What Affects My Free Throw Shot?
A Free Throw "Routine" Factor Screening

2023May01

ALEX SALCE
STAT571B Project, Spring Semester 2023

THE UNIVERSITY OF ARIZONA

About me...

- First year Statistics and Data Science MS GIDP
- Online section
- Group of one
- I enjoy basketball!

THE UNIVERSITY OF ARIZONA

Background

What is a Free Throw?

- "an unimpeded attempt at a basket (worth one point) awarded to a player following a foul or other infringement."

Why Study Free Throws?

- "Individual" and "unimpeded" basketball play that may be influenced by individual factors for the shooter

Free Throw Shooting Routine

- For this experiment we define "routine" as the aggregate all performative and technique **factors** that occur *prior* to the ball being shot
- Routine is unique to an individual, perceived to improve performance

Free Throw Performance

- Evaluated based on number of free throws made in a given sample number of attempts (the **response** in the experiment)

THE UNIVERSITY OF ARIZONA

Problem Definition, Experimental Design Selection Considerations

"Are there any factors in my routine that affect my free throw shooting performance?"

What experimental design makes sense?

Experimental design requirements

- Analyze **multiple <u>fixed</u> factors** of interest
- Factors can be **qualitative**
- Account for **nuisance factors**
- Can be **completely randomized**
- Describes **magnitude and direction** for impact of factor on response (cursory insight only)

2^k Factorial Design

(blocked replicates)

"Factor Screening" experiment

Goal - identify factor(s) that impact my free throw shooting to further study/improve

THE UNIVERSITY OF ARIZONA

Factors Selected for Study

Three factors selected that characterized my free throw routine

A: Time

YouTube

B: Stance Angle

The Ringer

C: “Spring” motion

GIPHY

	A	B	C
+	5 counts	~30 deg angle	“Spring” in legs
-	1 count	0 deg angle	“Stiff” legs

“+” levels correspond to my preferred free throw shooting routine.
“-” levels selected for contrast based on experience
Factors are fixed

THE UNIVERSITY OF ARIZONA

Procedure & Data Collection

Prep

- Mark shooting position with tape (repeatability)
- Warm up (15min) before stepping to the line
- Assistant opens worksheets

Experimental Procedure

1 RUN (worksheet row):

- Assistant announces factor combination for run, shooter adjusts **stance angle**
- Assistant passes shooter ball, shooter dribbles for **1 or 5 counts** and shoots **rigid or with spring**
- Assistant retrieves ball, passes and process repeated until ***X*** shots taken
- Assistant records number made in run

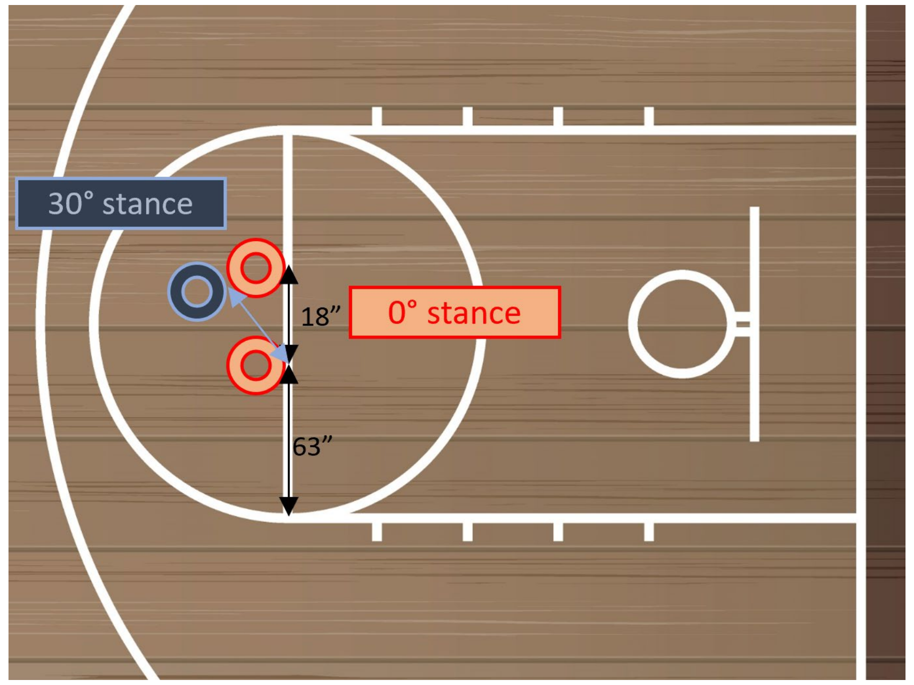
Each of 8 runs (completely randomized) is performed to complete 1 replicate. 3 replicates were performed at each location (upcoming slides)

