A Survival Guide to Data Analysis

BERDC Special Topics Talk 15

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Dr. Mark Williamson

Biostatistics, Epidemiology, and Research Design Core

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Opening

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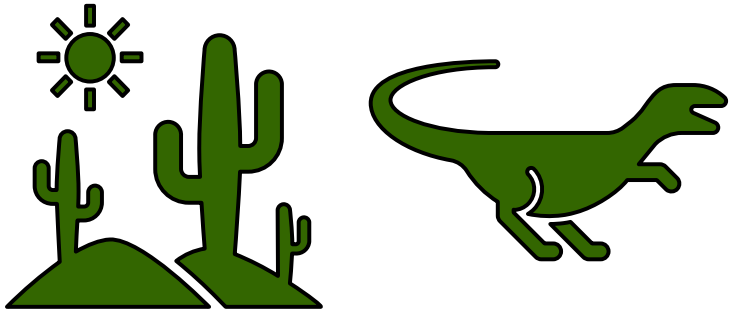
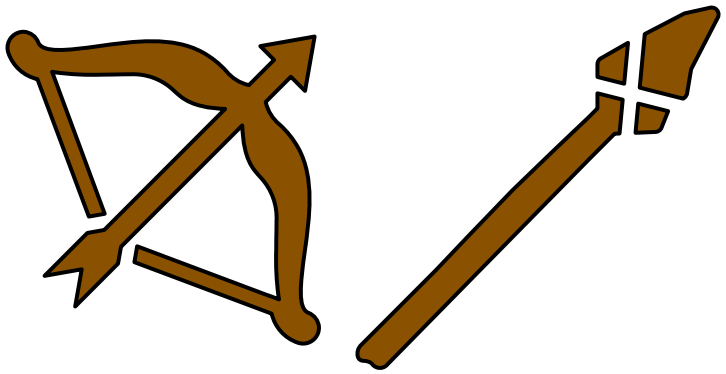
Goal: Deal with Data Analysis when backed against a wall

- Set the stage for dealing with data
- State three classes of problems
- Discuss three solutions for each problem
- Provide examples for each solution





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Introduction

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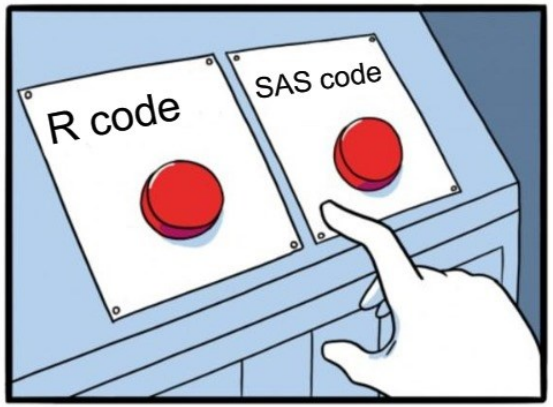
- Best case scenario for statistical analysis needs is to consult/collaborate with a statistician or statistically-minded researcher
- Not always possible (funding, location, educational situation, etc.)
- Take these tools with a grain of salt
- Steps in this guide are not mutually exclusive



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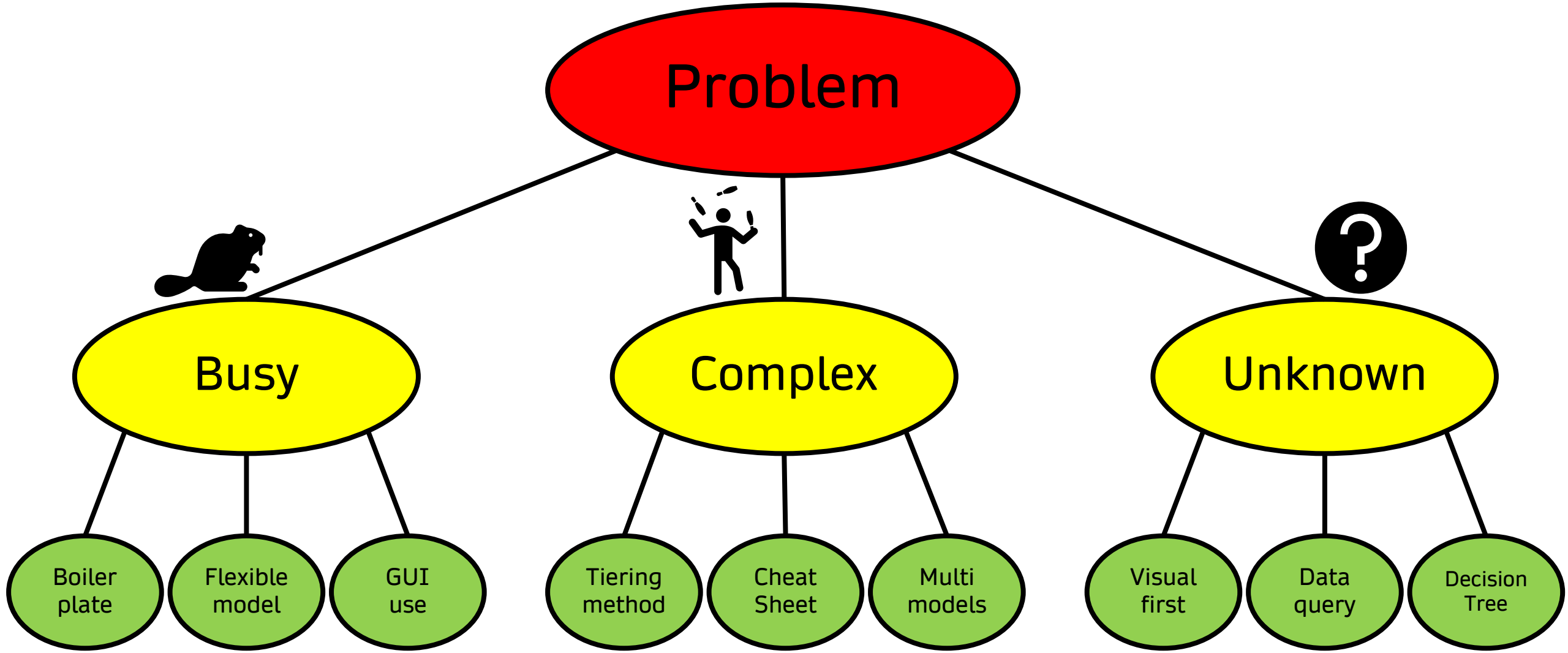
Content



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Boilerplate

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- Create a standardized document of code that is ready for common procedures and only needs to be filled in with specifics

Sample Comparisons

T-tests:

```
proc ttest data=one;
     var Var2; *Numeric variable;
     class Var1; *Categorical groups for comparison;
```

Paired t-test:

```
proc ttest data=one;
     paired Var1 Var2;
```

Multiple Testing:

```
proc glimmix data=one;
     class Var1; * Categorical groups for comparison;
     model Response = Var1;
     lsmeans Var1 / adjust=TUKEY;
     lsmeans Var1 / adjust=BON;
```

Non-parametric:

```
proc npar1way data=one;
     var Var2;
     class Var1;
```

FREQ tables and Chi-square tests:

```
proc freq data = one; BY Experiment;
     weight Count;
     tables Genotype*Disease / chisq;
```

SAS Coding Tips | 2017

Correlation and Regression

Correlation between multiple variables, with matrix scatter plot:

```
proc corr data=one plots=matrix;
     var Var1 Var2 Var3 Var4;
```

Linear Regression:

```
proc reg data=one;
     model depVar = Var2;
```

Multiple Regression with REG or GLM:

```
proc reg data=one;
     model depVar = Var1;
     model depVar = Var1 Var2; *can include multiple models;
     model depVar = Var1 Var2 Var3;

proc glm data=one;
     model depVar = Var1|Var2|Var3; *includes all interactions;
```

Polynomial Regression:

```
data one; set one;
     Var2=Var**2;
proc glm data=one;
     model clutch=length|length2;
```

Forward and Stepwise selection with GLMSELECT:

```
proc glmselect data=one plots=(Criteria Candidates);
     model response = var1 var2 var3 var4 var5 /
          selection=forward(select=AICC);
proc glmselect data=one plots=(Criteria Candidates);
     model response = var1 var2 var3 var4 var5 /
          selection=stepwise(select=AICC);
```

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⚒ Create a standardized document of code that is ready for common procedures and only needs to be filled in with specifics

```
#Simple histogram in ggplot
ggplot(data=DATASET, aes(Y_VAR))+
  geom_histogram(bins=6, fill="blue", col="black")

#Two-sample histogram in ggplot
ggplot(data=DATASET, aes(x=Y_VAR, fill=X_CAT))+
  geom_histogram(bins=6, col="black", alpha=0.6, position='identity')+
  scale_fill_manual(values=c("red", "blue"))

#Simple boxplot in ggplot
ggplot(data=DATASET, aes(x=X_CAT, y=Y_VAR)) +
  geom_boxplot()

#Two-way boxplot in ggplot
ggplot(data=DATASET, aes(x=X_CAT1, y=Y_VAR, fill=X_CAT2)) +
  geom_boxplot()
```

```
#Simple scatter plot in ggplot
ggplot(data=DATASET, aes(x=X_NUM, y=Y_VAR)) +
  geom_point()

#Two-way scatter plot in ggplot
ggplot(data=DATASET, aes(x=X_NUM, y=Y_VAR, fill=X_CAT, color=X_CAT)) +
  geom_point()

#Spaghetti plot in ggplot
ggplot(data=DATASET, aes(x=X_CAT, y=Y_VAR, group=ID)) +
  geom_line()

#Logistic regression plot in ggplot
ggplot(data=DATASET, aes(x=X_NUM, y=Y_BIN)) +
  geom_point() +
  stat_smooth(method="glm", se=FALSE, method.args=list(family=binomial))

#Bubble plot in ggplot
ggplot(data=DATASET, aes(x=X_NUM1, y=Y_VAR, size=X_NUM2))+
  geom_point()
```

```
#Simple bar plot in ggplot
DATASET_sum<-DATASET %>%
  group_by(X_CAT) %>%
  summarise(mean=mean(Y_VAR),
            sd = sd(Y_VAR),
            error = qt(0.975,df=n()-1)*sd/sqrt(n()),
            ul = mean + error,
            ll = mean - error)
ggplot(data=DATASET_sum, aes(x=X_CAT, y=mean, fill=X_CAT)) +
  geom_bar(stat="identity") +
  geom_errorbar(aes(ymin=ll, ymax=ul), width=0.1)

#Two-way bar plot in ggplot
DATASET_sum<-DATASET %>%
  group_by(X_CAT1, X_CAT2) %>%
  summarise(mean=mean(Y_VAR),
            sd = sd(Y_VAR),
            error = qt(0.975,df=n()-1)*sd/sqrt(n()),
            ul = mean + error,
            ll = mean - error)
ggplot(data=DATASET_sum, aes(x=X_CAT1, y=mean)) +
  geom_bar(aes(fill=X_CAT2), stat="identity",
  position=position_dodge()) +
  geom_errorbar(aes(ymin=ll, ymax=ul, group=tension), width=0.1,
  position=position_dodge(0.9))
```

