

# week3\_assessment

September 26, 2020

## 0.1 Creating confidence intervals in python

In this assessment, you will look at data from a study on toddler sleep habits.

The confidence intervals you create and the questions you answer in this Jupyter notebook will be used to answer questions in the following graded assignment.

```
In [1]: import numpy as np
import pandas as pd
from scipy.stats import t
pd.set_option('display.max_columns', 30) # set so can see all columns of the DataFrame
import scipy.stats as ss
```

Your goal is to analyse data which is the result of a study that examined differences in a number of sleep variables between napping and non-napping toddlers. Some of these sleep variables included: Bedtime (lights-off time in decimalized time), Night Sleep Onset Time (in decimalized time), Wake Time (sleep end time in decimalized time), Night Sleep Duration (interval between sleep onset and sleep end in minutes), and Total 24-Hour Sleep Duration (in minutes). Note: **Decimalized time** is the representation of the time of day using units which are decimally related.

The 20 study participants were healthy, normally developing toddlers with no sleep or behavioral problems. These children were categorized as napping or non-napping based upon parental report of children's habitual sleep patterns. Researchers then verified napping status with data from actigraphy (a non-invasive method of monitoring human rest/activity cycles by wearing of a sensor on the wrist) and sleep diaries during the 5 days before the study assessments were made.

You are specifically interested in the results for the Bedtime, Night Sleep Duration, and Total 24- Hour Sleep Duration.

Reference: Akacem LD, Simpkin CT, Carskadon MA, Wright KP Jr, Jenni OG, Achermann P, et al. (2015) The Timing of the Circadian Clock and Sleep Differ between Napping and Non-Napping Toddlers. PLoS ONE 10(4): e0125181. <https://doi.org/10.1371/journal.pone.0125181>

```
In [2]: # Import the data
df = pd.read_csv("nap_no_nap.csv")
df.head()
```

```
Out[2]:
```

	id	sex	age (months)	dlmo time	days napped	napping \
0	1	female	33.7	19.24	0	0
1	2	female	31.5	18.27	0	0
2	3	male	31.9	19.14	0	0
3	4	female	31.6	19.69	0	0
4	5	female	33.0	19.52	0	0

	nap lights outl time	nap sleep onset	nap midsleep	nap sleep offset	\
0	NaN	NaN	NaN	NaN	
1	NaN	NaN	NaN	NaN	
2	NaN	NaN	NaN	NaN	
3	NaN	NaN	NaN	NaN	
4	NaN	NaN	NaN	NaN	

	nap wake time	nap duration	nap time in bed	night bedtime	\
0	NaN	NaN	NaN	20.45	
1	NaN	NaN	NaN	19.23	
2	NaN	NaN	NaN	19.60	
3	NaN	NaN	NaN	19.46	
4	NaN	NaN	NaN	19.21	

	night sleep onset	sleep onset latency	night midsleep time	\
0	20.68	0.23	1.92	
1	19.48	0.25	1.09	
2	20.05	0.45	1.29	
3	19.50	0.05	1.89	
4	19.65	0.45	1.30	

	night wake time	night sleep duration	night time in bed	\
0	7.17	629.4	643.0	
1	6.69	672.4	700.4	
2	6.53	628.8	682.6	
3	8.28	766.6	784.0	
4	6.95	678.0	718.0	

	24 h sleep duration	bedtime phase difference	\
0	629.4	-1.21	
1	672.4	-0.96	
2	628.8	-0.46	
3	766.6	0.23	
4	678.0	0.31	

	sleep onset phase difference	midsleep phase difference	\
0	-1.44	6.68	
1	-1.21	6.82	
2	-0.91	6.15	
3	0.19	6.20	
4	-0.13	5.78	

	wake time phase difference
0	11.93
1	12.42
2	11.39
3	12.59

4 11.43

```
In [5]: n = len(df)
n
```

```
Out[5]: 20
```

```
In [4]: nap = df[['napping', 'night bedtime']].dropna()
napy = nap.loc[nap.napping == 0]
napysi = nap.loc[nap.napping == 1]
df.head()
```

```
Out[4]:
```

	id	sex	age (months)	dlmo time	days napped	napping \
0	1	female	33.7	19.24	0	0
1	2	female	31.5	18.27	0	0
2	3	male	31.9	19.14	0	0
3	4	female	31.6	19.69	0	0
4	5	female	33.0	19.52	0	0