	Factors			
Order	A	B	C	Made
1	Short	Square	Rigid	2
2	Short	Square	Spring	0
3	Short	Angled	Rigid	1
4	Long	Angled	Rigid	3
5	Short	Angled	Spring	5
6	Long	Square	Rigid	3
7	Long	Square	Spring	4
8	Long	Angled	Spring	5

	Factors			
Order	A	B	C	Made
1	Short	Square	Rigid	5
2	Short	Angled	Spring	3
3	Long	Angled	Rigid	2
4	Long	Angled	Spring	4
5	Long	Square	Spring	5
6	Short	Square	Spring	3
7	Short	Angled	Rigid	3
8	Long	Square	Rigid	5

	Factors			
Order	A	B	C	Made
1	Short	Angled	Spring	5
2	Long	Square	Spring	5
3	Short	Square	Rigid	2
4	Short	Square	Spring	6
5	Long	Angled	Spring	5
6	Short	Angled	Rigid	4
7	Long	Square	Rigid	1
8	Long	Angled	Rigid	2

Data collection worksheets



Tape marking measurements

Angled (+) Spring (+) run

Square (–) Rigid (-) run

THE UNIVERSITY OF ARIZONA

Model and Hypothesis Test

Statistical Model Summary

Design Matrix

	A	B	C
r_1	-	-	-
r_2	+	-	-
r_3	-	+	-
r_4	+	+	-
r_5	-	-	+
r_6	+	-	+
r_7	-	+	+
r_8	+	+	+

Model

$$y_{ijkm} = A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + \delta_m + \epsilon_{ijkm} \quad \begin{cases} i = 1,2 \\ j = 1,2 \\ k = 1,2 \\ m = 1,2 \end{cases}$$

Block run-to-run variation (nuisance factors)

Model Assumptions

$$\epsilon_{ijkm} \sim N(0, \sigma^2)$$

$$A_1 + A_2 = 0,\ B_1 + B_2 = 0,\ C_1 + C_2 = 0$$

$$\sum_{i=1}^{2}(AB)_{ij} = \sum_{j=1}^{2}(AB)_{ij} = 0,\ \sum_{i=1}^{2}(AC)_{ik} = \sum_{k=1}^{2}(AC)_{ik} = 0,\ \sum_{j=1}^{2}(BC)_{jk} = \sum_{k=1}^{2}(BC)_{jk} = 0$$

$$\sum_{i=1}^{2}(ABC)_{ijk} = \sum_{j=1}^{2}(ABC)_{ijk} = \sum_{k=1}^{2}(ABC)_{ijk} = 0$$

Hypotheses

$$H_0 : A_1 = A_2 = 0$$
$$H_1 : \text{at least one of } A_1 \text{ or } A_2 \neq 0$$

And similar hypotheses for factors B and C.

$$H_0 : (AB)_{ij} = 0 \text{ for all } i, j$$
$$H_1 : \text{at least one of } (AB)_{ij} \neq 0$$

And similar hypotheses are extended for interactions $(AC)_{ik}$, $(BC)_{jk}$, and $(ABC)_{ijk}$. Factors are **fixed** (factors were selected and controlled in the experiment), so

