twowayAnova

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1 Two Way ANOVA

[ ]:
```
# Import Libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

[ ]:
```
df = pd.DataFrame({'water': np.repeat(["daily","weekly"],15),
'sun': np.tile(np.repeat(["low","medium","high"],5),2),
'height':[6, 6, 6, 5, 6, 5, 5, 6, 4, 5,
                              6, 6, 7, 8, 7, 3, 4, 4, 4, 5,
                              4, 4, 4, 4, 4, 5, 6, 6, 7, 8]})
df.sample(10)
```

[ ]:

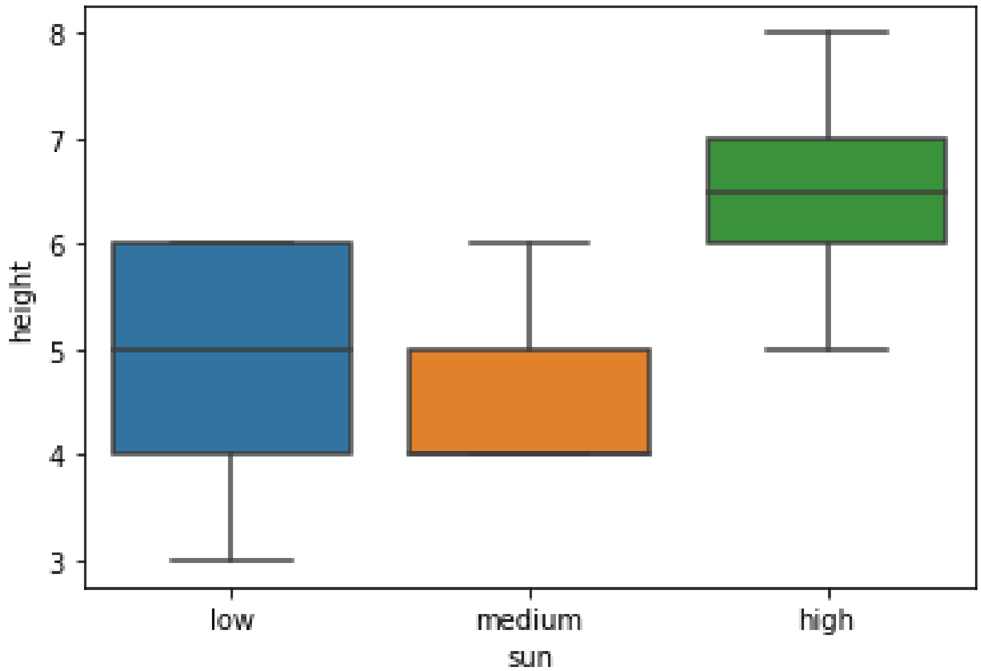
	water	sun	height
28	weekly	high	7
11	daily	high	6
14	daily	high	7
24	weekly	medium	4
15	weekly	low	3
22	weekly	medium	4
1	daily	low	6
7	daily	medium	6
12	daily	high	7
6	daily	medium	5

[ ]:
```
sns.boxplot(df['sun'],df['height'])
```

```
C:\Users\Sartaj\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variables as keyword args: x, y. From version
```

```
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

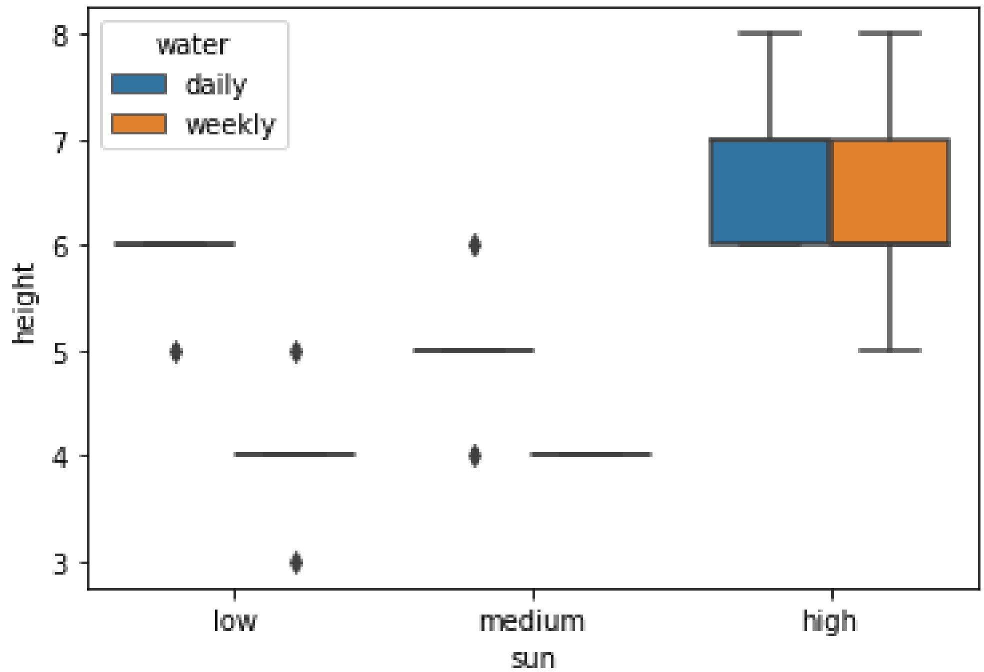
[ ]: <AxesSubplot:xlabel='sun', ylabel='height'>



