EGP Count = 6

Statistical Analysis of Distance Measurement Dataset from Nerf Dog Tennis Ball Blaster Experiment

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1. Background

The Nerf Dog Tennis Ball Blaster (Launcher) is used to collect dataset consisting of distance measurements. The Nerf Dog Blaster is primarily used for throwing ball for dog to catch. The ball can be launched vertically in the air or horizontally up to a distance of 35ft. This ball launcher is made from rubber, nylon, and plastic materials by a company named Hasbro and Gramercy, Inc.. This launcher comes with three balls of same size of 12 inches diameter.

Figure 1 below shows the Nerf Dog Tennis Ball Blaster used for data collection for this statistical analysis experiment project presented in this report.

Figure 1: Nerf Dog Tennis Ball Blaster

There are two factors in this collected dataset of distance measurement experiment. The shooters and balls are the factors. The distance travelled by the balls is the response.

The dataset collected from the experiment is analyzed to identify the best shooter and the ball based on distance response variable using factorial statistical analysis.

2. Design

The distance travelled by the ball is the response variable. [1]The two factors are the shooter and ball. There are a total of 3 levels for each factor for data measurement experiment. There are three shooters and three balls in this data collection experiment. Each shooter shot each ball six times. Hence, there are a total of 54 shots shot by three shooters using three balls.[3] This experiment resulted in a total of 54 distance measurements dataset. This design experiment is balanced 2 factors ANOVA.

The data collected will be analyzed to study and identify the best shooter and the ball.

3. Measurement Evaluation

The dataset for this project experiment is collected using the Nerf Dog Blaster. The Blaster was placed on the top of the table at a height of 28 inches. The blaster was held in place and not allowed to move. The moving blanket was used to get the clear mark for every shot. The blanket was located 124.5 inch away from the base of the table. The marks from all the shots were located within the blanket which made the measurement of distance travelled by the ball easier.

Figure 2: Experimental Setup – Data Collection

The balls were shot from the top of the table at a height of 28 inches as shown in Figure 1. Three shooters were selected for shooting the balls. Shooters 1, 2, and 3 were young child, teenager and an adult respectively. The three balls used in this experiment were slightly different in weight and color. The balls 1, 2, and 3 were yellow, orange, and blue respectively. The ball # 2 was the lightest and ball # 1 was the heaviest among all three balls.

Each shooter shot each ball six times. There are total of 54 shots which results in 54 distance measurements dataset. Before shooting, each ball was immersed into the colored water to get a clear mark on the blanket for measurement purpose. The tape measurement was used to measure the distance travelled by the ball.

The dataset was collected in normal day and weather. Hence, other nuisance factors will be the same for all the distance measurement of each shot.

Before conducting a complete experiment for data collection, one set of factors condition was selected to verify the consistency of the data measurement process. The standard deviation of a dataset consisting of 6 responses from Shooter 1 and Ball 1 was calculated and studied.

The response was found to fall within three standard deviations. The pilot experiment described in Section 4 was also conducted to verify the significance of factors. Then, the experiment for data collection was continued and experiment was completed

Table 1 summarizes the data collection from the Nerf Dog Tennis ball Blaster experiment. There are total of 54 data measurements from three shooters and three different balls.

Table 1: Distance (inch) Measurements for Three Shooters and Balls

Shooter No.	Ball No.		
	1	2	3
1	130	145.375	149
	138	159.25	149.875
	145.5	144.75	145.5
	139.84	164.5	141.75
	128.5	167.875	149.625
	136	157.75	149.5
2	136	159.875	146
	131.5	147.125	145.75
	142.875	161	158.5
	135.125	165.125	149.375
	138.625	160.75	160.25
	139.75	158.75	152.125
3	145.125	161.125	153.125
	148.75	158.875	154.625
	145.25	164.625	150.5
	147.75	161	154
	148.125	163	158.75
	148.375	165.875	160.125

4. Data Collection Plan

A pilot experiment was conducted before completing the entire experiment on a smaller dataset to identify if the chosen factors are significant. First, distance measurements from two extreme shooters 1 and 3 were completed. This measurement consisted of distance measurements of all three balls from these two extreme shooters. This dataset is randomized using SAS code given in

Appendix.[2] After performing the randomization of the pilot dataset, the ANOVA analysis is conducted using Minitab. This ANOVA analysis shows both factors shooter and ball are significant as shown in Table 2.

After verifying the shooter and ball factors are significant, the main experiment was continued and completed. A complete data set is shown in Table 1 and there are total of 54 data measurements.

The total dataset of 54 measurements are randomized using SAS code given in Appendix and subsequent statistical analysis is performed.