  

	nap lights outl time	nap sleep onset	nap midsleep	nap sleep offset \
0	NaN	NaN	NaN	NaN
1	NaN	NaN	NaN	NaN
2	NaN	NaN	NaN	NaN
3	NaN	NaN	NaN	NaN
4	NaN	NaN	NaN	NaN

  

	nap wake time	nap duration	nap time in bed	night bedtime \
0	NaN	NaN	NaN	20.45
1	NaN	NaN	NaN	19.23
2	NaN	NaN	NaN	19.60
3	NaN	NaN	NaN	19.46
4	NaN	NaN	NaN	19.21

  

	night sleep onset	sleep onset latency	night midsleep time \
0	20.68	0.23	1.92
1	19.48	0.25	1.09
2	20.05	0.45	1.29
3	19.50	0.05	1.89
4	19.65	0.45	1.30

  

	night wake time	night sleep duration	night time in bed \
0	7.17	629.4	643.0
1	6.69	672.4	700.4
2	6.53	628.8	682.6
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0	629.4	-1.21

1	672.4	-0.96
2	628.8	-0.46
3	766.6	0.23
4	678.0	0.31

	sleep onset phase difference	midsleep phase difference \
0	-1.44	6.68
1	-1.21	6.82
2	-0.91	6.15
3	0.19	6.20
4	-0.13	5.78

	wake time phase difference
0	11.93
1	12.42
2	11.39
3	12.59
4	11.43

```
In [6]: # First, look at the DataFrame to get a sense of the data
        #print(len(df.id))
        df.columns
```

```
Out[6]: Index(['id', 'sex', 'age (months)', 'dlmo time', 'days napped', 'napping',
              'nap lights outl time', 'nap sleep onset', 'nap midsleep',
              'nap sleep offset', 'nap wake time', 'nap duration', 'nap time in bed',
              'night bedtime', 'night sleep onset', 'sleep onset latency',
              'night midsleep time', 'night wake time', 'night sleep duration',
              'night time in bed', '24 h sleep duration', 'bedtime phase difference',
              'sleep onset phase difference', 'midsleep phase difference',
              'wake time phase difference'],
             dtype='object')
```

**Question:** What variable is used in the column ‘napping’ to indicate a toddler takes a nap?

**Question:** What is the sample size  $n$ ?

```
In [ ]: df[df['napping']==1]
```

```
In [5]: len(df)
```

```
Out[5]: 20
```

## 0.2 Hypothesis testing

We will look at two hypothesis test, each with  $\alpha = .025$ :

1. Is the average bedtime for toddlers who nap later than the average bedtime for toddlers who don't nap?

$$H_0 : \mu_{nap} = \mu_{no\ nap}, H_a : \mu_{nap} > \mu_{no\ nap}$$

Or equivalently:

$$H_0 : \mu_{nap} - \mu_{no\ nap} = 0, H_a : \mu_{nap} - \mu_{no\ nap} > 0$$

2. The average 24 h sleep duration (in minutes) for napping toddlers is different from toddlers who don't nap.

$$H_0 : \mu_{nap} = \mu_{no\ nap}, H_a : \mu_{nap} \neq \mu_{no\ nap}$$

Or equivalently:

$$H_0 : \mu_{nap} - \mu_{no\ nap} = 0, H_a : \mu_{nap} - \mu_{no\ nap} \neq 0$$

Aside: This  $\alpha$  level is equivalent to  $\alpha = .05$  and then applying the [Bonferonni correction](#).  
Before any analysis, we will convert 'night bedtime' into decimalized time.

```
In [6]: # Convert 'night bedtime' into decimalized time
        df.loc[:, 'night bedtime'] = np.floor(df['night bedtime'])*60 + np.round(df['night bedtime'], 1)
```

