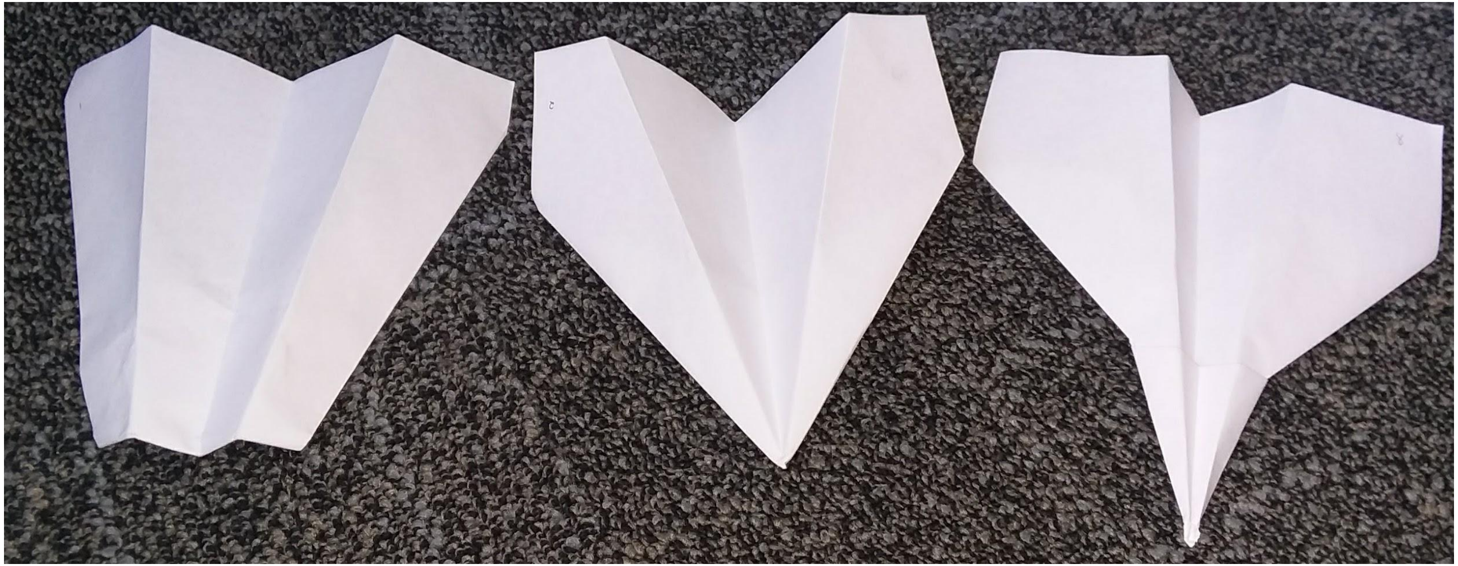
Paper Planes

Jacob Corum, Ricky Johnson, Noah Rose, Cortland Watson, Jason Rose

Introduction

How do we fold a paper plane to maximize distance?

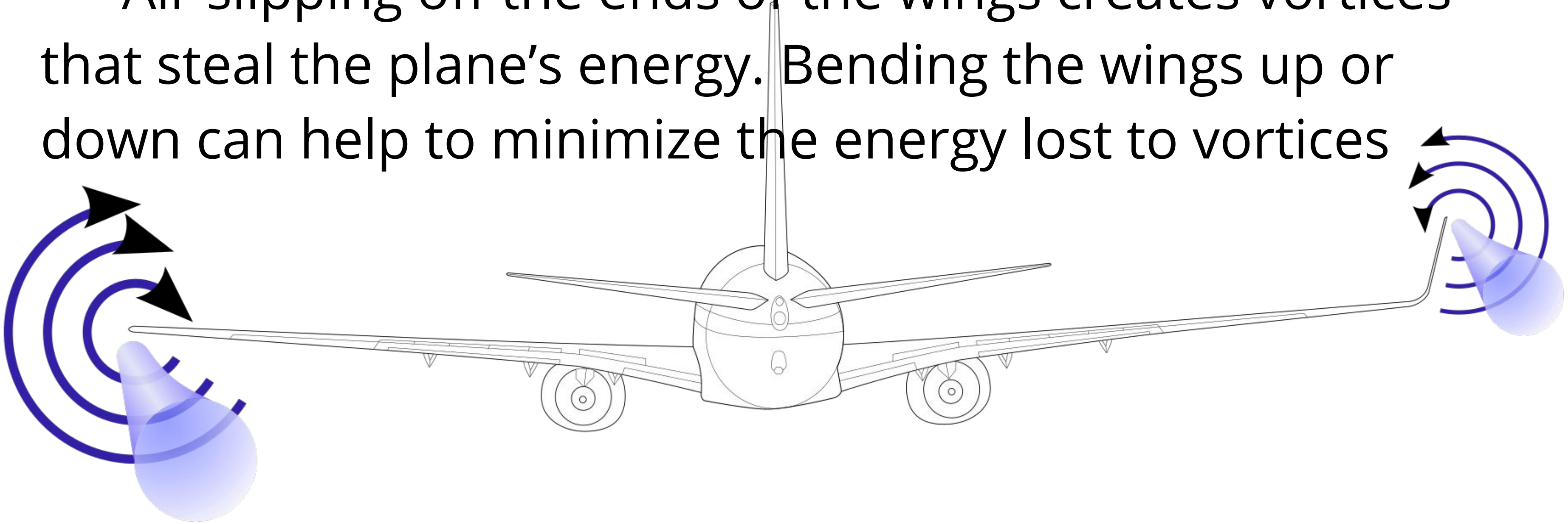
Factor 1: Plane design (snub, delta, and weighted.)