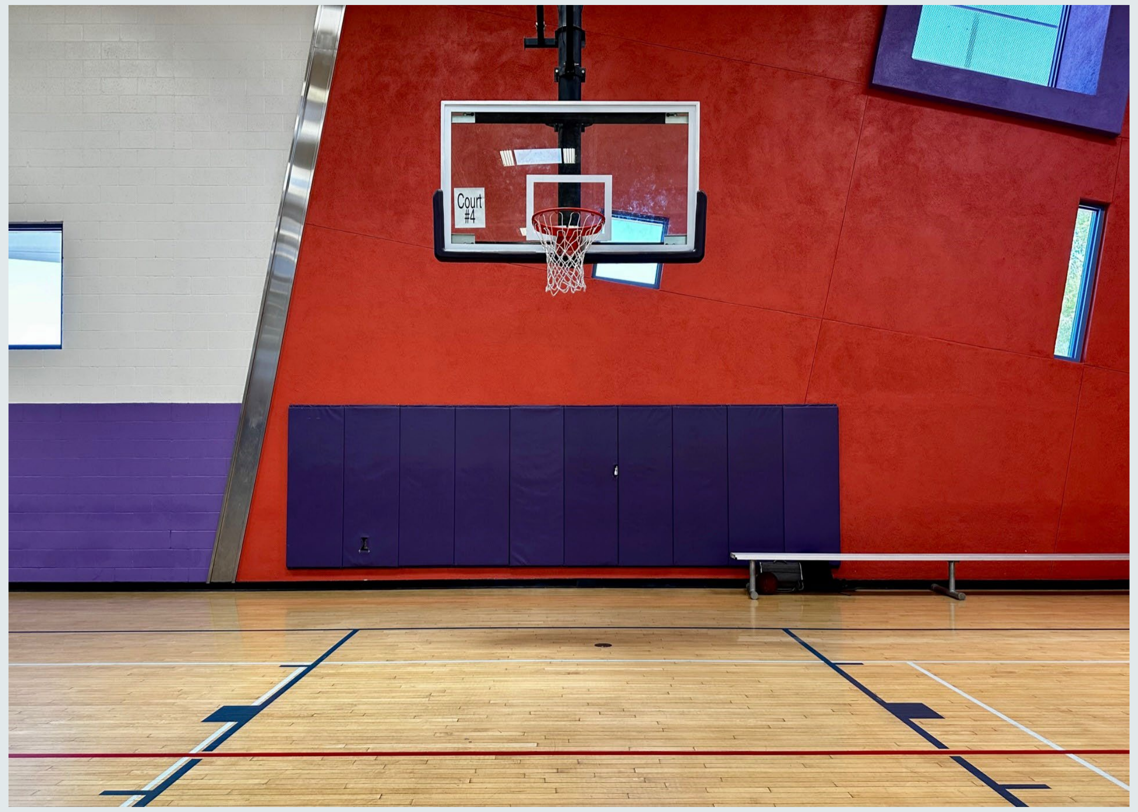
THE UNIVERSITY OF ARIZONA

Results

X=5 shots per run, 40 shots/replicate 120 shots total

Indoor Data

Indoor					
Factors			Replicates		
A	B	C	I	II	III
-	-	-	2	3	3
+	-	-	2	1	2
-	+	-	0	1	3
+	+	-	3	3	1
-	-	+	0	1	3
+	-	+	4	3	4
-	+	+	2	2	3
+	+	+	1	2	3



ANOVA

$\alpha = 0.05$ level

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	17.00000000	1.88888889	2.14	0.0970
Error	14	12.33333333	0.88095238		
Corrected Total	23	29.33333333			

