The Twins Data

Sherlock Holmes and the hat.

Long ago, there was more space in journals, and a journal called *Human Biology* used to publish raw data. The `twin data` contains educational test scores and physical measurements for a sample of high school age identical and fraternal twin pairs. Members of each twin pair were of the same sex. Except for a few cases where the parents were not sure, Twin One was born first and Twin Two was born second. The variables are:

1. SEX: 0=Male, 1=Female
2. IDENT: 0=Fraternal 1=Identical
3. PROGMAT1: Progressive matrices (puzzle) score for twin 1
4. REASON1: Reasoning score for twin 1
5. VERBAL1: Verbal (reading and vocabulary) score for twin 1
6. PROGMAT2: Progressive matrices (puzzle) score for twin 2
7. REASON2: Reasoning score for twin 2
8. VERBAL2: Verbal (reading and vocabulary) score for twin 2
9. HEADLNG1: Head Length of Twin 1
10. HEADBRD1: Head Breadth of Twin 1
11. HEADCIR1: Head Circumference of Twin 1
12. HEADLNG2: Head Length of Twin 2
13. HEADBRD2: Head Breadth of Twin 2
14. HEADCIR2: Head Circumference of Twin 2

This is a subset of the original data. Some variables like height and weight are not included. The reference is Clark, P. J., Vandenberg, S. G., and Proctor, C. H. (1961), "On the relationship of scores on certain psychological tests with a number of anthropometric characters and birth order in twins," *Human Biology*, **33**, 163-180.

