anova

ddxbugs

2024-02-26

# install.packages("agricolae")  
# install.packages("multcomp")  
# install.packages("DescTools")  
# install.packages("pairwiseCI")  
library(emmeans)  
library(agricolae)  
library(ggplot2)  
library(multcomp)

## Loading required package: mvtnorm

## Loading required package: survival

## Loading required package: TH.data

## Loading required package: MASS

##   
## Attaching package: 'TH.data'

## The following object is masked from 'package:MASS':  
##   
## geyser

library(onewaytests)  
library(car)

## Loading required package: carData

library(DescTools)

## Registered S3 method overwritten by 'DescTools':  
## method from   
## print.palette wesanderson

##   
## Attaching package: 'DescTools'

## The following object is masked from 'package:car':  
##   
## Recode

library(pairwiseCI)

## Loading required package: MCPAN

## Warning in .recacheSubclasses(def@className, def, env): undefined subclass  
## "ndiMatrix" of class "replValueSp"; definition not updated

## Loading required package: coin

library(tidyverse)

## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──  
## ✔ dplyr 1.1.4 ✔ readr 2.1.4  
## ✔ forcats 1.0.0 ✔ stringr 1.5.0  
## ✔ lubridate 1.9.3 ✔ tibble 3.2.1  
## ✔ purrr 1.0.2 ✔ tidyr 1.3.0

## ── Conflicts ────────────────────────────────────────── tidyverse\_conflicts() ──  
## ✖ dplyr::filter() masks stats::filter()  
## ✖ dplyr::lag() masks stats::lag()  
## ✖ dplyr::recode() masks car::recode()  
## ✖ dplyr::select() masks MASS::select()  
## ✖ purrr::some() masks car::some()  
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors

# Data import and preprocessing

df <- read.csv("handicap.csv")  
  
str(df)

## 'data.frame': 70 obs. of 2 variables:  
## $ Score : num 1.9 2.5 3 3.6 4.1 4.2 4.9 5.1 5.4 5.9 ...  
## $ Handicap: chr "None" "None" "None" "None" ...

df$Handicap <- factor(df$Handicap)  
unique(df$Handicap)

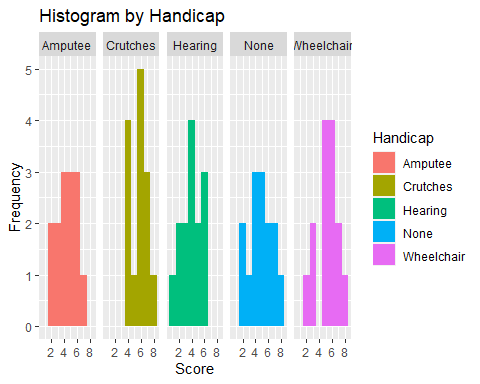
## [1] None Amputee Crutches Hearing Wheelchair  
## Levels: Amputee Crutches Hearing None Wheelchair

# Exploratory Data Analysis

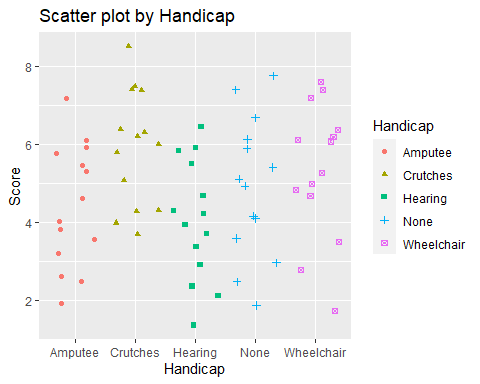
df %>% group\_by(Handicap) %>% summarise(xbar=mean(Score), s=sd(Score), n=n())

## # A tibble: 5 × 4  
## Handicap xbar s n  
## <fct> <dbl> <dbl> <int>  
## 1 Amputee 4.43 1.59 14  
## 2 Crutches 5.92 1.48 14  
## 3 Hearing 4.05 1.53 14  
## 4 None 4.9 1.79 14  
## 5 Wheelchair 5.34 1.75 14

