Enter the tidyverse: Processing across rows

Managing and Manipulating Data Using R

1 Introduction

Lecture outline

Libraries we will use today

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

- **you must run this code chunk**

```
library(tidyverse)
```

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 today

Data on off-campus recruiting events by public universities

- Object `df_event`
  - One observation per university, recruiting event

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

#load dataset with one obs per recruiting event
load(url("https://github.com/ozanj/rclass/raw/master/data/recruiting/recruit_ev
#load("../../data/recruiting/recruit_event_allvars.Rdata")
```

Processing across variables vs. processing across observations

Visits by UC Berkeley to public high schools

```
#> # A tibble: 5 x 6
#>   school_id    state tot_stu_pub fr_lunch pct_fr_lunch med_inc
#>   <chr>        <chr>       <dbl>    <dbl>        <dbl>   <dbl>
#> 1 340882002126 NJ           1846       29       0.0157 178732
#> 2 340147000250 NJ           1044       50       0.0479  62288
#> 3 340561003796 NJ           1505      298       0.198  100684.
#> 4 340165005124 NJ           1900       43       0.0226 160476.
#> 5 341341003182 NJ           1519      130       0.0856 144346
```

So far, we have focused on "processing across variables''

- Performing calculations across columns (i.e., vars), typically within a row (i.e., observation)
- Example: percent free-reduced lunch (above)

Processing across obs (focus of today's lecture)

- Performing calculations across rows (i.e., obs), often within a column (i.e., variable)
- Example: Average household income of visited high schools, by state

Why processing across observations

Note

- In today's lecture, I'll use the terms "observations" and "rows" interchangeably

Creation of analysis datasets often requires calculations across obs

Examples:

- You have a dataset with one observation per student-term and want to create a variable of credits attempted per term
- You have a dataset with one observation per student-term and want to create a variable of GPA for the semester or cumulative GPA for all semesters
- Number of off-campus recruiting events university makes to each state
- Average household income at visited versus non-visited high schools

Creating graphs and tables of descripive stats usually require calculations across obs

Example: Want to create a graph that shows number of recruiting events by event "type" (e.g., public HS, private HS) for each university

- Start with `df_event` dataset that has one obervation per university, recruiting event
- Create new data frame object that has one observation per university and event type and has variable for number of events
  - this variable calculated by counting number of rows in each combination of university and event type
- This new data frame object is the input for creating desired graph

2 Introduce group_by() and summarize()

Strategy for teaching processing across obs

In `tidyverse` the `group_by()` and `summarize()` functions are the primary means of performing calculations across observations

- Usually, processing across observations requires using `group_by()` and `summarize()` together
- `group_by()` typically not very useful by itself
- `summarize()` [with or without `group_by()`] can be helpful for creating summary statistics that are the inputs for tables or graphs you create

How we'll teach:

- introduce `group_by()` and `summarize()` separately
  - goal: you understand what each function does
- then we'll combine them

2.1 group_by

group_by()

Description: " `group_by()` takes an existing data frame and converts it into a grouped data frame where operations are performed"by group". `ungroup()` removes grouping."

- part of **dplyr** package within **tidyverse**; not part of **Base R**
- works best with pipes `%>%` and `summarize()` function [described below]

Basic syntax: `group_by(.data, ...)`

- `.data` argument refers to name of data frame
- `...` argument refers to names of "group_by" variables, separated by commas
  - Can "group by" one or many variables
  - Typically, "group_by" variables are character, factor, or integer variables

Possible "group by" variables in `df_event` data:

- university name/id; event type (e.g., public HS, private HS); state

Example: in `df_event`, create frequency count of `event_type` [output omitted]

```
names(df_event)
#without group_by()
df_event %>% count(event_type)
df_event %>% count(instnm)
#group_by() university
df_event %>% group_by(instnm) %>% count(event_type)
```

group_by()

By itself `group_by()` doesn't do much; it just prints data

- Below, group `df_event` data by university, event type, and event state

```
#group_by (without pipes)
group_by(df_event, univ_id, event_type, event_state)
#group_by (with pipes)
df_event %>% group_by(univ_id, event_type, event_state)
df_event %>% group_by(univ_id, event_type, event_state) %>% glimpse()
```

But once an object is grouped, all subsequent functions are run separately "by group"

- recall that `count()` counts number of observations by group

```
# count number of observations in group, ungrouped data
df_event  %>% count()
#group by and then count obs
df_event %>% group_by(univ_id) %>% count()
df_event %>% group_by(univ_id) %>% count() %>% glimpse()
  #df_event %>% group_by(univ_id) %>% count() %>% View()

df_event %>% group_by(univ_id, event_type) %>% count()
df_event %>% group_by(univ_id, event_type) %>% count() %>% glimpse()
  #df_event %>% group_by(univ_id, event_type) %>% count() %>% View()
```

Grouping not retained unless you **assign** it

Below, we'll use `class()` function to show whether data frame is grouped

- will talk more about `class()` next week, but for now, just think of it as a function that provides information about an object
- similar to `typeof()`, but `class()` provides different info about object

Grouping is not retained unless you **assign** it

```
class(df_event)
#> [1] "tbl_df"     "tbl"        "data.frame"
```

```
df_event %>% group_by(univ_id, event_type, event_state)
df_event_grp <- df_event %>% group_by(univ_id, event_type, event_state) # using
```

```
class(df_event_grp)
#> [1] "grouped_df" "tbl_df"     "tbl"        "data.frame"
```

Un-grouping an object

Use `ungroup(object)` to un-group grouped data

```
class(df_event_grp)
#> [1] "grouped_df" "tbl_df"     "tbl"        "data.frame"
df_event_grp <- ungroup(df_event_grp)
class(df_event_grp)
#> [1] "tbl_df"     "tbl"        "data.frame"
rm(df_event_grp)
```

`group_by()` student exercise

1. Group by "instnm" and get a frequency count.
   - How many rows and columns do you have? What do the number of rows mean?
2. Now group by "instnm" **and** "event_type" and get a frequency count.
   - How many rows and columns do you have? What do the number of rows mean?
3. **Bonus:** In the same code chunk, group by "instnm" and "event_type", but this time filter for observations where "med_inc" is greater than 75000 and get a frequency count.

`group_by()` student exercise solutions

1. Group by "instnm" and get a frequency count.
   - How many rows and columns do you have? What do the number of rows mean?