We want to see if performance on the educational tests is related to head size.

```
/res/jbrunner/www/442/S > head smalltwin.dat
sex ident progmat1 reason1 verbal1 progmat2 reason2 verbal2 headlng1 headbrd1
headcir1 headlng2 headbrd2 headcir2
    1    1   1  48  53  66  35  42  61   183 140 522 188 138 535
    2    1   1  47  69  88  53  74  84   189 137 542 186 140 543
    3    1   1  35  68  92  42  61  86   185 145 549 186 140 550
    4    1   1  34  42  73  26  38  68   183 151 544 185 147 545
    5    1   1  49  71  95  38  72  97   174 145 534 186 143 543
    6    1   1  50  90 122  46  82 101   191 143 551 191 141 552
    7    1   1  25  30  42  28  37  43   184 143 511 186 143 535
    8    1   1  25  74  64  41  78  65   180 146 532 179 144 527
    9    1   1  23  19  52  23  36  59   193 146 560 191 145 551

/res/jbrunner/www/442/S > R

> twinframe <-  read.table("smalltwin.dat")
> sex <- twinframe$sex ; ident <- twinframe$ident
> sexfac <- factor(twinframe$sex,levels=c(0,1),label=c("Male","Female"))
> identfac <- factor(twinframe$ident,levels=c(0,1),
+                  label=c("Fraternal","Identical"))
> table(sexfac,identfac)
        identfac
sexfac   Fraternal Identical
  Male          13        21
  Female        20        20
> mental <- twinframe[,3:8]  # All rows, cols 3 to 8
> phys   <- twinframe[,9:14] # All rows, cols 9 to 14
> cor(mental,phys)
          headlng1   headbrd1  headcir1  headlng2   headbrd2  headcir2
progmat1 0.1945786 0.02669260 0.2046808 0.2070390 0.09577333 0.2204541
reason1  0.1232977 0.03186775 0.2052615 0.0978289 0.04733736 0.1955942
verbal1  0.2259473 0.05372263 0.2452086 0.2132409 0.07487114 0.2333709
progmat2 0.2863199 0.19917360 0.3128950 0.3446627 0.22308623 0.3739253
reason2  0.2127977 0.06950846 0.2767257 0.1226885 0.11543427 0.2521013
verbal2  0.2933130 0.16693928 0.3242051 0.2537764 0.22801336 0.3350497

>
> # But that's IGNORING sex and ident-frat. Want to CONTROL for them.
```

```
> n <- length(sex)
> mf <- (1:n)[sex==0&ident==0] # mf are indices of male fraternal pairs
> mi <- (1:n)[sex==0&ident==1] # mi are indices of male identical pairs
> ff <- (1:n)[sex==1&ident==0] # ff are indices of female fraternal pairs
> fi <- (1:n)[sex==1&ident==1] # fi are indices of female identical pairs

> mf
 [1] 62 63 64 65 66 67 68 69 70 71 72 73 74

> # Sub-sample sizes
> nmf <- length(mf)  ; nmi <- length(mi)
> nff  <- length(ff) ; nfi <- length(fi)
> nmf ; nmi ; nff ; nfi
[1] 13
[1] 21
[1] 20
[1] 20
> table(sexfac,identfac)
        identfac
sexfac   Fraternal Identical
  Male          13        21
  Female        20        20

> # mentalmf are mental scores of male fraternal pairs, etc.
> mentalmf <- mental[mf,] ; physmf <- phys[mf,]
> mentalmi <- mental[mi,] ; physmi <- phys[mi,]
> mentalff <- mental[ff,] ; physff <- phys[ff,]
> mentalfi <- mental[fi,] ; physfi <- phys[fi,]

> mentalmf
   progmat1 reason1 verbal1 progmat2 reason2 verbal2
62       58      91     128       54      73     129
63       44      46      79       42      34      42
64       44      43      70       43      36      58
65       36      40      63       42      39      63
66       34      21      53       45      31      70
67       50      70      93       45      67     109
68       50      81     101       41      47      96
```

```
69        31       76      122        43       70       75
70        23       29       62        26       29       42
71        52       66      114        42       69      120
72        48       51       62        30       35       49
73        23       48       78        38       62       87
74        28       38       62        55       70      105

> # First three rows
> mentalmf[1:3,]
   progmat1 reason1 verbal1 progmat2 reason2 verbal2
62        58       91      128        54       73      129
63        44       46       79        42       34       42
64        44       43       70        43       36       58
> # Last 3 columns
> mentalmf[,4:6]
   progmat2 reason2 verbal2
62        54       73      129
63        42       34       42
64        43       36       58
65        42       39       63
66        45       31       70
67        45       67      109
68        41       47       96
69        43       70       75
70        26       29       42
71        42       69      120
72        30       35       49
73        38       62       87
74        55       70      105
> # Rows in random order
> mentalmf[sample(1:13),]
   progmat1 reason1 verbal1 progmat2 reason2 verbal2
71        52       66      114        42       69      120
73        23       48       78        38       62       87
66        34       21       53        45       31       70
69        31       76      122        43       70       75
65        36       40       63        42       39       63
68        50       81      101        41       47       96
```

```
64        44       43       70        43       36       58
70        23       29       62        26       29       42
62        58       91      128        54       73      129
63        44       46       79        42       34       42
74        28       38       62        55       70      105
67        50       70       93        45       67      109
72        48       51       62        30       35       49
>
```

