

# Data Cleaning

Introduction to R for Public Health Researchers

# Data Cleaning

In general, data cleaning is a process of investigating your data for inaccuracies, or recoding it in a way that makes it more manageable.

**MOST IMPORTANT RULE - LOOK AT YOUR DATA!**

## Useful checking functions

- `is.na` - is TRUE if the data is FALSE otherwise
- `!` - negation (NOT)
  - if `is.na(x)` is TRUE, then `!is.na(x)` is FALSE
- `all` takes in a logical and will be TRUE if ALL are TRUE
  - `all(!is.na(x))` - are all values of `x` NOT NA
- `any` will be TRUE if ANY are true
  - `any(is.na(x))` - do we have any NA's in `x`?
- `complete.cases` - returns TRUE if EVERY value of a row is NOT NA
  - very stringent condition
  - FALSE missing one value (even if not important)

# Dealing with Missing Data

# Missing data types

One of the most important aspects of data cleaning is missing values.

Types of "missing" data:

- `NA` - general missing data
- `NaN` - stands for "**N**ot **a** **N**umber", happens when you do  $0/0$ .
- `Inf` and `-Inf` - Infinity, happens when you take a positive number (or negative number) by 0.

## Finding Missing data

Each missing data type has a function that returns `TRUE` if the data is missing:

- `NA` - `is.na`
- `NaN` - `is.nan`
- `Inf` and `-Inf` - `is.infinite`
- `is.finite` returns `FALSE` for all missing data and `TRUE` for non-missing

## Missing Data with Logicals

One important aspect (esp with subsetting) is that logical operations return NA for NA values. Think about it, the data could be  $> 2$  or not we don't know, so R says there is no TRUE or FALSE, so that is missing:

```
x = c(0, NA, 2, 3, 4)
x > 2
```

```
[1] FALSE      NA FALSE  TRUE  TRUE
```

# Missing Data with Logicals

What to do? What if we want if  $x > 2$  and  $x$  isn't NA?

Don't do  $x \neq \text{NA}$ , do  $x > 2$  and  $x$  is NOT NA:

```
x != NA
```

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

```
x > 2 & !is.na(x)
```

```
[1] FALSE FALSE FALSE  TRUE  TRUE
```



## Missing Data with Logicals

What about seeing if a value is equal to multiple values? You can do `(x == 1 | x == 2) & !is.na(x)`, but that is not efficient.

```
(x == 0 | x == 2) # has NA
```

```
[1] TRUE NA TRUE FALSE FALSE
```

```
(x == 0 | x == 2) & !is.na(x) # No NA
```

```
[1] TRUE FALSE TRUE FALSE FALSE
```

what to do?

## Missing Data with Logicals: %in%

NEVER has NA, even if you put it there (BUT DON'T DO THIS):

```
x %in% c(0, 2, NA) # NEVER has NA and returns logical
```

```
[1]  TRUE  TRUE  TRUE FALSE FALSE
```

```
x %in% c(0, 2) | is.na(x)
```

```
[1]  TRUE  TRUE  TRUE FALSE FALSE
```

# Missing Data with Operations

Similarly with logicals, operations/arithmetic with NA will result in NAs:

```
x + 2
```

```
[1]  2 NA  4  5  6
```

```
x * 2
```

```
[1]  0 NA  4  6  8
```

# Tables and Tabulations

## Useful checking functions

- `unique` - gives you the unique values of a variable
- `table(x)` - will give a one-way table of `x`
  - `table(x, useNA = "ifany")` - will have row NA
- `table(x, y)` - will give a cross-tab of `x` and `y`

# Creating One-way Tables

Here we will use `table` to make tabulations of the data. Look at `?table` to see options for missing data.

```
unique(x)
```

```
[1]  0 NA  2  3  4
```

```
table(x)
```

```
x
0 2 3 4
1 1 1 1
```

```
table(x, useNA = "ifany") # will not
```

```
x
  0    2    3    4 <NA>
1  1    1    1    1    1
```

# Creating One-way Tables

useNA = "ifany" will not have NA in table heading if no NA:

```
table(c(0, 1, 2, 3, 2, 3, 3, 2, 2, 3),  
      useNA = "ifany")
```

```
0 1 2 3  
1 1 4 4
```

# Creating One-way Tables

You can set `useNA = "always"` to have it always have a column for NA

```
table(c(0, 1, 2, 3, 2, 3, 3, 2, 2, 3),  
      useNA = "always")
```