Now, isolate the column 'night bedtime' for those who nap into a new variable, and those who didn't nap into another new variable.

```
In [7]: nap_bedtime = df[df['napping'] == 1]['night bedtime'].copy()
        len(nap_bedtime)
```

```
Out[7]: 15
```

```
In [8]: no_nap_bedtime = df[df['napping'] == 0]['night bedtime'].copy()
        no_nap_bedtime
```

```
Out[8]: 0      1245.0
        1      1163.0
        2      1200.0
        3      1186.0
        4      1161.0
        Name: night bedtime, dtype: float64
```

Now find the sample mean bedtime for nap and no\_nap.

```
In [9]: nap_mean_bedtime = nap_bedtime.mean()
        nap_mean_bedtime
```

```
Out[9]: 1233.0666666666666
```

```
In [10]: no_nap_mean_bedtime = no_nap_bedtime.mean()
         no_nap_mean_bedtime
```

```
Out[10]: 1191.0
```

```
In [11]: nap_mean_bedtime - no_nap_mean_bedtime
```

```
Out [11]: 42.066666666666606
```

**Question:** What is the sample difference of mean bedtime for nappers minus no nappers?  
Now find the sample standard deviation for  $X_{nap}$  and  $X_{no\ nap}$ .

```
In [12]: nap_s_bedtime = nap_bedtime.std()  
        nap_s_bedtime
```

```
Out [12]: 34.445540177143954
```

```
In [13]: no_nap_s_bedtime = no_nap_bedtime.std()  
        no_nap_s_bedtime
```

```
Out [13]: 34.30014577228499
```

**Question:** What is the s.e. ( $\bar{X}_{nap} - \bar{X}_{no\ nap}$ )?

We expect the variance in sleep time for toddlers who nap and toddlers who don't nap to be the same. So we use a pooled standard error.

Calculate the pooled standard error of  $\bar{X}_{nap} - \bar{X}_{no\ nap}$  using the formula below.

$$s.e.(\bar{X}_{nap} - \bar{X}_{no\ nap}) = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2} \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

```
In [14]: from math import sqrt  
        pooled_se = sqrt((((14*34.445**2)+(4*34.3**2))/(18))*((1/15)+(1/5)))  
        pooled_se
```

```
Out [14]: 17.770709296167354
```

**Question:** Given our sample size of  $n$ , how many degrees of freedom ( $df$ ) are there for the associated  $t$  distribution?

Now calculate the  $t$ -test statistic for our first hypothesis test using

\* pooled s.e. ( $\bar{X}_{nap} - \bar{X}_{no\ nap}$ )

\*  $\bar{X}_{nap} - \bar{X}_{no\ nap}$

\*  $\mu_{0, nap} - \mu_{0, no\ nap} = 0$ , the population difference in means under the null hypothesis

```
In [18]: diff_mean= nap_mean_bedtime - no_nap_mean_bedtime  
        diff_mean
```

```
Out [18]: 42.066666666666606
```

```
In [19]: t_test= diff_mean/pooled_se  
        t_test
```

```
Out [19]: 2.367191200170002
```

```
In [20]: len(no_nap_bedtime)
```

```
Out [20]: 5
```

**Question:** What is the p-value for the first hypothesis test?

To find the p-value, we can use the function:

```
t.cdf(y, df)
```

Which for  $X \sim t(df)$  returns  $P(X \leq y)$ .

Because of the symmetry of the  $t$  distribution, we have that

```
1-t.cdf(y, df)
```

returns  $P(X > y)$

The function `t.cdf(y, df)` will give you the same value as finding the one-tailed probability of  $y$  on a  $t$ -table with the specified degrees of freedom.

Use the function `t.cdf(y, df)` to find the p-value for the first hypothesis test.

```
In [17]: pvalue = 1-t.cdf(t_test, 19)
        pvalue
```

```
Out[17]: 0.014346739524981444
```

**Question:** What are the  $t$ -statistic and p-value for the second hypothesis test?

Calculate the  $t$  test statistics and corresponding p-value using the `scipy` function `scipy.stats.ttest_ind(a, b, equal_var=True)` and check with your answer.

**Question:** Does `scipy.stats.ttest_ind` return values for a one-sided or two-sided test?

**Question:** Can you think of a way to recover the results you got using `1-t.cdf` from the p-value given by `scipy.stats.ttest_ind`?

