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Lessons Learned from an Incompletely Randomized Test Design Case Study

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Revision 1.0 (16 May 2018) clarifies ambiguities in the barrel significance conclusions.

Executive Summary

This investigation seeks to understand the effects of several factors on the dispersion of two types of ammunition. These data were obtained under controlled conditions. The original test design was evaluated on its merits as a design of experiments and recommended improvements were provided. The executed design did not incorporate the recommendations so the results contained some level of ambiguity. The data was analyzed using graphical and regression methods for comparison. Recommendations for future testing are provided.

All data are real and unclassified but the factor names have been altered to conceal their specifics. The target range at which these results were obtained is not included. The requirements which the results would be compared against for score are not included in this paper.

Keywords: split plot, whole plot, analysis, replication, regression, unbalanced design

Background

The purpose of this testing is to investigate the possible sources of increased dispersion observed during vehicle weapon testing. Previous testing indicated dispersion profiles of Ammo A and B out of the Mann Barrel were found to be outside of performance specification requirements. Mann Barrel refers to a heavy-walled test barrel that is fitted with rings which are concentric with the bore. Such Barrels may be fitted with one of various kinds of actions and are used for accuracy testing (SAAMI Glossary, 2018). After a number of tests, two causes for the degraded dispersion values were found. The first cause is that the setup for the Mann Barrel did not provide for consistent aiming within shot groups. The previous Mann Barrel configuration allowed for a small amount of movement in the y-axis, and between shots it is possible that the aim point changed. The second cause for the high dispersion values was originally suspected to be due to the projectile impacting the muzzle brake upon muzzle exit, which would potentially influence projectile tip off.

Test Details

This testing will investigate the causes of poor dispersion values of the Ammo A and B and assess projectile launch anomalies and associated possible influences as the projectile exits. The analysis will compare the dispersion values in a more controlled and repeatable manner and uncover all statistically significant factors. Video was captured along with the data provided in this paper but the video is not part of this statistical analysis.

Response

The response is round impact location in the X and Y directions from the aim point. The resulting spread in the data is referred to as dispersion.

Factors

The factors (levels) are:

- Barrel (1, 2)
- Muzzle brake (on, off)
- Round Temperature (-1.0, 0.23, 1.0)
    - Temperature was controlled in actual F° and coded between -1 and 1 for this paper
- Ammunition (Ammo A, Ammo B)
- Ammunition lot (1, 2, 3, 4)
    - Ammunition A (old and new) and Ammunition B (old and new)

Design Assumptions

- The firing sequence shall be conducted in a manner that randomizes the factors
- Training rounds shall be fired at the start of testing each day, between Mann barrel changeover, and between long breaks to ensure proper target impact and data acquisition
- Aim point shall be verified before every shot
- Rounds will be fired one at a time (not rapid fire) in groups at each condition
- Rounds will be fired into a paper target and replaced after each shot group
- Ammo A old lot is a limiting resource
    - Only 22 rounds available for the entire design
    - All other Ammo Lots will supply 10 rounds per group
- Mann barrel is not expected to show any statistically significant effect on the data

Original Design

Table 1 shows the test point matrix from the original test plan.

Table 1: Original Design Test Point Matrix

Run Order	Mann Barrel	Ammo Type	Lot	Muzzle Brake	Temp Condition (F)	# of Rounds to be Fired
1	1	B	4	Off	0.23	10
2	1	A	2	Off	-1	10
3	1	A	1	On	-1	5
4	1	B	3	Off	0.23	10
5	1	B	4	Off	1	10
6	1	A	2	On	1	10
7	1	A	1	On	0.23	5
8	1	A	2	On	1	10
9	1	B	4	On	-1	10
10	1	A	2	Off	1	10
11	1	B	3	Off	-1	10
12	1	B	3	On	1	10
13	2	B	4	On	-1	10
14	2	B	4	On	0.23	10
15	2	A	2	Off	-1	10
16	2	A	1	Off	0.23	4
17	2	B	3	Off	-1	10
18	2	B	4	On	0.23	10
19	2	A	1	Off	1	4
20	2	B	4	Off	1	10
21	2	A	2	Off	0.23	10
22	2	B	3	On	1	10
23	2	A	1	On	-1	4
24	2	B	3	Off	1	10

Figure 1 shows a scatterplot of the design points.

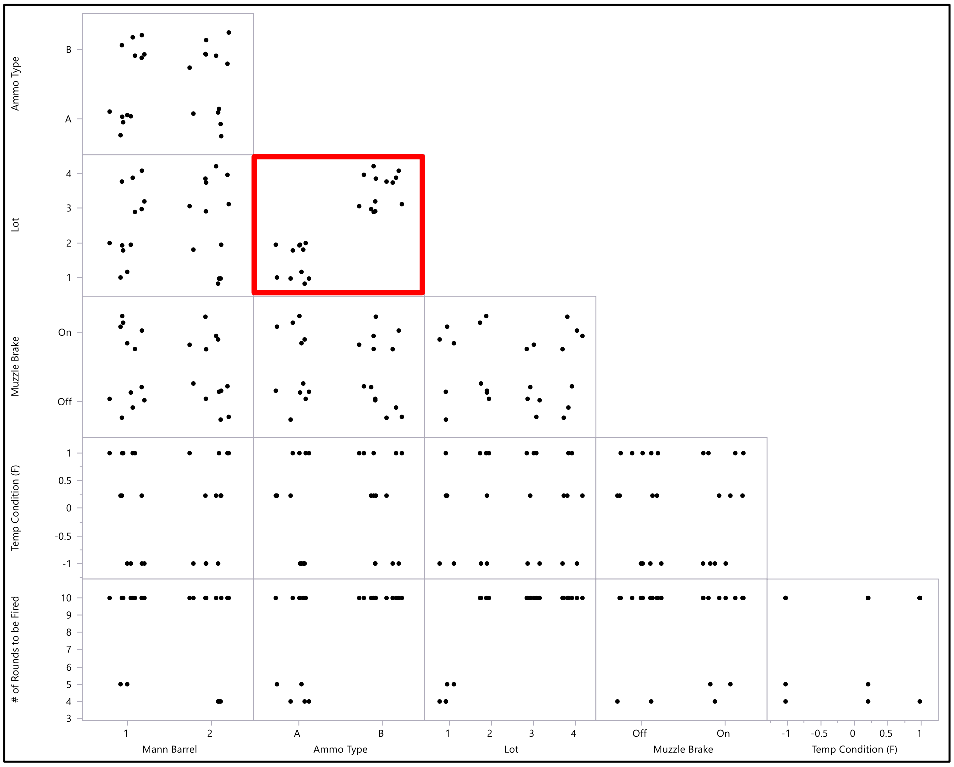

Figure 1: Original Test Point Scatterplot

Evaluating this design using JMP 13 Pro software reveals some issues if it is to be executed as a design of experiments (DOE).