0	1	2	3	<NA>
1	1	4	4	0



# Tables with Factors

If you use a `factor`, all levels will be given even if no exist! - (May be wanted or not):

```
fac = factor(c(0, 1, 2, 3, 2, 3, 3, 2, 2, 3),  
             levels = 1:4)  
tab = table(fac)  
tab
```

```
fac  
1 2 3 4  
1 4 4 0
```

```
tab[ tab > 0 ]
```

```
fac  
1 2 3  
1 4 4
```

## Creating Two-way Tables

A two-way table. If you pass in 2 vectors, `table` creates a 2-dimensional table.

```
tab <- table(c(0, 1, 2, 3, 2, 3, 3, 2, 2, 3),  
             c(0, 1, 2, 3, 2, 3, 3, 4, 4, 3),  
            useNA = "always")  
tab
```

	0	1	2	3	4	<NA>
0	1	0	0	0	0	0
1	0	1	0	0	0	0
2	0	0	2	0	2	0
3	0	0	0	4	0	0
<NA>	0	0	0	0	0	0

## Finding Row or Column Totals

`margin.table` finds the marginal sums of the table. `margin` is 1 for rows, 2 for columns in general in R. Here is the column sums of the table:

```
margin.table(tab, 2)
```

	0	1	2	3	4	<NA>
1	1	1	2	4	2	0

# Proportion Tables

`prop.table` finds the marginal proportions of the table. Think of it dividing the table by it's respective marginal totals. If `margin` not set, divides by overall total.

```
prop.table(tab)
```

	0	1	2	3	4	<NA>
0	0.1	0.0	0.0	0.0	0.0	0.0
1	0.0	0.1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.2	0.0	0.2	0.0
3	0.0	0.0	0.0	0.4	0.0	0.0
<NA>	0.0	0.0	0.0	0.0	0.0	0.0

```
prop.table(tab, 1)
```

	0	1	2	3	4	<NA>
0	1.0	0.0	0.0	0.0	0.0	0.0
1	0.0	1.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.5	0.0	0.5	0.0
3	0.0	0.0	0.0	1.0	0.0	0.0
<NA>						

## Download Salary FY2014 Data

From <https://data.baltimorecity.gov/City-Government/Baltimore-City-Employee-Salaries-FY2015/nsfe-bg53> <https://data.baltimorecity.gov/api/views/nsfe-bg53/rows.csv>

Read the CSV into R `Sal`:

```
Sal = read_csv("http://data.baltimorecity.gov/api/views/nsfe-bg53/rows.csv")  
Sal = rename(Sal, Name = name)
```

## Checking for logical conditions

- `any()` - checks if there are any TRUES
- `all()` - checks if ALL are true

```
head(Sal, 2)
```

	Name	JobTitle	AgencyID
1	Aaron, Patricia G	Facilities/Office Services II	A03031
2	Aaron, Petra L	ASSISTANT STATE'S ATTORNEY	A29045

  

	Agency	HireDate	AnnualSalary	GrossPay
1	OED-Employment Dev (031)	10/24/1979	\$55314.00	\$53626.04
2	States Attorneys Office (045)	09/25/2006	\$74000.00	\$73000.08

```
any(is.na(Sal$Name)) # are there any NAs?
```

```
[1] FALSE
```

# Recoding Variables

## Example of Recoding

For example, let's say gender was coded as Male, M, m, Female, F, f. Using Excel to find all of these would be a matter of filtering and changing all by hand or using if statements.

In R, you can simply do something like:

```
data$gender[data$gender %in%  
  c("Male", "M", "m")] <- "Male"
```

or use ifelse

```
data %>%  
  mutate(gender = ifelse(gender %in% c("Male", "M", "m"),  
                          "Male", gender))
```



# Example of Cleaning: more complicated

Sometimes though, it's not so simple. That's where functions that find patterns come in very useful.

```
table(gender)
```

gender									
F	FeMAle	FEMALE	Fm	M	Ma	mAle	Male	MaLe	MALE
75	82	74	89	89	79	87	89	88	95
Man	Woman								
73	80								

# String functions

## Pasting strings with `paste` and `paste0`

Paste can be very useful for joining vectors together:

```
paste("Visit", 1:5, sep = "_")
```

```
[1] "Visit_1" "Visit_2" "Visit_3" "Visit_4" "Visit_5"
```

```
paste("Visit", 1:5, sep = "_", collapse = " ")
```

```
[1] "Visit_1 Visit_2 Visit_3 Visit_4 Visit_5"
```

```
paste("To", "is going be the ", "we go to the store!", sep = "day ")
```

```
[1] "Today is going be the day we go to the store!"
```

```
# and paste0 can be even simpler see ?paste0  
paste0("Visit", 1:5)
```

```
[1] "Visit1" "Visit2" "Visit3" "Visit4" "Visit5"
```

