

# Take Home exercises ‘Simple Random Sampling’

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This file is the product of an R Markdown file (.Rmd). If you are reading the pdf-file, open the .Rmd file as well in R just to see what R Markdown does. There is no need yet to understand exactly how RMarkdown works. For now, the only thing that is worth knowing is that when you press “knit” in R studio (and you have the right dataset in the same folder as the .Rmd file) you will produce the pdf. You can also ask for a html file by stating “output: html\_document”.

The idea of a .Rmd file is that you can run R code (snippets) with comments in code, but also add text. Scroll through the document! More on R Markdown in the “Programming with R” course. For now, you don’t need to know how .Rmd works, but know that examples and exercises in the Survey data Analysis course will be produced by an R markdown file, that contains the answers. You will find that for some R snippets results are ‘hidden’, or snippets are not included at all in the pdf. So you can check answers by running parts of the RMarkdown and/or comparing code to your code. Or, if you get stuck in R, you can use the R markdown for hints, or partial solutions. What also works quite well is that you take the RMarkdown files, and then change code, just to see what happens if you (for example) draw a larger sample, do that on a different population dataset, etc.

Because there is no lecture next week, there is a batch of exercises to be done this week:

- i) how to sample from data using simple random sampling,
- ii) work with the {survey} package and
- iii) do some exercises ( by hand or in R) on sample size calculations
- iv) a further exercise on power and sample size calculations
- v) looking forward to next week - the sampling design of your adopted survey

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## Exercise 1 - Sampling

Open the file `boys.RDS` (Google how to read .R files in R, or see the Markdown if you don’t know how to do this). Inspect the variable labels and make yourself familiar with the dataset. The key variables in the dataset are the height and weight for *all* 738 boys under the age of 21 living in an imaginary county (gemeente) in the Netherlands in 2014. In other words, we have the whole population, and the idea of this and future exercises is we explore different hypothetical ways to sample from this population, and then study the consequences for bias, error, and the MSE (see week 2).

The dataset stems from a surveillance system, in which every child is seen every few years to measure various aspects of growth (like height, weight, but also onset of puberty). The following measures are available:

Variable	Description	Type of Variable
Age	age in years (0-21)	Auxiliary
hgt	Height (cm)	Auxiliary
wgt	Weight (kg)	Auxiliary

Variable	Description	Type of Variable
bmi	Body Mass Index	Auxiliary
hc	Head circumference	Auxiliary
gen	Genital Tanner Stage (G1-G5)	Target
phb	Pubic hair (Tanner P1-P6)	Target
tv	Testicular volume (ml)	Target
Town	Town 1 to Town 5	Auxiliary

Let's load the required libraries and the data file.

**\*\* Intermezzo \*\*** folders,data,projects Remember: if the data are stored in the same folder as your .R or .Rmd file, it should load the data without the need to specify the exact folder. If your file does not load, chances are that your datafile is in a different folder than you .r or .Rmd syntax. To avoid hassle with datasets and files being in the wrong folder, I always work with “R projects”. To start a new project, open in R studio:

- 1) click on file -> New project
- 2) Either create a new directory, or locate the directory where you are saving the datafiles for the “survey data analysis” course.
- 3) give the project a name, like “exercises week 3”

R will now always link syntax (.r or .rmd files) and datafiles you use in this project to each other, and keep Datasets that you loaded in your environment associated to the project linked. Handy!

**\*\* end of Intermezzo \*\***

Run the code below to install and load the libraries needed for this exercise, as well as the dataset. Then, load the data

```
#install.packages("tidyverse")
#install.packages("magrittr")
#install.packages("survey")
#install.packages("sampling")

library(tidyverse)
library(magrittr)
library(survey)
library(sampling)
```

