Homework4_Hwang

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Problem 1

```
rm(list=ls())
city<-c(1,2,3,5,6,7,9)
suburban<-c(10.5,13.5,13.5,17,17,17,20)
rural<-c(4,8,10.5,13.5,13.5,19)
ts<-c(city,suburban,rural)
g<-c(rep("City",length(city)),rep("Suburban",length(suburban)),rep("Rural",length(rural)))
# H0: mu_city = mu_suburban = mu_rural                        # Problem 1(a)
# HA: At least one mu_i is different
kruskal.test(ts~g)$statistic                                  # Problem 1(b)
```

```
## Kruskal-Wallis chi-squared
##                   11.97399
```

```
kruskal.test(ts~g)$p.value                                    # Problem 1(c)
```

```
## [1] 0.002511198
```

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0.002511198)
# that at least one of the means is different.
T<-data.frame(t.test(city,suburban)$p.value,t.test(city,rural)$p.value,t.test(suburban,rural)$p.value)
names(T)<-c("City vs. Sub","City vs. Rural","Sub. vs. Rural") # Problem 1(d)
row.names(T)<-"p-value"
T
```

```
##         City vs. Sub City vs. Rural Sub. vs. Rural
## p-value 2.359849e-05     0.02370961      0.1306973
```

```
# We reject H0 at the alpha = 0.05 level for the difference between city and rural
# schools and the difference between city and suburban schools. There is sufficient
# evidence (p = 0.00003, p = 0.02371) that the mean rank test scores of seventh graders
# of each of the two pairs of groups are different.
# We fail to reject H0 at the alpha = 0.05 level for the difference between suburban and
# rural schools. There is insufficient evidence (p = 0.1307) that mean rank test scores
# of seventh graders of each of the two pairs of groups are different.
                                                              # Problem 1(e)
pairwise.t.test(c(city,rural),c(rep("City",length(city)),rep("Rural",length(rural))),p.adjust.method="bo
```

```
##
##  Pairwise comparisons using t tests with pooled SD
##
## data:  c(city, rural) and c(rep("City", length(city)), rep("Rural", length(rural)))
##
##       City
## Rural 0.013
##
## P value adjustment method: bonferroni
```

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0.013)
# that the mean rank test scores of seventh graders in city schools is different
# than the mean rank test scores of seventh graders in rural schools.
# This test would be conducted at the alpha = 0.05 / k = 0.05 level (k = 2(2-1)/2 =
# 2(1)/2 = 1). However, the pairwise test functions in R automatically adjust the
# p-value to test with the original level of alpha (per February 25 email).
pairwise.wilcox.test(c(city,rural),c(rep("City",length(city)),rep("Rural",length(rural))),p.adjust.meth
```

```
##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correction
##
## data:  c(city, rural) and c(rep("City", length(city)), rep("Rural", length(rural)))
##
##       City
## Rural 0.027
##
## P value adjustment method: bonferroni
```

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0.027)
# that the mean rank test scores of seventh graders in city schools is different
# than the mean rank test scores of seventh graders in rural schools.
s<-data.frame(ts,g)                                         # Problem 1(f)
D<-matrix(NA,nrow=2500,ncol=length(table(g)))
set.seed(103,sample.kind="Rounding")
for(i in 1:2500){s$ts<-ts[sample(1:length(ts),length(ts))]
D[i,1]<-TukeyHSD(aov(s$ts~g))$g["Rural-City","diff"]
D[i,2]<-TukeyHSD(aov(s$ts~g))$g["Suburban-City","diff"]
D[i,3]<-TukeyHSD(aov(s$ts~g))$g["Suburban-Rural","diff"]
}
mean(D[,1]>TukeyHSD(aov(ts~g))$g["Rural-City","diff"])
```

```
## [1] 0.0168
```

```
mean(D[,2]>TukeyHSD(aov(ts~g))$g["Suburban-City","diff"])
```

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

