Lecture 6: Augmented vectors, Factor + Labelled Variables

Introduction

Logistics

Reading to do before next class:

- Work through slides from lecture 5 that we didn't get to in class (attaching aggregate measures)
- GW 15.1 - 15.2 (factors) [this is like 2-3 pages]
- [OPTIONAL] GW 15.3 - 15.5 (remainder of "factors" chapter)
- [OPTIONAL] GW 20.6 - 20.7 (attributes and augmented vectors)
- [OPTIONAL] GW 10 (tibbles)

Explanation about `beamer_header.tex` in YAML header:

- We are calling the beamer_header.tex file in the background to customize our slides. Without this LaTeX file, our slides would compile according to the default beamer presentation (PDF).
  - Why would we want to do this?
  - We can customize our slides with the beamer_header.tex LaTeX file to include page numbers, change heading options, or change slide colors (in addition to other things).
- `includes` option in the YAML header customizes the beamer presentation slides
  - Here is a link to a short description of the includes option in the YAML header.

What we will do today

Libraries we will use today

"Load" the package we will use today (output omitted)

- **you must run this code chunk after installing these packages**

```
library(tidyverse)
library(haven)
library(labelled)
library(lubridate)
```

If package not yet installed, then must install before you load. Install in "console" rather than .Rmd file

- Generic syntax: `install.packages("package_name")`
- Install "tidyverse": `install.packages("tidyverse")`

Note: when we load package, name of package is not in quotes; but when we install package, name of package is in quotes:

- `install.packages("tidyverse")`
- `library(tidyverse)`

Augmented vectors

Data we will use to introduce augmented vectors

```
rm(list = ls()) # remove all objects

#load("../../data/prospect_list/western_washington_college_board_list.RData")
load(url("https://github.com/ozanj/rclass/raw/master/data/prospect_list/wwlist_
```

Review data types and structures

Vectors are the primary data structures in R

Two types of vectors:

1. **atomic vectors**
2. **lists**

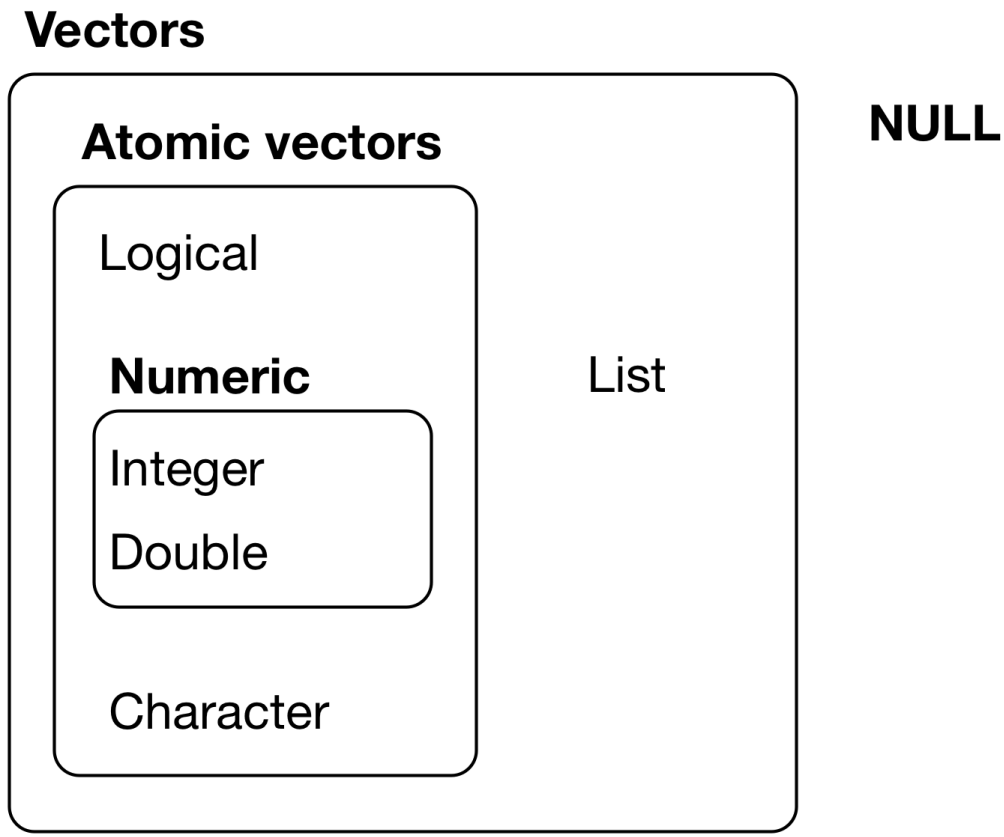

Figure 1: Overview of data structures (Grolemund and Wickham, 2018)

Review data structures: atomic vectors

An **atomic vector** is a collection of values

- each value in an atomic vector is an **element**
- all elements within vector must have same **data type**

```
(a <- c(1,2,3)) # parentheses () assign and print object in one step
#> [1] 1 2 3
length(a)
#> [1] 3
typeof(a)
#> [1] "double"
str(a)
#>  num [1:3] 1 2 3
```

Can assign **names** to vector elements, creating a **named atomic vector**

```
(b <- c(v1=1,v2=2,v3=3))
#> v1 v2 v3
#>  1  2  3
length(b)
#> [1] 3
typeof(b)
#> [1] "double"
str(b)
#>  Named num [1:3] 1 2 3
#>  - attr(*, "names")= chr [1:3] "v1" "v2" "v3"
```

Review data structures: lists

- Like atomic vectors, **lists** are objects that contain **elements**
- However, **data type** can differ across elements within a list
  - an element of a list can be another list

```
list_a <- list(1,2,"apple")
typeof(list_a)
#> [1] "list"
length(list_a)
#> [1] 3
str(list_a)
#> List of 3
#>  $ : num 1
#>  $ : num 2
#>  $ : chr "apple"

list_b <- list(1, c("apple", "orange"), list(1, 2))
length(list_b)
#> [1] 3
str(list_b)
#> List of 3
#>  $ : num 1
#>  $ : chr [1:2] "apple" "orange"
#>  $ :List of 2
#>   ..$ : num 1
#>   ..$ : num 2
```

Review data structures: lists

Like atomic vectors, elements within a list can be named, thereby creating a **named list**

```
# not named
str(list_b)
#> List of 3
#>  $ : num 1
#>  $ : chr [1:2] "apple" "orange"
#>  $ :List of 2
#>   ..$ : num 1
#>   ..$ : num 2

# named
list_c <- list(v1=1, v2=c("apple", "orange"), v3=list(1, 2, 3))
str(list_c)
#> List of 3
#>  $ v1: num 1
#>  $ v2: chr [1:2] "apple" "orange"
#>  $ v3:List of 3
#>   ..$ : num 1
#>   ..$ : num 2
#>   ..$ : num 3
```

Review data structures: a data frame is a list

A **data frame** is a list with the following characteristics:

- All the elements must be **vectors** with the same **length**
- Data frames are **augmented lists** because they have additional **attributes** [described later]

```
#a regular list
list_d <- list(col_a = c(1,2,3), col_b = c(4,5,6), col_c = c(7,8,9))
typeof(list_d)
#> [1] "list"
str(list_d)
#> List of 3
#>  $ col_a: num [1:3] 1 2 3
#>  $ col_b: num [1:3] 4 5 6
#>  $ col_c: num [1:3] 7 8 9

#a data frame
df_a <- data.frame(col_a = c(1,2,3), col_b = c(4,5,6), col_c = c(7,8,9))
typeof(df_a)
#> [1] "list"
str(df_a)
#> 'data.frame':    3 obs. of  3 variables:
#>  $ col_a: num  1 2 3
#>  $ col_b: num  4 5 6
#>  $ col_c: num  7 8 9
```

Attributes and augmented vectors

Atomic vectors versus augmented vectors

Atomic vectors [our focus so far]

- I think of atomic vectors as "just the data"
- Atomic vectors are the building blocks for augmented vectors

Augmented vectors

- **Augmented vectors** are atomic vectors with additional **attributes** attached