*Getting to know the population*

1. The variable town consists of five towns in the county, numbered town1 to town5. Investigate how age is distributed over the towns and write down the respective numbers of cases in the following crosstable. I first recode the variable ‘age’ into a new categorical variable as shown in the code below.

```
# create agecat
boys$agecat[boys$age<1] <- "under 1"
boys$agecat[boys$age>=1] <- "1-5"
boys$agecat[boys$age>=5] <- "5-10"
boys$agecat[boys$age>=10] <- "over 10"
# I am also adding an ID
boys$id <- 1:748
```

and now I create the crosstable, using both raw numbers, and proportions:

```
table(boys$agecat,boys$town)
prop.table(table(boys$agecat,boys$town))
```

	town1	town2	town3	town4	town5	total
age < 1	34	7	52	22	19	134
age 1 - <5	50	14	44	34	12	154
age 5 - <10	18	5	22	18	5	68
age >=10	89	55	121	87	37	389
total	191	81	239	161	79	745

2. Based on the above table, if we would draw a single person at random (using SRS), this person most likely would live in town 3 and most likely belongs to age category `age >= 10`. Based on the above table, what would be the least likely combination of characteristics if we would draw a single person at random using SRS ?
3. What is the mean age in the population?
4. Randomly sample 200 cases (without replacement) from the dataset and recompute the mean for the sample only using the code below. How large is the difference in your population mean? What is (for your single sample) the estimate of the mean age of the child?

*R code*

```
library(sampling) # see THE week 2
set.seed=123 #for replication purposes (so that we get the same results every time we run this syntax)
boys$sample <-srswor(200,nrow(boys))
# explanation: we add an indicator (0,1), that will be 1 for sample 200 cases
# we sample here WithOut Replacement (WOR).
# Explore the sampling package for advanced settings that we will use later
table(boys$sample) # check, does it work? Yes
```

```
##
##    0    1
## 548 200
```

You can also View the dataset with the `{View()}` command.

```
#View(boys)
```

Now, lets compute the mean age of the children that we drew in our sample!

```
srssample1 <- filter(boys,sample== 1) # selecting only the sampled boys
# or write srssample1 <- boys[boys$sample==1]
mean(srssample1$age)
mean(boys$age)- mean(srssample1$age) # error or bias!
```

Please note that the small bias that we observe here is actually due to random sampling error (because we 'know' SRS is unbiased, the difference must be error . Every time we sample we will get a slightly different estimate for the mean, but averaged over an infinite amount of samples we can draw, the bias will be 0. We can estimate the size of the random error (and empirically establish that our estimator is indeed unbiased) by running this code many times (see lecture). However, the Central Limit Theorem posits that we can simply predict the average error, and summarize this in the *standard error* statistic (s.e) .

5. We would normally always like to get an estimate of the standard error with our estimate of interest (in this case of the mean). The standard error is equal to: sample standard deviation (square root of variance /  $\sqrt{n}$ ). Compute the standard error of the mean by hand (or in R).
6. Can you also compute the 95% CI of the mean for the variable age in our srs?

## Exercise 2 - The survey package

Most statistical packages compute the s.e. for us assuming we always use a simple random sample. You have probably done this before. However, we will soon start using more complicated sampling designs, where computing the se. accurately is complicated, so I will show here how we can compute the *correct* standard error for any design using the {survey} package in R. The survey package can also deal with more complicated sampling designs quite easily. Although not needed yet now, I will also show how we can compute means across categories, compute a General Linear Model (ANOVA, regression), or plot the data using the {survey} package. You don't need to remember all of these.

1. First, explore the {survey} package by using the {help} function.

```
help(package="survey")
```

2. The idea of the {survey} package is that you “tell” R what sampling design was used to generate a sample. The survey package will then compute accurate statistics for you, no matter how complicated your design is. There are there always two steps in analyses you do with the survey package:
  - i. You tell R the structure of your sample using the {svydesign} function
  - ii. You do some analysis

This week we will start with a simple random sample. You can tell this to R using the function:

```
library(survey)
SomeName <- svydesign(ids=~1,fpc=NULL,data=srssample1)
```

```
## Warning in svydesign.default(ids = ~1, fpc = NULL, data = srssample1): No
## weights or probabilities supplied, assuming equal probability
```

The warning you get is normal and can be ignored. R “warns” us that our sample looks overly simple. It is! The elements in the function mean the following:

ids=~1. Here, you tell R there is no id variable. If you have an id-variable for people in your dataset, you can define this here. Later, the {ids=~} important when we use cluster sampling, for example when we have kids in schools.

fpc=... Here you need to specify the size of the population that your sample was drawn from, so that R knows how to apply the Finite Population Correction. We left this out for now (NULL), so we have assumed that the population is of infinite size.

data=... The original sample dataset.