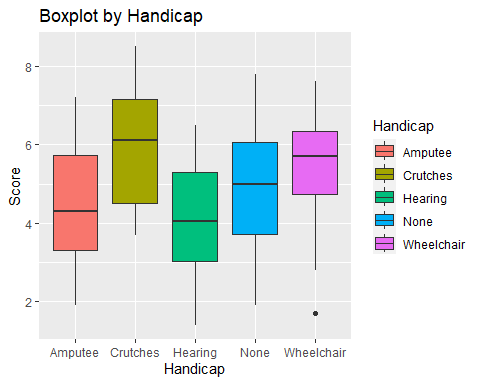
ggplot(df, aes(Score, fill=Handicap)) + geom\_histogram(binwidth=1) + facet\_grid(~Handicap) + labs(x="Score", y="Frequency", title="Histogram by Handicap")



ggplot(df, aes(Handicap, Score, shape=Handicap, color=Handicap)) + geom\_point(position="jitter") + labs(x="Handicap", y="Score", title="Scatter plot by Handicap")



ggplot(df, aes(Handicap, Score, fill=Handicap)) + geom\_boxplot() + labs(x="Handicap", y="Score", title="Boxplot by Handicap")

 # Preliminary analysis of variance

leveneTest(Score~Handicap, data=df)

## Levene's Test for Homogeneity of Variance (center = median)  
## Df F value Pr(>F)  
## group 4 0.1974 0.9389  
## 65

bf.test(Score~Handicap, data=df)

##   
## Brown-Forsythe Test (alpha = 0.05)   
## -------------------------------------------------------------   
## data : Score and Handicap   
##   
## statistic : 2.86158   
## num df : 4   
## denom df : 63.56818   
## p.value : 0.03031777   
##   
## Result : Difference is statistically significant.   
## -------------------------------------------------------------

# Multiple comparisons

fit <- aov(Score~Handicap, data=df)  
summary(fit)

## Df Sum Sq Mean Sq F value Pr(>F)   
## Handicap 4 30.52 7.630 2.862 0.0301 \*  
## Residuals 65 173.32 2.666   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

# Contrasts  
leastsquare <- lsmeans(fit, "Handicap")  
contrasts <- list(constrast <- c(0.5, -0.5, 0.5, 0, -0.5))  
contrast(leastsquare, contrasts, adjust="sidak")

## contrast estimate SE df t.ratio p.value  
## c(0.5, -0.5, 0.5, 0, -0.5) -1.39 0.436 65 -3.192 0.0022

contrast(leastsquare, contrasts)

## contrast estimate SE df t.ratio p.value  
## c(0.5, -0.5, 0.5, 0, -0.5) -1.39 0.436 65 -3.192 0.0022

# Post-hoc ANOVA

df.bon <- LSD.test(fit, 'Handicap', p.adj='bonferroni')  
df.lsd <- LSD.test(fit, 'Handicap', p.adj='none')  
df.scheffe <- scheffe.test(fit, 'Handicap')  
df.tukey <- HSD.test(fit, 'Handicap')  
df.dunnett <- DunnettTest(df$Score, df$Handicap, control='None')  
  
  
df.bon

## $statistics  
## MSerror Df Mean CV t.value MSD  
## 2.666484 65 4.928571 33.13206 2.906015 1.79357  
##   
## $parameters  
## test p.ajusted name.t ntr alpha  
## Fisher-LSD bonferroni Handicap 5 0.05  
##   
## $means  
## Score std r se LCL UCL Min Max Q25 Q50  
## Amputee 4.428571 1.585719 14 0.4364208 3.556979 5.300164 1.9 7.2 3.300 4.30  
## Crutches 5.921429 1.481776 14 0.4364208 5.049836 6.793021 3.7 8.5 4.500 6.10  
## Hearing 4.050000 1.532595 14 0.4364208 3.178407 4.921593 1.4 6.5 3.025 4.05  
## None 4.900000 1.793578 14 0.4364208 4.028407 5.771593 1.9 7.8 3.725 5.00  
## Wheelchair 5.342857 1.748280 14 0.4364208 4.471265 6.214450 1.7 7.6 4.725 5.70  
## Q75  
## Amputee 5.725  
## Crutches 7.150  
## Hearing 5.300  
## None 6.050  
## Wheelchair 6.350  
##   
## $comparison  
## NULL  
##   
## $groups  
## Score groups  
## Crutches 5.921429 a  
## Wheelchair 5.342857 ab  
## None 4.900000 ab  
## Amputee 4.428571 ab  
## Hearing 4.050000 b  
##   
## attr(,"class")  
## [1] "group"