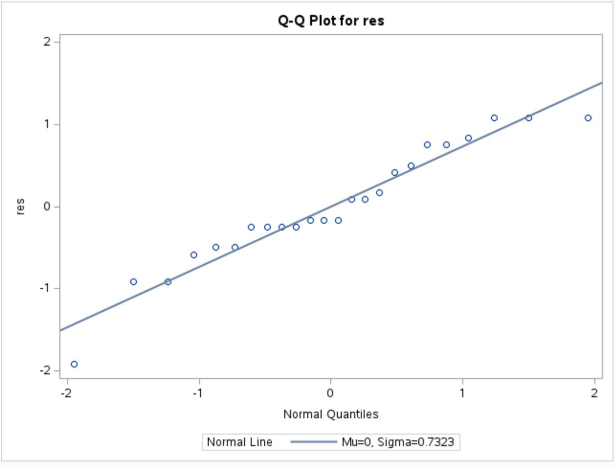
R-Square	Coeff Var	Root MSE	resp Mean
0.579545	43.31957	0.938591	2.166667

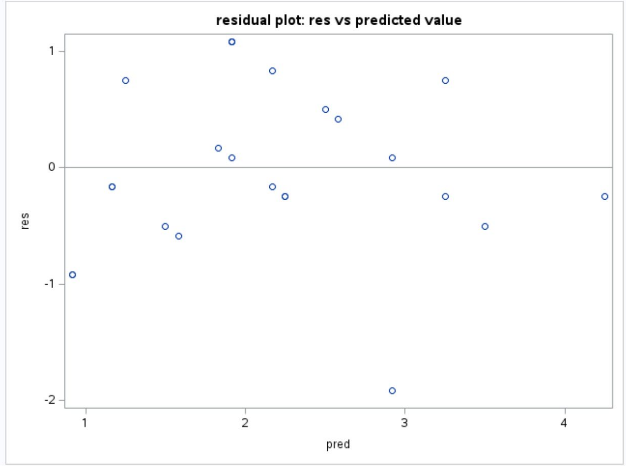
Source	DF	Type III SS	Mean Square	F Value	Pr > F
block	2	4.33333333	2.16666667	2.46	0.1215
A	1	1.50000000	1.50000000	1.70	0.2130
B	1	0.66666667	0.66666667	0.76	0.3990
C	1	0.66666667	0.66666667	0.76	0.3990
AB	1	0.16666667	0.16666667	0.19	0.6702
AC	1	1.50000000	1.50000000	1.70	0.2130
BC	1	0.00000000	0.00000000	0.00	1.0000
ABC	1	8.16666667	8.16666667	9.27	0.0087

Diagnostics

$$\epsilon_{ijkm} \sim N(0, \sigma^2)$$

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.945349	Pr < W	0.2144
Kolmogorov-Smirnov	D	0.131688	Pr > D	>0.1500
Cramer-von Mises	W-Sq	0.064044	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq	0.428198	Pr > A-Sq	>0.2500





Results

X=5 shots per run; 40 shots/replicate, 120 shots total

Outdoor I Data

Outdoor I					
Factors			Replicates		
A	B	C	I	II	III
-	-	-	2	4	3
+	-	-	2	1	2
-	+	-	2	2	1
+	+	-	1	3	3
-	-	+	1	3	2
+	-	+	4	2	5
-	+	+	2	3	0
+	+	+	0	3	2

ANOVA

$\alpha = 0.05$ level

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	15.04166667	1.67129630	1.24	0.3480
Error	14	18.91666667	1.35119048		
Corrected Total	23	33.95833333			

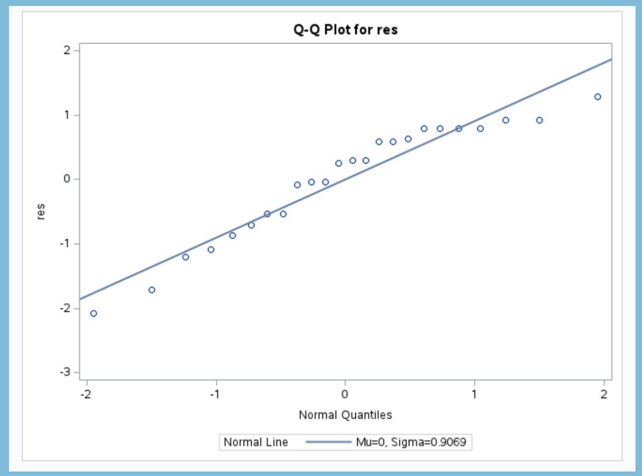
R-Square	Coeff Var	Root MSE	resp Mean
0.442945	52.63731	1.162407	2.208333