As a next step, lets indicate that our population is not of infinite size, but consists of 748 boys. We have to add the population size as a new variable to your dataset, and add that variable to the svydesign function.

3. In step 2 of the analysis you compute the thing you are interested in. In this exercise we are interested in the mean. The code below shows how to ask for a mean. Run the code, and compare your answer to the mean and standard error you computed in exercise 1. They should be the same (note the survey package rounds to 4 decimals).

```
svymean(~age,srs1)
```

4. In the code below, I will show you some other useful functions of the {survey} package that we will use in later package. Feel free to explore these functions

```
?svyby
svyby(~age,~town, srs1,svymean) # as a bonus, this shows the age distribution across towns
```

```
##      town      age      se
## 1      1  8.850365 0.7609030
## 2      2  8.320438 1.5343045
## 3      3  9.329405 0.6706842
## 4      4 11.820667 0.8343658
## 5      5  8.438118 1.3060773
```

```
svyglm(hgt ~ age,srs1)
```

```
## Independent Sampling design
## svydesign(ids = ~1, fpc = srssample1$popsize, data = srssample1)
##
## Call:  svyglm(formula = hgt ~ age, design = srs1)
##
## Coefficients:
## (Intercept)      age
##      70.945      6.685
##
## Degrees of Freedom: 191 Total (i.e. Null);  190 Residual
## (8 observations deleted due to missingness)
## Null Deviance:      399100
## Residual Deviance: 20880      AIC: 1451
```

```
svyglm(wgt ~ town+age+town:age,srs1) # formula can be more complicated, e.g. with interaction effects
```

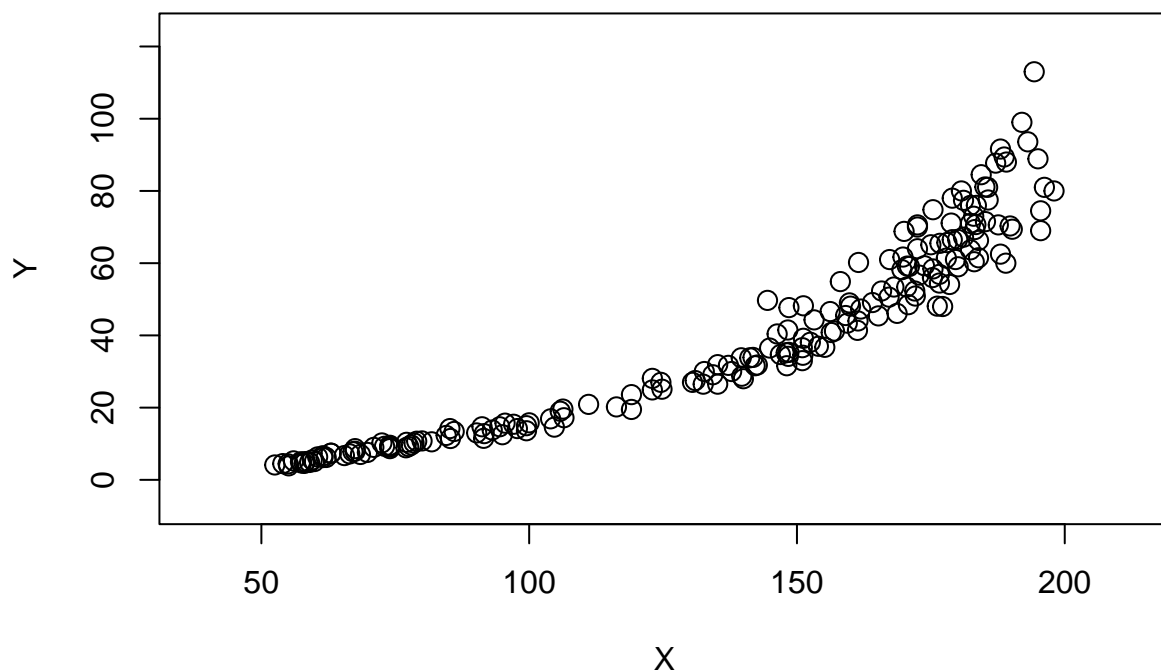
```
## Independent Sampling design
## svydesign(ids = ~1, fpc = srssample1$popsize, data = srssample1)
##
## Call:  svyglm(formula = wgt ~ town + age + town:age, design = srs1)
##
## Coefficients:
## (Intercept)      town      age      town:age
##      3.054084      0.191847      3.707055      0.002885
##
## Degrees of Freedom: 195 Total (i.e. Null);  192 Residual
## (4 observations deleted due to missingness)
## Null Deviance:      134900
## Residual Deviance: 15210      AIC: 1419
```

```
glm1 <- svyglm(wgt ~ town+age+town:age,srs1)
summary(glm1) # and we can get standard errors
```

```
##
## Call:
## svyglm(formula = wgt ~ town + age + town:age, design = srs1)
##
## Survey design:
## svydesign(ids = ~1, fpc = srssample1$popsize, data = srssample1)
```

```
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 3.054084   0.903812   3.379 0.000881 ***
## town        0.191847   0.317724   0.604 0.546678
## age         3.707055   0.195071  19.004 < 2e-16 ***
## town:age     0.002885   0.061762   0.047 0.962787
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 78.02151)
##
## Number of Fisher Scoring iterations: 2
```

```
# and plot the data using the survey package
# svyplot(formula, design, style = c("bubble", "hex", "grayhex", "subsample", "transparent"),
svyplot(wgt~hgt, design=srs1, style=c("bubble"))
```



```
# try to play with the plot styles!
```

```
# the plotting capabilities of the {survey} package are a bit limited. Therefore, you can also resort to
# ggplot2. However, functions like geom_smooth (below) will not be entirely correct.
```