```
df_event %>%
  group_by(instnm) %>%
  count()
#> # A tibble: 16 x 2
#> # Groups:   instnm [16]
#>    instnm          n
#>    <chr>       <int>
#>  1 Arkansas      994
#>  2 Bama         4258
#>  3 CU Boulder   1439
#>  4 Cinci         679
#>  5 Kansas       1014
#>  6 NC State      640
#>  7 Pitt         1225
#>  8 Rutgers      1135
#>  9 S Illinois    549
#> 10 Stony Brook   730
#> 11 UC Berkeley   879
#> 12 UC Irvine     539
#> 13 UGA           827
#> 14 UM Amherst    908
#> 15 UNL          1397
#> 16 USCC         1467
```

`group_by()` student exercise solutions

2. Now group by "instnm" **and** "event_type" and get a frequency count.
   - How many rows and columns do you have? What do the number of rows mean?

```
df_event %>%
  group_by(instnm, event_type) %>%
  count()
#> # A tibble: 80 x 3
#> # Groups:   instnm, event_type [80]
#>    instnm   event_type      n
#>    <chr>    <chr>       <int>
#>  1 Arkansas 2yr college    32
#>  2 Arkansas 4yr college    14
#>  3 Arkansas other         112
#>  4 Arkansas private hs    222
#>  5 Arkansas public hs     614
#>  6 Bama     2yr college   127
#>  7 Bama     4yr college   158
#>  8 Bama     other         608
#>  9 Bama     private hs    963
#> 10 Bama     public hs    2402
#> # i 70 more rows
```

`group_by()` student exercise solutions

3. **Bonus:** Group by "instnm" and "event_type", but this time filter for observations where "med_inc" is greater than 75000 and get a frequency count.

```
df_event %>%
  group_by(instnm, event_type) %>%
  filter(med_inc > 75000) %>%
  count()
#> # A tibble: 80 x 3
#> # Groups:   instnm, event_type [80]
#>    instnm   event_type      n
#>    <chr>    <chr>       <int>
#>  1 Arkansas 2yr college     7
#>  2 Arkansas 4yr college     3
#>  3 Arkansas other          30
#>  4 Arkansas private hs      99
#>  5 Arkansas public hs     303
#>  6 Bama     2yr college    21
#>  7 Bama     4yr college    42
#>  8 Bama     other         249
#>  9 Bama     private hs    477
#> 10 Bama     public hs    1478
#> # i 70 more rows
```

2.2 summarize()

`summarize()` function

Description: `summarize()` calculates across rows; then collapses into single row

- `summarize()` create scalar vars summarizing variables of existing data frame
- if you first group data frame using `group_by()`, `summarize()` creates summary vars separately for each group, returning object with one row per group
- if data frame not grouped, `summarize()` will result in one row.

Syntax: `summarize(.data, ...)`

- `.data`: a data frame; omit if using `summarize()` after pipe `%>%`
- `...`: Name-value pairs of summary functions separated by commas
  - "name" will be the name of new variable you will create
  - "value" should be expression that returns a single value like `min(x)`, `n()`
  - variable names do not need to be placed within quotes

Value (what `summarize()` returns/creates)

- Object of same class as `.data.`; object will have one obs per "by group"

Useful functions (i.e., "helper functions")

- Standalone functions called *within* `summarize()`, e.g., `mean()`, `n()`
- e.g., count function `n()` takes no arguments; returns number of rows in group

Investigate objects created by `summarize()`

Example: Count total number of events

- function `n()` from `dplyr` package (`dplyr::n`) returns the size of the current group

```
#?n # dplyr function n() gives current group size
summarize(df_event, num_events=n()) # without pipes

df_event %>% summarize(num_events=n()) # with pipes
df_event %>% summarize(num_events=n()) %>% str() # use str to see what pipe retu
  #df_event %>% summarize(num_events=n()) %>% View()
```

Example: What is max value of `med_inc` across all events

- function `max()` from `base` package (`base::max`) returns max value

```
#?max # base R function max() returns max value
df_event %>% summarize(max_inc=max(med_inc, na.rm = TRUE))
df_event %>% summarize(max_inc=max(med_inc, na.rm = TRUE)) %>% str()
```

Investigate objects created by `summarize()`

Example: Count total number of events AND max value of median income

```
df_event %>% summarize(
    num_events=n(),
    max_inc=max(med_inc, na.rm = TRUE)
  )
#> # A tibble: 1 x 2
#>   num_events max_inc
#>        <int>   <dbl>
#> 1      18680  250001

# show object returned by pipe
df_event %>% summarize(
    num_events=n(),
    max_inc=max(med_inc, na.rm = TRUE)
  ) %>% str()
#> tibble [1 x 2] (S3: tbl_df/tbl/data.frame)
#>  $ num_events: int 18680
#>  $ max_inc   : num 250001

#df_event %>% summarize(num_events=n(), max_inc=max(med_inc, na.rm = TRUE)) %>%
```

Investigate objects created by `summarize()`

Example: Count total number of events AND max value of median income

We can use assignment to keep the object created by `summarize()`

```
df_event_temp <- df_event %>%
  summarize(num_events=n(), max_inc=max(med_inc, na.rm = TRUE))

df_event_temp
rm(df_event_temp)
```

What if we forgot `na.rm = TRUE`?

- then `max_inc` equals `NA` cuz can't perform calculation on `NA` values

