

Multiple Regression & Model Selection

Justin Baumann

Table of contents

1	Multiple Regression and Model Selection	1
1.1	Load packages	1
1.2	Get our penguin data ready!	2
1.3	What is the effect of year on bill depth by species?	2
1.3.1	1.) Make a graph to visualize!	2
1.3.2	2.) Build the model	4
1.3.3	3.) view tabular results	4
1.3.4	4.) Model fit assessment	6
1.3.5	5.) A 95% CI plot of model coefficients	8
1.4	An example with numerical vars	10
1.4.1	1.) Run an additive model and an interactive model. View summaries .	10
1.4.2	2.) make the coef data neat and look at model fits	12
1.4.3	3.) make a pretty graph!	13
1.5	Model Selection	14
1.5.1	1.) test assumptions (use performance!)	14
1.5.2	2.) check the model performances and choose the best fit	17
1.5.3	3.) MORE COMPLEX EXAMPLE :)	18

1 Multiple Regression and Model Selection

1.1 Load packages

```
library(tidyverse)
library(broom)
library(palmerpenguins)
library(data.table)
library(performance)
```

```
library(patchwork)
library(car) #to check collinearity
```

My favorite mixed models selection tutorial: [Our Coding Club](#)

1.2 Get our penguin data ready!

```
penguins <- palmerpenguins::penguins

head(penguins)

# A tibble: 6 x 8
  species island bill_length_mm bill_depth_mm flipper_length_mm body_mass_g
  <fct>   <fct>         <dbl>         <dbl>           <int>         <int>
1 Adelie Torgersen         39.1           18.7             181           3750
2 Adelie Torgersen         39.5           17.4             186           3800
3 Adelie Torgersen         40.3            18             195           3250
4 Adelie Torgersen          NA            NA              NA            NA
5 Adelie Torgersen         36.7           19.3             193           3450
6 Adelie Torgersen         39.3           20.6             190           3650
# i 2 more variables: sex <fct>, year <int>
```

```
penguins<-drop_na(penguins)

penguins$year=as.factor(penguins$year) #we are interested in year as a grouping/categorical
```

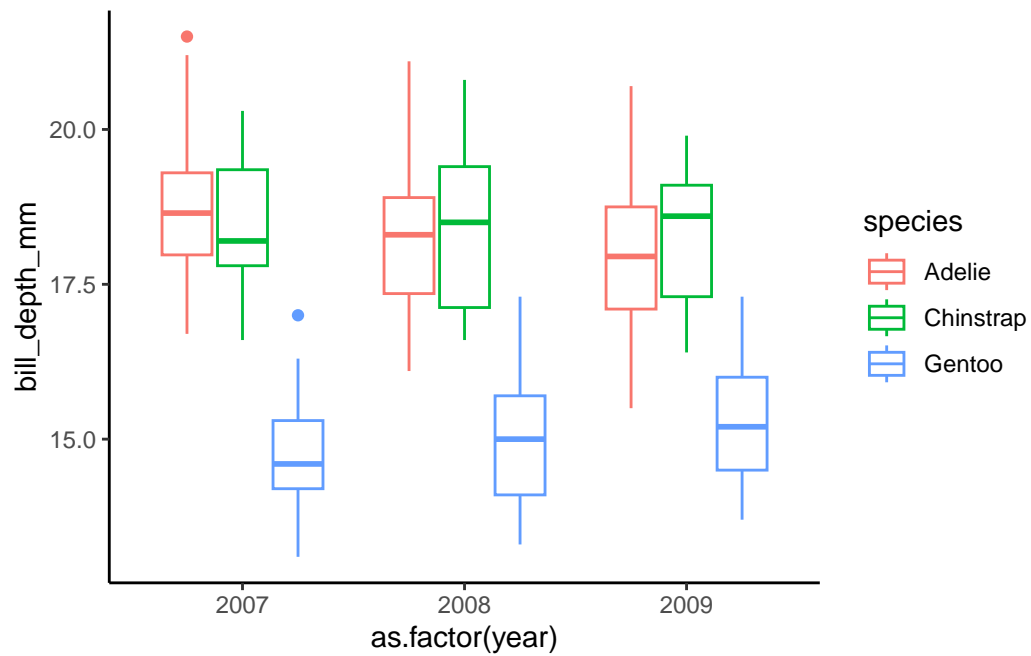
1.3 What is the effect of year on bill depth by species?

1.3.1 1.) Make a graph to visualize!

We will start with a boxplot for a quick check. We would eventually want to calculate means and error bars for the final visualization though! Note that the graph below is a good way to view the interaction of our explanatory variables, which is not what we modeled... We only consider the additive effects (each variable on its own)

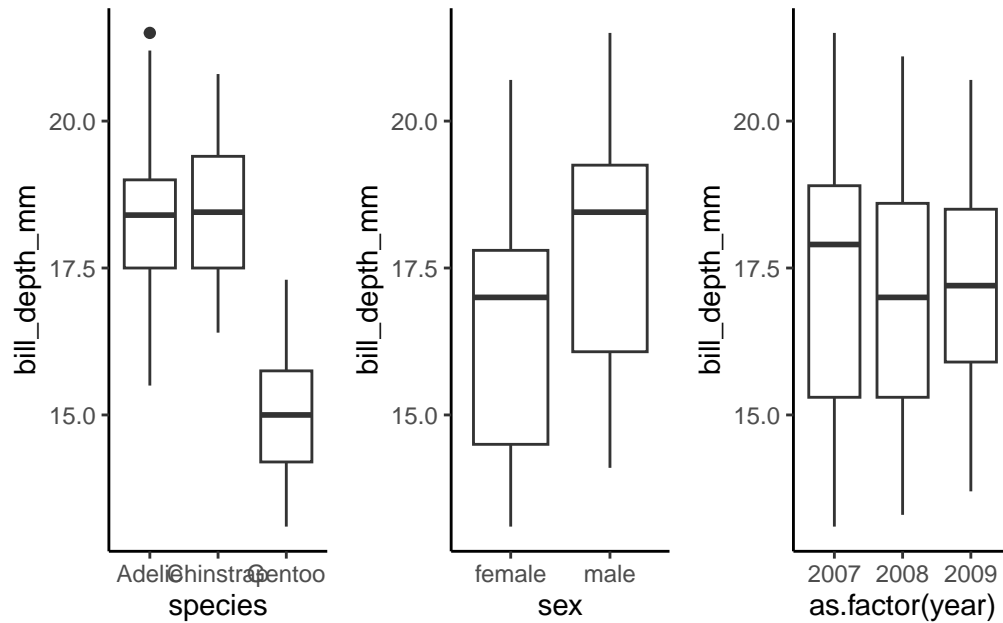
```
# effect of year on bill depth by species
ggplot(data=penguins, aes(x=as.factor(year), y=bill_depth_mm, color=species))+
  geom_boxplot()+
```

```
theme_classic()
```