Introduction

Factor 2: Winglets

Air slipping off the ends of the wings creates vortices that steal the plane’s energy. Bending the wings up or down can help to minimize the energy lost to vortices



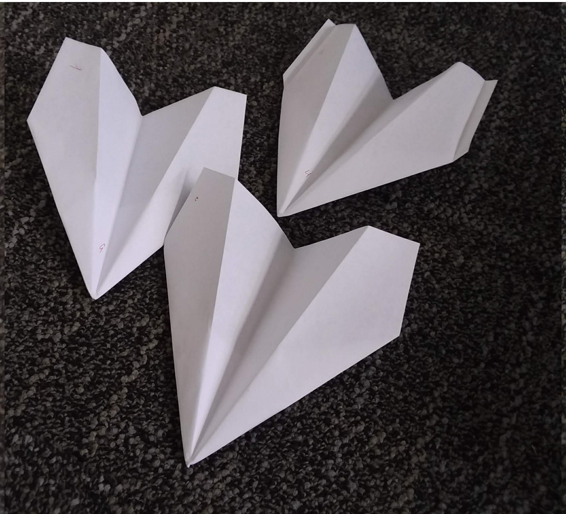
Introduction

Factor 2: Winglets

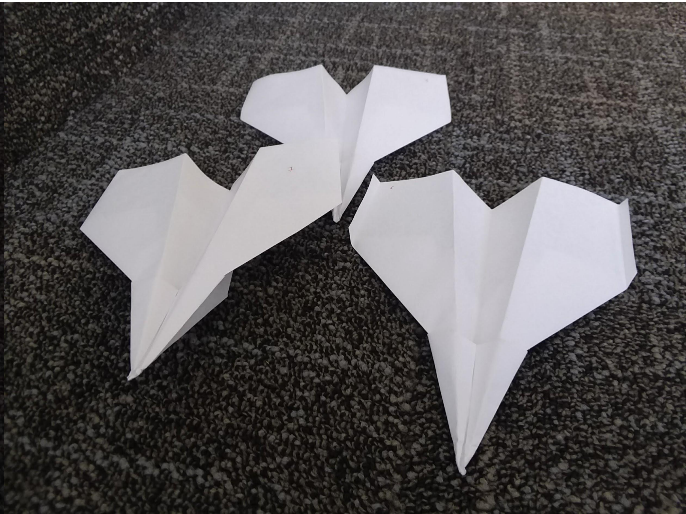
We tried each design with straight wings, up winglets, and down winglets

