Record of Final Project Analysis on Option 1

Presentation link:
https://docs.google.com/presentation/d/1g4zw2AAl91n7ixVO5JWWwLh13ZEgVO1gnXjCHqhVpnI/edit?usp=sharing

Research Questions:

1. By: Vivian Ho

2. Due: 7/11, 2024

    - Which factor(s) and/or interactions seem to have the greatest effect on this golfer's putting accuracy and warrant further study?
    - How does the length of the putt affect the golfer's putting accuracy?
    - What is the impact of the type of putter on the distance from the ball to the center of the cup?
    - Does the break of the putt significantly influence putting accuracy?
    - How does the slope of the putt affect the golfer's ability to make the putt?
    - Is there an interaction between the length of the putt and type of putter that affects putting accuracy?
    - Does the combination of putt length and break of the putt have a significant effect on putting accuracy?
    - How do the break of the putt and the slope of the putt interact to influence the distance from the ball to the center of the top?
    - How consistent are the effects of these factors across the seven replicates of the experiment?

SAS Programming

1. By: Junhong Chen

2. Due: 7/12, 2024

Presentation: Submit a recording of your presentation by the end of 7/12

1. Introduction (Junhong, 2-3 minutes)

a. Overview

b. Dataset description

c. Methods

    i. Analysis performed

    ii. Hypothesis

2. Results and discussion

    a. For Model 1 (Alex, 1 minutes)

        i. Check assumptions

        ii. Interpretation of p-values

        iii. Identify significantly different treatments using pairwise tests.

    b. For model 2 (Log transformed, Alex, 1 minutes)

        i. Check assumptions
        ii. Interpretation of p-values
        iii. Identify significantly different treatments using pairwise tests.

    c. For model 3 (Log transformed, Vivian, 1 minutes)

        i. Check assumptions
        ii. Interpretation of p-values
        iii. Identify significantly different treatments using pairwise tests.

    d. For model 4 (Log transformed, Vivian, 1 minutes)

        i. Check assumptions
        ii. Interpretation of p-values
        iii. Identify significantly different treatments using pairwise tests.

3. Limitations, Future Works, and Conclusion (person 4, 2-3 minutes) (Riddhi Dixit)

    a. Compare all models

    b. Limitations

    c. Future Works

d. Conclusion

Link to the audio recordings here (Please upload by 8 am 7/13):

ANALYSIS	**40**
Fit the appropriate model based on the experimental design.	
Correctly perform ANOVA on the data.	
Reduce the ANOVA model, if necessary.	
Verify the assumptions for inference, transforming the response and re-running ANOVA, if necessary.	
Identify significantly different treatments using pairwise tests.	

PRESENTATION	**60**
Introduction	5
Summarize the goals of the experiment, the experimental design, and the data.	
Results and Discussion	25
Present your analysis results, explaining your process along the way (i.e. justifying any model simplification, variable transformation, etc. using the prior results)	
Interpret and explain the ANOVA results and pairwise tests.	
Make the professor happy and show that you have learned how to interpret a p-value beyond the reject vs. fail to reject decision!	
Limitations and Future Work	20
Scrutinize the experimental design. What would you have done differently had you been involved in the design stage of this factor screening experiment?	
Scrutinize your analysis. Is there anything you wish you could have done differently? (Note that this limitations section is not to serve as an excuse for performing insufficient analysis.)	
Give your recommendations for how to carry out a larger follow-up factorial experiment based on your conclusions from factor screening.	
General	10
Your presentation duration is between 8 to 12 minutes, and all group members make roughly equal contributions to the presentation.	
Your presentation looks professional; it is well-organized and proofread to avoid grammatical mistakes.	