Visualization of each variable on its own:

```
speciesgraph<-ggplot(data=penguins, aes(x=species, y=bill_depth_mm))+  
  geom_boxplot()+  
  theme_classic()  
  
sexgraph<-ggplot(data=penguins, aes(x=sex, y=bill_depth_mm))+  
  geom_boxplot()+  
  theme_classic()  
  
yeargraph<-ggplot(data=penguins, aes(x=as.factor(year), y=bill_depth_mm))+  
  geom_boxplot()+  
  theme_classic()  
  
speciesgraph+sexgraph+yeargraph
```



1.3.2 2.) Build the model

```
#build the model
lm1<- lm(bill_depth_mm ~ species+sex+year, data=penguins)
```

1.3.3 3.) view tabular results

```
summary(lm1) #check R2 and p-value! How well does the model fit?
```

Call:

```
lm(formula = bill_depth_mm ~ species + sex + year, data = penguins)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-2.07890	-0.56431	-0.00782	0.48485	3.12581

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	17.71835	0.10760	164.672	<2e-16 ***

```

speciesChinstrap 0.05649    0.12232    0.462    0.6445
speciesGentoo    -3.36375    0.10268   -32.760   <2e-16 ***
sexmale          1.50471    0.09107    16.523   <2e-16 ***
year2008         -0.21053    0.11374    -1.851    0.0651 .
year2009         -0.14416    0.11239    -1.283    0.2005
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```

Residual standard error: 0.8308 on 327 degrees of freedom
Multiple R-squared:  0.8247,    Adjusted R-squared:  0.822
F-statistic: 307.6 on 5 and 327 DF,  p-value: < 2.2e-16

```

```
summary(lm1)$coefficient #just the coef table from the summary!
```

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	17.71835149	0.10759801	164.6717403	1.229960e-316
speciesChinstrap	0.05649237	0.12231501	0.4618597	6.444891e-01
speciesGentoo	-3.36375169	0.10267709	-32.7604888	2.664705e-105
sexmale	1.50470770	0.09106922	16.5226813	5.184519e-45
year2008	-0.21053181	0.11373677	-1.8510443	6.506474e-02
year2009	-0.14416134	0.11238907	-1.2826989	2.005060e-01

```
anova(lm1) # an ANOVA table of our lm
```

Analysis of Variance Table

```

Response: bill_depth_mm
      Df Sum Sq Mean Sq  F value Pr(>F)
species  2  870.79   435.39  630.7435 <2e-16 ***
sex       1  188.50   188.50  273.0716 <2e-16 ***
year      2    2.45    1.23   1.7771 0.1708
Residuals 327  225.72    0.69
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```
confint(lm1) #CIs for our model predictors!
```

	2.5 %	97.5 %
(Intercept)	17.5066798	17.93002315
speciesChinstrap	-0.1841312	0.29711599
speciesGentoo	-3.5657427	-3.16176068
sexmale	1.3255522	1.68386318
year2008	-0.4342799	0.01321630
year2009	-0.3652582	0.07693551

-t / pvalue tells us whether there is a sig association between the predictor and the outcome variable...

-in stats terms, this tells us whether the beta coef of predictor is significantly different from zero

-coefficient can be interpreted as average effect on y of a one unit increase in predictor, holding all other predictors fixed

Here, we have an additive model and we see from the anova table and the lm summary that there are significant effects of species and sex on bill depth but that there is not effect on year. Next, let's look at the data again to confirm!

1.3.4 4.) Model fit assessment

Here, we want to know how well the model represent the data. We need: 1. The R2 value of the model (closer to 1 is best) 2. The p-value of the model (<0.05 is required for there to be a relationship) 3. We can calculate residual standard error. Lower = more accurate!

The R2 and p are in the summary! Below is the formula for RMSE

```
summary(lm1)
```

Call:

```
lm(formula = bill_depth_mm ~ species + sex + year, data = penguins)
```

Residuals:

Min	1Q	Median	3Q	Max
-2.07890	-0.56431	-0.00782	0.48485	3.12581

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	17.71835	0.10760	164.672	<2e-16 ***
speciesChinstrap	0.05649	0.12232	0.462	0.6445
speciesGentoo	-3.36375	0.10268	-32.760	<2e-16 ***

```
sexmale          1.50471    0.09107   16.523   <2e-16 ***
year2008         -0.21053    0.11374   -1.851    0.0651 .
year2009         -0.14416    0.11239   -1.283    0.2005
```

```
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.8308 on 327 degrees of freedom
```

```
Multiple R-squared:  0.8247,    Adjusted R-squared:  0.822
```

```
F-statistic: 307.6 on 5 and 327 DF,  p-value: < 2.2e-16
```

```
#RSE: <- LOWER RSE= more accurate the model!
sigma(lm1)
```

```
[1] 0.8308337
```

```
mean(penguins$bill_depth_mm)
```

```
[1] 17.16486
```

```
sigma(lm1)/mean(penguins$bill_depth_mm)
```

```
[1] 0.04840316
```

```
#0.048, or 4.8% error rate
```

We can also get this information from the performance package using `model_performance`. This function tells us many things, including R2 and RMSE. We will discuss the rest of this later

```
model_performance(lm1)
```

```
# Indices of model performance
```

AIC		AICc		BIC		R2		R2 (adj.)		RMSE		Sigma
829.532		829.876		856.189		0.825		0.822		0.823		0.831

1.3.5 5.) A 95% CI plot of model coefficients

combine data! Use tidy() from the broom package to get nice neat dataframes from models