Snub

Delta

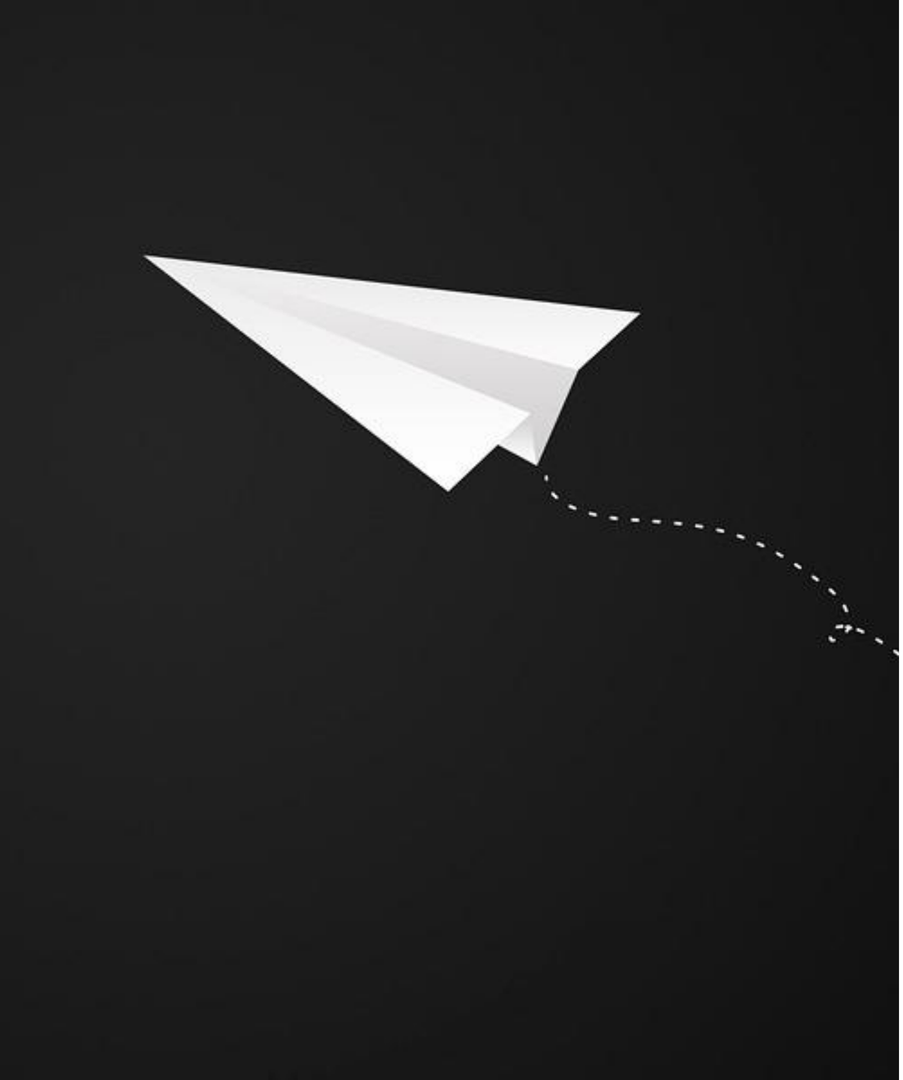


Weighted



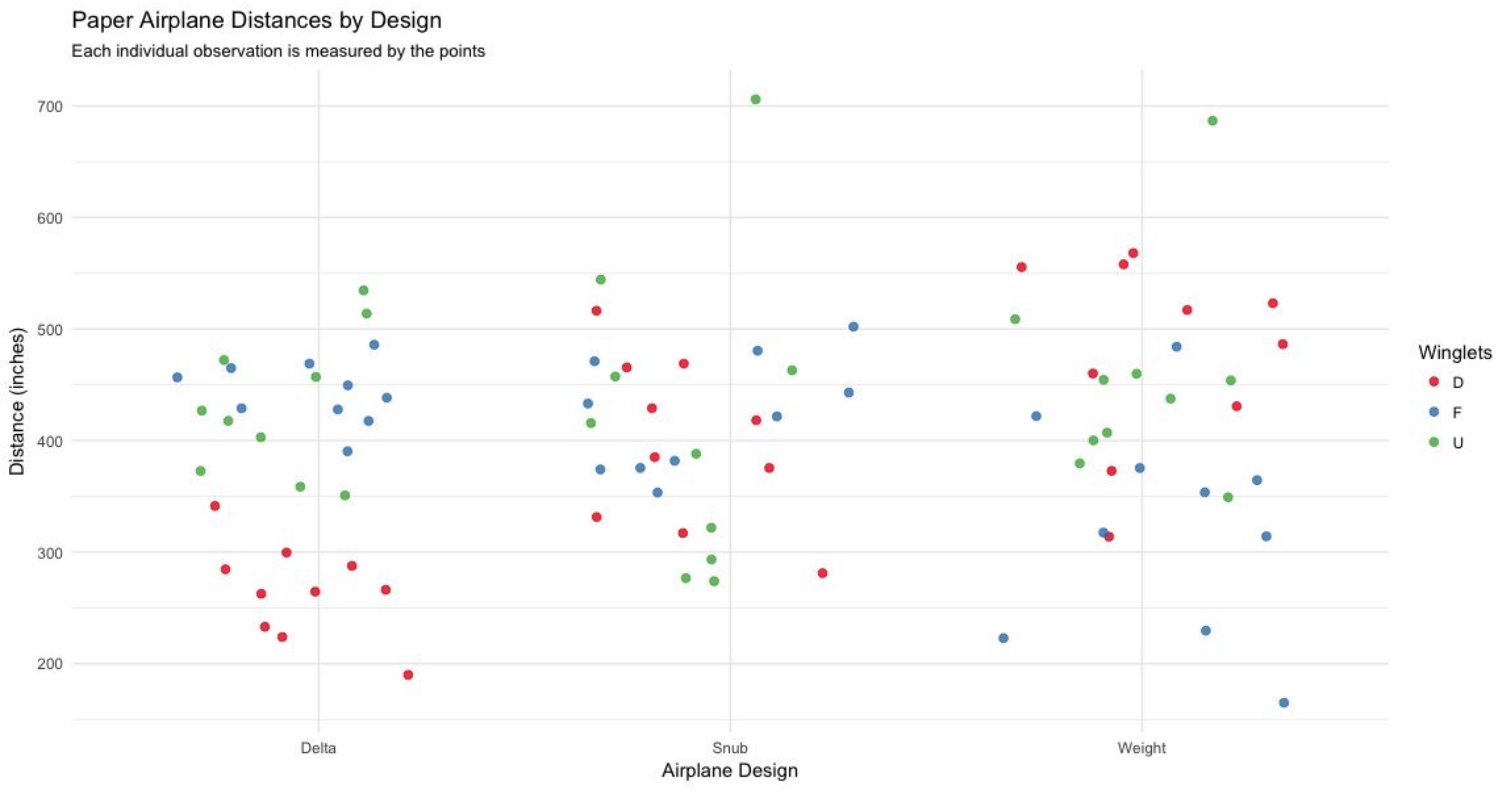
Controlling Nuisance Variables

- Randomization
  - 9 planes flown at random using die
- Control
  - One person throwing to control for differences in skill
  - One person folding planes
  - One type of paper to control for differences in material
- Overall sample size
  - 90 observations (9 planes each thrown 10 times)