That's how we'll randomize. Back to CONTROLLING for sex, ident.

```
> # mentalmf are mental scores of male fraternal pairs, etc.
> mentalmf <- mental[mf,] ; physmf <- phys[mf,]
> mentalmi <- mental[mi,] ; physmi <- phys[mi,]
> mentalff <- mental[ff,] ; physff <- phys[ff,]
> mentalfi <- mental[fi,] ; physfi <- phys[fi,]
>
> cor(mentalmf,physmf)
          headlng1    headbrd1   headcir1   headlng2   headbrd2   headcir2
progmat1 0.3534186 -0.53715165 0.05247501 -0.1486551 -0.3335911 -0.2541279
reason1  0.4784903 -0.04435345 0.40868525  0.2009069 -0.1853897  0.1574282
verbal1  0.3333061  0.02578888 0.36744645  0.1507982 -0.1958353  0.1267843
progmat2 0.5712273 -0.16389337 0.37080025  0.5622139 -0.1996214  0.4073323
reason2  0.4886337  0.38731941 0.63957418  0.4271557  0.2587126  0.6682264
verbal2  0.5278153  0.25599312 0.62836834  0.3403694  0.1966882  0.6113976
>
> # Don't want to correlate mental twin 1 with phys twin 2
>
> cor(mentalmf[,1:3],physmf[,1:3])
          headlng1    headbrd1   headcir1
progmat1 0.3534186 -0.53715165 0.05247501
reason1  0.4784903 -0.04435345 0.40868525
verbal1  0.3333061  0.02578888 0.36744645
> max(abs(cor(mentalmf[,1:3],physmf[,1:3])))
[1] 0.5371517
>
```

```
> cor(mentalmf[,4:6],physmf[,4:6])
          headlng2   headbrd2  headcir2
progmat2 0.5622139 -0.1996214 0.4073323
reason2  0.4271557  0.2587126 0.6682264
verbal2  0.3403694  0.1966882 0.6113976
> max(abs(cor(mentalmf[,4:6],physmf[,4:6])))
[1] 0.6682264
>
>
> cor(mentalmi[,1:3],physmi[,1:3])
          headlng1   headbrd1  headcir1
progmat1 0.2334577 0.26536909 0.3193472
reason1  0.2622690 0.37549903 0.3534622
verbal1  0.4436284 0.06643773 0.3480645
> max(abs(cor(mentalmi[,1:3],physmi[,1:3])))
[1] 0.4436284
> cor(mentalmi[,4:6],physmi[,4:6])
          headlng2  headbrd2  headcir2
progmat2 0.3645763 0.2537397 0.3699872
reason2  0.1682737 0.4212712 0.3873012
verbal2  0.1814358 0.1590209 0.2112241
> max(abs(cor(mentalmi[,4:6],physmi[,4:6])))
[1] 0.4212712
>
> cor(mentalff[,1:3],physff[,1:3])
            headlng1  headbrd1  headcir1
progmat1 -0.09894825 0.1031112 0.1024857
reason1   0.10353527 0.1974691 0.2299249
verbal1   0.04068947 0.1458637 0.0710240
> max(abs(cor(mentalff[,1:3],physff[,1:3])))
[1] 0.2299249
> cor(mentalff[,4:6],physff[,4:6])
            headlng2  headbrd2  headcir2
progmat2 -0.05058245 0.3809976 0.1205803
reason2   0.19569669 0.3570053 0.2617820
verbal2   0.24212501 0.3964967 0.2463883
> max(abs(cor(mentalff[,4:6],physff[,4:6])))
[1] 0.3964967
```

```
>
> cor(mentalfi[,1:3],physfi[,1:3])
            headlng1    headbrd1     headcir1
progmat1 -0.01443227 -0.34580801 -0.004887716
reason1   0.15174745  0.04052029  0.304039946
verbal1   0.22504203 -0.01581501  0.341174647
> max(abs(cor(mentalfi[,1:3],physfi[,1:3])))
[1] 0.345808
> cor(mentalfi[,4:6],physfi[,4:6])
          headlng2    headbrd2  headcir2
progmat2 0.4030654 -0.02036423 0.4244152
reason2  0.3233766  0.05661767 0.4178053
verbal2  0.2702130  0.15930201 0.4025376
> max(abs(cor(mentalfi[,4:6],physfi[,4:6])))
[1] 0.4244152
>
> # test sta will be absobs = 0.6682264
> obsmax <- max( c(
+                 cor(mentalmf[,1:3],physmf[,1:3]),
+                 cor(mentalmf[,4:6],physmf[,4:6]),
+                 cor(mentalmi[,1:3],physmi[,1:3]),
+                 cor(mentalmi[,4:6],physmi[,4:6]),
+                 cor(mentalff[,1:3],physff[,1:3]),
+                 cor(mentalff[,4:6],physff[,4:6]),
+                 cor(mentalfi[,1:3],physfi[,1:3]),
+                 cor(mentalfi[,4:6],physfi[,4:6])    )   )
>
> obsmax
[1] 0.6682264
>
> obsmin <- min( c(
+                 cor(mentalmf[,1:3],physmf[,1:3]),
+                 cor(mentalmf[,4:6],physmf[,4:6]),
+                 cor(mentalmi[,1:3],physmi[,1:3]),
+                 cor(mentalmi[,4:6],physmi[,4:6]),
+                 cor(mentalff[,1:3],physff[,1:3]),
+                 cor(mentalff[,4:6],physff[,4:6]),
+                 cor(mentalfi[,1:3],physfi[,1:3]),
```

```
+                  cor(mentalfi[,4:6],physfi[,4:6])    )   )
> obsmin
[1] -0.5371517
>
> absobs <- max(abs(obsmax),abs(obsmin)) # Test Statistic
> absobs
[1] 0.6682264
>
> ####