Record of Final Project Analysis on Option 1

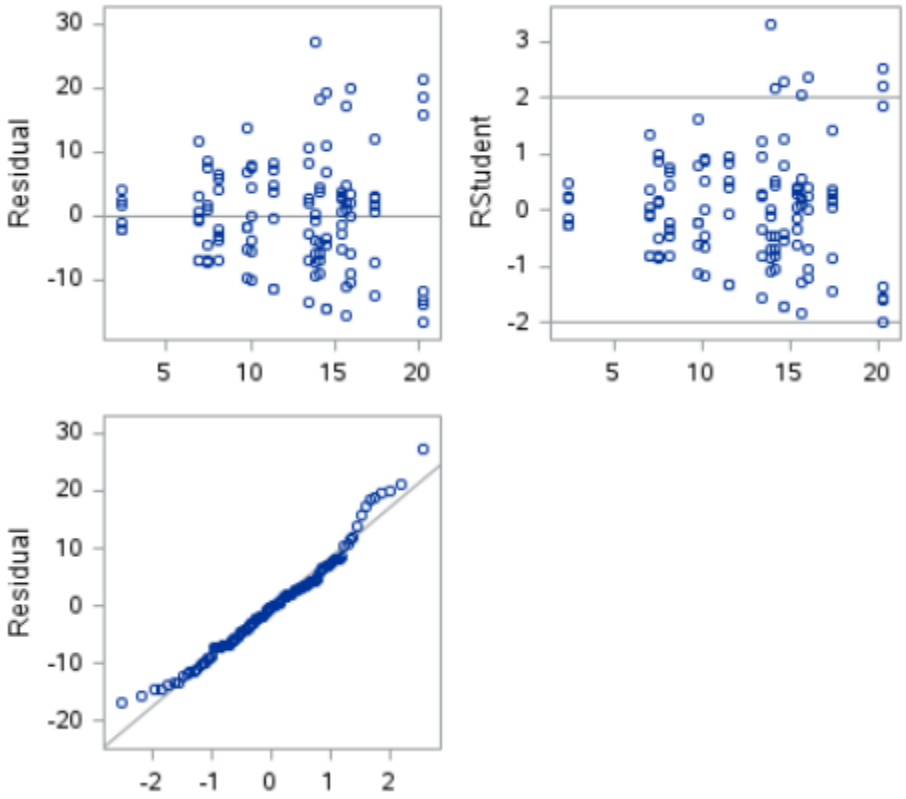
Alex Solar, Junhong Chen, Riddhi Dixit, Vivian Ho

a. Hypothesis.

H_0**:** There is no effect of length, putter type, break, slope, and their interactions on the putting accuracy.

H_1: At least one of the factors or their interactions affects the putting accuracy.

b. Check assumptions of the initial ANOVA.



To conduct an ANOVA for a factorial design, we need to test the following assumptions:

- The ϵij's have a Normal distribution.
- The variance of the ϵij's is constant.

The QQ-Plot shows that lots of points are not aligned on the diagonal line, this could indicate potential issues with normality. There are clear fanning patterns on the Residual vs. Predicted Values plots, this suggest that the variance of the residuals might not be constant across the range of predicted values. The studentized residual plot shows that the data are bounded between -2 and 3, so we can state that the data **do not** meet the condition for equal variance.

c. Relevant output.

The GLM Procedure

Dependent Variable: Response Response

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	2238.44420	149.22961	1.72	0.0589
Error	96	8315.78571	86.62277		
Corrected Total	111	10554.22991			

R-Square	Coeff Var	Root MSE	Response Mean
0.212090	75.67326	9.307135	12.29911

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Length	1	917.1450893	917.1450893	10.59	0.0016
Putter	1	388.1450893	388.1450893	4.48	0.0369
Length*Putter	1	218.6808036	218.6808036	2.52	0.1154
Break	1	145.1450893	145.1450893	1.68	0.1986
Length*Break	1	11.8950893	11.8950893	0.14	0.7118
Putter*Break	1	115.0200893	115.0200893	1.33	0.2521
Length*Putter*Break	1	7.2522321	7.2522321	0.08	0.7729
Slope	1	1.3950893	1.3950893	0.02	0.8993
Length*Slope	1	93.8058036	93.8058036	1.08	0.3007
Putter*Slope	1	56.4308036	56.4308036	0.65	0.4216
Length*Putter*Slope	1	113.0022321	113.0022321	1.30	0.2562
Break*Slope	1	1.6272321	1.6272321	0.02	0.8913
Length*Break*Slope	1	39.4843750	39.4843750	0.46	0.5012
Putter*Break*Slope	1	33.7700893	33.7700893	0.39	0.5339
Leng*Putt*Brea*Slope	1	95.6450893	95.6450893	1.10	0.2960