The design is unable to analyze the Ammo Lot effect. As one can see in the red square in Figure 1, the Ammo Type and Lot are confounded because they are mutually exclusive. Table 2 shows the estimable model terms and the associated statistical power for each (Assessed at 95% confidence and signal to noise ratio = 2.0). Power is high (goal is above 80%) for all terms but the list does not include Ammo Lot.

Table 2: Original Design Model Term Power

Term	Power
Intercept	0.991
Mann Barrel	0.972
Ammo Type	0.979
Muzzle Brake	0.979
Temp Condition (F)	0.952
Mann Barrel*Ammo Type	0.974
Mann Barrel*Muzzle Brake	0.974
Mann Barrel*Temp Condition (F)	0.933
Ammo Type*Muzzle Brake	0.971
Ammo Type*Temp Condition (F)	0.951
Muzzle Brake*Temp Condition (F)	0.951

The assumptions claim all points will be randomized; however, Table 1 does not show the barrel being randomized. The test point rows are executed with barrel 1 for 12 groups and then barrel 2 for the last 12 groups. The barrel is hard to change which results in a split plot condition requiring specific analytical techniques which will be covered later.

The points are not evenly distributed throughout the factor space. This results in aliasing between terms and it can be seen graphically in Figure 2.

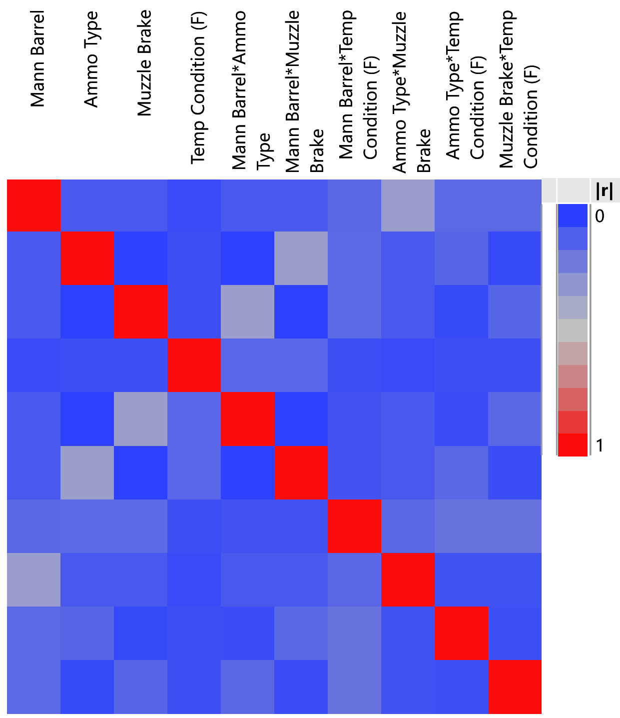

Figure 2: Original Design Color Correlation Matrix

A color matrix for completely uncorrelated terms would display as a dark blue field with a bright red diagonal. The color bar along the right side shows the gray cells indicate about 50% correlation which may result in incorrect model term estimates.

These issues can be corrected with the following changes

- The design must support the stated analytical goals
    - Analytical goals indicate analysis of variance (ANOVA) and regression are designed to determine significant effects so the design must be capable of delivering this evaluation
- Mann Barrel must be randomized using a split plot design to effect the correct analysis
    - This will require additional runs/whole plots to correctly evaluate barrel effect
    - While the barrel effect is expected to be minimal we must include it as a main effect in the design in order to prove it statistically
- Combine Ammo Type and Lots into a single categorical factor with four levels

- These two factors are correlated, removing the ability to discern the Ammo Lot effect
- Change Ammo Type (A/B) and Lot (1, 2, 3, 4), to Ammo A Old, A New, B Old, B New
- This supports lot discrimination in the regression model

- Remove # Rounds Fired
    - Replace non-randomized replicates on each row with a single shot on each row
    - Each row can be randomized inside the barrel whole plots

Improved Design Options

DOE does not result in a single design output; rather, it provides options within the design space so the team can select what is considered to be the most optimal design. In this case, the number of rounds were varied along with the number of whole plots for the barrel so the team could choose the best option. Each design was created new using these updated factors:

- Barrel (1, 2)
- Muzzle brake (on, off)
- Temperature (-1.0, 0.23, 1.0)
- Ammo (A Old, A New, B Old, B New)

Using JMP 13 Pro we specify all main effects and two-factor interactions in the regression model. For each design option we specify the number of whole plots and the number of total points and evaluate the design at 95% confidence and a signal to noise ratio = 2.0. Three designs were generated:

- Revision 1 (R1)
    - 4 whole plots (WP)
        - 3 barrel changes during testing
    - 36 runs (9 rounds/lot)
    - Power is acceptable (>80%) for all model terms
        - WP power is low (typical for split plot designs)
- Revision 2 (R2)
    - 4 WP
    - 88 runs (22 rounds/lot)
    - Additional power margin for main effects, two-factor interaction (2FI) above design R1
        - WP power remains low (typical for split plot designs)
- Revision 3 (R3)
    - Created to demonstrate number of WPs needed to increase WP power
    - 12 WP (11 barrel changes)
    - 88 runs (22 rounds/lot)
    - Best power for hard to change (HTC) factor, main effects, 2FI
    - <u>Not recommended</u> unless barrel influence expected to be significant
        - 11 barrel changes is prohibitive

Recommendation

Design R2 was recommended because the number of barrel changes (3) is manageable and the slight increase in power over R1 provides some margin in case the signal to noise ratio turns out to be smaller than planned. This design also randomizes Round Temperature, Muzzle Brake, and Ammo Lot inside each Barrel whole plot. From an efficiency perspective, the original design contained 212 rounds and R2 contains only 88 but also improves the results and correctly accounts for the way the test will actually be executed. The R2 test matrix is in Appendix A: Design Revision 2.

