Homework 05

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1 Task 1. Designing a Human-Robot Interaction Experiment

Suppose that you are developing a scenario where the Atlas robot should assist a plumber by bringing necessary tools and objects when requested. Let's say, you have developed several ways in which the robot can handover an object to the plumber. Now, you would like to evaluate these by conducting an empirical study with experienced plumbers.

a) Define at least one research question that you would like to investigate in the context of human-robot interaction in the above scenario.

Which cooperative work steps can a robot take over to support the job of a plumber efficiently and sustainably during their work time?

How safely and reliably can a robot support the job of a plumber during the working progress?

b) Identify the constructs involved in this research question(s).

C1: Cooperation between robot and human in plumber work
C2: Security & Reliability of Cooperative Human-Robot work
C3: Distributing work steps between humans and robot efficiently and sustainable
Baseline: No cooperation between humans and robot possible

c) Formulate at least one hypothesis based on the research question(s) and the identified constructs.

H1: Robots can cooperate with humans during the work of a plumber by assisting with small requests such as bringing necessary tools and objects.

H2: By including sensitive sensors the robot can be programmed to work safely and reliably in order not support humans without causing damage or harm to the environment.

H3: Through human feedback the efficiency and sustainability of the robot's work can be reviewed and continuously improved.

d) How would you operationalize the constructs in the above hypotheses?

I would choose an "in-between subjects"-strategy and invite 21 plumbers as testing persons. The plumbers are furthermore split into groups depending on their experience.

e) How would you design your study (context, conditions, allocation of subjects)? Justify your study design.

Each person will get the same plumbing tasks which should be fulfilled with the help of a robot. It is a laboratory experiment so that all workers will individually solve the tasks in the same room that the robot is used to. Each plumber has to answer questions and fill out a questionnaire afterward referring to the hypotheses.

f) What would your null hypothesis look like, for each of the hypotheses that you formulated above?

H0: Robots cannot assist during the wokr of a plumber.

H0: Including sensitive sensors will not affect safety or reliability.

H0: Human feedback will not help improve the robot's work concerning its efficiency and sustainability.

2 Task 2. Understanding Power Analysis for t-tests

With the help of statsmodels1 library, create plots showing the relationship between alpha level, effect size, sample size and statistical power for (i) two independent sample t-test, and (ii) paired sample t-test. Explain your observations based on the plots.
Note: Take a look at the Python classes:
statsmodels.stats.power.TTestPower and statsmodels.stats.power.TTestIndPower.
Submission: Insert the plots and explanations in the PDF and submit the Python code that you used to create the plots as a separate file.

2.1 Independent sample t-test

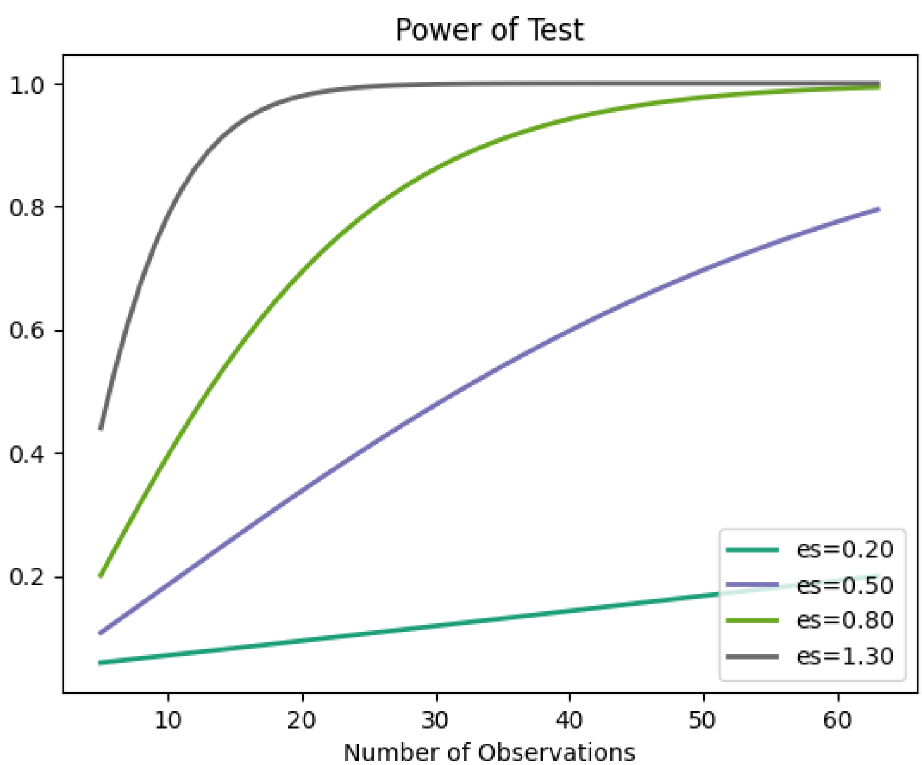

Figure 1: Independent sample power test results for varying effect sizes.