## Paste Depicting How Collapse Works

```
paste(1:5)
```

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

```
paste(1:5, collapse = " ")
```

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

# Useful String Functions

## Useful String functions

- `toupper()`, `tolower()` - uppercase or lowercase your data:
- `str_trim()` (in the `stringr` package) or `trimws` in base
  - will trim whitespace
- `nchar` - get the number of characters in a string

# The **stringr** package

Like `dplyr`, the `stringr` package:

- Makes some things more intuitive
- Is different than base R
- Is used on forums for answers
- Has a standard format for most functions
  - the first argument is a string like first argument is a `data.frame` in `dplyr`

# Splitting/Find/Replace and Regular Expressions

- R can do much more than find exact matches for a whole string
- Like Perl and other languages, it can use regular expressions.
- What are regular expressions?
  - Ways to search for specific strings
  - Can be very complicated or simple
  - Highly Useful - think "Find" on steroids

## A bit on Regular Expressions

- <http://www.regular-expressions.info/reference.html>
- They can use to match a large number of strings in one statement
- . matches any single character
- \* means repeat as many (even if 0) more times the last character
- ? makes the last thing optional
- ^ matches start of vector ^a - starts with "a"
- \$ matches end of vector b\$ - ends with "b"



# Splitting Strings

# Substringing

Very similar:

Base R

- `substr(x, start, stop)` - substrings from position start to position stop
- `strsplit(x, split)` - splits strings up - returns list!

stringr

- `str_sub(x, start, end)` - substrings from position start to position end
- `str_split(string, pattern)` - splits strings up - returns list!

## Splitting String: base R

In base R, `strsplit` splits a vector on a string into a list

```
x <- c("I really", "like writing", "R code programs")  
y <- strsplit(x, split = " ") # returns a list  
y
```

```
[[1]]  
[1] "I"      "really"
```

```
[[2]]  
[1] "like"   "writing"
```

```
[[3]]  
[1] "R"      "code"   "programs"
```

## Splitting String: **stringr**

`stringr::str_split` do the same thing:

```
library(stringr)
y2 <- str_split(x, " ") # returns a list
y2
```

```
[[1]]
[1] "I"      "really"
```

```
[[2]]
[1] "like"    "writing"
```

```
[[3]]
[1] "R"      "code"    "programs"
```

## Using a fixed expression

One example case is when you want to split on a period ".". In regular expressions . means **ANY** character, so

```
str_split("I.like.strings", ".")
```

```
[[1]]  
[1] "" "" "" "" "" "" "" "" "" "" "" "" "" "" "" ""
```

```
str_split("I.like.strings", fixed("."))
```

```
[[1]]  
[1] "I"      "like"    "strings"
```

## Let's extract from **y**

```
suppressPackageStartupMessages(library(dplyr)) # must be loaded AFTER plyr
y[[2]]
```

```
[1] "like"      "writing"
```

```
sapply(y, dplyr::first) # on the fly
```

```
[1] "I"        "like" "R"
```

```
sapply(y, nth, 2) # on the fly
```

```
[1] "really" "writing" "code"
```

```
sapply(y, last) # on the fly
```

```
[1] "really" "writing" "programs"
```

## 'Find' functions: **stringr**

`str_detect`, `str_subset`, `str_replace`, and `str_replace_all` search for matches to argument pattern within each element of a character vector: they differ in the format of and amount of detail in the results.

- `str_detect` - returns TRUE if pattern is found
- `str_subset` - returns only the strings which pattern were detected
  - convenient wrapper around `x[str_detect(x, pattern)]`
- `str_extract` - returns only strings which pattern were detected, but ONLY the pattern
- `str_replace` - replaces pattern with replacement the first time
- `str_replace_all` - replaces pattern with replacement as many times matched

## Let's look at modifier for `stringr`

?modifiers

- `fixed` - match everything exactly
- `regex` - default - uses **regular expressions**
- `ignore_case` is an option to not have to use `tolower`



## 'Find' functions: finding values, stringr and dplyr

```
str_subset(Sal$Name, "Rawlings")
```

```
[1] "Rawlings,Kellye A"          "Rawlings,Paula M"  
[3] "Rawlings-Blake,Stephanie C"
```

```
Sal %>% filter(str_detect(Name, "Rawlings"))
```