> # Here's how we'll sample. Recall mentalmf <- mental[mf,]
> ####
> mf
 [1] 62 63 64 65 66 67 68 69 70 71 72 73 74
> mentalmf
   progmat1 reason1 verbal1 progmat2 reason2 verbal2
62       58      91     128       54      73     129
63       44      46      79       42      34      42
64       44      43      70       43      36      58
65       36      40      63       42      39      63
66       34      21      53       45      31      70
67       50      70      93       45      67     109
68       50      81     101       41      47      96
69       31      76     122       43      70      75
70       23      29      62       26      29      42
71       52      66     114       42      69     120
72       48      51      62       30      35      49
73       23      48      78       38      62      87
74       28      38      62       55      70     105
> mental[sample(mf),]
   progmat1 reason1 verbal1 progmat2 reason2 verbal2
72       48      51      62       30      35      49
66       34      21      53       45      31      70
62       58      91     128       54      73     129
69       31      76     122       43      70      75
70       23      29      62       26      29      42
71       52      66     114       42      69     120
67       50      70      93       45      67     109
74       28      38      62       55      70     105
```

```
63        44       46       79         42       34       42
68        50       81      101         41       47       96
73        23       48       78         38       62       87
65        36       40       63         42       39       63
64        44       43       70         43       36       58
>
> rmentalmf <- mental[sample(mf),]
> rmentalmi <- mental[sample(mi),]
> rmentalff <- mental[sample(ff),]
> rmentalfi <- mental[sample(fi),]
>
> rcorrs <- c(
+             cor(rmentalmf[,1:3],physmf[,1:3]),
+             cor(rmentalmf[,4:6],physmf[,4:6]),
+             cor(rmentalmi[,1:3],physmi[,1:3]),
+             cor(rmentalmi[,4:6],physmi[,4:6]),
+             cor(rmentalff[,1:3],physff[,1:3]),
+             cor(rmentalff[,4:6],physff[,4:6]),
+             cor(rmentalfi[,1:3],physff[,1:3]),
+             cor(rmentalfi[,4:6],physff[,4:6])  )
>
> min(rcorrs) ; max(rcorrs)
[1] -0.5673855
[1] 0.5166834
> rmin <- NULL ; rmax <- NULL ; rabs <- NULL
>
> # Now simulate
> M <- 200 ; set.seed(4444)
> for(i in 1:M)
+     {
+     rmentalmf <- mental[sample(mf),]
+     rmentalmi <- mental[sample(mi),]
+     rmentalff <- mental[sample(ff),]
+     rmentalfi <- mental[sample(fi),]
+     rcorrs <- c(
+             cor(rmentalmf[,1:3],physmf[,1:3]),
+             cor(rmentalmf[,4:6],physmf[,4:6]),
+             cor(rmentalmi[,1:3],physmi[,1:3]),
```

```
+              cor(rmentalmi[,4:6],physmi[,4:6]),
+              cor(rmentalff[,1:3],physff[,1:3]),
+              cor(rmentalff[,4:6],physff[,4:6]),
+              cor(rmentalfi[,1:3],physff[,1:3]),
+              cor(rmentalfi[,4:6],physff[,4:6])  )
+      rmin <- c(rmin,min(rcorrs))
+      rmax <- c(rmax,max(rcorrs))
+      rabs <- c(rabs,max(abs(min(rcorrs)),abs(max(rcorrs))))
+      }
> cbind(rmin,rmax,rabs)[1:20,] # First 20 rows
            rmin      rmax      rabs
 [1,] -0.6521097 0.6024060 0.6521097
 [2,] -0.4410713 0.6091124 0.6091124
 [3,] -0.5635999 0.3953340 0.5635999
 [4,] -0.6655059 0.6937127 0.6937127
 [5,] -0.5110777 0.3692450 0.5110777
 [6,] -0.4513148 0.7600707 0.7600707
 [7,] -0.3180858 0.5724620 0.5724620
 [8,] -0.6258317 0.4013421 0.6258317
 [9,] -0.4061387 0.5174977 0.5174977
[10,] -0.5004209 0.4688702 0.5004209
[11,] -0.6437074 0.3458846 0.6437074
[12,] -0.4065318 0.2945435 0.4065318
[13,] -0.6115288 0.5631299 0.6115288
[14,] -0.4709578 0.5452405 0.5452405
[15,] -0.6060098 0.6110585 0.6110585
[16,] -0.4220454 0.3177893 0.4220454
[17,] -0.3407132 0.5021933 0.5021933
[18,] -0.5861414 0.3645763 0.5861414
[19,] -0.6137978 0.4693924 0.6137978
[20,] -0.4509271 0.4157352 0.4509271
>
> length(rabs[rabs>=absobs])/M # Two sided
[1] 0.135
> length(rmin[rmin<=obsmin])/M # Lower tailed
[1] 0.395
> length(rmax[rmax>=obsmax])/M # Upper tailed
[1] 0.07
```

