

Lesson 3: Control flow with `if` and `ifelse`

Suggested Solutions

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Warm-up: Conditional statements and `ifelse`:

1. Without running the code, predict what the output will be. Then, see if you were right by running the code in the console.

True or False

- a. TRUE | FALSE
- b. TRUE | (FALSE & FALSE)
- c. TRUE | (10 < 4)
- d. TRUE | (10 < 4 &)
- e. TRUE | (4 > pi & 3 < pi & exp(1) >= 3 & 1e6 < 2^30)
- f. 4 > 2 | 2 > 4
- g. What rule do these problems demonstrate?

Solution a. TRUE b. TRUE c. TRUE d. Error, (10 < 4 &) is an incomplete statement e. TRUE f. TRUE g. OR (|) returns TRUE if at least one term is TRUE

True and False

- a. TRUE & FALSE
- b. TRUE & (FALSE & FALSE)
- c. TRUE & (10 < 4)
- d. TRUE & (10 < 4 &)
- e. TRUE & (4 > pi & 3 < pi & exp(1) >= 3 & 1e6 < 2^30)
- f. 4 > 2 & 2 > 4
- g. What rule do these problems demonstrate?

Solution a. FALSE b. FALSE c. FALSE d. Error, (10 < 4 &) is an incomplete statement e. FALSE f. FALSE g. AND (&) returns TRUE *only* when *both* operands are TRUE

True and NA

1. There are a few times when NA are not contagious. Run the code and think about how this relates to your findings above.

```
TRUE & NA
FALSE & NA
TRUE | NA
FALSE | NA
```

Solution

```
TRUE & NA
```

```
## [1] NA
```

```
FALSE & NA
```

```
## [1] FALSE
```

```
TRUE | NA
```

```
## [1] TRUE
```

```
FALSE | NA
```

```
## [1] NA
```

NA is valid logical object, and the results of statements including NA will evaluate to NA when the outcome is ambiguous. Think of NA as an *unknown*.

TRUE & NA evaluates to NA because we do not know if NA represents a TRUE or FALSE statements, so the outcome is ambiguous. If NA were a TRUE statement, then this example would evaluate to TRUE. If NA were a FALSE statement, then this example would evaluate to FALSE.

FALSE & NA evaluates to FALSE because at least one of the statements is FALSE.

TRUE | NA evaluates to TRUE because at least one of the statements is TRUE.

FALSE | NA evaluates to NA again because we do not know if NA represents a TRUE or FALSE statements, so the outcome is ambiguous. If NA were a TRUE statement, then this example would evaluate to TRUE. If NA were a FALSE statement, then this example would evaluate to FALSE.

2. Without running the code, predict what the output will be. Then, see if you were right by running the code in the console.

```
ifelse(TRUE, "yes", "no")
ifelse(FALSE, "yes", "no")
ifelse(c(TRUE, FALSE, TRUE, FALSE), "yes", "no")
ifelse(c(TRUE & FALSE,
         FALSE | TRUE,
         TRUE | TRUE,
         FALSE & FALSE),
       "yes", "no")
ifelse(c(NA, TRUE, FALSE), "yes", "no")
ifelse(c(NA, NA, TRUE, FALSE), "yes", "no")
```

Solution

```
ifelse(TRUE, "yes", "no")
```

```
## [1] "yes"
```

```
ifelse(FALSE, "yes", "no")
```

```
## [1] "no"
```

```
ifelse(c(TRUE, FALSE, TRUE, FALSE), "yes", "no")
```

```
## [1] "yes" "no" "yes" "no"
```

```
ifelse(c(TRUE & FALSE,
         FALSE | TRUE,
         TRUE | TRUE,
         FALSE & FALSE),
       "yes", "no")
```

```
## [1] "no" "yes" "yes" "no"
```

```
ifelse(c(NA, TRUE, FALSE), "yes", "no")
```

```
## [1] NA "yes" "no"
```

```
ifelse(c(NA, NA, TRUE, FALSE), "yes", "no")
```

```
## [1] NA NA "yes" "no"
```

Recall that `ifelse()` asks, “Does the statement in the first position evaluate to `TRUE`?” If it does, then return what sits in the second position. If it does not, then return what sits in the third position. As always, `NA` will be returned if the outcome of a statement is ambiguous.

If what sits in the first position is a vector, then repeat this process for every element of the vector one by one.

