R Programming - Part 2

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Who am i?

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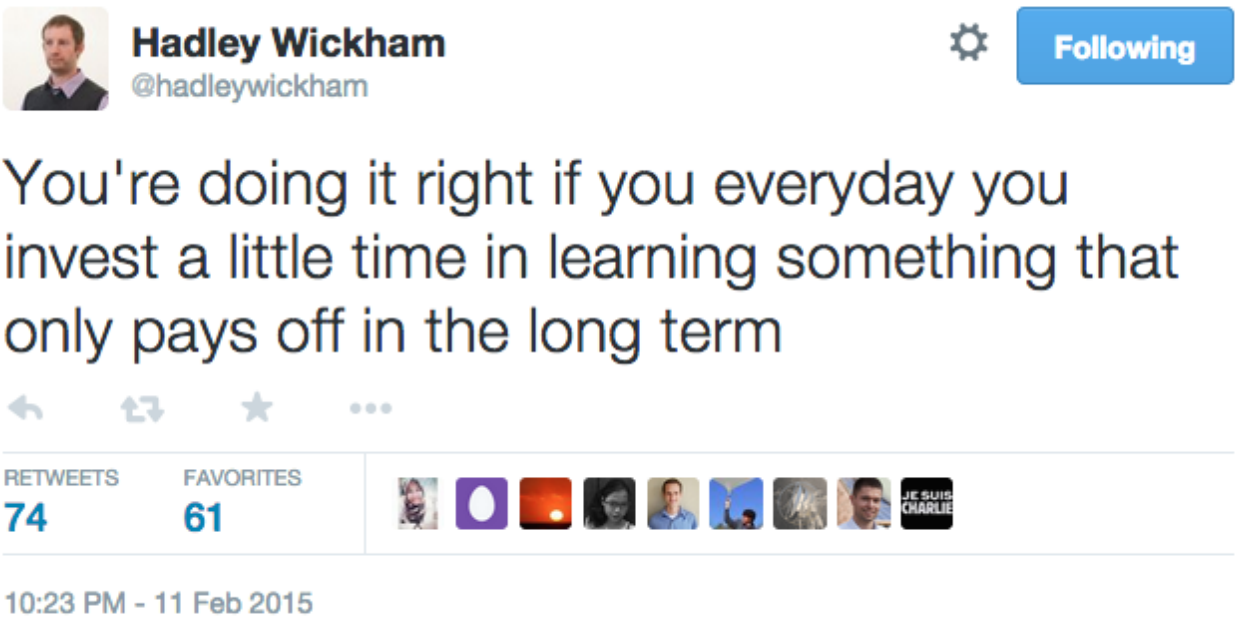
Learning frustrations

As you learn to program, you are going to get frustrated. You are learning a new language, and it will take time to become fluent. But frustration is not just natural, it's actually a positive sign that you should watch for. Frustration is your brain's way of being lazy; it's trying to get you to quit and go do something easy or fun. If you want to get physically fitter, you need to push your body even though it complains. If you want to get better at programming, you'll need to push your brain. Recognize when you get

frustrated and see it as a good thing: you're now stretching yourself. Push yourself a little further every day, and you'll soon be a confident programmer.

https://twitter.com/dsquintana/status/509654633464471552

Invest a little time



https://twitter.com/hadleywickham/status/565516534089785344

Refresher

Coding convention used in these slides

```
(x <- c(1, 2, 3, 4)) # preferred method
```