5. Results

The results from ANOVA Analysis of dataset from pilot experiment are summarized in Table 2. This analysis indicates both main effects are significant (P-value < 0.001) on individual levels.[1] However, an interaction effect is not significant.

Table 2: Two – Way ANOVA for Pilot Experiment

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Shooter	1	595.44	595.44	21.52	0.000
Ball	2	1890.83	945.42	34.18	0.000
Shooter*Ball	2	39.92	19.96	0.72	0.494
Error	30	829.91	27.66		
Total	35	3356.10			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
5.25961	75.27%	71.15%	64.39%

The AD test for pilot experiment shown in Figure 3 shows normality is marginal (p=0.077) for pilot experiment.

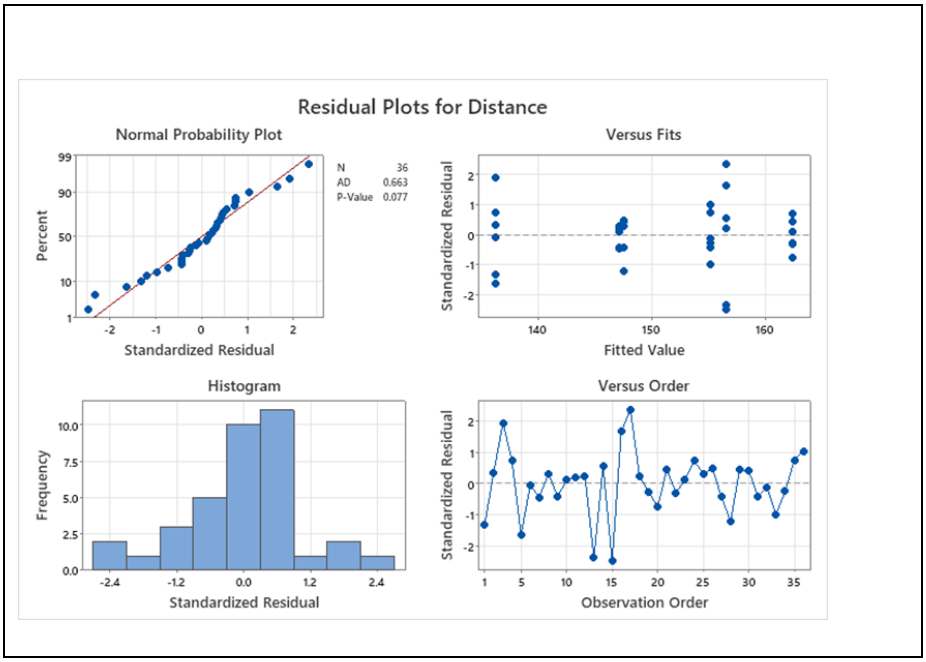


Figure 3: Residual Analysis of Pilot Experiment Dataset

The ANOVA Analysis of main experiment shown in Table 3 indicates both main effects are significant (P-value < 0.001) on individual levels. However, an interaction effect is not significant.

Table 3: Two – Way ANOVA for Distance Travelled

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Shooter	2	623.03	311.52	10.89	0.000
Ball	2	3279.33	1639.67	57.32	0.000
Shooter*Ball	4	95.47	23.87	0.83	0.511
Error	45	1287.19	28.60		
Total	53	5285.03			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
5.34830	75.64%	71.31%	64.93%

The interaction between shooters and balls is not significant and P-value is also above 0.25.[8] Therefore, interaction is eliminated from the model. Then ANOVA analysis is conducted without interaction effects as shown in Table 4. The ANOVA Analysis shown in Table 4 indicates both factors are significant (P-value < 0.001).

