Spot_asymmetry

Following the predictions made for the plasiticity experiments, we would expect **variation at extreme temperatures are expected to be mainly driven by asymmetric variation, FA especially** as this is where developmental noise caused by temperature stress is expressed.

We start by loading the data, including the estimation of the spot residuals, and the libraries we will need for the analyses:

```
spot.data <- read.table(paste('/Users/ceferino_vg/Documents/Drosophila_suzukii/',
                              'Spot_evolution/data/results_plasticity.txt',
                              sep=''),
                        header=T, sep=',')

spot.data$TEMP <- factor(spot.data$TEMP)

head(spot.data)
```

```
##   IND   POP TEMP SIDE    Wing     Spot      Ratio
## 1 L04 PARIS   16    D 1995044 101003.5 0.05068861
## 2 L04 PARIS   16    G 1977244  83436.5 0.04219839
## 3 L06 PARIS   16    D 1959810  86874.5 0.04432802
## 4 L06 PARIS   16    G 1932712  82319.5 0.04259274
## 5 L07 PARIS   16    G 2026222  78718.5 0.03884989
## 6 L09 PARIS   16    D 1892918  75860.0 0.04007569
```

```
library(ggplot2)
library(ggsignif)
library(car)
library(wesanderson)
library(cvequality)

cohens.d <- function(pop1, pop2) {
  d <- (mean(pop1)-mean(pop2))/
    sqrt(((length(pop1)-1)*var(pop1)+(length(pop2)-1)*var(pop2))/(length(pop1)+length(pop2)-2))

  return(d)
}
```

We first create a matrix with the just the complete individuals of the dataset and then we add the second measure of the whole dataset:

```
non.sym <- c(0)

for (i in 1:length(spot.data$IND)) {

if (length(intersect(intersect(
    which(as.character(spot.data$IND[i]) == as.character(spot.data$IND[-i])),
    which(spot.data$TEMP[i] == spot.data$TEMP[-i])
), which(spot.data$POP[i] == spot.data$POP[-i]))) == 0) {

  non.sym <- c(non.sym,i)
  }

}
```

```r
spot.sym <- spot.data[-non.sym,]

spot.ind <- aov(Spot ~ Wing, data = spot.sym)

spot.sym$Res <- spot.ind$residuals

error <- read.table(paste("/Users/ceferino_vg/Documents/Drosophila_suzukii/",
                          "Spot_evolution/data/errors.txt",
                          sep = ""
), header = T, sep = ",")

error$Res <- aov(Spot ~ Wing, data = error)$residuals

spot.sym.error <- rbind(spot.sym, error)
```

We create the same categories to run the analyses:

```r
Paris_idx <- which(spot.sym.error$POP=='PARIS')
Sappo_idx <- which(spot.sym.error$POP=='SAPPORO')
Sokol_idx <- which(spot.sym.error$POP=='SOKOL')
temp16_idx <- which(spot.sym.error$TEMP==16)
temp22_idx <- which(spot.sym.error$TEMP==22)
temp28_idx <- which(spot.sym.error$TEMP==28)

Paris16 <- intersect(Paris_idx, temp16_idx)
Paris22 <- intersect(Paris_idx, temp22_idx)
Paris28 <- intersect(Paris_idx, temp28_idx)
Sokol16 <- intersect(Sokol_idx, temp16_idx)
Sokol22 <- intersect(Sokol_idx, temp22_idx)
Sokol28 <- intersect(Sokol_idx, temp28_idx)
Sapporo16 <- intersect(Sappo_idx, temp16_idx)
Sapporo22 <- intersect(Sappo_idx, temp22_idx)
Sapporo28 <- intersect(Sappo_idx, temp28_idx)

Pops <- list(Paris16, Paris22, Paris28, Sapporo16, Sapporo22, Sapporo28,
             Sokol16, Sokol22, Sokol28)
```

