Structured Barrel Experiment

JB.IC

2024-01-04

Acknowledgments

This design is not going to generalize to every combination possible in the population of all possible combinations. Experiments should be narrow and should not set out to examine everything all at once. When experiments are too large and complex, mistakes can be made and the time and expense of said mistakes should be considered. The proposed experiment here is a bite size experiment that can be controlled with a focus narrowed on the effects of group size given a structured or unstructured barrel. Different experiments can be conducted under different designs and conditions.

Factors

Factor 1 Structured: structured and unstructured

Factor 2 Shooter: shooter A and shooter B

Response

The response can be the extreme spread of the group size or the mean radius. It is assumed some type of target marker recording device would be needed to record impacts because as groups accumulate, many impacts might be overlapping. If the impacts cannot be tracked, then knowing precisely where the impacts where is nearly impossible without some sort of recording device.

Assumptions

The mean group size of a **structured barrel** is estimated to be 0.95” at 100 yards for a string of 30 rounds with a standard deviation (STD) of 0.07071068”.

The hypothetical mean group size of a **unstructured barrel** is estimated to be 1.28” at 100 yards for a string of 30 rounds with an STD of 0.1923538”.

The mean and STD are estimates which are not necessarily perfect. They are only used for simulation which will test if there was no difference between barrel factors and if there was a difference between barrel factors.

Barrel Assumptions:

The barrels are homogeneous in the context that they are from the same manufacture and have similar specifications such as length, rifling type, twist rate, and muzzle attachment. Essentially, the only difference should be if it is structured or not. It is acknowledged that the structured barrel might have a larger outside diameter (OD) than the unstructured due to the specification requirements for the structured process.

Shooter Assumption:

There are two shooters, A & B. For this simulation, the shooters are homogeneous which would be highly desirable so that we can rule out the shooter’s influence. However, this factor must be included if there is an emergence of variation between shooters. If the shooters are heterogeneous, then the shooters will need to shoot the different combinations of rifle configurations and barrel type.

Rifle Configuration Assumption:

There will be two rifle configurations.

A rifle configuration is defined as the configuration of the rifle excluding the barrel. So, the action, stock/chassis, trigger, bipod, etc. Additionally, the type of bipod and rear bag should match closely.

If these can be closely matched, such as two MRADs with the same scope , scope rings, bipod, rear bag and bag rider, then this factor can be eliminated completely. This simulation will assume both rifles are the same. If they are not, then there is added complexity in the design of the experiment which can greatly increase the cost.

Benefits of using a rifle like the MRAD:

1. A rifle can be configured to the shooter’s body such as length of pull and comb height. Essentially, the shooter can be comfortable with their rifle as opposed to switching between rifles they might not be comfortable with. This is a factor we want to a non-factor because there could be interaction effects and unfortunately interaction effects complicated the analysis.
2. Users can swap barrels so that each shooter gets to use a structured and unstructured barrel. This will allow us to block out the effects of a shooter since we are wanting to isolate the performance of the barrel.

Environment Assumptions:

The rifles are measured under the same firing conditions to include weather and shooting surfaces. Something like both rifles firing at the same intervals. Otherwise these are factors that need to be included.

Ammunition Assumptions:

Ammunition is the same for both rifles such as factory ammunition. Suppose 500 rounds are needed which would consist of 25 boxes of 20 round ammunition. The boxes will be labeled 1 - 20, 21 - 40, …, 481 - 500. Within an individual box, the rounds position will determine the index number of individual rounds. A uniform random number generator will determine the order of the ammunition is to be fired.

Example:

```
##   [1]  75 174 351 238 471 395 103 318 283 291  31  67 149 392 455 221 371  46
##  [19] 281 359 322 139 203 150 400 380   7 429 328  98 305 275  10 385 302 169
##  [37] 228  22 327 444 346 210 333 166 121 261  39 178 300  85 195  72  60 123
##  [55]  55 402  13 383  21 186 158 106 335 230  92 424 447 264  44  11 430  24
##  [73] 216 259 226 365 105 475 433  66 284 171 131 175 160 373 401  16 381 407
##  [91] 280 456  78 141   1 138 223 334 477 177 207 132 276 240  52  15 370  12
## [109]  40 235 104  33 274 268 435 453 152 225 339  99 441  97 472 366 227 183
## [127] 288 114  73 320 232 348 405 250 446 361 249  69  82 309 190 323 347 410
## [145] 315 266 325  71 192 205 378 212 258 118 233 414 382 467 357 406 265 286
## [163] 247 252 412  37 452 379 293  83 271 458  17 443 201  62  51 386 279 419
## [181] 422 473  49 344 324 187 218  28 336 272 142  14  27 387 145 209 198   8
## [199] 368 341 349 167 369 463 116 449 179 260 206 236 331 399  30 224  95 445
## [217] 350  79 307 161 454 157 450 119 176 159 290  54  48   9 112 420 129 329
## [235] 303 162  43 417 374 310 110 466 460 389 168 451 418 170 108 214 364 262
## [253]  59 416 243  19 196  42 263 462 194 338 439  63 151 306 409 296  74   3
## [271]  25 181  47 278 375 372  77 390 421 197 319 295 436 202  35 425  58 478
## [289]   6 269 140 384 299  90 111 431 397 213 137 464 234 470 469 337 120 345
## [307] 134  29 185  56 113 229 376  26  20 432 237 340 311 144 122 239  80 253
## [325]  68 220 136 251 165 153 391  64 326 135 352  76   5 427 217  94 437 100
## [343] 304  70 163 479 285 164 415 301 362 332  65 246   4  18 173 316 222 354
## [361] 457  91 154 480  36  41 126 191 277 287 314 438 200  87 189 270 442 434
## [379] 107 208  57 215 115 172 245  34  61 355 360 244 465 125 294  81 468 241
## [397]  84 321  86 255 184  88 358 117 101 180 404 211 148  23 289 267 426 256
## [415] 459 193 248 130 411  32 298 147 393 146 109 408 257 254  96 403 474 143
## [433] 188 297 317   2 242 330 423 377 476 133  53 388  50 396 282 363 155  89
## [451] 182 461 428 398 313 394  45 367 356 204 440 273 124 219 448 156  93 127
## [469] 292 128 312  38 343 342 199 231 102 413 353 308
```