Common uses of `ifelse`

1. Run the following code and you will see the distinct `tier_names` available in the dataset.

```
mrc_data %>% distinct(tier_name)
```

- a. `ifelse` can be used to adjust entries in the `tier_name` column. Change “Two-year (public and private not-for-profit)” to “Two-year (public and private)”.¹

```
# Fill in the ... with the appropriate code
mrc_data %>%
  mutate(tier_name = ifelse( ... , ..., tier_name))
```

Solution

```
mrc_data %>%
  mutate(tier_name = ifelse(
    tier_name == "Two-year (public and private not-for-profit)",
    "Two-year (public and private)",
    tier_name)) %>%
  distinct(tier_name)
```

```
## # A tibble: 12 x 1
##   tier_name
##   <chr>
## 1 Two-year for-profit
## 2 Selective private
## 3 Nonselective four-year public
## 4 Four-year for-profit
## 5 Selective public
## 6 Two-year (public and private)
## 7 Nonselective four-year private not-for-profit
## 8 Highly selective private
## 9 Less than two-year schools of any type
## 10 Other elite schools (public and private)
## 11 Highly selective public
## 12 Ivy Plus
```

Notice that a good way to check if you’ve executed this correctly, is to call `distinct()` once again and see for yourself if “Two-year (public and private not-for-profit)” is still a value for `tier_name`.

¹Hint: In the first position, put a condition testing if `tier_name` matches the string. If it does, we replace the string with “Two-year (public and private)”, otherwise keep the same data.

b. `ifelse` is often used to collapse tiers. Redefine `tier_name` so that "Nonselective four-year public

Solution

```
mrc_data %>%
  mutate(tier_name = ifelse(
    tier_name == "Nonselective four-year public" |
    tier_name == "Nonselective four-year private not-for-profit",
    "Nonselective four-year (public and private)",
    tier_name)) %>%
  distinct(tier_name)

## # A tibble: 11 x 1
##   tier_name
##   <chr>
## 1 Two-year for-profit
## 2 Selective private
## 3 Nonselective four-year (public and private)
## 4 Four-year for-profit
## 5 Selective public
## 6 Two-year (public and private not-for-profit)
## 7 Highly selective private
## 8 Less than two-year schools of any type
## 9 Other elite schools (public and private)
## 10 Highly selective public
## 11 Ivy Plus
```

- As you can see, there are 1466 colleges missing average SAT scores. Sometimes we want to replace NAs with a value. For example, linear regressions will drop any row with NAs, and we might not want that.²

```
mrc_data %>%
  summarise(missing_sat_2013 = sum(is.na(sat_avg_2013)))

## # A tibble: 1 x 1
##   missing_sat_2013
##   <int>
## 1             1466
```

To avoid dropping rows, sometimes people replace the NA with the mean and add a new column that is an indicator of missingness. Using `mutate()` and `ifelse()`, fill NA in `sat_avg_2013` with the average SAT score of the other colleges and create a column called `missing_sat_avg_2013` that is 1 if NA and 0 otherwise.³

Here's a small example of what we expect. Try reproducing this example and then applying your code to `mrc_data`.

```
before <- tibble(fake_data = c(1, 2, NA))
before

## # A tibble: 3 x 1
##   fake_data
##   <dbl>
## 1         1
## 2         2
## 3        NA
```

²I believe you'll discuss missing data problems in stats I.

³Hint: First, make the indicator column. Hint 2: When replacing NA in the example, I used the following code to find the mean `mean(fake_data, na.rm = TRUE)`.

after

```
## # A tibble: 3 x 2
##   fake_data missing_fake_data
##   <dbl>         <dbl>
## 1     1             0
## 2     2             0
## 3    1.5           1
```

Solution

```
mrc_data <- mrc_data %>%
  mutate(missing_sat_avg_2013 = ifelse(
    is.na(sat_avg_2013), 1, 0),
    sat_avg_2013 = ifelse(
      is.na(sat_avg_2013),
      mean(sat_avg_2013, na.rm = TRUE),
      sat_avg_2013))

mrc_data %>%
  summarise(sum(is.na(sat_avg_2013)),
            sum(missing_sat_avg_2013),
            sum(sat_avg_2013 == mean(sat_avg_2013, na.rm = TRUE)))
```

```
## # A tibble: 1 x 3
##   `sum(is.na(sat_avg_2013))` `sum(missing_sat_avg_2013)` `sum(sat_avg_2013 == mean(sat_avg_2013, na.rm = TRUE))`
##   <int>                   <dbl>                   <int>
## 1             0             1466                   1466
```