Figure 2 shows how the power test value varies as the number of observations rises. The experiment was conducted for different effect value sizes to investigate how these affect the relation between the number of observations and the power test. From the plot, we can notice that the smaller the effect size the more number of observations we need. Since the effect size measures the difference between two conditions, a small effect size corresponds to the situation in which the two Gaussian means are close to each other. In this case, if we want to increase the power test, we have to be more accurate in estimating the mean μ_1. This can be done by reducing the variance of the distribution by collecting more observations, resulting in a "sharper" Gaussian. If we were to collect an infinite number of observations, the estimator converges to the Dirac distribution centered on the mean. On the other hand, if two Gaussians are centered far apart from each other (high effect size), we need only a few observations to obtain a high power.

2.2 Paired sample t-test

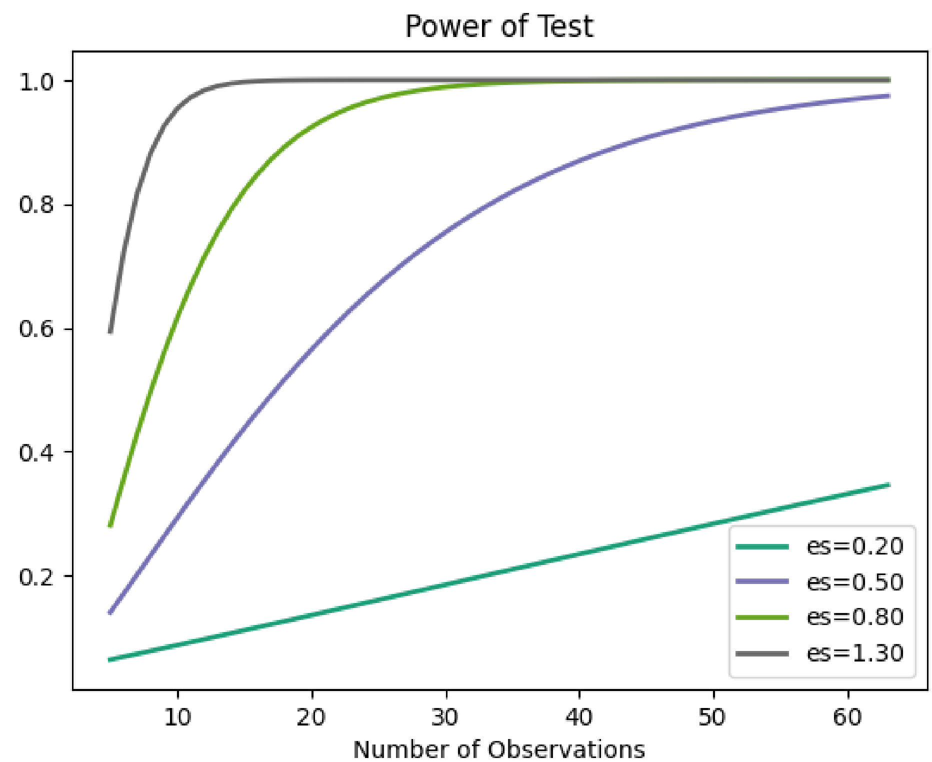

Figure 2: Paired sample power test results for varying effect sizes.

Every consideration made for the independent t-test holds for the paired t-test as well. However, the two plots highlight a significant difference: the within-subject experiment requires fewer observations to achieve the same power value. Indeed, we chose identical effect size values to make the two plots comparable, revealing a notable difference, especially at higher effect size values. For instance, the curve corresponding to an effect size of 1.30 converges to a power of 1.0 around 15 observations for the paired sample case, whereas it takes roughly 25 observations in the independent sample case. This occurs because, in within-subject experiments, each person is exposed to multiple conditions, yielding more observations per person. In contrast, in between-subject experiments, each person is exposed to just one condition, resulting in only one observation.