



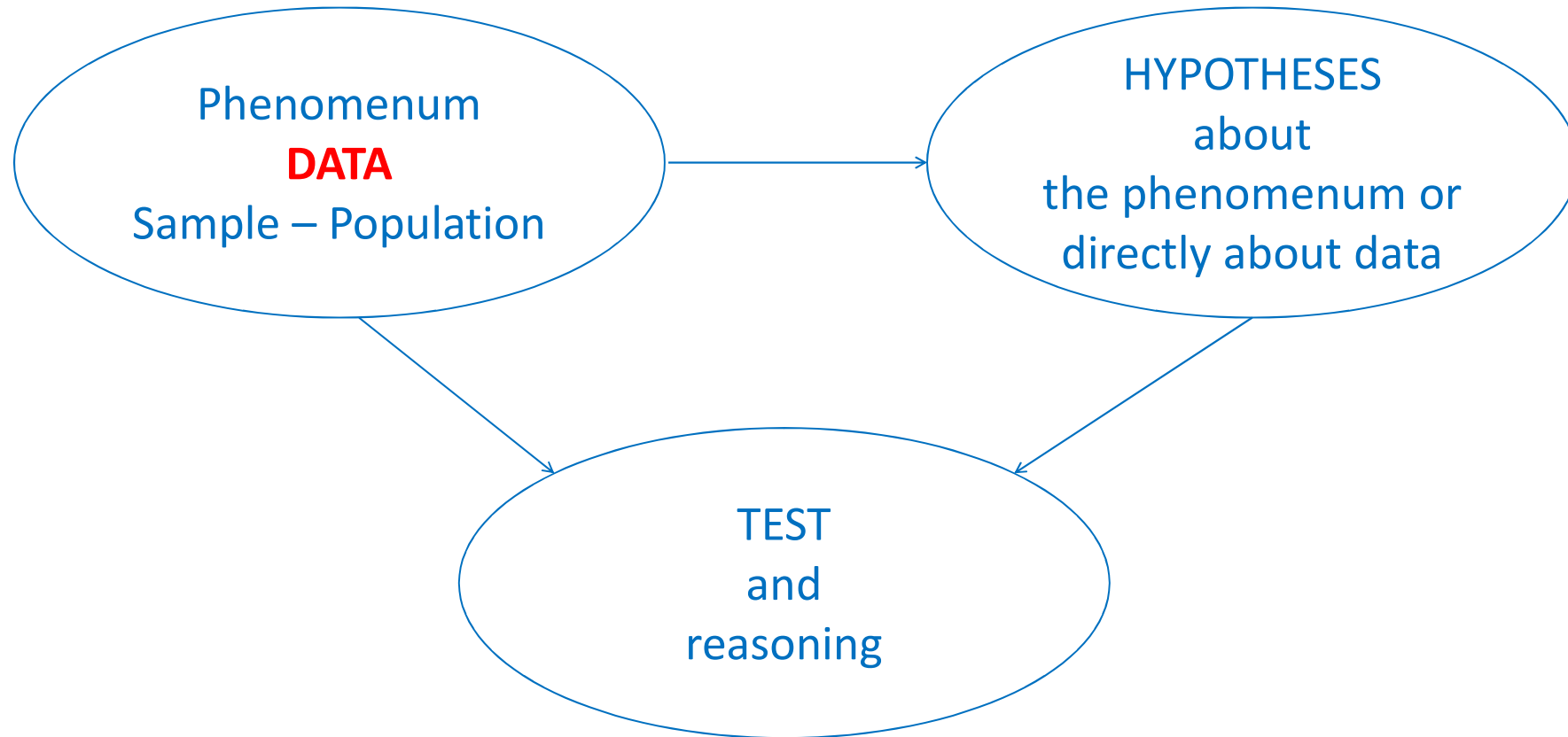
# TOOLS AND METHODS: HOW TO ANALYZE THE OUTPUT OF RESEARCH HOW TO DO HYPOTHESIS TESTS