More on Homogeneity

It is critical for all factors that can be similar, will be similar. The goal is to control or block the factors out so that the effect can be estimated. Furthermore, we want to be able to prevent any holes in the research.

Simulation

If the above assumptions can be met, then the design of the experiment would be a 2^2 factor design. If there are 30 rounds per group, and say 4 replications at each level, then it would take 480 rounds of ammunition. This is a tentative assumption on ammunition requirements as that will be determined from power analysis.

The methodology is pending and up for debate. But a simple idea would be for each shooter to shoot at the same time at their own target at a specified interval such as 1 shot every 15 seconds. The way the test is administered should simulate some sort of application such as slow fire prone shooting or some other application like fast firing prone shooting. Different shooting disciplines will have different constraints and expectations.

structured	shooter	test1	test2	test3	test4
Y	A	0.9267979	0.9267979	1.2253173	1.1273522
Y	B	1.0769417	1.0769417	1.0769417	1.0769417
N	B	1.2168830	1.0214382	1.2168830	1.0214382
N	A	1.6253190	0.9322626	1.9268962	1.1319823
Y	A	0.9862504	0.9862504	1.2852937	1.1880256
Y	B	0.9445627	0.9445627	0.9445627	0.9445627
N	B	1.3786120	0.9974398	1.3786120	0.9974398
N	A	1.2652090	0.9731552	1.5642890	1.1733425
N	A	1.3344640	0.8901262	1.6324664	1.0912687
Y	B	0.9700213	0.9700213	0.9700213	0.9700213
Y	A	0.9250296	0.9250296	1.2247573	1.1254451
N	B	1.2120730	0.9089127	1.2120730	0.9089127
Y	A	0.9114168	0.9114168	1.2111015	1.1126463
N	B	1.1750420	0.8892140	1.1750420	0.8892140
N	A	1.0710480	0.9586460	1.3704197	1.1588827
Y	B	0.8731877	0.8731877	0.8731877	0.8731877

If there was a significant difference between barrels

This test randomly sampled from the assumed group sizes and STD and tested if there was a difference.

The power is 1.

```
##             Df Sum Sq Mean Sq F value   Pr(>F)    
## structured   1 0.4437  0.4437  26.318 0.000193 ***
## shooter      1 0.0025  0.0025   0.146 0.708897    
## Residuals   13 0.2192  0.0169                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## ==============================================
##                         Dependent variable:
##                     ---------------------------
##                                test1
## ----------------------------------------------
## structured1                  0.167***
##                               (0.032)
##
## shooter1                      -0.012
##                               (0.032)
##
## Constant                     1.118***
##                               (0.032)
##
## ----------------------------------------------
## Observations                    16
## R2                             0.671
## Adjusted R2                    0.620
## Residual Std. Error       0.130 (df = 13)
## F Statistic           13.232*** (df = 2; 13)
## ==============================================
## Note:               *p<0.1; **p<0.05; ***p<0.01
```

Note: `structured1` represents an unstructured barrel. It's estimated coefficient represents an increase of 0.167" in group size on average.

```
##      alpha a b nreps     Delta  sigma powera powerb
## [1,]  0.05 2 2     2 0.3330552 0.0169      1      1
## [2,]  0.05 2 2     3 0.3330552 0.0169      1      1
## [3,]  0.05 2 2     4 0.3330552 0.0169      1      1
```

