My M&M OCD

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Intro

Objective of Simulation

The goal of this simulation is to test the statistics of M&M and other stacks even chocolate lentils by color.

I wanted to know what is the chance of my finishing the package of M&M without mixing any color in one bite, eating them 2 by 2

In addition, here are some BI insights that needed to be checked:

1. What is the probability of M&M packages packaged fairly?
2. What is the probability of M&M packages packaged without one color?
3. How does the size of the package or number of colors affect this probability?

Method

This report explores the randomness and fairness of color distribution in M&M-style candy packs.
We simulate hundreds of packages with varying sizes and color counts, then apply statistical analysis
to understand how often one might get "balanced" packs — and what impacts those odds.

I do not have an inner information of how does (M&M)[https://www.mms.com/en-us] make their delicious snacks nor we know how they make sure each package have fair amount of each color. Therefore, the method I chose is based of simulation of some M&M bags, according to the most common sizes of packages.

Each time we sample x lentils(units of M&M), name them by colors (V1,V2…), and see the results for many packages as a statistic data.

My hypothesis is that the probability of perfect package (aka a package with all colors number been even) is very small, at least for a standard 6 colors pack.

Parameters

Basic parameters:

We define a "pack" as a vector of integers representing the count of each color.
Each simulation uses random sampling with replacement to mimic real-world packaging.
Key variables:

- `n-color`: Number of distinct colors

- `n-unit`: Total candies in the pack

```
n= 800                #numbers of bags per sample
n_color= 6            #unique colors of M&M
gram= 0.91            #weight of one M&M
bag_g= 250            #common weight of M&M package
n_unit= bag_g/gram    #M&M per packagenm,
```

```
## [1] "The avarage number of lentils per color is 45.79"
```

Creating the Sample

General Sample

In order to test the theoretical data, I need to simulate it using customize functions. here are there:

- `Create_bag`- function to create one snack package for chosen package size and number of colors.
- `sample_MnM`- function to create n bags from the Create_bag function.

key parameters for `sample_MnM`

- `n`: Number of packages in the sample
- `x_units`: Total candies in each package
- `t_colors`: Number of distinct colors in each package

```
## [1] "One bag of 100:"
```

```
##       1  2  3  4  5  6
## [1,] 13 15 14 21 19 19
```

```
## [1] "3 bags of 100:"
```

```
##       Red Blue Green Orange Yellow Brown
## Bag_1  26   14    15     16     19    10
## Bag_2  18   15    18     15     12    22
## Bag_3  16   20    13     15     14    23
```

Preview Graph

Now will be creating n bugs of M&M

columns:

1. `V1:V6`- the number of lentils per color
2. `even_count`- how many evens colors there are
3. `even_evens`- are the uneven colors even

4. `Variance`- variance of lentils per color
5. `low_col`- sum true if one color's count is lower than $\frac{2}{3}$ of expected value
6. `min`- the lowest color in each row

here are the first rows:

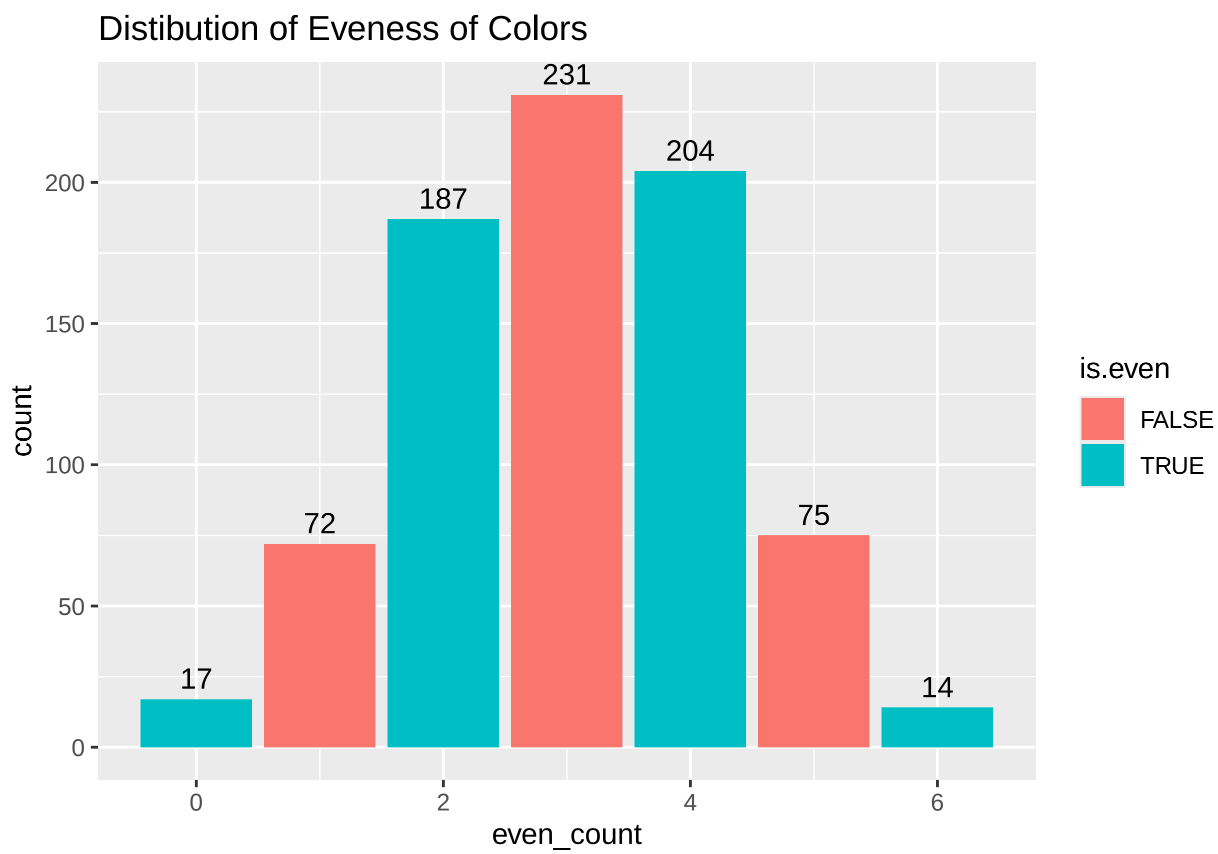
Table 1: M&M sample random rows

Red	Blue	Green	Orange	Yellow	Brown	even_count	even_evens	low_col	Variance	min	all_even
40	44	48	46	48	48	6	TRUE	0	10.26667	40	TRUE
41	45	35	56	49	48	2	TRUE	0	51.86667	35	FALSE
42	49	38	50	42	53	4	TRUE	0	33.86667	38	FALSE
42	52	52	44	46	38	6	TRUE	0	31.06667	38	TRUE