[ ]:
```
sns.boxplot(df['sun'],df['height'],df['water'])
```

```
C:\Users\Sartaj\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variables as keyword args: x, y, hue. From
version 0.12, the only valid positional argument will be `data`, and passing
other arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

[ ]: <AxesSubplot:xlabel='sun', ylabel='height'>



[ ]:
```
#Perform one way Anova
import statsmodels.api as sm
from statsmodels.formula.api import ols
model = ols('height ~ sun', data = df).fit()
sm.stats.anova_lm(model, type=2)
```

[ ]:

	df	sum_sq	mean_sq	F	PR(>F)
sun	2.0	24.866667	12.433333	14.105042	0.000064
Residual	27.0	23.800000	0.881481	NaN	NaN

[ ]:
```
model = ols('height ~ C(sun)+C(water)+C(sun):C(water)', data = df).fit()
table = sm.stats.anova_lm(model, type=2)
print(table)
```

```
                    df     sum_sq    mean_sq        F    PR(>F)
C(sun)             2.0  24.866667  12.433333  23.3125  0.000002
C(water)           1.0   8.533333   8.533333  16.0000  0.000527
C(sun):C(water)    2.0   2.466667   1.233333   2.3125  0.120667
Residual          24.0  12.800000   0.533333      NaN       NaN
```

[ ]:
```
# we will use bioinfokit (v1.0.3 or later) for performing tukey HSD test
# check documentation here https://github.com/reneshbedre/bioinfokit
from bioinfokit.analys import stat
# perform multiple pairwise comparison (Tukey HSD)
# unequal sample size data, tukey_hsd uses Tukey-Kramer test
```

```
res = stat()
# for main effect Sun
res.tukey_hsd(df=df, res_var='height', xfac_var='sun', anova_model='height ~
 ↪C(sun)+C(water)+C(sun):C(water)')
new=res.tukey_summary
print(new)
```

```
   group1  group2  Diff     Lower     Upper   q-value   p-value
0     low  medium   0.4  -0.41546  1.21546  1.732051  0.452202
1     low    high   1.7   0.88454  2.51546  7.361216  0.001000
2  medium    high   2.1   1.28454  2.91546  9.093267  0.001000
```

[ ]:
```
from statannotations.Annotator import Annotator
plotting_parameters = {
    'data':    df,
    'x':       'sun',
    'y':       'height',

}

pairs = [('low', 'medium'),
         ('low', 'high'),
         ('medium', 'high')]
```

[ ]:
```
pvalues =new['p-value']
```

[ ]:
```
with sns.plotting_context('notebook', font_scale = 1.4):
    # Create new plot
    ax = sns.boxplot('sun', 'height', data = df)

    # Plot with seaborn
    sns.boxplot(**plotting_parameters)

    # Add annotations
    annotator = Annotator(ax, pairs, **plotting_parameters)
    annotator.set_pvalues(pvalues)
    annotator.annotate()

    # Label and show

    plt.show()
```

```
p-value annotation legend:
      ns: p <= 1.00e+00
       *: 1.00e-02 < p <= 5.00e-02
      **: 1.00e-03 < p <= 1.00e-02
     ***: 1.00e-04 < p <= 1.00e-03
    ****: p <= 1.00e-04
```

```
low vs. medium: Custom statistical test, P_val:4.522e-01
medium vs. high: Custom statistical test, P_val:1.000e-03
low vs. high: Custom statistical test, P_val:1.000e-03
```

