

Lecture 6: Augmented vectors, Factor + Labelled Variables

Introduction

What we will do today

1. Introduction
2. Attributes and augmented vectors
 - 2.1 Review data types and structures
 - 2.2 Attributes and augmented vectors
3. Object class
4. Class == factor
5. Class == labelled
 - 5.1 Set variable and value labels
 - 5.2 Comparing labelled class to factor class
6. Appendix. Creating factor variables

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)`

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_

# will this get rid of warnings "Unknown or uninitialised column: 'ethn_code_fac"
wwlist <- wwlist %>% mutate(eth_code_fac = NULL) # remove variable
```

Attributes and augmented vectors

Review data types and structures

Review data structures: **Vectors**

Two types of vectors:

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

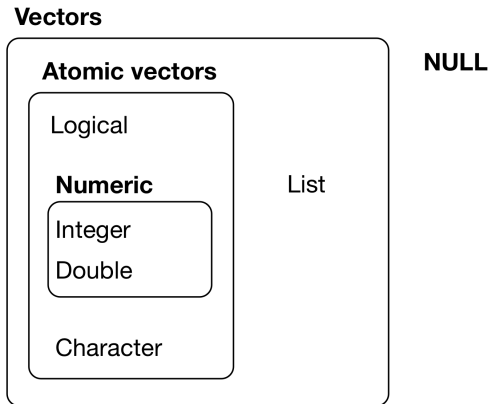


Figure 1: Overview of data structures (Grolemund and Wickham, 2018)

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) # length = number of elements
#> [1] 3
typeof(a) # numeric atomic vector, type=double
#> [1] "double"
str(a) # investigate structure of object
#> 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**

#a regular list

```
(list_d <- list(col_a = c(1,2,3), col_b = c(4,5,6), col_c = c(7,8,9)))
```

```
#> $col_a
```

```
#> [1] 1 2 3
```

```
#>
```

```
#> $col_b
```

```
#> [1] 4 5 6
```

```
#>
```

```
#> $col_c
```

```
#> [1] 7 8 9
```

```
typeof(list_d)
```

```
#> [1] "list"
```

#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)))
```

```
#>   col_a col_b col_c
```

```
#> 1     1     4     7
```

```
#> 2     2     5     8
```

```
#> 3     3     6     9
```

```
typeof(df_a)
```

```
#> [1] "list"
```

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)

Example: variables of a dataset

- ▶ a data frame is a list
- ▶ each element in the list is a variable, which consists of:
 - ▶ atomic vector (“just the data”);
 - ▶ variable **name**, which is an attribute we attach to the element/variable
 - ▶ any other attributes we want to attach to element/variable

Other examples of attributes in R

- ▶ **value labels**: character labels (e.g., “Charter School”) attached to numeric values
- ▶ **Object class**: Specifies how object treated by object oriented programming language

Main takaway:

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

Attributes and functions to identify/modify attributes

Description of attributes from Grolemund and Wickham 20.6

- ▶ “Any vector can contain arbitrary additional **metadata** through its **attributes**”
- ▶ “You can think of **attributes** as named list of vectors that can be attached to any object”

Functions to identify and modify attributes

- ▶ `attributes()` function to describe all attributes of an object
- ▶ `attr()` to see individual attribute of an object or set/change an individual attribute of an object

attributes() function describes all attributes of an object

```
?attributes
```

An atomic vector

```
#vector with name attributes
```

```
(vector1 <- c(a = 1, b = 2, c = 3, d = 4))
```

```
#> a b c d
```

```
#> 1 2 3 4
```

```
attributes(vector1)
```

```
#> $names
```

```
#> [1] "a" "b" "c" "d"
```

```
#remove all attributes from object
```

```
attributes(vector1) <- NULL
```

```
vector1
```

```
#> [1] 1 2 3 4
```

```
attributes(vector1)
```

```
#> NULL
```


attributes() function, attributes of a variable in a dataset

Accessing variable using `[[]]` subset operator

- ▶ recall `object_name[["element_name"]]` accesses contents of the element
- ▶ If object is a data frame, `df_name[["var_name"]]` accesses contents of variable
 - ▶ for simple vars like `firstgen` syntax yields an atomic vector ("just the data")
- ▶ shorthand syntax for `df_name[["var_name"]]` is `df_name$var_name`

```
str(wwlist[["firstgen"]])
#> chr [1:268396] NA "N" "N" "N" NA "N" "N" "Y" "Y" "N" "N" "N" "N" "N" ...
attributes(wwlist[["firstgen"]])
#> NULL

str(wwlist$firstgen) # same same
#> chr [1:268396] NA "N" "N" "N" NA "N" "N" "Y" "Y" "N" "N" "N" "N" "N" ...
attributes(wwlist$firstgen)
#> NULL
```