```
df_event %>%
  summarize(num_events=n(),max_inc=max(med_inc, na.rm = FALSE))
```

Takeaways, `summarize()`

- By default, objects created by `summarize()` are data frames that contain variables created within `summarize()` and one observation [per "by group"]
- most "helper" functions (e.g., `max()`, `mean()` have option `na.rm` to keep/remove missing obs before performing calculations)
  - `na.rm = FALSE` (default); don't remove `NAs` prior to calculation
    - if any obs missing, then result of calculation is `NA`
  - `na.rm = TRUE` (default); remove `NAs` prior to calculation
- Object created by `summarize()` not retained unless you **assign** it (output omitted)

```
event_temp <- df_event %>% summarize(num_events=n(),
  mean_inc=mean(med_inc, na.rm = TRUE))

event_temp
rm(event_temp)
```

Using [] operator to filter observations within summarize

Imagine we want to calculate avg. income, separately for in-state vs. out-of-state visits

- first, make sure we can identify in vs. out-state (output omitted)

```
df_event %>% filter(event_state == instst) %>% count() #in state
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1  5425

df_event %>% filter(event_state != instst) %>% count() #out state
#> # A tibble: 1 x 1
#>       n
#>   <int>
#> 1 13255
```

Using [] operator to filter observations within summarize

Task: calculate mean income for: all events; in-state events; out-of-state events

```
df_event %>%
  summarize(
    avg_inc = mean(med_inc, na.rm = TRUE), # all events
    avg_inc_inst = mean(med_inc[event_state == instst], na.rm = TRUE), # in-sta
    avg_inc_outst = mean(med_inc[event_state != instst], na.rm = TRUE) # out-st
  )
#> # A tibble: 1 x 3
#>   avg_inc avg_inc_inst avg_inc_outst
#>     <dbl>        <dbl>         <dbl>
#> 1  89089.       71589.        96162.
```

Understanding code: `mean(med_inc[event_state == instst], na.rm = TRUE)`

- `mean()` function takes atomic vector as first argument
- the variable `med_inc` is an numeric atomic vector
- `event_state == instst` is condition that yields a logical atomic vector
- From Base R lecture, `med_inc[event_state == instst]` is:
  - "subset atomic vectors using `[]`" approach 3: "Using logicals to return elements where corresponding logical is `TRUE`"
  - isolates observations of `med_inc` where `event_state` is same as state the university is located in (`instst`)

Using `summarize()` to create descriptive statistics table

Often helpful to use `summarize()` to calculate summary statistics that are the basis for a table of descriptive statistics

Task: create a table of descriptive statistics about variable `med_inc`

- want these measures: number of non-missing obs; mean; standard deviation

```
df_event %>% mutate(non_miss_inc = is.na(med_inc)==0) %>%
  summarize(
    n = sum(non_miss_inc, na.rm = TRUE), #SAMPLE SIZE all
    avg_inc = mean(med_inc, na.rm = TRUE), # MEAN
    std_inc = sd(med_inc, na.rm = TRUE) # STANDARD DEVIATION all events
  )
```

Task: same as above but separate measures for: all events; in-state; out-of-state

```
df_event %>% mutate(non_miss_inc = is.na(med_inc)==0) %>%
  summarize(
    n = sum(non_miss_inc, na.rm = TRUE), #SAMPLE SIZE
    n_inst = sum(non_miss_inc[event_state == instst], na.rm = TRUE),
    n_outst = sum(non_miss_inc[event_state != instst], na.rm = TRUE),
    avg_inc = mean(med_inc, na.rm = TRUE), # MEAN
    avg_inc_inst = mean(med_inc[event_state == instst], na.rm = TRUE),
    avg_inc_outst = mean(med_inc[event_state != instst], na.rm = TRUE),
    std_inc = sd(med_inc, na.rm = TRUE), # STANDARD DEVIATION
    std_inc_inst = sd(med_inc[event_state == instst], na.rm = TRUE),
    std_inc_outst = sd(med_inc[event_state != instst], na.rm = TRUE)
  )
```

`summarize()` student exercise

1. What is the min value of `med_inc` across all events?
   - Hint: Use min()
2. What is the mean value of `fr_lunch` across all events?
   - Hint: Use mean()

`summarize()` student exercise

1. What is min value of `med_inc` across all events?

```
df_event %>%
  summarize(min_med_income = min(med_inc, na.rm = TRUE))
#> # A tibble: 1 x 1
#>   min_med_income
#>            <dbl>
#> 1          12894.
```

`summarize()` student exercise

2. What is the mean value of `fr_lunch` across all events?
   - Hint: Use mean()

```
df_event %>%
  summarize(mean_fr_lunch = mean(fr_lunch, na.rm = TRUE))
#> # A tibble: 1 x 1
#>   mean_fr_lunch
#>           <dbl>
#> 1          475.
```

3 Combining group_by() and summarize()

Combining `summarize()` and `group_by`

`summarize()` on ungrouped vs. grouped data:

- By itself, `summarize()` performs calculations across all rows of data frame then collapses the data frame to a single row
- When data frame is grouped, `summarize()` performs calculations across rows within a group and then collapses to a single row for each group

Example: Count the number of events for each university

- remember: `df_event` has one observation per university, recruiting event

```
df_event %>% summarize(num_events=n())
df_event %>% group_by(instnm) %>% summarize(num_events=n())
```

- Investigate the object created above

```
df_event %>% group_by(instnm) %>% summarize(num_events=n()) %>% str()
  #df_event %>% group_by(instnm) %>% summarize(num_events=n()) %>% View()
```

- Or we could retain object for later use