```
coefs<-tidy(lm1, quick=FALSE)
coefs
```

```
# A tibble: 6 x 5
  term          estimate std.error statistic    p.value
<chr>          <dbl>     <dbl>     <dbl>    <dbl>
1 (Intercept)    17.7      0.108     165. 1.23e-316
2 speciesChinstrap 0.0565    0.122      0.462 6.44e- 1
3 speciesGentoo   -3.36     0.103     -32.8 2.66e-105
4 sexmale         1.50     0.0911     16.5 5.18e- 45
5 year2008        -0.211    0.114      -1.85 6.51e- 2
6 year2009        -0.144    0.112      -1.28 2.01e- 1
```

```
ci<-data.table(confint(lm1), keep.rownames='term')
ci
```

```
      term      2.5 %      97.5 %
1: (Intercept) 17.5066798 17.93002315
2: speciesChinstrap -0.1841312 0.29711599
3: speciesGentoo -3.5657427 -3.16176068
4: sexmale 1.3255522 1.68386318
5: year2008 -0.4342799 0.01321630
6: year2009 -0.3652582 0.07693551
```

```
cidf<-cbind(coefs,ci)
cidf
```

```
      term      estimate std.error  statistic    p.value
1 (Intercept) 17.71835149 0.10759801 164.6717403 1.229960e-316
2 speciesChinstrap 0.05649237 0.12231501  0.4618597 6.444891e-01
3 speciesGentoo -3.36375169 0.10267709 -32.7604888 2.664705e-105
4 sexmale 1.50470770 0.09106922 16.5226813 5.184519e-45
5 year2008 -0.21053181 0.11373677 -1.8510443 6.506474e-02
6 year2009 -0.14416134 0.11238907 -1.2826989 2.005060e-01
      term      2.5 %      97.5 %
```



```

1      (Intercept) 17.5066798 17.93002315
2 speciesChinstrap -0.1841312  0.29711599
3   speciesGentoo -3.5657427 -3.16176068
4         sexmale  1.3255522  1.68386318
5        year2008 -0.4342799  0.01321630
6        year2009 -0.3652582  0.07693551

```

```
colnames(cidf)
```

```

[1] "term"      "estimate"  "std.error" "statistic" "p.value"   "term"
[7] "2.5 %"     "97.5 %"

```

```

cidf<-cidf[,-6]

cidf<- cidf %>%
  rename("lower"="2.5 %",
         "upper"="97.5 %")

cidf

```

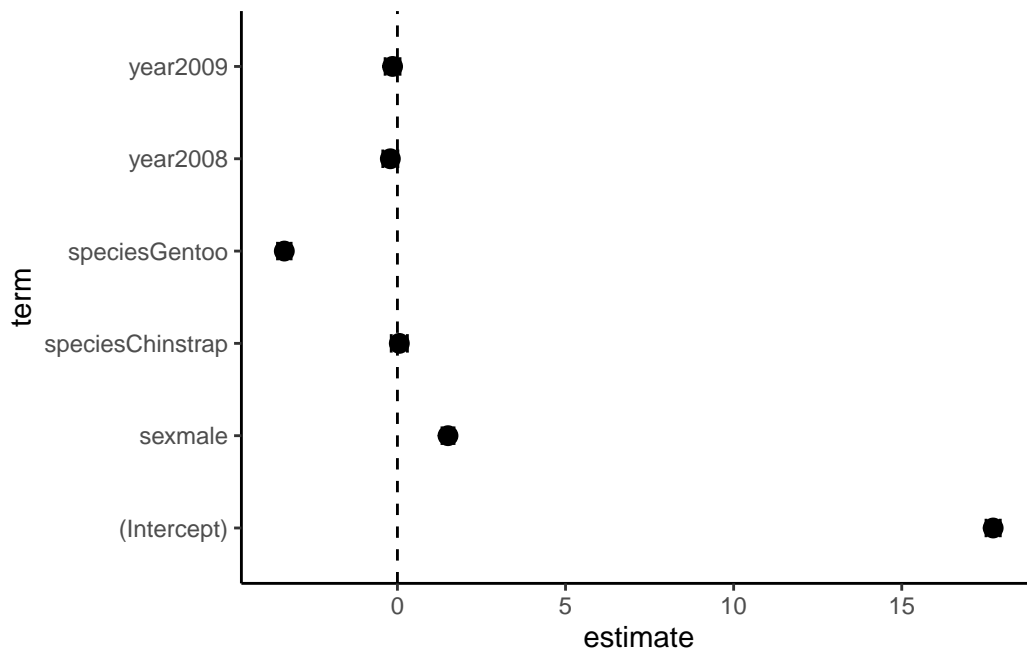
	term	estimate	std.error	statistic	p.value	lower
1	(Intercept)	17.71835149	0.10759801	164.6717403	1.229960e-316	17.5066798
2	speciesChinstrap	0.05649237	0.12231501	0.4618597	6.444891e-01	-0.1841312
3	speciesGentoo	-3.36375169	0.10267709	-32.7604888	2.664705e-105	-3.5657427
4	sexmale	1.50470770	0.09106922	16.5226813	5.184519e-45	1.3255522
5	year2008	-0.21053181	0.11373677	-1.8510443	6.506474e-02	-0.4342799
6	year2009	-0.14416134	0.11238907	-1.2826989	2.005060e-01	-0.3652582

	upper
1	17.93002315
2	0.29711599
3	-3.16176068
4	1.68386318
5	0.01321630
6	0.07693551

```
cidf$term=as.factor(cidf$term)
```

Now make a plot!

```
ggplot(data=cidf, aes(x=estimate, y=term))+
  geom_vline(xintercept = 0, linetype=2)+
  geom_point(size=3)+
  geom_errorbarh(aes(xmax=lower, xmin=upper),height=0.2)+
  theme_classic()
```



Note that there are many ways to build a dataframe and plot for these. This is just one example. Here we can visualize that the effects of each variable individually are not very large.

1.4 An example with numerical vars

1.4.1 1.) Run an additive model and an interactive model. View summaries

```
lm2<-lm(bill_depth_mm ~ bill_length_mm + species, data=penguins)
lm3<-lm(bill_depth_mm ~ bill_length_mm * species, data=penguins)

#look at summary
summary(lm2)
```

```
Call:
lm(formula = bill_depth_mm ~ bill_length_mm + species, data = penguins)
```