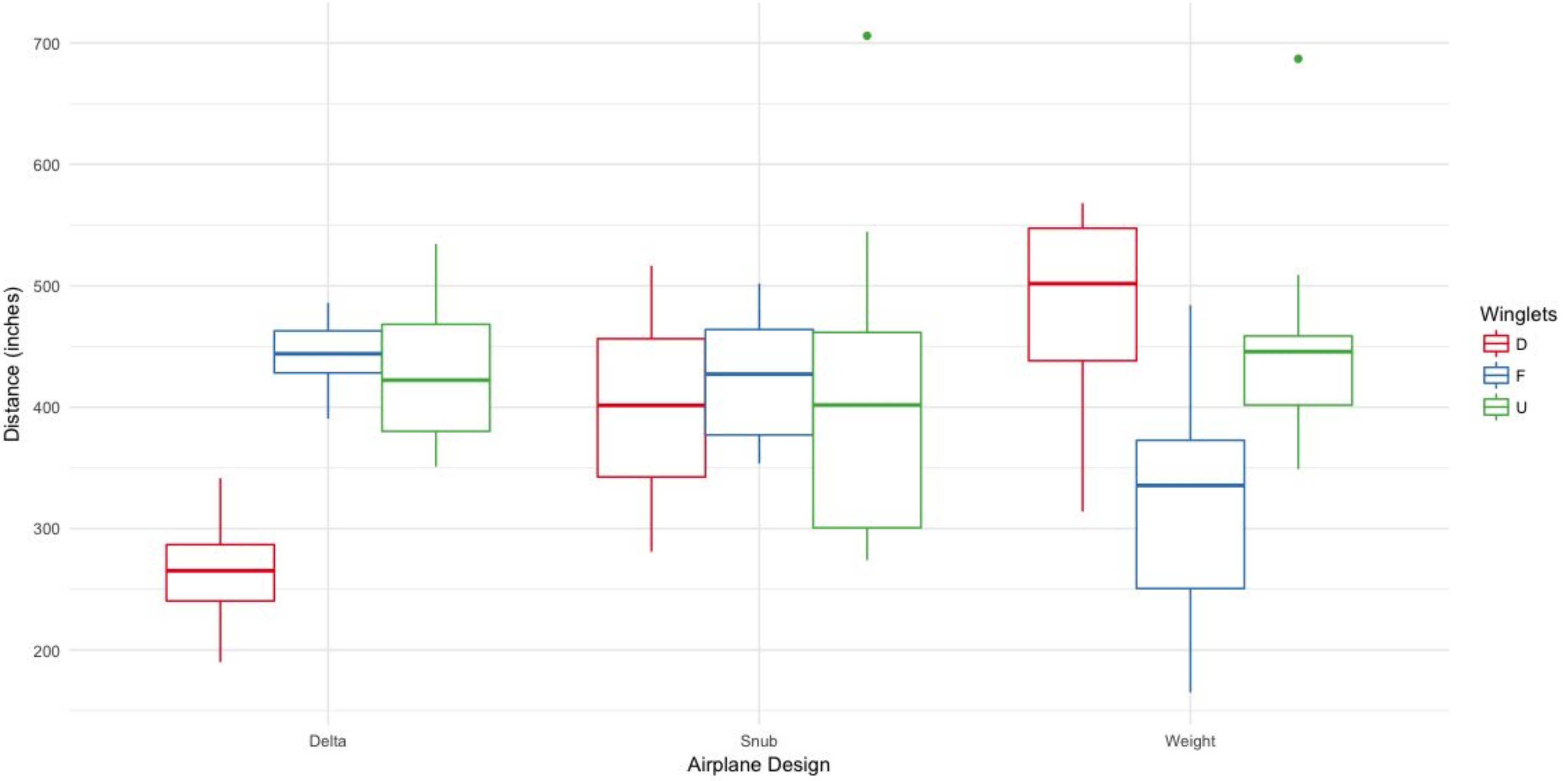


Design: Two-Way Basic Factorial

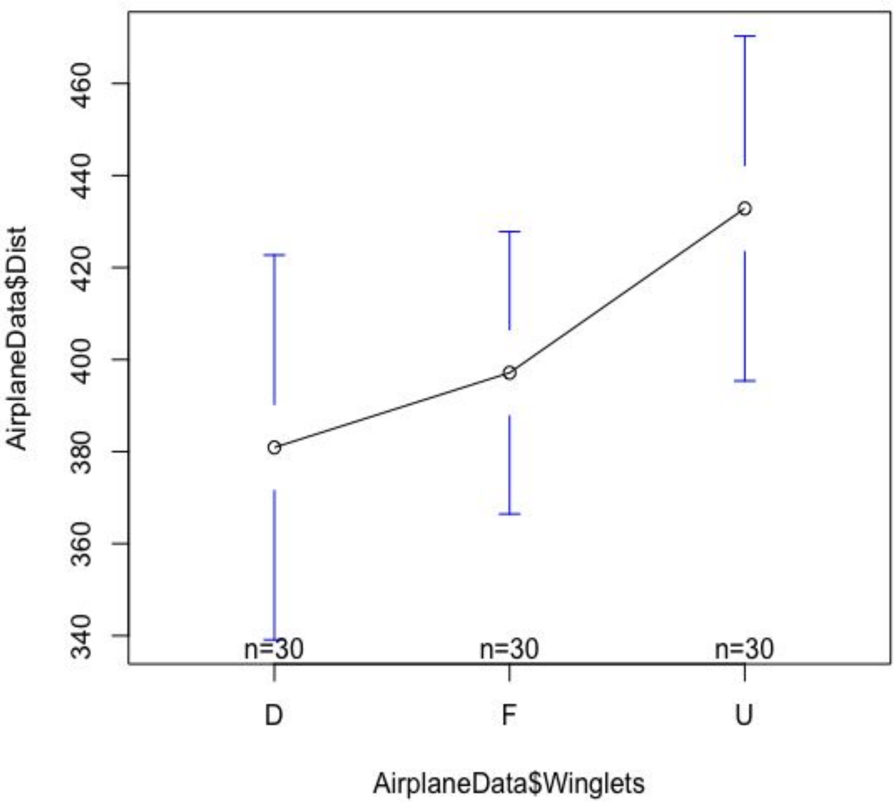
- Treatments
  - Plane design
  - Winglet (folded up, down, or no fold)
- Response
  - Absolute Flight distance from thrower

