Final Project

John Kaspers

11/28/2020

1 = Mug no baking soda 2 = Mug 1/8 tsp baking soda 3 = Mug 1/4 tsp baking soda 4 = Pint 0 tsp baking soda 5 = Pint 1/8 tsp baking soda 6 = Pint 1/4 tsp baking soda

Randomization

```
sample(1:6)
```

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

```
entries <- c(0, 0.3, 1.3, 0, 0.1, 0, 0.3, 1.1, 0, 0.2, 1, 1.1, 2.2, 1.2, 1.1, 2, 0.8, 1.9, 0.6, 0.6, 2.7
length(entries)
```

```
## [1] 30
```

```
container <- as.factor(c("Mug", "Mug", "Mug", "Mug", "Mug", "Pint", "Pint", "Pint", "Pint", "Pint", "Mug
length(container)
```

```
## [1] 30
```

```
bakeSodaAmount <- as.factor(c(rep("0 tsp", 10), rep("1/8 tsp", 10), rep("1/4 tsp", 10)))
cbind(entries, container, bakeSodaAmount)
```

```
##         entries container bakeSodaAmount
## [1,]      0.0         1            1
## [2,]      0.3         1            1
## [3,]      1.3         1            1
## [4,]      0.0         1            1
## [5,]      0.1         1            1
## [6,]      0.0         2            1
## [7,]      0.3         2            1
## [8,]      1.1         2            1
## [9,]      0.0         2            1
## [10,]     0.2         2            1
## [11,]     1.0         1            3
## [12,]     1.1         1            3
## [13,]     2.2         1            3
## [14,]     1.2         1            3
```

```
## [15,]      1.1         1              3
## [16,]      2.0         2              3
## [17,]      0.8         2              3
## [18,]      1.9         2              3
## [19,]      0.6         2              3
## [20,]      0.6         2              3
## [21,]      2.7         1              2
## [22,]      1.6         1              2
## [23,]      2.4         1              2
## [24,]      2.2         1              2
## [25,]      1.8         1              2
## [26,]      1.3         2              2
## [27,]      2.7         2              2
## [28,]      2.1         2              2
## [29,]      2.5         2              2
## [30,]      2.5         2              2
```

```r
length(bakeSodaAmount)
```

```
## [1] 30
```

```r
twoway <- aov(entries~bakeSodaAmount+container+bakeSodaAmount*container)
summary(twoway)
```

```
##                          Df Sum Sq Mean Sq F value   Pr(>F)
## bakeSodaAmount            2 17.113   8.556  29.021 3.93e-07 ***
## container                 1  0.005   0.005   0.018    0.894
## bakeSodaAmount:container  2  0.061   0.030   0.103    0.903
## Residuals                24  7.076   0.295
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```
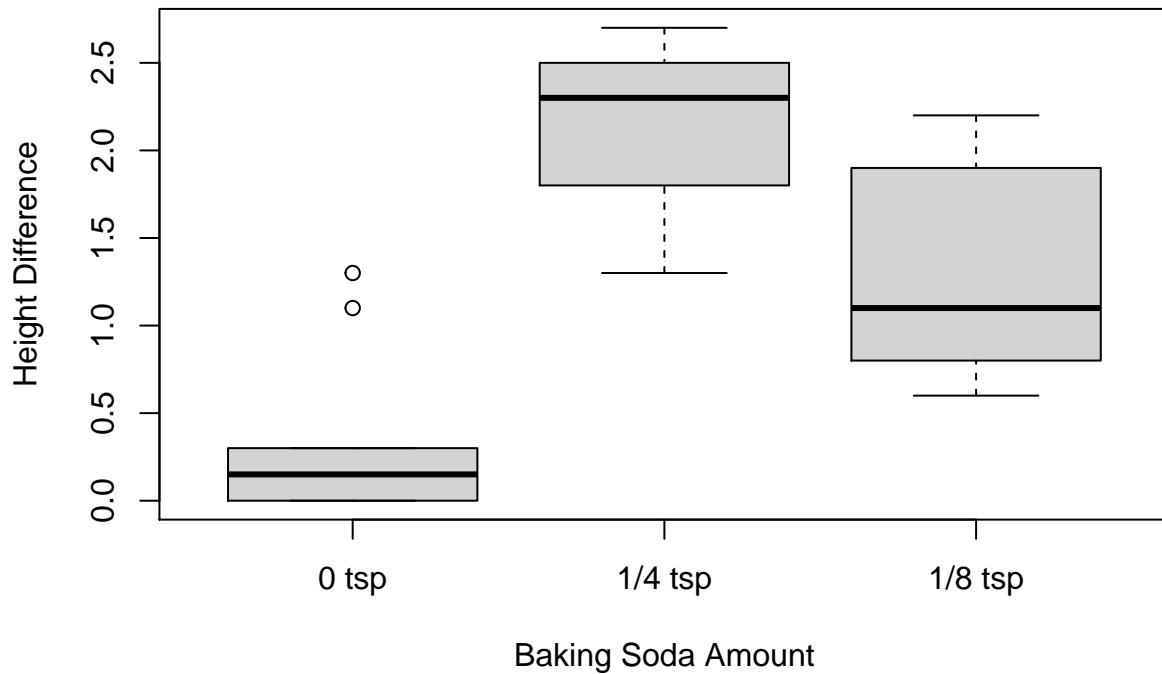
```r
#Diagnostics
plot(container, entries, xlab="Container", ylab="Height Difference")
```

```r
plot(bakeSodaAmount, entries, xlab="Baking Soda Amount", ylab="Height Difference")
```



```r
alpha=0.05
a=3#number of levels of a
b=2#number of levels of b
sigsq=0.295

#For Factor A=AmountBakingSoda
n=18:35
D=0.5#desired difference in means to detect with prob 1-beta
```

```r
Fcrit=qf(1-alpha,a-1,a*b*(n-1))#value at which we reject H0
lam=n*b*(D^2)/(2*sigsq)
beta=pf(Fcrit,a-1,a*b*(n-1),ncp=lam)
power=1-beta
nforA=cbind(n,Fcrit,beta,power)#output for A
nforA
```

