Python Data Types

- Numpy

Numpy Basics

- N-Dimensiomnal array data structure

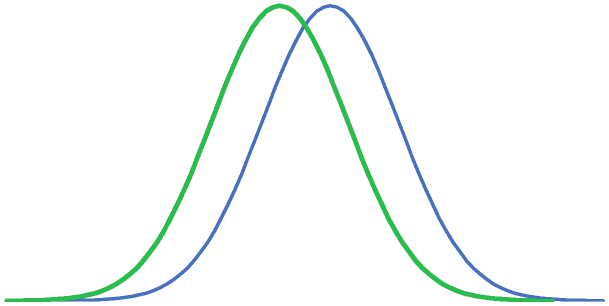
- comprehensive mathematical functions, random number generators, linear algebra routines, Fourier transforms, etc.

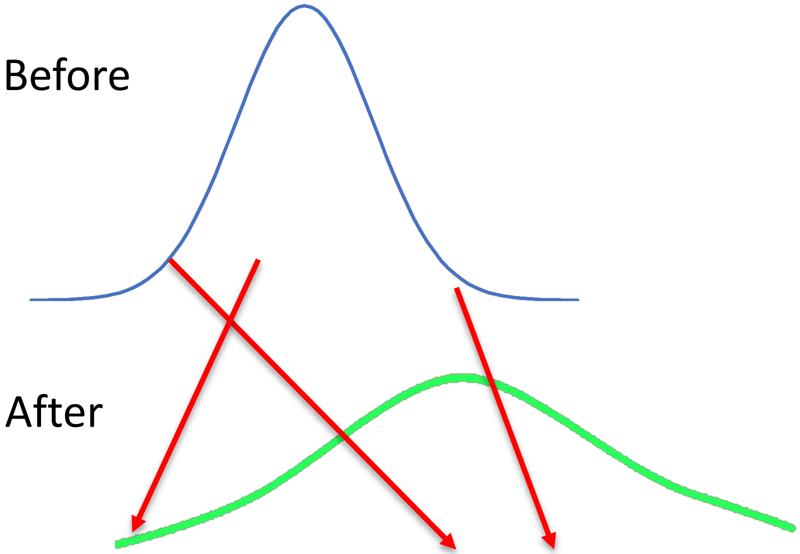
- Scientific computing

```python
import numpy as np

# Create a 1-Dimensional array

temperature = np.array([60,70,80,90,100])
customer = np.array([100, 150, 180, 190, 195])

type(customer)

temperature.mean()

print("temperature data collected = ",temperature)
print("customer data collected = ", customer)

temperature[0]

# Correlation Analysis - Generate correlation matrix

np.corrcoef(temperature, customer)

Temp_Cust_2D = np.array([(60,70,80,90,100),(100, 150, 180, 190, 195)])

print (Temp_Cust_2D)

Temp_Cust_2D[0,2]

# Element wise operation - not possible on List data type

Temp_Cust_2D = Temp_Cust_2D*4

print (Temp_Cust_2D)

# Using Numpy Random number generator to generate a 2 dimensional array

TempCust = np.array([np.random.randint(50,100,20), np.random.randint(10,200,20)])
TempCust

correlMatrix=np.corrcoef(TempCust[0], TempCust[1])

print (correlMatrix)
```

T-Test

- A test of statistical differences




Before
After

Independent Sample T-Test

$$t = \frac{m_A - m_B}{\sqrt{\frac{S^2}{n_A} + \frac{S^2}{n_B}}}$$

m = mean

n = size

S^2 = estimator of the common variance of the two samples

$$S^2 = \frac{\sum (x - m_A)^2 + \sum (x - m_B)^2}{n_A + n_B - 2}$$

$$df = n_A + n_B - 2$$

Degrees of freedom	Significance level					
	20% (0.20)	10% (0.10)	5% (0.05)	2% (0.02)	1% (0.01)	0.1% (0.001)
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850
21	1.323	1.721	2.080	2.518	2.831	3.819
22	1.321	1.717	2.074	2.508	2.819	3.792
23	1.319	1.714	2.069	2.500	2.807	3.767
24	1.318	1.711	2.064	2.492	2.797	3.745
25	1.316	1.708	2.060	2.485	2.787	3.725
26	1.315	1.706	2.056	2.479	2.779	3.707
27	1.314	1.703	2.052	2.473	2.771	3.690
28	1.313	1.701	2.048	2.467	2.763	3.674
29	1.311	1.699	2.043	2.462	2.756	3.659
30	1.310	1.697	2.042	2.457	2.750	3.646
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.158	2.617	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.291

if the absolute value of the t-test statistics (|t|) is greater than the critical value, then the difference is significant.

Paired Sample t-test

$$t = \frac{m}{s/\sqrt{n}}$$

d = the differences between all pairs
m = mean of the difference (d)
s = standard deviation of the difference (d)
n = size of d

$$df = n - 1$$

If the absolute value of the t-test statistics (|t|) is greater than the critical value, then the difference is significant.