And here we go! First we test for FA in all nine different populations, storing the mean squares to manually estimate the significance of DA and individual variation in future analyses. We report the ratio between the Mean Sq of the IND:SIDE interaction and the Mean Sq of the Residuals and the p-value and effect size of the DA estimation. We also include which of the two wings has the largest spot size:

```r
combinations <- matrix(c(rep(5:8,9), rep(1:9, each=4)),ncol=2)

for (i in 1:36) {

Pop <- spot.sym.error[Pops[[combinations[i,2]]],]

FA <- summary(aov(Pop[,combinations[i,1]] ~ IND*SIDE, data = Pop))

DA <- 1 - pf((FA[[1]]['Mean Sq'][2,]/FA[[1]]['Mean Sq'][3,]),1,FA[[1]]['Df'][3,])

cat(as.character(Pop[1,2]),' ', as.character(Pop[1,3]) , ' ', 'FA results for',
    colnames(Pop)[combinations[i,1]], "\n")
```

```r
cat('Error (ratio) = ', FA[[1]]['Mean Sq'][3,]/FA[[1]]['Mean Sq'][4,], "\n")

cat(as.character(Pop[1,2]),' ', as.character(Pop[1,3]) , ' ', 'DA results for',
    colnames(Pop)[combinations[i,1]], "\n")
cat('F value = ', FA[[1]]['Mean Sq'][2,]/FA[[1]]['Mean Sq'][3,], '; df2 = ',
    FA[[1]]['Df'][3,], '; p-val =', DA, "\n")

if (DA < 0.05) {
  meanDA <- aggregate(Spot ~ SIDE, data=Pop, FUN = mean)
  side_DA <- as.character(meanDA$SIDE[which(meanDA$Spot==max(meanDA$Spot))])
  cat('The larger spot size is in the ',side_DA, ' wing.', "\n")
}

}
```

```
## PARIS   16   FA results for Wing
## Error (ratio) =  27.15904
## PARIS   16   DA results for Wing
## F value =  0.8044544 ; df2 =  6 ; p-val = 0.404314
## PARIS   16   FA results for Spot
## Error (ratio) =  5.984192
## PARIS   16   DA results for Spot
## F value =  1.947844 ; df2 =  6 ; p-val = 0.2122823
## PARIS   16   FA results for Ratio
## Error (ratio) =  6.205058
## PARIS   16   DA results for Ratio
## F value =  1.971083 ; df2 =  6 ; p-val = 0.2099192
## PARIS   16   FA results for Res
## Error (ratio) =  6.582908
## PARIS   16   DA results for Res
## F value =  2.160808 ; df2 =  6 ; p-val = 0.1919674
## PARIS   22   FA results for Wing
## Error (ratio) =  65.06422
## PARIS   22   DA results for Wing
## F value =  1.442039 ; df2 =  11 ; p-val = 0.2550298
## PARIS   22   FA results for Spot
## Error (ratio) =  12.67938
## PARIS   22   DA results for Spot
## F value =  17.84582 ; df2 =  11 ; p-val = 0.001425709
## The larger spot size is in the  D  wing.
## PARIS   22   FA results for Ratio
## Error (ratio) =  13.51184
## PARIS   22   DA results for Ratio
## F value =  12.29544 ; df2 =  11 ; p-val = 0.004913887
## The larger spot size is in the  D  wing.
## PARIS   22   FA results for Res
## Error (ratio) =  14.71576
## PARIS   22   DA results for Res
## F value =  11.84046 ; df2 =  11 ; p-val = 0.005514956
## The larger spot size is in the  D  wing.
## PARIS   28   FA results for Wing
## Error (ratio) =  25.72928
## PARIS   28   DA results for Wing
## F value =  1.667539 ; df2 =  12 ; p-val = 0.2209091
```

```
## PARIS   28   FA results for Spot
## Error (ratio) =  198.9337
## PARIS   28   DA results for Spot
## F value =  6.155342 ; df2 =  12 ; p-val = 0.02890526
## The larger spot size is in the  D  wing.
## PARIS   28   FA results for Ratio
## Error (ratio) =  192.8433
## PARIS   28   DA results for Ratio
## F value =  6.004318 ; df2 =  12 ; p-val = 0.03057244
## The larger spot size is in the  D  wing.
## PARIS   28   FA results for Res
## Error (ratio) =  178.7393
## PARIS   28   DA results for Res
## F value =  5.733005 ; df2 =  12 ; p-val = 0.03386451
## The larger spot size is in the  D  wing.
## SAPPORO   16   FA results for Wing
## Error (ratio) =  10.4987
## SAPPORO   16   DA results for Wing
## F value =  1.631945 ; df2 =  11 ; p-val = 0.2277376
## SAPPORO   16   FA results for Spot
## Error (ratio) =  7.27965
## SAPPORO   16   DA results for Spot
## F value =  25.44203 ; df2 =  11 ; p-val = 0.0003755921
## The larger spot size is in the  D  wing.
## SAPPORO   16   FA results for Ratio
## Error (ratio) =  8.579777
## SAPPORO   16   DA results for Ratio
## F value =  19.74721 ; df2 =  11 ; p-val = 0.0009888071
## The larger spot size is in the  D  wing.
## SAPPORO   16   FA results for Res
## Error (ratio) =  7.842425
## SAPPORO   16   DA results for Res
## F value =  20.13967 ; df2 =  11 ; p-val = 0.0009196161
## The larger spot size is in the  D  wing.
## SAPPORO   22   FA results for Wing
## Error (ratio) =  15.60197
## SAPPORO   22   DA results for Wing
## F value =  0.4732123 ; df2 =  11 ; p-val = 0.5057601
## SAPPORO   22   FA results for Spot
## Error (ratio) =  110.5867
## SAPPORO   22   DA results for Spot
## F value =  0.1132701 ; df2 =  11 ; p-val = 0.7427846
## SAPPORO   22   FA results for Ratio
## Error (ratio) =  108.5214
## SAPPORO   22   DA results for Ratio
## F value =  0.04079544 ; df2 =  11 ; p-val = 0.8436202
## SAPPORO   22   FA results for Res
## Error (ratio) =  122.995
## SAPPORO   22   DA results for Res
## F value =  0.0777248 ; df2 =  11 ; p-val = 0.7855762
## SAPPORO   28   FA results for Wing
## Error (ratio) =  18.01684
## SAPPORO   28   DA results for Wing
## F value =  0.4517414 ; df2 =  14 ; p-val = 0.5124493
```

```
## SAPPORO   28   FA results for Spot
## Error (ratio) =  26.39958
## SAPPORO   28   DA results for Spot
## F value =  2.996871 ; df2 =  14 ; p-val = 0.1053932
## SAPPORO   28   FA results for Ratio
## Error (ratio) =  32.21979
## SAPPORO   28   DA results for Ratio
## F value =  2.388111 ; df2 =  14 ; p-val = 0.1445616
## SAPPORO   28   FA results for Res
## Error (ratio) =  35.23728
## SAPPORO   28   DA results for Res
## F value =  2.46008 ; df2 =  14 ; p-val = 0.1390923
## SOKOL   16   FA results for Wing
## Error (ratio) =  71.06317
## SOKOL   16   DA results for Wing
## F value =  0.9397218 ; df2 =  9 ; p-val = 0.3576777
## SOKOL   16   FA results for Spot
## Error (ratio) =  8.596647
## SOKOL   16   DA results for Spot
## F value =  4.441974 ; df2 =  9 ; p-val = 0.06432001
## SOKOL   16   FA results for Ratio
## Error (ratio) =  8.592499
## SOKOL   16   DA results for Ratio
## F value =  3.980105 ; df2 =  9 ; p-val = 0.07716983
## SOKOL   16   FA results for Res
## Error (ratio) =  9.037187
## SOKOL   16   DA results for Res
## F value =  3.713459 ; df2 =  9 ; p-val = 0.08608085
## SOKOL   22   FA results for Wing
## Error (ratio) =  31.02616
## SOKOL   22   DA results for Wing
## F value =  0.8261475 ; df2 =  10 ; p-val = 0.3847715
## SOKOL   22   FA results for Spot
## Error (ratio) =  21.51362
## SOKOL   22   DA results for Spot
## F value =  8.298962 ; df2 =  10 ; p-val = 0.0163633
## The larger spot size is in the  D  wing.
## SOKOL   22   FA results for Ratio
## Error (ratio) =  24.55957
## SOKOL   22   DA results for Ratio
## F value =  9.559751 ; df2 =  10 ; p-val = 0.01140728
## The larger spot size is in the  D  wing.
## SOKOL   22   FA results for Res
## Error (ratio) =  23.99074
## SOKOL   22   DA results for Res
## F value =  9.111226 ; df2 =  10 ; p-val = 0.01292897
## The larger spot size is in the  D  wing.
## SOKOL   28   FA results for Wing
## Error (ratio) =  1.816481
## SOKOL   28   DA results for Wing
## F value =  3.339042 ; df2 =  13 ; p-val = 0.09069199
## SOKOL   28   FA results for Spot
## Error (ratio) =  70.02448
## SOKOL   28   DA results for Spot
```

```
## F value =  9.68205 ; df2 =  13 ; p-val = 0.008260259
## The larger spot size is in the  D  wing.
## SOKOL   28   FA results for Ratio
## Error (ratio) =  64.45344
## SOKOL   28   DA results for Ratio
## F value =  10.26345 ; df2 =  13 ; p-val = 0.006918648
## The larger spot size is in the  D  wing.
## SOKOL   28   FA results for Res
## Error (ratio) =  62.54225
## SOKOL   28   DA results for Res
## F value =  9.999089 ; df2 =  13 ; p-val = 0.007494505
## The larger spot size is in the  D  wing.
```