Attributes

- **Attributes** are additional "metadata" that can be attached to any object (e.g., vector or list)
- Examples of some important attributes in R:
  - **Names**: name the elements of a vector (e.g., variable names)
  - **value labels**: character labels (e.g., "Charter School") attached to numeric values
  - **Object class**: How object should be treated by object oriented programming language [discussed below]

Main takaway:

- Augmented vectors are atomic vectors (just the data) with additional attributes attached

Attributes in vectors

Identify attributes in any object using the `attributes()` function

```
#vector with no attributes
vector1 <- c(1,2,3,4)
vector1
#> [1] 1 2 3 4
attributes(vector1)
#> NULL

#vector with name attributes
vector2 <- c(a = 1, b= 2, c= 3, d = 4)
vector2
#> a b c d
#> 1 2 3 4
attributes(vector2)
#> $names
#> [1] "a" "b" "c" "d"
```

Attributes in lists

```r
#no attributes
list1 <- list(c(1,2,3), c(4,5,6))
attributes(list1)
#> NULL

#list with attributes
list2 <- list(col_a = c(1,2,3), col_b = c(4,5,6))
str(list2)
#> List of 2
#>  $ col_a: num [1:3] 1 2 3
#>  $ col_b: num [1:3] 4 5 6
attributes(list2)
#> $names
#> [1] "col_a" "col_b"

#data frame with attributes
list3 <- data.frame(col_a = c(1,2,3), col_b = c(4,5,6))
str(list3)
#> 'data.frame':    3 obs. of  2 variables:
#>  $ col_a: num  1 2 3
#>  $ col_b: num  4 5 6
attributes(list3)
#> $names
#> [1] "col_a" "col_b"
#>
#> $class
#> [1] "data.frame"
```

Object class

Object class

Every object in R has a **class**

- Object class defines rules for how object can be treated by object oriented programming language (e.g., which functions you can apply to object)
- class is an **attribute** of an object

Identify the class of an object using the `class()` function

```
(vector2 <- c(a = 1, b= 2, c= 3, d = 4))
#> a b c d
#> 1 2 3 4
class(vector2)
#> [1] "numeric"
```

When I encounter a new object I often investigate object by applying `typeof()`, `class()`, and `attributes()` functions to that object

```
vector2
#> a b c d
#> 1 2 3 4
typeof(vector2)
#> [1] "double"
class(vector2)
#> [1] "numeric"
attributes(vector2)
#> $names
#> [1] "a" "b" "c" "d"
```

Object class

Why is **class** important?

- Specific functions usually work with only particular **classes** of objects
  - e.g., "date"" functions usually only work on objects with a date class
  - "string" functions usually only work with on objects with a character class
  - Functions that do mathematical computation usually work on objects with a numeric class
- Note: functions care about object **class**, not object **type**

object with `numeric` class (output omitted)

```
str(wwlist)

typeof(wwlist$med_inc_zip)
class(wwlist$med_inc_zip)
sum(wwlist$med_inc_zip[1:10], na.rm = TRUE) # numeric function

# load library with date functions
library(lubridate)
#Sys.setenv(TZ="America/Los_Angeles") #setting time zone to Los Angeles time
year(wwlist$med_inc_zip[1:10]) # date function
```

Object class

Why is **class** important?

- Specific functions usually work with only particular **classes** of objects
- Note: functions care about object **class**, not object **type**

Object with `character` class

```
str(wwlist$hs_city)
typeof(wwlist$hs_city)
class(wwlist$hs_city)

tolower(wwlist$hs_city[1:10]) # string function
sum(wwlist$hs_city, na.rm = TRUE) # numeric function
```

Object with a date class

```
typeof(wwlist$receive_date)
class(wwlist$receive_date)

year(wwlist$receive_date[1:10]) # date function
sum(wwlist$receive_date) # numeric function
```

Class and object oriented programming

Definition of object oriented programming from this LINK

> *"Object-oriented programming (OOP) refers to a type of computer programming in which programmers define not only the data type of a data structure, but also the types of operations (functions) that can be applied to the data structure."*

Object **class** is fundamental to object oriented programming because:

- object class determines which functions can be applied to the object
- object class also determines what those functions do to the object

Many different object classes exist in R

- we can also create our own classes
- but in this course we will work with classes that have been created by others

Class == factor

Factors

Factors are an object *class* used to display categorical data (e.g., marital status)

- A factor is an **augmented vector** built by attaching a "levels" attribute to an (atomic) integer vectors

Usually, we would prefer a categorical variable (e.g., race, school type) to be a factor variable rather than a character variable

- So far in the course I have made all categorical variables character variables because we had not introduced factors yet

Below, I'll create a factor version of the character variable `ethn_code`

- (don't worry about understanding this code; I'll explain it later)

```
str(wwlist$ethn_code)
#>  chr [1:268396] "other-2 or more" "white" "white" "other-2 or more" ...
class(wwlist$ethn_code)
#> [1] "character"
# create factor var; tidyverse approach
wwlist <- wwlist %>% mutate(ethn_code_fac = factor(ethn_code))
#wwlist$ethn_code_fac <- factor(wwlist$ethn_code) # base r approach

str(wwlist$ethn_code_fac)
#>  Factor w/ 10 levels "american indian or alaska native",..: 7 10 10 7 10 7 7
```

Factors

A factor is an **augmented vector** built by attaching a "levels" attribute to an (atomic) integer vector

Compare (character) `ethn_code` to (factor) `ethn_code_fac` (output omitted)

```
#character var
typeof(wwlist$ethn_code)
class(wwlist$ethn_code)
str(wwlist$ethn_code)
attributes(wwlist$ethn_code)

#factor var
typeof(wwlist$ethn_code_fac)
class(wwlist$ethn_code_fac)
str(wwlist$ethn_code_fac)
attributes(wwlist$ethn_code_fac)
```

Main takeaway

- `ethn_code_fac` has `type=integer` and `class=factor` because the variable has a "levels" attribute
- Underlying data are integers but levels attribute is used to display the data.

```
wwlist$ethn_code_fac[1:4] # print first few obs of ethn_code_fac
#> [1] other-2 or more white           white           other-2 or more
#> 10 Levels: american indian or alaska native ...
```

Working with factor variables

```
attributes(wwlist$ethn_code_fac)
```

Refer to categories of a factor by the values of the **level attribute** rather than the underlying values of the variable

Task

- count the number of prospects in object `wwlist` who identify as "white"

```
# referring to variable value; this doesn't work
wwlist %>% filter(ethn_code_fac==10) %>% count
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1     0

#referring to value of level attribute; this works
wwlist %>% filter(ethn_code_fac=="white") %>% count
#> # A tibble: 1 x 1
#>        n
#>    <int>
#> 1 159680
```

Working with factor variables

Task

- count the number of prospects in object `wwlist` who identify as "white"

If you want to refer to underlying values, then apply `as.integer()` function to the factor variable

```
attributes(wwlist$ethn_code_fac)
#> $levels
#>  [1] "american indian or alaska native"
#>  [2] "asian or native hawaiian or other pacific islander"
#>  [3] "black or african american"
#>  [4] "cuban"
#>  [5] "mexican/mexican american"
#>  [6] "not reported"
#>  [7] "other-2 or more"
#>  [8] "other spanish/hispanic"
#>  [9] "puerto rican"
#> [10] "white"
#>
#> $class
#> [1] "factor"
wwlist %>% filter(as.integer(ethn_code_fac)==10) %>% count
#> # A tibble: 1 x 1
#>        n
#>    <int>
#> 1 159680
```

How to identify the variable values associated with factor levels

Let's create a factor version of the character variable `psat_range`

```
wwlist <- wwlist %>% mutate(psat_range_fac = factor(psat_range)) # create factor
```

Run below code in console rather than code chunk to see values associated with each factor

```
wwlist %>% count(psat_range_fac)
#> Warning: Factor `psat_range_fac` contains implicit NA, consider using
#> `forcats::fct_explicit_na`
attributes(wwlist$psat_range_fac)
levels(wwlist$psat_range_fac) #starts at 1
nlevels(wwlist$psat_range_fac) #7 levels total
levels(wwlist$psat_range_fac)[1:3] #prints levels 1-3
```