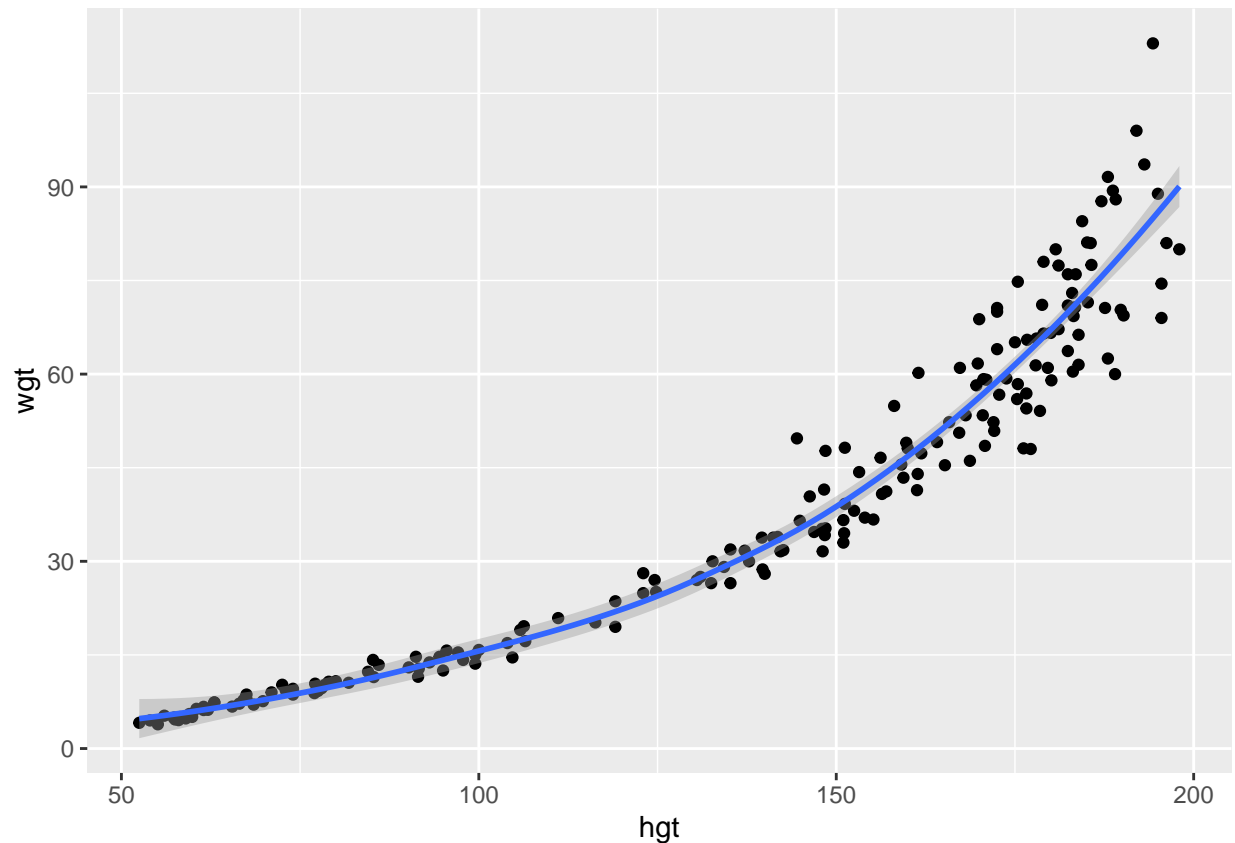
```
# compare with non-survey plot GGplot (note that s.e. may be wrong if you use something like geom_smooth)
ggplot(data=subset(boys, sample==1), aes(y=wgt, x=hgt)) +
```

```
geom_point()+
geom_smooth(method="loess")
```

```
## 'geom_smooth()' using formula 'y ~ x'
```

```
## Warning: Removed 8 rows containing non-finite values (stat_smooth).
```

```
## Warning: Removed 8 rows containing missing values (geom_point).
```



