Problem Set 2

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Contents

1 What happens when pilgrims attend the Hajj pilgrimage to Mecca?

1.1 State a null hypothesis

State the sharp-null hypothesis that you will be testing.

Answer: ...

1.2 Group by average

Using `data.table`, group the data by `success` and report whether views toward others are generally more positive among lottery winners or lottery non-winners. This answer should be of the form `d[ , .(mean_views = ...), keyby = ...]` where you have filled in the `...` with the appropriate functions and variables.

```
# the result should be a data.table with two columns and two rows
hajj_group_mean <- 'fill this in'

# from the `hajj_group_mean` produce a single, numeric vector that is the ate.
# check that it is numeric using `class(hajj_ate)`
hajj_ate        <- 'fill this in'
```

Answer: ...

```
## do your work to conduct the randomization inference here.
## as a reminder, RI will randomly permute / assign the treatment variable
## and recompute the test-statistic (i.e. the mean difference) under each permutation
## this should be a numeric vector that has a length equal to the number
## of RI permutations you ran
hajj_ri_distribution <- 'fill this in'
```

1.3 Randomization inference: At least as large

C. How many of the simulated random assignments generate an estimated ATE that is at least as large as the actual estimate of the ATE? Conduct your work in the code chunk below, saving the results into `hajj_count_larger`, but also support your coding with a narrative description. In that narrative description (and throughout), use R's "inline code chunks" to write your answer consistent with each time your run your code.

```
# length 1 numeric vector from comparison of `hajj_ate` and `hajj_ri_distribution`
hajj_count_larger <- 'fill this in'
```

Answer: ...

1.4 Randomization inference: one-sided p-value

If there are `hajj_count_larger` (fill this in) randomizations that are larger than `hajj_ate` (fill this in), what is the *one-tailed* p-value? Both write the code in the following chunk, and include a narrative description of the result following your code.

```
# length 1 numeric vector
hajj_one_tailed_p_value <- 'fill this in'
```

Answer: ...

1.5 Randomization inference: two-sided p-value

Now, conduct a similar test, but for a two-sided p-value. You can either use two tests, one for larger than and another for smaller than; or, you can use an absolute value (`abs`). Both write the code in the following chunk, and include a narrative description of the result following your code.

```
# length 1 numeric vector
hajj_two_tailed_p_value <- 'fill this in'
```

Answer: ...

2 Sports Cards

2.1 t-test and confidence interval

Using a `t.test`, compute a 95% confidence interval for the difference between the treatment mean and the control mean. After you conduct your test, write a narrative statement, *using inline code evaluation* that describes what your tests find, and how you interpret these results. (You should be able to look into `str(t_test_cards)` to find the pieces that you want to pull to include in your written results.)

```
# this should be the t.test object. Extract pieces from this object
# in-text below the code chunk.
t_test_cards <- 'fill this in'
```

Narrative Analysis: . . .

2.2 Interpretation of confidence interval

In your own words, what does this confidence interval mean? This can be simple language, but it has to be statistically appropriate language.

Answer: . . .

2.3 Randomization inference, and confidence interval?

Conduct a randomization inference process, with `n_ri_loops = 1000`, using an estimator that you write by hand (i.e. in the same way as earlier questions). On the sharp-null distribution that this process creates, compute the 2.5% quantile and the 97.5% quantile using the function `quantile` with the appropriate vector passed to the `probs` argument. This is the randomization-based uncertainty that is generated by your design. After you conduct your test, write a narrative statement of your test results.

```
## first, do you work for the randomization inference
n_ri_loops <- 1000

cards_ate              <- 'fill this in'
cards_ri_distribution <- 'fill this in' # numeric vector of length equal
                                        # to your number of RI permutations
cards_ri_quantiles    <- 'fill this in' # there's a built-in to pull these.
cards_ri_p_value      <- 'fill this in'
```

Narrative: . . .

2.4 Compare regression and randomization inference

Do you learn anything different if you regress the outcome on a binary treatment variable? To answer this question, regress `bid` on a binary variable equal to 0 for the control auction and 1 for the treatment auction and then calculate the 95% confidence interval using *classical standard errors* (in a moment you will calculate with *robust standard errors*). There are two ways to do this – you can code them by hand; or use a built-in, `confint`. After you conduct your test, write a narrative statement of your test results.

```
# this should be a model object, class = 'lm'.
mod <- 'fill this in'
```

Narrative: . . .

2.5 Regression with robust confidence interval

Calculate the 95% confidence interval using robust standard errors, using the `sandwich` package. There is a function in `lmtest` called `coefci` that can help with this. It is also possible to do this work by hand. After you conduct your test, write a narrative statement of your test results.

```
# this should be a numeric vector of length 2
cards_robust_ci <- 'fill this in'
```

Narrative: . . .

2.6 Compare and contrast results

Characterize what you learn from each of these different methods – are the results contingent on the method of analysis that you choose?

Answer: . . .

3 Power Analysis

3.1 Describe your testing procedure

Describe a t-test based testing procedure that you might conduct for this experiment. What is your null hypothesis, and what would it take for you to reject this null hypothesis? (This second statement could either be in terms of p-values, or critical values.)

Answer: ...

3.2 Suppose you only had ten subjects, what would you learn

Suppose that you are only able to recruit 10 people to be a part of your experiment – 5 in treatment and another 5 in control. Simulate "re-conducting" the sports card experiment once by sampling from the data you previously collected, and conducting the test that you've written down in part 1 above. *Given the results of this 10 person simulation, would your test reject the null hypothesis?*

```r
# this should be a test object
t_test_ten_people <- 'fill this in'
```

Answer: ...

3.3 With only ten subjects, what is your power?

Repeat this process – sampling 10 people from your existing data and conducting the appropriate test – one-thousand times. Each time that you conduct this sample and test, pull the p-value from your t-test and store it in an object for later use. *Consider whether your sampling process should sample with or without replacement.*

```r
# fill this in with the p-values from your power analysis
t_test_p_values <- rep(NA, 1000)

## you can either write a for loop, use an apply method, or use replicate
## (which is an easy-of-use wrapper to an apply method)
```

Answer: ...

3.4 Visual analysis

Use `ggplot` and either `geom_hist()` or `geom_density()` to produce a distribution of your p-values, and describe what you see. *What impression does this leave you with about the power of your test?*

Answer: ...

3.5 Interpret your results, given your power

Suppose that you and David were to actually run this experiment and design – sample 10 people, conduct a t-test, and draw a conclusion. **And** suppose that when you get the data back, **lo and behold** it happens to reject the null hypothesis. Given the power that your design possesses, does the result seem reliable? Or, does it seem like it might be a false-positive result?

Answer: ...

3.6 Conduct a power analysis

Apply the decision rule that you wrote down in part 1 above to each of the simulations you have conducted. What proportion of your simulations have rejected your null hypothesis? This is the power that this design and testing procedure generates. After you write and execute your code, include a narrative sentence or two about what you see.

```
t_test_rejects <- 'fill this in'
```

Answer: ...

3.7 Moar power!

Does buying more sample increase the power of your test? Apply the algorithm you have just written onto different sizes of data. Namely, conduct the exact same process that you have for 10 people, but now conduct the process for every 10% of recruitment size of the original data: Conduct a power analysis with a 10%, 20%, 30%, ... 200% sample of the original data. (You could be more granular if you like, perhaps running this task for every 1% of the data).

```
percentages_to_sample <- 'fill this in'
```

Answer: ...