Once you know values associated with factor, you can filter based on values

```
wwlist %>% filter(as.integer(psat_range_fac)==4) %>% count()
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1  8348
```

Or you can just filter based on value of **factor levels**

```
wwlist %>% filter(psat_range=="1270-1520") %>% count()
#> # A tibble: 1 x 1
#>       n
#>   <int>
```

Creating factor variables from character variables or from integer variables

See Appendix

Factor student exercise

1. After running the code below, use `typeof`, `class`, `str`, and `attributes` functions to check the new variable `receive_year`
2. Create a factor variable from the input variable `receive_year` and name it `receive_year_fac`
3. Run the same functions (`typeof`, `class`, etc.) from the first question using the new variable you created
4. Get a count of `receive_year_fac`. **hint:** you could also run this in the console to see values associated with each factor

Run this code to create a year variable from the input variable "receive_date"

```
#wwlist %>% glimpse()

library(lubridate) #load library if you haven't already
wwlist <- wwlist %>%
  mutate(receive_year = year(receive_date)) #creating year variable with the lub

#Check variable
wwlist %>%
  count(receive_year)

wwlist %>%
  group_by(receive_year) %>%
  count(receive_date)
```

Factor student exercise solutions

1. Use `typeof`, `class`, `str`, and `attributes` functions to check the new variable `receive_year`

```
typeof(wwlist$receive_year)
#> [1] "double"
class(wwlist$receive_year)
#> [1] "numeric"
str(wwlist$receive_year)
#>  num [1:268396] 2016 2016 2016 2016 2016 ...
attributes(wwlist$receive_year)
#> NULL
```

Factor student exercise solutions

2. Now create a factor variable from the input variable `receive_year` and name it `receive_year_fac`

```
# create factor var; tidyverse approach
wwlist <- wwlist %>%
  mutate(receive_year_fac = factor(receive_year))
```

Factor student exercise solutions

3. Run the same functions (`typeof` , `class` , etc.) from the first question using the new variable you created

```
typeof(wwlist$receive_year_fac)
#> [1] "integer"
class(wwlist$receive_year_fac)
#> [1] "factor"
str(wwlist$receive_year_fac)
#>  Factor w/ 3 levels "2016","2017",..: 1 1 1 1 1 1 1 1 1 1 ...
attributes(wwlist$receive_year_fac)
#> $levels
#> [1] "2016" "2017" "2018"
#>
#> $class
#> [1] "factor"
```

Factor student exercise solutions

4. Get a count of `receive_year_fac`. **hint:** you could also run this in the console to see values associated with each factor

```
wwlist %>%
  count(receive_year_fac)
#> # A tibble: 3 x 2
#>   receive_year_fac     n
#>   <fct>            <int>
#> 1 2016             89637
#> 2 2017             89816
#> 3 2018             88943
```

Class == labelled

Data we will use to introduce `labelled` class

High school longitudinal surveys from National Center for Education Statistics (NCES)

- Follow U.S. students from high school through college, labor market

We will be working with High School Longitudinal Study of 2009 (HSLS:09)

- Follows 9th graders from 2009
- Data collection waves

```
- Base Year (2009)
- First Follow-up (2012)
- 2013 Update (2013)
- High School Transcripts (2013-2014)
- Second Follow-up (2016)
```

`haven` package

`haven`, which is part of **tidyverse**, "enables R to read and write various data formats" from the following statistical packages:

- SAS
- SPSS
- Stata

When using `haven` to read data, resulting R objects have these characteristics:

- Are **tibbles**, a particular type of data frame we discuss in future weeks
- Transform variables with "value labels" into the `labelled()` class [our focus today]
  - `labelled` is an object **class** created by folks who created `haven` package
  - `labelled` is an object class, just like `factor` is an object class
  - `labelled` and `factor` classes are both viable alternatives for categorical variables
  - Helpful description of `labelled` class HERE
- Dates and times converted to R date/time classes
- Character vectors not converted to factors