Now let's put the wole thing together. Make a file that just does the analysis and prints the results. How many simulations should we use? I'd like to make sure that $\widehat{P}$ is significantly different from 0.07, so I run

```
> findm
function(wantpow=.8,mstart=1,aa=0.05,pp=0.04,LL=0.01)
    {
    pow <- 0
    mm <- mstart
    while(pow < wantpow)
        {
        mm <- mm+1
        pow <- randmpow(mm,aa,pp,LL)
        } # End while
    findm <- mm
    findm
    } # End function findm
>
> findm(pp=.07)
[1] 1506
```

and choose $m = 1600$. First I'll show you the output, then a listing of the program `twins.R`.

```
> source("twins.R")
Male Fraternal
   Twin 1
          headlng1    headbrd1   headcir1
progmat1 0.3534186 -0.53715165 0.05247501
reason1  0.4784903 -0.04435345 0.40868525
verbal1  0.3333061  0.02578888 0.36744645

   Twin 2
          headlng2   headbrd2  headcir2
progmat2 0.5622139 -0.1996214 0.4073323
reason2  0.4271557  0.2587126 0.6682264
verbal2  0.3403694  0.1966882 0.6113976
```

Male Identical

Twin 1

	headlng1	headbrd1	headcir1
progmat1	0.2334577	0.26536909	0.3193472
reason1	0.2622690	0.37549903	0.3534622
verbal1	0.4436284	0.06643773	0.3480645

Twin 2

	headlng2	headbrd2	headcir2
progmat2	0.3645763	0.2537397	0.3699872
reason2	0.1682737	0.4212712	0.3873012
verbal2	0.1814358	0.1590209	0.2112241