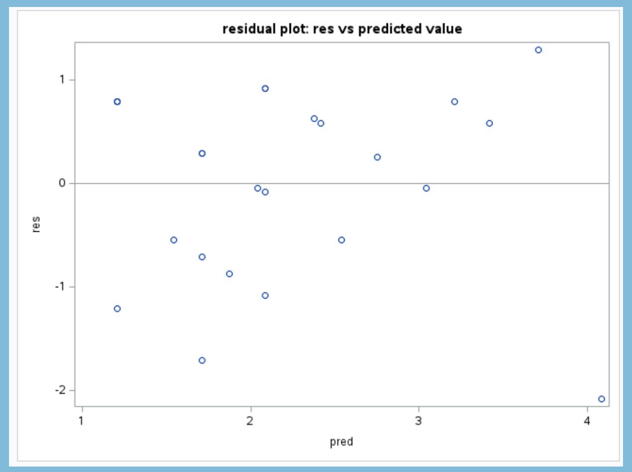
Source	DF	Type III SS	Mean Square	F Value	Pr > F
block	2	3.08333333	1.54166667	1.14	0.3475
A	1	0.37500000	0.37500000	0.28	0.6066
B	1	3.37500000	3.37500000	2.50	0.1363
C	1	0.04166667	0.04166667	0.03	0.8631
AB	1	0.04166667	0.04166667	0.03	0.8631
AC	1	2.04166667	2.04166667	1.51	0.2392
BC	1	1.04166667	1.04166667	0.77	0.3948
ABC	1	5.04166667	5.04166667	3.73	0.0739

Diagnostics

$$\epsilon_{ijkm} \sim N(0, \sigma^2)$$

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.924349	Pr < W	0.0729
Kolmogorov-Smirnov	D	0.156625	Pr > D	0.1296
Cramer-von Mises	W-Sq	0.117049	Pr > W-Sq	0.0648
Anderson-Darling	A-Sq	0.693365	Pr > A-Sq	0.0642





Results

X=10 shots per run; 80 shots/replicate, 240 shots total

Outdoor II Data

Outdoor II					
Factors			Replicates		
A	B	C	I	II	III
-	-	-	2	5	2
+	-	-	3	5	1
-	+	-	1	3	4
+	+	-	3	2	2
-	-	+	0	3	6
+	-	+	4	5	5
-	+	+	5	3	5
+	+	+	5	4	5

ANOVA

$\alpha = 0.05$ level

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	22.70833333	2.52314815	0.95	0.5165
Error	14	37.25000000	2.66071429		

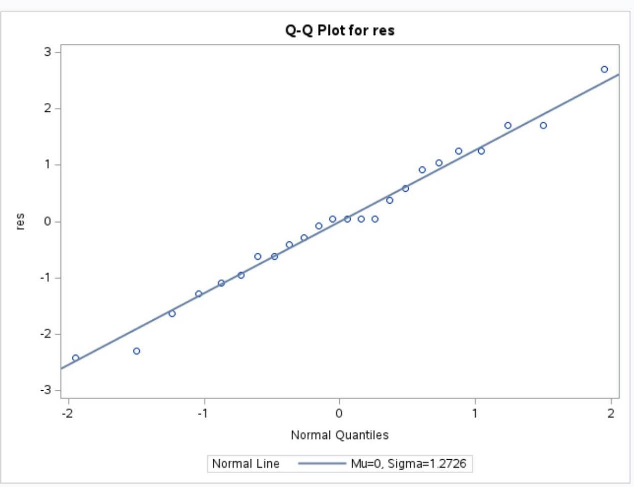
R-Square	Coeff Var	Root MSE	resp Mean
0.378735	47.16635	1.631170	3.458333