Use the `scipy` function `scipy.stats.ttest_ind(a, b, equal_var=True)` to find the  $t$  test statistic and corresponding p-value for the second hypothesis test.

```
In [31]: df.napping.value_counts()
```

```
Out[31]: 1    15
         0     5
         Name: napping, dtype: int64
```

```
In [33]: df[df.napping==1]
```

```
Out[33]:
```

	id	sex	age (months)	dlmo time	days napped	napping \
5	6	female	36.2	18.22	4	1
6	7	male	36.3	19.28	1	1
7	8	male	30.0	21.06	5	1
8	9	male	33.2	19.38	2	1
9	10	female	37.1	19.93	3	1
10	11	male	32.9	18.79	4	1
11	12	female	35.0	19.65	5	1
12	13	male	35.1	19.83	3	1
13	14	female	35.6	19.88	4	1
14	15	female	36.6	19.94	4	1
15	16	male	36.5	20.25	3	1
16	17	female	33.7	20.33	5	1
17	18	male	36.4	20.16	5	1
18	19	female	33.6	19.68	3	1

19	20	male	33.8	20.51	3	1
----	----	------	------	-------	---	---

  

	nap lights outl time	nap sleep onset	nap midsleep	nap sleep offset \
5	14.00	14.22	15.00	15.78
6	14.75	15.03	15.92	16.80
7	13.09	13.43	14.44	15.46
8	14.41	14.42	15.71	17.01
9	13.12	13.42	14.31	15.19
10	13.99	14.03	14.85	15.68
11	13.18	13.45	14.33	15.21
12	13.94	14.48	15.26	16.03
13	12.68	13.08	13.92	14.76
14	12.71	12.88	13.80	14.72
15	13.74	14.68	15.66	16.64
16	13.15	13.87	14.49	15.11
17	12.47	12.56	13.30	14.05
18	14.71	14.85	15.46	16.07
19	12.68	13.54	14.30	15.07

  

	nap wake time	nap duration	nap time in bed	night bedtime \
5	16.28	93.75	137.00	1235.0
6	16.08	106.00	80.00	1260.0
7	15.82	121.60	163.80	1321.0
8	16.60	155.50	131.25	1224.0
9	15.30	106.67	130.67	1278.0
10	16.10	98.75	126.60	1185.0
11	15.35	105.80	130.40	1218.0
12	15.78	93.33	110.20	1222.0
13	15.00	100.75	139.33	1226.0
14	14.88	110.75	130.00	1228.0
15	16.45	117.33	162.75	1246.0
16	15.40	74.20	135.00	1243.0
17	14.25	89.80	107.00	1202.0
18	16.20	73.00	89.40	1190.0
19	15.23	91.67	152.67	1218.0

  

	night sleep onset	sleep onset latency	night midsleep time \
5	20.25	0.29	1.26
6	20.96	0.36	2.12
7	22.53	0.51	2.92
8	20.37	0.13	1.60
9	21.63	0.84	2.20
10	19.88	0.44	1.34
11	20.84	0.66	1.93
12	20.89	0.67	1.99
13	20.80	0.54	1.96
14	20.92	0.64	1.49
15	21.25	0.79	2.19



16	21.03	0.60	2.44
17	20.45	0.43	1.23
18	19.64	0.14	1.42
19	21.38	1.19	2.51

	night wake time	night sleep duration	night time in bed \
5	6.28	602.20	653.80
6	7.27	618.40	655.40
7	7.31	526.80	582.40
8	6.82	626.80	660.33
9	6.52	549.50	626.00
10	6.80	655.20	694.80
11	7.03	611.20	660.40
12	7.09	611.80	662.20
13	7.11	618.80	671.20
14	6.33	548.00	595.00
15	7.13	593.25	662.00
16	7.86	649.80	708.60
17	6.01	573.60	614.60
18	7.20	693.40	715.00
19	7.63	615.33	692.00