```
C:\Users\Sartaj\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variables as keyword args: x, y. From version
0.12, the only valid positional argument will be `data`, and passing other
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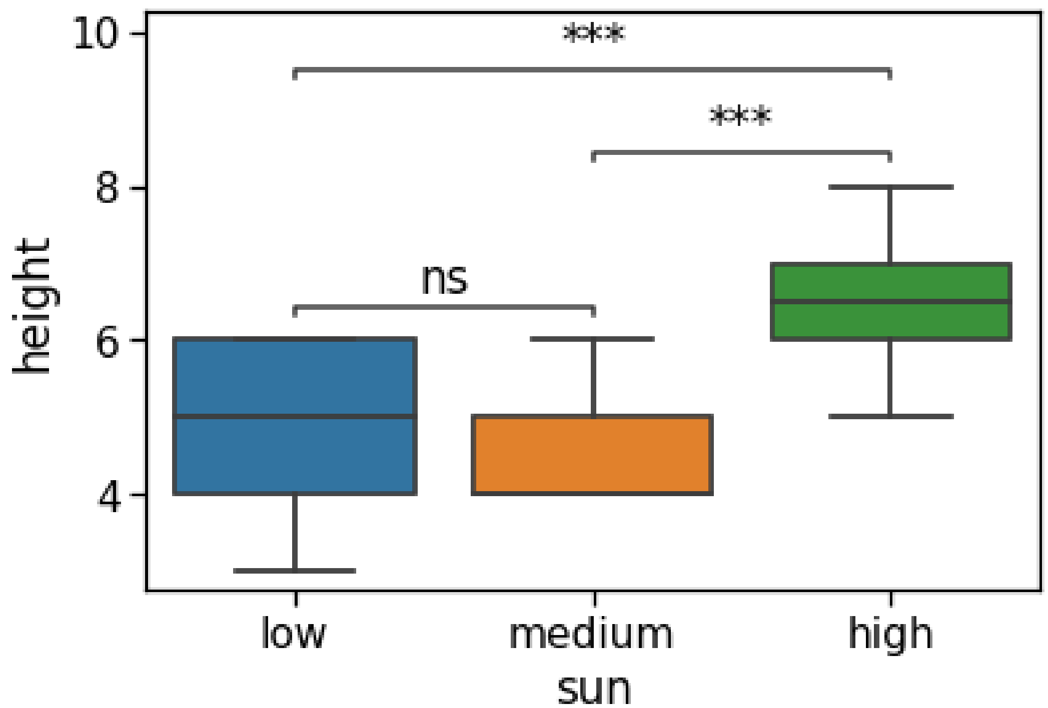

[ ]:
```
# for main effect Water
res.tukey_hsd(df=df, res_var='height', xfac_var='water', anova_model='height ~␣
↪C(sun)+C(water)+C(sun):C(water)')
new=res.tukey_summary
print(new)
```

```
  group1  group2      Diff     Lower    Upper   q-value  p-value
0  daily  weekly  1.066667  0.516294  1.61704  5.656854    0.001
```

[ ]:
```
from statannotations.Annotator import Annotator
plotting_parameters = {
    'data':    df,
```

```
    'x':        'water',
    'y':        'height',

}

pairs = [('daily', 'weekly')]
```