df.lsd

## $statistics  
## MSerror Df Mean CV t.value LSD  
## 2.666484 65 4.928571 33.13206 1.997138 1.232618  
##   
## $parameters  
## test p.ajusted name.t ntr alpha  
## Fisher-LSD none Handicap 5 0.05  
##   
## $means  
## Score std r se LCL UCL Min Max Q25 Q50  
## Amputee 4.428571 1.585719 14 0.4364208 3.556979 5.300164 1.9 7.2 3.300 4.30  
## Crutches 5.921429 1.481776 14 0.4364208 5.049836 6.793021 3.7 8.5 4.500 6.10  
## Hearing 4.050000 1.532595 14 0.4364208 3.178407 4.921593 1.4 6.5 3.025 4.05  
## None 4.900000 1.793578 14 0.4364208 4.028407 5.771593 1.9 7.8 3.725 5.00  
## Wheelchair 5.342857 1.748280 14 0.4364208 4.471265 6.214450 1.7 7.6 4.725 5.70  
## Q75  
## Amputee 5.725  
## Crutches 7.150  
## Hearing 5.300  
## None 6.050  
## Wheelchair 6.350  
##   
## $comparison  
## NULL  
##   
## $groups  
## Score groups  
## Crutches 5.921429 a  
## Wheelchair 5.342857 ab  
## None 4.900000 abc  
## Amputee 4.428571 bc  
## Hearing 4.050000 c  
##   
## attr(,"class")  
## [1] "group"

df.scheffe

## $statistics  
## MSerror Df F Mean CV Scheffe CriticalDifference  
## 2.666484 65 2.51304 4.928571 33.13206 3.170514 1.956817  
##   
## $parameters  
## test name.t ntr alpha  
## Scheffe Handicap 5 0.05  
##   
## $means  
## Score std r se Min Max Q25 Q50 Q75  
## Amputee 4.428571 1.585719 14 0.4364208 1.9 7.2 3.300 4.30 5.725  
## Crutches 5.921429 1.481776 14 0.4364208 3.7 8.5 4.500 6.10 7.150  
## Hearing 4.050000 1.532595 14 0.4364208 1.4 6.5 3.025 4.05 5.300  
## None 4.900000 1.793578 14 0.4364208 1.9 7.8 3.725 5.00 6.050  
## Wheelchair 5.342857 1.748280 14 0.4364208 1.7 7.6 4.725 5.70 6.350  
##   
## $comparison  
## NULL  
##   
## $groups  
## Score groups  
## Crutches 5.921429 a  
## Wheelchair 5.342857 a  
## None 4.900000 a  
## Amputee 4.428571 a  
## Hearing 4.050000 a  
##   
## attr(,"class")  
## [1] "group"

df.tukey

## $statistics  
## MSerror Df Mean CV MSD  
## 2.666484 65 4.928571 33.13206 1.731733  
##   
## $parameters  
## test name.t ntr StudentizedRange alpha  
## Tukey Handicap 5 3.968034 0.05  
##   
## $means  
## Score std r se Min Max Q25 Q50 Q75  
## Amputee 4.428571 1.585719 14 0.4364208 1.9 7.2 3.300 4.30 5.725  
## Crutches 5.921429 1.481776 14 0.4364208 3.7 8.5 4.500 6.10 7.150  
## Hearing 4.050000 1.532595 14 0.4364208 1.4 6.5 3.025 4.05 5.300  
## None 4.900000 1.793578 14 0.4364208 1.9 7.8 3.725 5.00 6.050  
## Wheelchair 5.342857 1.748280 14 0.4364208 1.7 7.6 4.725 5.70 6.350  
##   
## $comparison  
## NULL  
##   
## $groups  
## Score groups  
## Crutches 5.921429 a  
## Wheelchair 5.342857 ab  
## None 4.900000 ab  
## Amputee 4.428571 ab  
## Hearing 4.050000 b  
##   
## attr(,"class")  
## [1] "group"

df.dunnett

##   
## Dunnett's test for comparing several treatments with a control :   
## 95% family-wise confidence level  
##   
## $None  
## diff lwr.ci upr.ci pval   
## Amputee-None -0.4714286 -2.0164427 1.0735855 0.8598   
## Crutches-None 1.0214286 -0.5235855 2.5664427 0.2918   
## Hearing-None -0.8500000 -2.3950141 0.6950141 0.4515   
## Wheelchair-None 0.4428571 -1.1021570 1.9878712 0.8836   
##   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