Accessing variable using `[]` subset operator

- ▶ `object_name["element_name"]` creates object of same type as `object_name`
- ▶ contains attributes of `object_name`, atomic vector associated with `element_name`, and any attributes associated with `element_name`

```
str(wwlist["firstgen"])
attributes(wwlist["firstgen"])
```

Attributes of lists and data frames

```
#attributes of a named list
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"

#attributes of a data frame
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"
#>
#> $row.names
#> [1] 1 2 3
```

attr() function: get or set specific attributes of an object

Syntax

► Get: `attr(x, which, exact = FALSE)`

► Set: `attr(x, which) <- value`

Arguments

- `x` an object whose attributes are to be accessed.
- `which` a non-empty character string specifying which attribute is to be accessed
- `exact` logical: should `which` be matched exactly? default is `exact = FALSE`
- `value` an object, new value of attribute, or NULL to remove attribute.

Using `attr()` to get specific attribute of an object

```
(vector1 <- c(a = 1, b = 2, c = 3, d = 4))  
#> a b c d  
#> 1 2 3 4  
attributes(vector1)  
#> $names  
#> [1] "a" "b" "c" "d"  
attr(x=vector1, which = "names", exact = FALSE)  
#> [1] "a" "b" "c" "d"  
attr(vector1, "names")  
#> [1] "a" "b" "c" "d"  
attr(vector1, "name") # we don't provide exact name of attribute  
#> [1] "a" "b" "c" "d"  
attr(vector1, "name", exact = TRUE) # don't provide exact name of attribute  
#> NULL
```

attr() function: get or set specific attributes of an object

Syntax

- ▶ Get: `attr(x, which, exact = FALSE)`
- ▶ Set: `attr(x, which) <- value`

Arguments

- ▶ `x` an object whose attributes are to be accessed.
- ▶ `which` a non-empty character string specifying which attribute is to be accessed
- ▶ `exact` logical: should `which` be matched exactly? default is `exact = FALSE`
- ▶ `value` an object, new value of attribute, or NULL to remove attribute.

Using `attr()` to set specific attribute of an object (output omitted)

```
vector1 <- c(a = 1, b = 2, c = 3, d = 4)
attributes(vector1) # see all attributes

attr(x=vector1, which = "greeting") <- "Hi!" # create new attribute
attr(x=vector1, which = "greeting") # see attribute

attr(vector1, "farewell") <- "Bye!" # create attribute

attr(x=vector1, which = "names") # see names attribute
attr(x=vector1, which = "names") <- NULL # delete names attribute

attributes(vector1) # see all attributes
```

Applying attr() to data frames

Using `wwlist`, create data frame with three variables

```
wwlist_small <- wwlist[1:25, ] %>% select(hs_state,firstgen,med_inc_zip)
str(wwlist_small)
attributes(wwlist_small)
```

Get/set attribute of a data frame

```
#get/examine names attribute
attr(x=wwlist_small, which = "names")
str(attr(x=wwlist_small, which = "names")) # names attribute is character atomic

#add new attribute to data frame
attr(x=wwlist_small, which = "new_attribute") <- "contents of new attribute"
attributes(wwlist_small)
```

Get/set attribute of a variable in data frame

```
str(wwlist_small$med_inc_zip)
attributes(wwlist_small$med_inc_zip)

#create attribute for variable med_inc_zip
attr(wwlist_small$med_inc_zip, "inc attribute") <- "inc attribute contents"

#investigate attribute for variable med_inc_zip
attributes(wwlist_small$med_inc_zip)
str(wwlist_small$med_inc_zip)
attr(wwlist_small$med_inc_zip, "inc attribute")
```

Why add attributes to data frame or variables of data frame?