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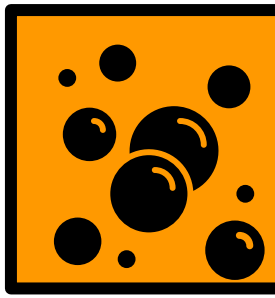

Boilerplate

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- Create a standardized document of code that is ready for common procedures and only needs to be filled in with specifics

```
barchart.anova <- function(df, cat_var, num_var) {
 cat_var <- enquo(cat_var)
 num_var <- enquo(num_var)
 df_sum<-df %>%
  group_by(!!cat_var) %>%
  summarise(mean=mean(!!num_var),
            sd = sd(!!num_var),
            error = qt(0.975,df=n()-1)*sd/sqrt(n()),
            ul = mean + error,
            ll = mean - error)
 #print(df_sum)
 df_plot <<-ggplot(df_sum, aes(!!cat_var, mean, fill=!!cat_var))+
  geom_bar(stat="identity", color="black")+
  geom_hline(yintercept = 0) +
  geom_errorbar(aes(ymin=ll, ymax=ul), width=0.1) +
  theme_classic() + theme(legend.position="none")
}
```

```
#Example
barchart.anova(iris, Species, Sepal.Length)
#basic
df_plot
#customized
df_plot + labs(y="Sepal length (cm", x="Species") +
 scale_y_continuous(limits=c(0,7),breaks=c(0:7))+
 geom_text(aes(label=c('*','*','*')), vjust=-0.8, size=6)
```

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Flexible Models

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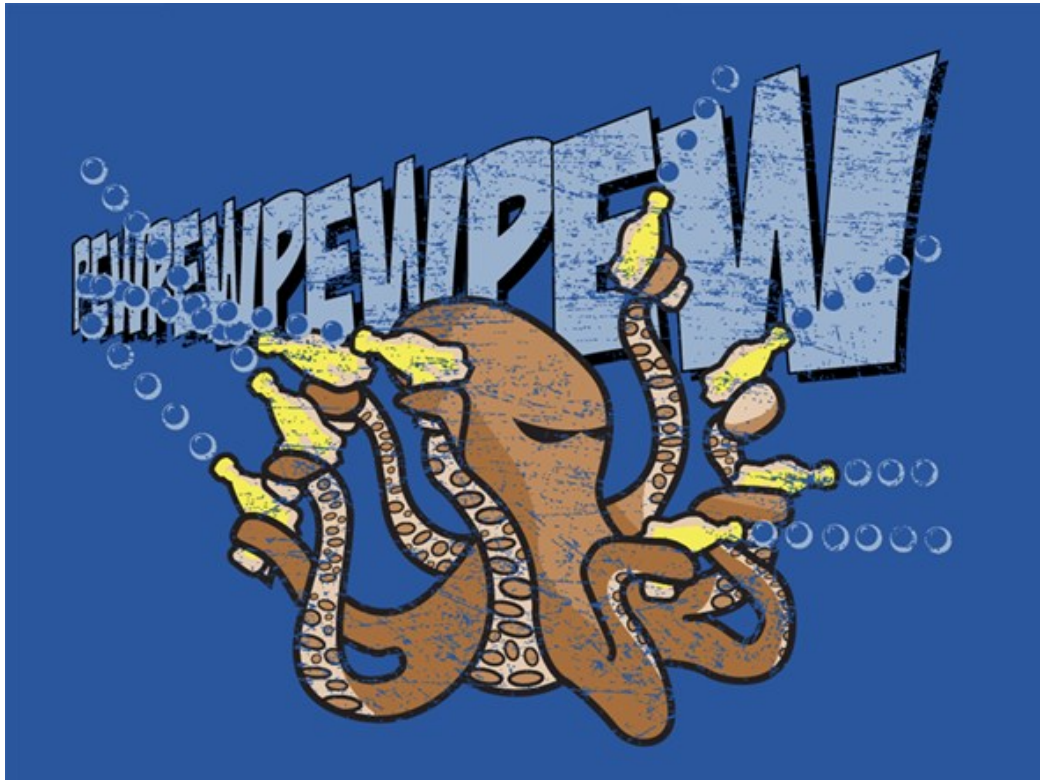
- Use flexible models that can run multiple tests just by tweaking parameters, rather than having to run different code for each and every test




```
#FLEXIBLE MODELS
head(mtcars)

t.model <-lm(mpg~as.factor(vs), data=mtcars)
summary(t.model)

a.model <-lm(mpg~as.factor(carb), data=mtcars)
summary(a.model)

r.model <-lm(mpg~wt, data=mtcars)
summary(r.model)
```

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Flexible Models

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⚒ Use flexible models that can run multiple tests just by tweaking parameters, rather than having to run different code for each and every test

T-test

```
PROC GLIMMIX data=sashelp.Class;
        class Sex;
        model Height=Sex /solution dist=normal;
        lsmeans Sex /cl;
        ods output LSmeans=Class_lsm;
PROC SGPLOT data=Class_lsm;
        vbarparm category=Sex  response=Estimate/limitupper=Upper
        limitlower=Lower;
```

ANOVA

```
PROC GLIMMIX data=sashelp.bweight;
        class MomEdLevel;
        model Weight=MomEdLevel/solution dist=normal;
        lsmeans MomEdLevel / cl;
        ods output LSMeans=Bweight_lsm;
PROC SGPLOT data=Bweight_lsm;
        vbarparm category=MomEdLevel
        response=Estimate/
        limitupper=Upper limitlower=Lower;
```

Regression

```
PROC GLIMMIX data=sashelp.bmimen;
        model BMI=age/solution dist=normal;
        output out=Bmimen_pred pred lcl ucl;
PROC SGPLOT data=Bmimen_pred;
        band x=age lower=lcl upper=ucl;
        scatter x=age y=BMI;
        series x=age y=Pred;
```

Generalized Linear Mixed Model

```
PROC GLIMMIX data=multicenter;
        class center group;
        model SideEffect/n = group / solution;
        random center;
        lsmeans group / ilink cl;
        ods output LSMeans=lsm1;
PROC SGPLOT data=lsm1;
        vbarparm category=group
        response=Mu /
        limitlower=LowerMu
        limitupper=UpperMu;
```

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GUI Use

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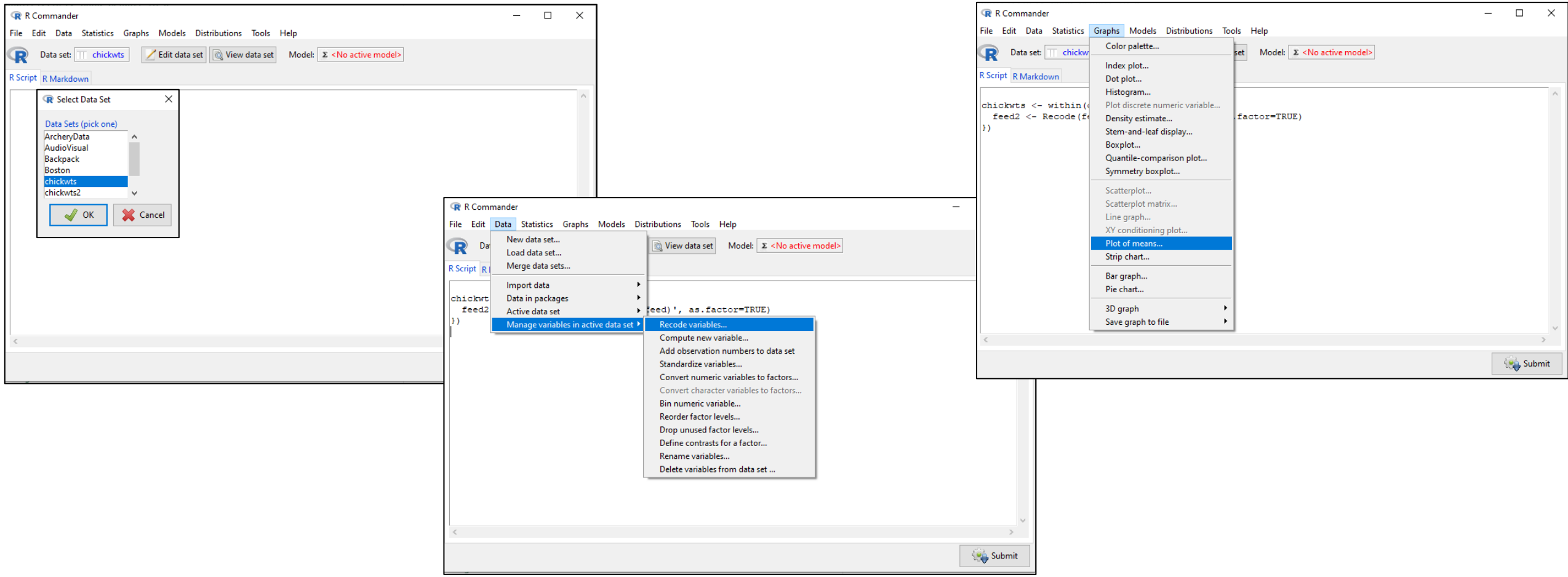
- Use a Graphical Use Interface to rapidly select and run tests



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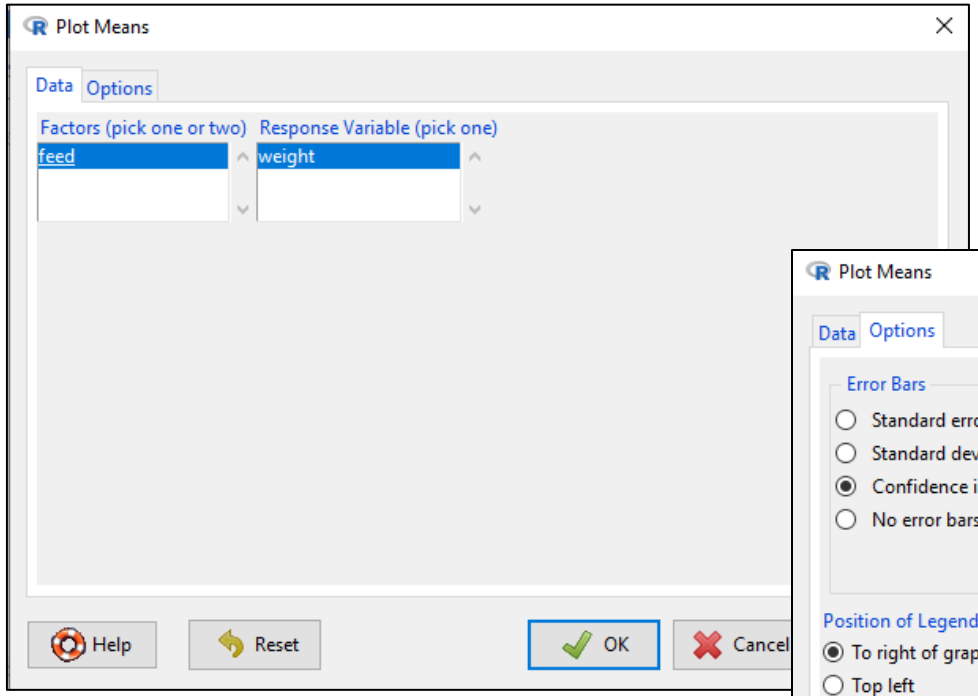