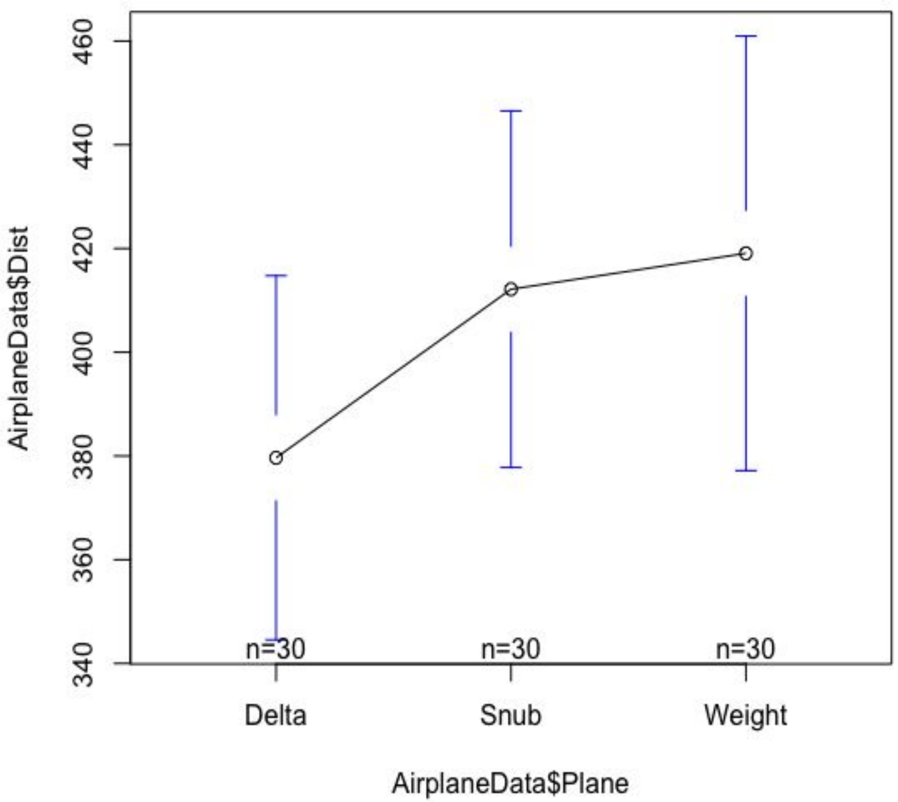

Paper Airplane Distances by Design
Each individual observation is measured by the points
Distance (inches)
700
600
500
400
300
200
Delta
Snub
Weight
Airplane Design
Winglets
D
F
U

Paper Airplane Distances by Design

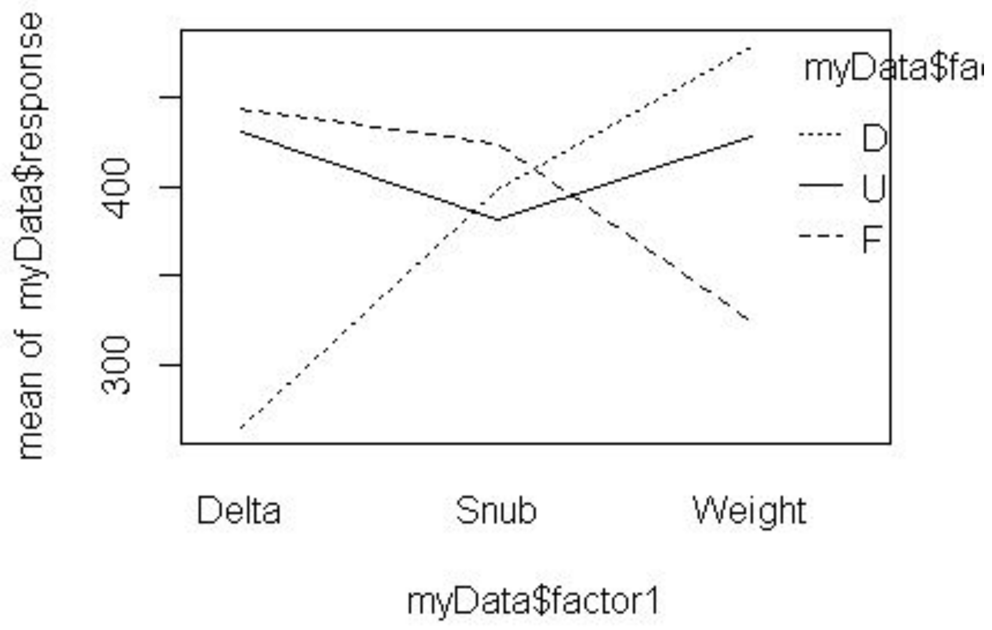


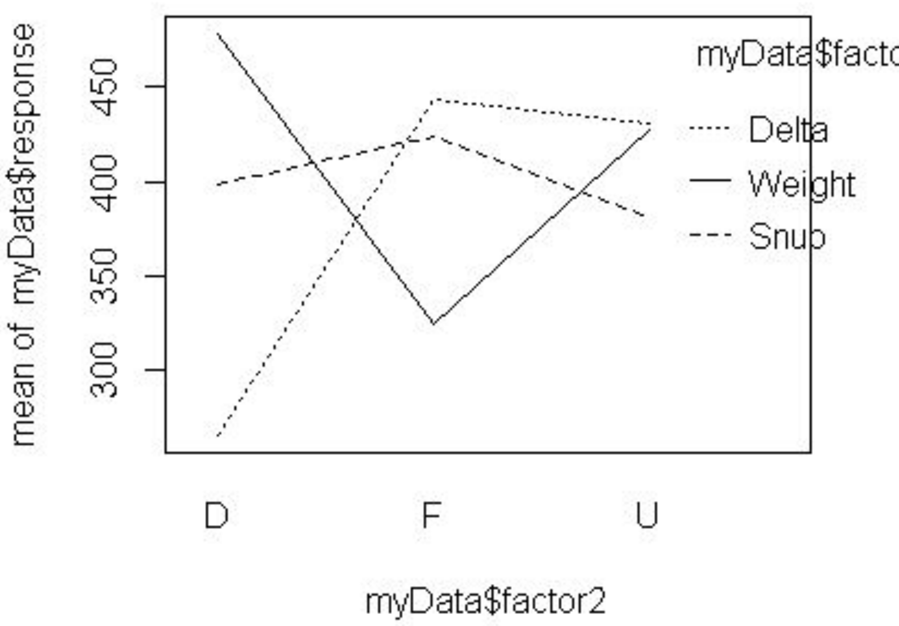
Mean Plots


AirplaneData$Dist
460
440
420
400
380
360
340
n=30
n=30
n=30
D
F
U
AirplaneData$Winglets