Pedagogical reasons

- ▶ Important to know how you can apply `attributes()` and `attr()` to data frames and to variables within data frames

Example practical application: interactive dashboards

- ▶ When creating “dashboard” you might want to add “tooltips”
 - ▶ “tooltip” is a message that appears when cursor positioned over an icon
 - ▶ The text in the tooltip message is the contents of an attribute
- ▶ Example dashboard: [LINK](#)

Student exercises

XIN CREATE SHORT STUDENT EXERCISES AND SOLUTIONS WHERE STUDENTS PRACTICE USING ATTRIBUTE() AND ATTR() ON DATA FRAME THAT IS A SUBSET (A FEW VARIABLES) OF THE DATA FRAME WWLIST EXERCISES SHOULD TAKE 5-10 MINUTES TO COMPLETE

Object class

Object class

Every object in R has a **class**

- ▶ class is an **attribute** of an object
- ▶ Object class controls how functions work; defines rules for how object can be treated by object oriented programming language
 - ▶ e.g., which functions you can apply to object of a particular class
 - ▶ e.g., what the function does to one object class, what it does to another object class

Many ways to identify object class

- ▶ Simplest is `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

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

Why is object class important?

Functions care about object **class**, not object **type**

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

Functions care about object **class**, not object **type**

Example: `sum()` applies to **numeric**, **logical**, or **complex** class objects

► Apply `sum()` to **logical** and **numeric** class

```
x <- c(TRUE,FALSE,NA,TRUE) # class = logical
typeof(x)
#> [1] "logical"
class(x)
#> [1] "logical"
sum(x, na.rm = TRUE)
#> [1] 2
# class = numeric
typeof(wwlist$med_inc_zip)
#> [1] "double"
class(wwlist$med_inc_zip)
#> [1] "numeric"
wwlist$med_inc_zip[1:5]
#> [1] 92320.5 63653.0 88344.5 88408.5 82895.0
sum(wwlist$med_inc_zip[1:5], na.rm = TRUE)
#> [1] 415621.5
```

► What happens when apply `sum()` to an object with class = **character**?

```
typeof(wwlist$hs_city)
class(wwlist$hs_city)
wwlist$hs_city[1:5]
sum(wwlist$hs_city[1:5], na.rm = TRUE)
```

Functions care about object **class**, not object **type**

Date functions can be applied to objects with a date-time class

- ▶ date-time objects have **type** = numeric
- ▶ date-time objects **class** = date or date-time

Example: `year()` function from `lubridate` package

- ▶ apply `year()` to object with **class** = date

```
wwlist$receive_date[1:5]
#> [1] "2016-05-31" "2016-05-31" "2016-05-31" "2016-05-31" "2016-05-31"
typeof(wwlist$receive_date)
#> [1] "double"
class(wwlist$receive_date)
#> [1] "Date"
year(wwlist$receive_date[1:5])
#> [1] 2016 2016 2016 2016 2016
```

- ▶ apply `year()` to object with **class** = numeric

```
typeof(wwlist$med_inc_zip)
class(wwlist$med_inc_zip)
year(wwlist$med_inc_zip[1:10])
```

Functions care about object **class**, not object **type**

Most string functions are intended to apply to objects with a **character** class.

▶ **type** = character

▶ **class** = character

Example: `tolower()` function

▶ syntax: `tolower(x)`

▶ where argument `x` is "a character vector, or an object that can be coerced to character by `as.character()`"

Apply `tolower()` to character class object

```
str(wwlist$hs_city)
#> chr [1:268396] "Seattle" "Covington" "Everett" "Seattle" ...
typeof(wwlist$hs_city)
#> [1] "character"
class(wwlist$hs_city)
#> [1] "character"

wwlist$hs_city[1:6]
#> [1] "Seattle"      "Covington"    "Everett"      "Seattle"
#> [5] "Lake Stevens" "Seattle"

tolower(wwlist$hs_city[1:6])
#> [1] "seattle"      "covington"    "everett"      "seattle"
#> [5] "lake stevens" "seattle"
```

Class and object-oriented programming

R is an object-oriented programming language

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
 - ▶ e.g., a specific function might do one thing to objects of **class** A and another thing to objects of **class** B
 - ▶ What a function does to objects of different class is determined by whoever wrote the function

Many different object classes exist in R

- ▶ You can also create our own classes
 - ▶ Example: the `labelled` class is an object class created by Hadley Wickham when he created the `haven` package
- ▶ In this course we will work with classes that have been created by others