```
##          n    Fcrit         beta     power
##  [1,] 18 3.085465 0.0587619941 0.9412380
##  [2,] 19 3.080387 0.0473193663 0.9526806
##  [3,] 20 3.075853 0.0379628516 0.9620371
##  [4,] 21 3.071779 0.0303487922 0.9696512
##  [5,] 22 3.068100 0.0241804697 0.9758195
##  [6,] 23 3.064761 0.0192043908 0.9807956
##  [7,] 24 3.061716 0.0152059983 0.9847940
##  [8,] 25 3.058928 0.0120051893 0.9879948
##  [9,] 26 3.056366 0.0094519042 0.9905481
## [10,] 27 3.054004 0.0074219552 0.9925780
## [11,] 28 3.051819 0.0058131941 0.9941868
## [12,] 29 3.049792 0.0045420747 0.9954579
## [13,] 30 3.047906 0.0035406182 0.9964594
## [14,] 31 3.046148 0.0027537785 0.9972462
## [15,] 32 3.044504 0.0021371803 0.9978628
## [16,] 33 3.042964 0.0016551998 0.9983448
## [17,] 34 3.041518 0.0012793506 0.9987206
## [18,] 35 3.040158 0.0009869371 0.9990131
```

```r
#For Factor B=ContainerType
n=18:35
D=0.5#desired difference in means to detect with prob 1-beta
Fcrit=qf(1-alpha,b-1,a*b*(n-1))#value at which we reject H0
lam=n*a*(D^2)/(2*sigsq)
beta=pf(Fcrit,b-1,a*b*(n-1),ncp=lam)
power=1-beta
nforB=cbind(n,Fcrit,beta,power)#output for B
nforB
```

```
##          n    Fcrit         beta     power
##  [1,] 18 3.934253 2.734685e-03 0.9972653
##  [2,] 19 3.929012 1.804609e-03 0.9981954
##  [3,] 20 3.924330 1.185439e-03 0.9988146
##  [4,] 21 3.920124 7.753811e-04 0.9992246
##  [5,] 22 3.916325 5.051259e-04 0.9994949
##  [6,] 23 3.912875 3.278163e-04 0.9996722
##  [7,] 24 3.909729 2.119812e-04 0.9997880
##  [8,] 25 3.906849 1.366097e-04 0.9998634
##  [9,] 26 3.904202 8.775217e-05 0.9999122
## [10,] 27 3.901761 5.619464e-05 0.9999438
## [11,] 28 3.899502 3.588028e-05 0.9999641
## [12,] 29 3.897407 2.284542e-05 0.9999772
## [13,] 30 3.895458 1.450704e-05 0.9999855
## [14,] 31 3.893640 9.188503e-06 0.9999908
## [15,] 32 3.891940 5.805558e-06 0.9999942
```

```
## [16,] 33 3.890348 3.659482e-06 0.9999963
## [17,] 34 3.888853 2.301508e-06 0.9999977
## [18,] 35 3.887447 1.444310e-06 0.9999986
```

Two Factor Design

```
#Specify means, sigma and replicates
#You will have to make appropriate changes for your experiment

set.seed(789)

n = 114 #replicates
a = 3 #Factor a
b = 2 #Factor b
sigma = sqrt(0.295) #value of sigma
mean11 = 0.34 #mean for treatment-combination 11
mean12 = 0.32 #mean for treatment-combination 12
mean21 = 1.32 #mean for treatment-combination 21
mean22 = 1.18 #mean for treatment-combination 22
mean31 = 2.14 #mean for treatment-combination 31
mean32 = 2.22 #mean for treatment-combination 32

#Generate the data
y11 = mean11+rnorm(n, 0, sigma); y11
```

```
##   [1]  0.624657376 -0.887911263  0.329311177  0.439470423  0.143735909
##   [6]  0.076857837 -0.021900564  0.245238926 -0.209091648  0.741757795
##  [11]  0.121497176 -0.204649127  0.243473763  0.075002707  0.843982715
##  [16] -0.080620561  0.569677810  0.010334497  0.453719721 -0.082202163
##  [21] -0.041310817  0.711218779 -0.125843592  0.539745262 -0.436521534
##  [26]  0.061736396  0.194378793  0.231789259  0.805238907  0.249410189
##  [31]  0.135958112 -0.276450232  0.670942621  0.647338105 -0.059776712
##  [36] -0.234940845 -0.375783516  0.228987931  0.013362199  0.698799060
##  [41]  0.250550527  1.295669968  1.215565496  0.776248506  1.027198629
##  [46]  0.617530349 -1.337006969  0.597572342  0.679947453  0.872915323
##  [51]  0.314086913 -0.485362118  0.771761002  0.261661695 -0.043726586
##  [56]  0.671701776  0.929339320 -0.046361536  0.968025161  1.011082372
##  [61]  0.164861938  0.737998917  0.183831873  1.615569212  0.528829898
##  [66]  0.152341401 -0.150248206  0.126081648 -0.183473123  0.757841459
##  [71]  0.635840349  0.910144001  0.987876075  0.156307374 -0.234552851
##  [76]  0.196418079  1.155653107  0.767819962  0.521788573 -0.543820793
##  [81]  1.344522299  0.597954772 -0.196196985  0.478968758 -0.426325161
##  [86]  0.387710302  0.510868092  0.101660789 -0.447567081  1.058967889
##  [91]  0.080435504  0.911673262 -0.103788110 -0.277516856 -1.082883007
##  [96]  0.875416873  0.447770665  0.001472083  0.584422613  1.154282085
## [101]  0.043634797  0.123304390  0.657943065  0.429000078  0.416596406
## [106]  0.650557752  0.724164334 -0.244498648  0.711928916  0.244366730
## [111]  0.469639803 -0.723799035 -1.277472436  0.726251585
```