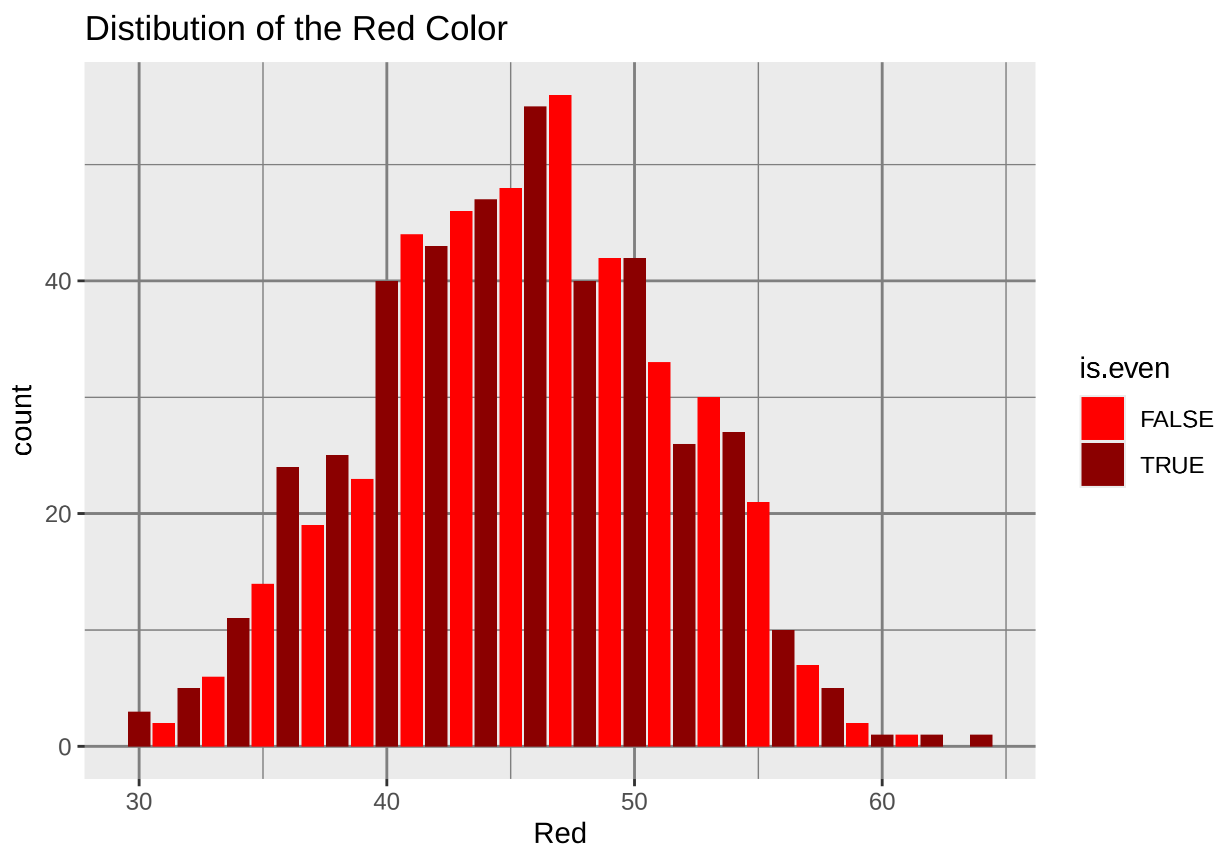
plot the M&M sample summary

Table 2: summary of all colors Distibution

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Var
Red	30	41	45.5	45.37000	50.00	64	35.73026
Blue	28	41	46.0	45.73750	49.25	67	36.86968
Green	28	41	46.0	45.93875	50.00	67	39.03629
Orange	24	42	46.0	45.96250	50.00	64	40.77957
Yellow	27	42	46.0	46.02375	50.00	63	37.49756
Brown	26	41	45.0	45.44000	49.00	69	38.21417



Distibution of Eveness of Colors
count
200
150
100
50
0
231
204
187
72
75
17
14
0
2
4
6
even_count
is.even
FALSE
TRUE



Statisics Checking of the Simullation

Test Expected Value

to see is the μ of the lentils per color are fair, I will test it per column with t.test for each color.

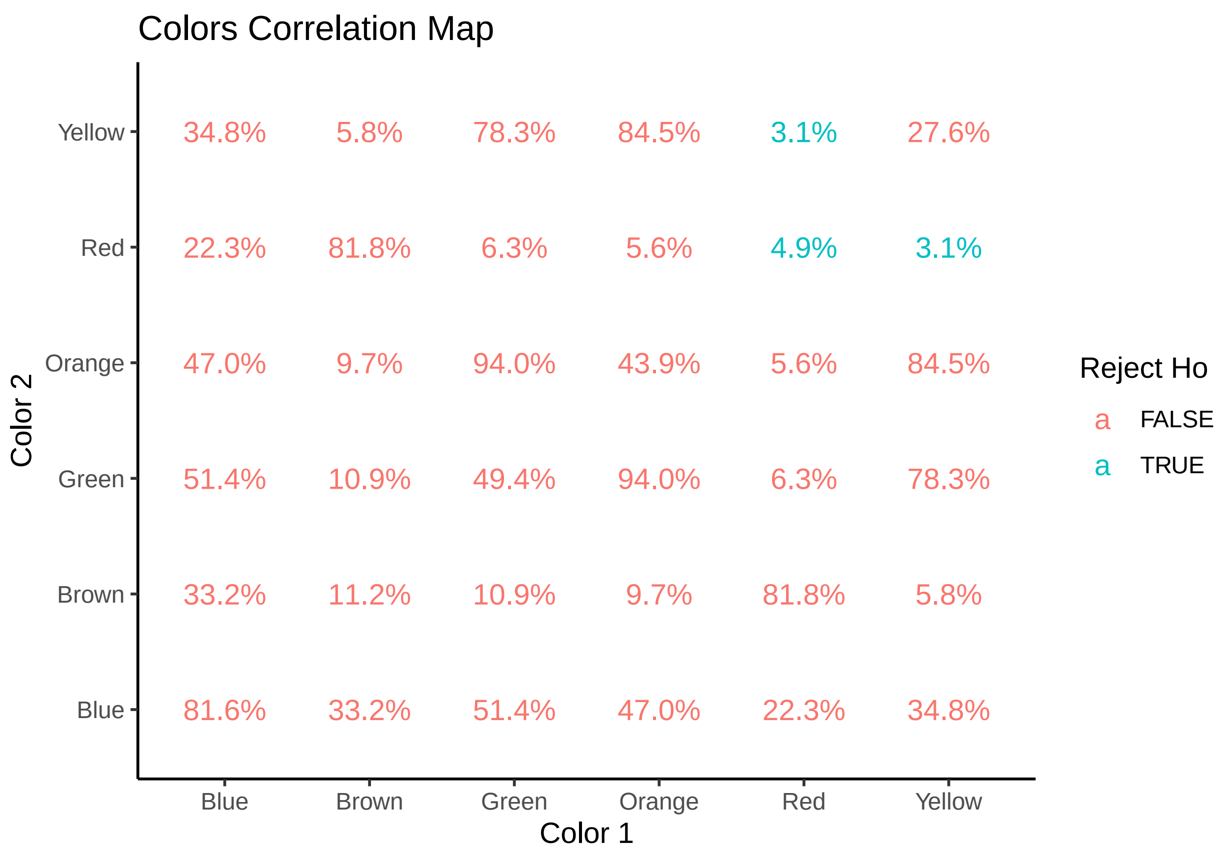
Here is the result, none of them bellow 5% P. value