Least Squares Means for Effect Leng*Putt*Brea*Slope
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: Response

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		-0.93326 0.9999	-1.03377 0.9996	-1.16299 0.9985	-2.32597 0.6059	-1.83781 0.8960	-1.56501 0.9707	-2.64185 0.3834	-2.38341 0.5644	-1.50758 0.9790	-3.61818 0.0374	-2.46955 0.5021	-2.23983 0.6673	-3.04387 0.1711	-2.75671 0.3120	-2.68492 0.3557
2	0.933261 0.9999		-0.10051 1.0000	-0.22973 1.0000	-1.39271 0.9901	-0.90455 0.9999	-0.63175 1.0000	-1.70859 0.9395	-1.45014 0.9854	-0.57431 1.0000	-2.68492 0.3557	-1.53629 0.9751	-1.30657 0.9948	-2.11061 0.7537	-1.82345 0.9016	-1.75166 0.9267
3	1.033767 0.9996	0.100505 1.0000		-0.12922 1.0000	-1.29221 0.9953	-0.80404 1.0000	-0.53124 1.0000	-1.60808 0.9631	-1.34964 0.9927	-0.47381 1.0000	-2.58442 0.4217	-1.43579 0.9867	-1.20606 0.9978	-2.0101 0.8136	-1.72294 0.9354	-1.65115 0.9540
4	1.162987 0.9985	0.229726 1.0000	0.129221 1.0000		-1.16299 0.9985	-0.67482 1.0000	-0.40202 1.0000	-1.47886 0.9824	-1.22042 0.9975	-0.34459 1.0000	-2.4552 0.5125	-1.30657 0.9948	-1.07684 0.9994	-1.88088 0.8780	-1.59372 0.9658	-1.52193 0.9771
5	2.325975 0.6059	1.392713 0.9901	1.292208 0.9953	1.162987 0.9985		0.488168 1.0000	0.760967 1.0000	-0.31587 1.0000	-0.05743 1.0000	0.818398 1.0000	-1.29221 0.9953	-0.14358 1.0000	0.086147 1.0000	-0.71789 1.0000	-0.43074 1.0000	-0.35895 1.0000
6	1.837807 0.8960	0.904546 0.9999	0.804041 1.0000	0.67482 1.0000	-0.48817 1.0000		0.272799 1.0000	-0.80404 1.0000	-0.5456 1.0000	0.330231 1.0000	-1.78038 0.9173	-0.63175 1.0000	-0.40202 1.0000	-1.20606 0.9978	-0.9189 0.9999	-0.84711 1.0000
7	1.565008 0.9707	0.631746 1.0000	0.531241 1.0000	0.40202 1.0000	-0.76097 1.0000	-0.2728 1.0000		-1.07684 0.9994	-0.8184 1.0000	0.057431 1.0000	-2.05318 0.7888	-0.90455 0.9999	-0.67482 1.0000	-1.47886 0.9824	-1.1917 0.9980	-1.11991 0.9990
8	2.641848 0.3834	1.708586 0.9395	1.608081 0.9631	1.47886 0.9824	0.315873 1.0000	0.804041 1.0000	1.07684 0.9994		0.258442 1.0000	1.134272 0.9989	-0.97634 0.9998	0.172294 1.0000	0.40202 1.0000	-0.40202 1.0000	-0.11486 1.0000	-0.04307 1.0000
9	2.383406 0.5644	1.450145 0.9854	1.34964 0.9927	1.220419 0.9975	0.057431 1.0000	0.545599 1.0000	0.818398 1.0000	-0.25844 1.0000		0.87583 0.9999	-1.23478 0.9971	-0.08615 1.0000	0.143579 1.0000	-0.66046 1.0000	-0.3733 1.0000	-0.30152 1.0000
10	1.507576 0.9790	0.574315 1.0000	0.47381 1.0000	0.344589 1.0000	-0.8184 1.0000	-0.33023 1.0000	-0.05743 1.0000	-1.13427 0.9989	-0.87583 0.9999		-2.11061 0.7537	-0.96198 0.9998	-0.73225 1.0000	-1.53629 0.9751	-1.24913 0.9967	-1.17735 0.9983
11	3.618183 0.0374	2.684921 0.3557	2.584416 0.4217	2.455195 0.5125	1.292208 0.9953	1.780376 0.9173	2.053175 0.7888	0.976335 0.9998	1.234777 0.9971	2.110607 0.7537		1.148629 0.9987	1.378355 0.9910	0.574315 1.0000	0.861472 1.0000	0.933261 0.9999
12	2.469553 0.5021	1.536292 0.9751	1.435787 0.9867	1.306566 0.9948	0.143579 1.0000	0.631746 1.0000	0.904546 0.9999	-0.17229 1.0000	0.086147 1.0000	0.961977 0.9998	-1.14863 0.9987		0.229726 1.0000	-0.57431 1.0000	-0.28716 1.0000	-0.21537 1.0000
13	2.239827 0.6673	1.306566 0.9948	1.206061 0.9978	1.07684 0.9994	-0.08615 1.0000	0.40202 1.0000	0.67482 1.0000	-0.40202 1.0000	-0.14358 1.0000	0.732251 1.0000	-1.37836 0.9910	-0.22973 1.0000		-0.80404 1.0000	-0.51688 1.0000	-0.44509 1.0000
14	3.043868 0.1711	2.110607 0.7537	2.010102 0.8136	1.880881 0.8780	0.717893 1.0000	1.206061 0.9978	1.47886 0.9824	0.40202 1.0000	0.660462 1.0000	1.536292 0.9751	-0.57431 1.0000	0.574315 1.0000	0.804041 1.0000		0.287157 1.0000	0.358947 1.0000
15	2.756711 0.3120	1.823449 0.9016	1.722944 0.9354	1.593723 0.9658	0.430736 1.0000	0.918904 0.9999	1.191703 0.9980	0.114863 1.0000	0.373305 1.0000	1.249135 0.9967	-0.86147 1.0000	0.287157 1.0000	0.516883 1.0000	-0.28716 1.0000		0.071789 1.0000
16	2.684921 0.3557	1.75166 0.9267	1.651155 0.9540	1.521934 0.9771	0.358947 1.0000	0.847114 1.0000	1.119914 0.9990	0.043074 1.0000	0.301515 1.0000	1.177345 0.9983	-0.93326 0.9999	0.215368 1.0000	0.445094 1.0000	-0.35895 1.0000	-0.07179 1.0000	