AirplaneData$Dist
460
440
420
400
380
360
340
n=30
n=30
n=30
Delta
Snub
Weight
AirplaneData$Plane

Interaction Plots





ANOVA Table

	Sum Sq	Df	F value	Pr(>F)	Reject Null Hypothesis
Design	26578	2	2.02	0.13824	- No
Winglets	42351	2	3.23	0.04465 *	- Yes
Interaction	293907	4	11.21	2.741e-07 *	- Yes
Residuals	530792	81			

$*\alpha = 0.05$

Results of Analysis

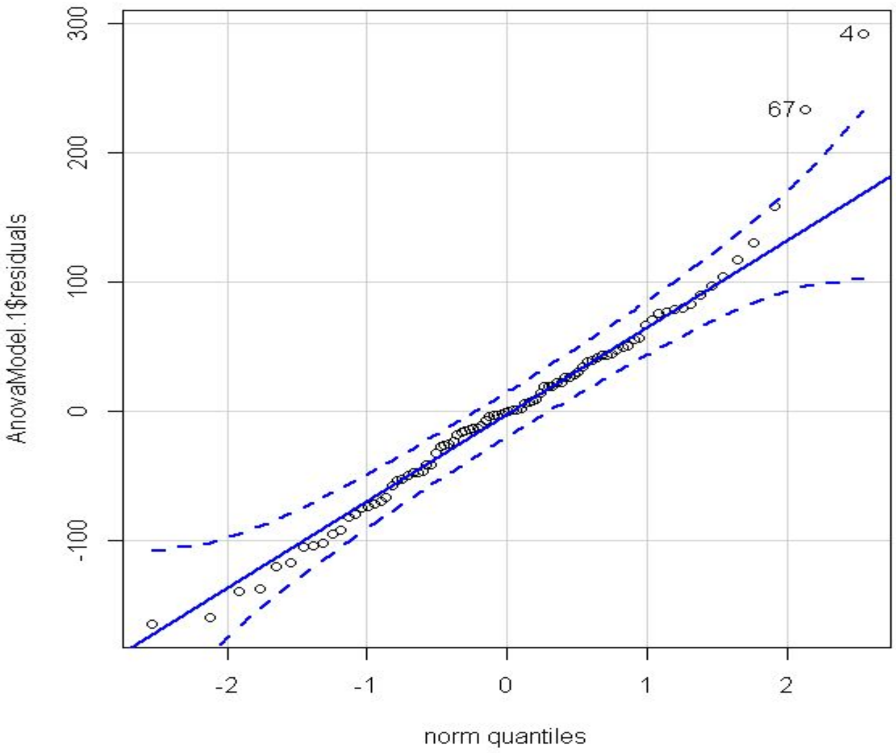
Design didn’t have a significant effect on distance