```
mean(D[,3]>TukeyHSD(aov(ts~g))$g["Suburban-Rural","diff"])
```

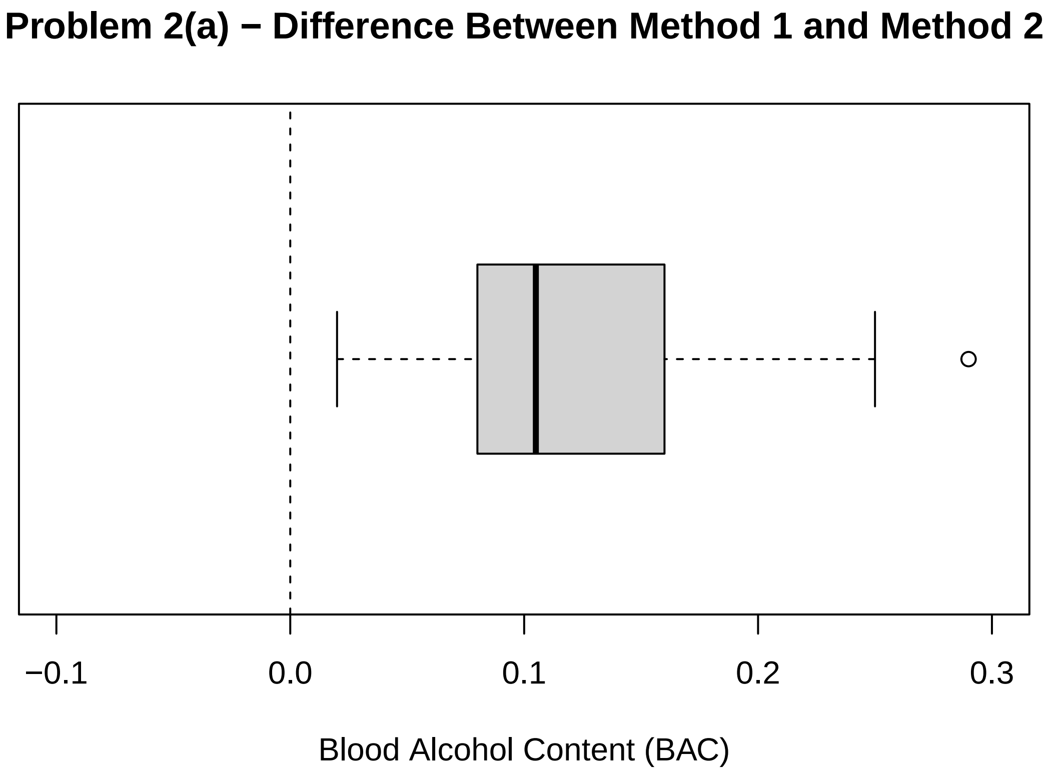
```
## [1] 0.1244
```

We reject H_0 at the $\alpha = 0.05$ level for the difference between city and rural schools and the difference between city and suburban schools. There is sufficient evidence ($p = 0.0168$, $p = 0$) that the mean rank test scores of seventh graders of each of the two pairs of groups are different.

We fail to reject H_0 at the $\alpha = 0.05$ level for the difference between suburban and rural schools. There is insufficient evidence ($p = 0.1244$) that mean rank test scores of seventh graders of each of the two pairs of groups are different.

Problem 2

```
BAC<-read.csv("/Users/newuser/Desktop/Notes/Graduate/STAT 451 - Nonparametric Statistical Methods/bac_2m
boxplot(BAC[BAC$Method==1,"BAC"]-BAC[BAC$Method==2,"BAC"],ylim=c(-0.1,0.3),horizontal=TRUE,main="Problem
abline(v=0,lty=2)
```




```
# The boxplot is right skew with one notable statistical outlier (the maximum).
# H0: mu_1 - mu_2 = 0  # Problem 2(b)
# HA: mu_1 - mu_2 =/= 0
t.test(BAC[BAC$Method==1,"BAC"],BAC[BAC$Method==2,"BAC"],paired=TRUE)
```

```
##
##  Paired t-test
##
## data:  BAC[BAC$Method == 1, "BAC"] and BAC[BAC$Method == 2, "BAC"]
## t = 7.5036, df = 17, p-value = 8.634e-07
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.08745716 0.15587617
## sample estimates:
## mean of the differences
##               0.1216667
```

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p < 0.000001)
# that the mean BAC of method 1 is different than the mean BAC of method 2.
# H0: T_1 - T_2 = 0    # Problem 2(c)
# HA: T_1 - T_2 =/= 0
P<-matrix(NA,nrow=nrow(BAC),ncol=2500)
R<-rep(0,2500)
set.seed(76,sample.kind="Rounding")
```

