




## Week 6: *Vectors*

 EMSE 4571 / 6571: Intro to Programming for Analytics

 John Paul Helveston

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# Quiz 5

10:00

Write your name on the quiz!

## Rules:

- Work alone; no outside help of any kind is allowed.
- No calculators, no notes, no books, no computers, no phones.

# Midterm

- Midterm is during class period on 3/6 and will **not** include strings (next week's content).
- Includes everything up to and including vectors.
- Paper and pen / pencil only (just like quizzes).
- You can bring a single 8.5×11 sheet of notes with anything on it (front & back).

# Week 6: *Vectors*

1. Making vectors

2. Vector operations

3. Comparing vectors

**BREAK**

4. Slicing vectors

5. Lists

# Week 6: *Vectors*

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# We've already been using vectors!

```
x <- 1  
x
```

```
#> [1] 1
```

```
is.vector(x)
```

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

```
length(x)
```

```
#> [1] 1
```

# The universal vector generator: `c()`

Numeric vectors

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

```
#> [1] 1 2 3
```

Character vectors

```
y <- c('a', 'b', 'c')  
y
```

```
#> [1] "a" "b" "c"
```

Logical vectors

```
z <- c(TRUE, FALSE, TRUE)  
z
```

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

# Elements in vectors must be the same type

Type hierarchy:

- `character` > `numeric` > `logical`
- `double` > `integer`

Coverts to characters:

```
c(1, "foo", TRUE)
```

```
#> [1] "1" "foo" "TRUE"
```

Coverts to numbers:

```
c(7, TRUE, FALSE)
```

```
#> [1] 7 1 0
```

Coverts to double:

```
c(1L, as.integer(2), 3.14)
```

```
#> [1] 1.00 2.00 3.14
```



# Other ways to make a vector

Sequences (we saw these last week):

```
seq(1, 5)
```

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

```
1:5
```

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

Repeating a value:

```
rep(5, 3)
```

```
#> [1] 5 5 5
```

```
rep("snarf", 3)
```

```
#> [1] "snarf" "snarf" "snarf"
```

# Repeating a vector

Repeating a sequence with `times`

```
x <- rep(seq(1, 3), times = 3)  
x
```

```
#> [1] 1 2 3 1 2 3 1 2 3
```

Repeating a sequence with `each`

```
x <- rep(seq(1, 3), each = 3)  
x
```

```
#> [1] 1 1 1 2 2 2 3 3 3
```

# You can name vector elements

```
x <- seq(5)  
x
```

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

```
names(x)
```

```
#> NULL
```

# You can name vector elements

```
x <- seq(5)
x
```

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

1) Add names with the `names()` function:

```
names(x) <- c('a', 'b', 'c', 'd', 'e')
x
```

```
#> a b c d e
#> 1 2 3 4 5
```

2) Create a named vector:

```
y <- c('a'=1, 'b'=2, 'c'=3, 'd'=4, 'e'=5)
y
```

```
#> a b c d e
#> 1 2 3 4 5
```

02:00

# Quick code tracing

What will each of these lines produce?

```
rep(c(TRUE, FALSE, "TRUE"), 2)
```

```
seq(FALSE, 3)
```

```
rep(c(seq(3), seq(2)), each = 2)
```

# Week 6: *Vectors*

1. Making vectors

2. **Vector operations**

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**BREAK**

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5. Lists

# Math on vectors is done **by element**

```
x <- 1:10
```

```
x + 2
```

```
#> [1] 3 4 5 6 7 8 9 10 11 12
```

```
x - 2
```

```
#> [1] -1 0 1 2 3 4 5 6 7 8
```

```
x * 2
```

```
#> [1] 2 4 6 8 10 12 14 16 18 20
```

```
x / 2
```

```
#> [1] 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
```

# Math on vectors is done **by element**

```
x
```

```
#> [1] 1 2 3 4 5 6 7 8 9 10
```

```
x %% 2
```

```
#> [1] 1 0 1 0 1 0 1 0 1 0
```