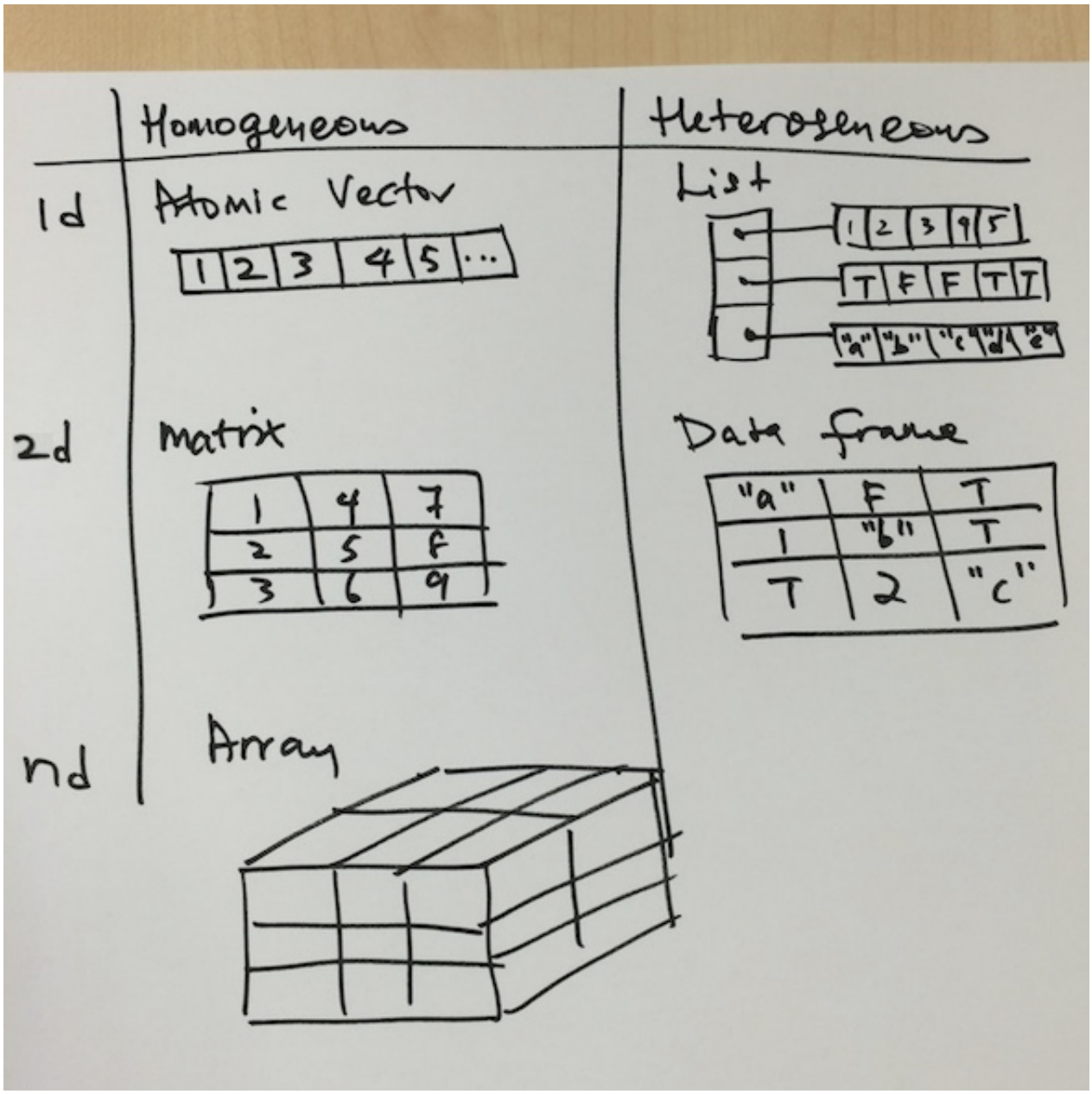
```
[1] 1 2 3 4
```

is the same as

```
x <- c(1, 2, 3, 4)
x
```

```
[1] 1 2 3 4
```

Refresher



Refresher

```
(x <- matrix(1:6, nrow = 2, ncol = 3))
```

```
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```

```
seq_len(nrow(x)) # indices of x's rows
```

```
[1] 1 2
```

```
seq_len(ncol(x)) # indices of x's columns
```

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

Refresher