```
event_by_univ <- df_event %>% group_by(instnm) %>% summarize(num_events=n())
str(event_by_univ)
event_by_univ # print
rm(event_by_univ)
```

Combining `summarize()` and `group_by`

Task

- Count number of recruiting events by institution and event_type
  - within `summarize()`, we will take advantage of the helper function `n()`
  - `n()` "gives the current group size"; i.e., how many observations in current group

```
#?n
df_event %>% group_by(instnm, event_type) %>% summarize(num_events=n())

#investigate object created
df_event %>% group_by(instnm, event_type) %>% summarize(num_events=n()) %>% glim
  #df_event %>% group_by(instnm, event_type) %>% summarize(num_events=n()) %>% V
```

Combining `summarize()` and `group_by`

Task

- Count number of recruiting events by institution and event_type

Note that data frame object created by `group_by()` and `summarize()` can be input to graph

```
#bar chart of number of events, all universities combined
df_event %>% group_by(instnm, event_type) %>%
  summarize(num_events=n()) %>%
    ggplot(aes(x=event_type, y=num_events)) +  # plot
    ylab("Number of events") + xlab("Event type") +geom_col()

#bar chart of number of events, separete chart for each university
df_event %>% group_by(instnm, event_type) %>%
  summarize(num_events=n()) %>%
    ggplot(aes(x=event_type, y=num_events)) +  # plot
    ylab("Number of events") + xlab("Event type") + geom_col() +
    coord_flip() + facet_wrap(~ instnm)
```

Combining `summarize()` and `group_by`

Task. Count number of recruiting events by institution, event_type, and whether event is in- or out-of-state (var= `event_inst`)

- Note: in `group_by()` , the optional `drop` argument controls whether empty groups dropped. default is `drop = TRUE`

```
df_event %>% group_by(instnm, event_type, event_inst) %>%
  summarize(num_events=n())

df_event %>% group_by(instnm, event_type, event_inst, .drop = TRUE) %>%
  summarize(num_events=n())

df_event %>%
  group_by(as.factor(instnm), as.factor(event_type), as.factor(event_inst),
           .drop = FALSE) %>% summarize(num_events=n()) %>% arrange(num_events)
# .drop=FALSE affects only grouping columns that are coded as factors
# combinations that include non-factor grouping variables are still
# silently dropped even with .drop=FALSE.
```

Combining `summarize()` and `group_by`

Make a graph, showing in/out state as fill color of bar

```
df_event %>% group_by(instnm, event_type, event_inst) %>%
  summarize(num_events=n()) %>%
    ggplot(aes(x=event_type, y=num_events, fill = event_inst)) +  # plot
    ylab("Number of events") + xlab("Event type") + geom_col() +
    coord_flip() + facet_wrap(~ instnm)
```

Combining `summarize()` and `group_by`

Task

- By university, event type, event_inst count the number of events and calculate the avg. pct white in the zip-code

```
df_event %>% group_by(instnm, event_type, event_inst) %>%
  summarize(num_events=n(),
    mean_pct_white=mean(pct_white_zip, na.rm = TRUE)
  )

#investigate object you created
df_event %>% group_by(instnm, event_type, event_inst) %>%
  summarize(num_events=n(),
    mean_pct_white=mean(pct_white_zip, na.rm = FALSE)
  ) %>% glimpse()
```

Combining `summarize()` and `group_by`

Recruiting events by UC Berkeley

```
df_event %>% filter(univ_id == 110635) %>%
  group_by(event_type) %>% summarize(num_events=n())
```

Let's create a dataset of recruiting events at UC Berkeley

```
event_berk <- df_event %>% filter(univ_id == 110635)

event_berk %>% count(event_type)
```

3.1 summarize() and Counts

`summarize()` : Counts

The count function `n()` takes no arguments and returns the size of the current group

```
event_berk %>% group_by(event_type, event_inst) %>%
  summarize(num_events=n())
```

Because counts are so important, `dplyr` package includes separate `count()` function that can be called outside `summarize()` function

```
event_berk %>% group_by(event_type, event_inst) %>% count()
```

`summarize()` : count with logical vectors and `sum()`

Logical vectors have values `TRUE` and `FALSE`.

- When used with numeric functions, `TRUE` converted to 1 and `FALSE` to 0.

`sum()` is a numeric function that returns the sum of values

```
sum(c(5,10))
sum(c(TRUE,TRUE,FALSE,FALSE))
```

`is.na()` returns `TRUE` if value is `NA` and otherwise returns `FALSE`

```
is.na(c(5,NA,4,NA))
#> [1] FALSE  TRUE FALSE  TRUE
sum(is.na(c(5,NA,4,NA,5)))
#> [1] 2
sum(!is.na(c(5,NA,4,NA,5)))
#> [1] 3
```

Application: How many missing/non-missing obs in variable [**very important**]

```
event_berk %>% group_by(event_type) %>%
  summarize(
    n_events = n(),
    n_miss_inc = sum(is.na(med_inc)),
    n_nonmiss_inc = sum(!is.na(med_inc)),
    n_nonmiss_fr_lunch = sum(!is.na(fr_lunch))
  )
```

`summarize()` and count student exercise

Use one code chunk for this exercise. You could tackle this a step at a time and run the entire code chunk when you have answered all parts of this question. Create your own variable names.

1. Using the `event_berk` object, filter observations where `event_state` is VA and group by `event_type`.
   - 1.1 Using the summarize function to create a variable that represents the count for each `event_type`.
   - 1.2 Create a variable that represents the sum of missing obs for `med_inc`.
   - 1.3 Create a variable that represents the sum of non-missing obs for `med_inc`.
   - 1.4 **Bonus**: Arrange variable you created representing the count of each `event_type` in descending order.

`summarize()` and count student exercise SOLUTION

1. Using the `event_berk` object filter observations where `event_state` is VA and group by `event_type`.
   - 1.1 Using the summarize function, create a variable that represents the count for each `event_type`.
   - 1.2 Now get the sum of missing obs for `med_inc`.
   - 1.3 Now get the sum of non-missing obs for `med_inc`.