p.value of $H_0 : \mu = \frac{n_unit}{n_color}$

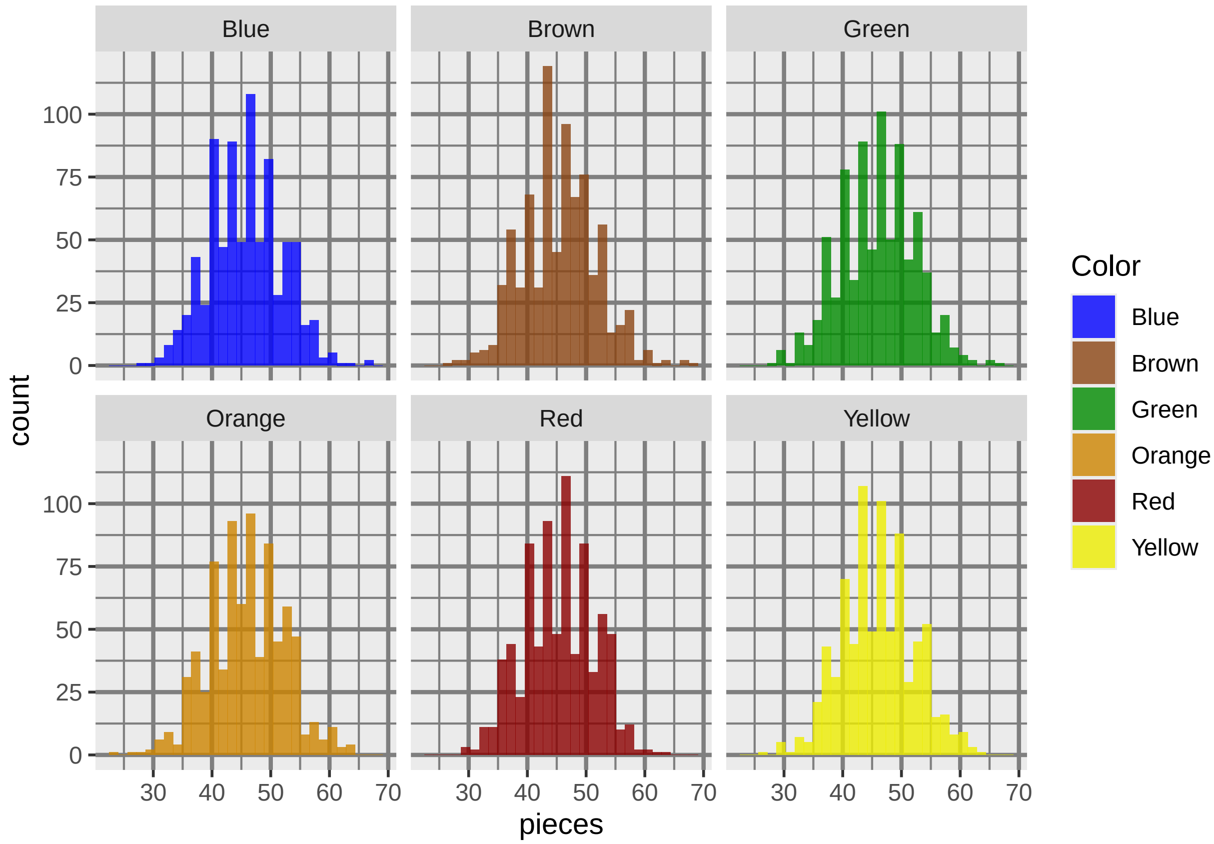
```
##      Red    Blue   Green  Orange  Yellow   Brown
##   "4.9%" "81.6%" "49.4%" "43.9%" "27.6%" "11.2%"
```

Now I will do the same checking for 2 samples, to see whether there is correlation between each 2 colors distribution.

for each row i and column j, 1) if i==j, this it the check from before of the expected value to n_unit/n_color 2) if i!=j, this is two samples test of same expected value hypothesis