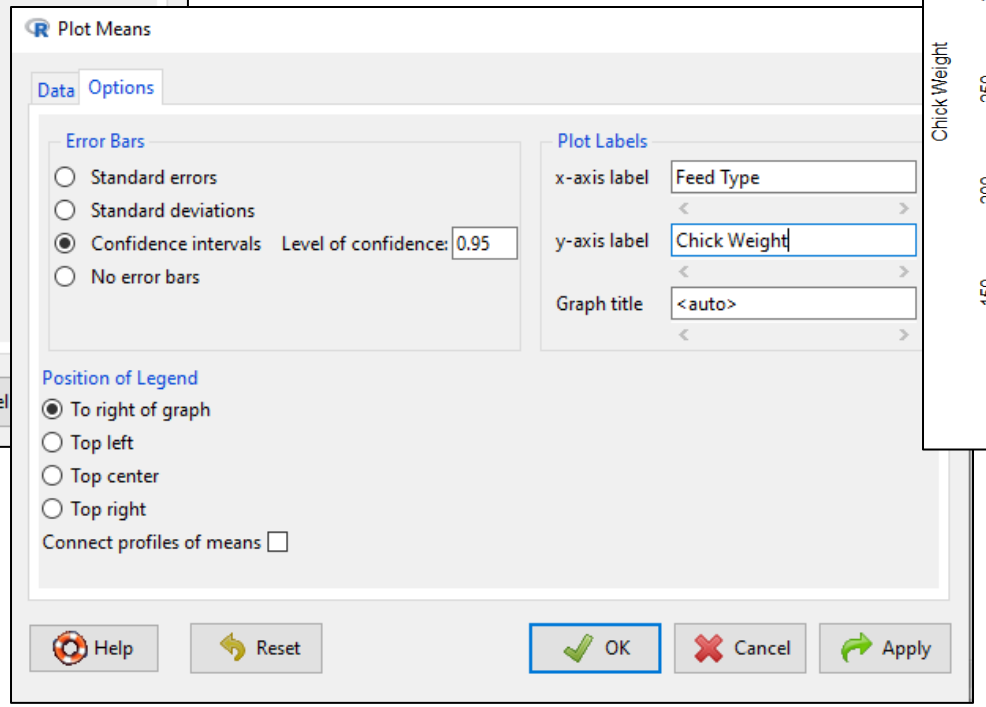

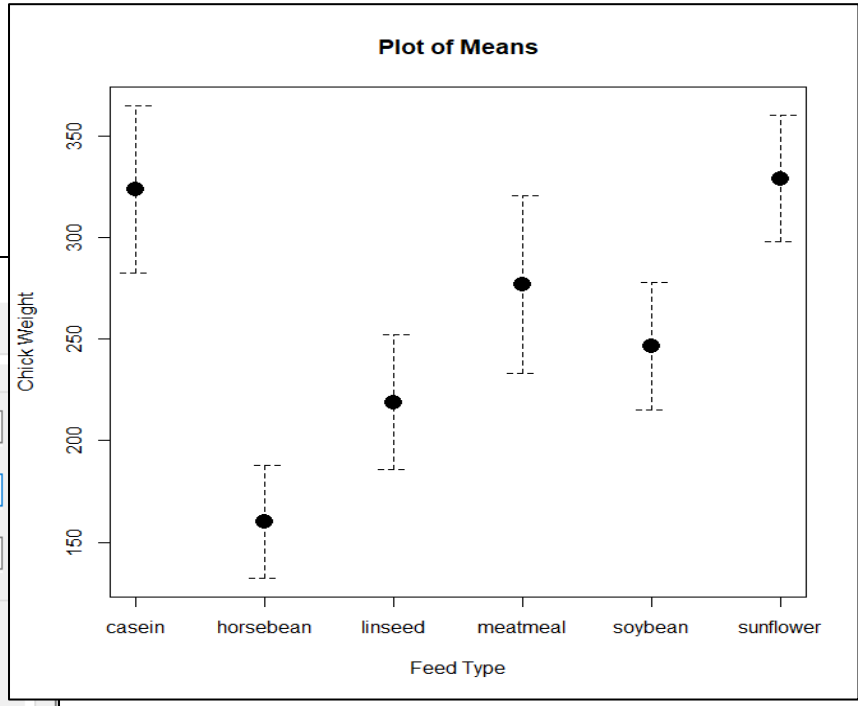

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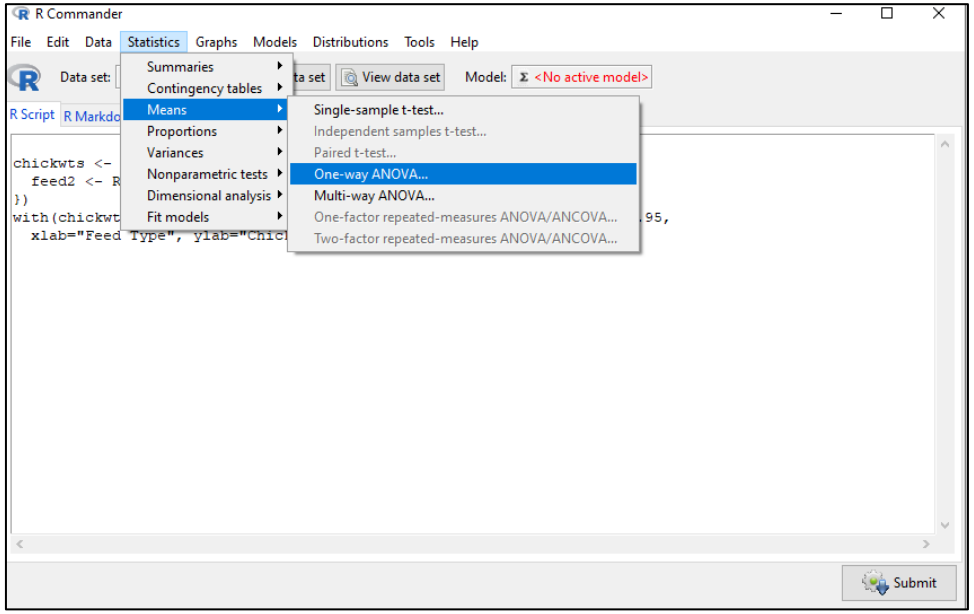


```
Rcmdr>  summary(AnovaModel.1)
            Df Sum Sq Mean Sq F value   Pr(>F)
feed         5 231129   46226   15.37 5.94e-10 ***
Residuals   65 195556    3009
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Rcmdr>  with(chickwts, numSummary(weight, groups=feed, statistics=c("mean", "sd")))
              mean       sd data:n
casein    323.5833 64.43384     12
horsebean 160.2000 38.62584     10
linseed   218.7500 52.23570     12
meatmeal  276.9091 64.90062     11
soybean   246.4286 54.12907     14
sunflower 328.9167 48.83638     12
```

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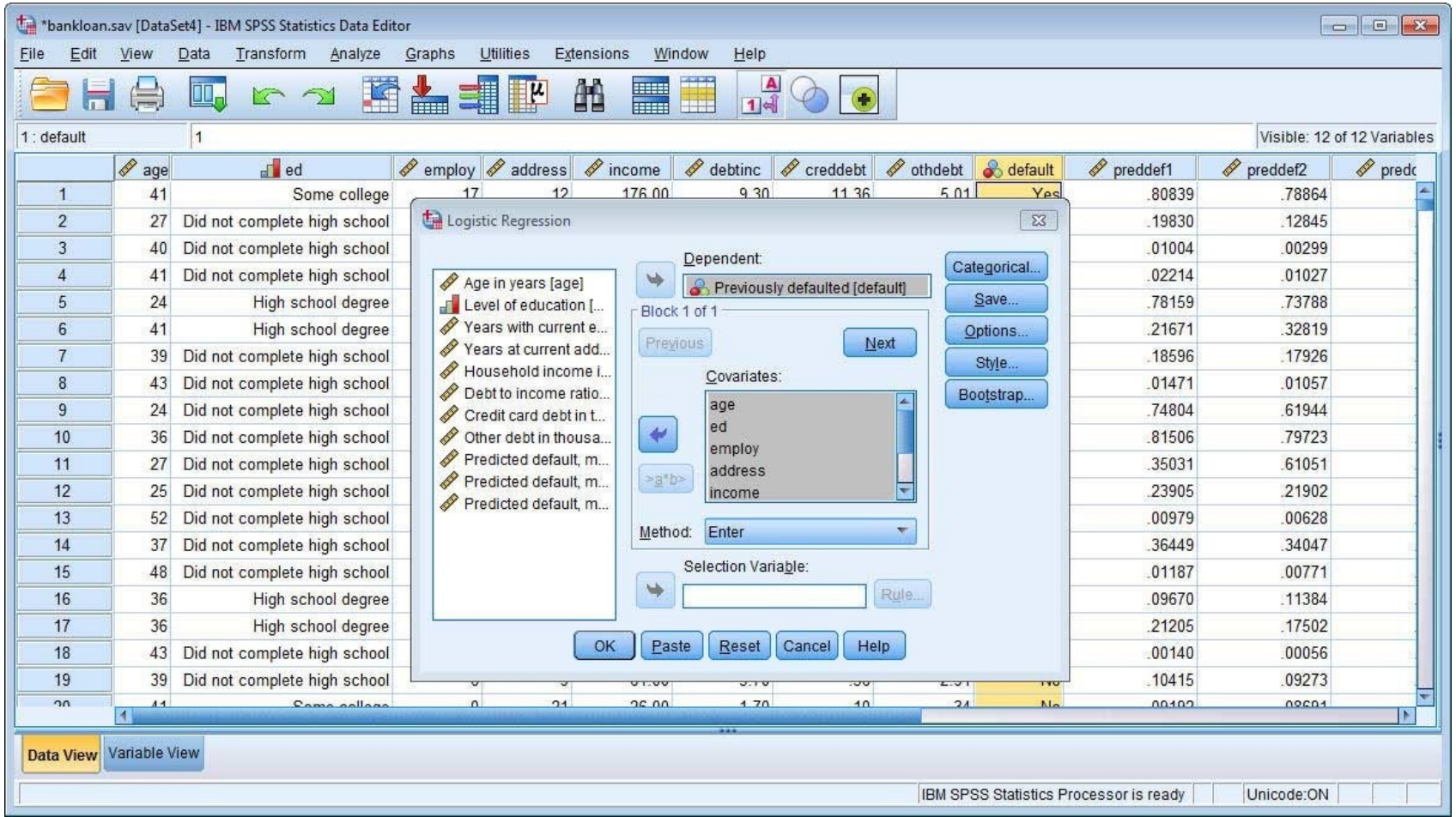