Figure 3 shows the R2 test point scatterplot. This looks similar to the original design in Figure 1 but these points are more evenly placed throughout the factor space. This difference will become more apparent in Figure 5.

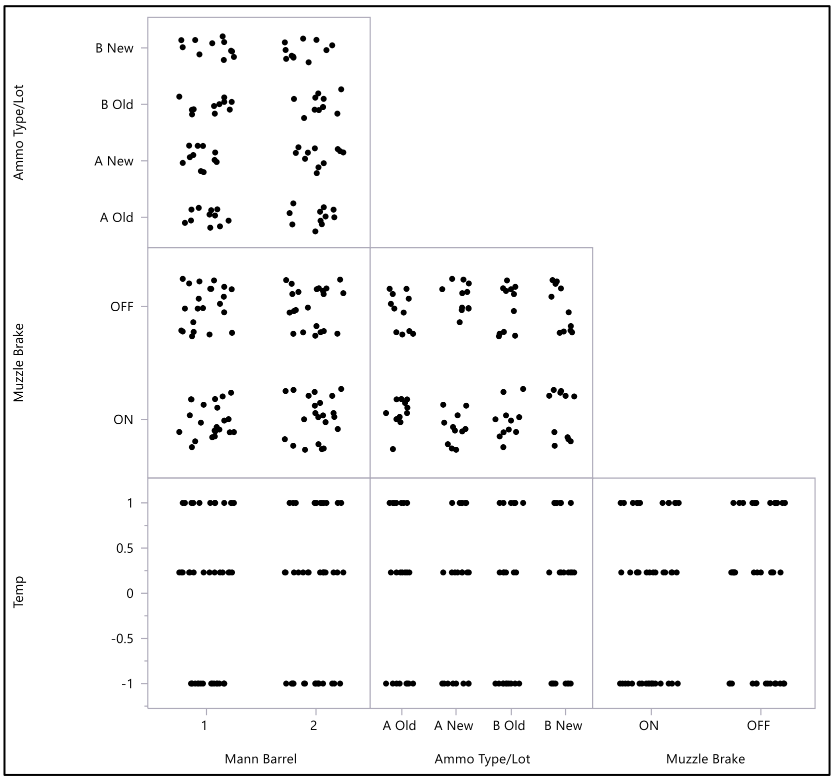

Figure 3: Design R2 Test Point Scatterplot

Table 3 shows the power table for design R2.

Table 3: Design R2 Model Term Power

Term	Power
Intercept	0.197
Mann Barrel	0.212
Ammo Type/Lot	1.000
Muzzle Brake	1.000
Temp	1.000
Temp*Temp	0.977
Mann Barrel*Ammo Type/Lot	1.000
Mann Barrel*Muzzle Brake	1.000
Mann Barrel*Temp	1.000
Ammo Type/Lot*Muzzle Brake	1.000
Ammo Type/Lot*Temp	0.991
Muzzle Brake*Temp	1.000

Note the low power for the Mann Barrel term (second from top) because the whole plot is only replicated 3 times.

Executed Test

Design R2 was discussed as acceptable but was not ultimately used (reason unknown). The original design shown in Table 1 (plus two additional conditions resulting in 26 total groups) was executed. No replicate whole plots were added and the points were not redistributed in the space. The as-executed design is in Appendix B: Executed Design. Warming rounds were fired but removed from the data table since no responses are recorded.

Analysis Overview

For each firing group the Average X and Y displacement and standard deviation were calculated along with the radial distance. These values are shown on the first line for every group in Appendix B: Executed Design. Four rounds broke up and so responses were not recorded. Because a true DOE was not executed the data was analyzed two ways for comparison: in its raw form (plotting direct displacement responses) and using linear regression using the grouped averages (as if it were a proper DOE).

Raw Displacement Data

The complete raw data set (every row/shot) was plotted to graphically interpret the results. These plots may be more informative than the calculated averages which may hide some dispersion noise. Figure 4 depicts the X/Y displacement by Ammo Lot, Muzzle Brake condition, and Barrel number.