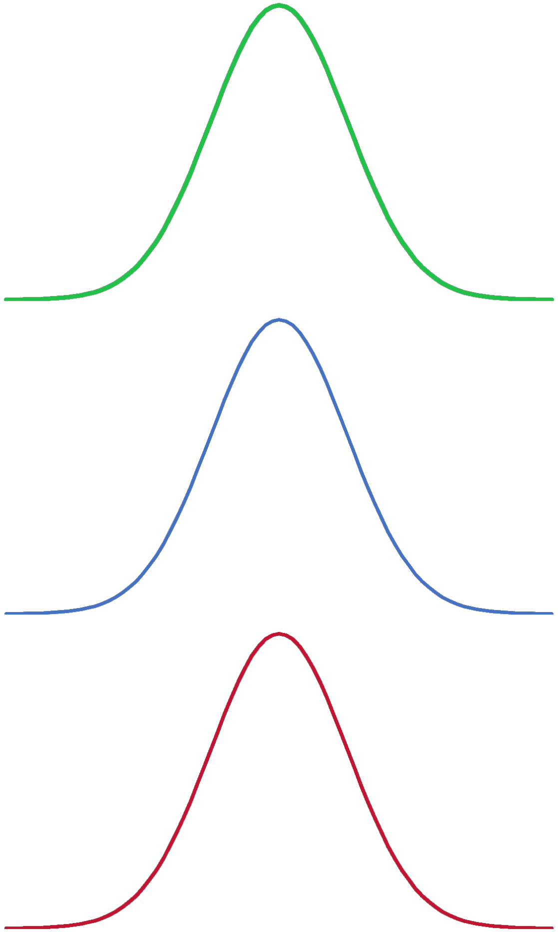
The average of the difference d is compared to 0. If there is any significant difference between the two pairs of samples, then the mean of d is expected to be far from 0.

William Sealy Gosset

- Guinness Brewery
- Differences between barley yields

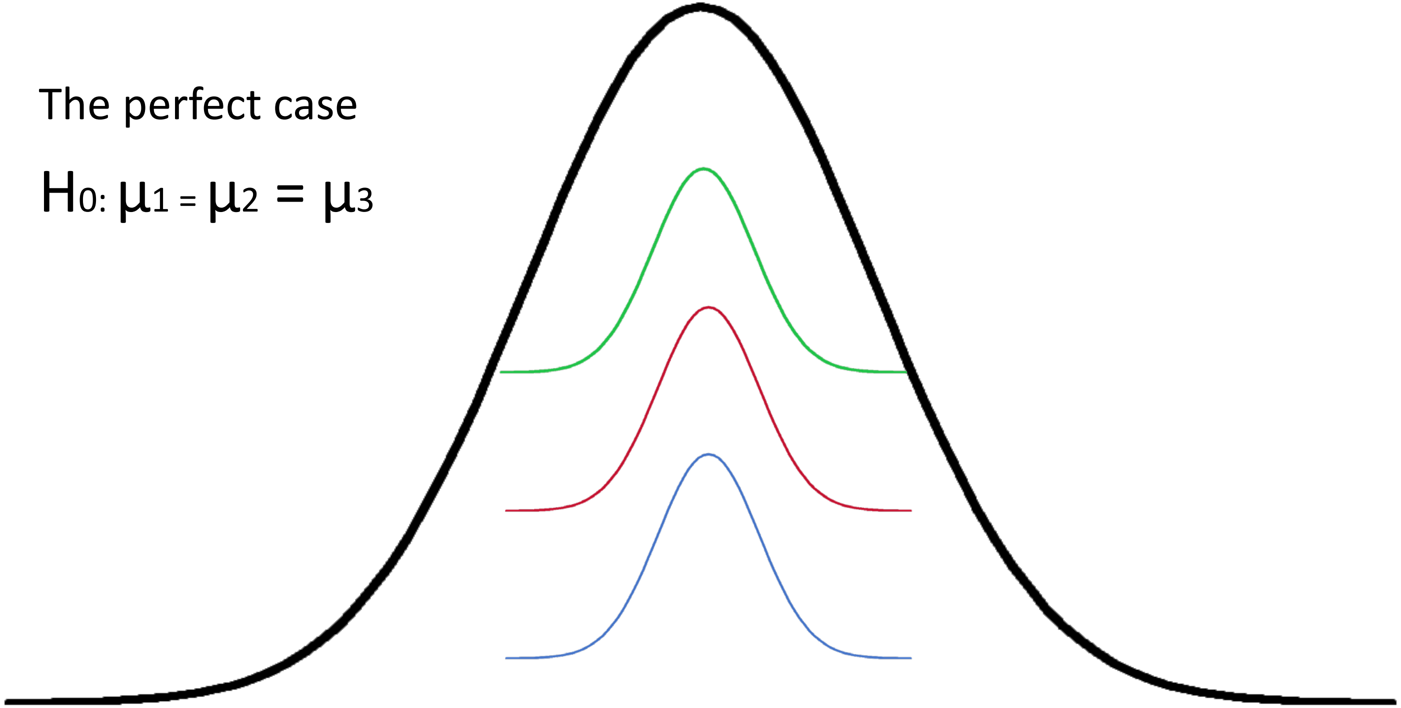
ANOVA

- An Analysis of Variance
  - Compare the means of more than two groups, samples, populations