	24 h sleep duration	bedtime phase difference \
5	695.95	-1.73
6	724.40	-1.32
7	648.40	-0.95
8	782.30	-0.86
9	656.17	-0.76
10	753.95	-0.66
11	717.00	-0.53
12	705.13	-0.39
13	719.55	-0.38
14	658.75	-0.34
15	710.58	-0.21
16	724.00	-0.10
17	663.40	0.14
18	766.40	0.18
19	707.00	0.33

	sleep onset phase difference	midsleep phase difference \
5	-2.03	7.05
6	-1.68	6.84
7	-1.47	5.86
8	-0.99	6.22
9	-1.82	6.21
10	-1.09	6.55
11	-1.19	6.28
12	-1.06	6.16

13	-0.92	6.08
14	-0.90	5.64
15	-1.00	5.94
16	-0.70	6.12
17	-0.29	5.07
18	0.04	5.74
19	-0.87	6.00

	wake time phase difference
5	12.06
6	11.99
7	10.25
8	11.44
9	10.59
10	12.01
11	11.38
12	11.26
13	11.23
14	10.39
15	10.88
16	11.53
17	9.85
18	11.52
19	11.12

In [34]: df.loc[df.napping==1]

```
Out[34]:
```

	id	sex	age (months)	dlmo time	days napped	napping	\
5	6	female	36.2	18.22	4	1	
6	7	male	36.3	19.28	1	1	
7	8	male	30.0	21.06	5	1	
8	9	male	33.2	19.38	2	1	
9	10	female	37.1	19.93	3	1	
10	11	male	32.9	18.79	4	1	
11	12	female	35.0	19.65	5	1	
12	13	male	35.1	19.83	3	1	
13	14	female	35.6	19.88	4	1	
14	15	female	36.6	19.94	4	1	
15	16	male	36.5	20.25	3	1	
16	17	female	33.7	20.33	5	1	
17	18	male	36.4	20.16	5	1	
18	19	female	33.6	19.68	3	1	
19	20	male	33.8	20.51	3	1	

  

	nap lights outl time	nap sleep onset	nap midsleep	nap sleep offset	\
5	14.00	14.22	15.00	15.78	
6	14.75	15.03	15.92	16.80	
7	13.09	13.43	14.44	15.46	

8	14.41	14.42	15.71	17.01
9	13.12	13.42	14.31	15.19
10	13.99	14.03	14.85	15.68
11	13.18	13.45	14.33	15.21
12	13.94	14.48	15.26	16.03
13	12.68	13.08	13.92	14.76
14	12.71	12.88	13.80	14.72
15	13.74	14.68	15.66	16.64
16	13.15	13.87	14.49	15.11
17	12.47	12.56	13.30	14.05
18	14.71	14.85	15.46	16.07
19	12.68	13.54	14.30	15.07

	nap wake time	nap duration	nap time in bed	night bedtime \
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10	16.10	98.75	126.60	1185.0
11	15.35	105.80	130.40	1218.0
12	15.78	93.33	110.20	1222.0
13	15.00	100.75	139.33	1226.0
14	14.88	110.75	130.00	1228.0
15	16.45	117.33	162.75	1246.0
16	15.40	74.20	135.00	1243.0
17	14.25	89.80	107.00	1202.0
18	16.20	73.00	89.40	1190.0
19	15.23	91.67	152.67	1218.0

	night sleep onset	sleep onset latency	night midsleep time \
5	20.25	0.29	1.26
6	20.96	0.36	2.12
7	22.53	0.51	2.92
8	20.37	0.13	1.60
9	21.63	0.84	2.20
10	19.88	0.44	1.34
11	20.84	0.66	1.93
12	20.89	0.67	1.99
13	20.80	0.54	1.96
14	20.92	0.64	1.49
15	21.25	0.79	2.19
16	21.03	0.60	2.44
17	20.45	0.43	1.23
18	19.64	0.14	1.42
19	21.38	1.19	2.51

night wake time    night sleep duration    night time in bed    \

5	6.28	602.20	653.80
6	7.27	618.40	655.40
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10	6.80	655.20	694.80
11	7.03	611.20	660.40
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14	6.33	548.00	595.00
15	7.13	593.25	662.00
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	24 h sleep duration	bedtime phase difference \
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12	705.13	-0.39
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14	658.75	-0.34
15	710.58	-0.21
16	724.00	-0.10
17	663.40	0.14
18	766.40	0.18
19	707.00	0.33