The only significant difference in the pairwise tests occurs between treatment combinations 1 and 11, with a p-value of 0.0374, indicating that this pair's mean responses are significantly different at the 95% confidence level. All other p-values are greater than 0.05, suggesting no significant differences between the other combinations. Therefore, focus on the specific conditions in treatment combinations 1 and 11 can potentially guiding future experimental designs or recommendations.

d. Interpretation and conclusion of the initial ANOVA.

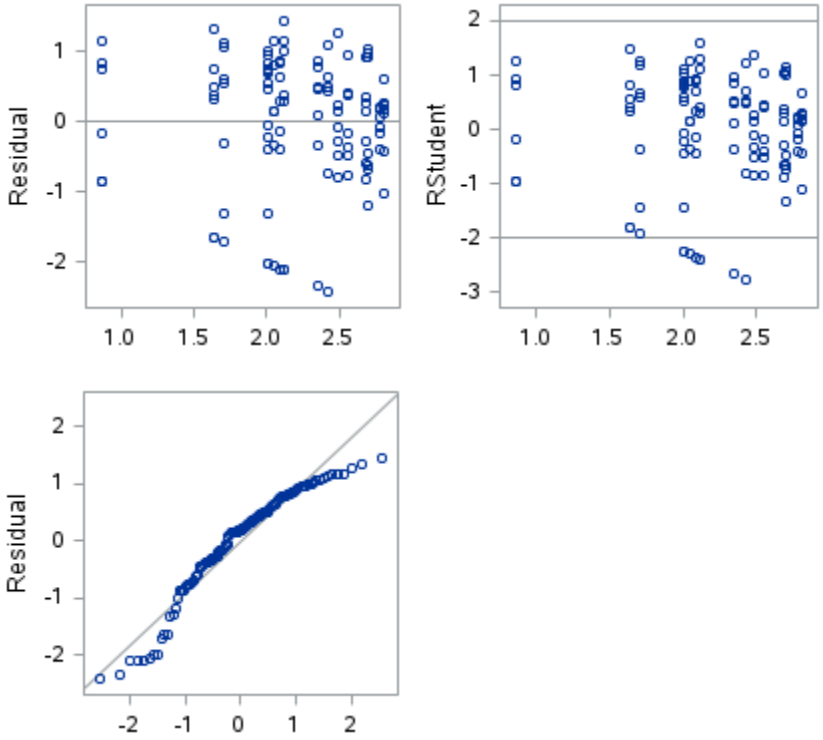
The only significant effects are:

- Length ($p = 0.0016$)
- Putter ($p = 0.0369$)

All other effects, including all interaction terms, are non-significant.

These findings suggest that other than the length of the putter and the type of putter used, other factors and their interactions do not significantly influence the putting accuracy in this experiment.

d. Need an additional model? (Ver 1, not working)



Dependent Variable: Log_Response

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	27.5285876	1.8352392	1.90	0.0319
Error	96	92.5311608	0.9638663		
Corrected Total	111	120.0597484			

R-Square	Coeff Var	Root MSE	Log_Response Mean
0.229291	44.53516	0.981767	2.204476

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Length	1	7.37341650	7.37341650	7.65	0.0068
Putter	1	6.97587873	6.97587873	7.24	0.0084
Length*Putter	1	2.35034639	2.35034639	2.44	0.1217
Break	1	1.34719362	1.34719362	1.40	0.2400
Length*Break	1	0.89116938	0.89116938	0.92	0.3387
Putter*Break	1	0.52941361	0.52941361	0.55	0.4604
Length*Putter*Break	1	0.14877808	0.14877808	0.15	0.6953
Slope	1	0.07506306	0.07506306	0.08	0.7808
Length*Slope	1	2.05347257	2.05347257	2.13	0.1477
Putter*Slope	1	0.08097623	0.08097623	0.08	0.7726
Length*Putter*Slope	1	2.04797987	2.04797987	2.12	0.1482
Break*Slope	1	0.00509478	0.00509478	0.01	0.9422
Length*Break*Slope	1	0.94805239	0.94805239	0.98	0.3238
Putter*Break*Slope	1	0.43784581	0.43784581	0.45	0.5019
Leng*Putt*Brea*Slope	1	2.26390658	2.26390658	2.35	0.1287

Least Squares Means for Effect Leng*Putt*Brea*Slope
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