[ ]:
```
pvalues =new['p-value']
```

[ ]:
```
with sns.plotting_context('notebook', font_scale = 1.4):
    # Create new plot
    ax = sns.boxplot('water', 'height', data = df)

    # Plot with seaborn
    sns.boxplot(**plotting_parameters)

    # Add annotations
    annotator = Annotator(ax, pairs, **plotting_parameters)
    annotator.set_pvalues(pvalues)
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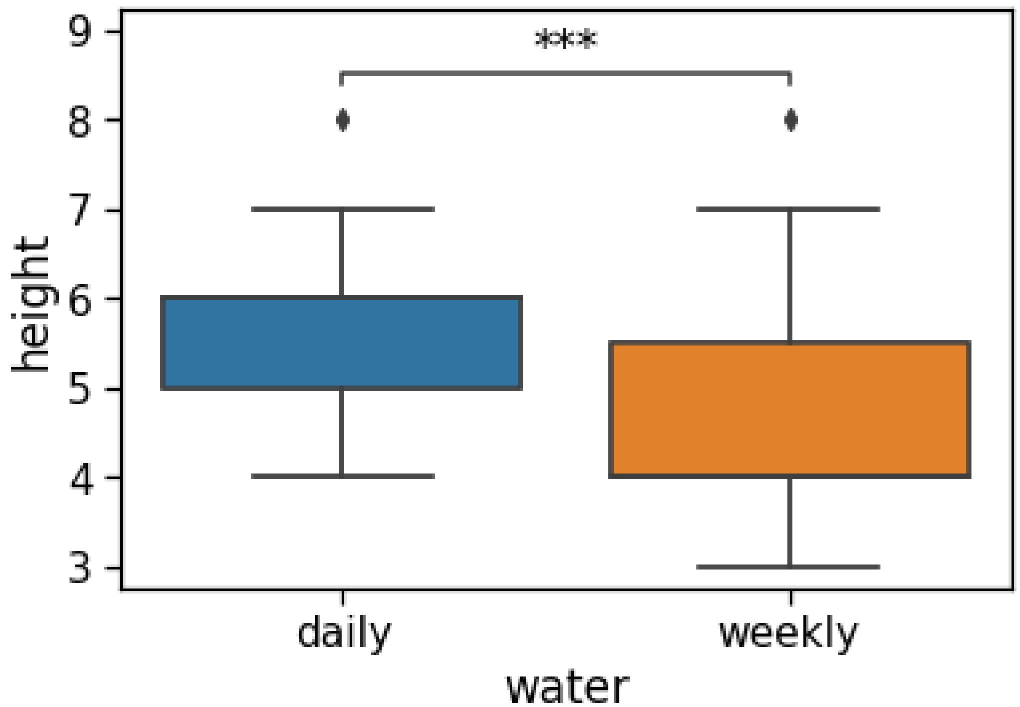
```

```
p-value annotation legend:
      ns: p <= 1.00e+00
       *: 1.00e-02 < p <= 5.00e-02
      **: 1.00e-03 < p <= 1.00e-02
     ***: 1.00e-04 < p <= 1.00e-03
    ****: p <= 1.00e-04

daily vs. weekly: Custom statistical test, P_val:1.000e-03
```

```
C:\Users\Sartaj\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variables as keyword args: x, y. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```




```
[ ]: # for main effect Water and Sun
res.tukey_hsd(df=df, res_var='height', xfac_var=['sun','water'],␣
 ↪anova_model='height ~ C(sun)+C(water)+C(sun):C(water)')
new = res.tukey_summary
print(new)
```

```
              group1           group2  Diff     Lower     Upper   q-value  \
0       (low, daily)     (low, weekly)   1.8  0.371833  3.228167  5.511352
1       (low, daily)  (medium, daily)   0.8 -0.628167  2.228167  2.449490
2       (low, daily) (medium, weekly)   1.8  0.371833  3.228167  5.511352
3       (low, daily)    (high, daily)   1.0 -0.428167  2.428167  3.061862
4       (low, daily)   (high, weekly)   0.6 -0.828167  2.028167  1.837117
5      (low, weekly)  (medium, daily)   1.0 -0.428167  2.428167  3.061862
6      (low, weekly) (medium, weekly)   0.0 -1.428167  1.428167  0.000000
7      (low, weekly)    (high, daily)   2.8  1.371833  4.228167  8.573214
8      (low, weekly)   (high, weekly)   2.4  0.971833  3.828167  7.348469
9    (medium, daily) (medium, weekly)   1.0 -0.428167  2.428167  3.061862
10   (medium, daily)    (high, daily)   1.8  0.371833  3.228167  5.511352
11   (medium, daily)   (high, weekly)   1.4 -0.028167  2.828167  4.286607
12  (medium, weekly)    (high, daily)   2.8  1.371833  4.228167  8.573214
13  (medium, weekly)   (high, weekly)   2.4  0.971833  3.828167  7.348469
14     (high, daily)   (high, weekly)   0.4 -1.028167  1.828167  1.224745

     p-value
```

```
0     0.007933
1     0.522189
2     0.007933
3     0.289956
4     0.757578
5     0.289956
6     0.900000
7     0.001000
8     0.001000
9     0.289956
10    0.007933
11    0.057010
12    0.001000
13    0.001000
14    0.900000
```

[ ]:
```
samp = new.sample(4)
```

[ ]:
```
samp
```

[ ]:
```
              group1            group2  Diff     Lower     Upper   q-value  \
8      (low, weekly)    (high, weekly)   2.4  0.971833  3.828167  7.348469
1       (low, daily)   (medium, daily)   0.8 -0.628167  2.228167  2.449490
10   (medium, daily)     (high, daily)   1.8  0.371833  3.228167  5.511352
14     (high, daily)    (high, weekly)   0.4 -1.028167  1.828167  1.224745