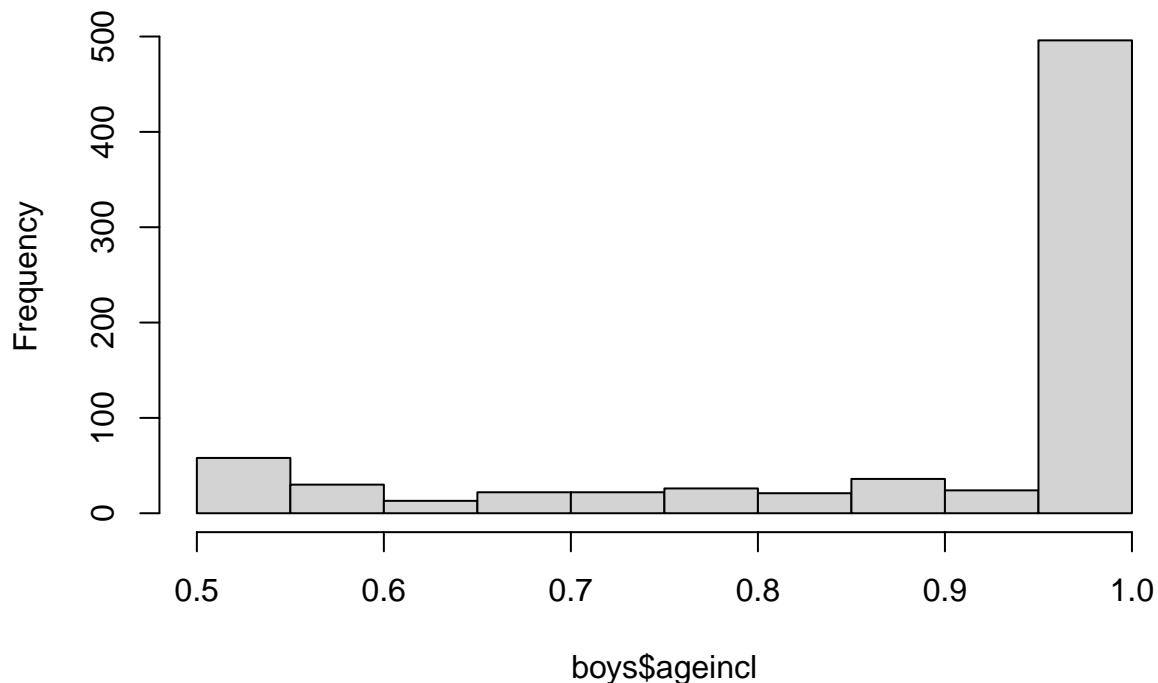
**bonus** only do this if you feel like it