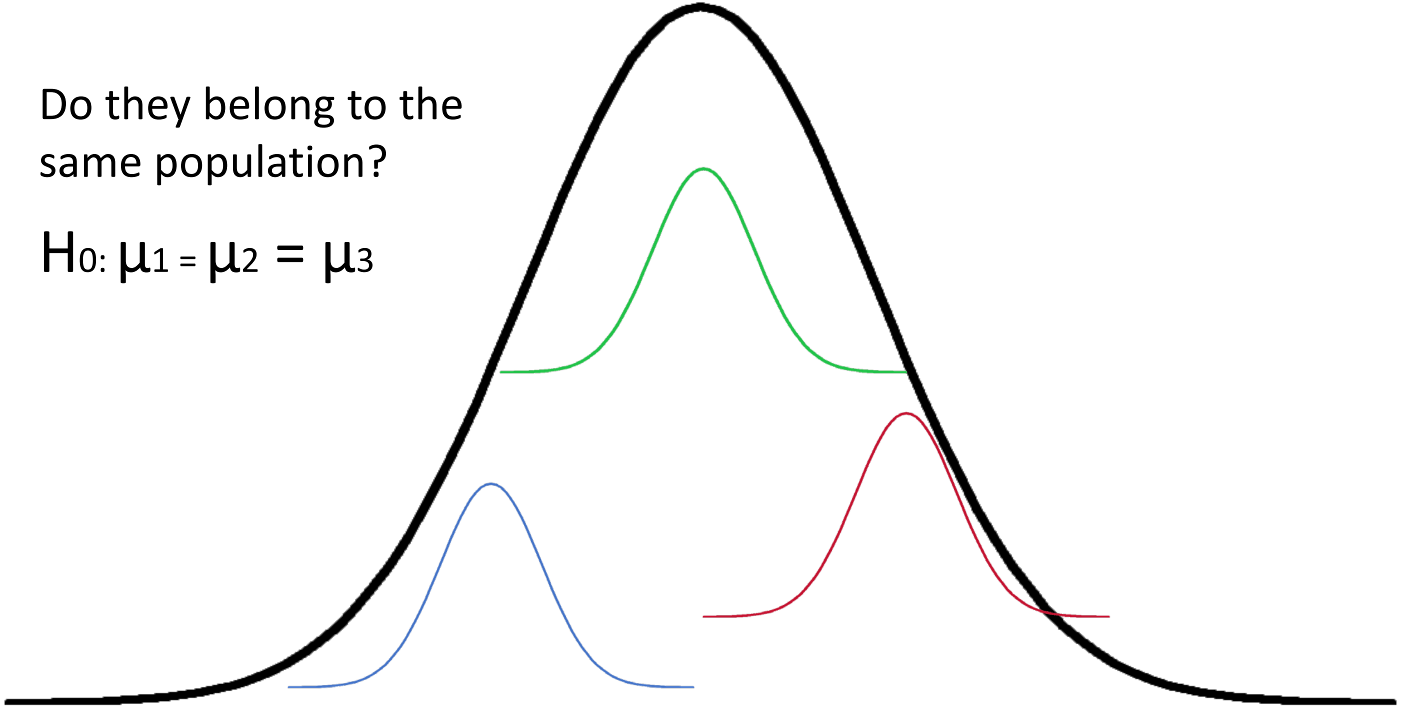
The perfect case

$H_0: \mu_1 = \mu_2 = \mu_3$



Do they belong to the same population?