```
Residuals:
    Min       1Q   Median       3Q      Max
-2.4579 -0.6814 -0.0431  0.5441  3.5994
```

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    10.56526     0.69093   15.291 < 2e-16 ***
bill_length_mm  0.20044     0.01768   11.337 < 2e-16 ***
speciesChinstrap -1.93308     0.22572   -8.564 4.26e-16 ***
speciesGentoo   -5.10332     0.19440  -26.252 < 2e-16 ***
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.9543 on 329 degrees of freedom
Multiple R-squared:  0.7673,    Adjusted R-squared:  0.7652
F-statistic: 361.6 on 3 and 329 DF,  p-value: < 2.2e-16
```

```
summary(lm3)
```

```
Call:
lm(formula = bill_depth_mm ~ bill_length_mm * species, data = penguins)
```

```
Residuals:
    Min       1Q   Median       3Q      Max
-2.6574 -0.6559 -0.0483  0.5203  3.4990
```

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    11.48771     1.15987   9.904 < 2e-16 ***
bill_length_mm  0.17668     0.02981   5.928 7.79e-09 ***
speciesChinstrap -3.91857     2.06731  -1.895  0.0589 .
speciesGentoo   -6.36675     1.77990  -3.577  0.0004 ***
bill_length_mm:speciesChinstrap  0.04553     0.04594   0.991  0.3224
bill_length_mm:speciesGentoo    0.03093     0.04112   0.752  0.4525
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.9556 on 327 degrees of freedom
```

Multiple R-squared: 0.7681, Adjusted R-squared: 0.7645
 F-statistic: 216.6 on 5 and 327 DF, p-value: < 2.2e-16

1.4.2 2.) make the coef data neat and look at model fits

```
tidy(lm2)
```

```
# A tibble: 4 x 5
```

	term <chr>	estimate <dbl>	std.error <dbl>	statistic <dbl>	p.value <dbl>
1	(Intercept)	10.6	0.691	15.3	2.98e-40
2	bill_length_mm	0.200	0.0177	11.3	2.26e-25
3	speciesChinstrap	-1.93	0.226	-8.56	4.26e-16
4	speciesGentoo	-5.10	0.194	-26.3	1.04e-82

```
tidy(lm3)
```

```
# A tibble: 6 x 5
```

	term <chr>	estimate <dbl>	std.error <dbl>	statistic <dbl>	p.value <dbl>
1	(Intercept)	11.5	1.16	9.90	2.14e-20
2	bill_length_mm	0.177	0.0298	5.93	7.79e- 9
3	speciesChinstrap	-3.92	2.07	-1.90	5.89e- 2
4	speciesGentoo	-6.37	1.78	-3.58	4.00e- 4
5	bill_length_mm:speciesChinstrap	0.0455	0.0459	0.991	3.22e- 1
6	bill_length_mm:speciesGentoo	0.0309	0.0411	0.752	4.52e- 1

```
#have a look at model fit
glance(lm2) #R2 is really good-> 76.5!
```

```
# A tibble: 1 x 12
```

	r.squared <dbl>	adj.r.squared <dbl>	sigma <dbl>	statistic <dbl>	p.value <dbl>	df <dbl>	logLik <dbl>	AIC <dbl>	BIC <dbl>
1	0.767	0.765	0.954	362.	8.88e-104	3	-455.	920.	939.

```
# i 3 more variables: deviance <dbl>, df.residual <int>, nobs <int>
```

```
glance(lm3) #r2 is 0.768!
```

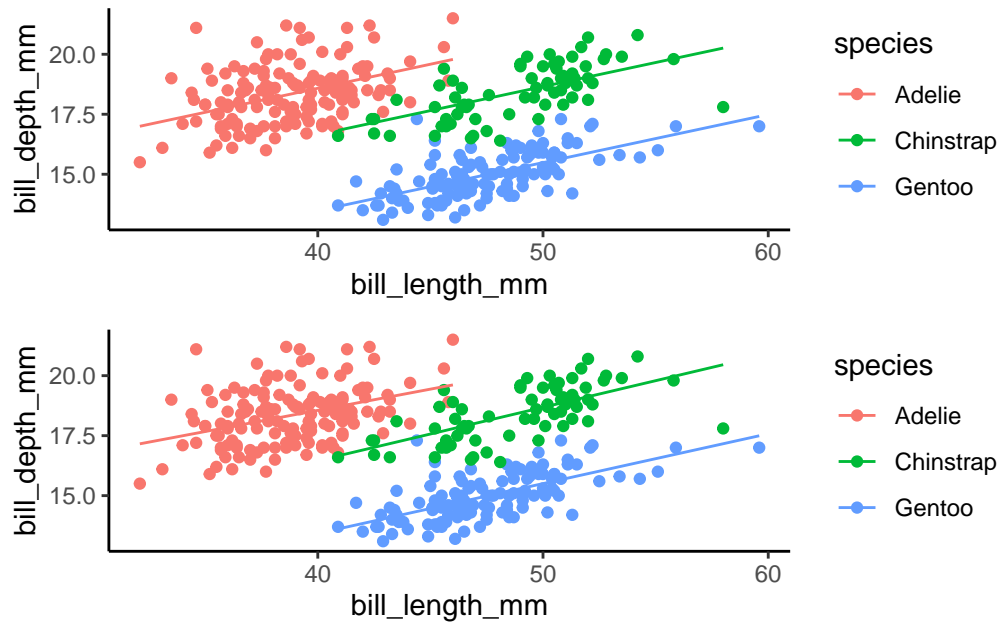
```
# A tibble: 1 x 12
  r.squared adj.r.squared sigma statistic  p.value    df logLik  AIC   BIC
    <dbl>         <dbl> <dbl>      <dbl>    <dbl> <dbl> <dbl> <dbl> <dbl>
1    0.768         0.765 0.956      217. 1.87e-101     5 -454.  923.  949.
# i 3 more variables: deviance <dbl>, df.residual <int>, nobs <int>
```

1.4.3 3.) make a pretty graph!