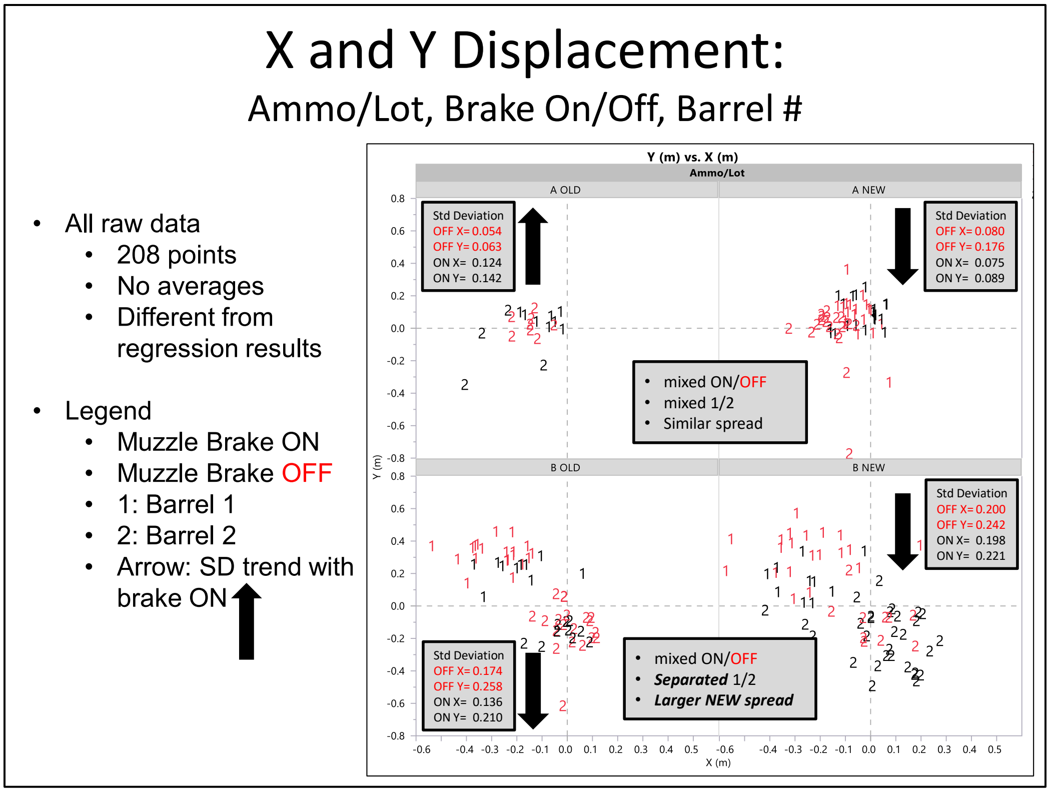

Figure 4: Raw Data Displacement Plot 1

Standard deviation (SD) was calculated for each of the four plot subsections with the muzzle brake on and off. The black arrow indicates the trend of the SD going from OFF to ON condition.

- In three cases the SD decreases with the brake on which would negate the thesis that it is increasing dispersion
- Ammo A is similarly centered between old and new
- Ammo A is similarly dispersed between old and new
- Ammo A is evenly mixed with muzzle brake on and off
- Ammo A is evenly mixed with barrel 1 and 2
- Ammo B is similarly centered between old and new
- Ammo B is **not** similarly dispersed between old and new
- Ammo B is evenly mixed with muzzle brake on and off
- Ammo B is **not** evenly mixed with barrel 1 and 2

Graphical Conclusions:

- Ammo Lot is a significant factor to dispersion (logically expected)
- Barrel looks to be a significant factor to dispersion (not expected)

Figure 5 shows this data plotted again with temperature added. The SD was not calculated because the data groups were smaller and of uneven sizes, which would produce potentially inaccurate and incomparable SD estimates.

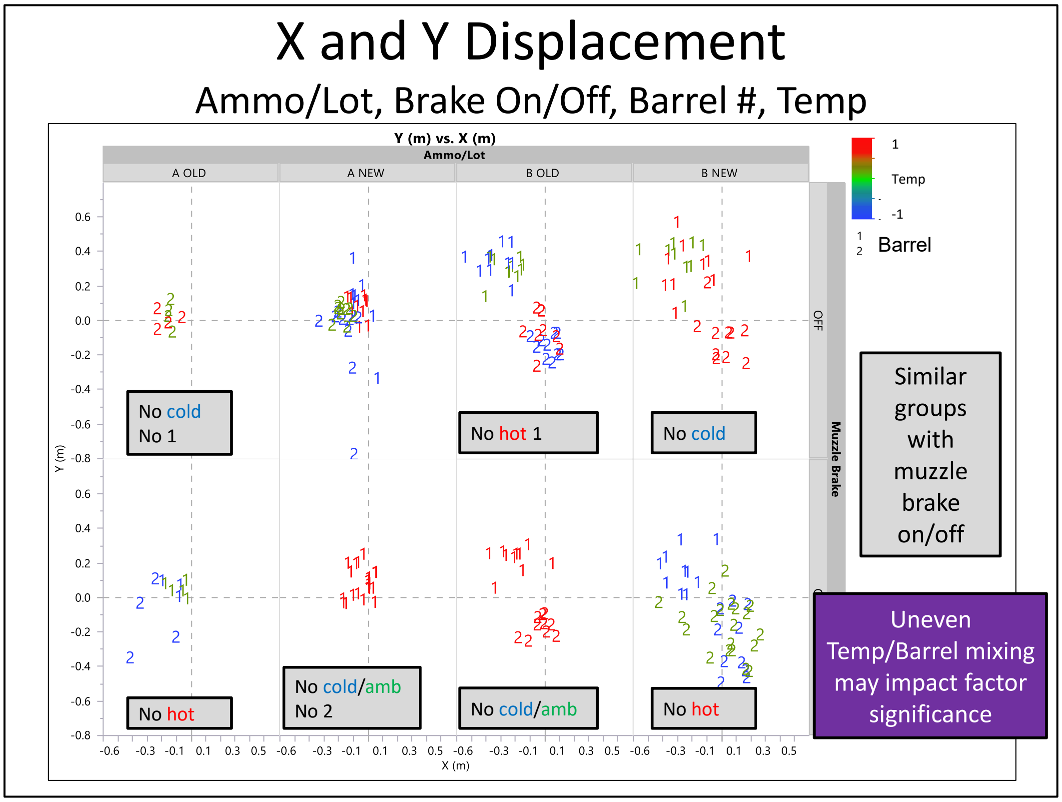

Figure 5: Raw Data Displacement Plot 2

This plot highlights that temperature and barrel are not evenly distributed across the test points. The missing factors are annotated for every group on the plot. The groups do show that temperature levels (colors) appear to mix evenly among the other factors (where more than 1 level was tested).

Graphical Conclusion 2:

- Muzzle Brake does not appear to be significant
- Temperature does not appear to be significant but the data lacks credibility
- Barrel significance looks more dubious, especially given the Temperature credibility

Average Displacement Regression

The averaging of the data resulted in 26 group averages and these are plotted in Figure 6 in a similar format to Figure 5.