To check your work, you can use `summarize()` again. We see the following. There are no more NA values in the `sat_avg_2013` column. There are 1466 instances of a value 1 in `missing_sat_avg_2013`, which matches the number of NA values were originally present in `sat_avg_2013`. There are 1466 instances of `sat_avg_2013` equalling the mean of `sat_avg_2013`, so we can feel fairly confident that NA values were replaced by the mean.

```
mrc_data %>%
  summarise(missing_sat_2013 = sum(is.na(sat_avg_2013)))
```

```
## # A tibble: 1 x 1
##   missing_sat_2013
##   <int>
## 1             0
```

Extension: College choice:

This part is admittedly silly! Imagine the situation: It's 2014 and a group of high school friends want to go to college together. They need to find a college that meets all their preferences. Your job is to find the perfect college.

Name	SAT Score	Preferences
A-plus Abdul	1430	Either ivy plus tier or a flagship school
Snooty Stephen	1450	not a public school
Nourishing Nancy	1590	school in the midwest so she can be near her grandma

Name	SAT Score	Preferences
Radical Rei	1490	strong social studies (as measured by the percentage of students majoring in social studies > 30 percent)
Cost-conscious Casey	1600	wants a public school in CA or a school where students from homes in the bottom 20th percentile of incomes pay less than 10000 per year

Here are the rules. They want to go to school where their test scores are within 100 points of the school average SAT score. To match their preferences, use the most recent data. You will need a few tools.

1. First, in order to understand what a column contains you can use `distinct()`⁴. For example, say you are trying to figure out how to identify “ivy plus” schools (or what that specifically means). Using `names()` you see there is a column called `tier_name`.

```
mrc_data %>% distinct(tier_name)

## # A tibble: 12 x 1
##   tier_name
##   <chr>
## 1 Two-year for-profit
## 2 Selective private
## 3 Nonselective four-year public
## 4 Four-year for-profit
## 5 Selective public
## 6 Two-year (public and private not-for-profit)
## 7 Nonselective four-year private not-for-profit
## 8 Highly selective private
## 9 Less than two-year schools of any type
## 10 Other elite schools (public and private)
## 11 Highly selective public
## 12 Ivy Plus
```

We see there are 12 tiers and one is “Ivy Plus”! Note the capitalization.

2. Second, we’re going to have to find schools that match ranges of SAT scores. Welcome `between()`.⁵

```
mrc_data %>% filter(1330 <= sat_avg_2013, sat_avg_2013 <= 1530)
mrc_data %>% filter(between(sat_avg_2013, 1330, 1530))
```

- a. Figure out whether `between()` use `<` or `<=`?

Solution

As always, `?between` is the first thing to do. In the R Documentation, you should see “This is a shortcut for `x >= left & x <= right`, implemented efficiently in ...”

```
?between
```

You can also test things out in R. In this case, we see that the lower bound (1330) is included in the final output. However, this way would not be helpful to tell whether `between()` use `<` or `<=` if there is no 1330 entry in the data.

```
mrc_data %>%
  filter(between(sat_avg_2013, 1330, 1530)) %>%
```

⁴from `dplyr`. The codebook is also useful.

⁵from `dplyr`

```
summarize(min(sat_avg_2013),
          max(sat_avg_2013))
```

```
## # A tibble: 1 x 2
##   `min(sat_avg_2013)` `max(sat_avg_2013)`
##   <dbl>                <dbl>
## 1           1330                1518.
```

3. The final thing is a concept. You're probably about to write code that looks like the following pseudo code.⁶

```
# This is pseudo code
mrc_data %>%
  mutate(abdul_choices = ifelse(CONDITIONS, yes, no),
         stephens_choices = ifelse(CONDITIONS, yes, no),
         ...) %>%
  filter(abdul_choices == yes, stephens_choices == yes, ...)
```