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Tiering Method

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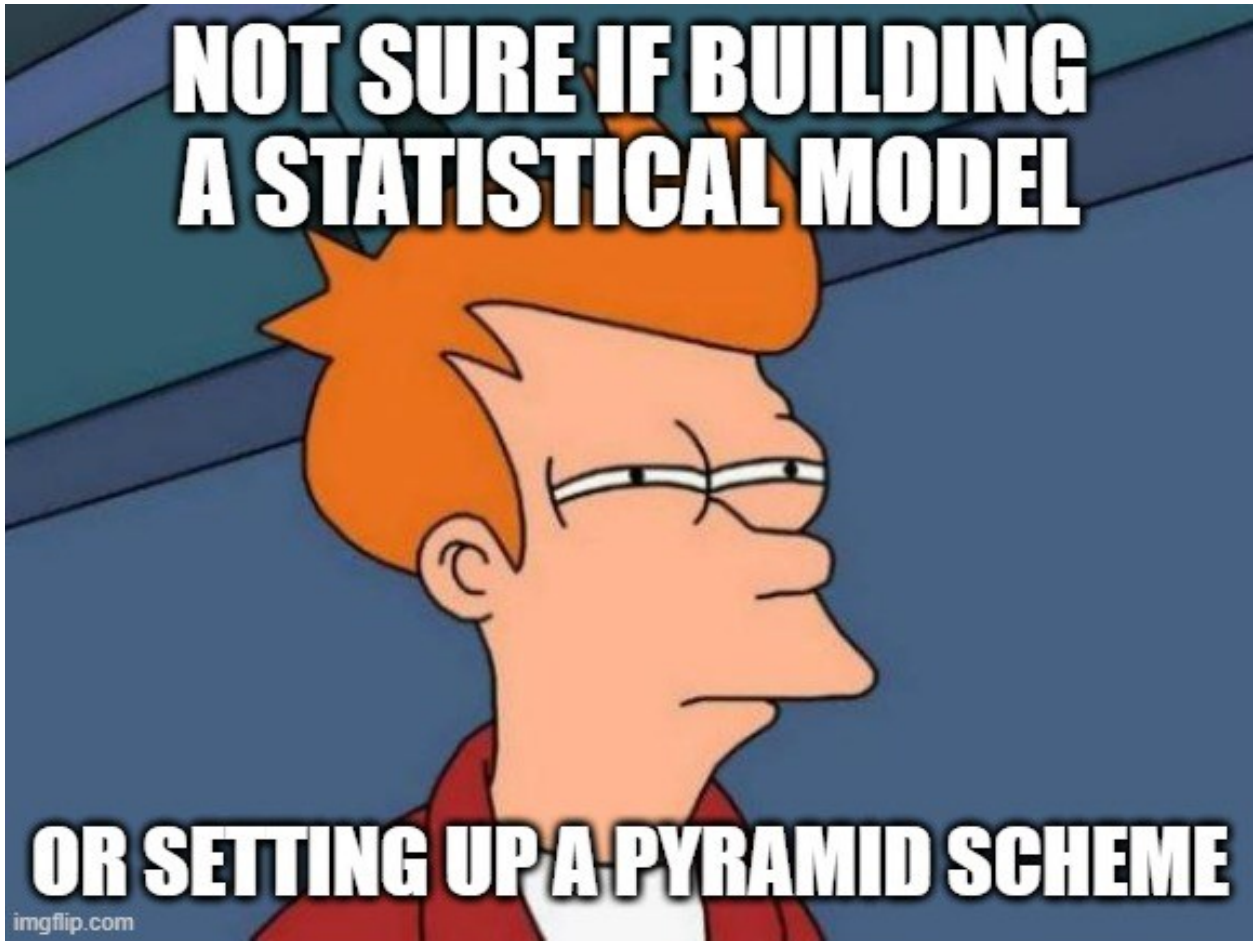
- ⚒ Start with simplest model design and progressively build from there



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Tiering Method

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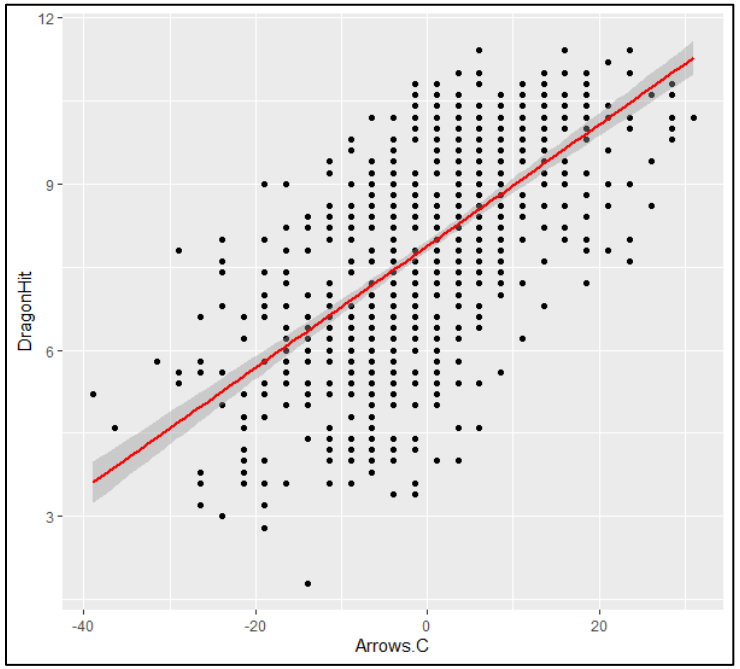
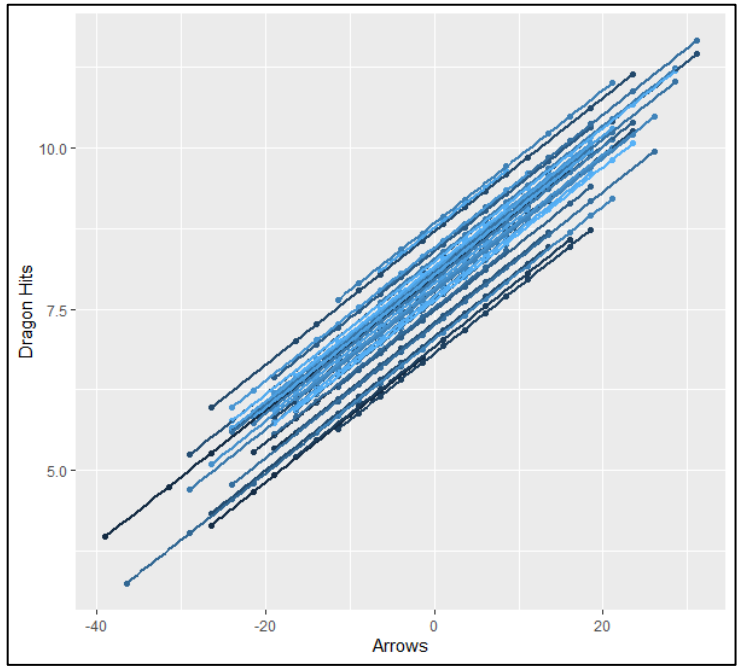
⚒ Start with simplest model design and progressively build from there

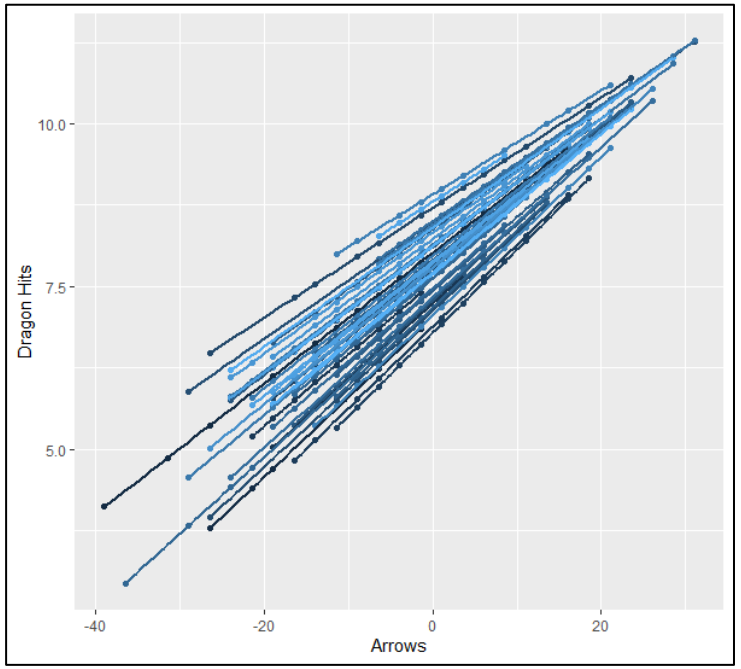
D3_M1 <- lm(DragonHit ~ Arrows.C, data=Dragon2)



D3_M2 <- lmer(DragonHit ~ Arrows.C + (1|Cathedral), data=Dragon2, REML=F)



D3_M3 <- lmer(DragonHit ~ Arrows.C + (Arrows.C|Cathedral), data=Dragon2, REML=F)