Now here Is visualization of the actual data per color



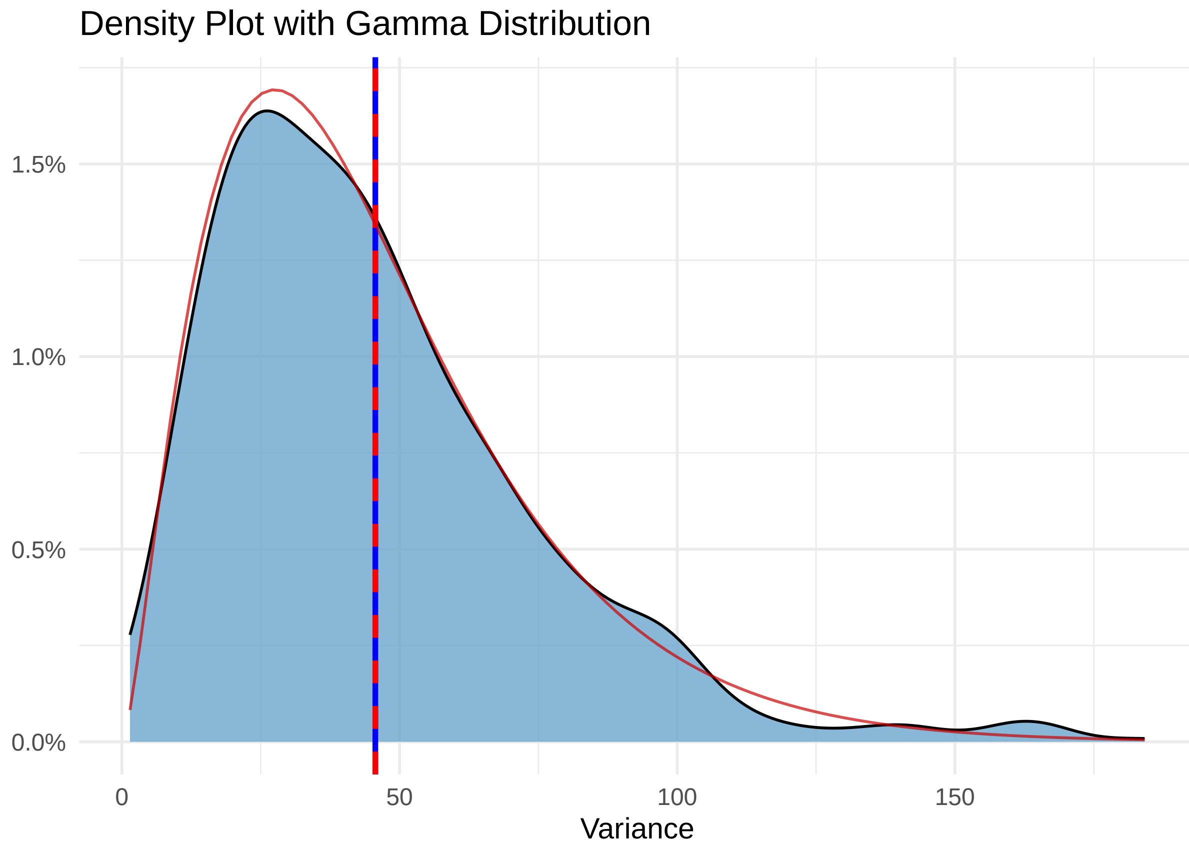
Variance Distribution Checking

I know that the distribution of variance is approximately Gamma distribution:

$$f(x) = \frac{1}{\Gamma(\alpha)\theta^{\alpha}} x^{\alpha-1} e^{-x/\theta}$$

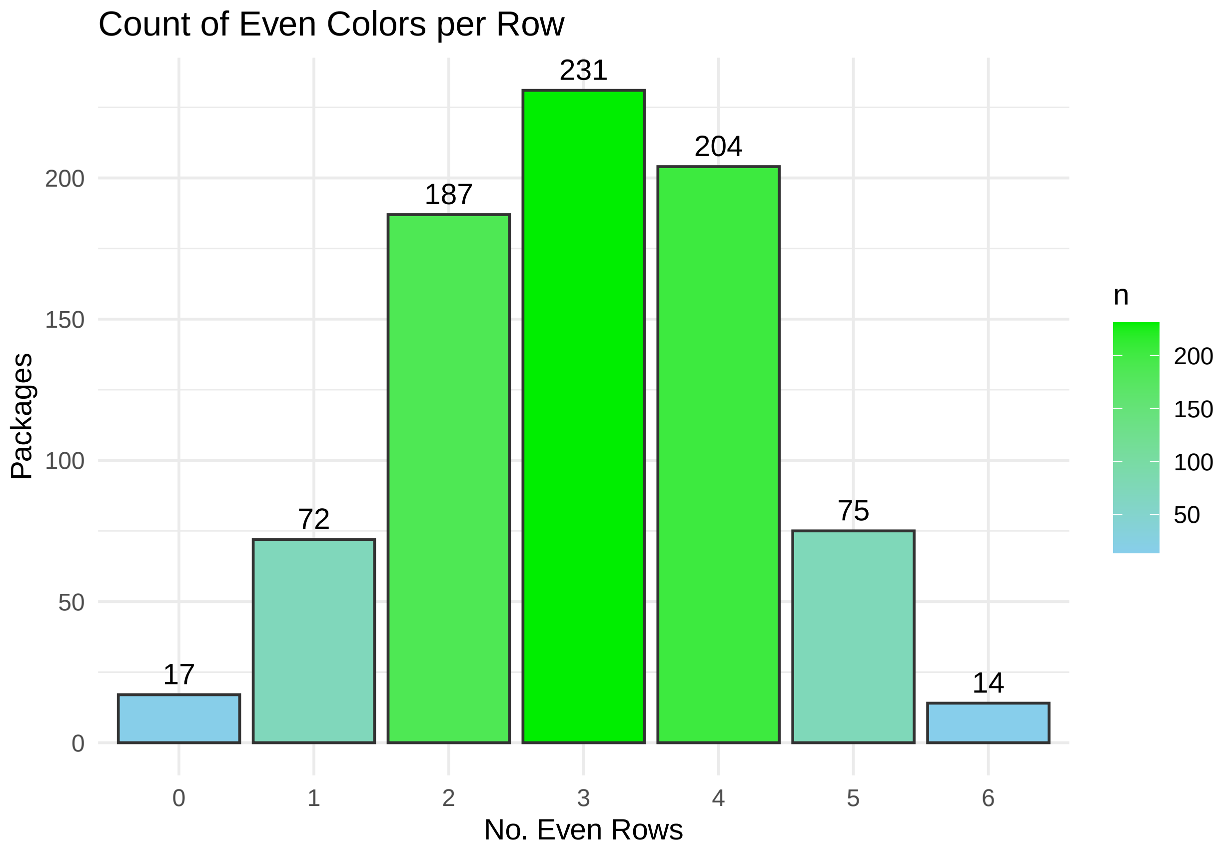
I can see that the variance distribution is Gamma like with shape and rate as seen below

```
## [1] "The parameters of the gamma shaped variance is shape 2.521 and rate 0.055"
```



Density Plot with Gamma Distribution
1.5%
1.0%
0.5%
0.0%
0
50
100
150
Variance

Are All Even in the Sample?



n*m types of snacks

I will create a function that create sample for each number of colors and package size I want, and then calculate some interesting parameters

I will make the multiple sample. parameters:

```
n_color<- 2:8 #Number of distinct colors in each package option
grams_op<- c(25,45,150,250,330,500,750,1000) #Weight of each package option
n_unit_op<- grams_op/gram #Total candies in each package option
nn<- 800 #Number of packages in the sample
```