```
lm2g<-lm2 %>%
  augment() %>%
  ggplot(aes(x=bill_length_mm, y=bill_depth_mm, color=species))+
  geom_point()+
  geom_line(aes(y=.fitted))+
  theme_classic()

lm3g<-lm3 %>%
  augment() %>%
  ggplot(aes(x=bill_length_mm, y=bill_depth_mm, color=species))+
  geom_point()+
  geom_line(aes(y=.fitted))+
  theme_classic()

lm2g/lm3g #lm2 has same y int for all! lm3 does not (because of the interaction term!!!)
```



1.5 Model Selection

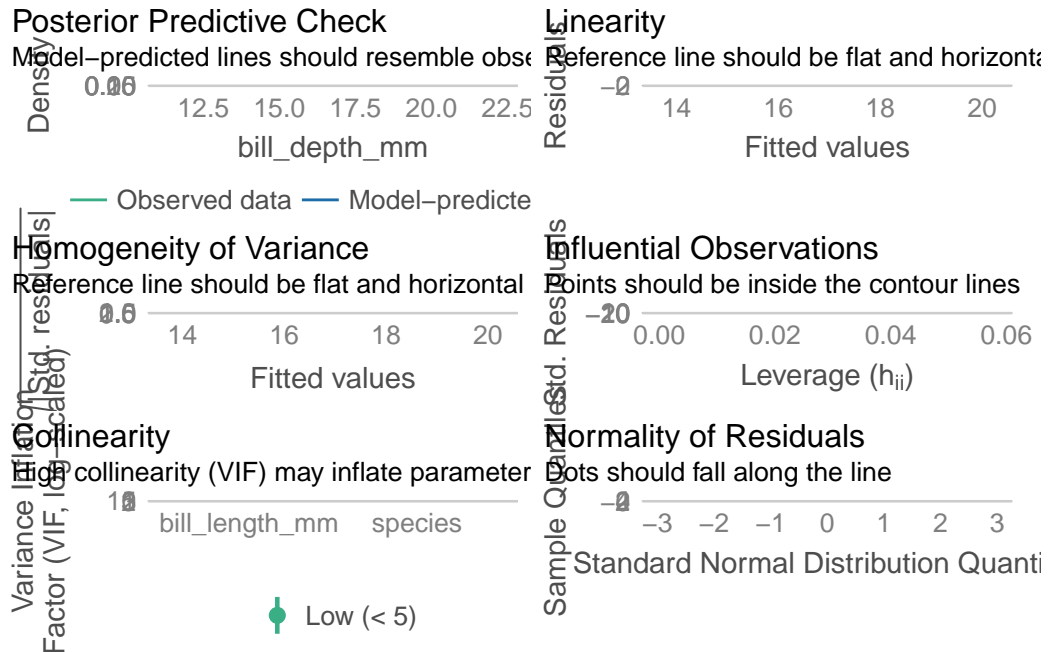
1.5.1 1.) test assumptions (use performance!)

```
model_performance(lm2)
```

```
# Indices of model performance
```

AIC		AICc		BIC		R2		R2 (adj.)		RMSE		Sigma
919.835		920.018		938.875		0.767		0.765		0.949		0.954

```
check_model(lm2)#things look good, including low collinearity (VIF)
```



```
vif(lm2)
```

	GVIF	Df	GVIF ^{1/(2*Df)}
<code>bill_length_mm</code>	3.407875	1	1.846043
<code>species</code>	3.407875	2	1.358692

```
model_performance(lm3)
```

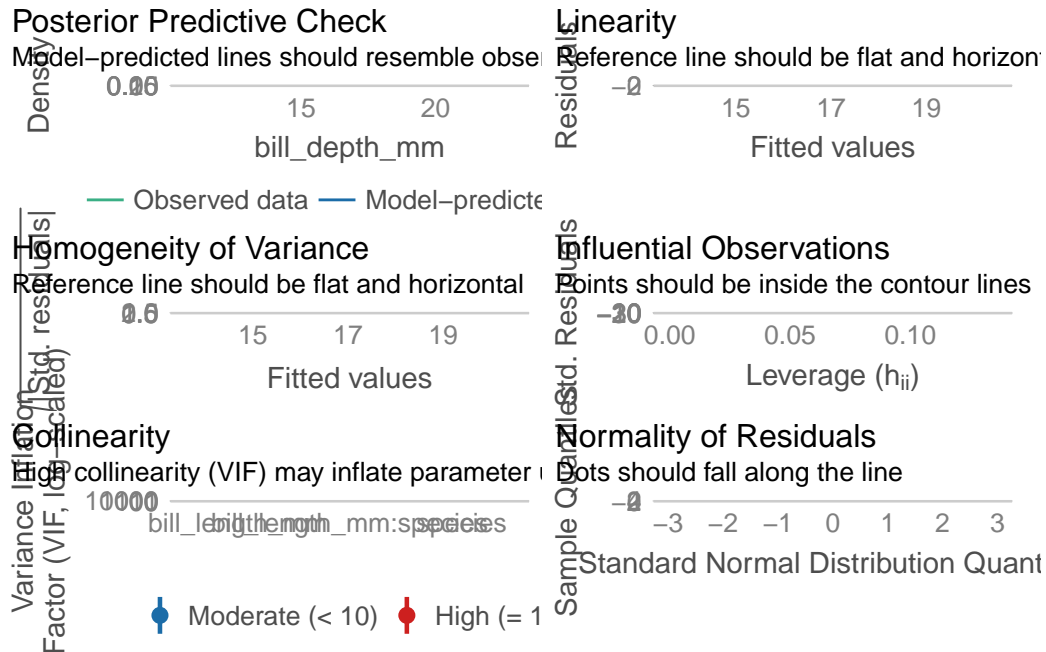
```
# Indices of model performance
```

AIC	AICc	BIC	R2	R2 (adj.)	RMSE	Sigma
922.729	923.074	949.386	0.768	0.765	0.947	0.956

```
check_model(lm3) #things look good, but we have super high VIF
```

Model has interaction terms. VIFs might be inflated.

You may check multicollinearity among predictors of a model without interaction terms.