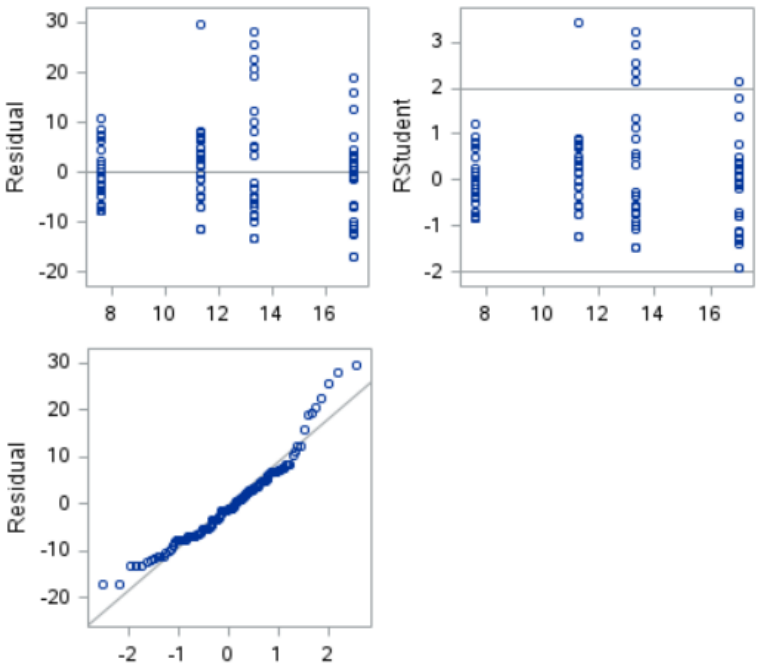
Dependent Variable: Log_Response

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		-1.4828 0.9820	-1.61408 0.9619	-2.18647 0.7040	-3.09719 0.1511	-2.19394 0.6989	-2.34913 0.5892	-3.65603 0.0334	-3.23144 0.1087	-2.26901 0.6467	-3.50538 0.0519	-2.39737 0.5543	-2.83222 0.2695	-3.71257 0.0281	-3.46703 0.0579	-2.98758 0.1943
2	1.482795 0.9820		-0.13128 1.0000	-0.70368 1.0000	-1.61439 0.9618	-0.71115 1.0000	-0.86633 1.0000	-2.17324 0.7129	-1.74864 0.9277	-0.78621 1.0000	-2.02258 0.8065	-0.91457 0.9999	-1.34943 0.9927	-2.22978 0.6743	-1.98423 0.8277	-1.50478 0.9794
3	1.614076 0.9619	0.13128 1.0000		-0.57239 1.0000	-1.48311 0.9819	-0.57987 1.0000	-0.73505 1.0000	-2.04196 0.7954	-1.61736 0.9612	-0.65493 1.0000	-1.8913 0.8734	-0.78329 1.0000	-1.21814 0.9975	-2.0985 0.7613	-1.85295 0.8899	-1.3735 0.9913
4	2.18647 0.7040	0.703675 1.0000	0.572395 1.0000		-0.91072 0.9999	-0.00747 1.0000	-0.16266 1.0000	-1.46956 0.9834	-1.04497 0.9996	-0.08254 1.0000	-1.31891 0.9942	-0.2109 1.0000	-0.64575 1.0000	-1.5261 0.9766	-1.28056 0.9958	-0.80111 1.0000
5	3.097186 0.1511	1.61439 0.9618	1.48311 0.9819	0.910715 0.9999		0.903242 0.9999	0.748059 1.0000	-0.55885 1.0000	-0.13425 1.0000	0.828176 1.0000	-0.40819 1.0000	0.699819 1.0000	0.264965 1.0000	-0.61539 1.0000	-0.36984 1.0000	0.10961 1.0000
6	2.193944 0.6989	0.711149 1.0000	0.579869 1.0000	0.007474 1.0000	-0.90324 0.9999		-0.15518 1.0000	-1.46209 0.9842	-1.0375 0.9996	-0.07507 1.0000	-1.31143 0.9946	-0.20342 1.0000	-0.63828 1.0000	-1.51863 0.9776	-1.27308 0.9960	-0.79363 1.0000
7	2.349127 0.5892	0.866332 1.0000	0.735052 1.0000	0.162657 1.0000	-0.74806 1.0000	0.155183 1.0000		-1.3069 0.9948	-0.88231 0.9999	0.080118 1.0000	-1.15625 0.9986	-0.04824 1.0000	-0.48309 1.0000	-1.36344 0.9919	-1.1179 0.9990	-0.63845 1.0000
8	3.656032 0.0334	2.173237 0.7129	2.041957 0.7954	1.469562 0.9834	0.558846 1.0000	1.462088 0.9842	1.306905 0.9948		0.424593 1.0000	1.387023 0.9905	0.150654 1.0000	1.258665 0.9965	0.823812 1.0000	-0.05654 1.0000	0.189006 1.0000	0.668456 1.0000
9	3.231439 0.1087	1.748644 0.9277	1.617364 0.9612	1.044969 0.9996	0.134254 1.0000	1.037495 0.9996	0.882312 0.9999	-0.42459 1.0000		0.96243 0.9998	-0.27394 1.0000	0.834072 1.0000	0.399219 1.0000	-0.48113 1.0000	-0.23559 1.0000	0.243863 1.0000
10	2.269009 0.6467	0.786214 1.0000	0.654934 1.0000	0.082539 1.0000	-0.82818 1.0000	0.075065 1.0000	-0.08012 1.0000	-1.38702 0.9905	-0.96243 0.9998		-1.23637 0.9971	-0.12836 1.0000	-0.56321 1.0000	-1.44356 0.9860	-1.19802 0.9979	-0.71857 1.0000
11	3.505378 0.0519	2.022582 0.8065	1.891302 0.8734	1.318907 0.9942	0.408192 1.0000	1.311434 0.9946	1.156251 0.9986	-0.15065 1.0000	0.273939 1.0000	1.236368 0.9971		1.108011 0.9991	0.673157 1.0000	-0.20719 1.0000	0.038351 1.0000	0.517802 1.0000
12	2.397367 0.5543	0.914572 0.9999	0.783292 1.0000	0.210897 1.0000	-0.69982 1.0000	0.203423 1.0000	0.04824 1.0000	-1.25866 0.9965	-0.83407 1.0000	0.128358 1.0000	-1.10801 0.9991		-0.43485 1.0000	-1.3152 0.9944	-1.06966 0.9994	-0.59021 1.0000
13	2.83222 0.2695	1.349425 0.9927	1.218145 0.9975	0.64575 1.0000	-0.26497 1.0000	0.638276 1.0000	0.483093 1.0000	-0.82381 1.0000	-0.39922 1.0000	0.563211 1.0000	-0.67316 1.0000	0.434853 1.0000		-0.88035 0.9999	-0.63481 1.0000	-0.15536 1.0000
14	3.712572 0.0281	2.229776 0.6743	2.098496 0.7613	1.526101 0.9766	0.615386 1.0000	1.518627 0.9776	1.363444 0.9919	0.056539 1.0000	0.481132 1.0000	1.443562 0.9860	0.207194 1.0000	1.315204 0.9944	0.880351 0.9999		0.245545 1.0000	0.724996 1.0000
15	3.467027 0.0579	1.984231 0.8277	1.852951 0.8899	1.280556 0.9958	0.369841 1.0000	1.273082 0.9960	1.117899 0.9990	-0.18901 1.0000	0.235587 1.0000	1.198017 0.9979	-0.03835 1.0000	1.069659 0.9994	0.634806 1.0000	-0.24555 1.0000		0.47945 1.0000
16	2.987576 0.1943	1.504781 0.9794	1.373501 0.9913	0.801106 1.0000	-0.10961 1.0000	0.793632 1.0000	0.638449 1.0000	-0.66846 1.0000	-0.24386 1.0000	0.718567 1.0000	-0.5178 1.0000	0.590209 1.0000	0.155356 1.0000	-0.725 1.0000	-0.47945 1.0000	