We then decompose our data into a symmetric component (the individual average between wings) and the asymmetric component (the individual differences between wings). Computationally, it is easier to estimate the latter if we first build the matrix for the symmetric component, so we do that:

```
Sym.comp <- aggregate(Ratio ~ IND + TEMP + POP,
  data = spot.sym, FUN = mean
)

Sym.comp$Spot <- aggregate(Spot ~ IND + TEMP + POP,
  data = spot.sym, FUN = mean
)[, 4]

Sym.comp$Wing <- aggregate(Wing ~ IND + TEMP + POP,
  data = spot.sym, FUN = mean
)[, 4]

Sym.comp$Res <- aggregate(Res ~ IND + TEMP + POP,
  data = spot.sym, FUN = mean
)[, 4]
```

As we have build a matrix where each row is an individual, we use it as a 'model' matrix for the asymmetric component matrix. Then, for each individual (for each name within the first column) we find the position of its two wings in the raw data, we identify right and left wings and then we estimate the asymmetric component as the difference of the right wing minus the left wing. Finally, we discard the NAs (those individuals that have just one wing within the raw dataset):

```
Asym.comp <- Sym.comp

for (i in 1:nrow(Sym.comp)) {
  indexes <- intersect(intersect(
    which(spot.sym$IND == Sym.comp[i, 1]),
    which(spot.sym$TEMP == Sym.comp[i, 2])
  ), which(spot.sym$POP == Sym.comp[i, 3]))

  if (spot.sym$SIDE[indexes[1]] == "D") {
    ind_droite <- indexes[1]
    ind_gauche <- indexes[2]
  } else {
    ind_gauche <- indexes[1]
    ind_droite <- indexes[2]
  }

  Asym.comp[i, 4] <- spot.sym$Ratio[ind_droite] - spot.sym$Ratio[ind_gauche]
```

```r
  Asym.comp[i, 5] <- spot.sym$Spot[ind_droite] - spot.sym$Spot[ind_gauche]
  Asym.comp[i, 6] <- spot.sym$Wing[ind_droite] - spot.sym$Wing[ind_gauche]
  Asym.comp[i, 7] <- spot.sym$Res[ind_droite] - spot.sym$Res[ind_gauche]
}
```

```r
ParisAsym_idx <- which(Asym.comp$POP=='PARIS')
SappoAsym_idx <- which(Asym.comp$POP=='SAPPORO')
SokolAsym_idx <- which(Asym.comp$POP=='SOKOL')
temp16Asym_idx <- which(Asym.comp$TEMP==16)
temp22Asym_idx <- which(Asym.comp$TEMP==22)
temp28Asym_idx <- which(Asym.comp$TEMP==28)
```