```
(x <- matrix(1:6, nrow = 2, ncol = 3))
```

```
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```

```
x[1, 2] # x[row, column]
```

```
[1] 3
```

```
x[2, 3]
```

```
[1] 6
```

Refresher

```
(x <- matrix(1:6, nrow = 2, ncol = 3))
```

```
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```

```r
for (a in seq_len(nrow(x))) # 1 2
   for (b in seq_len(ncol(x))) # 1 2 3
      print(x[a, b])
```

```
[1] 1
[1] 3
[1] 5
[1] 2
[1] 4
[1] 6
```

Week 3

Loop functions

Loop Functions

The use of functionals is an alternative to for-loops

- `lapply()` (loops a list and returns a list)
- `sapply()` (simplies the result of `lapply` if possible by returning a vector or matrix or list of values)
- `apply()` (applies a function to margins of an array or matrix, and returns a vector or array or list of values)
- `tapply()` (applies a function to groups of data)
- `mapply()` (applies a function to multiple list or vector arguments)

Loop functions - lapply

Applies a function over a list or vector

```r
lapply
```

```
function (X, FUN, ...)
{
    FUN <- match.fun(FUN)
    if (!is.vector(X) || is.object(X))
        X <- as.list(X)
    .Internal(lapply(X, FUN))
}
<bytecode: 0x7fbe59934508>
<environment: namespace:base>
```

Loop functions

```r
(x <- list(a = 1:3, b = rnorm(3)))
```

```
$a
[1] 1 2 3

$b
[1] -0.06331  1.59713  1.94097
```

```
for (a in 1:length(x)) { # 1:2
   print(mean(x[[a]])) # remember [[?]]?
}
```

```
[1] 2
[1] 1.158
```

Loop functions - lapply

```
(x <- list(a = 1:3, b = rnorm(3)))
```

```
$a
[1] 1 2 3

$b
[1]  2.41059  0.35056 -0.01228
```

```
lapply(x, mean) # mean(x$a) and mean(x$b)
```

```
$a
[1] 2

$b
[1] 0.9163
```

Loop functions - lapply

`runif()` generates random deviates

```
x <- 1:3 # number of observations
lapply(x, runif) # runif(n, min = 0, max = 1)
```

```
[[1]]
[1] 0.6476

[[2]]
[1] 0.7777 0.2263
```

```
[[3]]
[1] 0.9976 0.4284 0.3140
```

Loop functions - lapply

```
(x <- list(a = matrix(1:4, nrow=2, ncol=2),
           b = matrix(1:6, nrow=3, ncol=2)))
```

```
$a
     [,1] [,2]
[1,]    1    3
[2,]    2    4

$b
     [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6
```

Loop functions - lapply

```
x <- list(a = matrix(1:4, nrow=2, ncol=2),
          b = matrix(1:6, nrow=3, ncol=2))
# show column 1 in matrix format
lapply(x, function(elt) elt[, 1, drop = F])
```

```
$a
     [,1]
[1,]    1
[2,]    2

$b
     [,1]
[1,]    1
[2,]    2
[3,]    3
```

Loop functions - sapply

`sapply()` simplies the result of `lapply()` if possible

- If the result is a list where every element is length 1, then a vector is returned
- If the result is a list where every element is a vector of the same length (>1), a matrix is returned
- If the result is a list where every element is of different types or lengths, it will silently return a list

Loop functions - sapply

```r
data(mtcars) # in-built dataset
str(mtcars[1, ]) # first row
```

```
'data.frame':   1 obs. of  11 variables:
 $ mpg : num 21
 $ cyl : num 6
 $ disp: num 160
 $ hp  : num 110
 $ drat: num 3.9
 $ wt  : num 2.62
 $ qsec: num 16.5
 $ vs  : num 0
 $ am  : num 1
 $ gear: num 4
 $ carb: num 4
```

Loop functions - sapply

If the result is a list where every element is length 1, then a vector is returned

```r
data(mtcars) # in-built dataset
# mtcars[1, ] # show first row
sapply(mtcars, is.numeric) # returns a vector
```