     p-value
8   0.001000
1   0.522189
10  0.007933
14  0.900000
```

[ ]:
```
g1 = samp['group1']
g2 = samp['group2']
```

[ ]:
```
g1
```

[ ]:
```
8       (low, weekly)
1        (low, daily)
10    (medium, daily)
14      (high, daily)
Name: group1, dtype: object
```

[ ]:
```
g2
```

[ ]:
```
8      (high, weekly)
1     (medium, daily)
10      (high, daily)
```

```
14     (high, weekly)
Name: group2, dtype: object
```

[ ]:
```
from statannotations.Annotator import Annotator
plotting_parameters = {
    'data':    df,
    'x':       ['sun','water'],
    'y':       'height',

}

pairs = [((g1[8]), (g2[8])),((g1[1]), (g2[1])),((g1[10]), (g2[10])),((g1[14]),␣
 ↪(g2[14]))]
```

[ ]:
```
pvalues =samp['p-value']
```

[ ]:
```
with sns.plotting_context('notebook', font_scale = 1.4):
    # Create new plot
    ax = sns.boxplot(['sun','water'], 'height', data = df)

    # Plot with seaborn
    sns.boxplot(**plotting_parameters)

    # Add annotations
    annotator = Annotator(ax, pairs, **plotting_parameters)
    annotator.set_pvalues(pvalues)
    annotator.annotate()