Now, we can start the analyses on the asymmetric component. We start by looking at whether there is a systematic effect on DA:

```r
summary(aov(Spot ~ TEMP*POP, data = Asym.comp))
```

```
##             Df    Sum Sq   Mean Sq F value Pr(>F)
## TEMP         2 2.383e+08 119173849   1.476  0.234
## POP          2 6.494e+08 324701194   4.022  0.021 *
## TEMP:POP     4 2.017e+08  50425074   0.625  0.646
## Residuals   97 7.830e+09  80724332
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
cohens.d(Asym.comp$Spot[ParisAsym_idx],Asym.comp$Spot[SappoAsym_idx])
```

```
## [1] 0.6321301
```

```r
cohens.d(Asym.comp$Spot[ParisAsym_idx],Asym.comp$Spot[SokolAsym_idx])
```

```
## [1] 0.2406642
```

```r
cohens.d(Asym.comp$Spot[SokolAsym_idx],Asym.comp$Spot[SappoAsym_idx])
```

```
## [1] 0.4667466
```

```r
summary(aov(Wing ~ TEMP*POP, data = Asym.comp))
```

```
##             Df    Sum Sq   Mean Sq F value Pr(>F)
## TEMP         2 5.356e+08 267797599   0.563  0.571
## POP          2 6.894e+08 344688498   0.725  0.487
## TEMP:POP     4 3.776e+09 943919656   1.985  0.103
## Residuals   97 4.612e+10 475459629
```

```r
summary(aov(Ratio ~ TEMP*POP, data = Asym.comp))
```

```
##             Df   Sum Sq   Mean Sq F value Pr(>F)
## TEMP         2 0.000313 1.564e-04   3.323 0.0402 *
## POP          2 0.000345 1.723e-04   3.661 0.0293 *
## TEMP:POP     4 0.000131 3.281e-05   0.697 0.5957
## Residuals   97 0.004565 4.706e-05
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(lm(Ratio ~ TEMP, data = Asym.comp))$r.squared
```

```
## [1] 0.05842831
```

```r
cohens.d(Asym.comp$Ratio[ParisAsym_idx],Asym.comp$Ratio[SappoAsym_idx])
```

```
## [1] 0.597357
```

```r
cohens.d(Asym.comp$Ratio[ParisAsym_idx],Asym.comp$Ratio[SokolAsym_idx])
```

```
## [1] 0.2145836
```

```r
cohens.d(Asym.comp$Ratio[SokolAsym_idx],Asym.comp$Ratio[SappoAsym_idx])
```

```
## [1] 0.4936126
```

```r
summary(aov(Ratio ~ TEMP:POP, data = Asym.comp))
```

```
##             Df   Sum Sq   Mean Sq F value Pr(>F)  
## TEMP:POP     8 0.000789 9.858e-05   2.095 0.0434 *
## Residuals   97 0.004565 4.706e-05                 
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(lm(Ratio ~ TEMP:POP, data = Asym.comp))$r.squared
```

```
## [1] 0.1473159
```

```r
summary(aov(Res ~ TEMP*POP, data = Asym.comp))
```

```
##             Df    Sum Sq   Mean Sq F value Pr(>F)  
## TEMP         2 2.280e+08 114021818   1.369 0.2592  
## POP          2 6.364e+08 318177144   3.821 0.0253 *
## TEMP:POP     4 1.730e+08  43252736   0.519 0.7217  
## Residuals   97 8.078e+09  83275158                 
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(lm(Res ~ TEMP:POP, data = Asym.comp))$r.squared
```

```
## [1] 0.1138121
```

```r
cohens.d(Asym.comp$Res[ParisAsym_idx],Asym.comp$Res[SappoAsym_idx])
```

```
## [1] 0.6139757
```

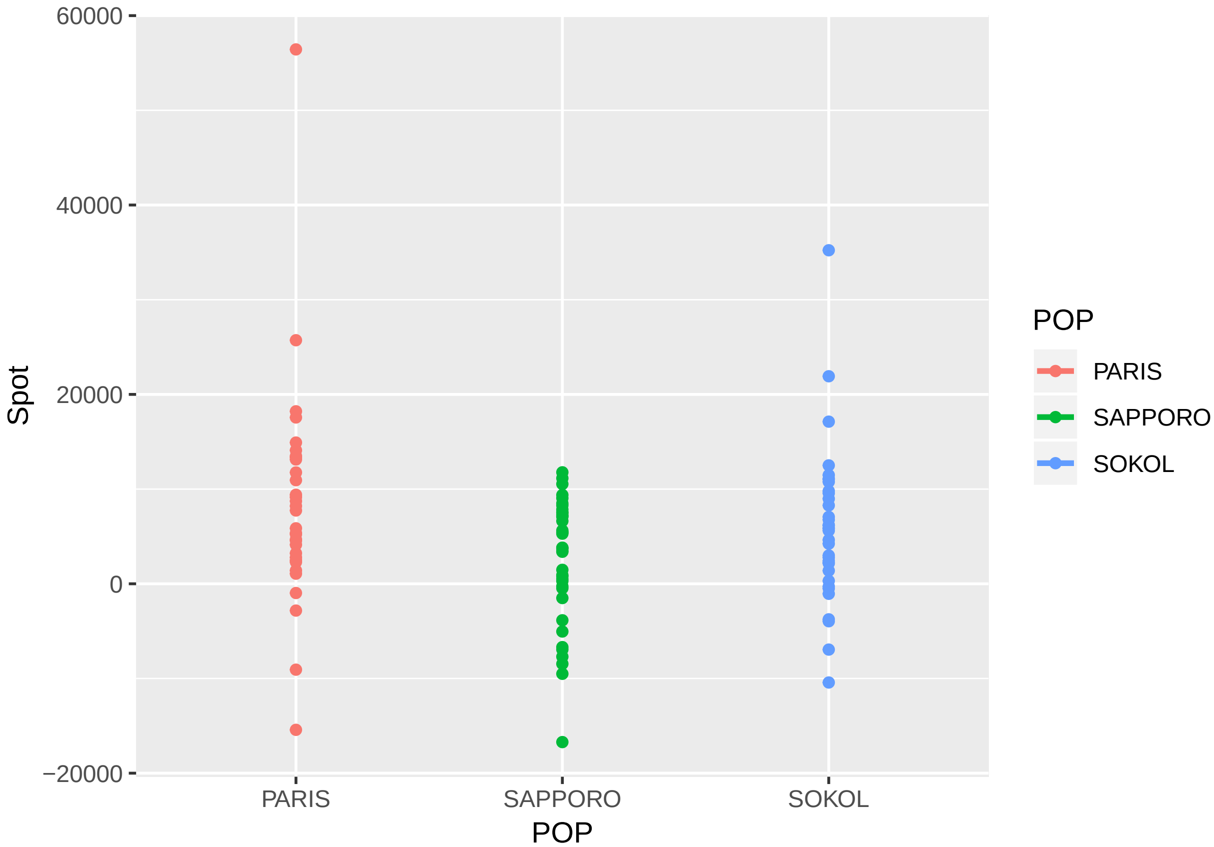
```r
cohens.d(Asym.comp$Res[ParisAsym_idx],Asym.comp$Res[SokolAsym_idx])
```

```
## [1] 0.2079479
```