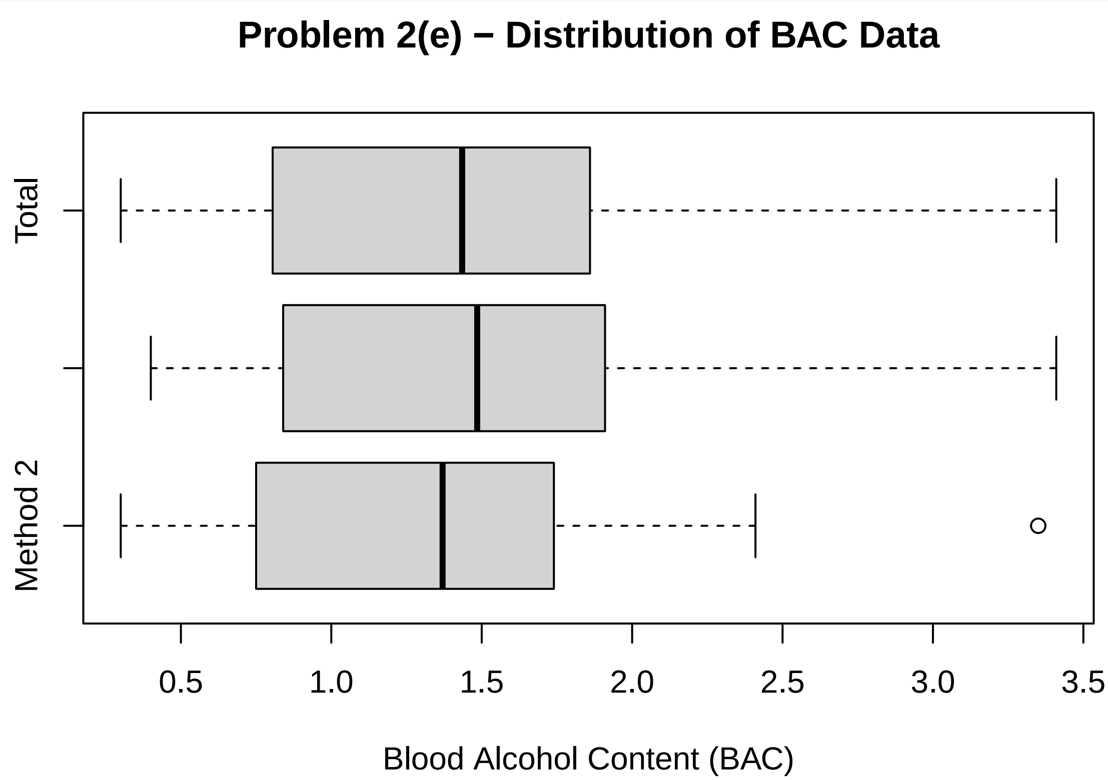
```r
for(i in 1:2500){P[,i]<-sample(BAC$BAC,size=nrow(BAC),replace=FALSE)
R[i]<-t.test(P[BAC$Method==1,i],P[BAC$Method==2,i],paired=TRUE)$estimate}
mean(R>mean(BAC[BAC$Method==1,"BAC"])-mean(BAC[BAC$Method==2,"BAC"]))
```

```
## [1] 0.3144
```

```r
# We fail to reject H0 at the alpha = 0.05 level. There is insufficient evidence (p = 0.3144)
# that the mean BAC of method 1 is different than the mean BAC of method 2.
# H0: m_1 - m_2 = 0    # Problem 2(d)
# HA: m_1 - m_2 =/= 0
wilcox.test(BAC[BAC$Method==1,"BAC"],BAC[BAC$Method==2,"BAC"],paired=TRUE)
```

```
##
##  Wilcoxon signed rank test with continuity correction
##
## data:  BAC[BAC$Method == 1, "BAC"] and BAC[BAC$Method == 2, "BAC"]
## V = 171, p-value = 0.0002137
## alternative hypothesis: true location shift is not equal to 0
```

```r
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0.00022)
# that the two methods are different.
boxplot(BAC[BAC$Method==2,"BAC"],BAC[BAC$Method==1,"BAC"],BAC[,"BAC"],names=c("Method 2","Method 1","To
```



Problem 2(e)

I believe the Wilcoxon Signed-Rank test is the most appropriate method. Although the paired t-test is robust, the BAC variable for the subsets of methods 1 and 2 as well as the whole sample do not appear to be normally distributed which is a required assumption.