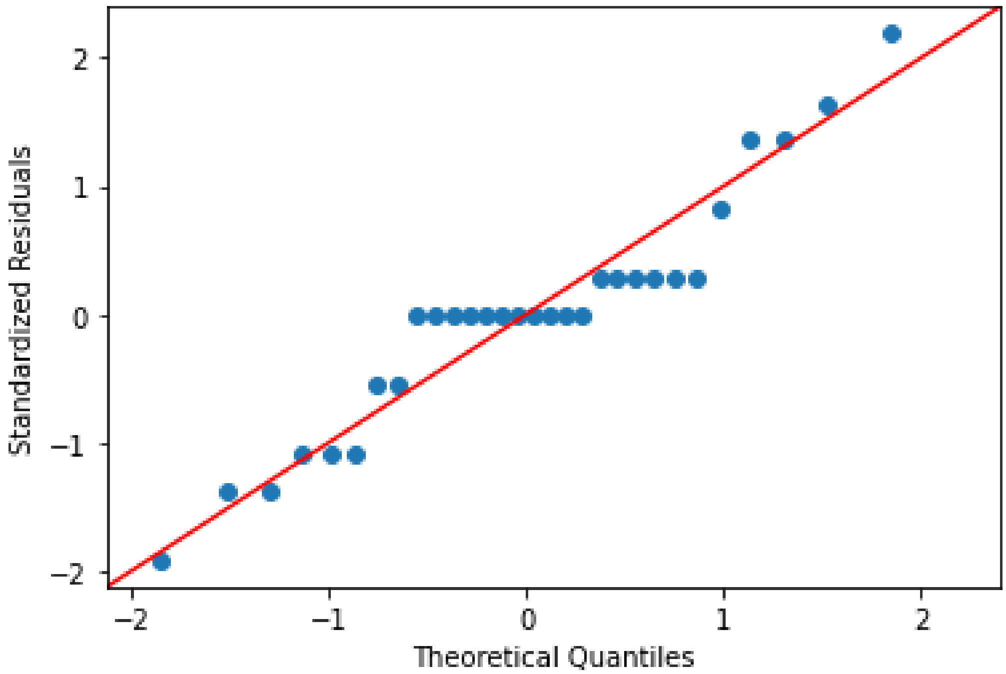
    # Label and show

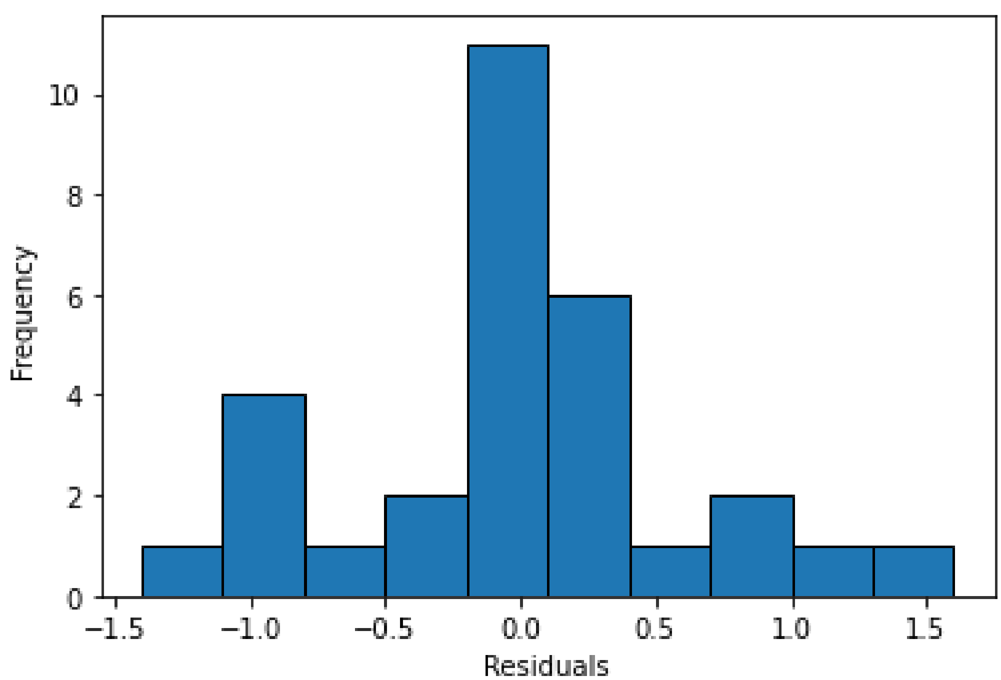
    plt.show()
```

[ ]:
```
# QQ-plot
import statsmodels.api as sm
import matplotlib.pyplot as plt
# res.anova_std_residuals are standardized residuals obtained from two-way␣
 ↪ANOVA (check above)
sm.qqplot(res.anova_std_residuals, line='45')
plt.xlabel("Theoretical Quantiles")
plt.ylabel("Standardized Residuals")
plt.show()

# histogram
plt.hist(res.anova_model_out.resid, bins='auto', histtype='bar', ec='k')
plt.xlabel("Residuals")
plt.ylabel('Frequency')
plt.show()
```

```python
# Shapiro-Wilk test
import scipy.stats as stats
w, pvalue = stats.shapiro(res.anova_model_out.resid)
print(w, pvalue)
```





0.9254432320594788 0.037210531532764435

[ ]:
```
# from statsmodels.stats.multicomp import pairwise_tukeyhsd

# df['combination'] = df.sun + " / " + df.water
# m_comp = pairwise_tukeyhsd(endog=df['height'], groups=df['combination'],␣
↪alpha=0.05)
# print(m_comp)
```

[ ]:
```
# # coerce the tukeyhsd table to a DataFrame
# tukey_data = pd.DataFrame(data=m_comp._results_table.data[1:], columns =␣
↪m_comp._results_table.data[0])

# group1_comp =tukey_data.loc[tukey_data.reject == True].groupby('group1').
↪reject.count()
# group2_comp = tukey_data.loc[tukey_data.reject == True].groupby('group2').
↪reject.count()
# tukey_data = pd.concat([group1_comp, group2_comp], axis=1)

# tukey_data = tukey_data.fillna(0)
# tukey_data.columns = ['reject1', 'reject2']
# tukey_data['total_sum'] = tukey_data.reject1 + tukey_data.reject2

# # just show the top 20 results
# tukey_data.sort_values('total_sum',ascending=False).head(5)
```

[ ]:
```
# Another Way is pingoiun
import pingouin as pg
# First calculate anova table
aov = pg.anova(data = df , dv = 'height', between=['sun','water'],␣
↪detailed=True)
print(aov)
```

```
       Source         SS  DF         MS        F     p-unc       np2
0         sun  24.866667   2  12.433333  23.3125  0.000002  0.660177
1       water   8.533333   1   8.533333  16.0000  0.000527  0.400000
2  sun * water   2.466667   2   1.233333   2.3125  0.120667  0.161572
3    Residual  12.800000  24   0.533333      NaN       NaN       NaN
```