Class == factor

Recoding variable `ethn_code` from data frame `wwlist`

Want to recode variable `ethn_code` so that it has fewer categories

```
wwlist <- wwlist %>%  
  mutate(ethn_code =  
    recode(ethn_code,  
      "american indian or alaska native" = "nativeam",  
      "asian or native hawaiian or other pacific islander" = "api",  
      "black or african american" = "black",  
      "cuban" = "latinx",  
      "mexican/mexican american" = "latinx",  
      "not reported" = "not_reported",  
      "other-2 or more" = "multirace",  
      "other spanish/hispanic" = "latinx",  
      "puerto rican" = "latinx",  
      "white" = "white",  
    )  
  )  
  
str(wwlist$ethn_code)  
wwlist %>% count(ethn_code)
```


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

Create factor version of character variable `ethn_code` using base R `factor()` function

```
str(wwlist$ethn_code)
#> chr [1:268396] "multirace" "white" "white" "multirace" "white" ...
class(wwlist$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/ 7 levels "api","black",...: 4 7 7 4 7 4 4 4 4 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 variable `ethn_code`

```
typeof(wwlist$ethn_code)
class(wwlist$ethn_code)
attributes(wwlist$ethn_code)
str(wwlist$ethn_code)
```

► Factor variable `ethn_code_fac`

```
typeof(wwlist$ethn_code_fac)
class(wwlist$ethn_code_fac)
attributes(wwlist$ethn_code_fac)
str(wwlist$ethn_code_fac)
```

Main things to note about variable `ethn_code_fac`

► has `type=integer`

► has `class=factor` because the variable has a “levels” attribute

► Underlying data are integers but levels attribute used to display the data.

```
wwlist$ethn_code_fac[1:3] # print first few obs of ethn_code_fac
#> [1] multirace white      white
#> Levels: api black latinx multirace nativeam not_reported white
```

Working with factor variables

When displaying data, factor variables display values of **level attribute** rather than underlying integer values of variable

```
wwlist %>% count(ethn_code_fac)
```

```
#> # A tibble: 7 x 2
```

```
#>   ethn_code_fac      n
```

```
#>   <fct>         <int>
```

```
#> 1 api           2385
```

```
#> 2 black          563
```

```
#> 3 latinx         9245
```

```
#> 4 multirace      90584
```

```
#> 5 nativeam       202
```

```
#> 6 not_reported   5737
```

```
#> 7 white         159680
```

Working with factor variables

Apply `as.integer()` function to to display underlying integer values of factor variable

Investigate `as.integer()` function

```
typeof(wwlist$ethn_code_fac)
#> [1] "integer"
class(wwlist$ethn_code_fac)
#> [1] "factor"

typeof(as.integer(wwlist$ethn_code_fac))
#> [1] "integer"
class(as.integer(wwlist$ethn_code_fac))
#> [1] "integer"
```

Display underling integer values of variable `ethn_code_fac`

```
wwlist %>% count(as.integer(ethn_code_fac))
#> # A tibble: 7 x 2
#>   `as.integer(ethn_code_fac)`      n
#>   <int> <int>
#> 1         1    2385
#> 2         2     563
#> 3         3    9245
#> 4         4   90584
#> 5         5     202
#> 6         6    5737
#> 7         7  159680
```

Working with factor variables

Refer to categories of a factor (e.g., when filtering obs) using values of **level attribute** rather than underlying values of variable

► values of **level attribute** for `ethn_code_fac` (output omitted)

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

Task: count the number of prospects in `wwlist` who identify as “white”

```
# referring to variable value; this doesn't work
```

```
wwlist %>% filter(ethn_code_fac==7) %>% 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 `wwlist` who identify as “white”

- ▶ To refer to underlying integer values, apply `as.integer()` function to factor variable

```
attributes(wwlist$ethn_code_fac)
#> $levels
#> [1] "api"          "black"          "latinx"          "multirace"
#> [5] "nativeam"      "not_reported"  "white"
#>
#> $class
#> [1] "factor"
wwlist %>% filter(as.integer(ethn_code_fac)==7) %>% count
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1 159680
```

How to identify the variable values associated with factor levels

Create a factor version of the character variable `psat_range`

```
wwlist <- wwlist %>% mutate(psat_range_fac = factor(psat_range))  
wwlist %>% count(psat_range_fac)  
attributes(wwlist$psat_range_fac)
```