Problem 3

```
CPK<-read.csv("/Users/newuser/Desktop/Notes/Graduate/STAT 451 - Nonparametric Statistical Methods/CPK.c
row.names(CPK)<-CPK$Subject
CPK<-CPK[c("Preexercise","X18.h.post","X42.h.post","Peak.CPK")]
p<-c(CPK$Preexercise,CPK$Peak.CPK,CPK$X18.h.post,CPK$X42.h.post)
Treatment<-as.factor(rep(c("Pre","18","42","Peak"),each=nrow(CPK)))
Block<-as.factor(rep(1:nrow(CPK),times=length(CPK)))
# H0: mu_pre = mu_18 = mu_42 = mu_peak                    # Problem 3(a)
# HA: At least one mu_i is different
Y<-data.frame(p,Treatment)
F<-rep(NA,5000)
set.seed(103)
for (i in 1:5000){Y$p<-p[sample(1:length(p),length(p))]
F[i]=anova(lm(p~Treatment+Block,data=Y))["Treatment","F value"]}
mean(F>anova(lm(p~Treatment+Block))["Treatment","F value"])
```

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

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0)
# that at least one mean is different.
# H0: m_pre = m_18 = m_42 = m_peak                        # Problem 3(b)
# HA: At least one m_i is different
friedman.test(p,Treatment,Block)
```

```
##
##  Friedman rank sum test
##
## data:  p, Treatment and Block
## Friedman chi-squared = 23.4, df = 3, p-value = 3.333e-05
```

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0.000034)
# that at least one of the medians is different.
anova(lm(p~Treatment+Block))                              # Problem 3(c)
```

```
## Analysis of Variance Table
##
## Response: p
##           Df Sum Sq Mean Sq F value   Pr(>F)
## Treatment  3 384384  128128   5.141 0.004311 **
## Block     13 430899   33146   1.330 0.237950
## Residuals 39 971987   24923
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# We reject H0 at the alpha = 0.05 level. There is sufficient evidence (p = 0.004311)
# that at least one of the means is different.
# We can see that this p-value is greater than the p-values obtained from the permutation
# test and Friedman's test, but still is below alpha = 0.05.
pairwise.t.test(p,Treatment,p.adjust.method="bonferroni") # Problem 3(d)
```

```
##
##  Pairwise comparisons using t tests with pooled SD
##
## data:  p and Treatment
##
```

```
##      18    42    Peak
## 42   0.024 -     -
## Peak 0.028 1.000 -
## Pre  0.012 1.000 1.000
##
## P value adjustment method: bonferroni
```

```r
# We reject H0 at the alpha = 0.05 level for the pairwise comparisons between 18 hours
# after exercise and the other three groups. There is sufficient evidence (p = 0.024,
# p = 0.028, p = 0.012) that the mean plasma CPK activity 18 hours after exercise
# is different than the mean plasma CPK activity for the other three groups.
# We fail to reject H0 at the alpha = 0.05 level for the pairwise comparisons between
# 42 hours after exercise and both preexercise and peak level as well as between
# preexercise and peak level. There is insufficient evidence (p = 1, p = 1, p = 1)
# that the mean plasma CPK activity between these pairs of groups is different.
pairwise.wilcox.test(p,Treatment,p.adjust.method="bonferroni")
```

```
##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correction
##
## data:  p and Treatment
##
##      18      42     Peak
## 42   0.0037  -      -
## Peak 0.0034  1.0000 -
## Pre  8.4e-05 1.0000 0.2728
##
## P value adjustment method: bonferroni
```

Since we tested at the $\alpha = 0.05$ level, we should use $\alpha = \frac{0.05}{k} = \frac{0.05}{6} = 0.008\overline{3}$ ($k = \frac{4(4-1)}{2} = \frac{4(3)}{2} = 6$). However, the pairwise test functions in R automatically adjust the p-value to test with the original level of α (per February 25 email).

We reject H_0 at the $\alpha = 0.008\overline{3}$ level for the pairwise comparisons between 18 hours after exercise and the other three groups. There is sufficient evidence ($p = 8.423622 \times 10^{-5}$, $p = 0.0037019$, $p = 0.0033949$) that the mean plasma CPK activity 18 hours after exercise is different than the mean plasma CPK activity for the other three groups.

We fail to reject H_0 at the $\alpha = 0.008\overline{3}$ level for the pairwise comparisons between 42 hours after exercise and both preexercise and peak level as well as between preexercise and peak level. There is insufficient evidence ($p = 1$, $p = 1$, $p = 0.2727638$) that the mean plasma CPK activity between these pairs of groups is different.

Problem 4

Yes, it is *possible* to use Friedman's test on a one-way ANOVA that has equal sample sizes in each group by adding an additional blocking variable. However, Friedman's test *should not* be used in this situation because the data would have to be somewhat manipulated which could impact the test results and conclusion.