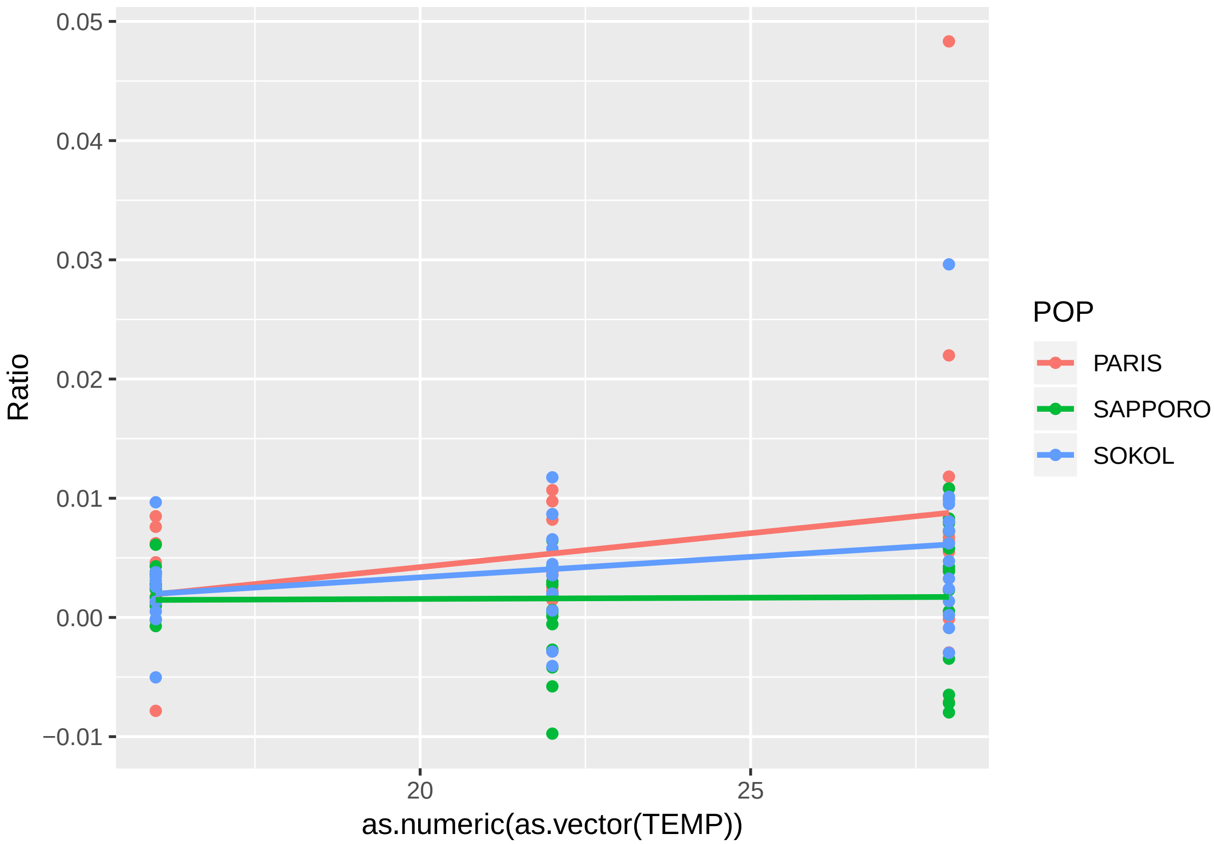
```r
cohens.d(Asym.comp$Res[SokolAsym_idx],Asym.comp$Res[SappoAsym_idx])
```

```
## [1] 0.4935809
```