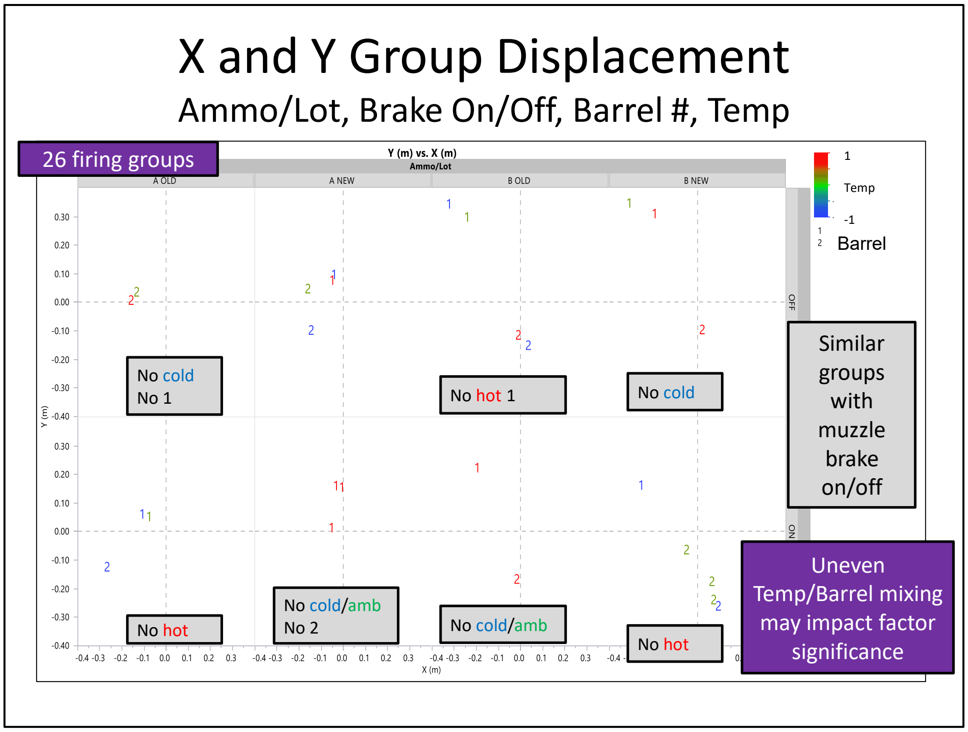

Figure 6: Average Displacement Plot

Averaging the data results in even smaller data groups but the trends remain the same as cited previously, if less obviously so. The regression results are:

- X(m)
  - Significant factors (95% confidence)
    - Ammo Lot * Barrel Number
    - Ammo Lot
    - Barrel Number
  - Model R-squared Adjusted: 0.84
  - SD/Root mean square error (RMSE): 0.048
- Y(m)
  - Significant factors (95% confidence)
    - Barrel Number
    - Ammo Lot * Barrel Number
    - Ammo Lot
    - Muzzle Brake
  - Model R-squared Adjusted: 0.87
  - SD/RMSE: 0.065
- R(m)
  - Significant factors (95% confidence)

        - Ammo Lot
        - Ammo Lot * Barrel Number
        - Muzzle Brake * Barrel Number
        - Barrel Number
        - Muzzle Brake
    - Model R-squared Adjusted: 0.72
    - SD/RMSE: 0.063

Regression Conclusions:

- Graphical and regression results conflict on some significant factors
- Muzzle brake is significant to Y (and R) dispersion
- Barrel is significant to X, Y, and R dispersion
    - Mann Barrel is specifically used to remove or negate barrel effects
    - Un-replicated whole plot design may have produced incorrect results for this factor
    - Actual barrel effect on dispersion cannot be effectively determined using this design
- Temperature was not significant at 5% alpha
    - P-value of 8% for Y (X and R Temperature p-values were not nearly as low)
    - JMP reports a realized adjusted power of only 27% for this term, probably due to the lack of evenly distributed points
    - Temperature may be significant which can be evaluated using a correctly scoped DOE

Analytical Conclusions

- Temp/Barrel point mixing may be insufficient to evaluate significance
- Ammo Type/Lot is significant
    - Graph and Regression results AGREE
- Mann Barrel is significant (?)
    - Graph and Regression results (might) DISAGREE
    - Not expected as per baseline assumptions
    - Mann Barrel specifically employed to remove barrel effects
    - Use of non-split plot design increases ambiguity in this result
- Muzzle Brake is significant
    - Graph and Regression results DISAGREE
    - Poor randomization may be an issue
- Temperature is not significant (at 5% alpha)
    - Graph and Regression results AGREE
    - Low p-value (8%) may indicate factor significant is clouded by lack of data
    - Term had low power for estimation
    - A better DOE may improve the estimate and remove ambiguity
- Some interactions were present

Recommendations for Future Testing

- Employ a split plot design
    - A correctly formulated design produces clear analytical results
    - A balanced design requires fewer points to generate similar term power
    - All factors should be randomized inside each whole plot
    - Regression analysis should be conducted on the whole data set not averages
- Single shot events should not be aggregated into groups
    - Single shot tests are meant to produce independent and unrelated results
        - Rapid fire events might justify using averages
    - Averaging group results decreases the information contained in the raw data and may mask dispersion effects

Conclusion

Design of experiments is a proven method to isolate effects and provide information for further investigation. Improperly formulated designs may produce ambiguous results and complicate the understanding of the system.

References

SAAMI Glossary, *Sporting Arms and Ammunition Manufacturers' Institute (SAAMI)*, saami.org/saami-glossary/?letter=B, 2018.