- There are many cases where you in practice want to sample with unequal probabilities. This is now no longer a Simple Random Sample! Consider a case where we want to give older kids a higher probability to be included into the sample. In the case of our dataset, there will perhaps be more variation in how boys grow during puberty, and for that reason, we may want to ‘oversample’ older boys. We can do this formally using stratification, which we will discuss next time. Here we will for now use the cumulative probability-distribution of the variable age (pdf) to different inclusion probabilities.

```
# add the pdf to the population using a logistic function
boys$ageincl <- (1 / (1 + exp(-boys$age)))
hist(boys$ageincl) # plot it
```



## Histogram of boys\$ageincl



```
# now sample using the sample function from base r
set.seed=123 #for replication purposes
# adding an Id varianle (not strickly needed)
boys$id <- 1:nrow(boys)
# the code below samples proportional to the probability distribution
# using the {sample} function from base R
sample2 <- boys[sample(nrow(boys), 200, prob=boys$ageincl),]
```

**bonus 6.** Because we now gave boys who are older a higher probability to be included in our sample, our mean will be biased. By how much?

```
# The mean in our sample 2 is now biased! (why?)
mean(sample2$age) # way too high
```

```
## [1] 9.80303
```

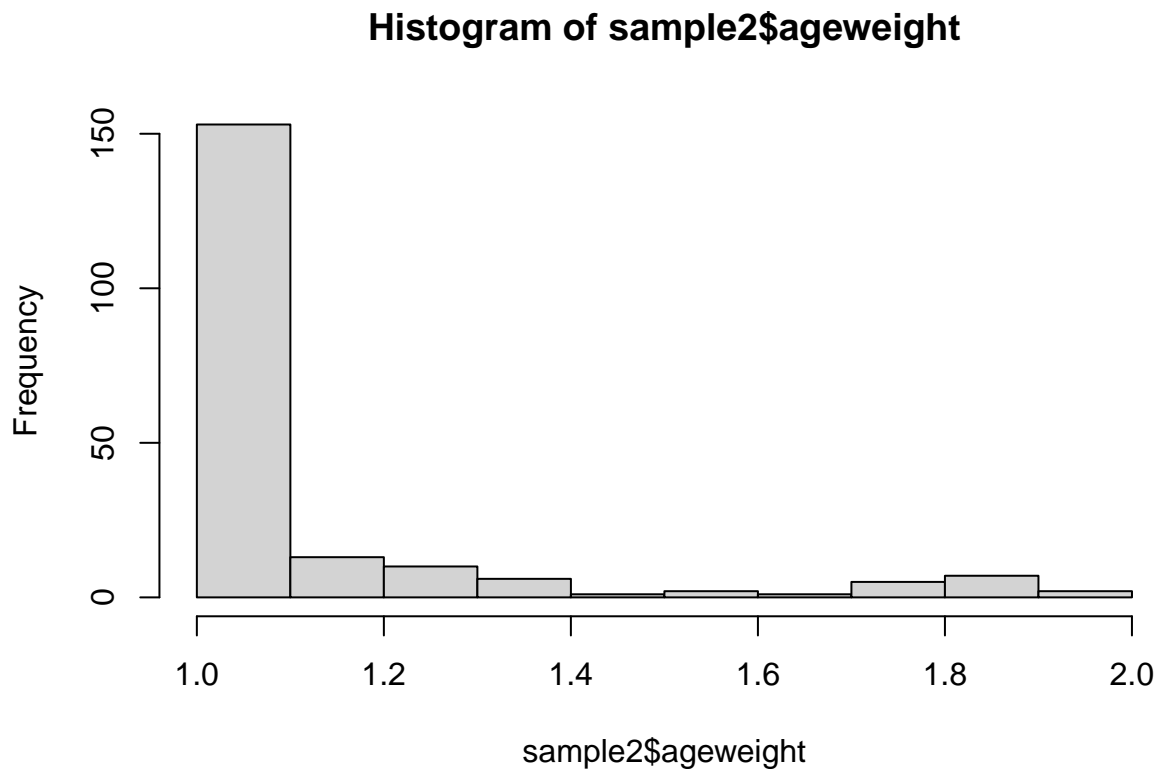
```
mean(sample2$age) - mean(boys$age)
```

```
## [1] 0.6441637
```