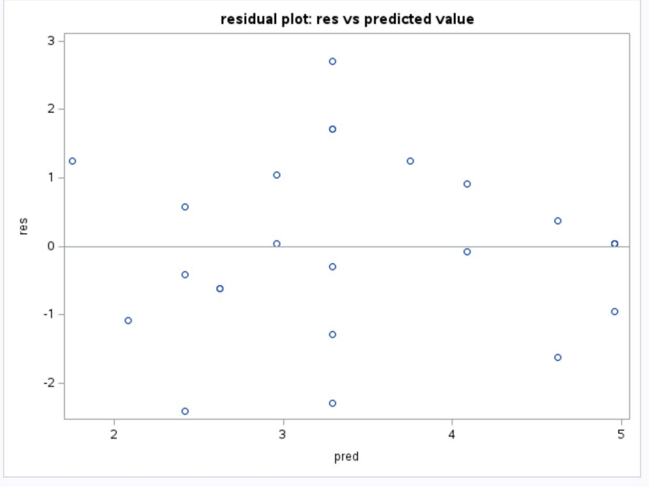
Source	DF	Type III SS	Mean Square	F Value	Pr > F
block	2	4.08333333	2.04166667	0.77	0.4828
A	1	1.04166667	1.04166667	0.39	0.5416
B	1	0.04166667	0.04166667	0.02	0.9022
C	1	12.04166667	12.04166667	4.53	0.0516
AB	1	1.04166667	1.04166667	0.39	0.5416
AC	1	2.04166667	2.04166667	0.77	0.3958
BC	1	2.04166667	2.04166667	0.77	0.3958
ABC	1	0.37500000	0.37500000	0.14	0.7130

Diagnostics

$$\epsilon_{ijkm} \sim N(0, \sigma^2)$$

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.985509	Pr < W	0.9723
Kolmogorov-Smirnov	D	0.111941	Pr > D	>0.1500
Cramer-von Mises	W-Sq	0.024512	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq	0.156421	Pr > A-Sq	>0.2500



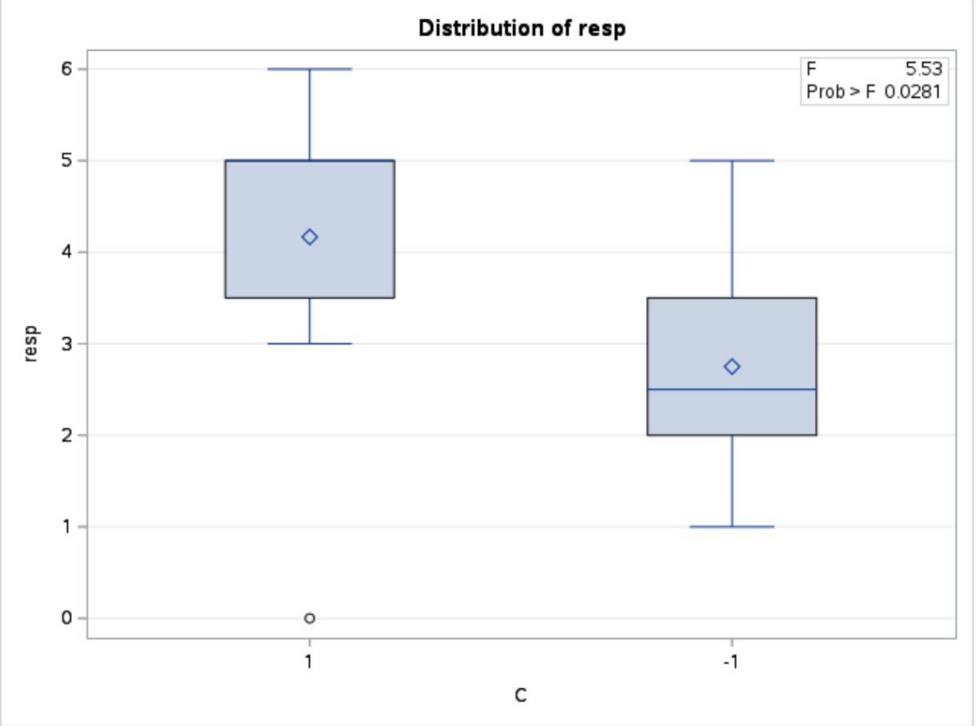


Quick look Factor C

X=10 shots per run; 80 shots/replicate, 240 shots total

Outdoor II Data

Outdoor II					
Factors			Replicates		
A	B	C	I	II	III
-	-	-	2	5	2
+	-	-	3	5	1
-	+	-	1	3	4
+	+	-	3	2	2
-	-	+	0	3	6
+	-	+	4	5	5
-	+	+	5	3	5
+	+	+	5	4	5