```
event_berk %>%
  filter(event_state == "VA") %>%
  group_by(event_type) %>%
  summarize(
    n_events = n(),
    n_miss_inc = sum(is.na(med_inc)),
    n_nonmiss_inc = sum(!is.na(med_inc))) %>%
  arrange(desc(n_events))
#> # A tibble: 3 x 4
#>   event_type n_events n_miss_inc n_nonmiss_inc
#>   <chr>         <int>      <int>          <int>
#> 1 public hs        20          0             20
#> 2 private hs       13          0             13
#> 3 other             3          0              3
```

3.2 summarize() and means

`summarize()` : means

The `mean()` function within `summarize()` calculates means, separately for each group

```
event_berk %>% group_by(event_inst, event_type) %>% summarize(
  n_events=n(),
  mean_inc=mean(med_inc, na.rm = TRUE),
  mean_pct_white=mean(pct_white_zip, na.rm = TRUE))
#> # A tibble: 10 x 5
#> # Groups:   event_inst [2]
#>    event_inst event_type  n_events mean_inc mean_pct_white
#>    <chr>      <chr>          <int>    <dbl>          <dbl>
#>  1 In-State   2yr college      111   78486.           40.1
#>  2 In-State   4yr college       14  131691.           58.0
#>  3 In-State   other             49   75040.           37.6
#>  4 In-State   private hs        35   95229.           48.4
#>  5 In-State   public hs        259   87097.           39.6
#>  6 Out-State  2yr college        1  153070.           89.7
#>  7 Out-State  4yr college        4   76913.           65.8
#>  8 Out-State  other             89   69004.           56.5
#>  9 Out-State  private hs       134   87654.           64.3
#> 10 Out-State  public hs        183  103603.           62.0
```

`summarize()` : means and `na.rm` argument

Default behavior of "aggregation functions" (e.g., `summarize()`)

- if *input* has any missing values (`NA`), than output will be missing.

Many functions have argument `na.rm` (means "remove `NAs` ")

- `na.rm = FALSE` [the default for `mean()`]
  - Do not remove missing values from input before calculating
  - Therefore, missing values in input will cause output to be missing
- `na.rm = TRUE`
  - Remove missing values from input before calculating
  - Therefore, missing values in input will not cause output to be missing

```
#na.rm = FALSE; the default setting
event_berk %>% group_by(event_inst, event_type) %>% summarize(
  n_events=n(),
  n_miss_inc = sum(is.na(med_inc)),
  mean_inc=mean(med_inc, na.rm = FALSE),
  n_miss_frlunch = sum(is.na(fr_lunch)),
  mean_fr_lunch=mean(fr_lunch, na.rm = FALSE))
# na.rm = TRUE
event_berk %>% group_by(event_inst, event_type) %>% summarize(
  n_events=n(),
  n_miss_inc = sum(is.na(med_inc)),
  mean_inc=mean(med_inc, na.rm = TRUE),
  n_miss_frlunch = sum(is.na(fr_lunch)),
  mean_fr_lunch=mean(fr_lunch, na.rm = TRUE))
```

Student exercise

1. Using the `event_berk` object, group by `instnm`, `event_inst`, & `event_type`.
   1.1 Create vars for number non_missing for these racial/ethnic groups (`pct_white_zip`, `pct_black_zip`, `pct_asian_zip`, `pct_hispanic_zip`, `pct_amerindian_zip`, `pct_nativehawaii_zip`)
   1.2 Create vars for mean percent for each racial/ethnic group

Student exercise solutions

```
event_berk %>% group_by(instnm, event_inst, event_type) %>%
  summarize(
  n_events=n(),
  n_miss_white = sum(!is.na(pct_white_zip)),
  mean_white = mean(pct_white_zip, na.rm = TRUE),
  n_miss_black = sum(!is.na(pct_black_zip)),
  mean_black = mean(pct_black_zip, na.rm = TRUE),
  n_miss_asian = sum(!is.na(pct_asian_zip)),
  mean_asian = mean(pct_asian_zip, na.rm = TRUE),
  n_miss_lat = sum(!is.na(pct_hispanic_zip)),
  mean_lat = mean(pct_hispanic_zip, na.rm = TRUE),
  n_miss_na = sum(!is.na(pct_amerindian_zip)),
  mean_na = mean(pct_amerindian_zip, na.rm = TRUE),
  n_miss_nh = sum(!is.na(pct_nativehawaii_zip)),
  mean_nh = mean(pct_nativehawaii_zip, na.rm = TRUE)) %>%
  head(6)
#> # A tibble: 6 x 16
#> # Groups:   instnm, event_inst [2]
#>   instnm     event_inst event_type n_events n_miss_white mean_white n_miss_bl
#>   <chr>      <chr>      <chr>          <int>        <int>      <dbl>        <i
#> 1 UC Berkel~ In-State   2yr colle~       111          106       40.1
#> 2 UC Berkel~ In-State   4yr colle~        14           12       58.0
#> 3 UC Berkel~ In-State   other             49           48       37.6
#> 4 UC Berkel~ In-State   private hs        35           35       48.4
#> 5 UC Berkel~ In-State   public hs        259          258       39.6
#> 6 UC Berkel~ Out-State  2yr colle~         1            1       89.7
#> # i 9 more variables: mean_black <dbl>, n_miss_asian <int>, mean_asian <dbl>
```

3.3 summarize() and logical vectors, part II

`summarize()` : counts with logical vectors, part II

Logical vectors (e.g., `is.na()`) useful for counting obs that satisfy some condition