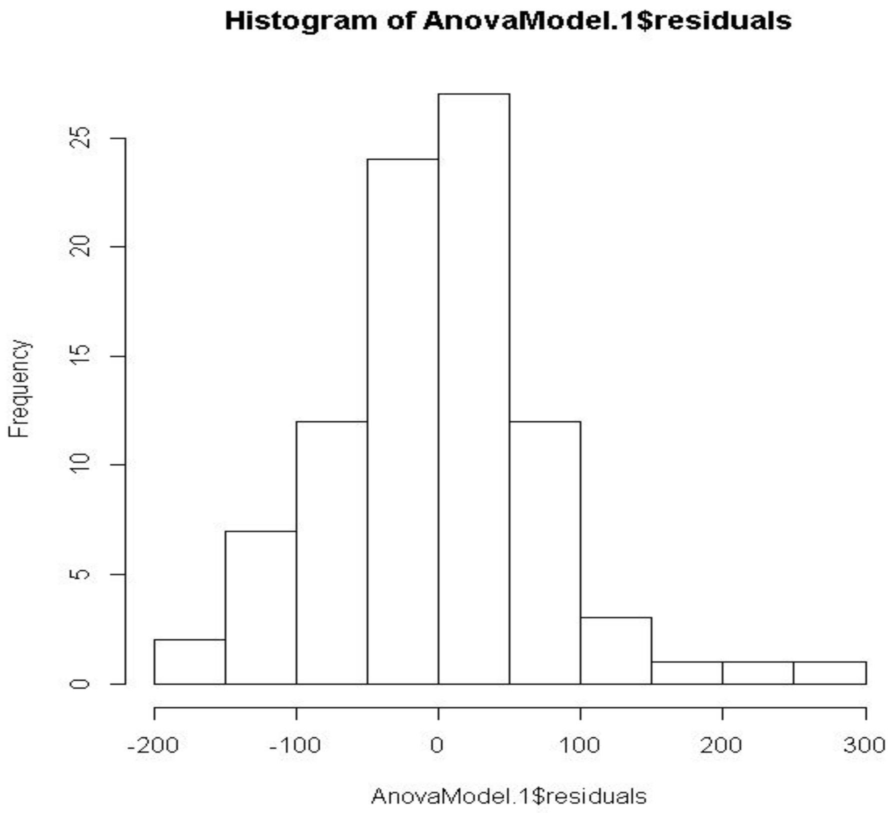
Winglets had a significant effect

There was a significant interaction between winglets and design

Checking Assumptions:

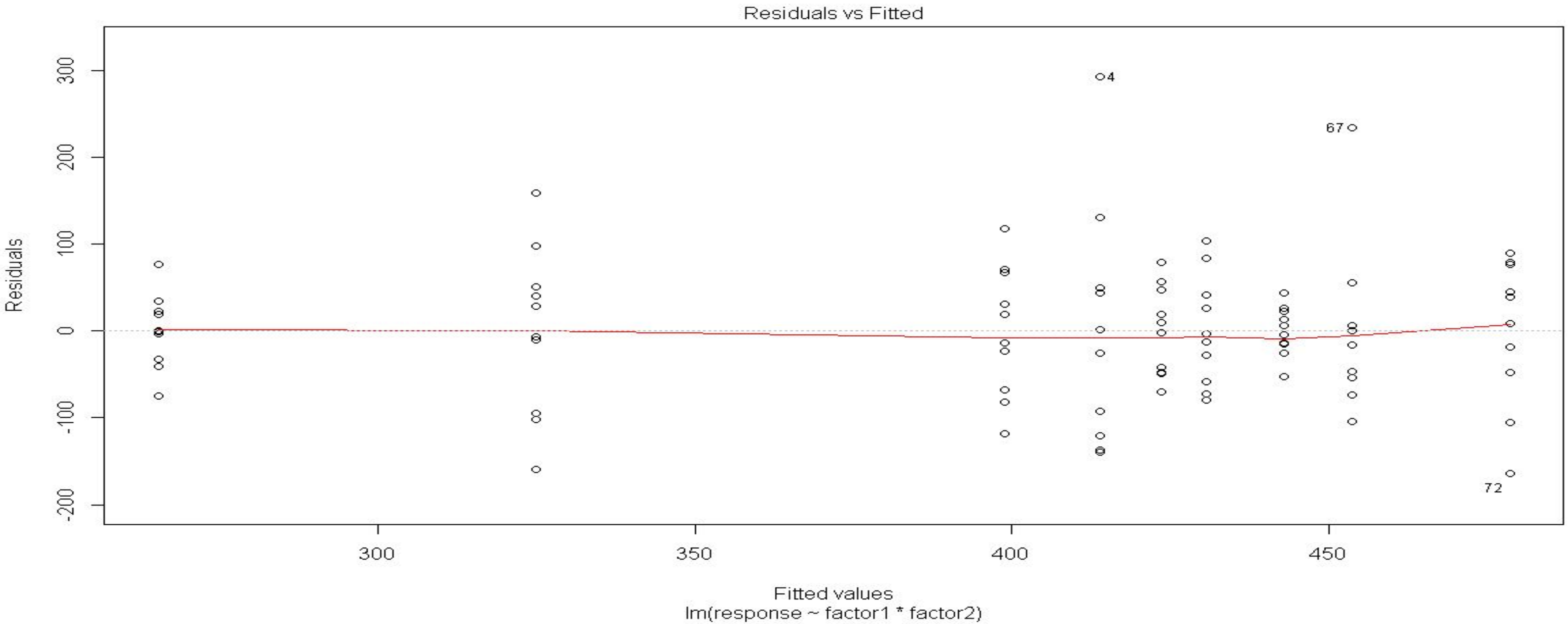
Residuals are generally normally distributed





Checking Assumptions:

Variance for each group is not the same



Discussion

What would we have done differently?

More replications

Multiple copies of the same plane to prevent degradation

Find a better way to measure distance for planes that travel in an arc

Follow-up studies:

Test winglets with more plane designs

Try different sizes of winglets

References

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