Appendix A: Design Revision 2

Run Order	Whole Plots	Mann Barrel	Ammo Type/Lot	Muzzle Brake	Temp
1	1	2	A Old	ON	0.23
2	1	2	A New	ON	-1.00
3	1	2	A Old	ON	0.23
4	1	2	A New	OFF	0.23
5	1	2	B Old	ON	-1.00
6	1	2	A New	OFF	-1.00
7	1	2	B New	OFF	0.23
8	1	2	A Old	OFF	-1.00
9	1	2	B New	ON	1.00
10	1	2	A New	ON	0.23
11	1	2	A New	ON	1.00
12	1	2	B New	ON	0.23
13	1	2	B New	ON	-1.00
14	1	2	B Old	OFF	-1.00
15	1	2	B Old	ON	1.00
16	1	2	A Old	ON	-1.00
17	1	2	A Old	ON	1.00
18	1	2	B Old	OFF	0.23
19	1	2	A New	OFF	1.00
20	1	2	B Old	OFF	0.23
21	1	2	B New	OFF	-1.00
22	1	2	A Old	OFF	1.00
23	2	1	A Old	ON	0.23
24	2	1	B New	OFF	0.23
25	2	1	A Old	ON	-1.00
26	2	1	B New	ON	1.00
27	2	1	A New	OFF	-1.00
28	2	1	A Old	OFF	-1.00
29	2	1	A New	ON	-1.00
30	2	1	B Old	ON	-1.00
31	2	1	B Old	ON	1.00
32	2	1	B New	OFF	0.23
33	2	1	A New	OFF	0.23
34	2	1	B Old	OFF	-1.00
35	2	1	A New	ON	1.00
36	2	1	A New	OFF	1.00
37	2	1	B New	ON	-1.00
38	2	1	B Old	ON	-1.00
39	2	1	A Old	OFF	1.00
40	2	1	B Old	ON	0.23
41	2	1	B Old	OFF	1.00
42	2	1	A Old	OFF	1.00
43	2	1	B New	OFF	-1.00
44	2	1	A New	ON	0.23

Run Order	Whole Plots	Mann Barrel	Ammo Type/Lot	Muzzle Brake	Temp
45	3	2	B Old	OFF	-1.00
46	3	2	B Old	ON	-1.00
47	3	2	B Old	OFF	1.00
48	3	2	B New	OFF	-1.00
49	3	2	A New	OFF	0.23
50	3	2	B New	ON	-1.00
51	3	2	A Old	OFF	-1.00
52	3	2	A New	OFF	-1.00
53	3	2	A New	ON	1.00
54	3	2	A New	OFF	0.23
55	3	2	B Old	ON	1.00
56	3	2	B New	OFF	1.00
57	3	2	B New	ON	0.23
58	3	2	B Old	OFF	0.23
59	3	2	A Old	ON	0.23
60	3	2	A Old	ON	-1.00
61	3	2	A New	ON	-1.00
62	3	2	A Old	OFF	0.23
63	3	2	A Old	OFF	1.00
64	3	2	B New	OFF	1.00
65	3	2	B Old	ON	-1.00
66	3	2	B New	ON	0.23
67	4	1	B Old	OFF	0.23
68	4	1	A Old	ON	1.00
69	4	1	B New	OFF	1.00
70	4	1	A Old	ON	1.00
71	4	1	A New	OFF	-1.00
72	4	1	A Old	OFF	0.23
73	4	1	B New	ON	1.00
74	4	1	A New	OFF	1.00
75	4	1	B Old	OFF	1.00
76	4	1	B Old	OFF	-1.00
77	4	1	B New	OFF	0.23
78	4	1	A New	ON	0.23
79	4	1	A Old	ON	-1.00
80	4	1	A Old	OFF	0.23
81	4	1	B New	OFF	-1.00
82	4	1	B New	ON	-1.00
83	4	1	B Old	ON	-1.00
84	4	1	A New	ON	-1.00
85	4	1	A Old	OFF	-1.00
86	4	1	B New	ON	0.23
87	4	1	A New	ON	0.23
88	4	1	B Old	ON	0.23

Appendix B: Executed Design

Event	Round Temp (F)	Ammo/Lot	Barrel Number	Muzzle Brake	X (m)	Y (m)	Avg X(m)	SD X(m)	Avg Y(m)	SD Y(m)	R(m)
1	0.23	B New	1	N	-0.564	0.217	-0.301	0.151	0.348	0.119	0.460
2	0.23	B New	1	N	-0.544	0.413					
3	0.23	B New	1	N	-0.345	0.409					
4	0.23	B New	1	N	-0.180	0.453					
5	0.23	B New	1	N	-0.304	0.388					
6	0.23	B New	1	N	-0.222	0.312					
7	0.23	B New	1	N	-0.193	0.316					
8	0.23	B New	1	N	-0.233	0.084					
9	0.23	B New	1	N	-0.311	0.449					
10	0.23	B New	1	N	-0.110	0.437					
11	-1.00	A New	1	N	0.052	0.028	-0.033	0.066	0.098	0.199	0.103
12	-1.00	A New	1	N	-	-					
13	-1.00	A New	1	N	-	-					
14	-1.00	A New	1	N	-0.082	0.100					
15	-1.00	A New	1	N	-0.084	0.363					
16	-1.00	A New	1	N	-0.022	0.205					
17	-1.00	A New	1	N	-0.050	0.118					
18	-1.00	A New	1	N	-0.087	0.153					
19	-1.00	A New	1	N	0.084	-0.333					
20	-1.00	A New	1	N	-0.073	0.146					
21	-1.00	A Old	1	Y	-0.064	0.009	-0.099	0.069	0.062	0.047	0.117
22	-1.00	A Old	1	Y	-	-					
23	-1.00	A Old	1	Y	-0.055	0.076					
24	-1.00	A Old	1	Y	-0.178	0.100					
25	-1.00	A Old	1	Y	-	-					
26	0.23	B Old	1	N	-0.387	0.141	-0.233	0.094	0.299	0.068	0.379
27	0.23	B Old	1	N	-0.130	0.324					
28	0.23	B Old	1	N	-0.205	0.315					
29	0.23	B Old	1	N	-0.144	0.296					
30	0.23	B Old	1	N	-0.329	0.355					
31	0.23	B Old	1	N	-0.357	0.371					
32	0.23	B Old	1	N	-0.230	0.281					
33	0.23	B Old	1	N	-0.227	0.284					
34	0.23	B Old	1	N	-0.169	0.257					
35	0.23	B Old	1	N	-0.149	0.370					
36	1.00	B New	1	N	-0.347	0.360	-0.186	0.181	0.311	0.145	0.363
37	1.00	B New	1	N	-0.296	0.045					
38	1.00	B New	1	N	-0.107	0.328					
39	1.00	B New	1	N	0.206	0.374					
40	1.00	B New	1	N	-0.311	0.211					
41	1.00	B New	1	N	-0.284	0.572					
42	1.00	B New	1	N	-0.037	0.235					
43	1.00	B New	1	N	-0.367	0.206					
44	1.00	B New	1	N	-0.246	0.435					
45	1.00	B New	1	N	-0.073	0.347					
46	1.00	A New	1	Y	-0.099	0.151	-0.024	0.068	0.161	0.043	0.163
47	1.00	A New	1	Y	-0.049	0.206					
48	1.00	A New	1	Y	-0.062	0.199					
49	1.00	A New	1	Y	0.019	0.100					
50	1.00	A New	1	Y	0.070	0.149					
51	1.00	A New	1	Y	-0.012	0.254	0.003	0.075	0.156	0.076	0.156
52	1.00	A New	1	Y	-0.119	0.202					
53	1.00	A New	1	Y	0.052	0.057					