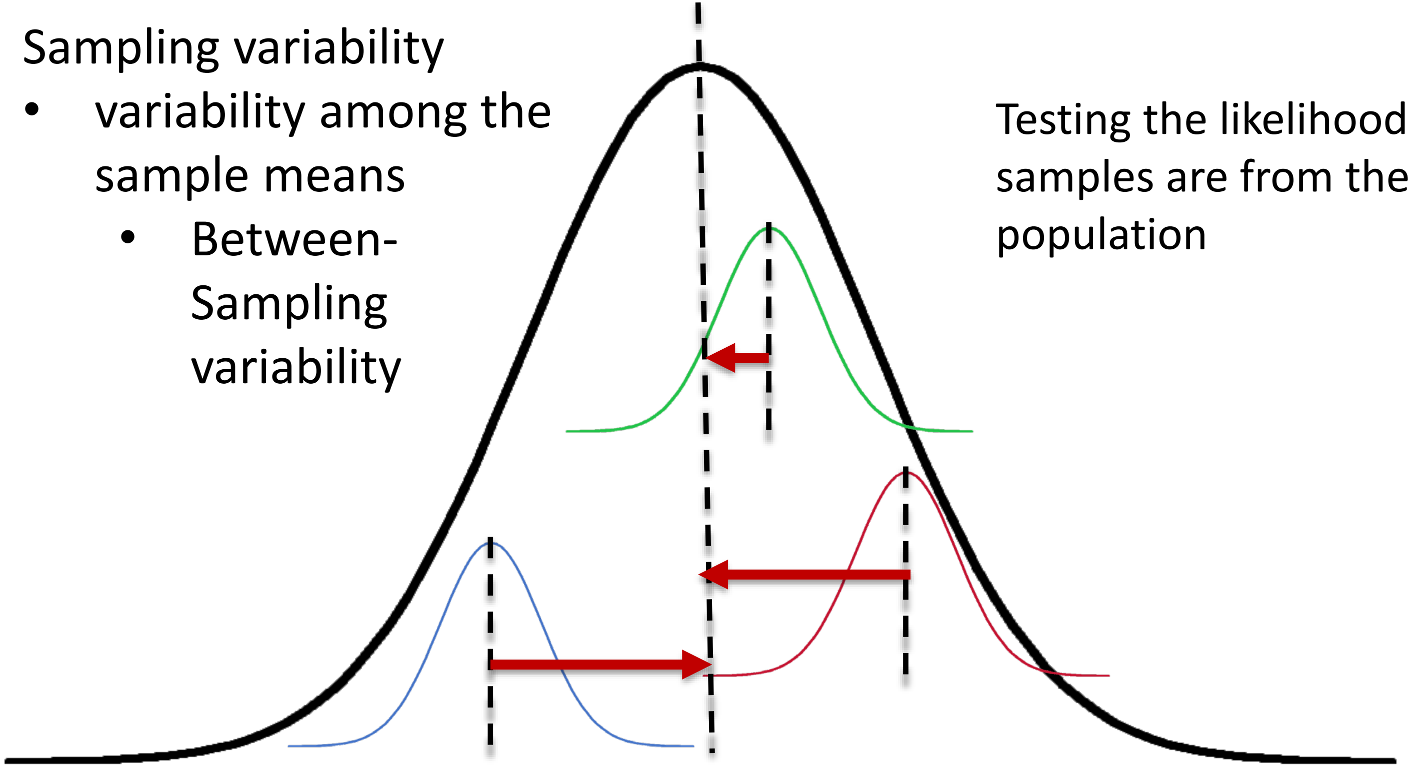
$H_0: \mu_1 = \mu_2 = \mu_3$



Sampling variability

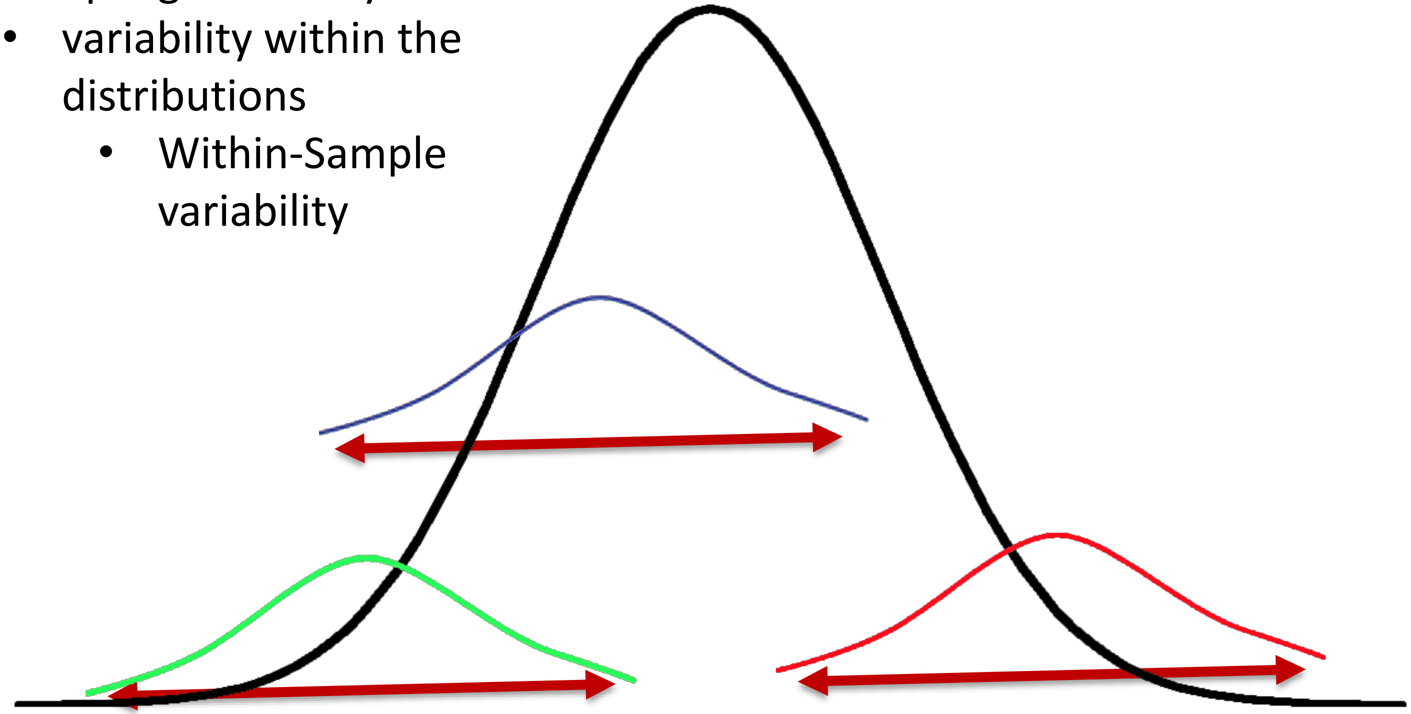
- variability among the sample means
    - Between-Sampling variability

Testing the likelihood that these samples are from the same population



Sampling variability

- variability within the distributions
    - Within-Sample variability

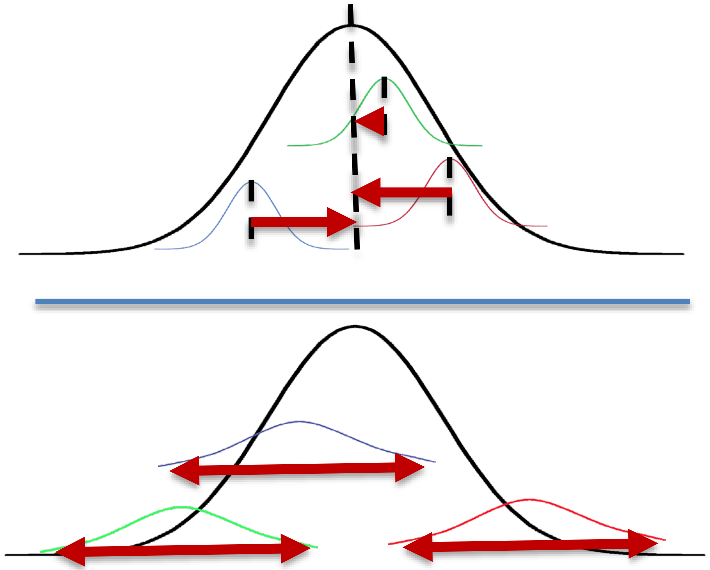


ANOVA =

variability among the sample means

---

variability within the distributions



Signal

Noise

Independent Sample T-Test: Comparing Two Groups

- Professor Huang is teaching two data science classes. One of these classes is delivered online and the other one is delivered in person on campus.