```
y12 = mean12+rnorm(n, 0, sigma); y12
```

```
##    [1]  0.12961856  0.79156426  0.52945609 -0.10972134  0.50531000  1.07075612
##    [7] -0.12014825  0.51797005  0.54325900  0.84201070  0.21056288  0.62709883
##   [13]  0.55586947  0.32756741  0.25665898  0.48230540 -0.37943652  0.59474733
##   [19] -0.51360538  0.43808674  0.32926718 -0.76079662 -0.07026369  0.62784606
##   [25]  0.28570612  1.97764568 -0.28921038 -0.67182759  0.25376671  0.64244264
##   [31]  0.17636989 -0.12006575  0.59698067  0.96695794  1.32642776 -0.04276701
##   [37]  0.02058378  0.06162491  0.42152194  1.07548377 -0.09589817  0.40033534
##   [43]  0.10158530 -0.04330978  0.27730068  0.70570815  0.90919390  0.10651146
##   [49] -0.11535646  0.30959623  0.93814380 -0.44011774 -0.58065332 -0.04831089
##   [55]  1.15116616  0.33953395 -0.45076308  0.05298347  0.38023661  1.39725849
##   [61]  0.99379698 -0.13139533  0.44984003 -0.87959610 -0.70949697  0.60167566
##   [67]  1.23978395  0.28310074  0.69264978 -0.49165993  0.57155483  1.14927944
##   [73]  0.31097911 -0.01135145  0.31182275  0.16574668 -0.21206169 -0.17213343
##   [79] -0.46986079  1.21894220  0.88027352  0.87663381 -0.20319776  0.28757970
##   [85] -0.84872633  0.13479068 -1.39715166 -0.57930912 -0.31451478  1.43169596
##   [91]  0.08721116 -0.12263850  0.26237596  0.83594286 -0.58134147  0.44657065
##   [97]  0.20336668  0.32856627  0.78847665  0.23652498  0.20279876  0.76590266
##  [103]  0.86268703 -0.55526626  0.17523520  0.35123646  0.02383310  0.88210124
##  [109] -0.10022318 -0.55337909  0.10551514  0.58703939 -0.58160209  1.03017847
```

```r
y21 = mean21+rnorm(n, 0, sigma); y21
```

```
##    [1] 1.0372215 1.3861393 1.3330694 2.0464011 0.9551546 1.9291793 1.0145020
##    [8] 1.4709237 1.7671371 1.6609038 0.9701286 0.6633769 0.4616193 1.5975685
##   [15] 1.1313108 0.9014070 1.4232261 2.0721234 1.7697497 1.4659249 1.2250516
##   [22] 1.8054134 0.9845748 1.4012566 1.3090137 0.6518147 0.5087295 1.7481706
##   [29] 0.7643009 0.8938189 1.4709160 0.5115885 0.1474231 1.6135712 1.3700875
##   [36] 1.0634158 0.9197620 1.5957996 0.5961596 1.5851227 1.4975968 1.2866188
##   [43] 1.6673661 1.4496314 1.0402025 1.5723535 0.4371592 1.2277920 1.6916557
##   [50] 0.3540117 1.8827896 2.4004243 1.6507183 1.5946639 0.2797025 1.6012035
##   [57] 1.2594093 1.7619227 1.1200284 1.3395273 1.3329674 1.5193372 0.8386703
##   [64] 1.9241881 1.3419002 1.8290340 1.4330569 2.2091819 0.7091784 0.8402477
##   [71] 1.8939091 1.9002247 0.7389201 0.8241475 1.9482292 0.8589936 1.5196455
##   [78] 0.4525434 1.8390689 1.3584081 0.4583625 0.6780651 1.3684519 1.3114334
##   [85] 1.0258784 1.7438060 0.5015500 1.3150387 1.7590801 1.2082656 1.8797383
##   [92] 0.7090902 0.8711806 2.6777689 1.2489194 2.5286670 1.8788976 1.6671162
##   [99] 0.9387493 1.4423659 2.5689292 1.3900737 1.6035412 0.3591011 1.5890448
##  [106] 0.3283198 0.4882721 1.4106758 0.9057476 1.9321347 1.5095339 1.8432989
##  [113] 1.8905229 2.1604485
```

```r
y22 = mean22+rnorm(n, 0, sigma); y22
```

```
##    [1]  1.98283423  1.52127528  1.14475621  1.76341679  1.88468203  1.16130867
##    [7]  1.28304764  0.83187803  0.99484996  2.12035943  1.36244537  1.31752659
##   [13]  1.37062957  1.78997119  0.21340938  2.12802536  0.78527778  1.71120303
##   [19]  1.16099414  0.73670864  0.94154038  1.02775855  1.10033729  1.60495355
##   [25]  1.37053893  0.67572017  1.24632136  1.02051771  1.90849193  1.53369819
##   [31]  0.94953084  1.12707351  1.85408437  1.93084266  0.92171557  1.89540069
##   [37]  0.77505065 -0.44708068  0.74815786  1.41924651  0.32206033  0.43115073
##   [43]  1.23240234  1.48541563  1.58079997  1.60828076  2.09432139  1.39171041
##   [49]  1.15188963  1.70040097  1.04498279  1.45054280  1.07388477  1.67836775
##   [55]  1.39400377  0.95402380  2.18581420  0.29488283  1.75029224  1.42788210
##   [61]  0.90455125  0.68225516  2.15770401  1.09067269  1.03588865  0.47808010
```

```
## [67]   1.16259166  0.92625394  2.23464921  1.46674888 -0.02568833  0.98596413
## [73]   0.40986930  0.48939310  1.42682901  0.89296052  0.44370677  1.02830129
## [79]   1.30845841  1.02419720  0.82233243  1.46309107  0.70573027  1.33488880
## [85]   1.98233483  1.40337507  1.01100355  1.22503157  1.95699494  1.69656113
## [91]   1.93280940  0.83625341  1.02197615  1.89710779  1.29159754  1.51164790
## [97]   1.61171756  0.95341654  1.27036898  1.24847245  1.10975448  1.64868570
## [103]  2.18787756  1.11886526  1.68652345  1.80638137  1.68236127  2.42254717
## [109]  0.84321584  0.72394210  1.29281147  1.54347566  2.04116155  1.22547492
```

