Paper Helicopter Experiment 4

-Isaiah Morgan, Joshua Singer, Cloe Wynn

Introduction:

Paper helicopters have been the subject of several statistical studies over the years. They serve well as a statistical experiment because of the relative ease of performing the experiment and the potential factors that can be examined, such as wing length or material used. (Jiju Antony, 1999) From a practical perspective, paper helicopters do little to advance scientific understanding, though some studies have used paper helicopters to understand certain aspects of aerodynamics. (Stefano Barone, 2002) Regardless, these experiments serve as an excellent starting place for understanding statistical reasoning (Jiju Antony, 2001).

As an added plus, folding paper helicopters and dropping them from great heights has a cathartic effect that has great potential benefit to a stressed college student.

Methods:

- Design - A Basic Two Factor Experiment was performed analyzing the effects of both paper type and tail fold length of a paper helicopter design. 20 helicopters were made (5 replicates for each treatment) and dropped from a set height in the Wilkinson Student Center. The fall time of each helicopter was measured with standard phone stopwatch and compared to each other.
    - Response: Fall Time (seconds)
    - Factors: Paper Type (Regular, Cardstock), Tail Length (0.5 in, 1.0 in)
    - Treatments: (Regular, 0.5), (Regular, 1.0), (Cardstock, 0.5), (Cardstock, 1.0)
    - Experimental Unit: Each folded Helicopter
    - Replicates: 5 replicates of each treatment group, total = 20. By the nature of this experiment this will provide adequate power to determine significant effects. Expect 2-3 hours preparing and performing the entire experiment.
- Hypotheses
    - $H_o : \alpha_1 = \alpha_2 = 0$
      $H_a : \alpha_1 \neq \alpha_2 \neq 0$

  Where α_i is the paper type effect of level i.

  i = 1 = regular

  i = 2 = cardstock

    - $H_o : \beta_1 = \beta_2 = 0$
      $H_a : \beta_1 \neq \beta_2 \neq 0$

  Where β_j is the tail length effect of level j.

  j = 1 = 0.5 inch

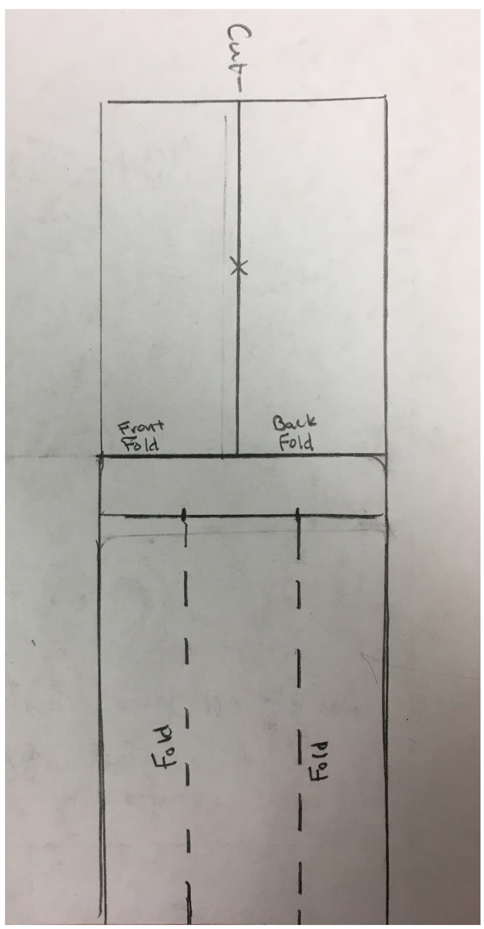
j = 2 = 1.0 inch

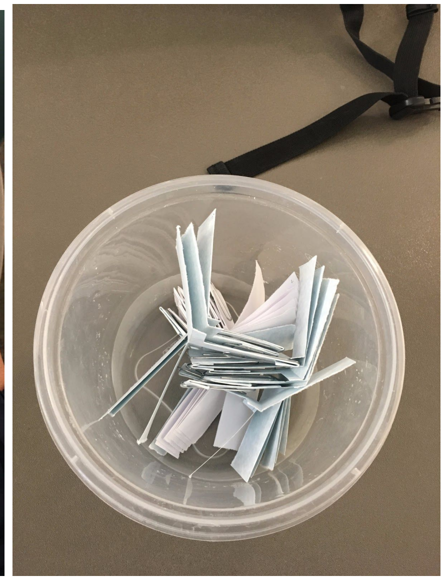
- $H_o: (\alpha\beta)_{1,1} = (\alpha\beta)_{1,2} = (\alpha\beta)_{2,1} = (\alpha\beta)_{2,2} = 0$
  $H_a:$ at least one of the means different

Where $(\alpha\beta)_{ij}$ is the interaction effect of level i for paper type and level j for tail length.