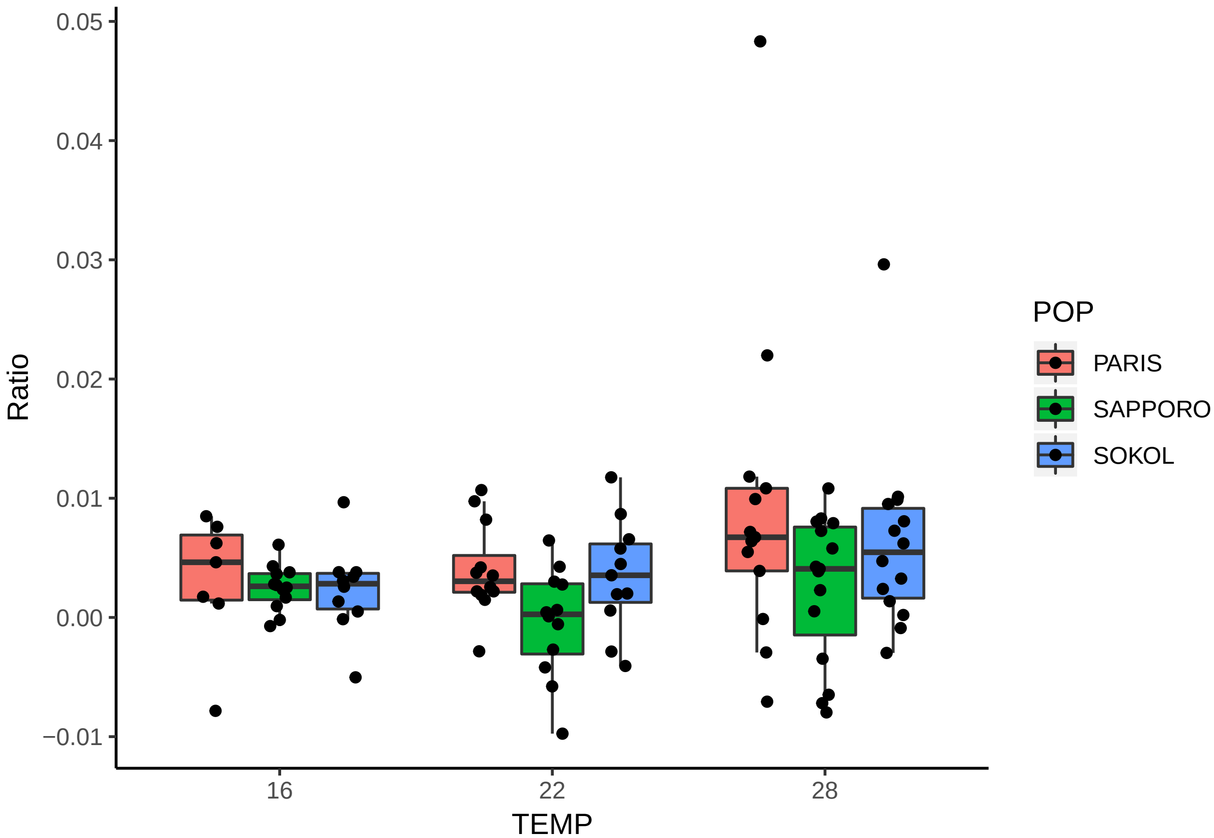
```r
ggplot(data=Asym.comp,
       aes(x = POP, y = Spot, color = POP)) +
    geom_point() +
    geom_smooth(method = 'lm', se = FALSE)
```



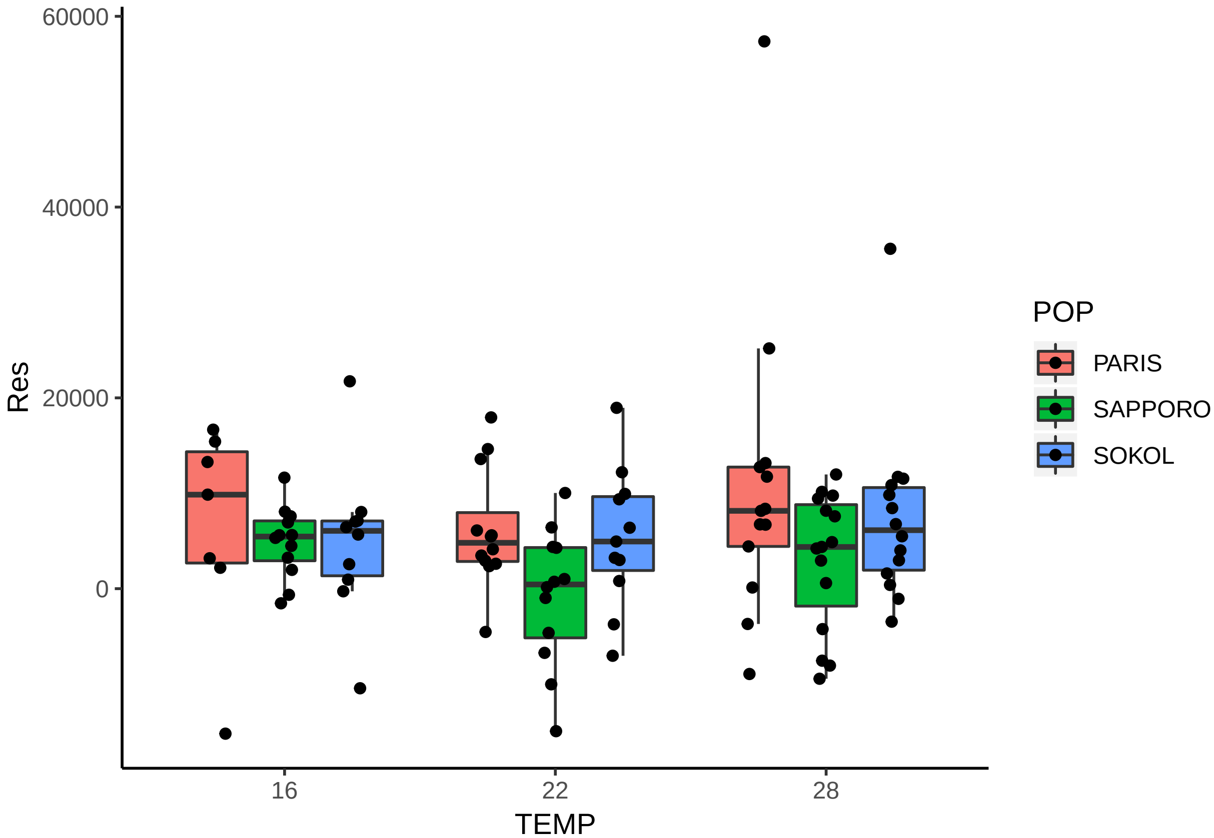

```r
ggplot(data=Asym.comp,
       aes(x = as.numeric(as.vector(TEMP)), y = Ratio, color = POP)) +
    geom_point() +
    geom_smooth(method = 'lm', se = FALSE)
```




```r
ggplot(data = Asym.comp,
       aes(x = TEMP, y = Ratio, fill = POP)) +
    geom_boxplot(outlier.shape = NA) +
    geom_jitter(position = position_jitterdodge(jitter.width = 0.2)) +
    theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
          panel.background = element_blank(), axis.line = element_line(colour = "black"))
```




```
ggplot(data = Asym.comp,
       aes(x = TEMP, y = Res, fill = POP)) +
    geom_boxplot(outlier.shape = NA) +
    geom_jitter(position = position_jitterdodge(jitter.width = 0.2)) +
    theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
          panel.background = element_blank(), axis.line = element_line(colour = "black"))
```