Investigate values associated with factor levels using `levels()` and `nlevels()`

```
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 values associated with factor levels known:

► Can filter based on underlying integer values using `as.integer()`

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

► Or filter based on value of **factor levels**

```
wwlist %>% filter(psat_range=="1270-1520") %>% count()  
#> # A tibble: 1 x 1  
#>       n  
#>   <int>  
#> 1  8348
```

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 lubridate
```

```
#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 \(HSL:09\)](#)

- ▶ 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)

Using `haven` package to read SAS/SPSS/Stata datasets into R

`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:

- ▶ Data frames are **tibbles**, Tidyverse’s preferred **class** of data frames
- ▶ Transform variables with “value labels” into the `labelled()` class
 - ▶ `labelled` is an object class, just like `factor` is an object class
 - ▶ `labelled` is an object **class** created by folks who created `haven` package
 - ▶ `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

Using `haven` package to read SAS/SPSS/Stata datasets into R

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

```
hsls <- read_dta(file="https://github.com/ozanj/rclass/raw/master/data/hsls/hs1
```

Must run this code chunk; permanently changes uppercase variable names to lowercase

```
names(hs1s)
names(hs1s) <- tolower(names(hs1s)) # convert names to lowercase
names(hs1s) # names now lowercase

str(hs1s) # ugh
```

Investigate variable `s3classes` from data frame `hs1s`

► identifies whether respondent taking postsecondary classes as of 11/1/2013

```
typeof(hs1s$s3classes)
class(hs1s$s3classes)
str(hs1s$s3classes)
```

Investigate attributes of `s3classes`

```
attributes(hs1s$s3classes) # all attributes

#specific attributes: using syntax: attr(x, which, exact = FALSE)
attr(x=hs1s$s3classes, which = "label") # label attribute
attr(x=hs1s$s3classes, which = "labels") # labels attribute
```

What is object class = labelled ?

value labels [in Stata] are labels attached to specific values of a variable, e.g.:

- ▶ var value 1 attached to value label “married”, 2 = “single”, 3 = “divorced”

labelled is object class for importing vars with **value labels** from SAS/SPSS/Stata

- ▶ **labelled** object class created by **haven** package
- ▶ Characteristics of variables in R data frame with **class==labelled**:
 - ▶ data type can be numeric(double) or character
 - ▶ To see **value labels** associated with each value:
 - ▶ `attr(df_name$var_name,"labels")`
 - ▶ e.g., `attr(hs1s$s3classes,"labels")`

Investigate the attributes of **hs1s\$s3classes**

```
typeof(hs1s$s3classes)
class(hs1s$s3classes)
str(hs1s$s3classes)
attributes(hs1s$s3classes)
```

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

```
attr(hs1s$s3classes,"label")
attr(hs1s$s3classes,"format.stata")
attr(hs1s$s3classes,"class")
attr(hs1s$s3classes,"labels")
```

labelled package

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

- ▶ `labelled` package contains 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(hs1s$s3classes)
```

```
hs1s %>% select(s3classes) %>% var_label()  
hs1s %>% select(s3classes) %>% val_labels()
```

Working with labelled class data

Variable type and class

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

Show variable labels using `var_label()` function

```
hsls %>% select(s3classes,s3clglvl) %>% var_label
#> $s3classes
#> [1] "S3 B01A Taking postsecondary classes as of Nov 1 2013"
#>
#> $s3clglvl
#> [1] "S3 Enrolled college IPEDS level"
```

Show value labels associated with variable values using `val_labels()` (output omitted)

```
hsls %>% select(s3classes,s3clglvl) %>% val_labels
```

Working with labelled class data

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

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

```
hsls %>% count(s3classes)
#> # A tibble: 5 x 2
#>       s3classes      n
#>       <dbl+lbl> <int>
#> 1 -9 [Missing]      59
#> 2 -8 [Unit non-response] 4945
#> 3  1 [Yes]        13477
#> 4  2 [No]         3401
#> 5  3 [Don't know]  1621
```