Table 4: Two – Way ANOVA for Distance Travelled Pooling Interaction

Analysis of Variance

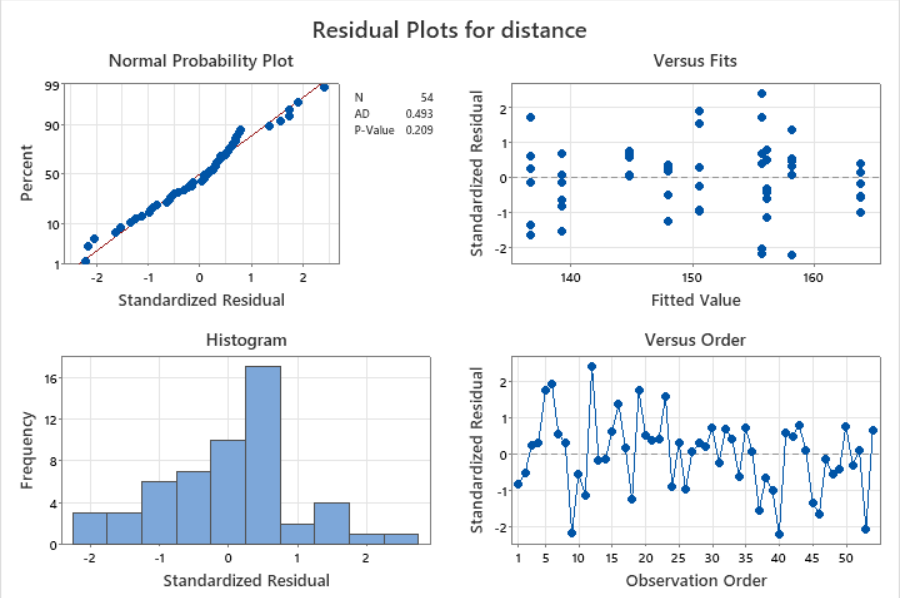
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Shooter	2	623.03	311.52	11.04	0.000
Ball	2	3279.33	1639.67	58.11	0.000
Error	49	1382.66	28.22		
Lack-of-Fit	4	95.47	23.87	0.83	0.511
Pure Error	45	1287.19	28.60		
Total	53	5285.03			

Model Summary

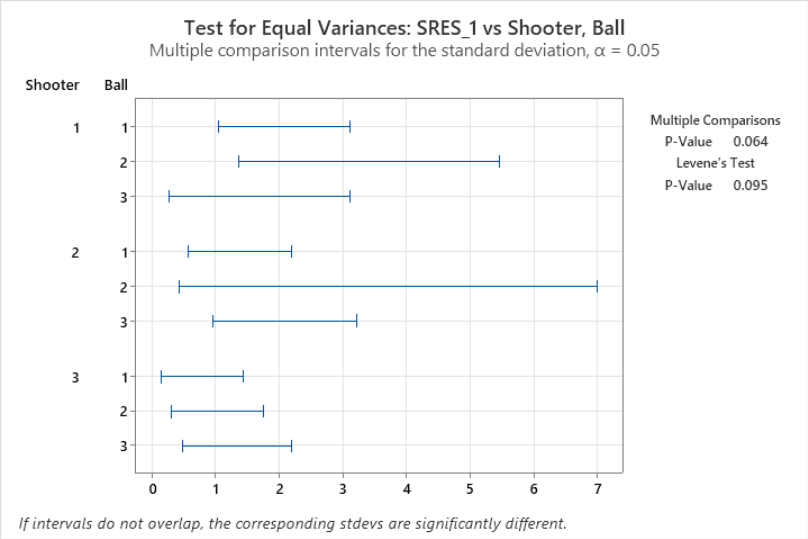
S	R-sq	R-sq(adj)	R-sq(pred)
5.31203	73.84%	71.70%	68.23%

The residual analysis is performed to confirm normality and homogeneity.[7] The results from Residual Analysis are summarized below:

- The AD test in Figure 4 indicates the normality is reasonable (P-value=0.209) after pooling the interaction.
- The Residual is within ±3, so it has no outliers.
- The residual plots in Figure 4 don't show any unusual patterns and Levene's Test isn't significant (P-value=0.095).
- Figure 5 shows that Shooter 3 has slightly lower variability than Shooters 1 and 2. However, Ball has almost equal variability.
- The Histogram is normal and Versus Order plot is independent because it shows no trends or patterns when displayed in time order.[5]



Levene's Test



Fits and Diagnostics for Unusual Observation

Fits and Diagnostics for Unusual Observations

Obs	distance	Fit	Resid	Std Resid	
9	144.75	155.70	-10.95	-2.16	R
12	167.88	155.70	12.18	2.41	R
40	147.13	158.25	-11.12	-2.20	R
53	145.38	155.70	-10.32	-2.04	R

R Large residual

Figure 4: Residual Analysis of Response Variable Distance

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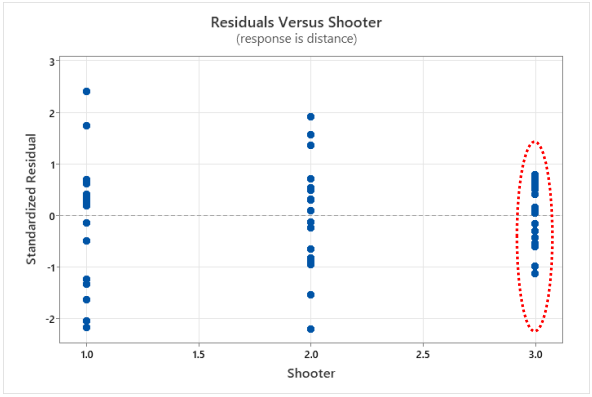
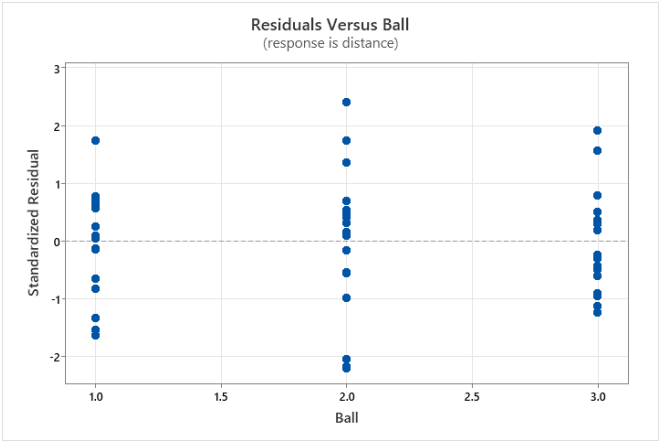
Operator vs. Std. Residuals	Ball vs. Std. Residuals
	