# Bonferroni  
summary(glht(fit, linfct=mcp(Handicap="Tukey")), test=adjusted(type="bonferroni"))

##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## Crutches - Amputee == 0 1.4929 0.6172 2.419 0.1838   
## Hearing - Amputee == 0 -0.3786 0.6172 -0.613 1.0000   
## None - Amputee == 0 0.4714 0.6172 0.764 1.0000   
## Wheelchair - Amputee == 0 0.9143 0.6172 1.481 1.0000   
## Hearing - Crutches == 0 -1.8714 0.6172 -3.032 0.0349 \*  
## None - Crutches == 0 -1.0214 0.6172 -1.655 1.0000   
## Wheelchair - Crutches == 0 -0.5786 0.6172 -0.937 1.0000   
## None - Hearing == 0 0.8500 0.6172 1.377 1.0000   
## Wheelchair - Hearing == 0 1.2929 0.6172 2.095 0.4010   
## Wheelchair - None == 0 0.4429 0.6172 0.718 1.0000   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- bonferroni method)

pairwiseCI(Score~Handicap, data=df)

##   
## 95 %-confidence intervals   
## Method: Difference of means assuming Normal distribution, allowing unequal variances   
##   
##   
## estimate lower upper  
## Crutches-Amputee 1.4929 0.3003 2.6854  
## Hearing-Amputee -0.3786 -1.5902 0.8330  
## None-Amputee 0.4714 -0.8447 1.7876  
## Wheelchair-Amputee 0.9143 -0.3830 2.2115  
## Hearing-Crutches -1.8714 -3.0426 -0.7002  
## None-Crutches -1.0214 -2.3017 0.2589  
## Wheelchair-Crutches -0.5786 -1.8392 0.6821  
## None-Hearing 0.8500 -0.4476 2.1476  
## Wheelchair-Hearing 1.2929 0.0146 2.5712  
## Wheelchair-None 0.4429 -0.9332 1.8189  
##   
##

pairwise.t.test(df$Score, df$Handicap, p.adjust="bonferroni")

##   
## Pairwise comparisons using t tests with pooled SD   
##   
## data: df$Score and df$Handicap   
##   
## Amputee Crutches Hearing None   
## Crutches 0.184 - - -   
## Hearing 1.000 0.035 - -   
## None 1.000 1.000 1.000 -   
## Wheelchair 1.000 1.000 0.401 1.000  
##   
## P value adjustment method: bonferroni

# LSD  
summary(glht(fit, linfct=mcp(Handicap="Tukey")), test=adjusted(type="none"))

##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## Crutches - Amputee == 0 1.4929 0.6172 2.419 0.01838 \*   
## Hearing - Amputee == 0 -0.3786 0.6172 -0.613 0.54177   
## None - Amputee == 0 0.4714 0.6172 0.764 0.44773   
## Wheelchair - Amputee == 0 0.9143 0.6172 1.481 0.14334   
## Hearing - Crutches == 0 -1.8714 0.6172 -3.032 0.00349 \*\*  
## None - Crutches == 0 -1.0214 0.6172 -1.655 0.10275   
## Wheelchair - Crutches == 0 -0.5786 0.6172 -0.937 0.35201   
## None - Hearing == 0 0.8500 0.6172 1.377 0.17317   
## Wheelchair - Hearing == 0 1.2929 0.6172 2.095 0.04010 \*   
## Wheelchair - None == 0 0.4429 0.6172 0.718 0.47561   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- none method)

confint(glht(fit, linfct=mcp(Handicap="Tukey")))

##   
## Simultaneous Confidence Intervals  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Quantile = 2.8067  
## 95% family-wise confidence level  
##   
##   
## Linear Hypotheses:  
## Estimate lwr upr   
## Crutches - Amputee == 0 1.4929 -0.2394 3.2251  
## Hearing - Amputee == 0 -0.3786 -2.1109 1.3537  
## None - Amputee == 0 0.4714 -1.2609 2.2037  
## Wheelchair - Amputee == 0 0.9143 -0.8180 2.6466  
## Hearing - Crutches == 0 -1.8714 -3.6037 -0.1391  
## None - Crutches == 0 -1.0214 -2.7537 0.7109  
## Wheelchair - Crutches == 0 -0.5786 -2.3109 1.1537  
## None - Hearing == 0 0.8500 -0.8823 2.5823  
## Wheelchair - Hearing == 0 1.2929 -0.4394 3.0251  
## Wheelchair - None == 0 0.4429 -1.2894 2.1751