```
is.na(c(5,NA,4,NA))
#> [1] FALSE  TRUE FALSE  TRUE
typeof(is.na(c(5,NA,4,NA)))
#> [1] "logical"
sum(is.na(c(5,NA,4,NA)))
#> [1] 2
```

Task: Using object `event_berk`, calculate the following measures for each combination of `event_type` and `event_inst`:

- count of number of rows for each group
- count of rows non-missing for both `pct_black_zip` and `pct_hispanic_zip`
- count of number of visits to communities where the `sum` of Black and Latinx people comprise more than 50% of the total population

```
event_berk %>% group_by (event_inst, event_type) %>% summarize(
    n_events=n(),
    n_nonmiss_latbl = sum(!is.na(pct_black_zip) & !is.na(pct_hispanic_zip)),
    n_majority_latbl= sum(pct_black_zip+ pct_hispanic_zip>50, na.rm = TRUE)
  )
```

`(!is.na(pct_black_zip) & !is.na(pct_hispanic_zip))` is a logical condition

- condition is `TRUE` (evaluates to `1`) or `FALSE` (evaluates to `0`) for each obs

`summarize()` : logical vectors to count *proportions*

Synatx: `group_by(vars) %>% summarize(prop = mean(TRUE/FALSE conditon))`

Task: separately for in-state/out-of-state, what proportion of visits to public high schools are to communities with median income greater than $100,000?

Steps:

1. Filter public HS visits
2. group by in-state vs. out-of-state
3. Create measure

```
event_berk %>% filter(event_type == "public hs") %>% # filter public hs visits
  group_by (event_inst) %>% # group by in-state vs. out-of-state
  summarize(
    n_events=n(), # number of events by group
    n_nonmiss_inc = sum(!is.na(med_inc)), # w/ nonmissings values median inc,
    p_incgt100k = mean(med_inc>100000, na.rm=TRUE)) # proportion visits to $100
#> # A tibble: 2 x 4
#>   event_inst n_events n_nonmiss_inc p_incgt100k
#>   <chr>         <int>         <int>       <dbl>
#> 1 In-State        259           256       0.273
#> 2 Out-State       183           183       0.519
```

`summarize()` : logical vectors to count *proportions*

What if we forgot to put `na.rm=TRUE` in the above task?

Task: separately for in-state/out-of-state, what proportion of visits to public high schools are to communities with median income greater than $100,000?

```
event_berk %>% filter(event_type == "public hs") %>% # filter public hs visits
  group_by (event_inst) %>% # group by in-state vs. out-of-state
  summarize(
    n_events=n(), # number of events by group
    n_nonmiss_inc = sum(!is.na(med_inc)), # w/ nonmissings values median inc,
    p_incgt100k = mean(med_inc>100000, na.rm=FALSE)) # proportion visits to $10
#> # A tibble: 2 x 4
#>   event_inst n_events n_nonmiss_inc p_incgt100k
#>   <chr>         <int>         <int>       <dbl>
#> 1 In-State        259           256      NA
#> 2 Out-State       183           183       0.519
```

`summarize()` : Other "helper" functions

Lots of other functions we can use within `summarize()`

Common functions to use with `summarize()` :

Function	Description
`n`	count
`n_distinct`	count unique values
`mean`	mean
`median`	median
`max`	largest value
`min`	smallest value
`sd`	standard deviation
`sum`	sum of values
`first`	first value
`last`	last value
`nth`	nth value
`any`	condition true for at least one value

Note: These functions can also be used on their own or with `mutate()`

`summarize()` : Other functions

Maximum value in a group

```
max(c(10,50,8))
#> [1] 50
```

Task: For each combination of in-state/out-of-state and event type, what is the maximum value of `med_inc`?

```
event_berk %>% group_by(event_type, event_inst) %>%
  summarize(max_inc = max(med_inc)) # oops, we forgot to remove NAs!

event_berk %>% group_by(event_type, event_inst) %>%
  summarize(max_inc = max(med_inc, na.rm = TRUE))
```

`summarize()` : Other functions

Isolate first/last/nth observation in a group

```
x <- c(10,15,20,25,30)
first(x)
last(x)
nth(x,1)
nth(x,3)
nth(x,10)
```

Task: after sorting object `event_berk` by `event_type` and `event_datetime_start`, what is the value of `event_date` for:

- first event for each event type?
- the last event for each event type?
- the 50th event for each event type?

```
event_berk %>% arrange(event_type, event_datetime_start) %>%
  group_by(event_type) %>%
  summarize(
    n_events = n(),
    date_first= first(event_date),
    date_last= last(event_date),
    date_50th= nth(event_date, 50)
  )
```

Student exercise

Identify value of `event_date` for the *nth* event in each by group

Specific task:

- arrange (i.e., sort) by `event_type` and `event_datetme_start`, then group by `event_type`, and then identify the value of `event_date` for:
  - the first event in each by group (`event_type`)
  - the second event in each by group
  - the third event in each by group
  - the fourth event in each by group
  - the fifth event in each by group

Student exercise solution