Now we compare the effect of temperature for invasive and native populations:

```
Sappotemp <- summary(lm(Ratio ~ TEMP, data = Asym.comp[SappoAsym_idx,]))$coefficients
Sokoltemp <- summary(lm(Ratio ~ TEMP, data = Asym.comp[SokolAsym_idx,]))$coefficients
Paristemp <- summary(lm(Ratio ~ TEMP, data = Asym.comp[ParisAsym_idx,]))$coefficients

db <- (Sokoltemp[2,1]-Sappotemp[2,1])
sd <- sqrt(Sokoltemp[2,2]^2+Sappotemp[2,2]^2)
df <- (lm(Ratio ~ TEMP, data = Asym.comp[SappoAsym_idx,])$df.residual+lm(Ratio ~ TEMP,
                                        data = Asym.comp[SokolAsym_idx,])$df.residual)
td <- db/sd
td
```

```
## [1] 1.267522
```

```
df
```

```
## [1] 68
```

```
2*pt(-abs(td), df)
```

```
## [1] 0.209292
```

```
db <- (Paristemp[2,1]-Sappotemp[2,1])
sd <- sqrt(Paristemp[2,2]^2+Sappotemp[2,2]^2)
df <- (lm(Ratio ~ TEMP, data = Asym.comp[SappoAsym_idx,])$df.residual+lm(Ratio ~ TEMP,
                                        data = Asym.comp[ParisAsym_idx,])$df.residual)
td <- db/sd
td
```

```
## [1] 0.7651761
```

```r
df
```

```
## [1] 65
```

```r
2*pt(-abs(td), df)
```

```
## [1] 0.4469361
```

```r
db <- (Paristemp[2,1]-Sokoltemp[2,1])
sd <- sqrt(Paristemp[2,2]^2+Sokoltemp[2,2]^2)
df <- (lm(Ratio ~ TEMP, data = Asym.comp[SokolAsym_idx,])$df.residual+lm(Ratio ~ TEMP,
                                        data = Asym.comp[ParisAsym_idx,])$df.residual)
td <- db/sd
td
```

```
## [1] -0.07134414
```

```r
df
```

```
## [1] 61
```

```r
2*pt(-abs(td), df)
```

```
## [1] 0.9433573
```

To study the effect of temperature and population on fluctuating asymmetry we use Levene tests. We follow the same procedure than for the variation tests than for the symmetric component of variation:

```r
leveneTest(Asym.comp$Wing, group = Asym.comp$TEMP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value  Pr(>F)
## group   2  2.4491 0.09138 .
##       103
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Spot, group = Asym.comp$TEMP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   2   1.166 0.3157
##       103
```

```r
leveneTest(Asym.comp$Ratio, group = Asym.comp$TEMP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value  Pr(>F)
## group   2  4.5289 0.01303 *
##       103
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Res, group = Asym.comp$TEMP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   2  0.9736 0.3812
##       103
```

We can then look at what temperature is different in the wing FA:

```r
leveneTest(Asym.comp$Wing[-temp16Asym_idx], group = Asym.comp$TEMP[-temp16Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)  
## group  1  3.9876 0.04947 *
##       75                  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Wing[-temp22Asym_idx], group = Asym.comp$TEMP[-temp22Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)  
## group  1  5.8114 0.01859 *
##       69                  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Wing[-temp28Asym_idx], group = Asym.comp$TEMP[-temp28Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0165 0.8983
##       62
```

```r
sd(Asym.comp$Wing[temp16Asym_idx])
```

```
## [1] 23468.35
```

```r
sd(Asym.comp$Wing[temp22Asym_idx])
```

```
## [1] 29213.05
```

```r
sd(Asym.comp$Wing[temp28Asym_idx])
```

```
## [1] 12245.05
```

Overall, FA is reduced for the wing at 28?.