	sleep onset phase difference	midsleep phase difference \
5	-2.03	7.05
6	-1.68	6.84
7	-1.47	5.86
8	-0.99	6.22
9	-1.82	6.21
10	-1.09	6.55
11	-1.19	6.28
12	-1.06	6.16
13	-0.92	6.08
14	-0.90	5.64
15	-1.00	5.94
16	-0.70	6.12
17	-0.29	5.07
18	0.04	5.74

```
19                                -0.87                                6.00
```

```

wake time phase difference
5                                12.06
6                                11.99
7                                10.25
8                                11.44
9                                10.59
10                               12.01
11                               11.38
12                               11.26
13                               11.23
14                               10.39
15                               10.88
16                               11.53
17                                9.85
18                               11.52
19                               11.12

```

## Hypothesis 2: Is night time sleep duration different between napping / non-napping groups?

```

In [41]: nap_night_sleep = df.loc[df.napping==1]['24 h sleep duration']
        nap_night_sleep_mean = nap_night_sleep.mean()
        no_nap_night_sleep = df.loc[df.napping==0]['24 h sleep duration']
        no_nap_night_sleep_mean = nap_night_sleep.mean()

import scipy
scipy.stats.ttest_ind(nap_night_sleep, no_nap_night_sleep, equal_var=True)

```

```
Out[41]: Ttest_indResult(statistic=1.4811248223284985, pvalue=0.1558664953018476)
```

```
In [19]: df.head()
```

```

Out[19]:   id    sex  age (months)  dlmo time  days napped  napping \
0     1  female         33.7        19.24           0         0
1     2  female         31.5        18.27           0         0
2     3   male         31.9        19.14           0         0
3     4  female         31.6        19.69           0         0
4     5  female         33.0        19.52           0         0

nap lights outl time  nap sleep onset  nap midsleep  nap sleep offset \
0                                NaN                NaN                NaN                NaN
1                                NaN                NaN                NaN                NaN
2                                NaN                NaN                NaN                NaN
3                                NaN                NaN                NaN                NaN
4                                NaN                NaN                NaN                NaN

nap wake time  nap duration  nap time in bed  night bedtime \

```

0	NaN	NaN	NaN	1245.0
1	NaN	NaN	NaN	1163.0
2	NaN	NaN	NaN	1200.0
3	NaN	NaN	NaN	1186.0
4	NaN	NaN	NaN	1161.0

	night sleep onset	sleep onset latency	night midsleep time \
0	20.68	0.23	1.92
1	19.48	0.25	1.09
2	20.05	0.45	1.29
3	19.50	0.05	1.89
4	19.65	0.45	1.30

	night wake time	night sleep duration	night time in bed \
0	7.17	629.4	643.0
1	6.69	672.4	700.4
2	6.53	628.8	682.6
3	8.28	766.6	784.0
4	6.95	678.0	718.0

	24 h sleep duration	bedtime phase difference \
0	629.4	-1.21
1	672.4	-0.96
2	628.8	-0.46
3	766.6	0.23
4	678.0	0.31

	sleep onset phase difference	midsleep phase difference \
0	-1.44	6.68
1	-1.21	6.82
2	-0.91	6.15
3	0.19	6.20
4	-0.13	5.78

	wake time phase difference
0	11.93
1	12.42
2	11.39
3	12.59
4	11.43

```
In [21]: df.groupby('napping')['night sleep duration'].mean()/60
```

```
Out[21]: napping
0      11.250667
1      10.104533
Name: night sleep duration, dtype: float64
```

```
In [40]: df.groupby('napping')['24 h sleep duration'].mean()
```

```
Out[40]: napping
0      675.040000
1      708.865333
Name: 24 h sleep duration, dtype: float64
```

```
In [24]: import statsmodels.api as sm
```

```
#Hypothesis 1: Bedtime (no nap) < bed time (nap)
sm.stats.ttest_ind(nap_bedtime, no_nap_bedtime, alternative='two-sided')
```

```
Out[24]: (2.367160052079275, 0.029334902861805394, 18.0)
```

**Question:** For the  $\alpha = .025$ , do you reject or fail to reject the first hypothesis?

**Question:** For the  $\alpha = .025$ , do you reject or fail to reject the second hypothesis?