```
check_collinearity(lm3) #a table of collinearity results - we would need to remove stuff f
```

Model has interaction terms. VIFs might be inflated.

You may check multicollinearity among predictors of a model without interaction terms.

Check for Multicollinearity

Moderate Correlation

Term	VIF	VIF 95% CI	Increased SE	Tolerance
bill_length_mm	9.66	[7.94, 11.81]	3.11	0.10
Tolerance 95% CI [0.08, 0.13]				

High Correlation

Term	VIF	VIF 95% CI	Increased SE	Tolerance
species	49899.43	[40473.88, 61520.04]	223.38	2.00e-05
bill_length_mm:species	64717.85	[52493.21, 79789.42]	254.40	1.55e-05
Tolerance 95% CI				


```
[0.00, 0.00]
[0.00, 0.00]
```

```
vif(lm3) #gives us a more useful table- tells us that species and species*bill length are
```

there are higher-order terms (interactions) in this model
consider setting type = 'predictor'; see ?vif

	GVIF	Df	GVIF ^{1/(2*Df)}
bill_length_mm	9.658784	1	3.107858
species	49899.425896	2	14.945962
bill_length_mm:species	64717.849261	2	15.949829

What do we do? We remove interaction terms one by one, thereby simplifying the model, until the VIF are low enough to be meaningful (all below 5 is a good rule of thumb)

since the model without the * is just lm2, we are all set.

1.5.2 2.) check the model performances and choose the best fit

```
compare_performance(lm2,lm3,rank=TRUE)
```

Comparison of Model Performance Indices

Name	Model	R2	R2 (adj.)	RMSE	Sigma	AIC weights	AICc weights	BIC weights
lm2	lm	0.767	0.765	0.949	0.954	0.810	0.822	0.995
lm3	lm	0.768	0.765	0.947	0.956	0.190	0.178	0.005

-This is a comprehensive model check that uses many vars to assess the best model.

-Here, lm2 wins easily! R2 are about the same, RMSE (residual mean square error) is about the same.

-AICweights tell us thje relative likelihood of a model– closer to 1 is best. ***when you look at AIC scores (slightly different from AIC weights, the lower the value, the better)

1.5.3 3.) MORE COMPLEX EXAMPLE :)

```
lm4<-lm(bill_depth_mm ~ bill_length_mm * species * sex, data=penguins)

#look at summary
summary(lm4)
```

Call:

```
lm(formula = bill_depth_mm ~ bill_length_mm * species * sex,
    data = penguins)
```

Residuals:

Min	1Q	Median	3Q	Max
-2.06730	-0.52452	-0.06471	0.45593	2.90319

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	14.84023	1.77185	8.376	1.73e-15
bill_length_mm	0.07466	0.04749	1.572	0.1169
speciesChinstrap	-0.25160	2.77579	-0.091	0.9278
speciesGentoo	-5.76780	2.98938	-1.929	0.0546
sexmale	4.92359	2.46355	1.999	0.0465
bill_length_mm:speciesChinstrap	-0.01026	0.06596	-0.155	0.8765
bill_length_mm:speciesGentoo	0.03871	0.07101	0.545	0.5860
bill_length_mm:sexmale	-0.09177	0.06360	-1.443	0.1500
speciesChinstrap:sexmale	-11.35403	5.67926	-1.999	0.0464
speciesGentoo:sexmale	-2.41202	3.94469	-0.611	0.5413
bill_length_mm:speciesChinstrap:sexmale	0.24451	0.12006	2.037	0.0425
bill_length_mm:speciesGentoo:sexmale	0.06197	0.09131	0.679	0.4978

(Intercept)	***
bill_length_mm	
speciesChinstrap	
speciesGentoo	.
sexmale	*
bill_length_mm:speciesChinstrap	
bill_length_mm:speciesGentoo	
bill_length_mm:sexmale	
speciesChinstrap:sexmale	*
speciesGentoo:sexmale	
bill_length_mm:speciesChinstrap:sexmale	*

```
bill_length_mm:speciesGentoo:sexmale
```

```
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.8175 on 321 degrees of freedom
```

```
Multiple R-squared:  0.8334,    Adjusted R-squared:  0.8277
```

```
F-statistic: 145.9 on 11 and 321 DF,  p-value: < 2.2e-16
```

```
#make that pretty
tidy(lm4)
```

```
# A tibble: 12 x 5
```

term	estimate	std.error	statistic	p.value
<chr>	<dbl>	<dbl>	<dbl>	<dbl>
1 (Intercept)	14.8	1.77	8.38	1.73e-15
2 bill_length_mm	0.0747	0.0475	1.57	1.17e- 1
3 speciesChinstrap	-0.252	2.78	-0.0906	9.28e- 1
4 speciesGentoo	-5.77	2.99	-1.93	5.46e- 2
5 sexmale	4.92	2.46	2.00	4.65e- 2
6 bill_length_mm:speciesChinstrap	-0.0103	0.0660	-0.155	8.77e- 1
7 bill_length_mm:speciesGentoo	0.0387	0.0710	0.545	5.86e- 1
8 bill_length_mm:sexmale	-0.0918	0.0636	-1.44	1.50e- 1
9 speciesChinstrap:sexmale	-11.4	5.68	-2.00	4.64e- 2
10 speciesGentoo:sexmale	-2.41	3.94	-0.611	5.41e- 1
11 bill_length_mm:speciesChinstrap:sexmale	0.245	0.120	2.04	4.25e- 2
12 bill_length_mm:speciesGentoo:sexmale	0.0620	0.0913	0.679	4.98e- 1

```
#look at fit
glance(lm4) #nice r2!
```

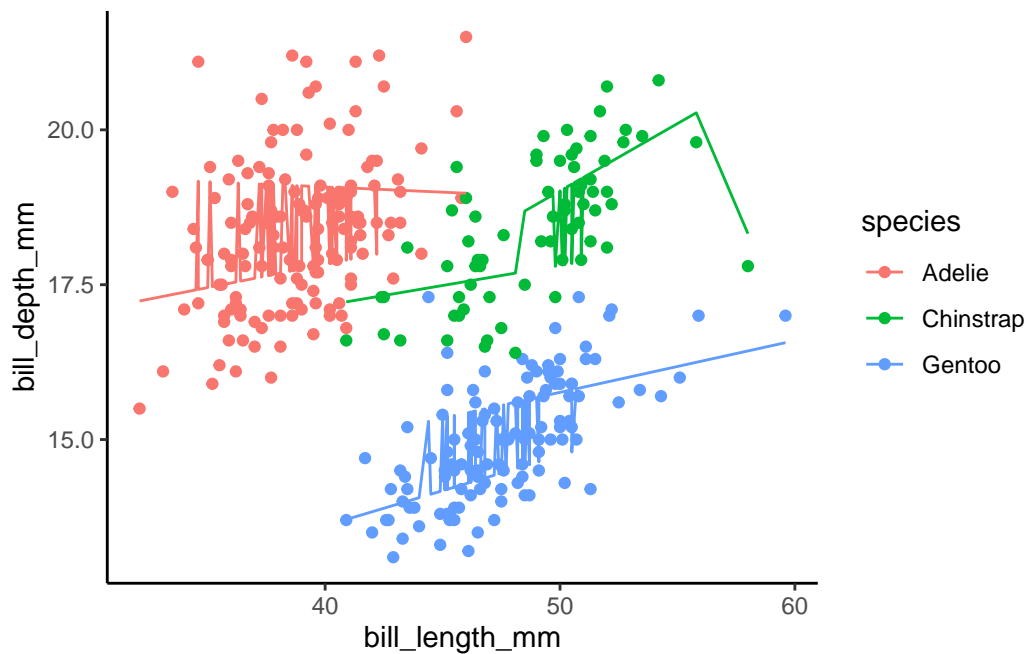
```
# A tibble: 1 x 12
```

r.squared	adj.r.squared	sigma	statistic	p.value	df	logLik	AIC	BIC
<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
1 0.833	0.828	0.818	146.	9.55e-118	11	-399.	825.	874.