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Cheat Sheet

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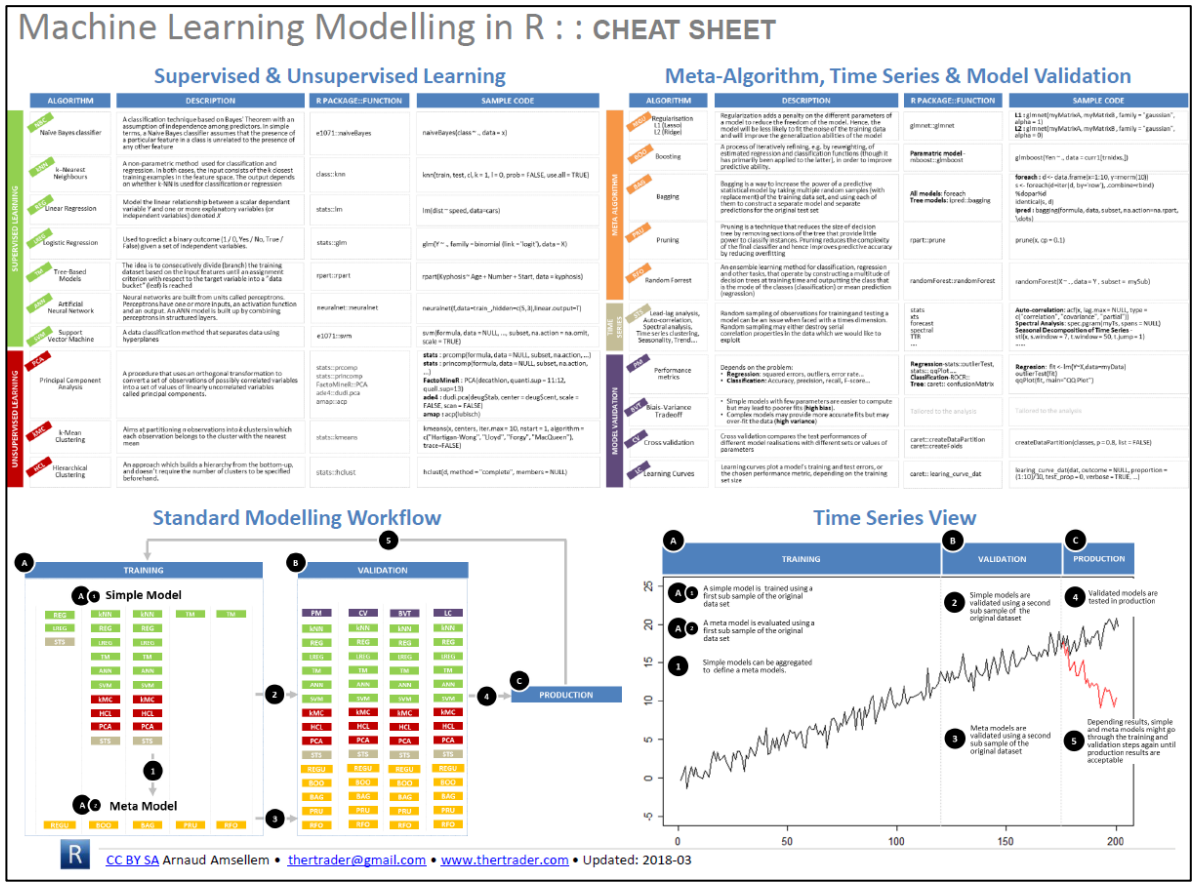
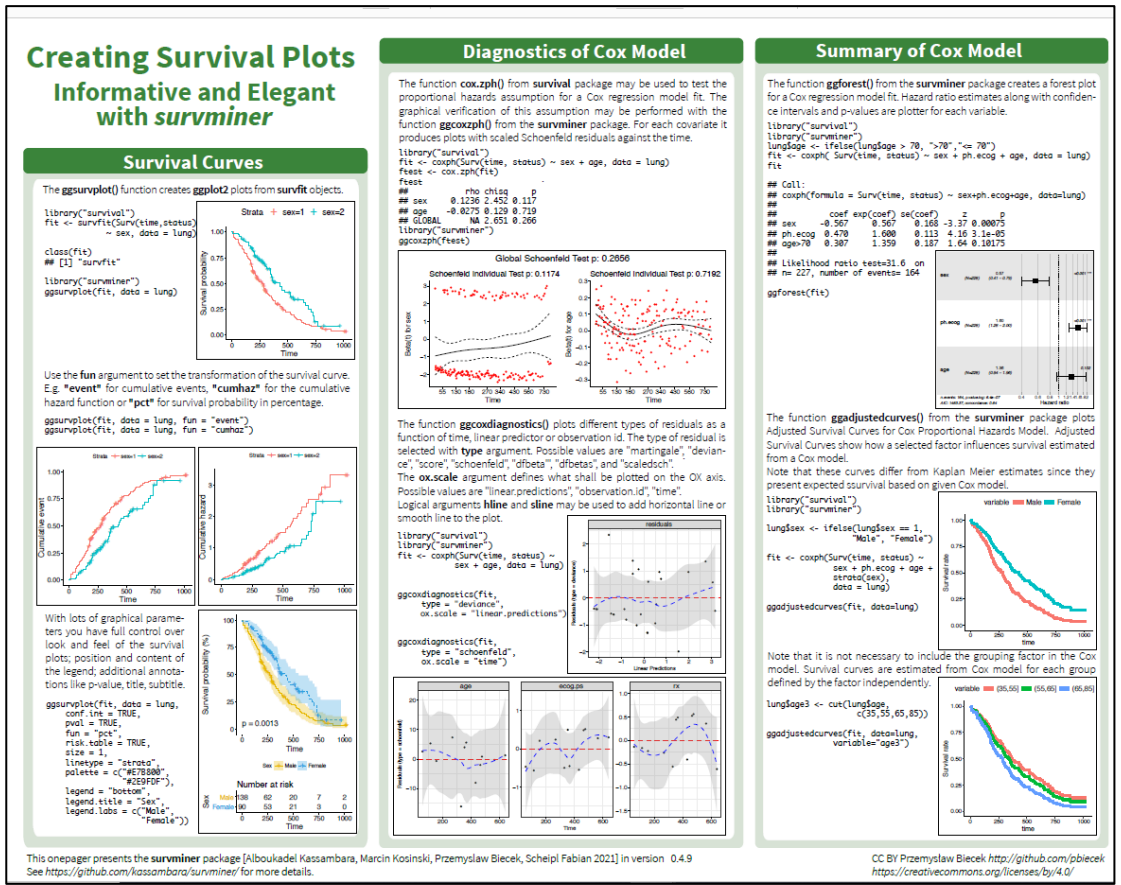
⚒ Deploy sheets with quickly available information for statistical methods, especially more advanced concepts





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Cheat Sheet

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- Deploy sheets with quickly available information for statistical methods, especially more advanced concepts

Examples	STATA	SPSS	Excel	SAS	R
Summary statistics	Data->Describe Data-> Summary Statistics **OR** summarize ***num_var***	Analyze -> Descriptive Statistics -> Descriptives	=AVERAGE(***num_var***) =MEDIAN(***num_var***) =STDEV.S(***num_var***) …	PROC UNIVARIATE; var ***num_var;***	summary(***num_var***)
Histogram	Graphics-> Histogram **OR** histogram ***num_var***	Graphs -> Chart Builder -> Histogram	Insert (Charts)-> Histogram	PROC SGPLOT; histogram ***num_var;***	hist(***num_var***)
Boxplot	Graphics-> Box plot **OR** graph box ***num_var***, over(***cat_var***)	Graphs -> Chart Builder -> Boxplot	Insert (Charts)-> Box and Whisker	PROC SGPLOT; vbox ***num_var***/ group=***cat_var;***	plot(***num_var~cat_var***)
Bar plot	Graphics-> Bar Chart **OR** graph bar (mean) ***num_var***, over(***cat_var***)	Graphs -> Chart Builder -> Bar	Insert (Charts)-> Column	PROC SGPLOT; vbarparm category=***cat_var*** treatment=***num_mean***;	***means*** <- c(***mean_cat1, mean_cat2***) barplot(***means***)
Scatterplot	Graphics -> Twoway graph **OR** twoway (scatter ***num_var1 num_var2***)	Graphs -> Chart Builder -> Scatter/Dot	Insert (Charts)-> Scatter	PROC SGPLOT; Scatter y=***num_var1*** x=***num_var2***;	plot(***num_var1, num_var2***)
T-test	Statistics -> Summaries, tables, and tests -> Classical tests of hypotheses -> t tests **OR** ttest ***num_var***, by(***cat_var***)	Analyze -> Compare means-> Independent-Samples T Test	=TTEST(***num_var1, num_var2, tails, type***)	PROC TTESt; var ***num_var***; class ***cat_var***;	t.test(***num_var~cat_var***)
ANOVA	Statistics-> Linear models and related -> ANOVA/MANOVA -> One-way ANOVA **OR** oneway ***num_var cat_var***	Analyze -> Compare means-> One-Way ANOVA	Data Analysis (add-on) -> Anova: Single Factor	PROC ANOVA; class ***cat_var***; model ***num_var=cat_var***;	aov(***num_var~cat_var***)
Normal linear regression model	Statistics-> Linear models and related -> Linear regression **OR** regress ***num_var1 num_var2***	Analyze -> Regression-> Linear	Data Analysis (add-on) -> Regression	PROC REG; model ***num_var1= num_var2***;	lm(***num_var1 ~num_var2***)
Logistic regression model	Statistics-> Binary outcomes-> Logistic regression **OR** logit ***binary_var num_var***	Analyze -> Regression-> Binary Logistic	N/A	PROC LOGISTIC; model ***event/trial= num_var2***;	glm(***binary_var ~ num_var***, family=biniomial)
Poisson regression model	Statistics -> Count outcomes-> Poisson regression **OR** Poisson ***count_var num_var***	Analyze -> Regression-> Generalized Linear Models	N/A	PROC GLIMMIX; model ***count_var= num_var*** /dist=Poisson;	glm(***count_var ~ num_var***, family=Poisson)
Generalized linear mixed model	Statistics -> Multilevel mixed-effects models -> Generalized linear model **OR** meglm ***var1 var2*** || ***rand_var_eqn***, family(***distribution***) link(***link_function***)	Analyze-> Mixed Models-> Generalized Linear	N/A	PROC GLIMMIX; class ***cat_var***; model ***num_var1= num_var2 cat_var rand_var***; random ***rand_var***;	Package lme4 Lmer(***num_var1~ num_var2 + cat_var*** + (1|***rand_var***)

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Multi Models

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⚒ Be ready to run multiple models that could fit the data and compare best fit

```
btb_lmer1 <- lmer(bdi ~ bdi.pre + time + treatment + drug + length + (1 | subject),
                  data = BtheB_long, REML=FALSE, na.action = na.omit) #Rand Int

btb_lmer2 <- lmer(bdi ~ bdi.pre + time + treatment + drug + length + (time | subject),
                  data = BtheB_long, REML=FALSE, na.action = na.omit) #Rand Int & Slope

btb_gee1 <- gee(bdi ~ bdi.pre + treatment + length + drug,
              data = BtheB_long, id = subject, family = gaussian, corstr = "independence")

btb_gee2 <- gee(bdi ~ bdi.pre + treatment + length + drug,
               data = BtheB_long, id = subject, family = gaussian, corstr = "exchangeable")

anova(btb_lmer1, btb_lmer2, btb_gee1, btb_gee2)
```

```
PROC GLIMMIX data=DATASET method=RSPL;
        class RAND1;
        model Y_VAR=X_VAR1 |  X_VAR2;
        random RAND1;
```

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⚒ Be ready to run multiple models that could fit the data and compare best fit

```
reg1 <- lm(Dep ~ Ind1 + Ind2 + Ind3 + Ind4)
sreg1 <- step(reg1, direction="forward")
sreg2 <- step(reg1, direction="backward")
sreg3 <- step(reg1, direction="both")
```

```
PROC GLMSELECT data=sashelp.baseball
plots=all;
  class league division;
  model logSalary = nAtBat nHits nHome nRuns
                    nRBI nBB yrMajor crAtBat
                    crHits crHome crRuns crRbi
                    crBB league division nOuts
                    nAssts nError
                    / details=all stats=all;
```