If there was not a significant difference between barrels

This test randomly sampled from the assumed group sizes and STD and tested if there was **no** difference.

```
##            Df  Sum Sq  Mean Sq F value Pr(>F)
## structured   1 0.00012 0.000116   0.036  0.852
## shooter      1 0.00198 0.001981   0.620  0.445
## Residuals   13 0.04155 0.003196
```

```
##
## ==============================================
##                         Dependent variable:
##                     ---------------------------
##                                test2
## ----------------------------------------------
## structured1                   -0.003
##                               (0.014)
##
## shooter1                       0.011
##                               (0.014)
##
## Constant                     0.949***
##                               (0.014)
##
## ----------------------------------------------
## Observations                    16
## R2                             0.048
## Adjusted R2                   -0.098
## Residual Std. Error       0.057 (df = 13)
## F Statistic             0.328 (df = 2; 13)
## ==============================================
## Note:               *p<0.1; **p<0.05; ***p<0.01
```

Note: `structured1` represents an unstructured barrel. In this case there is practically and statistically no difference between barrels.

```
##      alpha a b nreps       Delta    sigma    powera    powerb
## [1,]  0.05 2 2     3 0.005376675 0.003196 0.7236890 0.7236890
## [2,]  0.05 2 2     4 0.005376675 0.003196 0.8698896 0.8698896
## [3,]  0.05 2 2     5 0.005376675 0.003196 0.9415445 0.9415445
## [4,]  0.05 2 2     6 0.005376675 0.003196 0.9747652 0.9747652
```

The power is 0.87 at 4 replications. When there is no difference between means, this is typically where sample sizes are need to be increased to ensure there is no Type II Errors. There does not appear to be an issue here because the power is 0.87 which typically an experiment wants to be between 0.8 and 0.9 or higher if you have time and money to spare.

If the shooters are not homogeneous but there is significance between barrels

This test randomly sampled from the assumed group sizes and STD and tested if there was a difference between barrels while controlling for heterogeneous shooters.

Random noise was added to shooter A

```
##            Df Sum Sq Mean Sq F value   Pr(>F)    
## structured   1 0.4441  0.4441   26.18 0.000198 ***
## shooter      1 0.4203  0.4203   24.78 0.000253 ***
## Residuals   13 0.2205  0.0170                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## 
## ===============================================
##                         Dependent variable:    
##                     ---------------------------
##                                test3           
## -----------------------------------------------
## structured1                  0.167***          
##                               (0.033)          
##                                                
## shooter1                     -0.162***         
##                               (0.033)          
##                                                
## Constant                     1.268***          
##                               (0.033)          
##                                                
## -----------------------------------------------
## Observations                    16             
## R2                             0.797           
## Adjusted R2                    0.765           
## Residual Std. Error       0.130 (df = 13)      
## F Statistic           25.476*** (df = 2; 13)   
## ===============================================
## Note:               *p<0.1; **p<0.05; ***p<0.01
```

Note: `structured1` represents an unstructured barrel. It's estimated coefficient represents an increase of 0.167” in group size on average. `shooter1` represents shooter B, which recall that shooter A was made to be the worse of the two shooters. Shooter B has a smaller group size on average by 0.162”

```
##      alpha a b nreps     Delta sigma powera powerb
## [1,]  0.05 2 2     2 0.2356585 0.017      1      1
## [2,]  0.05 2 2     3 0.2356585 0.017      1      1
## [3,]  0.05 2 2     4 0.2356585 0.017      1      1
```

If the shooters are not homogeneous and there is not significance between barrels

This test randomly sampled from the assumed group sizes and STD and tested if there was no difference between barrels while controlling for heterogeneous shooters.

Random noise was added to shooter A

```
##            Df  Sum Sq Mean Sq F value   Pr(>F)    
## structured   1 0.00013 0.00013   0.041    0.843    
## shooter      1 0.12731 0.12731  39.847 2.69e-05 ***
## Residuals   13 0.04154 0.00320                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## 
## ===============================================
##                         Dependent variable:    
##                     ---------------------------
##                                test4           
## -----------------------------------------------
## structured1                   -0.003           
##                               (0.014)          
##                                                
## shooter1                     -0.089***         
##                               (0.014)          
##                                                
## Constant                     1.049***          
##                               (0.014)          
##                                                
## -----------------------------------------------
## Observations                    16             
## R2                             0.754           
## Adjusted R2                    0.716           
## Residual Std. Error       0.057 (df = 13)      
## F Statistic           19.944*** (df = 2; 13)   
## ===============================================
## Note:               *p<0.1; **p<0.05; ***p<0.01
```

Note: `structured1` represents an unstructured barrel. In this case there is no difference between barrels. `shooter1` represents shooter B, which recall that shooter A was made to be the worse of the two shooters. Shooter B has a smaller group size on average by 0.089”

```
##      alpha a b nreps     Delta  sigma powera powerb
## [1,]  0.05 2 2     2 0.1830666 0.0032      1      1
## [2,]  0.05 2 2     3 0.1830666 0.0032      1      1
## [3,]  0.05 2 2     4 0.1830666 0.0032      1      1
```

Conclusion

This experimental design is simple with considerably less combination of factors to test. If the assumptions are correct, then the number of rounds needed are 480. The number of rifles needed would be two and the number of shooters is also two. Please note that this is only a simulation to help design the experiment and not final. It can be iteratively updated as it would occur in normal engineering experiments. A pilot study would greately help determine the number of replications, but this simulation does not seem to be an unreasonable estimation.