`haven` package

Use `read_dta()` function from `haven` to import Stata dataset into R

```
hsls <- read_dta(file="https://github.com/ozanj/rclass/raw/master/data/hsls/hsl
```

Let's examine the data [you **must** run this code chunk]

```
names(hsls)
names(hsls) <- tolower(names(hsls)) # convert names to lowercase
names(hsls)

str(hsls) # ugh

str(hsls$s3classes)
attributes(hsls$s3classes)
typeof(hsls$s3classes)
class(hsls$s3classes)
```

`labelled` package

Purpose of the `labelled` package is to work with data imported from SPSS/Stata/SAS using the `haven` package.

- In particular, `labelled` package creates functions to work with objects that have `labelled` class
- From package documentation: "purpose of the `labelled` package is to provide functions to manipulate *metadata* as variable labels, value labels and defined missing values using the `labelled` class and the `label` attribute introduced in `haven` package.
- More info on the `labelled` package: LINK

Functions in `labelled` package

- Full list
- A couple relevant functions
  - `val_labels` : get or set variable *value labels*
  - `var_label` : get or set a *variable label*

```
attributes(hsls$s3classes)

hsls %>% select(s3classes) %>% var_label()
hsls %>% select(s3classes) %>% val_labels()
```

Core concepts for understanding `labelled` class [SKIP]

atomic vectors (and lists) the underlying data

- data structures: vector or list
- data type: numeric (integer or double); character; logical

```
typeof(hsls$s3classes)
#> [1] "double"
```

augmented vectors are atomic vectors with **attributes** attached

attributes are "metadata" attached to an object. Examples

- **names**: names of elements of a vector or list (e.g., variable names)
- **levels**: display output associated with values of a factor variable
- **class**: e.g., factor, labelled

```
attributes(hsls$s3classes)
```

class is an object oriented programming concept. The `class` of an object determines which functions can be applied to the object and what those functions do

- e.g., can't apply `sum()` to an object where `class=character`

What is `labelled` class?

- `labelled` is an object class created by the `haven` package for importing variables from SAS/SPSS/Stata that have **value labels**
- **value labels** [in Stata] are labels attached to specific values of a variable:
  - e.g., variable value `1` attached to value label "married", `2` ="single", `3` ="divorced"
- Variables in an R data frame with `class==labelled`:
  - data `type` can be numeric(double) or character
  - To see `value labels` associated with each value:
    - `attr(data_frame_name$variable_name,"labels")`
    - e.g., `attr(hsls$s3classes,"labels")`

Let's investigate the attributes of `hsls$s3classes`

```
typeof(hsls$s3classes)
class(hsls$s3classes)
str(hsls$s3classes)
attributes(hsls$s3classes)
```

use `attr(object_name,"attribute_name")` to refer to each attribute

```
attr(hsls$s3classes,"label")
attr(hsls$s3classes,"labels")
attr(hsls$s3classes,"class")
attr(hsls$s3classes,"format.stata")
```

Working with `labelled` class data

Show variable labels (`var_label`); and show value labels (`val_labels`)

```
hsls %>% select(s3classes,s3clglvl) %>% var_label #show variable label
hsls %>% select(s3classes,s3clglvl) %>% val_labels #show value labels
```

Create frequency tables with `labelled` class variables using `count()`

- Default setting is to show variable **values** not **value labels**

```
hsls %>% count(s3classes)
#investigate the object created
hsls_freq_temp <- hsls %>% count(s3classes)
hsls_freq_temp
rm(hsls_freq_temp)
```

To make frequency table show **value labels** add `%>% as_factor()` to pipe

- `as_factor()` is function from `haven` that converts an object to a factor

```
hsls %>% count(s3classes) %>% as_factor()
#investigate the object created
hsls_freq_temp <- hsls %>% count(s3classes)  %>% as_factor()
hsls_freq_temp
rm(hsls_freq_temp)
```

Working with `labelled` class data

To isolate values of `labelled` class variables in `filter()` function:

- refer to variable **value**, not the **value label**

Task

- how many observations in var `s3classes` associated with "Unit non-response"
- how many observations in var `s3classes` associated with "Yes"