Student	Score
1	88
1	91
1	86
1	92
1	89
1	94
1	87
1	91
1	93
1	88
1	84
1	86
1	86
1	89
1	88
1	90
1	82
1	92
1	85
1	87
2	92
2	95
2	87
2	94
2	86
2	99
2	90
2	93
2	99
2	90
2	85
2	85
2	88
2	96
2	88
2	94
2	88
2	95
2	89
2	86

Steps

- Determine 1-tail or 2-tail test
- Determine if the groups are paired or unpaired
- Determine equal Variance or unequal variance

G1	G2
88	92
91	95
86	87
92	94
89	86
94	99
87	90
91	93
93	99
88	90
84	85
86	85
86	88
89	96
88	88
90	94
82	88
92	95
85	89
87	86

G1	**G2**
88	92
91	95
86	87
92	94
89	86
94	99
87	90
91	93
93	99
88	90
84	85
86	85
86	88
89	96
88	88
90	94
82	88
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85	89
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Determine equal Variance or unequal variance

G1	**G2**
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88	90
84	85
86	85
86	88
89	96
88	88
90	94
82	88
92	95
85	89
87	86

```
# read Excel or CSV File
import pandas as pd
# Store Columns as Arrays
import numpy as np

# Perform Independent-Samples T-Test
from scipy.stats import ttest_ind

# Load sample data file
df = pd.read_csv ("Huang Class Differences 2 samples.csv")

# Convert df to Numpy Array
ScoreArray=np.array(df.Score)

# Reshape Numpy Array
ScoreArr = ScoreArray.reshape(2,20)

# Determine Equal Variance by testing if (the Larger Stand Deviation / the smaller Standard
Deviation) > 2
# Assume no equal vaqriance if (the Larger Stand Deviation / the smaller Standard Deviation)
> 2
if ScoreArr[0].std() > ScoreArr[1].std():
    if (ScoreArr[0].std() / ScoreArr[1]) > 2:
        EqualVar = False
    else:
        EqualVar = True
else:
    if (ScoreArr[1].std() / ScoreArr[0].std()) > 2:
        EqualVar = False
    else:
        EqualVar = True

# Obtain T-Stat and Pvalue
SampleT = ttest_ind(ScoreArr[0], ScoreArr[1], equal_var=EqualVar)

SampleT.pvalue
```

Paired Sample T-Test

- Professor Huang wants to know student’s performance before and after taking the course.

Student	Pre-Test	Post-Test
1	51	82
2	47	98
3	36	84
4	54	88
5	51	85
6	51	99
7	66	86
8	63	95
9	68	89
10	36	97
11	46	81
12	64	93
13	41	91
14	64	96
15	50	89
16	46	92
17	62	88
18	64	98
19	35	82
20	57	98

Steps

- Determine 1-tail or 2-tail test
- Determine if the groups are paired or unpaired

Student	Pre-Test	Post-Test
1	51	82
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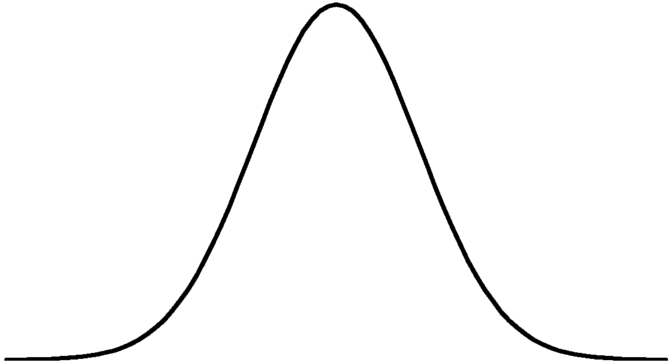
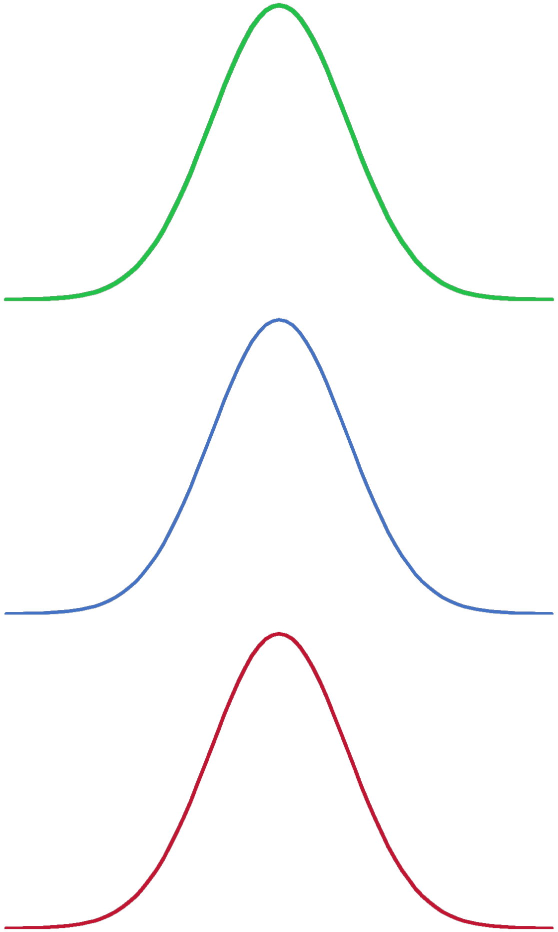
18	64	98
19	35	82
20	57	98



```
# read Excel or CSV File
import pandas as pd

# Store Columns as Arrays
import numpy as np

# Perform Paired-Samples T-Test
from scipy.stats import ttest_rel

# Load sample data file

df = pd.read_csv ("Huang Class Differences.csv")

# Convert df columns to individual arrays

Student= np.array(df["Student"])
PreTest= np.array(df["Pre-Test"])
PostTest= np.array(df["Post-Test"])

print("student array = ", Student)
print("pre-test array = ", PreTest)
print("post-test array = ", PostTest)

# Compare Means - Paired Samples T-Test

PairedT = ttest_rel(PreTest,PostTest)

print(PairedT)

if PairedT.pvalue < 0.05:
   print("Performamnce of InPerson Students and Online Students are Different")
else:
   print("Performamnce of InPerson Students and Online Students are the same")
```