Parameter Estimates

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	2.58333	0.86264	2.99	0.0091
block		1	0.43750	0.39933	1.10	0.2905
A	A	1	0.20833	0.32605	0.64	0.5325
B	B	1	0.04167	0.32605	0.13	0.9000
C	C	1	0.70833	0.32605	2.17	0.0463
AB		1	-0.20833	0.32605	-0.64	0.5325
AC		1	0.29167	0.32605	0.89	0.3852
BC		1	0.29167	0.32605	0.89	0.3852
ABC		1	-0.12500	0.32605	-0.38	0.7068

Positive effect on response from (-) to (+)

Conclusions

Inference Conclusions

- Factor C (Spring/Rigid) is approximately significant at the $\alpha = 0.05$ level in Outdoor II factor screening experiment
- Factor C has a positive effect on response from low level to high level (Rigid to Spring) for the Outdoor II factor screening experiment

Inference Caveats

- Can only infer about fixed factors
- Specific locations and conditions
- Study only “screens” for factor of interest

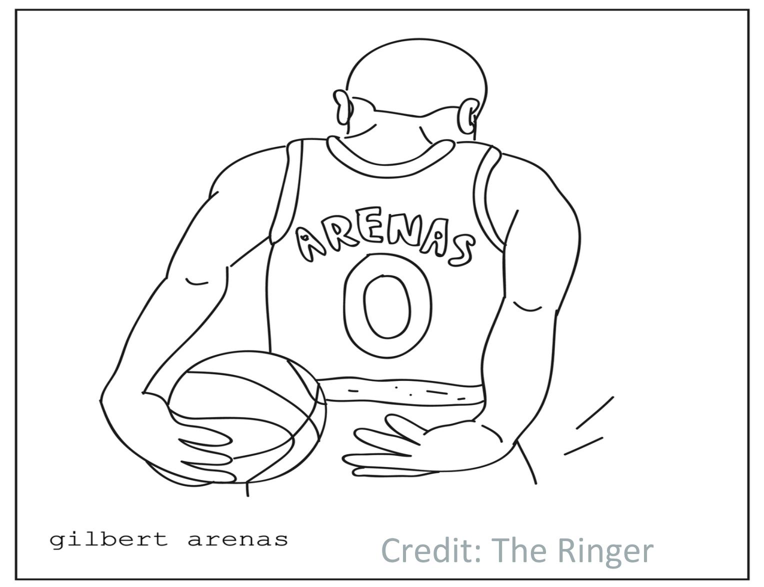
Lessons Learned

- Larger sample size, repeated experiments; proper power analysis may be warranted
- Time planning for full factorial experiment; fewer runs with confounding factors may be better plan

Recommended Further Study

- Focused study on “Spring” factor effects, new experimental design
- Factor screening of additional subjects

THE UNIVERSITY OF ARIZONA



Credit: The Ringer

QUESTIONS & DISCUSSION

THE UNIVERSITY OF ARIZONA

References

- Montgomery, D. C. (2013). Design and Analysis of Experiments (8th ed.). John Wiley & Sons, Inc.
- May, Andrew J., "A Comparison of the Effectiveness of Two Free Throw Shooting Methods" (2011). Theses and Dissertations. 2918. https://scholarsarchive.byu.edu/etd/2918
- Cannon, Jamaal Edward, "Effects of imagery use in basketball free throw shooting" (2008). Theses Digitization Project. 3354. https://scholarworks.lib.csusb.edu/etd-project/3354