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Visual First

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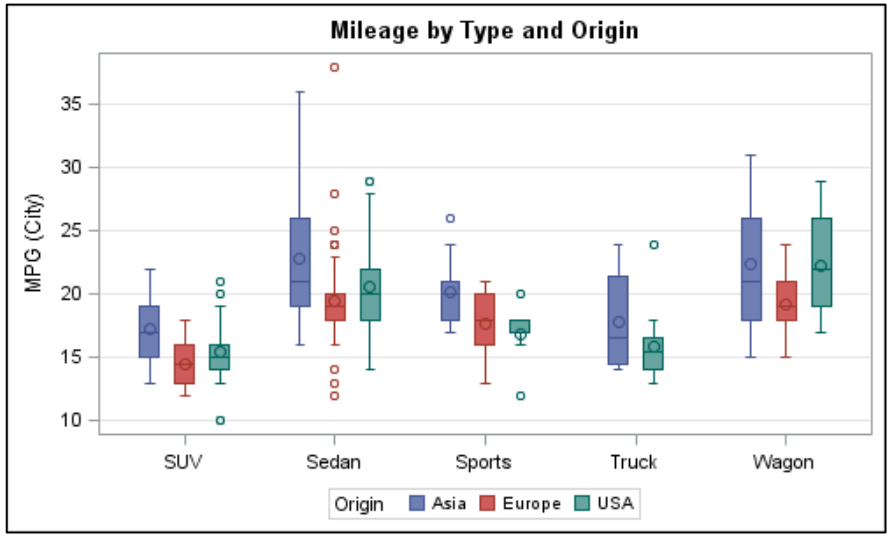
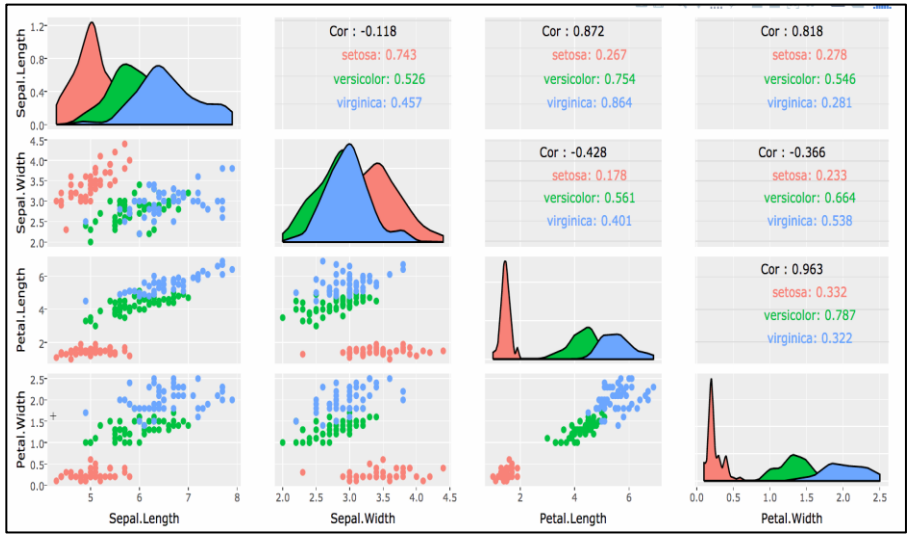
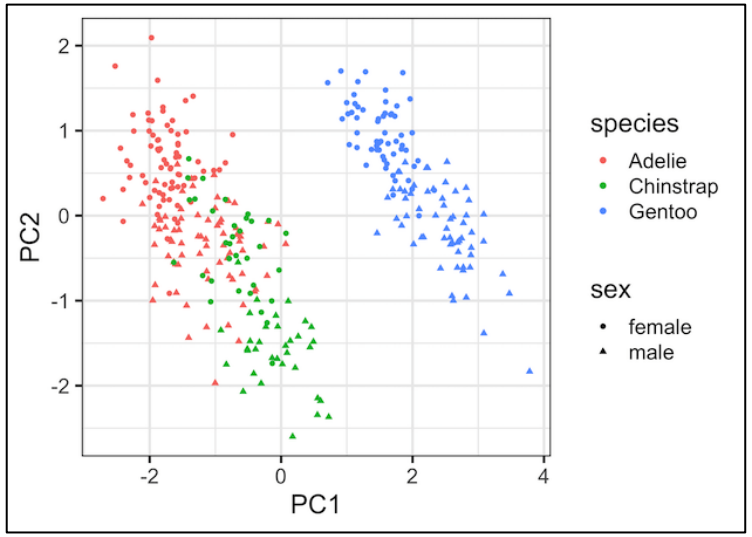
- Get to know your data through exploratory data visualization (summary tables, boxplots, scatter plots, dimensional reduction, etc.)







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Visual First

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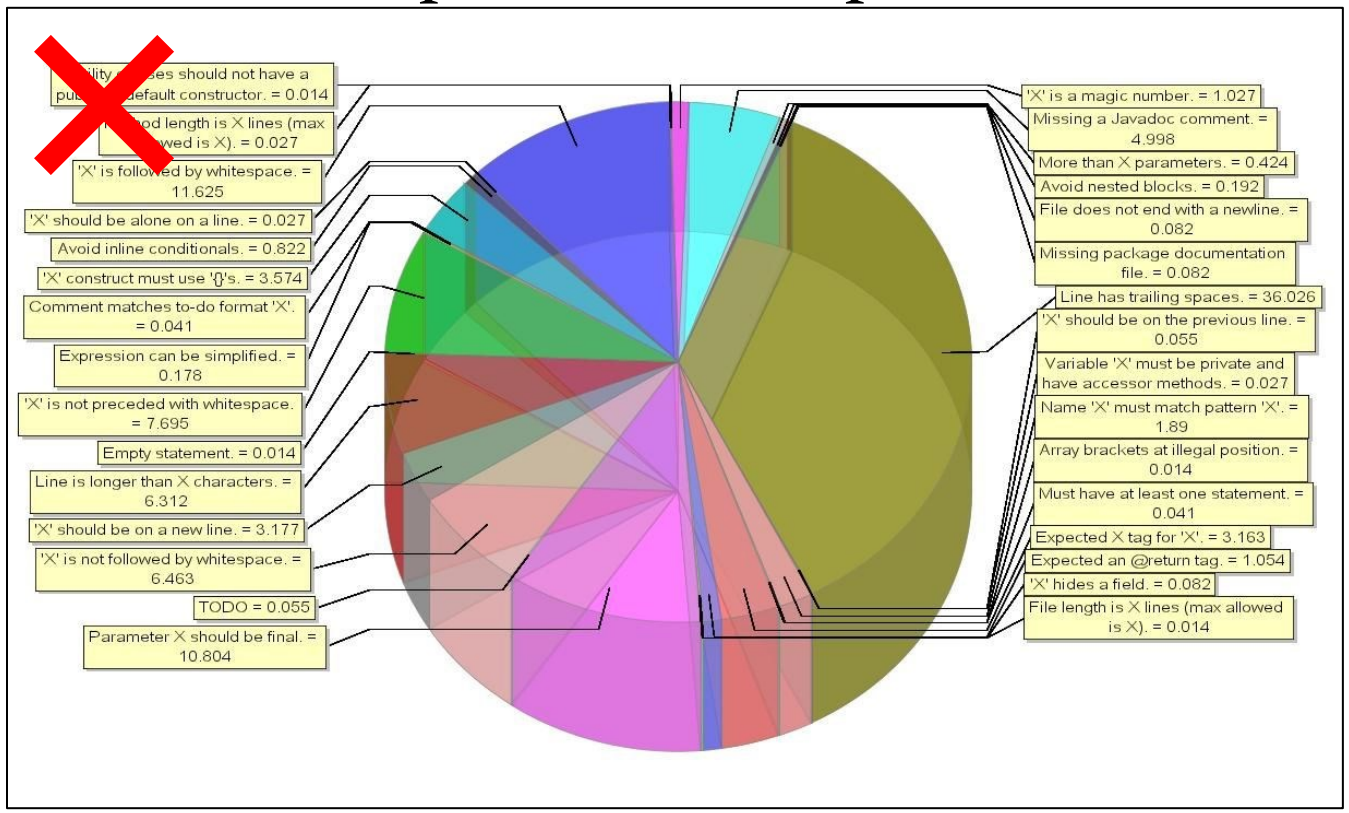
- Get to know your data through exploratory data visualization (summary tables, boxplots, scatter plots, dimensional reduction, etc.)



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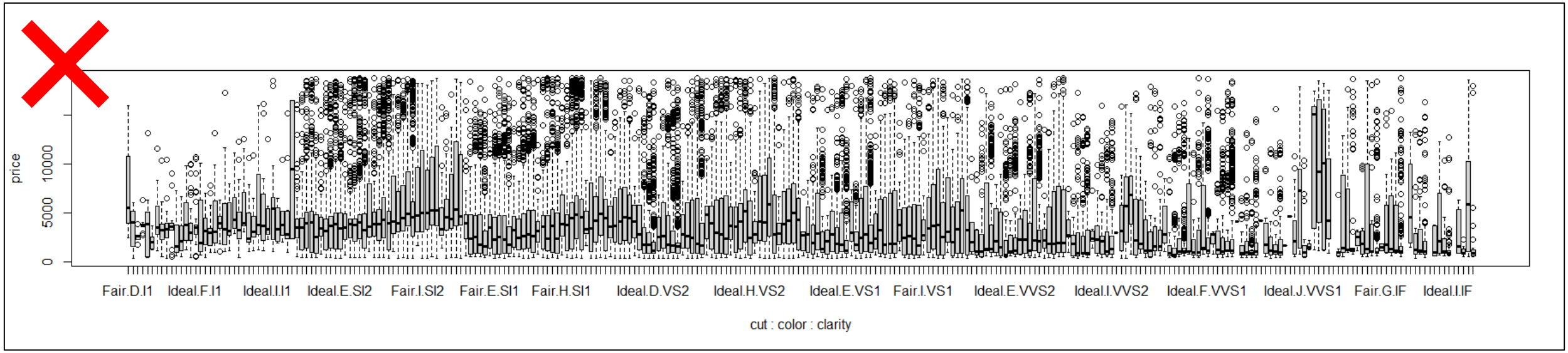

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? Data Query

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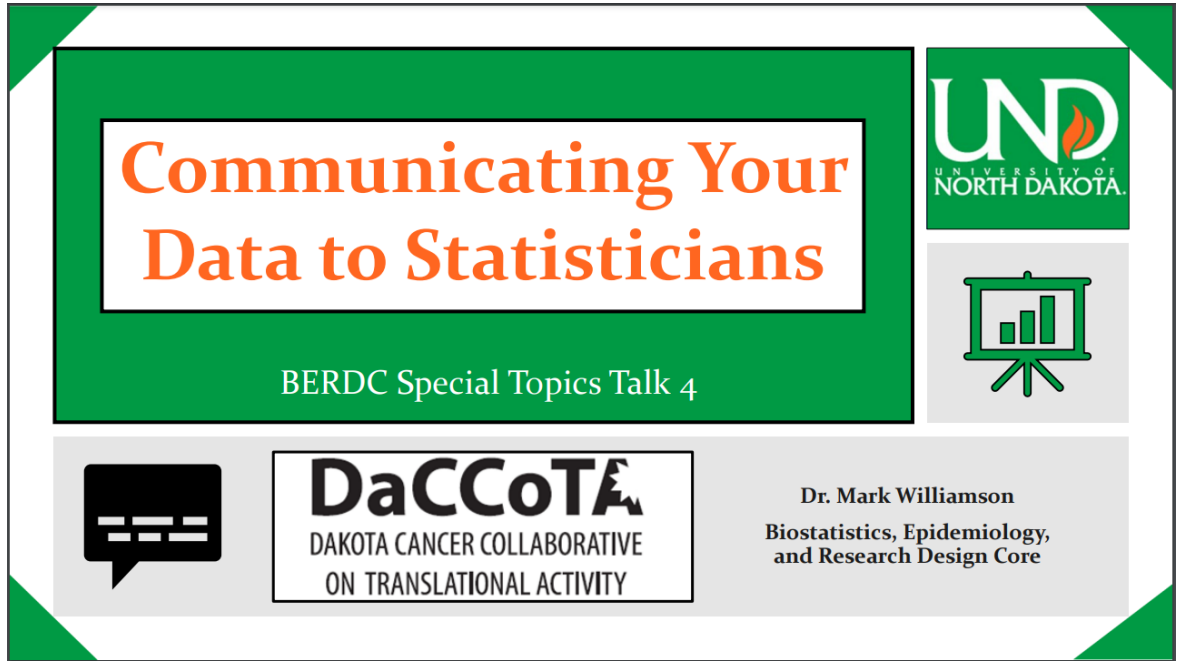
- Answer questions to get you thinking about your data to figure out structure and variable information