```
event_berk %>% arrange(event_type, event_datetime_start) %>%
  group_by(event_type) %>%
  summarize(
    n_events = n(),
    date_1st= first(event_date),
    date_2nd= nth(event_date,2),
    date_3rd= nth(event_date,3),
    date_4th= nth(event_date,4),
    date_5th= nth(event_date,5))
#> # A tibble: 5 x 7
#>   event_type  n_events date_1st   date_2nd   date_3rd   date_4th   date_5th
#>   <chr>          <int> <date>     <date>     <date>     <date>     <date>
#> 1 2yr college      112 2017-04-25 2017-09-05 2017-09-05 2017-09-06 2017-09-06
#> 2 4yr college       18 2017-04-30 2017-05-01 2017-05-06 2017-09-13 2017-09-14
#> 3 other            138 2017-04-11 2017-04-23 2017-04-25 2017-04-29 2017-05-14
#> 4 private hs       169 2017-04-23 2017-04-24 2017-04-29 2017-04-30 2017-09-05
#> 5 public hs        442 2017-04-14 2017-04-24 2017-04-26 2017-04-27 2017-04-27
```

4 Summarize across multiple columns

What are column-wise operations?

`across()` allows you to perform the same operation on multiple columns.

Description - `across()` apply the same transformation to multiple columns.

Syntax - `across(.cols, .fns, .names)`

Arguments

- `.cols` Columns to transform
- `.fns` Function to apply to each of the selected columns. Some values include:
  - A function, e.g. `mean()`
  - A purr-style lambda, e.g. ~ mean(.x, na.rm = TRUE)
  - A named list of functions or lambdas,
    e.g. `list(mean = mean, n_miss = ~sum(is.na(.x)))`
- `.names` A glue specification that describes how to name the output columns.
  Use `{.col}` to stand for the selected column name and `{.fn}` to stand for the name of the function being applied, e.g. " `{.col}_{.fn}` "

across() affects every variable

Syntax: `across(.cols, .fns, .names)`

- `.cols` Columns to transform
- `.fns` Function to apply to each of the selected columns. Some values include:
  - A function, e.g. `mean()` ; A purr-style lambda, e.g. ~ mean(.x, na.rm = TRUE); A named list of functions or lambdas,
    e.g. `list(mean = mean, n_miss = ~sum(is.na(.x)))`

Task:

- For U. Pittsburgh (`univ_id = 215293`) events at public and private high schools, caclulate the **mean** value of `med_inc` and `pct_white_zip` for each combination of `event_type` and `event_inst`

```
df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pct_white_zip) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(c(med_inc, pct_white_zip), mean))
```

Try again, this time applying `na.rm = TRUE` - this is an example of a purr style lambda `~ mean(.x, na.rm = TRUE)` argument "for the function calls in `.fns` ."

```
df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pct_white_zip) %>%
```

across() affects every variable

Syntax: `across(.cols, .fns, .names)`

- `.cols` Columns to transform
- `.fns` Function to apply to each of the selected columns. Some values include:
  - A function, e.g. `mean()` ; A purr-style lambda, e.g. ~ mean(.x, na.rm = TRUE); A named list of functions or lambdas,
    e.g. `list(mean = mean, n_miss = ~sum(is.na(.x)))`

Task:

- For U. Pittsburgh (`univ_id = 215293`) events at public and private high schools, caclulate **mean** and **standard deviation** of `med_inc` and `pct_white_zip` for each combination of `event_type` and `event_inst`
- You can create a named list of functions to supply into the second argument `.fns`

```
mean_sd <- list(
  mean = ~mean(.x, na.rm = TRUE),
  sd = ~sd(.x, na.rm = TRUE)
)

df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pct_white_zip) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(c(med_inc, pct_white_zip), mean_sd))
```

across() affects every variable

Syntax: `across(.cols, .fns, .names)`

- `.names` A glue specification that describes how to name the output columns. Use `{.col}` to stand for the selected column name and `{.fn}` to stand for the name of the function being applied, e.g. " `{.col}_{.fn}` "

Use this syntax to control variable name suffixes:

- `.names = "{.col}_{.fn}"`

```
df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pct_white_zip) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(c(med_inc, pct_white_zip), mean_sd, .names = "{.col}_{.fn}"))
```

- `.names = "{.fn}_{.col}"` Change the order of the name to include function first and then the column name

```
df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pct_white_zip) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(c(med_inc, pct_white_zip), mean_sd, .names = "{.fn}_{.col}"))
```

across() affects every variable

Task:

- Same task as before, but now calculate **mean**, **standard deviation**, **min**, and **max** of `med_inc` and `pct_white_zip` for each combination of `event_type` and `event_inst`

```
desc_stat <- list(
  mean = ~mean(.x, na.rm = TRUE),
  sd = ~sd(.x, na.rm = TRUE),
  low = ~min(.x, na.rm = TRUE),
  high = ~max(.x, na.rm=TRUE)
)

df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pct_white_zip) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(c(med_inc, pct_white_zip), desc_stat, .names = "{.col}_{.fn}
#> # A tibble: 4 x 10
#> # Groups:   event_type [2]
#>   event_type event_inst med_inc_mean med_inc_sd med_inc_low med_inc_high
#>   <chr>      <chr>             <dbl>      <dbl>       <dbl>        <dbl>
#> 1 private hs In-State          77115.     36559.      12894.      224163
#> 2 private hs Out-State        103915.     44220.      29630.      223556.
#> 3 public hs  In-State          78408.     25841.      23168.      169036.
#> 4 public hs  Out-State        114212.     39745.      21581       250001
#> # i 4 more variables: pct_white_zip_mean <dbl>, pct_white_zip_sd <dbl>,
```

across(), quosure style lambdas ~ func_name(.x)

Syntax: `across(.cols, .fns, .names)`

- `.fns` Function to apply to each of the selected columns. Some values include:
  - A function, e.g. `mean()` ; A purr-style lambda, e.g. ~ mean(.x, na.rm = TRUE); A named list of functions or lambdas,
    e.g. `list(mean = mean, n_miss = ~sum(is.na(.x)))`

Task: Calculate mean, number of obs, and number of non-missing obs for variables

- Can exclude `n()` from the `.cols` argument in `across()` function because you only need to calculate once to get the number of observations for each group.