```
# i 3 more variables: deviance <dbl>, df.residual <int>, nobs <int>
```

```
# make a pretty graph!
lm4 %>%
  augment() %>%
```

```
ggplot(aes(x=bill_length_mm, y=bill_depth_mm,color=species))+
  geom_point()+
  geom_line(aes(y=.fitted))+
  theme_classic()
```



#oops, that isn't quite right. What are we missing?

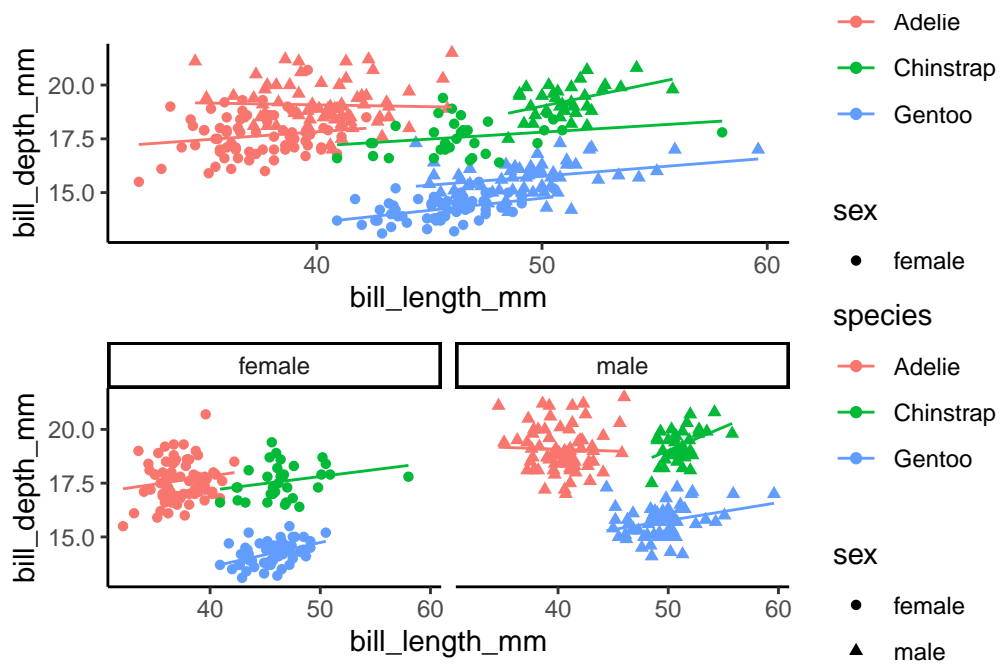
```
lm4g2<-lm4 %>%
  augment() %>%
  ggplot(aes(x=bill_length_mm, y=bill_depth_mm,color=species, shape=sex))+
  geom_point()+
  geom_line(aes(y=.fitted))+
  theme_classic()
```

#OR

```
lm4g3<-lm4 %>%
  augment() %>%
  ggplot(aes(x=bill_length_mm, y=bill_depth_mm,color=species, shape=sex))+
  geom_point()+
  geom_line(aes(y=.fitted))+
  theme_classic()+
```

```
facet_wrap(~sex)
```

```
#compare graphs!  
lm4g2/lm4g3
```



1.5.3.1 CIs and a graph for this one!

```
coefs<-tidy(lm4)  
coefs
```

```
# A tibble: 12 x 5
```

term	estimate	std.error	statistic	p.value
<chr>	<dbl>	<dbl>	<dbl>	<dbl>
1 (Intercept)	14.8	1.77	8.38	1.73e-15
2 bill_length_mm	0.0747	0.0475	1.57	1.17e-1
3 speciesChinstrap	-0.252	2.78	-0.0906	9.28e-1
4 speciesGentoo	-5.77	2.99	-1.93	5.46e-2
5 sexmale	4.92	2.46	2.00	4.65e-2
6 bill_length_mm:speciesChinstrap	-0.0103	0.0660	-0.155	8.77e-1
7 bill_length_mm:speciesGentoo	0.0387	0.0710	0.545	5.86e-1
8 bill_length_mm:sexmale	-0.0918	0.0636	-1.44	1.50e-1

9	speciesChinstrap:sexmale	-11.4	5.68	-2.00	4.64e- 2
10	speciesGentoo:sexmale	-2.41	3.94	-0.611	5.41e- 1
11	bill_length_mm:speciesChinstrap:sexmale	0.245	0.120	2.04	4.25e- 2
12	bill_length_mm:speciesGentoo:sexmale	0.0620	0.0913	0.679	4.98e- 1

```
cis<-data.table(confint(lm4), keep.rownames = 'term')
cis
```

	term	2.5 %	97.5 %
1:	(Intercept)	11.354321139	18.32613470
2:	bill_length_mm	-0.018764802	0.16808708
3:	speciesChinstrap	-5.712636771	5.20943941
4:	speciesGentoo	-11.649049135	0.11344307
5:	sexmale	0.076849623	9.77033563
6:	bill_length_mm:speciesChinstrap	-0.140025236	0.11951459
7:	bill_length_mm:speciesGentoo	-0.100987370	0.17840241
8:	bill_length_mm:sexmale	-0.216904270	0.03335517
9:	speciesChinstrap:sexmale	-22.527308826	-0.18075321
10:	speciesGentoo:sexmale	-10.172726533	5.34869591
11:	bill_length_mm:speciesChinstrap:sexmale	0.008304843	0.48071943
12:	bill_length_mm:speciesGentoo:sexmale	-0.117669226	0.24160110