Maciej Wolny



Silesian University  
of Technology

# How to analyze the output of research

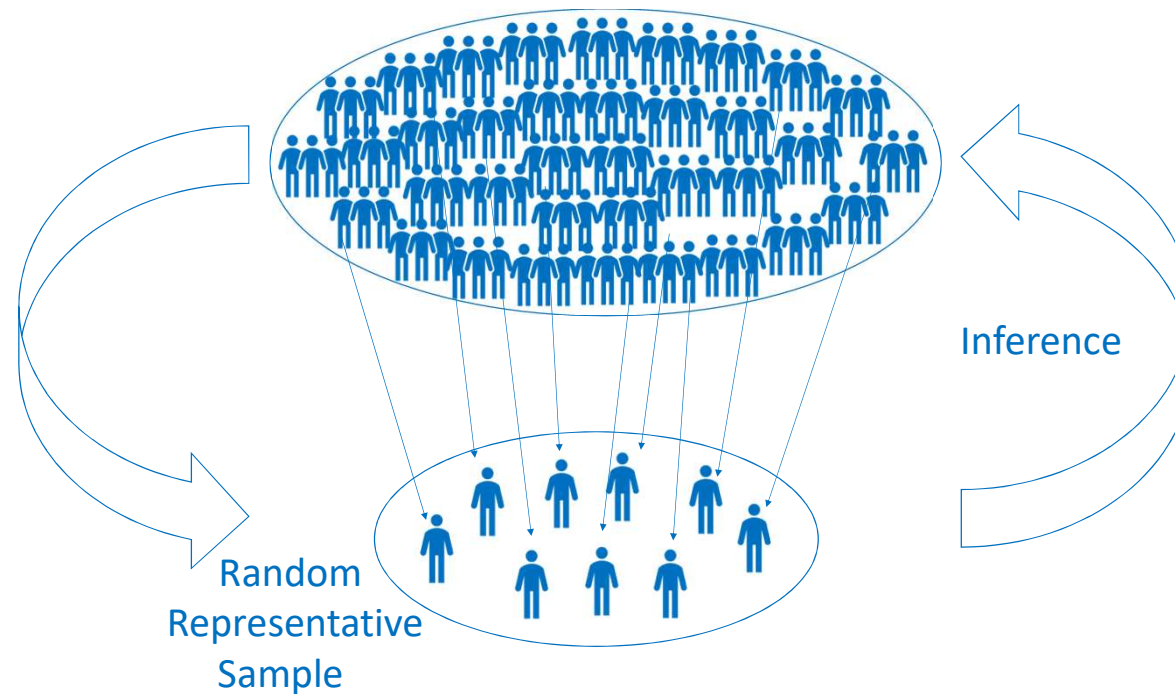


## Agenda – how to test statistical hypothesis

- Introduction
- Statistical inference and statistical hypotheses
- Significance level and p-value
- Hypotesis test
- Example(s): soap vs shower gel



# Introduction - Inferential statistics



Inferential statistics use a random sample of data taken from a population to describe and make inferences about the population.



# Statistical hypotheses

- Every judgement about population without research of the entire population.

Hypothesis testing is formulated in terms of *two* hypotheses:

- $H_0$ : the null hypothesis;
- $H_1$ : the alternate hypothesis.

- Null hypothesis ( $H_0$ ) is general statement, that there is no relationship between two (or more) measured phenomena (or no association among groups). It can be a statement about value of the parameter for one variable.

I.e. Null hypothesis – The population mean of weekly size of soap distribution is equal to 1650 boxes. Formally:  **$H_0: m = 1650$**

- The null hypothesis is assumed to be true until **there is no reason to reject the hypothesis**.
- If the  $H_0$  is rejected, then alternative hypothesis  $H_1$  is accepted.



## Error types

	Real situation	
	$H_0$ is true	$H_1$ is true
Accept null hypothesis	Right decision $(1-\alpha)$	Wrong decision Type II Error $(\beta)$
Reject null hypothesis	Wrong decision Type I Error $(\alpha)$	Right decision $(1-\beta)$



## Significance level and p-value

- Significance level ( $\alpha$ ) – the probability of the study rejecting the null hypothesis, when it is true.
- Significance level must be stated by researcher (usually: 0,001; 0,01; **0,05**; 0,1)
- Confidence level ( $1-\alpha$ ) – the probability that the value of a parameter falls within a specified range of values (confidence interval).
- P-value – tested value of probability, is a borderline value of statistical significance.
- The result is statistically significant, by the standards of the study, when  $p < \alpha$ .

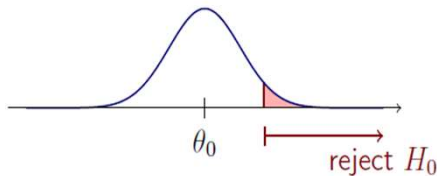


# • Alternative hypothesis $H_1$

- Alternative hypothesis can be formulated one-tailed or two-tailed.
- The definition of hypothesis  $H_1$  determines type of statistical test.
- 

- $H_0: \theta = \theta_0$
- $H_1: \theta > \theta_0$ .

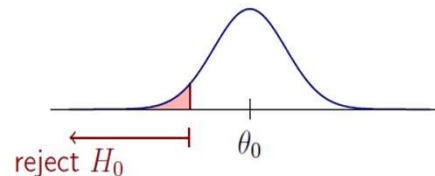
This is a one-tailed test with the critical region in the right-tail of the test statistic  $X$ .



Another one-tailed test could have the form,

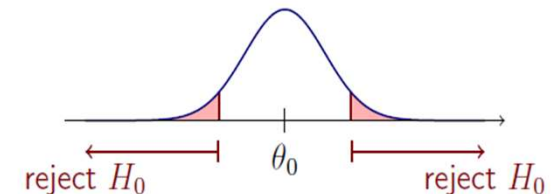
- $H_0: \theta = \theta_0$
- $H_1: \theta < \theta_0$ ,

in which the critical region is in the left-tail.