Event	Round Temp (F)	Ammo/Lot	Barrel Number	Muzzle Brake	X (m)	Y (m)	Avg X(m)	SD X(m)	Avg Y(m)	SD Y(m)	R(m)
54	1.00	A New	1	Y	0.024	0.117					
55	1.00	A New	1	Y	0.072	0.148					
56	0.23	A Old	1	Y	-0.040	0.041	-0.068	0.066	0.053	0.042	0.086
57	0.23	A Old	1	Y	-0.009	-0.005					
58	0.23	A Old	1	Y	-0.159	0.083					
59	0.23	A Old	1	Y	-0.017	0.103					
60	0.23	A Old	1	Y	-0.113	0.042					
61	1.00	A New	1	Y	-0.150	-0.028	-0.044	0.081	0.014	0.041	0.046
62	1.00	A New	1	Y	0.022	0.061					
63	1.00	A New	1	Y	-0.012	-0.011					
64	1.00	A New	1	Y	-0.084	0.016					
65	1.00	A New	1	Y	0.065	-0.025					
66	1.00	A New	1	Y	0.025	0.056					
67	1.00	A New	1	Y	-0.050	0.024					
68	1.00	A New	1	Y	0.028	0.082					
69	1.00	A New	1	Y	-0.133	-0.032					
70	1.00	A New	1	Y	-0.151	-0.005					
71	-1.00	B New	1	Y	-0.143	0.090	-0.247	0.114	0.163	0.115	0.296
72	-1.00	B New	1	Y	-0.401	0.198					
73	-1.00	B New	1	Y	-0.358	0.087					
74	-1.00	B New	1	Y	-0.222	0.019					
75	-1.00	B New	1	Y	-0.261	0.337					
76	-1.00	B New	1	Y	-0.363	0.237					
77	-1.00	B New	1	Y	-0.215	0.150					
78	-1.00	B New	1	Y	-0.015	0.339					
79	-1.00	B New	1	Y	-0.233	0.155					
80	-1.00	B New	1	Y	-0.256	0.022					
81	1.00	A New	1	N	-0.122	0.139	-0.041	0.050	0.078	0.067	0.088
82	1.00	A New	1	N	-0.042	-0.036					
83	1.00	A New	1	N	-0.092	0.048					
84	1.00	A New	1	N	0.018	-0.029					
85	1.00	A New	1	N	0.002	0.121					
86	1.00	A New	1	N	-0.100	0.133					
87	1.00	A New	1	N	-0.055	0.086					
88	1.00	A New	1	N	-0.018	0.054					
89	1.00	A New	1	N	0.009	0.113					
90	1.00	A New	1	N	-0.008	0.146					
91	-1.00	B Old	1	N	-0.207	0.175	-0.315	0.109	0.345	0.083	0.467
92	-1.00	B Old	1	N	-0.347	0.380					
93	-1.00	B Old	1	N	-0.209	0.456					
94	-1.00	B Old	1	N	-0.425	0.289					
95	-1.00	B Old	1	N	-0.354	0.294					
96	-1.00	B Old	1	N	-0.367	0.359					
97	-1.00	B Old	1	N	-0.204	0.334					
98	-1.00	B Old	1	N	-0.273	0.459					
99	-1.00	B Old	1	N	-0.232	0.334					
100	-1.00	B Old	1	N	-0.527	0.370					
101	1.00	B Old	1	Y	-0.266	0.268	-0.187	0.124	0.224	0.071	0.292
102	1.00	B Old	1	Y	-0.133	0.159					
103	1.00	B Old	1	Y	-0.154	0.255					
104	1.00	B Old	1	Y	-0.322	0.057					
105	1.00	B Old	1	Y	-0.361	0.257					
106	1.00	B Old	1	Y	-0.175	0.255					