# Tukey-Kramer  
summary(glht(fit, linfct=mcp(Handicap="Tukey")))

##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## Crutches - Amputee == 0 1.4929 0.6172 2.419 0.1233   
## Hearing - Amputee == 0 -0.3786 0.6172 -0.613 0.9725   
## None - Amputee == 0 0.4714 0.6172 0.764 0.9400   
## Wheelchair - Amputee == 0 0.9143 0.6172 1.481 0.5781   
## Hearing - Crutches == 0 -1.8714 0.6172 -3.032 0.0278 \*  
## None - Crutches == 0 -1.0214 0.6172 -1.655 0.4686   
## Wheelchair - Crutches == 0 -0.5786 0.6172 -0.937 0.8812   
## None - Hearing == 0 0.8500 0.6172 1.377 0.6443   
## Wheelchair - Hearing == 0 1.2929 0.6172 2.095 0.2348   
## Wheelchair - None == 0 0.4429 0.6172 0.718 0.9517   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- single-step method)

confint(glht(fit, linfct=mcp(Handicap="Tukey")))

##   
## Simultaneous Confidence Intervals  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Quantile = 2.8064  
## 95% family-wise confidence level  
##   
##   
## Linear Hypotheses:  
## Estimate lwr upr   
## Crutches - Amputee == 0 1.4929 -0.2392 3.2249  
## Hearing - Amputee == 0 -0.3786 -2.1106 1.3535  
## None - Amputee == 0 0.4714 -1.2606 2.2035  
## Wheelchair - Amputee == 0 0.9143 -0.8178 2.6464  
## Hearing - Crutches == 0 -1.8714 -3.6035 -0.1394  
## None - Crutches == 0 -1.0214 -2.7535 0.7106  
## Wheelchair - Crutches == 0 -0.5786 -2.3106 1.1535  
## None - Hearing == 0 0.8500 -0.8821 2.5821  
## Wheelchair - Hearing == 0 1.2929 -0.4392 3.0249  
## Wheelchair - None == 0 0.4429 -1.2892 2.1749

# Scheffe  
ScheffeTest(x=fit, data=df, which="Handicap")

##   
## Posthoc multiple comparisons of means: Scheffe Test   
## 95% family-wise confidence level  
##   
## $Handicap  
## diff lwr.ci upr.ci pval   
## Crutches-Amputee 1.4928571 -0.4639595 3.44967380 0.2238   
## Hearing-Amputee -0.3785714 -2.3353881 1.57824523 0.9840   
## None-Amputee 0.4714286 -1.4853881 2.42824523 0.9642   
## Wheelchair-Amputee 0.9142857 -1.0425309 2.87110237 0.7007   
## Hearing-Crutches -1.8714286 -3.8282452 0.08538808 0.0682 .   
## None-Crutches -1.0214286 -2.9782452 0.93538808 0.6051   
## Wheelchair-Crutches -0.5785714 -2.5353881 1.37824523 0.9265   
## None-Hearing 0.8500000 -1.1068167 2.80681666 0.7545   
## Wheelchair-Hearing 1.2928571 -0.6639595 3.24967380 0.3656   
## Wheelchair-None 0.4428571 -1.5139595 2.39967380 0.9715   
##   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

# Dunnett Contrast  
summary(glht(fit, linfct=mcp(Handicap="Dunnett")))

##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Dunnett Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## Crutches - Amputee == 0 1.4929 0.6172 2.419 0.0612 .  
## Hearing - Amputee == 0 -0.3786 0.6172 -0.613 0.9289   
## None - Amputee == 0 0.4714 0.6172 0.764 0.8598   
## Wheelchair - Amputee == 0 0.9143 0.6172 1.481 0.3868   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- single-step method)

confint(glht(fit, linfct=mcp(Handicap="Dunnett")))

##   
## Simultaneous Confidence Intervals  
##   
## Multiple Comparisons of Means: Dunnett Contrasts  
##   
##   
## Fit: aov(formula = Score ~ Handicap, data = df)  
##   
## Quantile = 2.5048  
## 95% family-wise confidence level  
##   
##   
## Linear Hypotheses:  
## Estimate lwr upr   
## Crutches - Amputee == 0 1.4929 -0.0531 3.0388  
## Hearing - Amputee == 0 -0.3786 -1.9245 1.1674  
## None - Amputee == 0 0.4714 -1.0745 2.0174  
## Wheelchair - Amputee == 0 0.9143 -0.6317 2.4602