General steps to follow:

1. investigate object
2. use filter to isolate desired observations

Investigate object

```
class(hsls$s3classes)
hsls %>% select(s3classes,s3clglvl) %>% var_label #show variable label
hsls %>% select(s3classes,s3clglvl) %>% val_labels #show value label
hsls %>% count(s3classes) # freq table, values
hsls %>% count(s3classes) %>% as_factor() # freq table, value labels
```

filter specific values

```
hsls %>% filter(s3classes==-8) %>% count() # -8 = unit non-response
hsls %>% filter(s3classes==1) %>% count() # 1 = yes
```

Labelled student exercise

1. Get variable and value labels of `s3hs`
2. Get a count of the variable showing the values and the value labels. **hint** use factor()
3. Filter if value is associated with "Missing"
4. Filter if value is associated with "Missing" or "Unit non-response"

Labelled student exercise solutions

1. Get variable and value labels of `s3hs`

```
hsls %>%
  select(s3hs) %>%
  var_label()
#> $s3hs
#> [1] "S3 B01F Attending high school or homeschool as of Nov 1 2013"

hsls %>%
  select(s3hs) %>%
  val_labels()
#> $s3hs
#>                                     Missing
#>                                          -9
#>                               Unit non-response
#>                                          -8
#>                         Item legitimate skip/NA
#>                                          -7
#>                       Component not applicable
#>                                          -6
#> Item not administered: abbreviated interview
#>                                          -4
#>                                         Yes
#>                                           1
#>                                          No
#>                                           2
#>                                    Don't know
```

Labelled student exercise solutions

2. Get a count of the variable `s3hs` showing the value labels. **hint** use factor()

```
hsls %>%
  count(s3hs)
#> # A tibble: 6 x 2
#>                              s3hs     n
#>                      <dbl+lbl> <int>
#> 1 -9 [Missing]                  22
#> 2 -8 [Unit non-response]      4945
#> 3 -7 [Item legitimate skip/NA] 16770
#> 4  1 [Yes]                      624
#> 5  2 [No]                       985
#> 6  3 [Don't know]               157

hsls %>%
  count(s3hs) %>%
  as_factor()
#> # A tibble: 6 x 2
#>   s3hs                        n
#>   <fct>                   <int>
#> 1 Missing                    22
#> 2 Unit non-response        4945
#> 3 Item legitimate skip/NA 16770
#> 4 Yes                        624
#> 5 No                         985
#> 6 Don't know                 157
```

Labelled student exercise solutions

3. Filter if value is associated with "Missing"

```
hsls %>%
  filter(s3hs== -9) %>%
  count()
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1    22
```

Labelled student exercise solutions

4. Filter if value is associated with "Missing" or "Unit non-response"

```
hsls %>%
  filter(s3hs== -9 | s3hs== -8) %>%
  count()
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1  4967
```

Comparing labelled class to factor class

Comparing `class==labelled` to `class==factor`

	`class==labelled`	`class==factor`
data type	numeric or character	integer
name of value label attribute	labels	levels
refer to data using	variable values	levels attribute

Converting `class==labelled` to `class==factor`

The `as_factor()` function from `haven` package converts variables with `class==labelled` to `class==factor`

- Can be used for descriptive statistics

```
hsls %>% select(s3classes) %>% count(s3classes) %>% as_factor()
```

- Can create object with some or all `labelled` vars converted to `factor`

```
hsls_f <- as_factor(hsls,only_labelled = TRUE)
```

Let's examine this object

```
glimpse(hsls_f)
hsls_f %>% select(s3classes,s3clglvl) %>% str()
typeof(hsls_f$s3classes)
class(hsls_f$s3classes)
attributes(hsls_f$s3classes)

hsls_f %>% select(s3classes) %>% var_label()
hsls_f %>% select(s3classes) %>% val_labels()
```

Working with `class==factor` data

Showing values associated with factor levels

```
hsls_f %>% count(s3classes)
#> # A tibble: 5 x 2
#>   s3classes             n
#>   <fct>             <int>
#> 1 Missing              59
#> 2 Unit non-response  4945
#> 3 Yes               13477
#> 4 No                 3401
#> 5 Don't know         1621
```