ANOVA

- An Analysis of Variance
  - Compare the means of more than two groups, samples, populations



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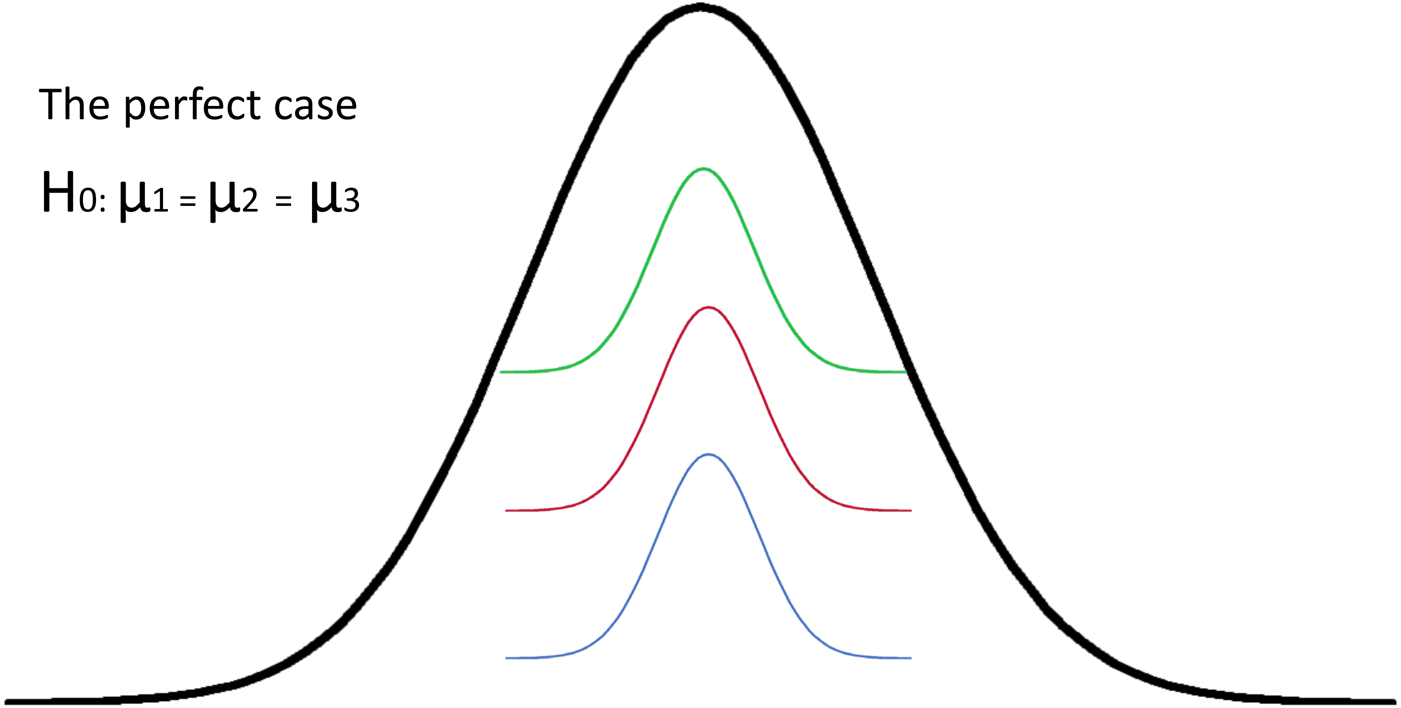
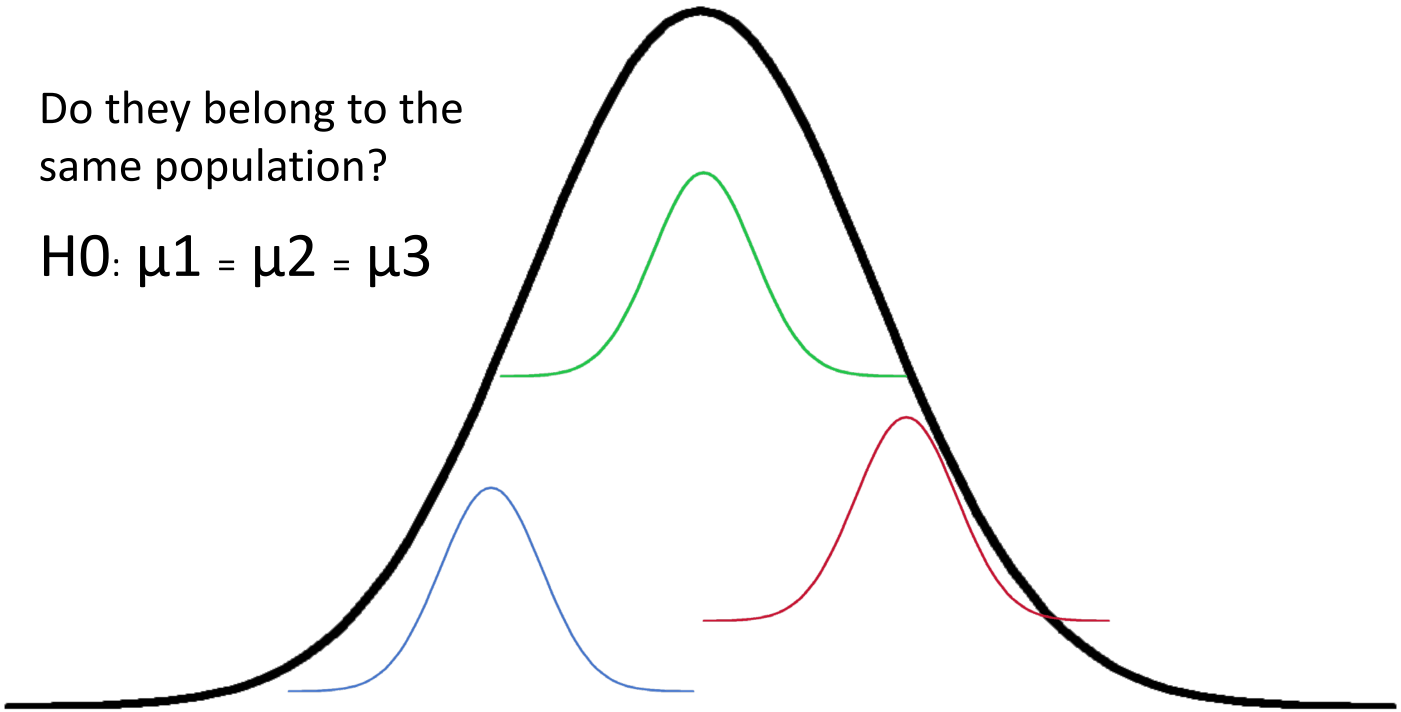