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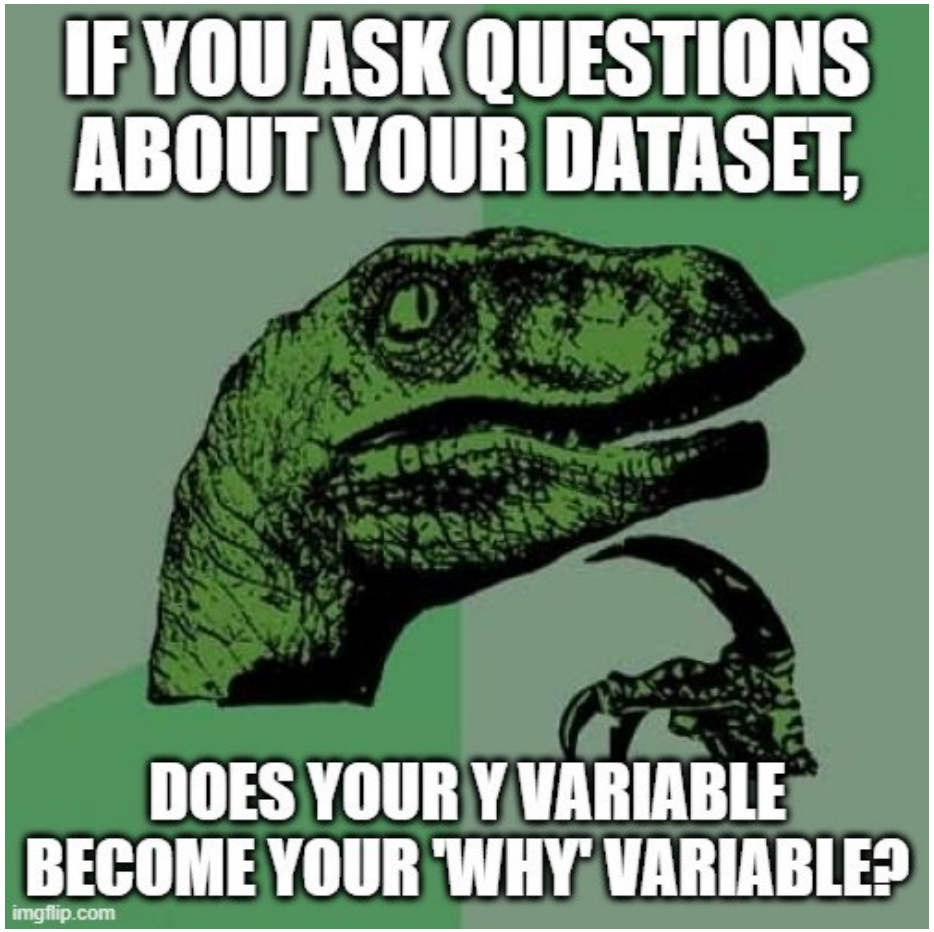

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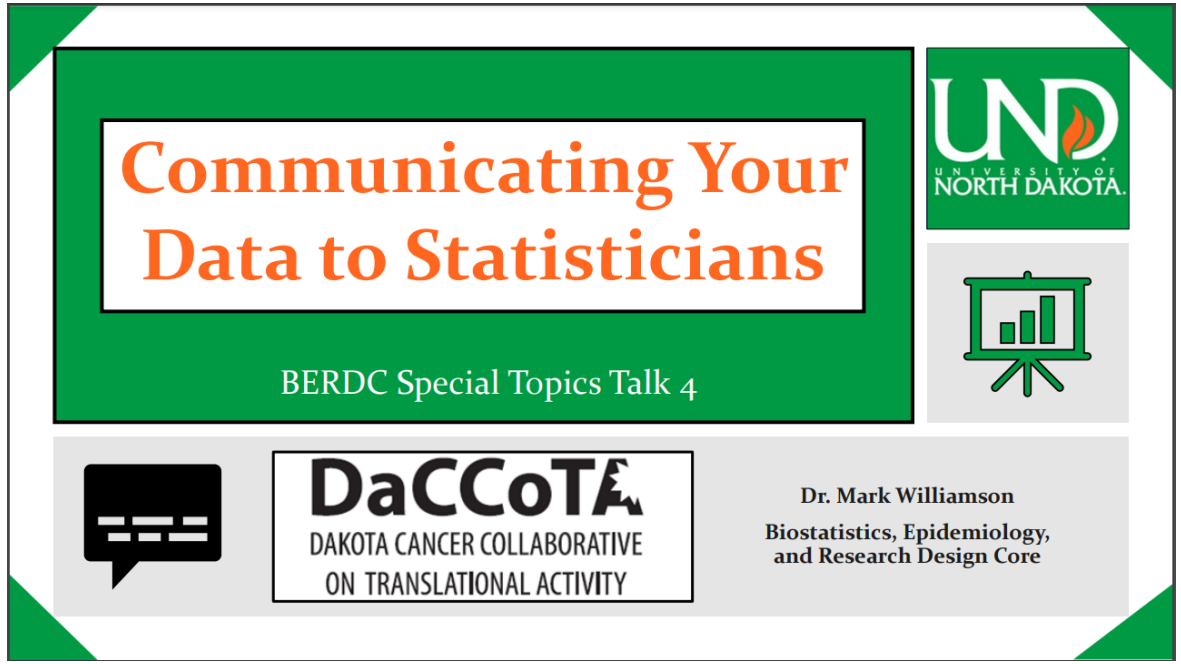
⚒ Answer questions to get you thinking about your data to figure out structure and variable information



https://und.qualtrics.com/jfe/form/SV_dcyUSPLhD4cmP5Q

#	Question
1	What is your **Y variable**?
2	How is your **Y variable measured** (categorical-> ordinal or nominal, numerical -> continuous or discrete)?
3	What are your **X variables**?
4	How are your **X variables measured** (categorical-> ordinal or nominal, numerical -> continuous or discrete)?
5	Are their **major considerations** you need to be aware of (confounding factors, longitudinal design, missing data, etc.)?

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Decision Tree

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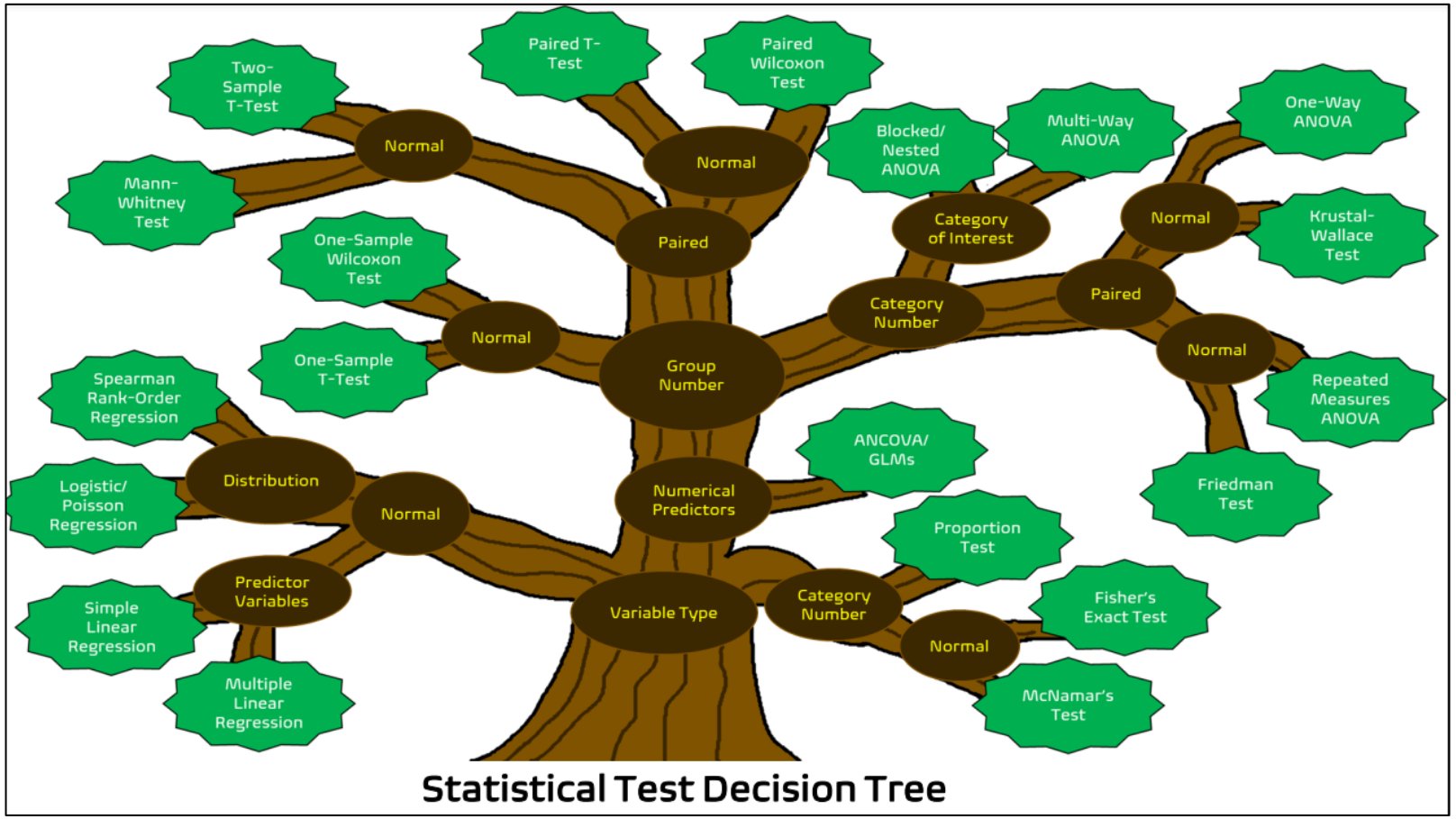
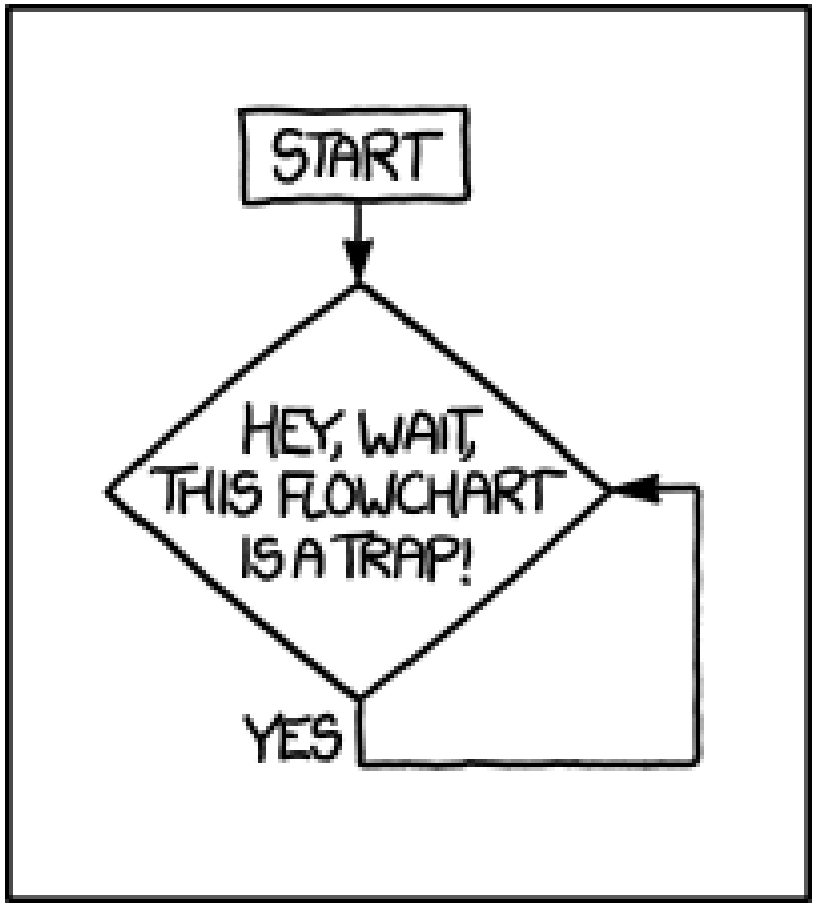
- Walk through branching decisions to determine appropriate test to use