In code, refer `level` attribute not variable value

```
hsls_f %>% filter(s3classes=="Yes") %>% count(s3classes)
#> # A tibble: 1 x 2
#>   s3classes     n
#>   <fct>     <int>
#> 1 Yes       13477
```

Creating factor variables

Create factors [from string variables]

To create a factor variable from string variable

1. create a character vector containing underlying data
2. create a vector containing valid levels
3. Attach levels to the data using the `factor()` function

```
#underlying data: months my fam is born
x1 <- c("Jan", "Aug", "Apr", "Mar")
#create vector with valid levels
month_levels <- c("Jan", "Feb", "Mar", "Apr", "May", "Jun",
  "Jul", "Aug", "Sep", "Oct", "Nov", "Dec")
#attach levels to data
x2 <- factor(x1, levels = month_levels)
```

Note how attributes differ

```
str(x1)
#>  chr [1:4] "Jan" "Aug" "Apr" "Mar"
str(x2)
#>  Factor w/ 12 levels "Jan","Feb","Mar",..: 1 8 4 3
```

Sorting differs

```
sort(x1)
#> [1] "Apr" "Aug" "Jan" "Mar"
sort(x2)
#> [1] Jan Mar Apr Aug
#> Levels: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
```

Create factors [from string variables]

Let's create a character version of variable `hs_state` and then turn it into a factor

```
#wwlist %>%
#  count(hs_state)
#Subset obs to West Coast states
wwlist_temp <- wwlist %>%
  filter(hs_state %in% c("CA", "OR", "WA"))

#Create character version of high school state for West Coast states only
wwlist_temp$hs_state_char <- as.character(wwlist_temp$hs_state)

#investigate character variable
str(wwlist_temp$hs_state_char)
table(wwlist_temp$hs_state_char)

#create new variable that assigns levels
wwlist_temp$hs_state_fac <- factor(wwlist_temp$hs_state_char, levels = c("CA","
str(wwlist_temp$hs_state_fac)
attributes(wwlist_temp$hs_state_fac)

#wwlist_temp %>%
#  count(hs_state_fac)
rm(wwlist_temp)
```

Create factors [from string variables]

How the `levels` argument works when underlying data is character

- Matches value of underlying data to value of the level attribute
- Converts underlying data to integer, with level attribute attached

See chapter 15 of Wickham for more on factors (e.g., modifying factor order, modifying factor levels)

Creating factors [from integer vectors]

Factors are just integer vectors with level attributes attached to them. So, to create a factor:

1. create a vector for the underlying data
2. create a vector that has level attributes
3. Attach levels to the data using the `factor()` function

```
a1 <- c(1,1,1,0,1,1,0) #a vector of data
a2 <- c("zero","one") #a vector of labels

#attach labels to values
a3 <- factor(a1, labels = a2)
a3
#> [1] one  one  one  zero one  one  zero
#> Levels: zero one
str(a3)
#>  Factor w/ 2 levels "zero","one": 2 2 2 1 2 2 1
```

Note: By default, `factor()` function attached "zero" to the lowest value of vector `a1` because "zero" was the first element of vector `a2`

Creating factors [from integer vectors]

Let's turn an integer variable into a factor variable in the `wwlist` data frame

Create integer version of `receive_year`

```
#typeof(wwlist_temp$receive_year)
wwlist$receive_year_int <- as.integer(wwlist$receive_year)
str(wwlist$receive_year_int)
#>  int [1:268396] 2016 2016 2016 2016 2016 2016 2016 2016 2016 2016 ...
typeof(wwlist$receive_year_int)
#> [1] "integer"
```

Assign levels to values of integer variable

```
wwlist$receive_year_fac <- factor(wwlist$receive_year_int,
      labels=c("Twenty-sixteen","Twenty-seventeen","Twenty-eighteen"))
str(wwlist$receive_year_fac)
str(wwlist$receive_year)

#Check variable
wwlist %>%
  count(receive_year_fac)

wwlist %>%
  count(receive_year)
```