```
CI<-merge(coefs,cis)
CI
```

	term	estimate	std.error	statistic
1	(Intercept)	14.84022792	1.77185076	8.37555183
2	bill_length_mm	0.07466114	0.04748745	1.57222883
3	bill_length_mm:sexmale	-0.09177455	0.06360216	-1.44294716
4	bill_length_mm:speciesChinstrap	-0.01025532	0.06596072	-0.15547623
5	bill_length_mm:speciesChinstrap:sexmale	0.24451214	0.12006175	2.03655314
6	bill_length_mm:speciesGentoo	0.03870752	0.07100548	0.54513425
7	bill_length_mm:speciesGentoo:sexmale	0.06196594	0.09130672	0.67865695
8	sexmale	4.92359263	2.46354990	1.99857638
9	speciesChinstrap	-0.25159868	2.77578981	-0.09064039
10	speciesChinstrap:sexmale	-11.35403102	5.67926283	-1.99920859
11	speciesGentoo	-5.76780303	2.98937724	-1.92943298
12	speciesGentoo:sexmale	-2.41201531	3.94469014	-0.61145875
	p.value	2.5 %	97.5 %	
1	1.731943e-15	11.354321139	18.32613470	

2	1.168826e-01	-0.018764802	0.16808708
3	1.500104e-01	-0.216904270	0.03335517
4	8.765436e-01	-0.140025236	0.11951459
5	4.251519e-02	0.008304843	0.48071943
6	5.860397e-01	-0.100987370	0.17840241
7	4.978442e-01	-0.117669226	0.24160110
8	4.649725e-02	0.076849623	9.77033563
9	9.278349e-01	-5.712636771	5.20943941
10	4.642846e-02	-22.527308826	-0.18075321
11	5.455827e-02	-11.649049135	0.11344307
12	5.413287e-01	-10.172726533	5.34869591

```
CI<- CI %>%
  rename("lower"="2.5 %",
         "upper"="97.5 %")
CI
```

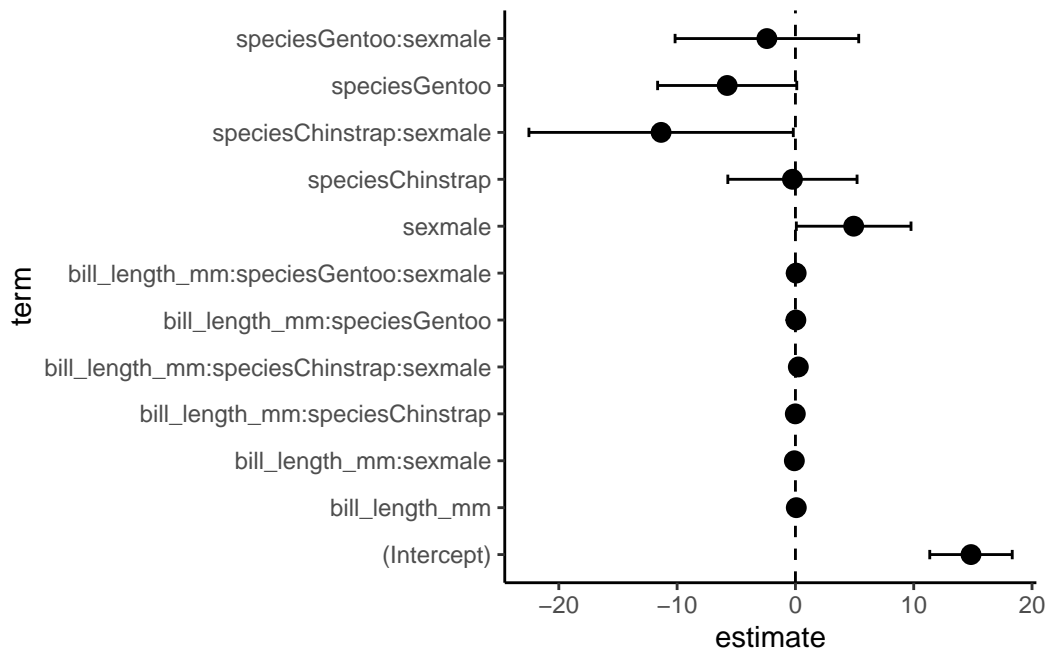
	term	estimate	std.error	statistic
1	(Intercept)	14.84022792	1.77185076	8.37555183
2	bill_length_mm	0.07466114	0.04748745	1.57222883
3	bill_length_mm:sexmale	-0.09177455	0.06360216	-1.44294716
4	bill_length_mm:speciesChinstrap	-0.01025532	0.06596072	-0.15547623
5	bill_length_mm:speciesChinstrap:sexmale	0.24451214	0.12006175	2.03655314
6	bill_length_mm:speciesGentoo	0.03870752	0.07100548	0.54513425
7	bill_length_mm:speciesGentoo:sexmale	0.06196594	0.09130672	0.67865695
8	sexmale	4.92359263	2.46354990	1.99857638
9	speciesChinstrap	-0.25159868	2.77578981	-0.09064039
10	speciesChinstrap:sexmale	-11.35403102	5.67926283	-1.99920859
11	speciesGentoo	-5.76780303	2.98937724	-1.92943298
12	speciesGentoo:sexmale	-2.41201531	3.94469014	-0.61145875

	p.value	lower	upper
1	1.731943e-15	11.354321139	18.32613470
2	1.168826e-01	-0.018764802	0.16808708
3	1.500104e-01	-0.216904270	0.03335517
4	8.765436e-01	-0.140025236	0.11951459
5	4.251519e-02	0.008304843	0.48071943
6	5.860397e-01	-0.100987370	0.17840241
7	4.978442e-01	-0.117669226	0.24160110
8	4.649725e-02	0.076849623	9.77033563
9	9.278349e-01	-5.712636771	5.20943941
10	4.642846e-02	-22.527308826	-0.18075321
11	5.455827e-02	-11.649049135	0.11344307

12 5.413287e-01 -10.172726533 5.34869591

```
ciplot<-ggplot(data=CI, aes(x=estimate, y=term))+  
  geom_vline(xintercept = 0, linetype=2)+  
  geom_point(size=3)+  
  geom_errorbarh(aes(xmin=lower, xmax=upper), height=0.2)+  
  theme_classic()
```

ciplot



```
#a graph of the good stuff  
ciplot/lm4g2
```