```
y31 = mean31+rnorm(n, 0, sigma); y31
```

```
##   [1] 1.4778069 2.0313963 2.2468165 2.8217914 1.8464848 1.8626904 1.2490318
##   [8] 1.6037729 2.8629439 1.4885272 2.0874970 1.8832707 1.6061036 1.9414008
##  [15] 2.9259307 2.3048682 1.8784510 2.3258689 2.1921187 2.2497661 2.4809978
##  [22] 1.8031431 2.1583578 2.2831440 2.6189228 2.3424082 2.3819904 2.7799738
##  [29] 1.5210819 2.8629913 1.8495432 2.7923993 1.3702116 2.7772847 2.8141444
##  [36] 0.9284525 2.5719412 2.3702051 2.0413555 2.0047460 0.4378717 1.8152057
##  [43] 2.2012482 2.3591679 2.0856031 1.6023634 2.2930151 2.1735918 1.5370330
##  [50] 1.8707038 1.7592320 1.8127291 2.6275674 1.3870774 1.9179565 1.7172549
##  [57] 2.3028232 2.1570341 1.9180542 2.4445412 1.6121424 1.6563596 2.2898842
##  [64] 2.3011276 1.7138335 2.8957850 1.9365245 2.9758048 2.3701298 2.7510407
##  [71] 1.8607023 2.6336047 2.2938576 2.1933299 1.6874278 1.6093177 2.1549068
##  [78] 2.3909349 2.2971409 2.3700608 2.7660703 1.8281246 2.3526585 2.1988345
##  [85] 2.1955232 2.1009893 2.2215709 2.5325775 2.7999352 2.6542880 1.6969397
##  [92] 2.5454875 2.4339716 2.6854086 2.4971025 3.1751120 1.6196599 1.9183960
##  [99] 3.0746116 1.8878217 3.0648476 2.0937786 1.7769968 1.7125152 2.2225414
## [106] 2.2660234 2.0290089 3.0707161 1.3888013 1.8991473 2.0848711 1.6247692
## [113] 2.3302974 2.4459132
```

```
y32 = mean32+rnorm(n, 0, sigma); y32
```

```
##   [1] 1.294242 1.240725 1.607492 1.852979 2.083957 2.219490 2.044756 2.370304
##   [9] 1.638706 2.047788 2.512385 2.639700 3.681729 1.293790 2.403220 2.033494
##  [17] 2.558862 2.146661 1.933488 1.860043 2.762342 2.215200 2.359902 2.274752
##  [25] 2.085072 2.346496 2.745816 2.344474 3.248183 2.361364 2.489783 1.874175
##  [33] 1.548430 2.212572 3.082518 1.800329 1.769411 2.093244 1.258080 3.565679
##  [41] 1.459596 2.110429 2.408752 1.887759 3.168728 3.166686 2.355889 3.540317
##  [49] 1.235180 2.068052 2.751024 2.398137 2.350026 2.138635 1.834555 2.059219
##  [57] 2.722289 2.666650 2.082190 2.916223 2.938912 2.239000 1.394589 1.730589
##  [65] 1.318807 1.871416 1.935190 2.205870 2.562491 2.345934 1.513950 2.416707
##  [73] 1.820285 2.307354 1.324288 1.176280 2.614378 2.002240 2.659324 2.553753
##  [81] 2.159770 2.340450 1.810811 2.702368 1.690093 1.814259 2.777862 1.752544
##  [89] 1.816317 1.825920 2.582232 2.290680 2.096074 2.496799 2.167750 2.673520
##  [97] 2.095434 1.434610 2.800856 2.658297 2.073093 2.349317 1.651379 2.908693
## [105] 2.483705 2.234665 2.717014 1.792861 1.920809 2.620628 1.282374 1.455274
## [113] 2.180546 1.517328
```

```
#Create data table for ANOVA
yij = c(y11, y12, y21, y22, y31, y32)

fa=as.factor(c(rep(1,b*n),rep(2,b*n),rep(3,b*n)))
fb=as.factor(rep(c(rep(1,n),rep(2,n)), a))
```

```
#Remember to check your data to make sure you have generated the data you desire
head(cbind(yij,fa,fb))
```

```
##            yij fa fb
## [1,]  0.62465738  1  1
## [2,] -0.88791126  1  1
## [3,]  0.32931118  1  1
## [4,]  0.43947042  1  1
## [5,]  0.14373591  1  1
## [6,]  0.07685784  1  1
```
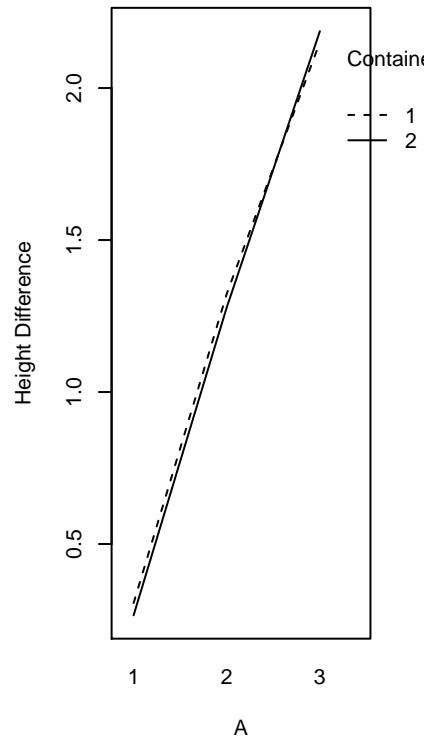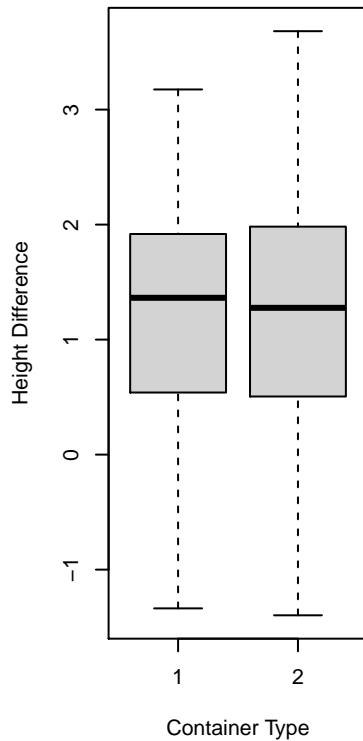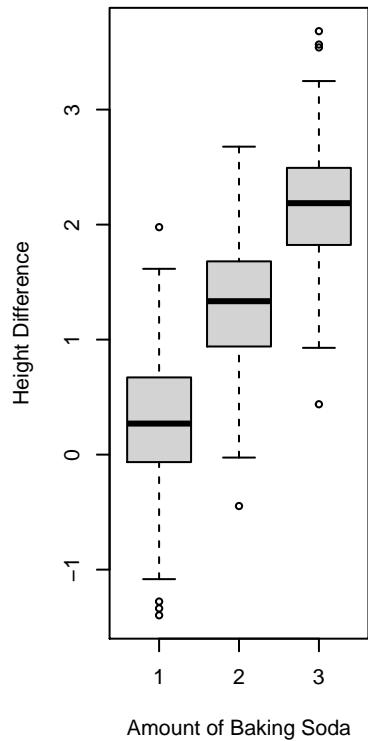
```
summary(yij)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## -1.3972  0.5271  1.3132  1.2519  1.9339  3.6817
```