We can then look at what temperature is different in the ratio FA:

```r
leveneTest(Asym.comp$Ratio[-temp16Asym_idx], group = Asym.comp$TEMP[-temp16Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)  
## group  1  3.5426 0.06369 .
##       75                  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Ratio[-temp22Asym_idx], group = Asym.comp$TEMP[-temp22Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)  
## group  1  6.0699 0.01625 *
##       69                  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Ratio[-temp28Asym_idx], group = Asym.comp$TEMP[-temp28Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  2.0689 0.1554
##       62
```

```r
sd(Asym.comp$Ratio[temp16Asym_idx])
```

```
## [1] 0.003557128
```

```r
sd(Asym.comp$Ratio[temp22Asym_idx])
```

```
## [1] 0.004699225
```

```r
sd(Asym.comp$Ratio[temp28Asym_idx])
```

```
## [1] 0.009797143
```

Overall, FA is increased for the ratio at 28?, probably as a consequence of the decreased variation in wing size.

Table 1: Populations significantly different and the sense of their difference

	16?	22?	28?
Spot	ND	ND	ND
Wing	+	+	-
Ratio	-	-	+
Residual	ND	ND	ND

Populations within and among temperatures

Overall we did not find significant differences in FA among geographic populations:

```r
leveneTest(Asym.comp$Wing, group = Asym.comp$POP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   2  0.9981 0.3721
##       103
```

```r
leveneTest(Asym.comp$Spot, group = Asym.comp$POP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   2  1.1761 0.3126
##       103
```

```r
leveneTest(Asym.comp$Ratio, group = Asym.comp$POP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   2  1.1568 0.3185
##       103
```

```r
leveneTest(Asym.comp$Res, group = Asym.comp$POP)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
```

```
##        Df F value Pr(>F)
## group   2  1.2464 0.2918
##       103
```

Within temperatures, just the Wing size at 28? presents differences among geographic populations, where the Sokol populations showed a decreased FA:

```r
leveneTest(Asym.comp$Wing[temp28Asym_idx], group = Asym.comp$POP[temp28Asym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  2  4.0177 0.02591 *
##       39
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Wing[c(intersect(temp28Asym_idx,ParisAsym_idx),
                            intersect(temp28Asym_idx,SappoAsym_idx))],
           group = Asym.comp$POP[c(intersect(temp28Asym_idx,ParisAsym_idx),
                                   intersect(temp28Asym_idx,SappoAsym_idx))])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.1816 0.6735
##       26
```

```r
sd(Asym.comp$Wing[intersect(temp28Asym_idx,SokolAsym_idx)])
```

```
## [1] 6192.193
```

```r
sd(Asym.comp$Wing[intersect(temp28Asym_idx,ParisAsym_idx)])
```

```
## [1] 15073.22
```

```r
sd(Asym.comp$Wing[intersect(temp28Asym_idx,SappoAsym_idx)])
```

```
## [1] 12949.33
```

Table 2: 28? temperature

	Sapporo	Paris	Sokol
Spot	ND	ND	ND
Wing	+	+	-
Ratio	ND	ND	ND
Residual	ND	ND	ND

Within populations, just Sapporo shows differences in FA: for the relative spot size FA is reduced for the 16?.

```r
leveneTest(Asym.comp$Ratio[SappoAsym_idx], group = Asym.comp$TEMP[SappoAsym_idx])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  2  3.8545 0.03042 *
##       36
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Ratio[c(intersect(temp28Asym_idx,SappoAsym_idx),
                             intersect(temp22Asym_idx,SappoAsym_idx))],
           group = Asym.comp$TEMP[c(intersect(temp28Asym_idx,SappoAsym_idx),
                                    intersect(temp22Asym_idx,SappoAsym_idx))])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.9307 0.3439
##       25
```

```r
leveneTest(Asym.comp$Ratio[c(intersect(temp22Asym_idx,SappoAsym_idx),
                             intersect(temp16Asym_idx,SappoAsym_idx))],
           group = Asym.comp$TEMP[c(intersect(temp22Asym_idx,SappoAsym_idx),
                                    intersect(temp16Asym_idx,SappoAsym_idx))])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  1  4.4545 0.04641 *
##       22
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
leveneTest(Asym.comp$Ratio[c(intersect(temp28Asym_idx,SappoAsym_idx),
                             intersect(temp16Asym_idx,SappoAsym_idx))],
           group = Asym.comp$TEMP[c(intersect(temp28Asym_idx,SappoAsym_idx),
                                    intersect(temp16Asym_idx,SappoAsym_idx))])
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  1  7.4777 0.01131 *
##       25
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
sd(Asym.comp$Ratio[intersect(temp16Asym_idx,SappoAsym_idx)])
```

```
## [1] 0.00190968
```

```r
sd(Asym.comp$Ratio[intersect(temp22Asym_idx,SappoAsym_idx)])
```

```
## [1] 0.004555277
```

```r
sd(Asym.comp$Ratio[intersect(temp28Asym_idx,SappoAsym_idx)])
```

```
## [1] 0.006138387
```

Table 3: Sapporo population

	16?	22?	28?
Spot	ND	ND	ND
Wing	ND	ND	ND
Ratio	-	+	+
Residual	ND	ND	ND