, one-sided, two-sided) why?

   one-sided, paired t-test

4 – river pH

The file, "River_pH.csv", includes data on pH measurements from one river in which **pH was sampled at 10 locations before and after a flood**.

C. Did the flood significantly decrease the pH of the river?

```
> t.test(ph$pH ~ ph$River_name, paired = T, 
alternative="greater")

> with(ph, t.test(x = pH[River_name == "A"], 
y = pH[River_name == "B"], paired = T, 
alternative = "greater"))

          Paired t-test

data:  phA and phB
t = 6.1308, df = 9, p-value = 8.634e-05
alternative hypothesis: true difference in 
means is greater than 0
95 percent confidence interval:
 1.579311      Inf
sample estimates:
mean of the differences 
               2.252937
```

5 – river pH

The file, "River_pH.csv", includes data on pH measurements from one river in the US.

D. Is the mean pH level of this river different from the national mean pH level of rivers of 7.0?

(5 mins)

1. state the H_0 and H_a
2. what type of test should be used? (one- or two-sample, one- or two-sided, etc.) why?
3. assume the data for each sample are normally distributed, but check that sample variances are not significantly different
4. conduct your test and draw conclusions

5 – river pH

The file, "River_pH.csv", includes data on pH measurements from one river in the US.

D. Is the mean pH level of this river different from the national mean pH level of rivers of 7.0?

1. state the H_0 and H_a

   H_0: $pH_{river} = pH_{7.0}$

   H_A: $pH_{river} \neq pH_{7.0}$

2. what type of test should be used? (one-sample, two-sample, one-sided, two-sided) why?

   one-sample, two-sided t-test

5 – river pH

The file, "River_pH.csv", includes data on pH measurements from one river in the US.

D. Is the mean pH level of this river different from the national mean pH level of rivers of 7.0?

```
> t.test(x=ph$pH, mu=7.0,
         alternative = "two.sided")

One Sample t-test

data:  ph$pH
t = 1.7691, df = 19, p-value = 0.09294
alternative hypothesis: true mean is not
equal to 7
95 percent confidence interval:
 6.902019 8.168039
sample estimates:
mean of x
 7.535029
```

Questions?