	Name	JobTitle	AgencyID
1	Rawlings,Kellye A	EMERGENCY DISPATCHER	A40302
2	Rawlings,Paula M	COMMUNITY AIDE	A04015
3	Rawlings-Blake,Stephanie C	MAYOR	A01001

  

	Agency	HireDate	AnnualSalary	GrossPay
1	M-R Info Technology (302)	01/06/2003	\$48940.00	\$73356.42
2	R&P-Recreation (015)	12/10/2007	\$19802.00	\$10443.70
3	Mayors Office (001)	12/07/1995	\$167449.00	\$165249.86

## Replacing and subbing: **stringr**

We can do the same thing (with 2 piping operations!) in dplyr

```
dplyr_sal = Sal
dplyr_sal = dplyr_sal %>% mutate(
  AnnualSalary = AnnualSalary %>%
    str_replace(fixed("$"), "") %>%
    as.numeric) %>%
  arrange(desc(AnnualSalary))
```

## Showing difference in `str_extract` and `str_extract_all`

`str_extract_all` extracts all the matched strings - `\\d` searches for DIGITS/numbers

```
head(str_extract(Sal$AgencyID, "\\d"))
```

```
[1] "0" "2" "6" "9" "4" "9"
```

```
head(str_extract_all(Sal$AgencyID, "\\d"), 2)
```

```
[[1]]
```

```
[1] "0" "3" "0" "3" "1"
```

```
[[2]]
```

```
[1] "2" "9" "0" "4" "5"
```

## Sorting characters

- `sort` - reorders the data - characters work, but not
- `rank` - gives the rank of the data - ties are split
- `order` - gives the indices, if subset, would give the data sorted
  - `x[order(x)]` is the same as sorting

```
sort(c("1", "2", "10")) # not sort correctly (order simply ranks the data)
```

```
[1] "1"  "10" "2"
```

```
order(c("1", "2", "10"))
```

```
[1] 1 3 2
```

```
x = rnorm(10)
x[1] = x[2] # create a tie
rank(x)
```

```
[1] 3.5 3.5 1.0 8.0 5.0 7.0 6.0 9.0 2.0 10.0
```

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## 'Find' functions: base R

`grep`: `grep`, `grepl`, `regexpr` and `gregexpr` search for matches to argument pattern within each element of a character vector: they differ in the format of and amount of detail in the results.

`grep(pattern, x, fixed=FALSE)`, where:

- `pattern` = character string containing a regular expression to be matched in the given character vector.
- `x` = a character vector where matches are sought, or an object which can be coerced by `as.character` to a character vector.
- If `fixed=TRUE`, it will do exact matching for the phrase anywhere in the vector (regular find)

## 'Find' functions: stringr compared to base R

Base R does not use these functions. Here is a "translator" of the `stringr` function to base R functions

- `str_detect` - similar to `grep1` (return logical)
- `grep(value = FALSE)` is similar to `which(str_detect())`
- `str_subset` - similar to `grep(value = TRUE)` - return value of matched
- `str_replace` - similar to `sub` - replace one time
- `str_replace_all` - similar to `gsub` - replace many times

# Important Comparisons

Base R:

- Argument order is `(pattern, x)`
- Uses option `(fixed = TRUE)`

`stringr`

- Argument order is `(string, pattern)` aka `(x, pattern)`
- Uses function `fixed(pattern)`



## 'Find' functions: Finding Indices

These are the indices where the pattern match occurs:

```
grep("Rawlings", Sal$Name)
```

```
[1] 10256 10257 10258
```

```
which(grepl("Rawlings", Sal$Name))
```

```
[1] 10256 10257 10258
```

```
which(str_detect(Sal$Name, "Rawlings"))
```

```
[1] 10256 10257 10258
```

## 'Find' functions: Finding Logicals

These are the indices where the pattern match occurs:

```
head(grepl("Rawlings", Sal$Name))
```

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

```
head(str_detect(Sal$Name, "Rawlings"))
```

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

## 'Find' functions: finding values, base R

```
grep("Rawlings", Sal$Name, value=TRUE)
```

```
[1] "Rawlings,Kellye A"      "Rawlings,Paula M"  
[3] "Rawlings-Blake,Stephanie C"
```

```
Sal[grep("Rawlings", Sal$Name),]
```

		Name		JobTitle	AgencyID
10256		Rawlings,Kellye A	EMERGENCY DISPATCHER		A40302
10257		Rawlings,Paula M	COMMUNITY AIDE		A04015
10258		Rawlings-Blake,Stephanie C	MAYOR		A01001

  