```
## Two factor
```

```
#Exploratory plots
par(mfrow=c(1,3))
plot(fa,yij, xlab="Amount of Baking Soda",ylab="Height Difference")
plot(fb,yij,xlab="Container Type",ylab="Height Difference")
interaction.plot(fa, fb, yij, xlab="A",ylab="Height Difference", trace.label = "Container Type", fixed =
```
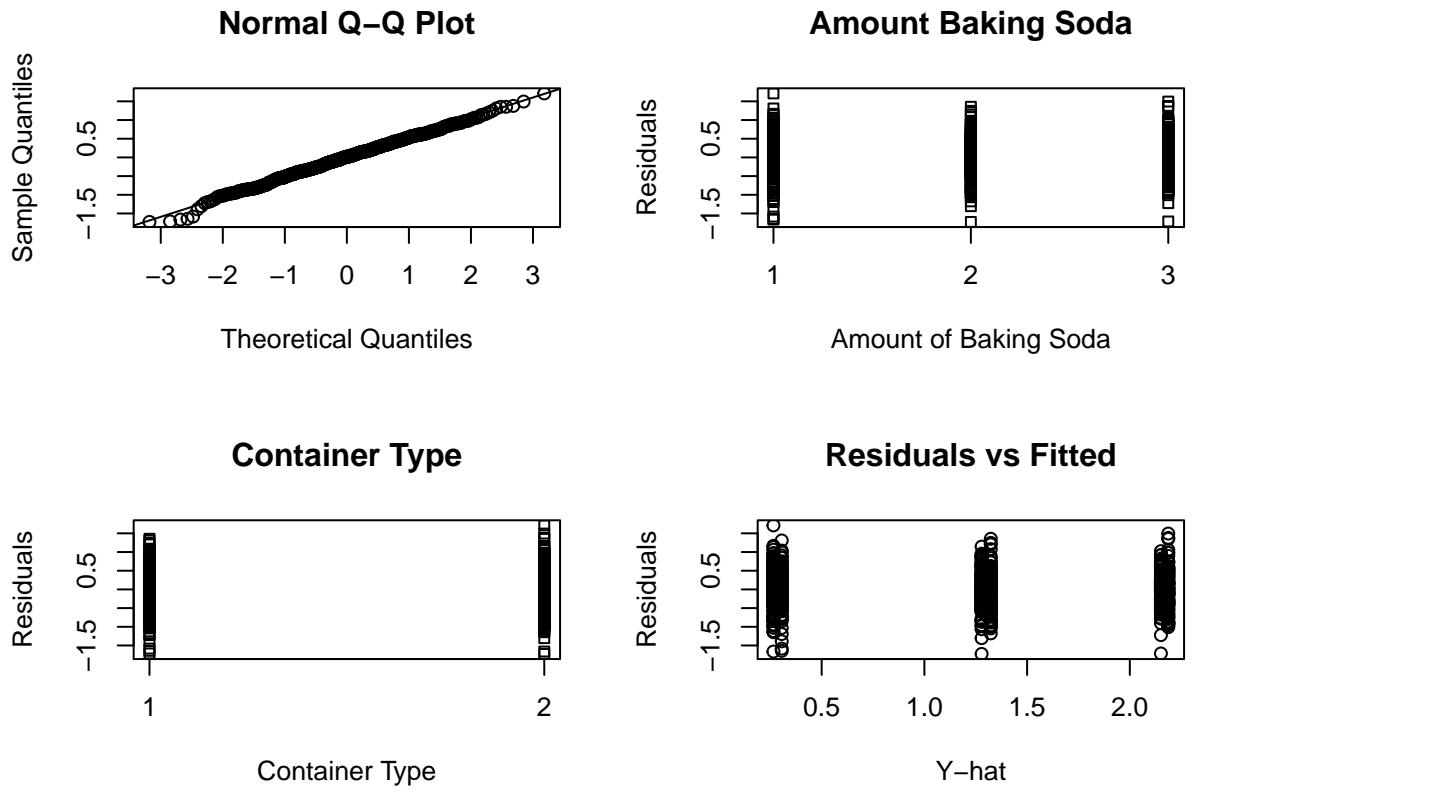
```
par(mfrow=c(1,1))

#anova
twoway=aov(yij~fa+fb+fa*fb)
summary(twoway)#ANOVA
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## fa            2  405.3  202.64 715.192 <2e-16 ***
## fb            1    0.0    0.05   0.162  0.687
## fa:fb         2    0.2    0.12   0.411  0.663
## Residuals   678  192.1    0.28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#Residual analysis
fits=twoway$fitted
res=twoway$residuals
par(mfrow=c(2,2))
qqnorm(res)
qqline(res)
stripchart(res~fa,vertical=T,xlab="Amount of Baking Soda",ylab="Residuals", main="Amount Baking Soda")
stripchart(res~fb,vertical=T,xlab="Container Type",ylab="Residuals", main="Container Type")
plot(fits,res,xlab="Y-hat",ylab="Residuals", main="Residuals vs Fitted")
```



#Exploratory
```

```
entries <- c(0, 0.3, 1.3, 0, 0.1, 0, 0.3, 1.1, 0, 0.2, 1, 1.1, 2.2, 1.2, 1.1, 2, 0.8, 1.9, 0.6, 0.6, 2.7
length(entries)
```

[1] 30

```
container <- as.factor(c("Mug", "Mug", "Mug", "Mug", "Mug", "Pint", "Pint", "Pint", "Pint", "Pint", "Mug
length(container)
```