$(\alpha\beta)_{1,1}$ = regular, 0.5
$(\alpha\beta)_{1,2}$ = regular, 1.0
$(\alpha\beta)_{2,1}$ = cardstock, 0.5
$(\alpha\beta)_{2,2}$ = cardstock, 1.0

- Procedure
  - With the following design build the helicopters with before mentioned specifications ((Regular, 0.5), (Regular, 1.0), (Cardstock, 0.5), (Cardstock, 1.0)) with 5 replicates for each treatment group
    - We followed a production line where each group member had a specific task to perform in the folding of the helicopter
    - Photos of the **design** and end result of the **helicopter** are found below:



-  

  - In random order drop each helicopter from a set height
    - Josh dropped them from the balcony in the WSC
  - Record the fall time of each helicopter
    - Isaiah recorded fall times and Cloe entered them into a computer

- Table of Results (see Appendix)

- Summary Statistics: means and standard deviations of interactions

Paper Type	Tail Fold	Mean (time is seconds)	Standard Deviation
Cardstock	0.5	2.762	0.2053534
Regular	0.5	3.448	0.2287357
Cardstock	1.0	2.432	0.4988687
Regular	1.0	3.404	0.2139626

- Summary Statistics: means and standard deviations of treatment effects

	Mean (time in seconds)	Standard Deviation
Regular	3.426	0.21899
Cardstock	2.597	0.3995011

0.5	3.105	0.4155919
1.0	2.918	0.6272125

Anaylsis

- The design we used was a 2 Factor ANOVA. The ANOVA looks at μ , the grand mean, the treatment effects, interaction effect, and the error. The treatment effect for the 1st factor (Paper Type) and the 2nd factor (Tail Fold) is represented by α_i and β_j respectively. The interaction effect between paper type and tail fold is represented by $(\alpha\beta)_{ij}$. The residual time of each observation is shown represented in ε_{ijk} .

$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$

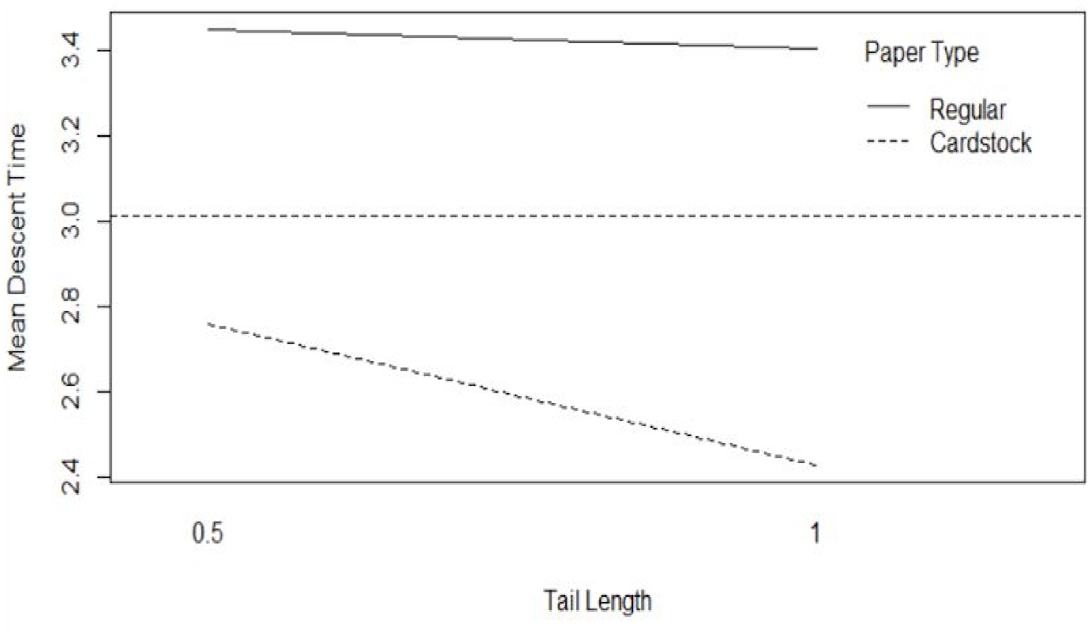
y_{ijk} = fall time of replicate k at i level of the paper type and j level of fold type
μ = grand mean time fall time
α_i = treatment effect for paper type i
β_j = treatment effect for tail fold j
$(\alpha\beta)_{ij}$ = interaction effect for paper type i & tail fold j
ε_{ijk} = error for replicate k for paper type i & tail fold j
i = level of paper type factor (1= regular, 2= cardstock)
j = level of fold length factor (1= 0.5 in, 2= 1.0 in)
k = replicate number (1,2,3,4,5)