Event	Round Temp (F)	Ammo/Lot	Barrel Number	Muzzle Brake	X (m)	Y (m)	Avg X(m)	SD X(m)	Avg Y(m)	SD Y(m)	R(m)
107	1.00	B Old	1	Y	-0.248	0.247					
108	1.00	B Old	1	Y	-0.191	0.234					
109	1.00	B Old	1	Y	-0.095	0.309					
110	1.00	B Old	1	Y	0.071	0.200					
111	-1.00	B New	2	Y	-0.005	-0.185	0.103	0.082	-0.260	0.184	0.280
112	-1.00	B New	2	Y	0.039	-0.369					
113	-1.00	B New	2	Y	0.017	-0.492					
114	-1.00	B New	2	Y	0.140	-0.175					
115	-1.00	B New	2	Y	0.158	-0.376					
116	-1.00	B New	2	Y	0.096	-0.018					
117	-1.00	B New	2	Y	0.012	-0.063					
118	-1.00	B New	2	Y	0.200	-0.038					
119	-1.00	B New	2	Y	0.192	-0.462					
120	-1.00	B New	2	Y	0.185	-0.422					
121	0.23	B New	2	Y	0.093	-0.306	0.074	0.197	-0.174	0.139	0.189
122	0.23	B New	2	Y	0.012	-0.072					
123	0.23	B New	2	Y	-0.408	-0.026					
124	0.23	B New	2	Y	0.285	-0.214					
125	0.23	B New	2	Y	0.105	-0.158					
126	0.23	B New	2	Y	0.188	-0.413					
127	0.23	B New	2	Y	0.117	-0.063					
128	0.23	B New	2	Y	0.217	-0.048					
129	0.23	B New	2	Y	0.192	-0.091					
130	0.23	B New	2	Y	-0.058	-0.348					
131	-1.00	A New	2	N	-0.114	-0.059	-0.136	0.080	-0.097	0.255	0.167
132	-1.00	A New	2	N	-0.102	0.009					
133	-1.00	A New	2	N	-0.046	0.018					
134	-1.00	A New	2	N	-0.074	-0.773					
135	-1.00	A New	2	N	-0.084	0.028					
136	-1.00	A New	2	N	-0.314	-0.001					
137	-1.00	A New	2	N	-0.085	-0.273					
138	-1.00	A New	2	N	-0.185	0.052					
139	-1.00	A New	2	N	-0.153	0.010					
140	-1.00	A New	2	N	-0.202	0.024					
141	0.23	A Old	2	N	-0.137	0.025	-0.124	0.013	0.037	0.079	0.129
142	0.23	A Old	2	N	-0.119	0.125					
143	0.23	A Old	2	N	-0.132	0.060					
144	0.23	A Old	2	N	-0.108	-0.064					
145	-1.00	B Old	2	N	-0.034	-0.152	0.045	0.067	-0.150	0.063	0.156
146	-1.00	B Old	2	N	0.106	-0.071					
147	-1.00	B Old	2	N	0.086	-0.071					
148	-1.00	B Old	2	N	0.108	-0.196					
149	-1.00	B Old	2	N	-0.078	-0.091					
150	-1.00	B Old	2	N	0.030	-0.222					
151	-1.00	B Old	2	N	0.037	-0.140					
152	-1.00	B Old	2	N	-0.004	-0.115					
153	-1.00	B Old	2	N	0.127	-0.196					
154	-1.00	B Old	2	N	0.071	-0.243					
155	0.23	B New	2	Y	0.245	-0.278	0.082	0.183	-0.238	0.143	0.252
156	0.23	B New	2	Y	0.085	-0.267					
157	0.23	B New	2	Y	0.209	-0.426					
158	0.23	B New	2	Y	-0.219	-0.185					
159	0.23	B New	2	Y	0.088	-0.036					

Event	Round Temp (F)	Ammo/Lot	Barrel Number	Muzzle Brake	X (m)	Y (m)	Avg X(m)	SD X(m)	Avg Y(m)	SD Y(m)	R(m)
160	0.23	B New	2	Y	0.073	-0.306	-0.041	0.126	-0.063	0.177	0.075
161	0.23	B New	2	Y	0.045	0.156					
162	0.23	B New	2	Y	-0.249	-0.113					
163	0.23	B New	2	Y	-0.029	-0.107					
164	0.23	B New	2	Y	-0.044	0.055					
165	1.00	A Old	2	N	-0.136	-0.011	-0.149	0.079	0.008	0.051	0.149
166	1.00	A Old	2	N	-0.210	0.071					
167	1.00	A Old	2	N	-0.209	-0.049					
168	1.00	A Old	2	N	-0.042	0.020					
169	1.00	B New	2	N	0.179	-0.057	0.030	0.106	-0.095	0.137	0.100
170	1.00	B New	2	N	0.083	-0.070					
171	1.00	B New	2	N	-0.018	-0.196					
172	1.00	B New	2	N	-0.145	-0.083					
173	1.00	B New	2	N	-0.015	-0.218					
174	1.00	B New	2	N	-0.020	-0.072					
175	1.00	B New	2	N	0.051	-0.212					
176	1.00	B New	2	N	0.188	-0.247					
177	1.00	B New	2	N	0.069	-0.069					
178	1.00	B New	2	N	-0.075	0.221					
179	0.23	A New	2	N	-0.163	0.108	-0.151	0.044	0.048	0.046	0.158
180	0.23	A New	2	N	-0.167	0.041					
181	0.23	A New	2	N	-0.076	0.027					
182	0.23	A New	2	N	-0.183	0.073					
183	0.23	A New	2	N	-0.122	-0.085					
184	0.23	A New	2	N	-0.224	-0.024					
185	0.23	A New	2	N	-0.161	0.066					
186	0.23	A New	2	N	-0.105	0.070					
187	0.23	A New	2	N	-0.185	0.086					
188	0.23	A New	2	N	-0.125	0.066					
189	1.00	B Old	2	Y	0.065	-0.156	-0.007	0.075	-0.166	0.057	0.166
190	1.00	B Old	2	Y	0.099	-0.222					
191	1.00	B Old	2	Y	0.020	-0.091					
192	1.00	B Old	2	Y	0.007	-0.096					
193	1.00	B Old	2	Y	-0.091	-0.250					
194	1.00	B Old	2	Y	-0.161	-0.230					
195	1.00	B Old	2	Y	0.032	-0.197					
196	1.00	B Old	2	Y	-0.027	-0.113					
197	1.00	B Old	2	Y	0.015	-0.149					
198	1.00	B Old	2	Y	-0.030	-0.156					
199	-1.00	A Old	2	Y	-0.328	-0.080	-0.258	0.136	-0.123	0.204	0.286
200	-1.00	A Old	2	Y	-0.083	-0.227					
201	-1.00	A Old	2	Y	-0.396	-0.347					
202	-1.00	A Old	2	Y	-0.224	0.111					
203	1.00	B Old	2	N	-0.034	0.075	0.000	0.070	-0.114	0.205	0.114
204	1.00	B Old	2	N	0.009	-0.056					
205	1.00	B Old	2	N	-0.128	-0.063					
206	1.00	B Old	2	N	-0.007	-0.615					
207	1.00	B Old	2	N	-0.024	-0.083					
208	1.00	B Old	2	N	-0.002	0.059					
209	1.00	B Old	2	N	0.123	-0.163					
210	1.00	B Old	2	N	-0.002	0.058					
211	1.00	B Old	2	N	0.100	-0.091					
212	1.00	B Old	2	N	-0.033	-0.262					