```
 mpg  cyl disp   hp drat   wt qsec   vs   am gear carb
TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
```

Loop functions - sapply

If the result is a list where every element is a vector of the same length (>1), a matrix is returned

```r
x <- c(8, 8, 8) # 3 columns of 8 observations
sapply(x, runif) # runif(8, min = 0, max = 1)
```

```
        [,1]   [,2]   [,3]
[1,] 0.44699 0.2540 0.1084
[2,] 0.90662 0.8159 0.8852
[3,] 0.04765 0.6212 0.7624
[4,] 0.27996 0.6961 0.7917
[5,] 0.60085 0.7474 0.8297
[6,] 0.26552 0.7800 0.9081
[7,] 0.65968 0.5381 0.4563
[8,] 0.72746 0.3930 0.9527
```

Loop functions - sapply

```r
(x <- data.frame(x = 1:10, y = Sys.time() + 1:10)) # plus 1:10 secs
```

```
    x                   y
1   1 2015-02-16 11:33:50
2   2 2015-02-16 11:33:51
3   3 2015-02-16 11:33:52
4   4 2015-02-16 11:33:53
5   5 2015-02-16 11:33:54
6   6 2015-02-16 11:33:55
7   7 2015-02-16 11:33:56
8   8 2015-02-16 11:33:57
9   9 2015-02-16 11:33:58
10 10 2015-02-16 11:33:59
```

Loop functions - sapply

If the result is a list where every element is of different types or lengths, it will silently return a list

```r
x <- data.frame(x = 1:10, y = Sys.time() + 1:10)
sapply(x, class) # returns a list
```

```
$x
[1] "integer"

$y
[1] "POSIXct" "POSIXt"
```

Loop functions - apply

Applies a function to margins of an array or matrix, and returns a vector or array or list of values

```r
str(apply)
```

```
function (X, MARGIN, FUN, ...)
```

`MARGIN` is a vector giving the subscripts which the function will be applied over: * `1` indicates rows * `2` indicates columns * `c(1, 2)` indicates rows and columns

Loop functions - apply

```r
(x <- matrix(1:16, nrow = 2))
```

```
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
[1,]    1    3    5    7    9   11   13   15
[2,]    2    4    6    8   10   12   14   16
```

```
apply(x, 1, mean) # row
```

```
[1] 8 9
```

```
apply(x, 2, mean) # col
```

```
[1]  1.5  3.5  5.5  7.5  9.5 11.5 13.5 15.5
```

Loop functions - apply

`quantile()` provides the sample quantiles based on the given probabilities

```
# quantile(x, probs = seq(0, 1, 0.25),
#          na.rm = FALSE, names = TRUE,
#          type = 7, ...)
quantile
```

```
function (x, ...)
UseMethod("quantile")
<bytecode: 0x7fbe5ab8d378>
<environment: namespace:stats>
```

Loop functions - apply

```
(x <- matrix(rnorm(15), ncol = 3))
```

```
        [,1]     [,2]    [,3]
[1,] -0.3405 -0.84050  0.6304
[2,]  0.6197  1.05733  1.9130
[3,] -1.3135  0.08270 -1.0532
[4,] -0.7158 -1.58314  1.9523
[5,]  0.1471 -0.01433 -0.3095
```

```
apply(x, 2, quantile, probs = c(0.25, 0.75))
```

```
       [,1]    [,2]    [,3]
25% -0.7158 -0.8405 -0.3095
75%  0.1471  0.0827  1.9130
```

Loop functions - tapply

Applies a function to groups of data using a grouping factor

```
str(tapply)
```

```
function (X, INDEX, FUN = NULL, ..., simplify = TRUE)
```

`X` is a vector and `INDEX` is a grouping factor. The function should expect one argument, which is a vector of elements taken from x according to their group

Loop functions - tapply