Female Fraternal

Twin 1

	headlng1	headbrd1	headcir1
progmat1	-0.09894825	0.1031112	0.1024857
reason1	0.10353527	0.1974691	0.2299249
verbal1	0.04068947	0.1458637	0.0710240

Twin 2

	headlng2	headbrd2	headcir2
progmat2	-0.05058245	0.3809976	0.1205803
reason2	0.19569669	0.3570053	0.2617820
verbal2	0.24212501	0.3964967	0.2463883

Female Identical

Twin 1

	headlng1	headbrd1	headcir1
progmat1	-0.01443227	-0.34580801	-0.004887716
reason1	0.15174745	0.04052029	0.304039946
verbal1	0.22504203	-0.01581501	0.341174647

Twin 2

	headlng2	headbrd2	headcir2
progmat2	0.4030654	-0.02036423	0.4244152
reason2	0.3233766	0.05661767	0.4178053
verbal2	0.2702130	0.15930201	0.4025376

Correlations Between Mental and Physical

```
Minimum Observed Correlation:  -0.5371517
Randomization p-value (one-sided): p-hat =  0.416875
Plus or minus 99% Margin of error =  0.03174979

Maximum Observed Correlation:  0.6682264
Randomization p-value (one-sided): p-hat =  0.10625
Plus or minus 99% Margin of error =  0.01984402

Maximum Observed Absolute Correlation:  0.6682264
Randomization p-value (two-sided): p-hat =  0.199375
Plus or minus 99% Margin of error =  0.02572806
```