Figure 5: Minitab Residual Factor Plots

The assumption of normality is reasonable for residual analysis. There is slight variability in Shooter 3. However, homogeneity is not severe. Hence, the assumptions for residual analysis are met.

The significant differences may be observed in the different shooters and balls, so Tukey pairwise comparison is used to determine the most effective one.

Tukey pairwise comparison method and PC Bar Plot in Table 4 indicate Shooter 3 and Ball 2 have the highest mean. The sigma distance between the two highest (Shooters 3 and 2) is (154.944-149.361)/√28.60 = 1.04, $\hat{\sigma} = \sqrt{\text{MSE}}$ =5.35. The sigma distance between the two highest (Balls 2 and 3) is (159.257-151.576)/√28.60 =1.44, $\hat{\sigma} = \sqrt{\text{MSE}}$ =5.35.

Therefore, the highest distance is shot by Shooter 3 with a Ball 2.

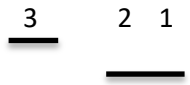
Table 5: Tukey's Multiple Comparison Method and PC Bar Chart

Grouping Information Using the Tukey Method and 95% Confidence

Shooter	N	Mean	Grouping
3	18	154.944	A
2	18	149.361	B
1	18	146.811	B

Means that do not share a letter are significantly different.

PC Bar Chart

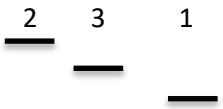


Grouping Information Using the Tukey Method and 95% Confidence

Ball	N	Mean	Grouping
2	18	159.257	A
3	18	151.576	B
1	18	140.283	C

Means that do not share a letter are significantly different.

PC Bar Chart



6. Conclusions

The summary of statistical analysis of dataset from Nerf Dog Blaster experiment is given below.

- Verification of consistency of data measurement process using Shooter 1 and Ball 1 data is performed and showed response is found to be within three standard deviations.
- More data was collected from two extreme shooters (Shooters 1 and 2) for pilot experiment to verify the both factors are significant. This data is randomized in SAS and the ANOVA analysis is performed which shows both factors are significant as shown in Table 2.
- The experiment was continued and completed by all the shooters. This experiment resulted in a dataset with 54 measurements as shown in Table 1.
- The ANOVA analysis of experimental dataset shown in Table 3 shows both the main effects (Shooter and Ball) are significant. However, interaction effect isn't significant.
- The interaction between shooters and ball isn't significant and p-value is above 0.25, so interaction effect is eliminated.

- The ANOVA analysis after eliminating interaction showed both factors are still significant as shown in Table 4.
- The residual analysis shown in Figures 4 and 5 show collected dataset is normal and homogeneity.
- Tukey pairwise comparison shown in Table 5 shows Shooter 3 shot the maximum distance with Ball 2. This experimental study shows Shooter 3 is the best shooter with Ball 2 (lightest ball). Before the experiment, it was guessed that the lightest ball would travel the longest distance. This agrees with the analysis outcome.

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7. Appendix

SAS Code to randomize dataset:

```
call randseed(4321);
random_digit= t(sample(1:54,54, "WOR"));

create rand var {random_digit};
append;
close rand;
quit;

data rand_order;
merge subj rand;
run;

proc print data=rand_order;
run;
```

8. References

1. Wikimedia Foundation. (2023, March 19). *Nerf*. Wikipedia. Retrieved March 22, 2023, from https://en.wikipedia.org/wiki/Nerf
2. O'Neil, S. T. (2012, August 6). *A statistical analysis of Nerf Blasters and darts*. · Shawn T. O'Neil. Retrieved March 22, 2023, from https://oneilsh.github.io/nerf/
3. *Nerf dog*. Nerf Wiki. (n.d.). Retrieved March 22, 2023, from https://nerf.fandom.com/wiki/Nerf_Dog#Nerf_Dog_products