Do they belong to the same population?

$H0: \mu1 = \mu2 = \mu3$



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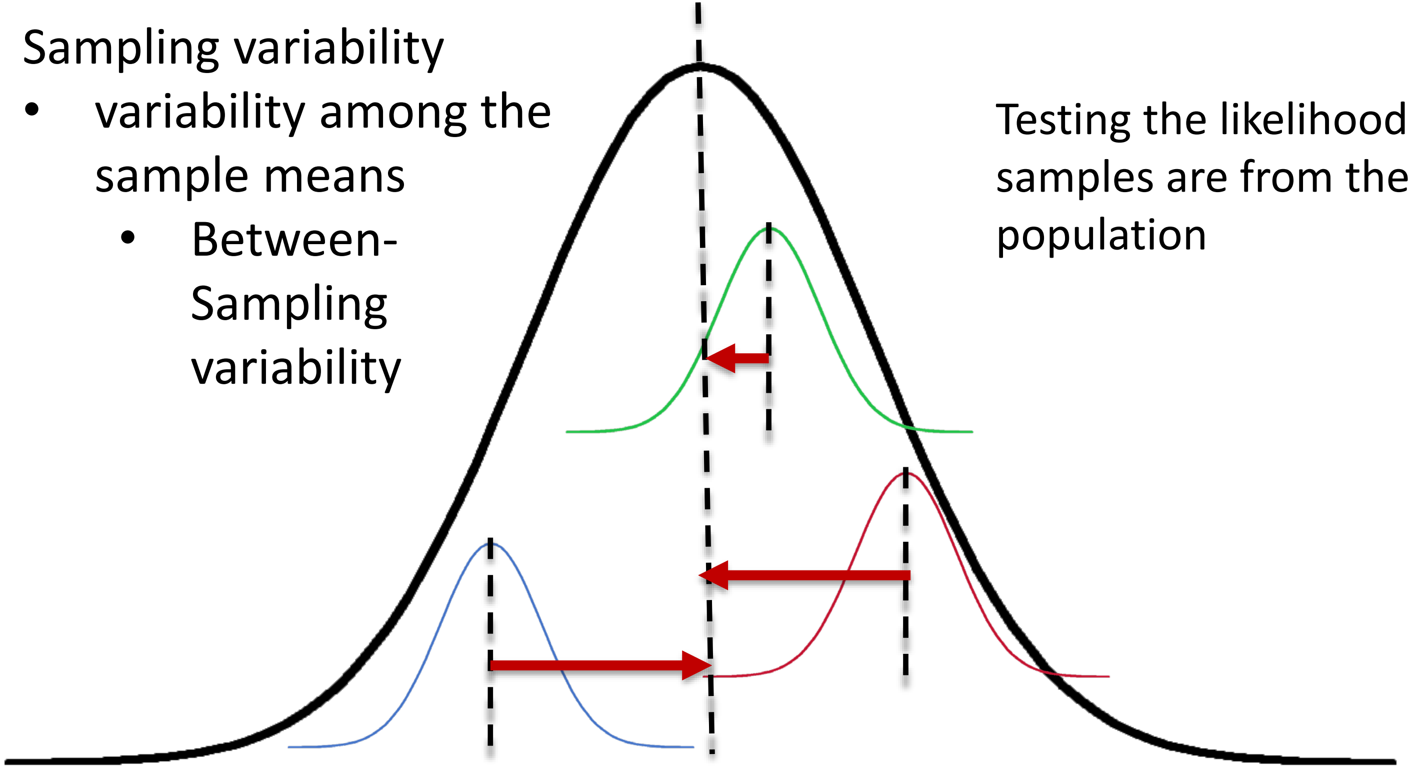
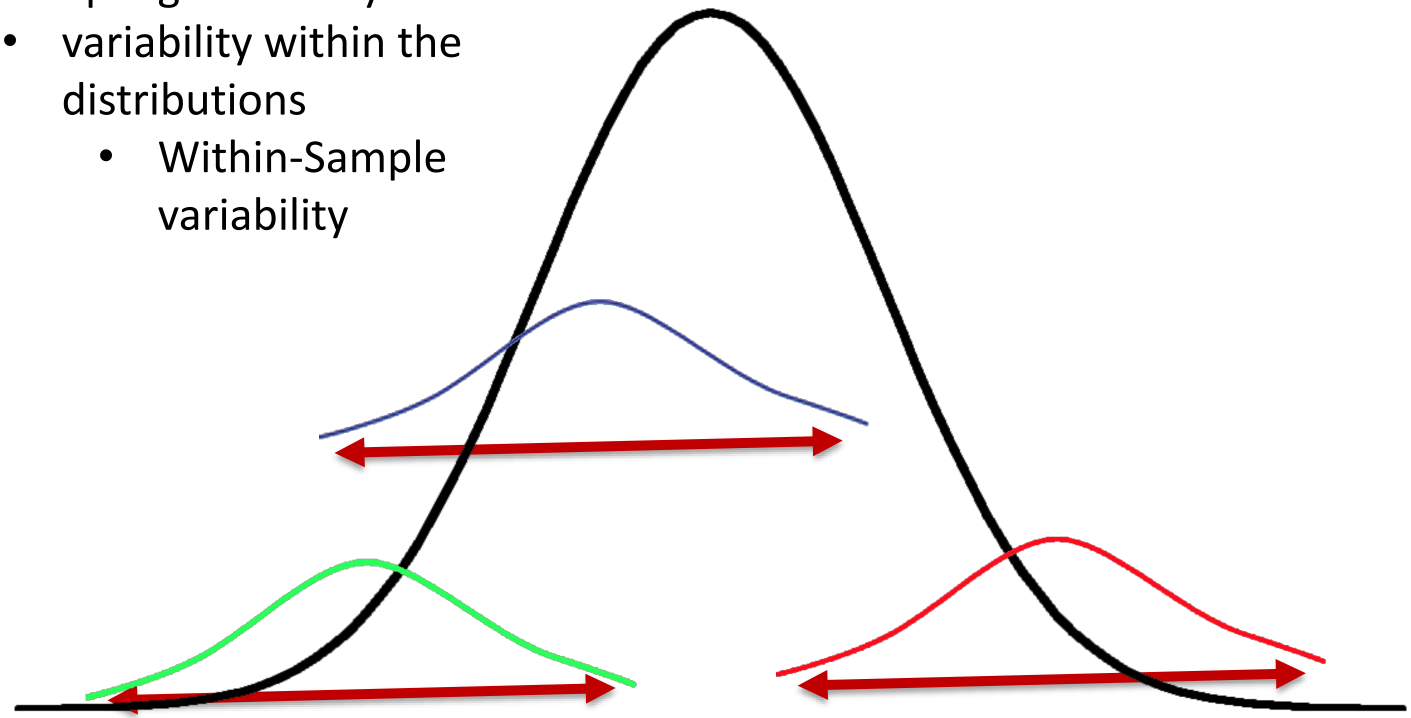