```
data(Orange) # Growth of Orange Trees
Orange[1:10, ]
```

```
   Tree  age circumference
1     1  118            30
2     1  484            58
3     1  664            87
4     1 1004           115
5     1 1231           120
6     1 1372           142
7     1 1582           145
8     2  118            33
9     2  484            69
10    2  664           111
```

Loop functions - tapply

```
data(Orange) # Growth of Orange Trees
str(Orange$Tree)
```

```
 Ord.factor w/ 5 levels "3"<"1"<"5"<"2"<..: 2 2 2 2 2 2 2 4 4 4 ...
```

```
levels(Orange$Tree)
```

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

```
nlevels(Orange$Tree)
```

```
[1] 5
```

Loop functions - tapply

```
data(Orange) # Growth of Orange Trees
```

```r
tapply(Orange$circumference, Orange$Tree, mean) # returns an array
```

```
     3      1      5      2      4
 94.00  99.57 111.14 135.29 139.29
```

If `simplify = FALSE` (not the default), it will return a list

Loop functions - tapply

```r
# 20x standard normals, 10x random deviates
x <- c(rnorm(10), runif(10), rnorm(10, 1))
# generate factor levels
(f <- gl(3, 10)) # 3 = levels, 10 = replications
```

```
 [1] 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3
Levels: 1 2 3
```

```r
tapply(x, f, mean)
```

```
     1      2      3
0.2715 0.5185 1.4648
```

Loop functions - tapply

Returns a list instead of an array, see `simplify = FALSE`

```r
x <- c(rnorm(10), runif(10), rnorm(10, 1))
f <- gl(3, 10)
tapply(x, f, mean, simplify = FALSE)
```

```
$`1`
[1] 0.08655

$`2`
[1] 0.5275

$`3`
[1] 1.118
```

Loop functions - tapply

`range()` returns a vector of min and max

```r
x <- c(rnorm(10), runif(10), rnorm(10, 1))
f <- gl(3, 10)
```

```r
# returns an array with the mode of the scalar
tapply(x, f, range)
```

```
$`1`
[1] -2.0849  0.8517

$`2`
[1] 0.02398 0.88222

$`3`
[1] -0.7537  2.8663
```

Loop functions - mapply

Applies a function to multiple list or vector arguments

```r
str(mapply)
```

```
function (FUN, ..., MoreArgs = NULL, SIMPLIFY = TRUE, USE.NAMES = TRUE)
```

Loop functions - mapply

```r
mapply(rep, 1:3, 3:1)
```

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

[[2]]
[1] 2 2

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

```r
# rep(1, 3) [1], 2, 3  [3], 2, 1
# rep(2, 2) 1, [2], 3  3, [2], 1
# rep(3, 1) 1, 2, [3]  3, 2, [1]
```

Loop functions - mapply

```r
l1 <- list(a = c(1:10), b = c(11:20))
l2 <- list(c = c(21:30), d = c(31:40))
# sum the corresponding elements of l1 and l2
mapply(sum, l1$a, l1$b, l2$c, l2$d)
```

```
 [1]  64  68  72  76  80  84  88  92  96 100
```

```
# sum(1, 11, 21, 31) = 64
# sum(2, 12, 22, 32) = 68
# sum(3, 13, 23, 33) = 72
# ...
# sum(8, 18, 28, 38) = 92
# sum(9, 19, 29, 39) = 96
# sum(10, 20, 30, 40) = 100
```

Loop functions - split

Takes a vector or other objects and splits it into groups determined by a factor or list of factors

```
str(split)
```

```
function (x, f, drop = FALSE, ...)
```

`x` is a vector or data frame containing values to be dividend into groups

`f` is a factor (or coerced to one) or a list of factors

`drop` indicates if empty factor levels should be dropped. FALSE by default

Loop functions - split

```
x <- c(rnorm(5), runif(5), rnorm(5, 1))
f <- gl(3, 5) # 3 levels, 5 replications
split(x, f) # returns a list of vectors
```