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()
#> # 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
```

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(hs1s$s3classes)
hs1s %>% select(s3classes) %>% var_label #show variable label
hs1s %>% select(s3classes) %>% val_labels #show value label

hs1s %>% count(s3classes) # freq table, values
hs1s %>% count(s3classes) %>% as_factor() # freq table, value labels
```

filter specific values

```
hs1s %>% filter(s3classes==8) %>% count() # 8 = unit non-response
hs1s %>% filter(s3classes==1) %>% count() # 1 = yes
```

Set variable and value labels

Functions to set variable labels and value labels

`set_variable_labels()` function from the `labelled` package sets variable labels
`?set_variable_labels`

`set_value_labels()` function from `labelled` package sets value labels
`?set_value_labels`

Set variable and value labels

Let's create a tibble first

```
df <- tribble(
  ~id, ~edu, ~sch,
  #--/--/----
  1, 2, 2,
  2, 1, 1,
  3, 3, 2,
  4, 4, 2,
  5, 1, 2
)
```

df

```
#> # A tibble: 5 x 3
#>       id    edu  sch
#>   <dbl> <dbl> <dbl>
#> 1     1     2     2
#> 2     2     1     1
#> 3     3     3     2
#> 4     4     4     2
#> 5     5     1     2
```

Set variable labels

Use `set_variable_labels` function to manually set variable labels

► syntax: `set_variable_labels(variable = "Variable label")`

```
#str(df)
class(df$sch)
#> [1] "numeric"

#set variabel labels
df <- df %>%
  set_variable_labels(
    id = "Unique identification number",
    edu = "Education level",
    sch = "Type of school attending"
  )

str(df)
#> Classes 'tbl_df', 'tbl' and 'data.frame':    5 obs. of  3 variables:
#> $ id : num  1 2 3 4 5
#> ..- attr(*, "label")= chr "Unique identification number"
#> $ edu: num  2 1 3 4 1
#> ..- attr(*, "label")= chr "Education level"
#> $ sch: num  2 1 2 2 2
#> ..- attr(*, "label")= chr "Type of school attending"
class(df$sch)
#> [1] "numeric"
```

Set value labels

Use `set_value_labels` function to manually set value labels

► syntax:

```
set_value_labels(var_name = c("val label" = 1, "val label" = 2))
```

```
class(df$sch)
```

```
#> [1] "numeric"
```

```
df <- df %>%
```

```
  set_value_labels(
    edu = c("High School" = 1,
            "AA degree" = 2,
            "BA degree" = 3,
            "MA or higher" = 4),
    sch = c("Private" = 1,
            "Public" = 2))
```

```
attributes(df$sch)
```

```
#> $label
```

```
#> [1] "Type of school attending"
```

```
#>
```

```
#> $labels
```

```
#> Private Public
```

```
#>      1      2
```

```
#>
```

```
#> $class
```

```
#> [1] "haven_labelled"
```

Set value labels

Now we can analyze data using tools we already introduced

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

XIN - BELOW FREQUENCY COUNT LOOKING ODD IN PDF. CAN YOU FIX? -
Default setting is to show variable **values** not **value labels**

```
df %>% count(edu)
#> # A tibble: 4 x 2
#>       edu      n
#>   <dbl+lbl> <int>
#> 1 1 [High School]      2
#> 2 2 [AA degree]        1
#> 3 3 [BA degree]        1
#> 4 4 [MA or higher]     1
```

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

```
df %>% count(edu) %>% as_factor()
#> # A tibble: 4 x 2
#>   edu      n
#>   <fct>   <int>
#> 1 High School      2
#> 2 AA degree        1
#> 3 BA degree        1
#> 4 MA or higher     1
```

XIN - ADD EXAMPLE

XIN ADD ONE OR TWO SLIDES WHERE STUDENTS APPLY
SET_VARIABLE_LABEL AND SET_VALUE_LABEL TO VARIABLES FROM DATA
FRAME WWLIST

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”

XIN ADD ONE OR TWO EXERCISE QUESTIONS WHERE STUDENTS APPLY SET_VARIABLE_LABEL AND SET_VALUE_LABEL TO VARIABLES FROM DATA FRAME WWLIST

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  
#> 3
```

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”

```
hs1s %>%  
  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”

```
hs1s %>%  
  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`

| | <code>class==labelled</code> | <code>class==factor</code> |
|-------------------------------|------------------------------|----------------------------|
| 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, s3clglvl1) %>% 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
```

Appendix. 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", "OR", "WA"))
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)
```