We first tried log transforming on the Response variable, but got similar results than above: failed assumptions and only Length and Putter are significant.

Tukey's test shows that only pairs (1 and 14), (1 and 8) are significant.

d. Need an additional model? (Ver 2, not working)



The GLM Procedure

Dependent Variable: Response Response

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1305.29018	652.64509	7.69	0.0008
Error	109	9248.93973	84.85266		
Corrected Total	111	10554.22991			

R-Square	Coeff Var	Root MSE	Response Mean
0.123675	74.89609	9.211550	12.29911

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Length	1	917.1450893	917.1450893	10.81	0.0014
Putter	1	388.1450893	388.1450893	4.57	0.0347

The GLM Procedure

Tukey's Studentized Range (HSD) Test for Response

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	109
Error Mean Square	84.85266
Critical Value of Studentized Range	2.80293
Minimum Significant Difference	3.4502

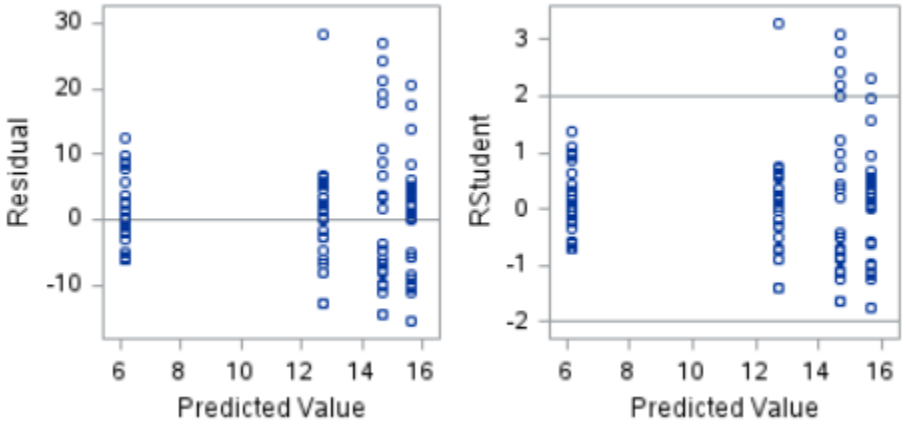
Response Tukey Grouping for Means of Length (Alpha = 0.05)

