Data Science
Foundations of Decision Making

Types of hypothesis tests

Purdue University | College of Science

Hypothesis tests

- One sample t-test: tests the mean of a single group against a known mean
- Two sample t-test:
  - Independent samples: compares the means for two groups
  - Paired test: compares means from the same group under different conditions
- Above tests can be performed as two sided (hypothesis is that means are different) or one-sided (hypothesis is that one mean is larger/smaller than the other)
  - These are also referred to as one-tailed and two-tailed tests.

Example in python

```
import scipy.stats as st

d1 = …            # observed data
h0mean = 30       # mean under null hypothesis

# t-test with scipy
t,p = st.ttest_1samp(d1, h0mean)

# t: returned t-statistic value
# p: calculated p-value
```

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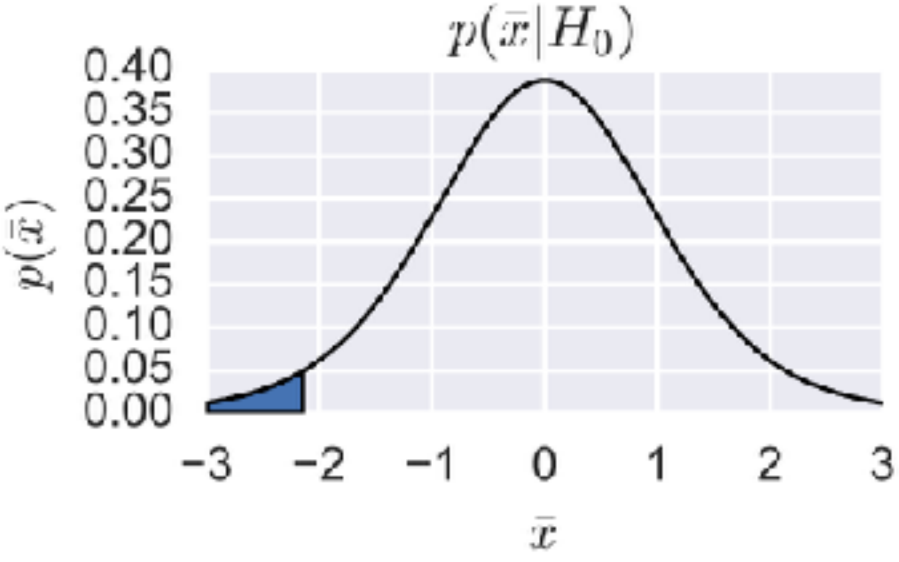
Two-sided vs. one-sided tests

- The previous code considered deviation from the null hypothesis in both direction (two-sides test is default)
- This corresponds to $H_0 = 30$, $H_1 \neq 30$
- We actually wanted to compute a one-sided test: $H_0 = 30$, $H_1 > 30$
- In this case, the probability corresponds to the area under the left side of the curve



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Two sample test

- The previous example assumed that the null hypothesis corresponds to a known mean, but in reality we may not know the mean that we want to compare to
- In this case, we often formulate hypothesis about difference in means

$$H_0: \mu_1 = \mu_2 \ (\text{or e.g. } \mu_1 \geq \mu_2)$$
$$H_1: \mu_1 \neq \mu_2 \ (\text{or e.g. } \mu_1 < \mu_2)$$

- In this case, we can use a two-sample t-test

Paired t-test

- A paired t-test is a two-sample used to compare population means when you have observations in one sample that can be paired with observations in the other sample. Usually this means the same examples observed under different conditions. E.g.:
    - Before-and-after observations on the same subjects (e.g. students' diagnostic test results before and after a particular module or course)
    - A comparison of two different algorithms applied to the same data instances (e.g. prediction accuracy of two classification algorithms on same examples)
- Pairing the examples before taking the difference increases the power of the test, because it reduces variability

Example in python

```
import scipy.stats as st
d1 = …          # first observed data set
d2 = …          # second observed data set

# two independent samples t-test with scipy
t,p = st.ttest_ind(d1, d2)

# paired two-sample t-test with scipy
t,p = st.ttest_rel(d1, d2)
```

Note: python methods do not have options for one-sided t-test, to change result from two-sided to one-sided, just divide the p-value in half (ie. p/2)

Types of hypothesis tests

		Continuous		Discrete
		Parametric	Non-parametric	
One sample		T-test	Wilcoxon test	Chi-square or binomial test
Two samples	Unpaired	T-test	Mann-Whitney test	Fisher’s or chi-square test
	Paired	Paired t-test	Wilcoxon test	McNemar’s test

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Contingency table

- A contingency table is a cross-tabulation of n paired observations into categories
  - Each cell shows the count of observations that fall into the category defined by its row (r) and column (c) heading

Exercise

Smoking

	Freq	None	Some
Heavy	7	1	3
Never	87	18	84
Occas	12	3	4
Regul	9	1	7

Chi-square test

- Given a contingency table for variables A and B, test the hypothesis that there is an association between the variables:
  - H_0: Variable A is independent of variable B
  - H_1: Variable A is not independent of variable B
- Use the chi-square test to test this hypothesis
  - This test compares the observed frequencies in the cells to the expected frequencies
  - The n observations are categorized into c columns and r rows and then the observed frequency o_{ij} is compared with the expected frequency e_{ij} (across all cells)

$$\chi^2 = \sum_{i,j} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Example in python

- Chi-square tests are often used in A/B testing

	not converted (f)	converted (t)
a	4514	486
b	4473	527

```
from scipy.stats import chi2_contingency

observed = ... # data in contingency table
chisq, p = chi2_contingency(observed)

# for this example chisq = 1.76 and p = 0.185
```