```
$`1`
[1] -0.9669 -0.9608 -1.1150 -0.7015 -0.2848

$`2`
[1] 0.05457 0.99981 0.85727 0.59342 0.92627

$`3`
[1] -0.1541  3.1983  1.5027  2.6935  1.1225
```

Loop functions - split

```
x <- c(rnorm(5), runif(5), rnorm(5, 1))
f <- gl(3, 5) # 3 levels, 5 replications
lapply(split(x, f), mean)
```

```
$`1`
[1] 0.1632
```

```
$`2`
[1] 0.4515

$`3`
[1] 0.8743
```

Loop functions - split

```
data(airquality)
str(airquality$Month)
```

```
 int [1:153] 5 5 5 5 5 5 5 5 5 5 ...
```

```
table(airquality$Month)
```

```

 5  6  7  8  9
31 30 31 31 30
```

Loop functions - split

```
head((s <- split(airquality, airquality$Month))$`5`) # May
```

```
  Ozone Solar.R Wind Temp Month Day
1    41     190  7.4   67     5   1
2    36     118  8.0   72     5   2
3    12     149 12.6   74     5   3
4    18     313 11.5   62     5   4
5    NA      NA 14.3   56     5   5
6    28      NA 14.9   66     5   6
```

Loop functions - split

```
data(airquality)
s <- split(airquality, airquality$Month)
# column mean
sapply(s,
       function(x) {
          apply(x[, c("Ozone", "Solar.R",
                      "Wind", "Temp")],
                2, mean, na.rm = TRUE)
       }
)
```

```
             5      6       7       8      9
Ozone    23.62  29.44  59.115  59.962  31.45
Solar.R 181.30 190.17 216.484 171.857 167.43
Wind     11.62  10.27   8.942   8.794  10.18
Temp     65.55  79.10  83.903  83.968  76.90
```

Optional - Loop functions - split

```
x <- 1:10
(f1 <- gl(2, 5)) # 2 - levels, 5 - repl
```

```
 [1] 1 1 1 1 1 2 2 2 2 2
Levels: 1 2
```

```
f2 <- gl(5, 2) # 5 - levels, 2 - replications
interaction(f1, f2) # Factor interactions
```

```
 [1] 1.1 1.1 1.2 1.2 1.3 2.3 2.4 2.4 2.5 2.5
Levels: 1.1 2.1 1.2 2.2 1.3 2.3 1.4 2.4 1.5 2.5
```

Optional - Loop functions - split

```
x <- 1:10
f1 <- gl(2, 5) # 2 - levels, 5 - repl
f2 <- gl(5, 2)
str(split(x, list(f1, f2)))
```

```
List of 10
 $ 1.1: int [1:2] 1 2
 $ 2.1: int(0)
 $ 1.2: int [1:2] 3 4
 $ 2.2: int(0)
 $ 1.3: int 5
 $ 2.3: int 6
 $ 1.4: int(0)
 $ 2.4: int [1:2] 7 8
 $ 1.5: int(0)
 $ 2.5: int [1:2] 9 10
```

Optional - Loop functions - split

Explanation:

```
# f1 = 11 11 1 2 22 22
# f2 = 11 22 3 3 44 55
```

```
# x  = 12 34 5 6 78 910
#       2  2 1 1  2  2
# There's 1.1, 1.2, 1.3, 2.3, 2.4, and 2.5
# There's no 2.1, 2.2, 1.4, and 1.5
```

Read Splitting on more than one level

Not covering

Debugging tools and R profiling

References

R Programming by Roger D. Peng, Jeff Leek and Brian Caffo

Advanced R by Hadley Wickham

R Cookbook by Paul Teetor

A brief introduction to “apply” in R by Neil Saunders

R tapply Function by endmemo.com

Repositories

https://github.com/eugeneteo/ida-mooc-rprog1

https://github.com/eugeneteo/ida-mooc-rprog2

Thanks

Join the first and second cohorts’ Facebook groups!

[@eugeneteo](http://www.twitter.com/eugeneteo)