[1] 30

```
bakeSodaAmount <- as.factor(c(rep("0 tsp", 10), rep("1/8 tsp", 10), rep("1/4 tsp", 10)))
cbind(entries, container, bakeSodaAmount)
```

```
##        entries container bakeSodaAmount
##  [1,]     0.0         1              1
##  [2,]     0.3         1              1
##  [3,]     1.3         1              1
##  [4,]     0.0         1              1
##  [5,]     0.1         1              1
##  [6,]     0.0         2              1
##  [7,]     0.3         2              1
##  [8,]     1.1         2              1
##  [9,]     0.0         2              1
## [10,]     0.2         2              1
## [11,]     1.0         1              3
## [12,]     1.1         1              3
## [13,]     2.2         1              3
## [14,]     1.2         1              3
## [15,]     1.1         1              3
## [16,]     2.0         2              3
## [17,]     0.8         2              3
## [18,]     1.9         2              3
## [19,]     0.6         2              3
## [20,]     0.6         2              3
## [21,]     2.7         1              2
## [22,]     1.6         1              2
## [23,]     2.4         1              2
## [24,]     2.2         1              2
## [25,]     1.8         1              2
## [26,]     1.3         2              2
## [27,]     2.7         2              2
## [28,]     2.1         2              2
## [29,]     2.5         2              2
## [30,]     2.5         2              2
```

```
plot(container, entries, xlab="Container", ylab="Height Difference")
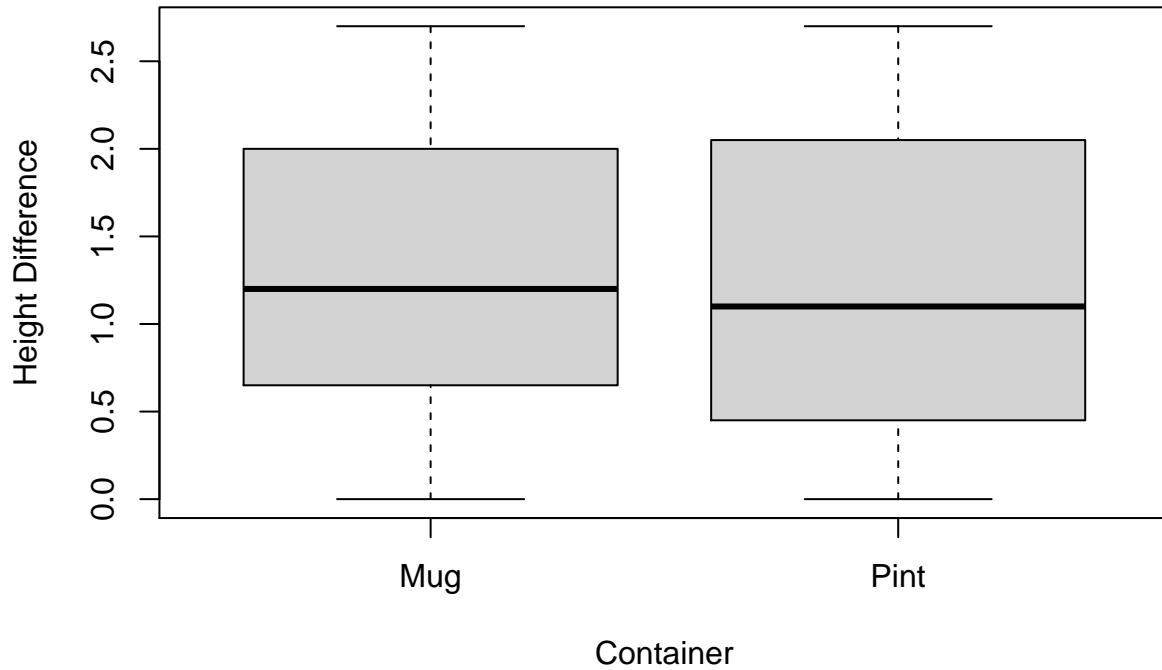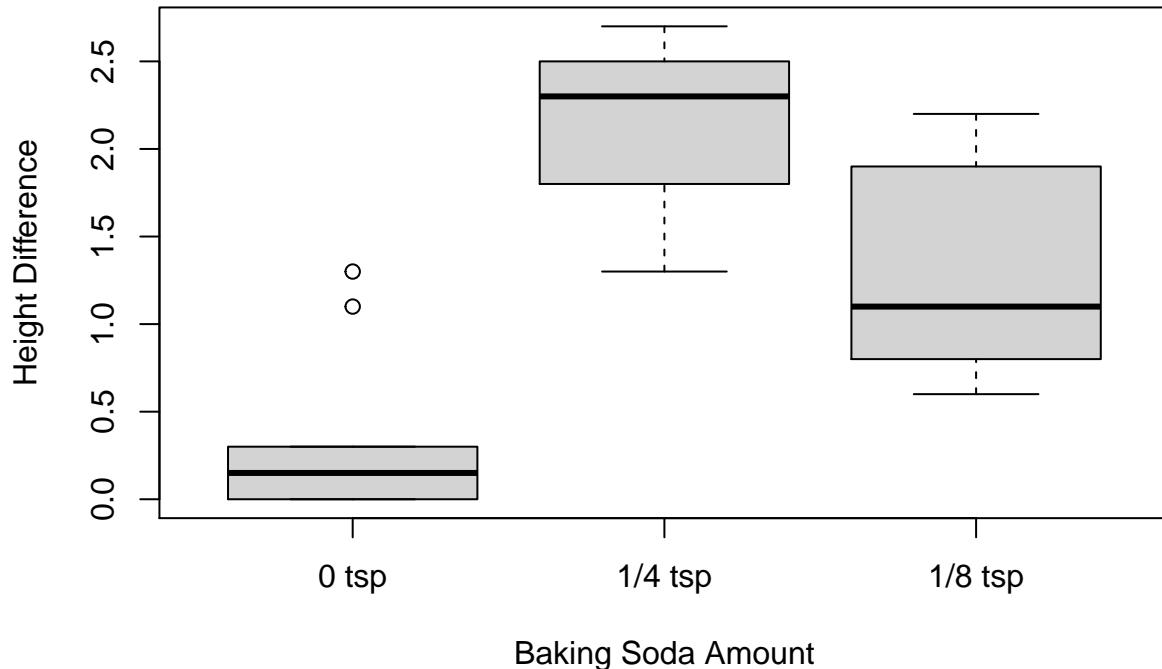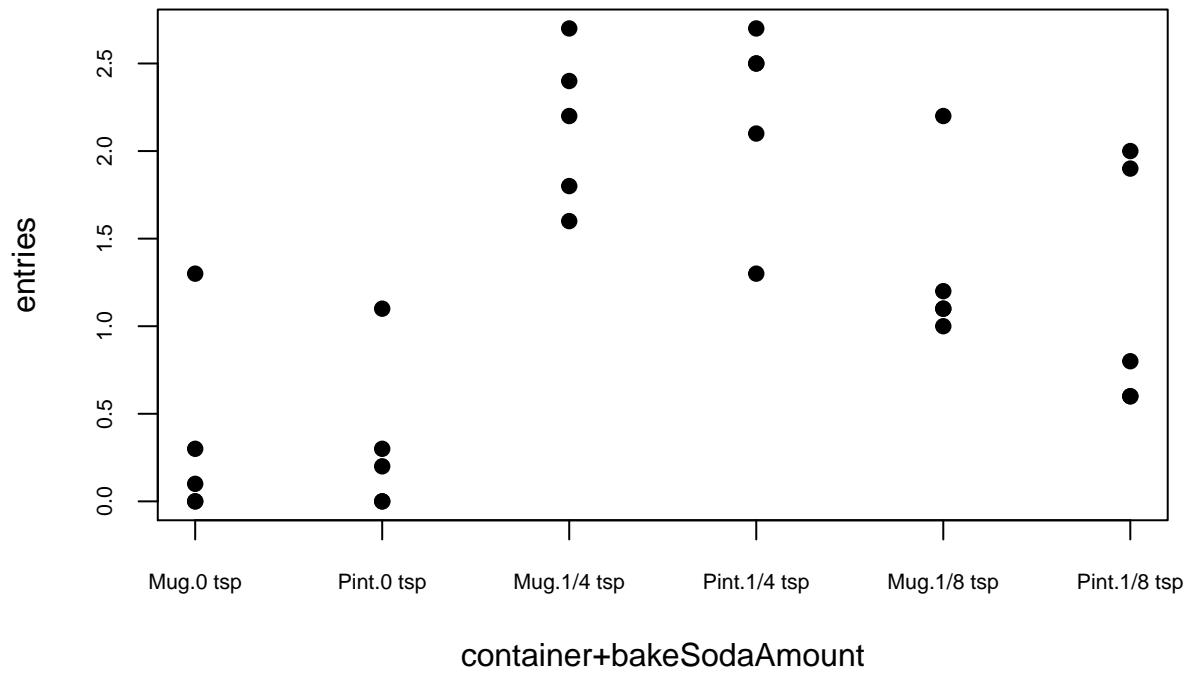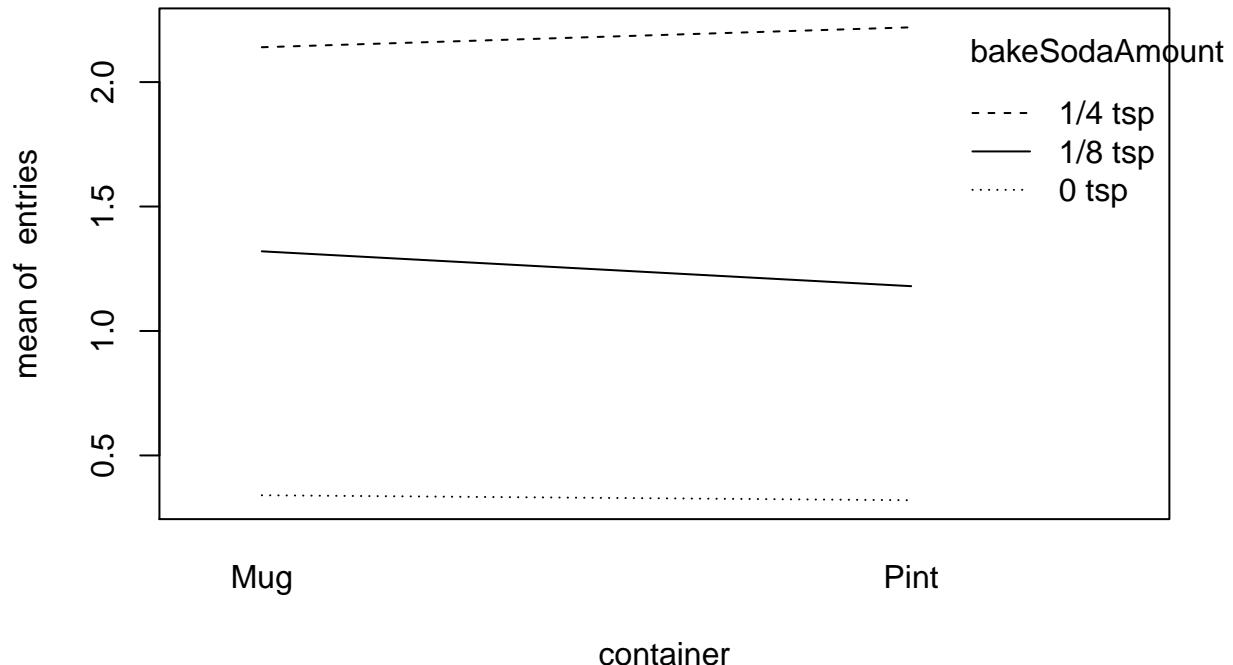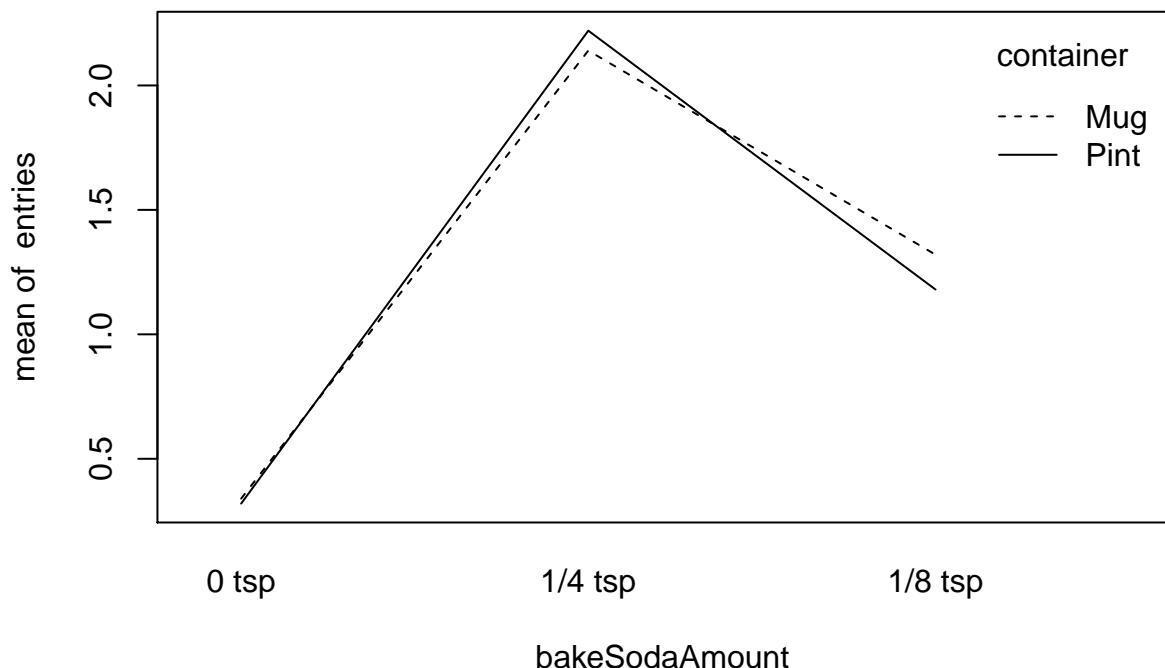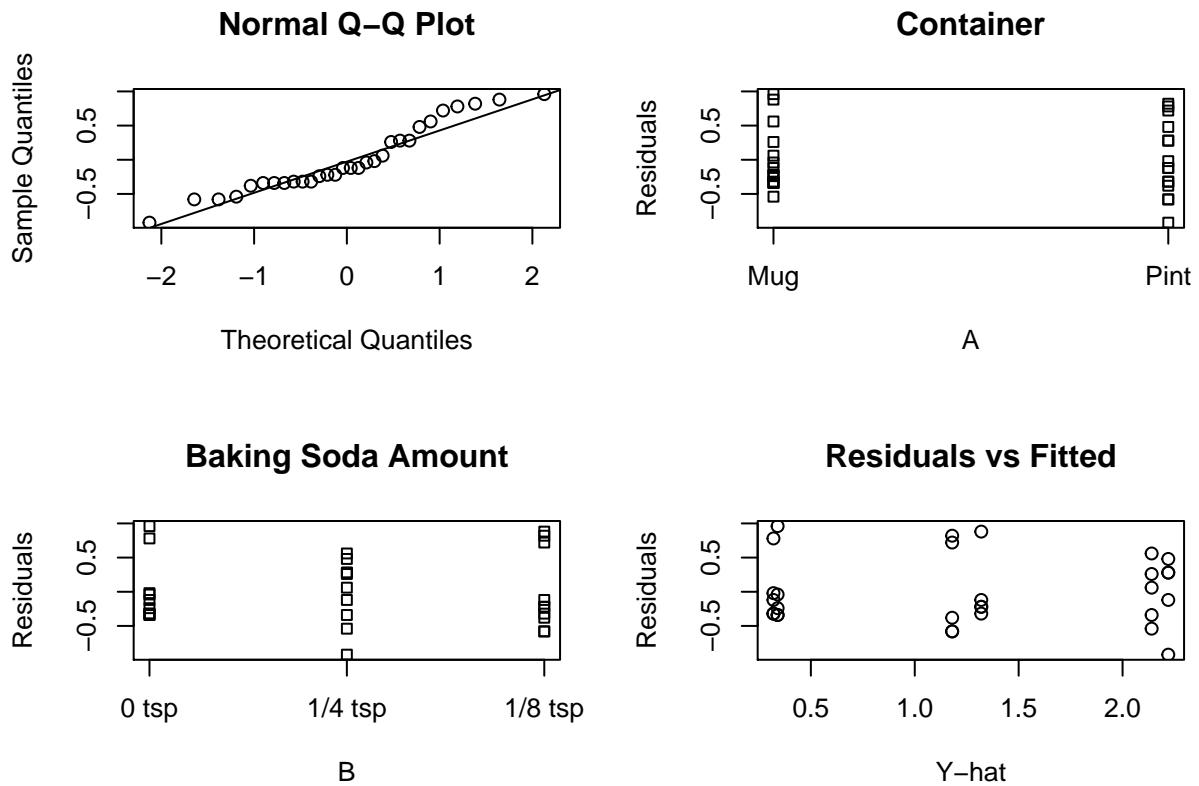
twoway <- aov(entries~bakeSodaAmount+container+bakeSodaAmount*container)
summary(twoway)
```

```
##                          Df Sum Sq Mean Sq F value   Pr(>F)
```

```
## bakeSodaAmount          2 17.113   8.556  29.021 3.93e-07 ***
## container               1  0.005   0.005   0.018   0.894
## bakeSodaAmount:container 2  0.061   0.030   0.103   0.903
## Residuals              24  7.076   0.295
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
plot(container, entries, xlab="Container",ylab="Height Difference")
```



```
plot(bakeSodaAmount, entries,xlab="Baking Soda Amount",ylab="Height Difference")
```

```
stripchart(entries~container+bakeSodaAmount,vertical=T,xlab="container+bakeSodaAmount", cex.lab=1, pch=
```


container+bakeSodaAmount

```
#Plotting interaction
interaction.plot(container, bakeSodaAmount, entries)
```



```
interaction.plot(bakeSodaAmount,container,entries)
```

#Diagnostic Plots

```
fits=twoway$fitted
res=twoway$residuals
par(mfrow=c(2,2))
qqnorm(res)
qqline(res)
stripchart(res~container,vertical=T,xlab="A",ylab="Residuals", main="Container")
stripchart(res~bakeSodaAmount,vertical=T,xlab="B",ylab="Residuals", main="Baking Soda Amount")
plot(fits, res, xlab="Y-hat", ylab="Residuals", main="Residuals vs Fitted")
```

Normal Q–Q Plot

Container

Baking Soda Amount

Residuals vs Fitted

```
par(mfrow=c(1,1))
plot.design(entries~container+bakeSodaAmount)
```

Factors