Statistical Test Decision Tree



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Decision Tree

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⚒ Walk through branching decisions to determine appropriate test to use

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Classification Problems

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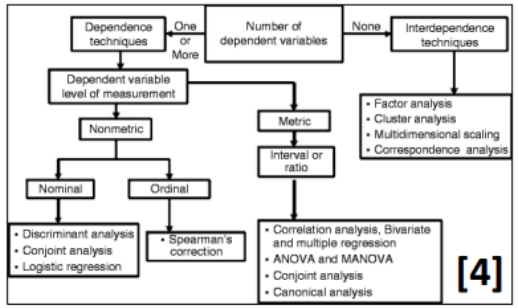

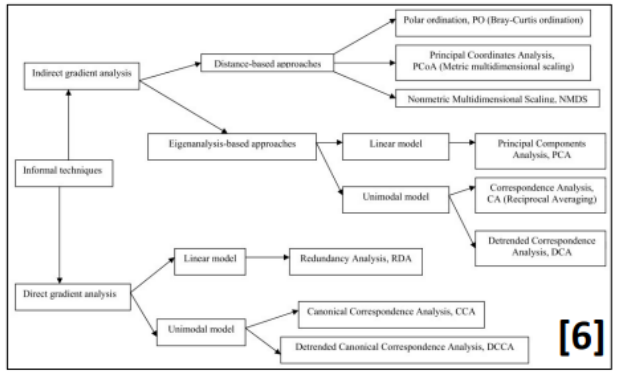

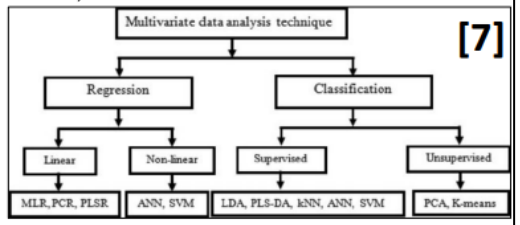

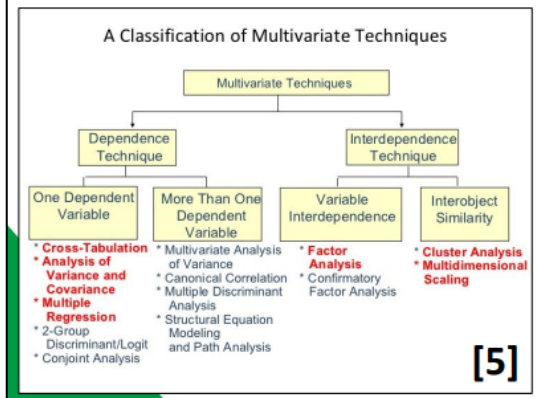

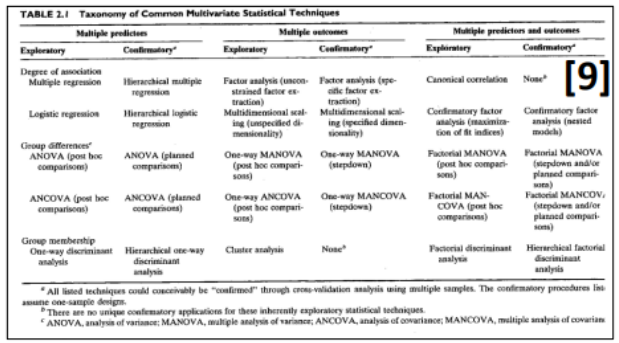

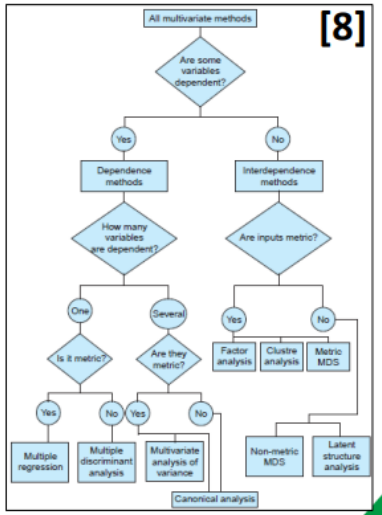

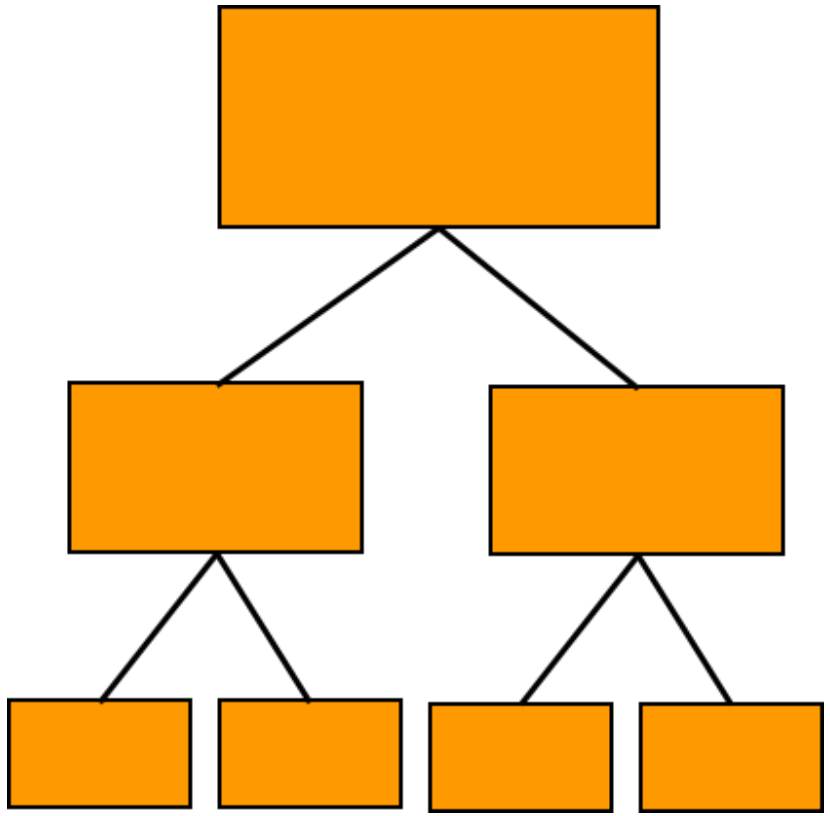

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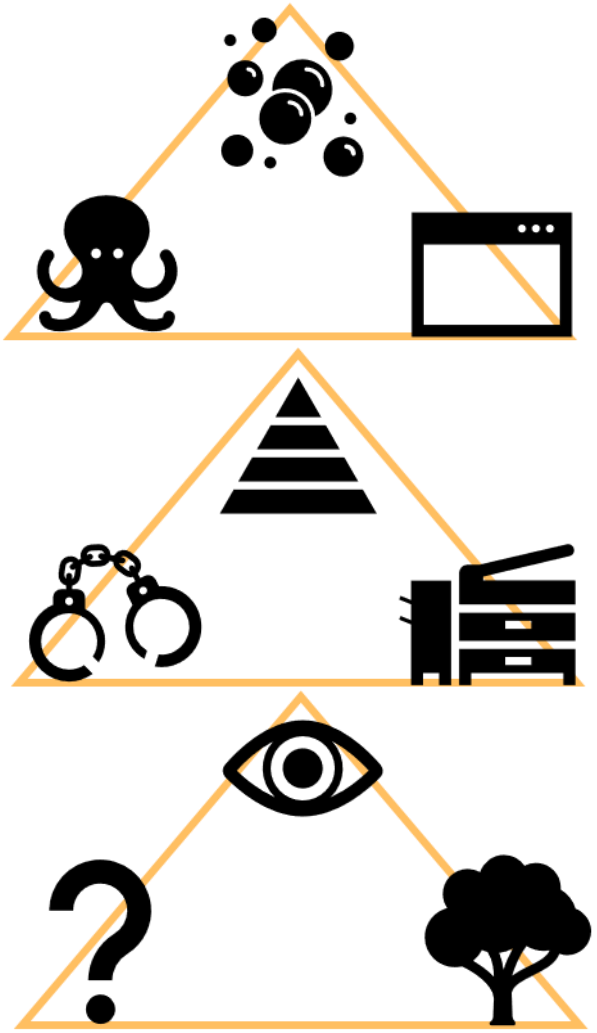
Conclusions

- Working with a biostatistician your best, but not only, option
- If you struggle with a busy schedule, analyzing complex data, or getting your head around unknown data, there are a bundle of strategies to help you survive
- Strategies are boilerplate code, flexible models, GUI usage, tiering methods, cheat sheets, multiple models, visualization first, data questionaries, and decision trees



Please take the survey:

Survey: https://und.qualtrics.com/jfe/form/SV_90Ww3jNUcqDL8Gy

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References

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Resources

[1] https://www.youtube.com/watch?v=nkkv96teOxs

[2] https://med.und.edu/daccota/_files/docs/berdc_docs/mmgg_r_code.txt

[3] https://www.youtube.com/watch?v=YtmloAwp2rI

[4] https://www.rstudio.com/resources/cheatsheets/

[5] https://med.und.edu/daccota/_files/docs/berdc_docs/statistical_software_toolkit_handout.docx

[6] http://www.ecostat.unical.it/Tarsitano/Didattica/LabStat2/Everitt.pdf

[7] https://www.youtube.com/watch?v=eiivMNBZvw8

[8] https://med.und.edu/daccota/_files/pdfs/berdc_resource_pdfs/stat_decision_tree.pdf

[9] https://www.youtube.com/watch?v=kpmnFMznYt8

[10] https://www.youtube.com/watch?v=YeKXdLFw0YI

Images

[1] https://d3gqasl9vmjfd8.cloudfront.net/83b73cac-f64d-4f7a-b6a5-78bbc6e6c559.png

[2] https://plotly-book.cpsievert.me/images/plotlyGGally.gif

[4] https://blogs.sas.com/content/graphicallyspeaking/files/2013/03/VBox4.png

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