7. We would ideally like to be able to use our sample with unequal inclusion probabilities as well to say something about the population. The `{survey}` package can do this by including a `{weight}` variable that is the inverse of the inclusion probabilities. The code below shows how we can include the weight variable (called 'ageweight'), and how we can add this weight to the `svydesign` object. Note that we now give a new name to the `{svydesign()}` object, to distinguish that we have a different sample now.

What is the bias in the mean if we specify the `svydesign()` object like this?

```
# compute the inverse of ageweight to use as weight
sample2$ageweight <- 1/sample2$ageincl
hist(sample2$ageweight)
```



```
# specify the Svydesign object
rsdesign2 <- svydesign(ids=~1, fpc=sample2$popsize, weights=~sample2$ageweight, data=sample2) # notice th
svymean(~age, rsdesign2) # this is again unbiased
```

```
##      mean      SE
## age 8.9331 0.5018
```

### Exercise 3 - sample size calculations, working with se

Imagine you are doing a survey to predict voting behavior in the upcoming Dutch elections (in March 2021). The Dutch electoral system is fully proportional, meaning that there is no threshold to acquire a seat in parliament. There are 150 seats, so whenever you reach 0.66% or a multiple thereof, you get a seat in parliament. For more info on the Dutch electoral system, see [https://en.wikipedia.org/wiki/Elections\\_in\\_the\\_Netherlands](https://en.wikipedia.org/wiki/Elections_in_the_Netherlands)

In this exercise, we will assume that you can do a Simple Random Sample of all Dutch people who are 18 years and older (the eligible voting population). In practice, it is hard to do an SRS because both telephone and e-mail lists are of poor quality (or don't exist), but we will return to this issue in a later week.

The data are a bit artificial, but resemble how the different Dutch parties polled in August 2020.

The polling data show the following in terms of the % voting for each party: | VVD | 21% | liberal-conservatives | | PVV | 15% | anti-establishment right | | D66 | 9% | liberals | | CDA | 9% | christian democrats | | PvdA | 10% | social democrats | | SP | 8% | socialists | | GL | 8% | greens | | FvD | 7 % | anti-establishment right | | PvdD | 4% | animal rights party | | others | 9% | small christian parties, elderly, immigrant parties | |

1. The Table just shows the point estimates. What would be the Confidence Interval for the percentage of people voting for the VVD (liberal-right) in the population if this sample was based on 1500 respondents? Use the formula for the standard error for a proportion (see also Stuart p. 32)

$$SEp = \sqrt{p(1 - p) / n}$$

and use  $\alpha = .05$

2. And what about if the sample would be larger ( $n=2500$ ) or smaller ( $n=700$ )? Compute the se again
3. The Netherlands has many smaller parties which usually only get a few seats. Please compute the confidence interval for the percentage of people voting for PvdD (animal rights party) who are polling at 4%. Please compare the width of the confidence interval to that of the VVD. What do you notice?
4. Imagine that the PvdA would ask you to conduct a study for them. They don't like the idea that estimates from samples are uncertain, and ask you to determine how large a sample should be so that the confidence interval is at most 4 seats (2.6%). Can you work out what the sample size should for a sample?
5. After hearing your estimate, there is someone within the PvdA who has taken a statistics course, and has picked up that if you would use a different value for  $\alpha$  the sample size would be different.
  - A) What would the sample size be if you would use an  $\alpha$  of .10?
  - B) And an  $\alpha$  of .01?
6. Another way of expressing uncertainty is by using the margin of error, or the coefficient of variation. What would the required sample size need to be if the PvdA would stick to using an of .05, but would ask you to instead of a confidence interval, use a margin of error of  $\pm 1\%$ ,
7. Forming a government is a complicated matter that usually takes a lot of time and negotiations. Imagine the VVD would prefer to govern with the following three parties: CDA (14 seats), FvD (10 seats) and PVV (23 seats). Together the point estimate for the coalition would be 78, enough to form a government. Can you calculate the probability that such a coalition would indeed be able to achieve at least 76 seats? For now, assume that the votes for this bloc are independent of votes for another party.