# Math on vectors is done **by element**

```
x1 <- c(1, 2, 3)
x2 <- c(4, 5, 6)
```

```
x1 + x2 # Returns (1+4, 2+5, 3+6)
```

```
#> [1] 5 7 9
```

```
x1 - x2 # Returns (1-4, 2-5, 3-6)
```

```
#> [1] -3 -3 -3
```

```
x1 * x2 # Returns (1*4, 2*5, 3*6)
```

```
#> [1] 4 10 18
```

```
x1 / x2 # Returns (1/4, 2/5, 3/6)
```

```
#> [1] 0.25 0.40 0.50
```

# If dimensions don't match, R "wraps" the vector

```
x1 <- c(1, 2, 3, 4)  
x2 <- c(4, 5)
```

```
x1 + x2
```

```
#> [1] 5 7 7 9
```

```
x1 <- c(1, 2, 3, 4)  
x2 <- c(1)
```

```
x1 + x2
```

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

# Most R functions work on vectors

```
x <- c(3.1415, 1.618, 2.718)
x
```

```
#> [1] 3.1415 1.6180 2.7180
```

```
round(x, 2)
```

```
#> [1] 3.14 1.62 2.72
```

```
sqrt(x)
```

```
#> [1] 1.772428 1.272006 1.648636
```

Works with your own functions too:

```
isEven <- function(x) {
  return((x %% 2) == 0)
}
```

```
x <- c(1, 4, 5, 10)
isEven(x)
```

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

# Using vectors instead of a loop: **Summation**

Example: Sum the integers from 1 to 10

Summing with a loop:

```
x <- seq(1, 10)

total <- 0
for (i in x) {
  total <- total + i
}
total
```

```
#> [1] 55
```

Use a *summary function* on the vector:

```
sum(x)
```

```
#> [1] 55
```

# Summary functions return one value

```
x <- 1:10
```

```
length(x)
```

```
#> [1] 10
```

```
sum(x)
```

```
#> [1] 55
```

```
prod(x)
```

```
#> [1] 3628800
```

```
min(x)
```

```
#> [1] 1
```

```
max(x)
```

```
#> [1] 10
```

```
mean(x)
```

```
#> [1] 5.5
```

```
median(x)
```

```
#> [1] 5.5
```

# Quick code tracing

03:00

Consider this function:

```
f <- function(x) {  
  m <- x  
  n <- sum(x + 4)  
  m <- m + 5  
  return(c(m, n))  
}
```

What will each of these lines return?

```
x <- c(1, 3)  
f(x)
```

```
y <- c(TRUE, FALSE, 1)  
f(y)
```

# Week 6: *Vectors*

1. Making vectors

2. Vector operations

3. **Comparing vectors**

BREAK

4. Slicing vectors

5. Lists

# Comparing vectors

Check if 2 vectors are the same:

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

```
x == y
```

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



# Comparing vectors with `all()` and `any()`

`all()`: Check if *all* elements are the same

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
x == y
```

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

```
all(x == y)
```

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

```
x <- c(1, 2, 3)
y <- c(-1, 2, 3)
x == y
```

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

```
all(x == y)
```

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

# Comparing vectors with `all()` and `any()`

`any()`: Check if *any* elements are the same

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
x == y
```

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

```
any(x == y)
```

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

```
x <- c(1, 2, 3)
y <- c(-1, 2, 3)
x == y
```

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

```
any(x == y)
```

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

# all() vs. identical()

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
names(x) <- c('a', 'b', 'c')
names(y) <- c('one', 'two', 'three')
```

all() only compares the element *values*:

```
all(x == y)
```

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

identical() compares *values* and *names*:

```
identical(x, y)
```

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

```
names(y) <- c('a', 'b', 'c')
identical(x, y)
```

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

# Your turn - solve with vectors, no loops!

- 1) `sumFromMToN(m, n)`: Write a function that sums the total of the integers between `m` and `n`.
  - `sumFromMToN(5, 10) == (5 + 6 + 7 + 8 + 9 + 10)`
  - `sumFromMToN(1, 1) == 1`
- 2) `sumEveryKthFromMToN(m, n, k)`: Write a function to sum every `k`th integer from `m` to `n`.
  - `sumEveryKthFromMToN(1, 10, 2) == (1 + 3 + 5 + 7 + 9)`
  - `sumEveryKthFromMToN(5, 20, 7) == (5 + 12 + 19)`
  - `sumEveryKthFromMToN(0, 0, 1) == 0`
- 3) `sumOfOddsFromMToN(m, n)`: Write a function that sums every *odd* integer between `m` and `n`.
  - `sumOfOddsFromMToN(4, 10) == (5 + 7 + 9)`
  - `sumOfOddsFromMToN(5, 9) == (5 + 7 + 9)`

06:00

# Your turn

Re-write `isPrime(n)` from last week, but **without loops!**

Remember, `isPrime(n)` takes a non-negative integer, `n`, and returns **TRUE** if it is a prime number and **FALSE** otherwise. Here are some test cases:

- `isPrime(1) == FALSE`
- `isPrime(2) == TRUE`
- `isPrime(7) == TRUE`
- `isPrime(13) == TRUE`
- `isPrime(14) == FALSE`

## Hint:

```
isPrime <- function(n) {  
  if (n <= 1) {  
    return(FALSE)  
  }  
  if (n == 2) {  
    return(TRUE)  
  }  
  for (i in seq(2, (n - 1))) {  
    if ((n %% i) == 0) {  
      return(FALSE)  
    }  
  }  
  return(TRUE)  
}
```

# *Intermission*

05:00

# Week 6: *Vectors*

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BREAK

4. **Slicing vectors**

5. Lists

# Use brackets `[]` to get elements from a vector

```
x <- seq(1, 10)
```

Indices start at 1:

```
x[1] # Returns the first element
```

```
#> [1] 1
```

```
x[3] # Returns the third element
```

```
#> [1] 3
```

```
x[length(x)] # Returns the last element
```

```
#> [1] 10
```

Slicing with a vector of indices:

```
x[1:3] # Returns the first three elements
```

```
#> [1] 1 2 3
```

```
x[c(2, 7)] # Returns the 2nd and 7th elements
```

```
#> [1] 2 7
```



# Use negative integers to *remove* elements

```
x <- seq(1, 10)
```

```
x[-1] # Drops the first element
```

```
#> [1] 2 3 4 5 6 7 8 9 10
```

```
x[-1:-3] # Drops the first three elements
```

```
#> [1] 4 5 6 7 8 9 10
```

```
x[-c(2, 7)] # Drops the 2nd and 7th elements
```

```
#> [1] 1 3 4 5 6 8 9 10
```

```
x[-length(x)] # Drops the last element
```

```
#> [1] 1 2 3 4 5 6 7 8 9
```

# Slicing with logical indices

```
x <- seq(1, 20, 3)  
x
```

```
#> [1] 1 4 7 10 13 16 19
```

Create a logical vector based on some condition:

```
x > 10
```

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

Slice `x` with logical vector - only `TRUE` indices will be returned:

```
x[x > 10]
```

```
#> [1] 13 16 19
```

# You can also use `which()` to find indices

```
x <- seq(1, 20, 3)  
x
```

```
#> [1] 1 4 7 10 13 16 19
```

Use `which()` around a condition to get the indices where condition is **TRUE**:

```
which(x > 10)
```

```
#> [1] 5 6 7
```

```
x[which(x > 10)]
```

```
#> [1] 13 16 19
```

# Using names to slice a vector

```
names(x) <- c('a', 'b', 'c', 'd', 'e', 'f', 'g')  
x
```

```
#>  a  b  c  d  e  f  g  
#>  1  4  7 10 13 16 19
```

```
x['a']
```

```
#> a  
#> 1
```

```
x[c('a', 'c')]
```

```
#> a c  
#> 1 7
```

# Sorting vectors with `sort()`

```
a = c(2, 4, 6, 3, 1, 5)  
a
```

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

```
sort(a)
```

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

```
sort(a, decreasing = TRUE)
```

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

`order()` returns the indices of the sorted vector

```
a
```

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

```
order(a)
```

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

This does the same thing as `sort(a)`:

```
a[order(a)]
```

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

# Look for membership with `%in%`

```
cities <- c("atlanta", "dc", "nyc", "sf")
cities
```

```
#> [1] "atlanta" "dc"      "nyc"     "sf"
```

```
"chicago" %in% cities
```

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

```
"dc" %in% cities
```

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

02:00

# Quick code tracing

Consider this function:

```
f <- function(x) {  
  for (i in seq(length(x))) {  
    x[i] <- x[i] + sum(x) + max(x)  
  }  
  return(x)  
}
```

What will this code return?

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



# Your turn

1) `reverse(x)`: Write a function that returns the vector in reverse order. You cannot use the `rev()` function.

- `all(reverseVector(c(5, 1, 3)) == c(3, 1, 5))`
- `all(reverseVector(c('a', 'b', 'c')) == c('c', 'b', 'a'))`
- `all(reverseVector(c(FALSE, TRUE, TRUE)) == c(TRUE, TRUE, FALSE))`

2) `alternatingSum(a)`: Write a function that takes a vector of numbers `a` and returns the alternating sum, where the sign alternates from positive to negative or vice versa.

- `alternatingSum(c(5,3,8,4)) == (5 - 3 + 8 - 4)`
- `alternatingSum(c(1,2,3)) == (1 - 2 + 3)`
- `alternatingSum(c(0,0,0)) == 0`
- `alternatingSum(c(-7,5,3)) == (-7 - 5 + 3)`

**Challenge:** For each function, try writing a solution that uses loops and another that only uses vectors.

# Week 6: *Vectors*

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BREAK

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5. **Lists**

# Elements in lists can be any object

Vectors force things to one type:

```
c(1, "foo", TRUE)
```

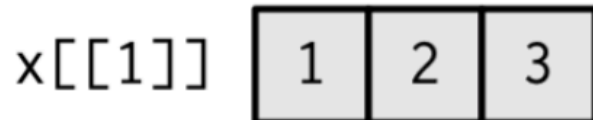
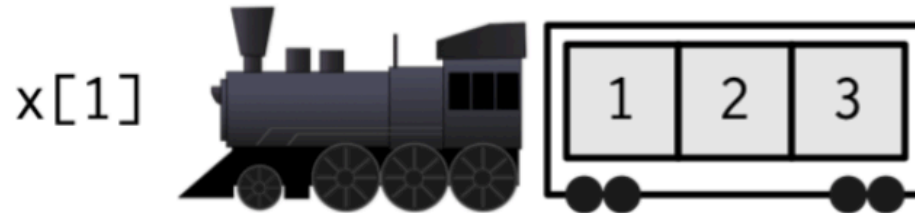
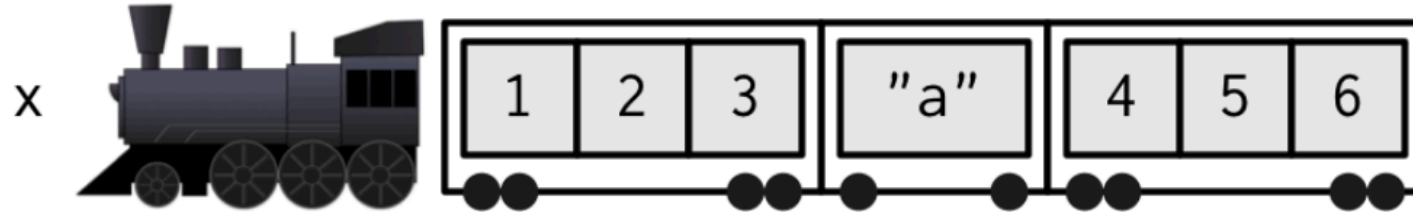
```
#> [1] "1" "foo" "TRUE"
```

Lists store any type:

```
list(1, "foo", TRUE)
```

```
#> [[1]]  
#> [1] 1  
#>  
#> [[2]]  
#> [1] "foo"  
#>  
#> [[3]]  
#> [1] TRUE
```

# Subsetting lists



# Slice list with indices or names

Slice with index using `[[ ]]`

```
x <- list(  
  c(1, 2, 3),  
  c("foo", "bar"),  
  TRUE  
)
```

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

```
#> [1] 1 2 3
```

```
x[[2]]
```

```
#> [1] "foo" "bar"
```

Slice with name using ``[[ ]]` or `$`

```
x <- list(  
  numbers = c(1, 2, 3),  
  chars   = c("foo", "bar"),  
  logical = TRUE  
)
```

```
x[['numbers']]
```

```
#> [1] 1 2 3
```

```
x$numbers
```

```
#> [1] 1 2 3
```

# HW 6