- ANOVA Table

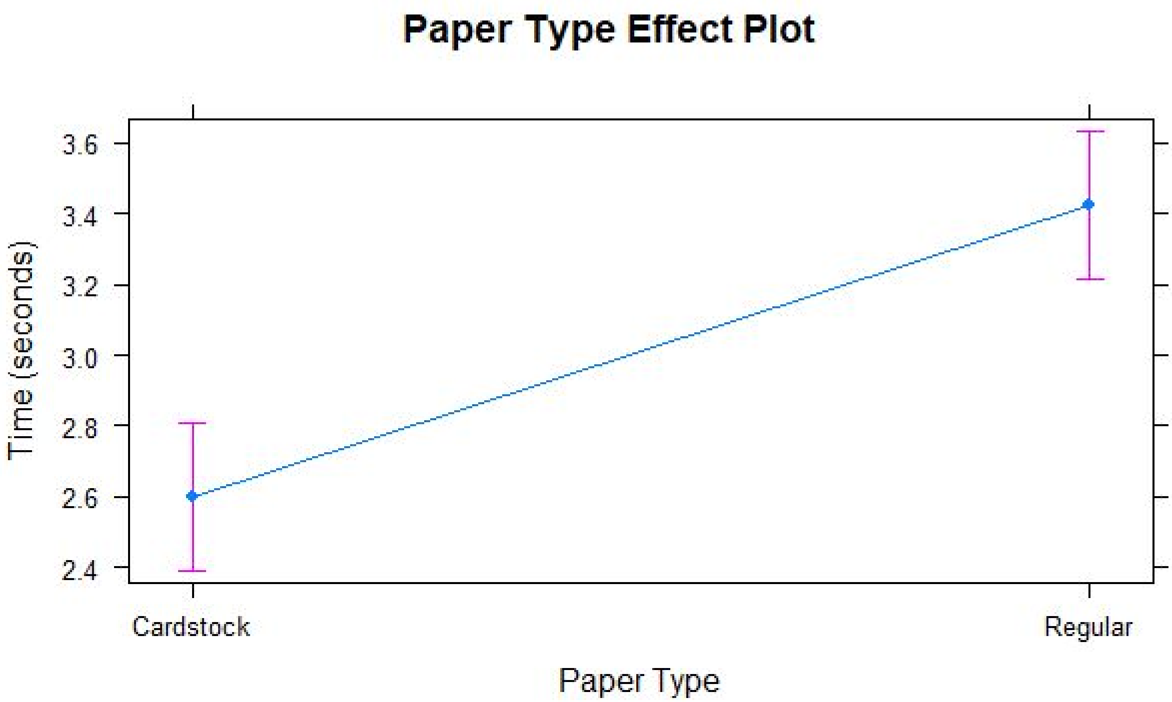
	Df	Sum Square	Mean Square	F-value	P-value
Paper Type	1	3.4362	3.4362	35.3210	2.063e-05
Tail Fold	1	0.1748	0.1748	1.7972	0.1988
Interaction	1	0.1022	0.1022	1.0510	0.3205
Residuals	16	1.5566	0.0973		

Results

- We found that the p-value for Paper Type was 2.063e-05 which is less than .05 and shows that paper type was the only statistically significant factor. As the p-value is small, there is strong evidence against the null hypothesis; therefore, there is strong evidence for the validity of the alternative hypothesis , which states there is a difference between regular paper and cardstock in airtime of paper helicopters.
- The fall time of regular paper helicopters is between .533 and 1.24 seconds longer than the fall time of cardstock paper helicopters (95% confidence).
- Interaction Plot of Significant Effects



- Effect Plot of Paper Type



<u>Summary</u>

We tested 3 sets of hypotheses with this experiment: whether paper type or tail length affected the falling rate of a paper helicopter, and whether there was any interaction between the two factors. We found sufficient evidence to conclude that the type of paper had a significant impact on falling time (p-value <.001) with cardstock helicopters falling between .553 to 1.24 faster the regular paper helicopters (95% confidence). There was no significant effect discovered in changing the tail length of the helicopter, nor was any interaction effect detected between the two factors. As an aside, we found that even though tail length did not significantly impact fall time it did impact the amount of time it took for the helicopter to stabilize its descent with longer tails appearing to take longer to stabilize than the shorter tails. We did nothing to measure this or quantify the difference, but this would be an interesting topic for further study. To do so would require more time and a greater drop height but would be manageable for future projects.

Our research on the topic aligns with previous research on the topic, and coincides with what the other groups in our class found as well. While not groundbreaking, our research further confirms previous research, which is valid in itself.

Our research was limited in scope by both our time and resources as busy college students, but with more time we could have examined more levels of our factors and different factors. For example, we could have additionally made helicopters from tissue or construction paper, or we could have examined additional tail lengths. Among potential other factors, we could have examined wingspan, additional helicopter designs, clipped wings, split wings, and so on. However, with the research performed we were able to practice the principles we have learned in class and through our homework as well as gain experience creating, performing, and evaluating our own research.

Bibliography:

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Appendix

Run	Experiment	Paper Type	Tail Fold	Response (time in seconds)
1	10	Regular	1	3.57
2	1	Regular	0.5	3.43
3	20	Cardstock	1	2.27
4	15	Cardstock	0.5	3.07
5	2	Regular	0.5	3.51
6	8	Regular	1	3.33
7	4	Regular	0.5	3.78

8	7	Regular	1	3.53
9	17	Cardstock	1	3.14
10	6	Regular	1	3.06
11	5	Regular	0.5	3.37
12	3	Regular	0.5	3.15
13	13	Cardstock	0.5	2.56
14	19	Cardstock	1	2.43
15	16	Cardstock	1	1.76
16	12	Cardstock	0.5	2.82
17	9	Regular	1	3.53
18	11	Cardstock	0.5	2.59
19	14	Cardstock	0.5	2.77
20	18	Cardstock	1	2.56