We can avoid the extra == yes by making abdul_choices a logical vector. In other words, write code like so:

```
# This is pseudo code
mrc_data %>%
  mutate(abdul_choices = ifelse(CONDITIONS, TRUE, FALSE),
         stephens_choices = ifelse(CONDITIONS, TRUE, FALSE),
         ...) %>%
  filter(abdul_choices, stephens_choices, ...)
```

b. Test out the concept with a simple example.⁷

Solution

```
mrc_data %>%
  mutate(abdul_choices = ifelse(
    tier_name == "Ivy Plus", TRUE, FALSE)) %>%
  filter(abdul_choices) %>%
  select(name, tier_name, abdul_choices, sat_avg_2013, flagship)
```

```
## # A tibble: 12 x 5
##   name                tier_name abdul_choices sat_avg_2013 flagship
##   <chr>                <chr>     <lgl>          <dbl>     <dbl>
## 1 Brown University    Ivy Plus  TRUE           1440       0
## 2 Columbia University In The Cit~ Ivy Plus  TRUE           1480       0
## 3 Cornell University   Ivy Plus  TRUE           1420       0
## 4 Dartmouth College    Ivy Plus  TRUE           1455       0
## 5 Duke University      Ivy Plus  TRUE           1460       0
## 6 Harvard University   Ivy Plus  TRUE           1505       0
## 7 Massachusetts Institute Of Tec~ Ivy Plus  TRUE           1495       0
## 8 Princeton University Ivy Plus  TRUE           1500       0
## 9 Stanford University  Ivy Plus  TRUE           1475       0
## 10 University Of Chicago Ivy Plus  TRUE           1518.      0
## 11 University Of Pennsylvania Ivy Plus  TRUE           1455       0
## 12 Yale University     Ivy Plus  TRUE           1505       0
```

4. Now you're ready to find the college for the five friends.

⁶pseudo code is a term for fake code that captures the logic of some coding idea without being actual code.

⁷For example, try it with Abdul's only condition being Ivy Plus.

```

# fill in the ... with appropriate code

# We'll give this a name so we can use it later.
bff_super_awesome_college_list <-
mrc %>%
  mutate(abdul_choices = ifelse(between(sat_avg_2013, 1330, 1530) &
                                (tier_name == "Ivy Plus" | ... ), TRUE, FALSE),
         stephen_choices = ifelse(..., ..., ...),
         nancy_choices = ifelse(..., ..., ...),
         rei_choices = ifelse(..., ..., ...),
         casey_choices = ifelse(..., ..., ...)
        )

bff_super_awesome_college_list %>%
  filter(abdul_choices, sam_choices, nancy_choices, rei_choices, casey_choices)

```

Solution

```

bff_super_awesome_college_list <- mrc_data %>%
  mutate(abdul = ifelse(between(sat_avg_2013, 1330, 1530) &
                        (tier_name == "Ivy Plus" | flagship == 1),
                        TRUE, FALSE),
         stephen = ifelse(between(sat_avg_2013, 1350, 1550) & public == 0,
                          TRUE, FALSE),
         nancy = ifelse(between(sat_avg_2013, 1490, 1690) & region == 2,
                        TRUE, FALSE),
         rei = ifelse(between(sat_avg_2013, 1390, 1590) & pct_socialscience_2000 > 30,
                     TRUE, FALSE),
         casey = ifelse(between(sat_avg_2013, 1500, 1600) &
                        (public == 1 & state == "CA" | scorecard_netprice_2013 < 10000),
                     TRUE, FALSE))

```

c. What school(s) are acceptable to all five

Solution

```

bff_super_awesome_college_list %>%
  filter(abdul, stephen, nancy, rei, casey) %>%
  select(name,abdul, stephen, nancy, rei, casey)

```

```

## # A tibble: 1 x 6
##   name                abdul stephen nancy rei   casey
##   <chr>                <lgl> <lgl>  <lgl> <lgl> <lgl>
## 1 University Of Chicago TRUE  TRUE   TRUE  TRUE  TRUE

```

```

# Alternative (notice it yields the same result)
bff_super_awesome_college_list %>%
  filter(abdul & stephen & nancy & rei & casey) %>%
  select(name,abdul, stephen, nancy, rei, casey)

```

```

## # A tibble: 1 x 6
##   name                abdul stephen nancy rei   casey
##   <chr>                <lgl> <lgl>  <lgl> <lgl> <lgl>
## 1 University Of Chicago TRUE  TRUE   TRUE  TRUE  TRUE

```


d. How many school(s) are available to any of the five. Adjust `filter` statement slightly.⁸

Solution

```
bff_super_awesome_college_list %>%
  filter(abdul | stephen | nancy | rei | casey) %>%
  nrow()
```

```
## [1] 52
```

5. The five friends have `NA` in their choice sets. Do the the school list change if we replace all the `NA`s with `TRUE`? Without coding, argue why the list will not change if we replace the `NA`s with `FALSE`.