THE UNIVERSITY OF ARIZONA

May (2011)

Time factor has been studied and has not shown significance

Studies were completed to show the improvements in free throw accuracy gained from a consistent pre-shot throw routine (Cohn, 1990; Czech, Ploszay, & Burke, 2004; Lobmeyer & Wasserman, 1986; Lonsdale & Tam, 2008; Wrisberg & Pein, 1992). Studies have also shown that there is no difference in duration of pre-shot routines and accuracy ($p>.05$) (Gooding & Gardner, 2009; Lonsdale & Tam, 2008; Wrisberg & Pein, 1992). Mack (2001) likewise confirmed this relationship, while adding that alterations to routine sequence significantly diminished free throw accuracy. Hadad & Tremayne (2009) found a significant improvement of free throw accuracy when incorporating a “centering” breath into their pre-shot routine ($p<.05$).

Quick look Factor C

k=10 shots per run

Outdoor II Data

Outdoor II					
Factors			Replicates		
A	B	C	I	II	III
-	-	-	2	5	2
+	-	-	3	5	1
-	+	-	1	3	4
+	+	-	3	2	2
-	-	+	0	3	6
+	-	+	4	5	5
-	+	+	5	3	5
+	+	+	5	4	5

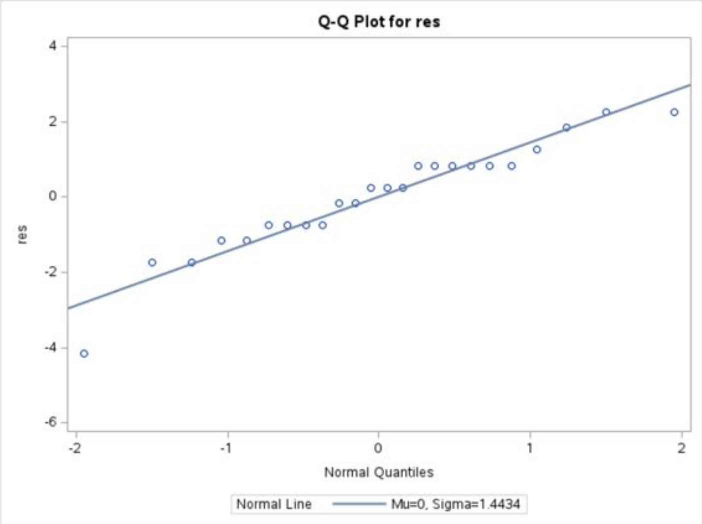
Refit to Factor C

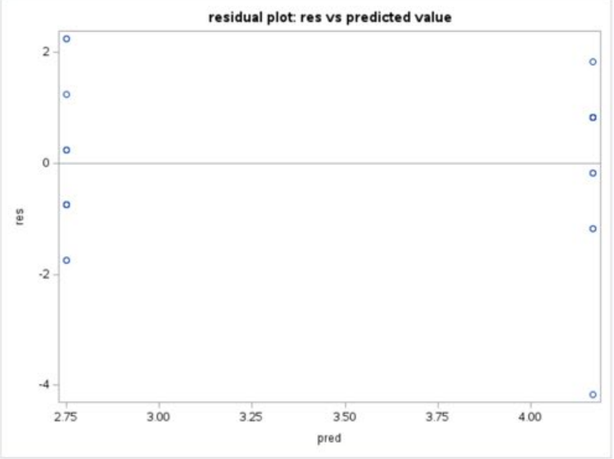
Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	3.45833	0.30125	11.48	<.0001
C	C	1	$\boxed{0.70833}$	0.30125	2.35	0.0281

Tests for Normality

Test	Statistic		p Value	
Shapiro-Wilk	W	0.936579	Pr < W	0.1368
Kolmogorov-Smirnov	D	0.134815	Pr > D	>0.1500
Cramer-von Mises	W-Sq	0.06877	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq	0.462813	Pr > A-Sq	0.2400





Positive effect on response from (-) to (+)