And here is a listing of the program.

```
# twins.R
# Just do the analysis - no examples or explanation with source("twins.R")
twinframe <-  read.table("smalltwin.dat")
sex <- twinframe$sex ; ident <- twinframe$ident
mental <- twinframe[,3:8]  # All rows, cols 3 to 8
phys   <- twinframe[,9:14] # All rows, cols 9 to 14
n <- length(sex)
mf <- (1:n)[sex==0&ident==0] # mf are indices of male fraternal pairs
mi <- (1:n)[sex==0&ident==1] # mi are indices of male identical pairs
ff <- (1:n)[sex==1&ident==0] # ff are indices of female fraternal pairs
fi <- (1:n)[sex==1&ident==1] # fi are indices of female identical pairs
# Sub-sample sizes
nmf <- length(mf)  ; nmi <- length(mi)
nff  <- length(ff) ; nfi <- length(fi)
# mentalmf are mental scores of male fraternal pairs, etc.
mentalmf <- mental[mf,] ; physmf <- phys[mf,]
mentalmi <- mental[mi,] ; physmi <- phys[mi,]
mentalff <- mental[ff,] ; physff <- phys[ff,]
mentalfi <- mental[fi,] ; physfi <- phys[fi,]

cat("Male Fraternal \n")
cat("   Twin 1   \n")
print(cor(mentalmf[,1:3],physmf[,1:3]))
```

```
cat("   Twin 2   \n")
print(cor(mentalmf[,4:6],physmf[,4:6]))
cat(" \n")

cat("Male Identical \n")
cat("   Twin 1   \n")
print(cor(mentalmi[,1:3],physmi[,1:3]))
cat("   Twin 2   \n")
print(cor(mentalmi[,4:6],physmi[,4:6]))
cat(" \n")

cat("Female Fraternal \n")
cat("   Twin 1   \n")
print(cor(mentalff[,1:3],physff[,1:3]))
cat("   Twin 2   \n")
print(cor(mentalff[,4:6],physff[,4:6]))
cat(" \n")

cat("Female Identical \n")
cat("   Twin 1   \n")
print(cor(mentalfi[,1:3],physfi[,1:3]))
cat("   Twin 2   \n")
print(cor(mentalfi[,4:6],physfi[,4:6]))
cat(" \n")

# test sta will be absobs = 0.6682264
# Keep track of minimum (neg corr: obsmin =  -0.5371517) and max too.


obsmax <- max( c(
                cor(mentalmf[,1:3],physmf[,1:3]),
                cor(mentalmf[,4:6],physmf[,4:6]),
                cor(mentalmi[,1:3],physmi[,1:3]),
                cor(mentalmi[,4:6],physmi[,4:6]),
                cor(mentalff[,1:3],physff[,1:3]),
                cor(mentalff[,4:6],physff[,4:6]),
                cor(mentalfi[,1:3],physfi[,1:3]),
                cor(mentalfi[,4:6],physfi[,4:6])    )   )
```

```
obsmin <- min( c(
                cor(mentalmf[,1:3],physmf[,1:3]),
                cor(mentalmf[,4:6],physmf[,4:6]),
                cor(mentalmi[,1:3],physmi[,1:3]),
                cor(mentalmi[,4:6],physmi[,4:6]),
                cor(mentalff[,1:3],physff[,1:3]),
                cor(mentalff[,4:6],physff[,4:6]),
                cor(mentalfi[,1:3],physfi[,1:3]),
                cor(mentalfi[,4:6],physfi[,4:6])    )   )

absobs <- max(abs(obsmax),abs(obsmin)) # Test Statistic

rmin <- NULL ; rmax <- NULL ; rabs <- NULL
# Now simulate. Want p-hat sig diff from 0.07. Use findm(pp=.07), get
# 1506, so use m=1600

M <- 1600 ; set.seed(4444)
for(i in 1:M)
    {
    rmentalmf <- mental[sample(mf),]
    rmentalmi <- mental[sample(mi),]
    rmentalff <- mental[sample(ff),]
    rmentalfi <- mental[sample(fi),]
    rcorrs <- c(
            cor(rmentalmf[,1:3],physmf[,1:3]),
            cor(rmentalmf[,4:6],physmf[,4:6]),
            cor(rmentalmi[,1:3],physmi[,1:3]),
            cor(rmentalmi[,4:6],physmi[,4:6]),
            cor(rmentalff[,1:3],physff[,1:3]),
            cor(rmentalff[,4:6],physff[,4:6]),
            cor(rmentalfi[,1:3],physff[,1:3]),
            cor(rmentalfi[,4:6],physff[,4:6])  )
    rmin <- c(rmin,min(rcorrs))
    rmax <- c(rmax,max(rcorrs))
    rabs <- c(rabs,max(abs(min(rcorrs)),abs(max(rcorrs))))
    }

twot <- length(rabs[rabs>=absobs])/M # Two sided
```

```
lowt <- length(rmin[rmin<=obsmin])/M # Lower tailed
upt <- length(rmax[rmax>=obsmax])/M # Upper tailed

merror <- function(phat,M,alpha) # (1-alpha)*100% merror for a proportion
     {
     z <- qnorm(1-alpha/2)
     merror <- z * sqrt(phat*(1-phat)/M)  # M is (Monte Carlo) sample size
     merror
     } # End function merror

cat("Correlations Between Mental and Physical \n")
cat(" \n") ; cat(" \n")
cat("     Minimum Observed Correlation: ",obsmin,"\n")
cat("     Randomization p-value (one-sided): p-hat = ",lowt," \n")
cat("     Plus or minus 99% Margin of error = ",merror(lowt,M,0.01),"\n")
cat(" \n")
cat("     Maximum Observed Correlation: ",obsmax,"\n")
cat("     Randomization p-value (one-sided): p-hat = ",upt," \n")
cat("     Plus or minus 99% Margin of error = ",merror(upt,M,0.01),"\n")
cat(" \n")
cat("     Maximum Observed Absolute Correlation: ",absobs,"\n")
cat("     Randomization p-value (two-sided): p-hat = ",twot," \n")
cat("     Plus or minus 99% Margin of error = ",merror(twot,M,0.01),"\n")
cat(" \n")
```

7.2 Bootstrap