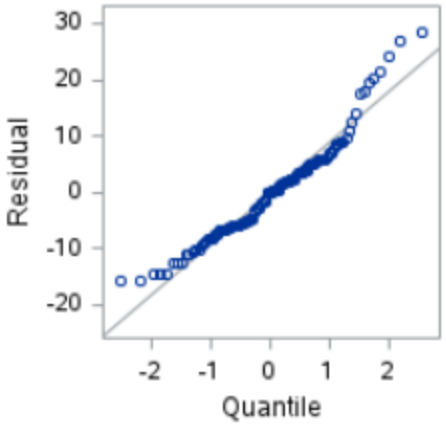
Means covered by the same bar are not significantly different.

Length	Estimate
30	15.1607
10	9.4375

We then tried a reduced model that contains only the significant effects: Length and Putter. Unfortunately, all assumptions failed. Tukey's HSD test results with a Minimum Significant Difference of 3.4502 show that differences between group means must exceed this value to be statistically significant at the 0.05 level.

d. Need an additional model? (Ver 3, not working)





The GLM Procedure

Dependent Variable: Response Response

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1523.97098	507.99033	6.08	0.0007
Error	108	9030.25893	83.61351		
Corrected Total	111	10554.22991			

R-Square	Coeff Var	Root MSE	Response Mean
0.144394	74.34720	9.144042	12.29911

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Length	1	917.1450893	917.1450893	10.97	0.0013
Putter	1	388.1450893	388.1450893	4.64	0.0334
Length*Putter	1	218.6808036	218.6808036	2.62	0.1087

Least Squares Means for Effect Length*Putter
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: Response

i/j	1	2	3	4
1		-2.66705 0.0432	-3.48543 0.0039	-3.86539 0.0011
2	2.667047 0.0432		-0.81838 0.8457	-1.19834 0.6292
3	3.485428 0.0039	0.818381 0.8457		-0.37996 0.9812
4	3.865391 0.0011	1.198344 0.6292	0.379963 0.9812	

The forth model includes the product effect of the Length and Putter, but still failed all assumptions

Pairs that involve combination 1 are all significant.

e. Compare all models.

- **Fit and Appropriateness:** Model 1 and Model 2, being full factorial designs, are comprehensive but don't improve much on significance or assumptions, which suggests overfitting with unnecessary complexity. Model 3, by focusing only on significant factors, offers simplicity and clearer insights, though at the expense of some potential interactions. Model 4 has slightly better R-square, however, the product effect is not significant.
- **Assumptions Adherence:** None of the models fully satisfy the normality and homoscedasticity requirements, with transformations not effectively mitigating these issues.
- **Model Effectiveness:** Model 3's higher significance level for its factors and lower complexity makes it a more practical choice for interpreting effects within this specific dataset.

  Best model: Model 3 (reduced to only significant variables).

Code:

```
proc glm data=clas4160.PROJECT_GOLF plots=diagnostics;
     class Length Putter Break Slope;
     model Response = Length|Putter|Break|Slope;
     LSMEANS Length*Putter*Break*Slope / ADJUST=tukey TDIFF;
run;

/* Not Working */
data golf_transformed;
    set clas4160.PROJECT_GOLF;
    Log_Response = log(Response + 1); /* +1 to avoid log(0) */
run;

proc glm data=golf_transformed plots=diagnostics;
    class Length Putter Break Slope;
    model Log_Response = Length|Putter|Break|Slope;
    LSMEANS Length*Putter*Break*Slope / ADJUST=tukey TDIFF;
run;

/* Reduce model ANOVA with only significant main effects */
proc glm data=clas4160.PROJECT_GOLF plots=diagnostics;
   class Length Putter;
   model Response = Length Putter;
   means length putter / tukey;
run;

/* Reduce model ANOVA with only significant main effects and
their product effect */
proc glm data=clas4160.PROJECT_GOLF plots=diagnostics;
    class Length Putter;
    model Response = Length Putter Length|Putter;
    LSMEANS Length*Putter / ADJUST=tukey TDIFF;
run;
```