

Introduction to R

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R as a calculator

Arithmetic operators

Addition	+
Subtraction	-
Multiplication	*
Division	/
Modulo	%%
Power	^

```
# Addition
2 + 2
# Subtraction
5.432 - 34234
# Multiplication
33 * 42
# Division
3 / 42
# Modulo (Remainder)
2 %% 2
# Power
2^2
# Combine operations
((2 + 2) * 5)^(10 %% 10)
```

R as a calculator

Relational operators

Equal to	<code>==</code>
Not equal to	<code>!=</code>
Less than	<code><</code>
Greater than	<code>></code>
Less or equal than	<code><=</code>
Greater or equal than	<code>>=</code>

```
2 == 2
## [1] TRUE
2 != 2
## [1] FALSE
33 <= 32
## [1] FALSE
20 < 20
## [1] FALSE
```

R as a calculator

Logical operators

Not

!

```
!TRUE  
## [1] FALSE  
!(3 < 1)  
## [1] TRUE
```

R as a calculator

Logical operators

Not	!
-----	---

And	&
-----	---

```
(3 < 1) & (3 == 3) # FALSE & TRUE = FALSE
## [1] FALSE
(1 < 3) & (3 == 3) # TRUE & TRUE = TRUE
## [1] TRUE
(3 < 1) & (3 != 3) # FALSE & FALSE = FALSE
## [1] FALSE
```

R as a calculator

Logical operators

Not	!
And	&
Or	

```
(3 < 1) | (3 == 3) # FALSE | TRUE = TRUE
## [1] TRUE
(1 < 3) | (3 == 3) # TRUE | TRUE = TRUE
## [1] TRUE
(3 < 1) | (3 != 3) # FALSE | FALSE = FALSE
## [1] FALSE
```

Comments in R

```
# Reading and cleaning the data -----  
  
data <- read_csv("data/my-data.csv")  
# clean all column headers  
# (found on https://stackoverflow.com/questions/68177507/)  
data <- janitor::clean_names(data)  
  
# Analysis -----
```

- Everything that follows a # is a comment
- Comments are not evaluated
- Notes that make code more readable or add information
- Comments can be used for
 - Explanation of code (if necessary)
 - Include links, names of authors, ...
 - Mark different sections of your code (💡 try `Ctrl/Cmd + Shift + R`)

Objects and data types in

Variables

- Store values under meaningful names **to reuse** them
- A variable has a **name** and **value** and is created using the **assignment operator**

```
radius <- 5
```

- Variables are available in the global environment
- R is case sensitive: **radius** != **Radius**
- Variables can hold any R objects, e.g.
 - Simple numbers
 - Lists
 - Tables with data
 - ...
- Choose meaningful variable names

Variables

```
# create a variable  
radius <- 5  
# use it in a calculation and save the result  
# pi is a built-in variable that comes with R  
circumference <- 2 * pi * radius  
# change value of variable radius  
radius <- radius + 1
```

```
# just use the name to print the value to the console  
radius
```

Atomic data types

There are 6 so-called **atomic data types** in R. The 4 most important are:

Numeric: There are two numeric data types:

- **Double:** can be specified in decimal (`1.243` or `-0.2134`), scientific notation (`2.32e4`) or hexadecimal (`0xd3f1`)
- **Integer:** numbers that are not represented by fraction. Must be followed by an `L` (`1L`, `2038459L`, `-5L`)

Logical: only two possible values `TRUE` and `FALSE` (abbreviation: `T` or `F` - but better use non-abbreviated form)

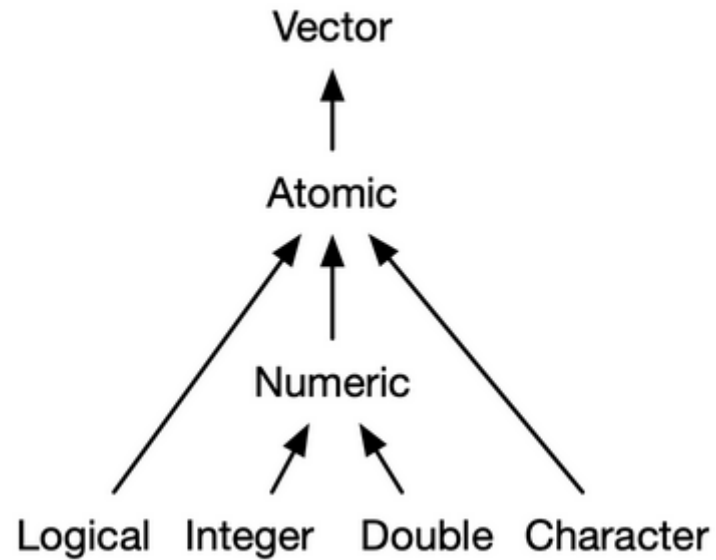
Character: also called string. Sequence of characters surrounded by quotes (`"hello"`, `"sample_1"`)

Vectors

Vectors

Vectors are data structures that are built on top of atomic data types.