```
mean_obs_nmiss <- list(
  mean = ~mean(.x, na.rm = TRUE),
  n_non_miss = ~sum(!is.na(.x))
)

df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,med_inc,pop_total) %>%
  group_by(event_type,event_inst) %>%
  summarize(nrow = n(), across(c(med_inc, pop_total), mean_obs_nmiss,.names = "
```

across() and where() affects selected variables if they meet a condition

Syntax: `across(where(fn)), .fns, .names)`

- `fn` A function that returns TRUE or FALSE
- `.fns` Function to apply to each of the selected columns. Some values include:
  - A function, e.g. `mean()` ; A purr-style lambda, e.g. ~ mean(.x, na.rm = TRUE); A named list of functions or lambdas,
    e.g. `list(mean = mean, n_miss = ~sum(is.na(.x)))`

Task: For U. Pittsburgh events at public and private high schools, caclulate **mean**, **min**, and **max** of variables `med_inc` and `event_date` for each combination of `event_type` and `event_inst`

```
mean_min_max <- list(
  mean = ~mean(.x, na.rm = TRUE),
  low = ~min(.x, na.rm=TRUE),
  high = ~max(.x, na.rm=TRUE)
)

df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst, med_inc, event_date) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(where(is.double), mean_min_max))
```

- Although `event_date` is a Date class, it is type double and therefore we can apply `is.double` to the `where()` function to calculate the mean, min, and

across() and where() affects selected variables if they meet a condition

Useful if you want to apply functions to variables that are particular `type` or `class`

Syntax: `across(where(fn)), .fns, .names)`

- `fn` A function that returns TRUE or FALSE
- `.fns` Function to apply to each of the selected columns. Some values include:
  - A function, e.g. `mean()` ; A purr-style lambda, e.g. ~ mean(.x, na.rm = TRUE); A named list of functions or lambdas,
    e.g. `list(mean = mean, n_miss = ~sum(is.na(.x)))`

Task: For events by U. Pittsburgh at public and private high schools, caclulate mean and standard deviation for **numeric variables**

```
#First, which vars are numeric
df_event %>%
  select(event_type, event_inst,instnm,school_id,med_inc,pct_white_zip) %>%
  glimpse()

df_event %>%
  filter(univ_id == 215293, event_type %in% c("private hs","public hs")) %>%
  select(event_type, event_inst,instnm,school_id,med_inc,pct_white_zip) %>%
  group_by(event_type,event_inst) %>%
  summarize(across(where(is.numeric), mean_sd))
```

5 Attach aggregate measures to your data frame

Attach aggregate measures to your data frame

We can attach aggregate measures to a data frame by using group_by without summarize()

What do I mean by "attaching aggregate measures to a data frame"?

- Calculate measures at the by_group level, but attach them to original object rather than creating an object with one row for each by_group

Task: Using `event_berk` data frame, create (1) a measure of average income across all events and (2) a measure of average income for each event type

- resulting object should have same number of observations as `event_berk`

Steps:

1. create measure of avg. income across all events without using `group_by()` or `summarize()` and assign as (new) object
2. Using object from previous step, create measure of avg. income across by event type using `group_by()` without `summarize()` and assign as new object

Attach aggregate measures to your data frame

Task: Using `event_berk` data frame, create (1) a measure of average income across all events and (2) a measure of average income for each event type

1. Create measure of average income across all events

```
event_berk_temp <- event_berk %>%
  arrange(event_date) %>% # sort by event_date (optional)
  select(event_date, event_type,med_inc) %>% # select vars to be retained (optio
  mutate(avg_inc = mean(med_inc, na.rm=TRUE)) # create avg. inc measure

dim(event_berk_temp)
event_berk_temp %>% head(5)
```

2. Create measure of average income by event type

```
event_berk_temp <- event_berk_temp %>%
  group_by(event_type) %>% # grouping by event type
  mutate(avg_inc_type = mean(med_inc, na.rm=TRUE)) # create avg. inc measure

str(event_berk_temp)
event_berk_temp %>% head(5)
```

Attach aggregate measures to your data frame

Task: Using `event_berk_temp` from previous question, create a measure that identifies whether `med_inc` associated with the event is higher/lower than average income for all events of that type

Steps:

1. Create measure of average income for each event type [already done]
2. Create 0/1 indicator that identifies whether median income at event location is higher than average median income for events of that type

```
# average income at recruiting events across all universities
event_berk_tempv2 <- event_berk_temp %>%
  mutate(gt_avg_inc_type = med_inc > avg_inc_type) %>%
  select(-(avg_inc)) # drop avg_inc (optional)
event_berk_tempv2 # note how med_ic = NA are treated
```

Same as above, but this time create integer indicator rather than logical

```
event_berk_tempv2 <- event_berk_tempv2 %>%
  mutate(gt_avg_inc_type = as.integer(med_inc > avg_inc_type))
event_berk_tempv2  %>% head(4)
```

Student exercise

Task: is `pct_white_zip` at a particular event higher or lower than the average pct_white_zip for that `event_type`?

- Note: all events attached to a particular zip_code
- `pct_white_zip`: pct of people in that zip_code who identify as white

Steps in task:

- Create measure of average pct white for each event_type
- Compare whether pct_white_zip is higher or lower than this average

Student exercise solution

Task: is `pct_white_zip` at a particular event higher or lower than the average pct_white_zip for that `event_type`?

```
event_berk_tempv3 <- event_berk %>%
  arrange(event_date) %>% # sort by event_date (optional)
  select(event_date, event_type, pct_white_zip) %>% #optional
  group_by(event_type) %>% # grouping by event type
  mutate(avg_pct_white = mean(pct_white_zip, na.rm=TRUE),
         gt_avg_pctwhite_type = as.integer(pct_white_zip > avg_pct_white))
event_berk_tempv3 %>% head(4)
#> # A tibble: 4 x 5
#> # Groups:   event_type [3]
#>   event_date event_type pct_white_zip avg_pct_white gt_avg_pctwhite_type
#>   <date>     <chr>              <dbl>         <dbl>                <int>
#> 1 2017-04-11 other               37.2          49.7                    0
#> 2 2017-04-14 public hs           78.3          48.9                    1
#> 3 2017-04-23 private hs          84.7          61.0                    1
#> 4 2017-04-23 other               20.9          49.7                    0
```