In a two-tailed test check for differences:

- $H_0: \theta = \theta_0$
- $H_1: \theta \neq \theta_0$ ,



[http://www.sci.utah.edu/~arpaiva/classes/UT\\_ece3530/hypothesis\\_testing.pdf](http://www.sci.utah.edu/~arpaiva/classes/UT_ece3530/hypothesis_testing.pdf)

**$H_0: m = 1650$**   
 **$H_1: m > 1650$**

**$H_0: m = 1650$**   
 **$H_1: m < 1650$**

**$H_0: m = 1650$**   
 **$H_1: m \neq 1650$**





# Test statistic

- Statistic – mathematical formula which allows to count the characteristic value of the sample on basis of theoretical background of hypothesis.
- P-value is a function of statistic.
- Decision rule - result of the comparison of values. If the test statistic is in the critical region ( $p < \alpha$ ), reject  $H_0$ . Otherwise, do not reject  $H_0$

Example

$$H_0: m - m_0 = 0$$

$$H_1: m - m_0 \neq 0$$

$$t = \frac{\bar{x} - m_0}{s_{n-1}} \sqrt{n}$$

One-Sample Test

Test Value = 1650						
95% Confidence Interval of the Difference						
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
soap [box]	-,498	307	,619	-21,815	-108,02	64,39

There is no reason to reject the hypothesis  $H_0$



- (Summary) Steps in the hypothesis testing
  1. State the null and alternate hypothesis.
  2. State significance level ( $\alpha$ ).
  3. Choose the test statistic and establish the critical region.
  4. Compute the test statistic (and p-value).
  5. If the test statistic is in the critical region ( $p < \alpha$ ), reject  $H_0$ . Otherwise, do not reject  $H_0$ .



## • Example: Test of means

Is there a significant difference between average weekly number of distributed soap boxes and average weekly number of distributed shower gel boxes?

$$H_0: m_1 - m_2 = 0$$

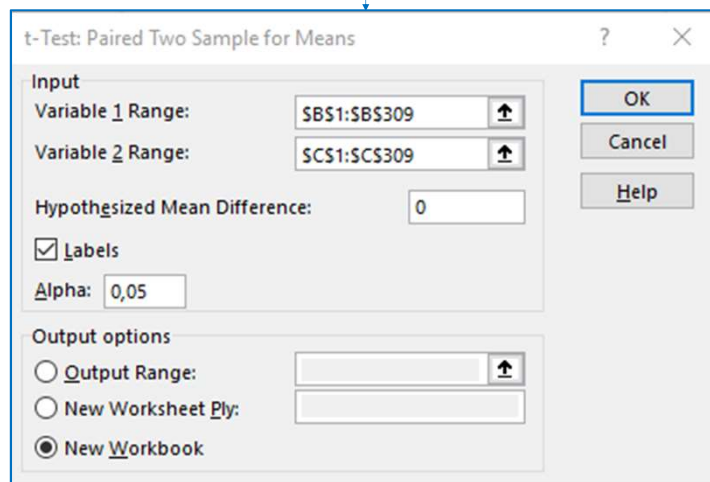
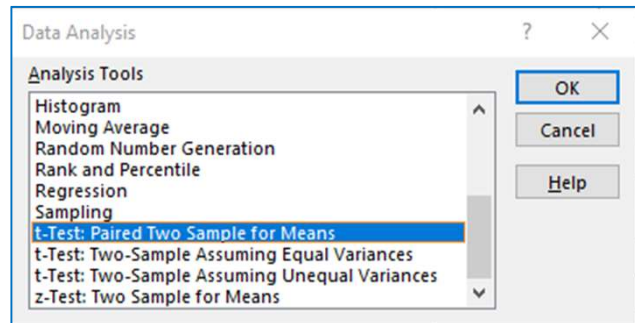
$$H_1: m_1 - m_2 \neq 0$$

Paired Samples Test									
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	soap [box] - shower gel [box]	68,786	502,903	28,656	12,400	125,172	2,400	307	<u>,017</u>

The hypothesis  $H_0$  is rejected, there is a significant difference between the average values.



# • Excel ... last time



t-Test: Paired Two Sample for Means		
	soap [box]	shower gel [box]
Mean	1628,185065	1559,399351
Variance	591126,679	394826,6446
Observations	308	308
Pearson Correlation	0,758673726	
Hypothesized Mean Difference	0	
df	307	
t Stat	2,400429861	
P(T<=t) one-tail	0,008485447	
t Critical one-tail	1,649832147	
P(T<=t) two-tail	0,016970894	
t Critical two-tail	1,967721288	

The hypothesis  $H_0$  is rejected, ...



## Internet References

- <http://onlinestatbook.com/>
- <https://support.minitab.com/en-us/minitab-express/1/>
- <https://medium.com/datadriveninvestor/p-value-significant-level-and-hypothesis-testing-4895524ec3f3>
- [http://www.sci.utah.edu/~arpaiva/classes/UT\\_ece3530/hypothesis\\_testing.pdf](http://www.sci.utah.edu/~arpaiva/classes/UT_ece3530/hypothesis_testing.pdf)



Təşəkkür edirəm



Silesian University  
of Technology