#### Exercise 4 - More sample size calculations

You rarely get asked to do power calculations for descriptive statistics, like means or proportions. Much more common are power calculations in experimental settings. Imagine for example that in the biomedical sciences, a Randomized Control Trial (RCT) is designed to study the effect of a new type of medication to lower blood pressure.

The common treatment against bloodpressure (care as usual) is administering Medicine A: the average bloodpressure among patients who take this medication is 140/100 (systolic/diastolic), with a standard deviation of 15/10.

The new medication (medicine B) is supposed to lower bloodpressure (both systolic/diastolic) with about 2 units. The standard deviation is supposed to remain about the same. The company bringing Medicine B to market comes to you with the question how many patients they should include in their RCT.

- 1) Although this exercise seems more complicated than the previous exercise, what we want to test for, is whether the difference in blood pressure (5 units) is 'significant'.

In order to do power analyses, and sample size calculations, what you need is: - a choice for alpha. There is a lot to say about what value you should choose here. Within the social and behavioral sciences, a value of .05 is typical, but in order to avoid type 1 errors (false positives) people have argued to generally go with lower alpha values (eg.005), or called to always argue for your size of alpha. The choice of your alpha here then depends on how much you'd like to exclude the possibility of false positives vs.

- a. choose your alpha
  - b. calculate how many participants you would need if the difference between medicine A and B is as expected, and you want to do a one-sided test to establish that medicine B is indeed working better for both systolic and diastolic bloodpressure (ignore for now the issue that both types of blood pressure are correlated).
- 2) The previous question 1) was overly simple in the sense that we expect the standard deviation to be the same (most often it isn't), and we are only testing for the difference between two groups. In real life situations, there is often more uncertainty about the effect size that you expect, the standard deviations across groups, and also the number of groups (e.g. in Multivariate Statistics you talked about ANOVAs where you want to do F-tests, and perhaps planned comparisons). Although the setup of such analyses are a bit more complex, the idea behind power analyses are the same. A programme like (Gpower)[<https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower>] can help you with relative simple analyses. For more complicated analyses, you will need to do simulation studies, which is a topic that will be covered later this semester in "Programming in R".

## Exercise 5 - Sampling designs

(for this exercise it helps to first do the readings on stratified and cluster designs scheduled for the next meeting)

In week 1, you adopted a survey. This week, you will work out for your adopted survey what the sampling plan is that was used. In practice, simple random samples are used rarely in surveys, and either stratification (to make the sample more efficient) or clustering (to make the sample cheaper) are used, often in combination.

We will see how we can deal with stratified and cluster designs next time, and how to deal with combinations of clustering and stratification the week after that in R. For this week (and as part of assignment 2) try to work out what combination of stratification and clustering is used. In case you have adopted a multi-national survey or a survey that is conducted repeatedly over time, this is the point where you should focus on one country and/or one year for your survey only.

- 1) Find the documentation about sampling. For some surveys there may be a separate document explaining the sampling design, but for other surveys, you may have to work your way through a manual.
- 2) Work out the sampling design. If that design is complex, it helps to make a drawing of the various stages. Start by writing down your target population and list that is used to sample (see take home exercise week 1). Then describe step by step what strata or clusters were used in step 1 of the design, what happens in any further steps, etc. It is ok at this point if you come across terms you don't know, or unclarities in the sampling design. Surveys don't always describe their sampling designs in a good way (although they should). Write down unclear terms that you encounter in the documentation and bring this list to class next time.

**end of file**