		Agency	HireDate	AnnualSalary	GrossPay
10256	M-R	Info Technology (302)	01/06/2003	\$48940.00	\$73356.42
10257		R&P-Recreation (015)	12/10/2007	\$19802.00	\$10443.70
10258		Mayors Office (001)	12/07/1995	\$167449.00	\$165249.86

## Showing difference in `str_extract`

`str_extract` extracts just the matched string

```
ss = str_extract(Sal$Name, "Rawling")  
head(ss)
```

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

```
ss[ !is.na(ss) ]
```

```
[1] "Rawling" "Rawling" "Rawling"
```

## Showing difference in `str_extract` and `str_extract_all`

`str_extract_all` extracts all the matched strings

```
head(str_extract(Sal$AgencyID, "\\d"))
```

```
[1] "0" "2" "6" "9" "4" "9"
```

```
head(str_extract_all(Sal$AgencyID, "\\d"), 2)
```

```
[[1]]
```

```
[1] "0" "3" "0" "3" "1"
```

```
[[2]]
```

```
[1] "2" "9" "0" "4" "5"
```

# Using Regular Expressions

- Look for any name that starts with:
  - Payne at the beginning,
  - Leonard and then an S
  - Spence then capital C

```
head(grep("^Payne.*", x = Sal$Name, value = TRUE), 3)
```

```
[1] "Payne El,Boaz L"          "Payne El,Jackie"  
[3] "Payne Johnson,Nickole A"
```

```
head(grep("Leonard.?S", x = Sal$Name, value = TRUE))
```

```
[1] "Payne,Leonard S"          "Szumlanski,Leonard S"
```

```
head(grep("Spence.*C.*", x = Sal$Name, value = TRUE))
```

```
[1] "Spencer,Charles A"  "Spencer,Clarence W" "Spencer,Michael C"
```

## Using Regular Expressions: `stringr`

```
head(str_subset( Sal$Name, "^Payne.*"), 3)
```

```
[1] "Payne El,Boaz L"          "Payne El,Jackie"  
[3] "Payne Johnson,Nickole A"
```

```
head(str_subset( Sal$Name, "Leonard.?S"))
```

```
[1] "Payne,Leonard S"          "Szumlanski,Leonard S"
```

```
head(str_subset( Sal$Name, "Spence.*C.*"))
```

```
[1] "Spencer,Charles A"  "Spencer,Clarence W" "Spencer,Michael C"
```

# Replace

Let's say we wanted to sort the data set by Annual Salary:

```
class(Sal$AnnualSalary)
```

```
[1] "factor"
```

```
sort(c("1", "2", "10")) # not sort correctly (order simply ranks the data)
```

```
[1] "1"  "10" "2"
```

```
order(c("1", "2", "10"))
```

```
[1] 1 3 2
```



# Replace

So we must change the annual pay into a numeric:

```
head(Sal$AnnualSalary, 4)
```

```
[1] $55314.00 $74000.00 $64500.00 $46309.00  
1654 Levels: $10000.00 $100000.00 $100013.00 $100200.00 ... $99994.00
```

```
head(as.numeric(Sal$AnnualSalary), 4)
```

```
[1] 908 1302 1094 722
```

R didn't like the \$ so it thought turned them all to NA.

`sub()` and `gsub()` can do the replacing part in base R.

## Replacing and subbing

Now we can replace the \$ with nothing (used `fixed=TRUE` because \$ means ending):

```
Sal$AnnualSalary <- as.numeric(gsub(pattern = "$", replacement="",  
                                   Sal$AnnualSalary, fixed=TRUE))  
Sal <- Sal[order(Sal$AnnualSalary, decreasing=TRUE), ]  
Sal[1:5, c("Name", "AnnualSalary", "JobTitle")]
```

	Name	AnnualSalary	JobTitle
8983	Mosby, Marilyn J	238772	STATE'S ATTORNEY
732	Batts, Anthony W	211785	Police Commissioner
13223	Wen, Leana	200000	Executive Director III
10274	Raymond, Henry J	192500	Executive Director III
12118	Swift, Michael	187200	CONTRACT SERV SPEC II

## Replacing and subbing: **stringr**

We can do the same thing (with 2 piping operations!) in dplyr

```
dplyr_sal = Sal
dplyr_sal = dplyr_sal %>% mutate(
  AnnualSalary = AnnualSalary %>%
    str_replace(
      fixed("$"),
      "") %>%
    as.numeric() %>%
    arrange(desc(AnnualSalary))
check_Sal = Sal
rownames(check_Sal) = NULL
all.equal(check_Sal, dplyr_sal)
```

```
[1] TRUE
```

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