Testing the likelihood that these samples are from the same population

Sampling variability

- variability within the distributions
    - Within-Sample variability

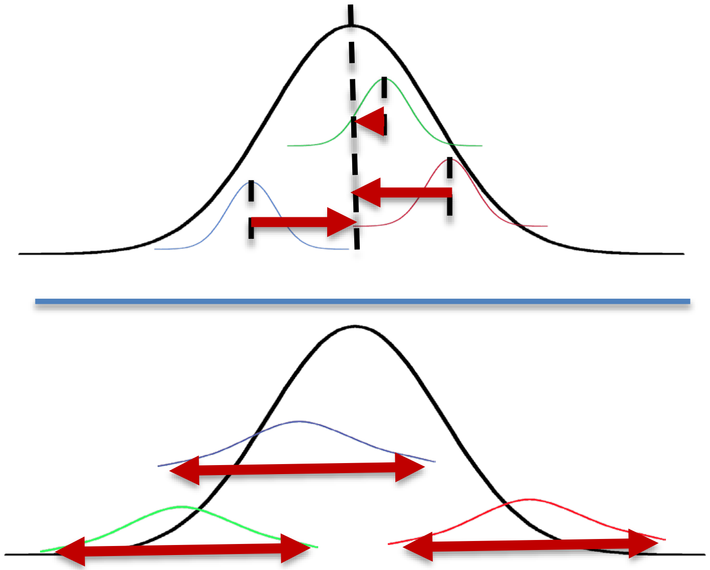


ANOVA =

variability among the sample means

---

variability within the distributions



Signal

Noise

Oneway ANOVA

Data Science: Comparison

- Professor Huang is teaching three data science fundamentals classes. One of these classes is delivered online, the second one is delivered in person on campus, and the third one is a hybrid class. Professor Huang wants to know if there are differences in performance due to the delivery platform.

ANOVA

ANOVA

```
import pandas as pd
import scipy.stats as st

# Read data stored in csv file
df = pd.read_csv("differences3.csv")

# assign label to each student type: Online, InPerson, Hybrid
df["Student"].replace({1:"Online", 2:"InPerson", 3:"Hybrid"}, inplace=True)

# Oneway ANOVA
rdf = st.f_oneway(df["Score"][df["Student"]=="Online"], df["Score"][df["Student"]=="InPerson"], df["Score"][df["Student"]=="Hybrid"])

print ("ANOVA Results: ", rdf)
```

ANOVA

```
ANOVA Results:  F_onewayResult(statistic=1.251646103688551, pvalue=0.2937751293444691)
```

If sig (p-value) < 0.05, then we reject null hypothesis. Therefore, we conclude that significant difference exists.

If sig > 0.05, then we accept the null hypothesis.

ANOVA with Post Hoc

```
import pandas as pd
# For oneway ANOVA
import scipy.stats as st

# For Post Hoc
from statsmodels.stats.multicomp import pairwise_tukeyhsd
from statsmodels.stats.multicomp import MultiComparison as multi

# Read data stored in csv file
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print ("ANOVA Results: ", rdf)

# Post Hoc
mc = multi(df["Score"], df["Student"])
posthoc = mc.tukeyhsd()

print ()
print (posthoc)
```

Oneway ANOVA

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