Imagine a vector as a **collection of values** that are all **of the same data type**.



Creating vectors: `c()`

Use the function `c()` to *combine* values into a vector

```
lgl_var <- c(TRUE, TRUE, FALSE)
dbl_var <- c(2.5, 3.4, 4.3)
int_var <- c(1L, 45L, 234L)
chr_var <- c("These are", "just", "some strings")
```

You can also combine multiple vectors into one:

```
# Combine multiple vectors
v1 <- c(1, 2, 3)
v2 <- c(800, 83, 37)
v3 <- c(v1, v2)
```

Creating vectors: `c()`

Be aware of implicit **type conversion** when combining vectors of different types

```
# integer + logical -> integer (same with double + logical)
c(int_var, lgl_var)
## [1] 1 45 234 1 1 0
# integer + character -> character (same with double + character)
c(int_var, chr_var)
## [1] "1" "45" "234" "These are" "just" "some strings"
# logical + character -> character
c(lgl_var, chr_var)
## [1] "TRUE" "TRUE" "FALSE" "These are" "just" "some strings"
```

Creating vectors: : and seq()

The `:` operator creates a sequence between two numbers with an increment of (-)1

```
1:10 # instead of c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
## [1] 1 2 3 4 5 6 7 8 9 10
```

The `seq()` function creates a sequence of values

```
seq(from = 1, to = 10, by = 1) # specify increment of sequence with by
## [1] 1 2 3 4 5 6 7 8 9 10
seq(from = 1, to = 10, length.out = 20) # specify desired length with length.out
## [1] 1.000000 1.473684 1.947368 2.421053 2.894737 3.368421 3.842105 4.315789 4.789474
5.263158 5.736842 6.210526 6.684211
## [14] 7.157895 7.631579 8.105263 8.578947 9.052632 9.526316 10.000000
```


Creating vectors: `rep()`

Repeat values multiple times with `rep()`

```
rep("hello", times = 5)  
## [1] "hello" "hello" "hello" "hello" "hello"
```

Working with vectors

Let's create some vectors to work with.

```
# list of 10 biggest cities in Europe
cities <- c("Istanbul", "Moscow", "London", "Saint Petersburg", "Berlin", "Madrid", "Kyiv",
"Rome", "Bucharest", "Paris")

population <- c(15.1e6, 12.5e6, 9e6, 5.4e6, 3.8e6, 3.2e6, 3e6, 2.8e6, 2.2e6, 2.1e6)

area_km2 <- c(2576, 2561, 1572, 1439, 891, 604, 839, 1285, 228, 105 )
```

We can check the length of a vector using the `length()` function:

```
length(cities)
## [1] 10
```

Working with vectors

Divide the population and area vector to calculate the population density in each city:

```
population / area_km2
## [1] 5861.801 4880.906 5725.191 3752.606 4264.871 5298.013 3575.685 2178.988 9649.123
20000.000
```

The operation is performed **separately** for each element of the two vectors and the result is a vector.

The same happens, if a **vector** is divided by vector of length 1 (i.e. a single number). The result is always a vector.

```
mean_population <- mean(population) # calculate the mean of population vector
mean_population
## [1] 5910000
population / mean_population # divide population vector by the mean
## [1] 2.5549915 2.1150592 1.5228426 0.9137056 0.6429780 0.5414552 0.5076142 0.4737733 0.3722504
0.3553299
```

Working with vectors

We can also work with relational and logical operators

```
population > mean_population  
## [1] TRUE TRUE TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

The result is a vector containing `TRUE` and `FALSE`, depending on whether the city's population is larger than the mean population or not.

Logical and relational operators can be combined

```
# population larger than mean population OR population larger than 3 million  
population > mean_population | population > 3e6  
## [1] TRUE TRUE TRUE TRUE TRUE TRUE FALSE FALSE FALSE FALSE
```

Working with vectors

Check whether elements occur in a vector:

```
cities == "Istanbul" | cities == "Berlin" | cities == "Madrid"  
## [1] TRUE FALSE FALSE FALSE TRUE TRUE FALSE FALSE FALSE FALSE
```

The `%in%` operator checks whether *multiple* elements occur in a vector.