Solution Yes, the school list will change if we replace all `NA`s with `TRUE`. The list will not change if we replace `NA`s with `FALSE` since we are using the `OR` (`|`) operator, and this operator evaluates to `TRUE` so long as at least one statement is `TRUE`.

6. **Challenge** Create a “Five friends college ranking”. A college is ranked 1 if it is acceptable to all 5 friends. 2 if it is acceptable to any 4 friends and so on.⁹ Colleges that are not acceptable to any friend should be marked “Unranked”.

Solution 1

We take advantage of the fact that the arithmetic operation of booleans (`TRUE` and `FALSE`) works like 1’s and 0’s. Since `abdul`, `stephen`, `nancy`, `rei`, and `casey` are logical vectors (vectors full of `TRUE`s and `FALSE`s), we get the number of friends who would accept going to that school when we add across the rows which represent schools. Finally, we use `case_when` to assign the rankings according to how many friends would accept going to that school.

```
bff_super_awesome_college_list %>%
  mutate(num_friends_accept = abdul + stephen + nancy + rei + casey,
         rank = case_when(num_friends_accept == 5 ~ "1",
                          num_friends_accept == 4 ~ "2",
                          num_friends_accept == 3 ~ "3",
                          num_friends_accept == 2 ~ "4",
                          num_friends_accept == 1 ~ "5",
                          num_friends_accept == 0 ~ "Unranked")) %>%
  arrange(rank) %>%
  select(name, num_friends_accept, rank)
```

```
## # A tibble: 2,463 x 3
##   name                               num_friends_accept rank
##   <chr>                               <int> <chr>
## 1 University Of Chicago                5 1
## 2 Harvard University                  4 2
## 3 Princeton University                4 2
## 4 Yale University                     4 2
## 5 Brown University                    3 3
## 6 Columbia University In The City Of New York 3 3
## 7 Dartmouth College                   3 3
## 8 Duke University                     3 3
## 9 Stanford University                 3 3
## 10 University Of Pennsylvania          3 3
## # ... with 2,453 more rows
```

Solution 2

⁸Hint: Think about the warm-up you did for this lab

⁹3 if it is acceptable to 3 friends. 4 if acceptable to 2 friends and 5 if acceptable to 1 friend

Listing all the possible cases can be mundane when the number of cases is very large. There are two functions that can be very helpful for this exercise: `recode()` and `dense_rank()`. If you are not sure what is going on in the `mutate()` step, please see the simple example provided below.

```
bff_super_awesome_college_list %>%
  mutate(num_friends_accept = abdul + stephen + nancy + rei + casey,
         rank = recode(as.character(dense_rank(-num_friends_accept)), "6" = "Unranked")) %>%
  arrange(rank) %>%
  select(name, num_friends_accept, rank)
```

```
## # A tibble: 2,463 x 3
##   name                               num_friends_accept rank
##   <chr>                               <int> <chr>
## 1 University Of Chicago                5 1
## 2 Harvard University                  4 2
## 3 Princeton University                4 2
## 4 Yale University                     4 2
## 5 Brown University                   3 3
## 6 Columbia University In The City Of New York 3 3
## 7 Dartmouth College                   3 3
## 8 Duke University                     3 3
## 9 Stanford University                 3 3
## 10 University Of Pennsylvania          3 3
## # ... with 2,453 more rows
```

Simple example

`dense_rank()` in `dplyr` can give you continuous ranks.

```
simple.example <- c(5,2,1,4,3)
dense_rank(simple.example)
```

```
## [1] 5 2 1 4 3
```

This is a common trick to obtain the descending ranks.

```
dense_rank(-simple.example)
```

```
## [1] 1 4 5 2 3
```

What if we want to label the last rank (which is 5 in this case) with “Last”? In the lecture, Ari has showed you an example where R cannot handle “numeric” and “character” type entries in the same column. To update the label with characters, let’s first convert the numeric ranks into characters.

```
simple.rank <- as.character(dense_rank(-simple.example))
```

Finally, let’s relabel 5 with “Last”. N.B. There are many other ways to do so.

```
recode(simple.rank, "5"="Last")
```

```
## [1] "1"    "4"    "Last" "2"    "3"
```