```
# for each element of cities, checks whether that element is contained in to_check  
to_check <- c("Istanbul", "Berlin", "Madrid")  
cities %in% to_check  
## [1] TRUE FALSE FALSE FALSE TRUE TRUE FALSE FALSE FALSE FALSE
```

```
# for each element of to_check, check whether that element is contained in cities  
to_check %in% cities  
## [1] TRUE TRUE TRUE
```

`%in%` always returns a vector of the same length as the vector on the left side

Indexing vectors

You can use square brackets `[]` to access specific elements from a vector.

The basic structure is:

`vector` `[` *vector of indexes to select* `]`

```
cities[5]  
## [1] "Berlin"
```

```
# the three most populated cities  
cities[1:3] # same as cities[c(1,2,3)]  
## [1] "Istanbul" "Moscow"   "London"
```

```
# the last entry of the cities vector  
cities[length(cities)] # same as cities[10]  
## [1] "Paris"
```

Indexing vectors

Change the values of a vector at specified indexes using the assignment operator `<-`

Imagine for example, that the population of

- Istanbul (index 1) increased to 20 Million
- Rome (index 8) changed but is unknown
- Paris (index 10) decreased by 200,000

```
# first copy the original vector to leave it untouched
population_new <- population
# Update Istanbul (1) and Rome(8)
population_new[c(1, 8)] <- c(20e6, NA) # NA means missing value
# Update Paris (10)
population_new[10] <- population_new[10] - 200000
```

```
population_new
## [1] 20000000 12500000 9000000 5400000 3800000 3200000 3000000      NA 2200000 1900000
```

Indexing vectors

You can also index a vector using logical tests. The basic structure is:

`vector` [`logical vector of same length`]

```
mega_city <- population > mean_population
mega_city
## [1] TRUE TRUE TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

Which are the mega cities?

```
cities[mega_city] # or short: cities[population > mean_population]
## [1] "Istanbul" "Moscow" "London"
```

Index only the cities that return `TRUE` for the comparison of their population against the mean population

Indexing vectors

We also use `%in%` for logical indexing.

```
population[ cities %in% c("Berlin", "Paris", "Stockholm", "Madrid")]  
## [1] 3800000 3200000 2100000
```

- Returns only 3 values for population, because Stockholm is not a city in our vector
 - No city in `cities` returns `TRUE` for the comparison with `"Stockholm"`

```
cities %in% c("Berlin", "Paris", "Stockholm", "Madrid")  
## [1] FALSE FALSE FALSE FALSE TRUE TRUE FALSE FALSE FALSE TRUE
```

Summary I

- Variables have a name and a value and are created using the assignment operator `<-`, e.g.

```
radius <- 5
```

- Vectors are a collection of values of the same data type:
 - character (`"hello"`)
 - numeric: integer (`23L`) and double (`2.23`)
 - logical (`TRUE` and `FALSE`)
- Be careful about implicit type conversion:
 - numeric to character
 - logical to character
 - logical to numeric

Summary II

Data types

```
# check the data type of a variable
typeof("hello")

# check if a variable is of a certain data type
is.*()
is.integer(1L)

# convert a variable into a certain data type
as.*()
as.logical("hello")
```

Summary III

Create vectors

```
# combine objects into vector
c(1,2,3)

# create a sequence of values
seq(from = 3, to = 6, by = 0.5)
seq(from = 3, to = 6, length.out = 10)
2:10

# repeat values from a vector
rep(c(1,2), times = 2)
rep(c("a", "b"), each = 2)
```

Summary IV

Indexing and subsetting vectors

```
# By index
v[3]
v[1:4]
v[c(1,5,7)]

# Logical indexing with 1 vector
v[v > 5]
v[v != "bird" | v == "rabbit"]
v[v %in% c(1,2,3)] # same as v[v == 1 | v == 2 | v == 3]

# Logical indexing with two vectors of same length
v[y == "bird"] # return the value in v for which index y == "bird"
v[y == max(y)] # return the value in v for which y is the maximum of y
```

Summary V

Working with vectors

```
# length
length(v)
# rounding numbers
round(v, digits = 2)
# sum
sum(v)
# mean
mean(v)
# median
median(v)
# standard deviation
sd(v)
# find the min value
min(v)
# find the max value
```

Now you

Task 2: Data types and vectors (35 min)

Find the task description [here](#)