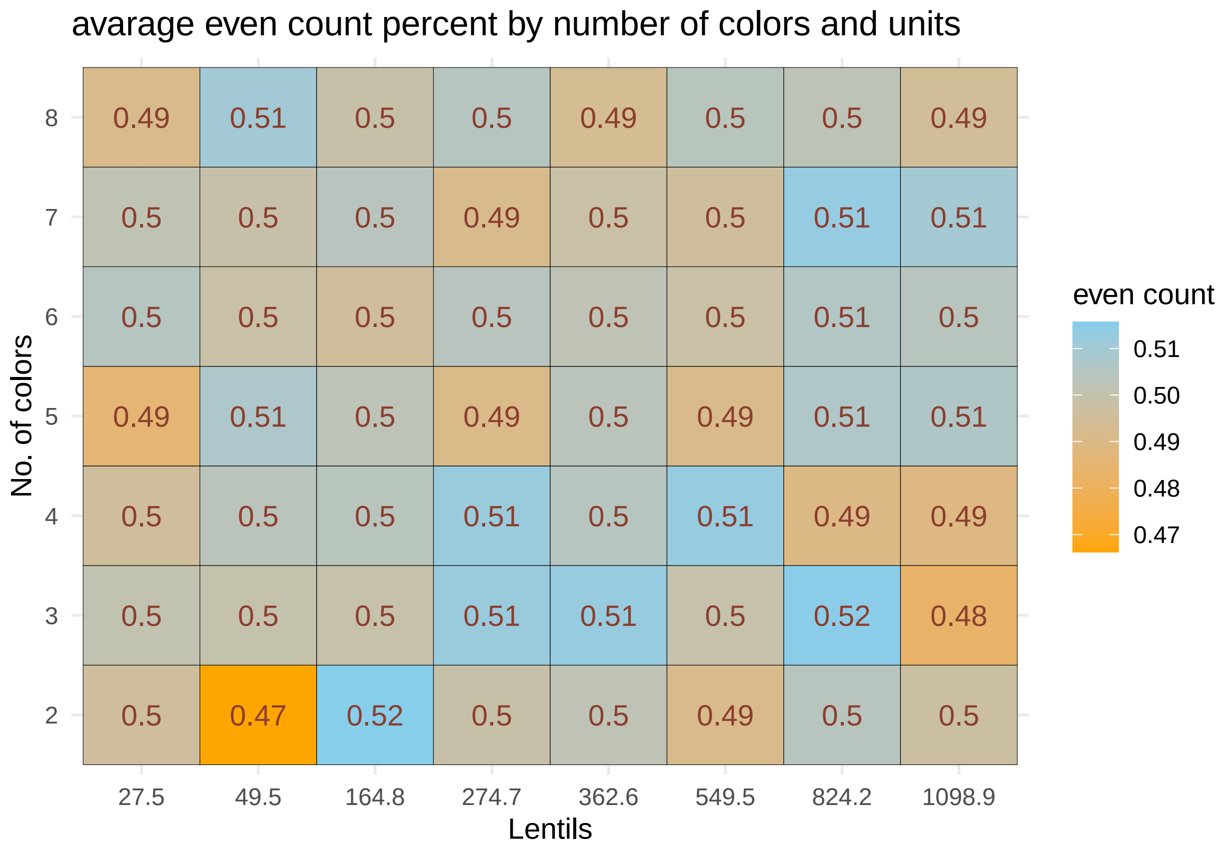
Here is some random rows:

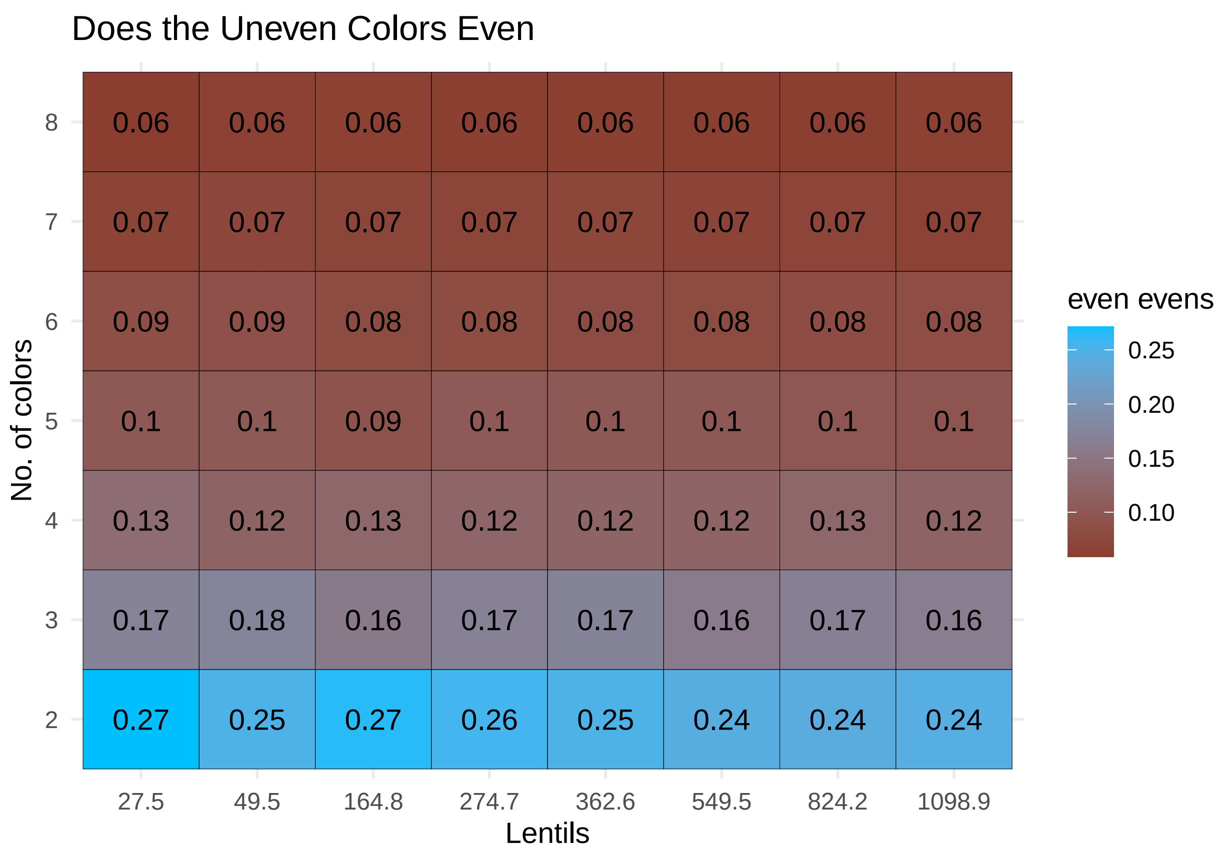
Table 3: Multiple sample example rows

n_unit	n_color	even_count	even_evens	var_col	all_even	low_color	smallest_col
164.8	6	0.495	0.081	28.258	0.010	0.058	13
549.5	6	0.498	0.081	92.693	0.015	0.001	59
1098.9	7	0.509	0.067	156.685	0.010	0.000	124
27.5	6	0.505	0.086	4.571	0.022	0.545	0
549.5	4	0.512	0.121	136.468	0.074	0.000	102

Deep Insight on the Data

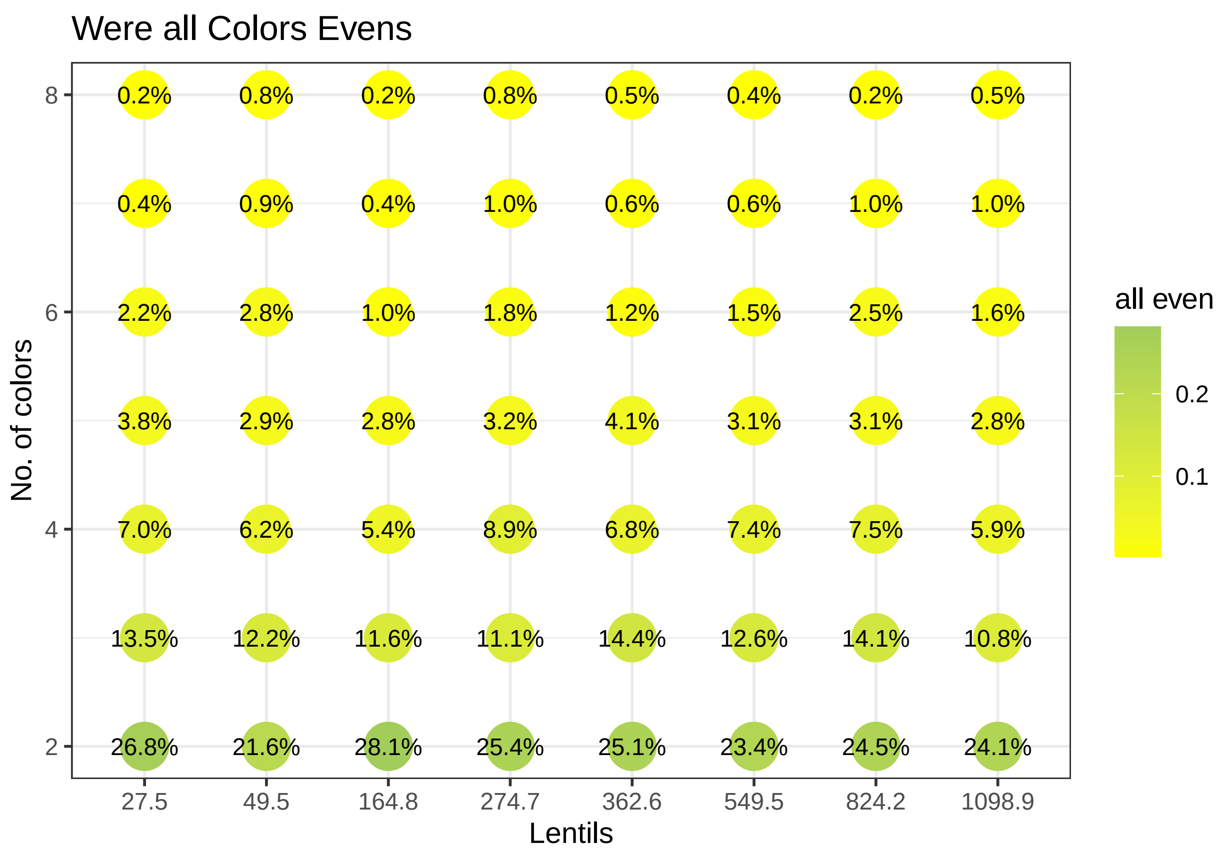
here are some insights:

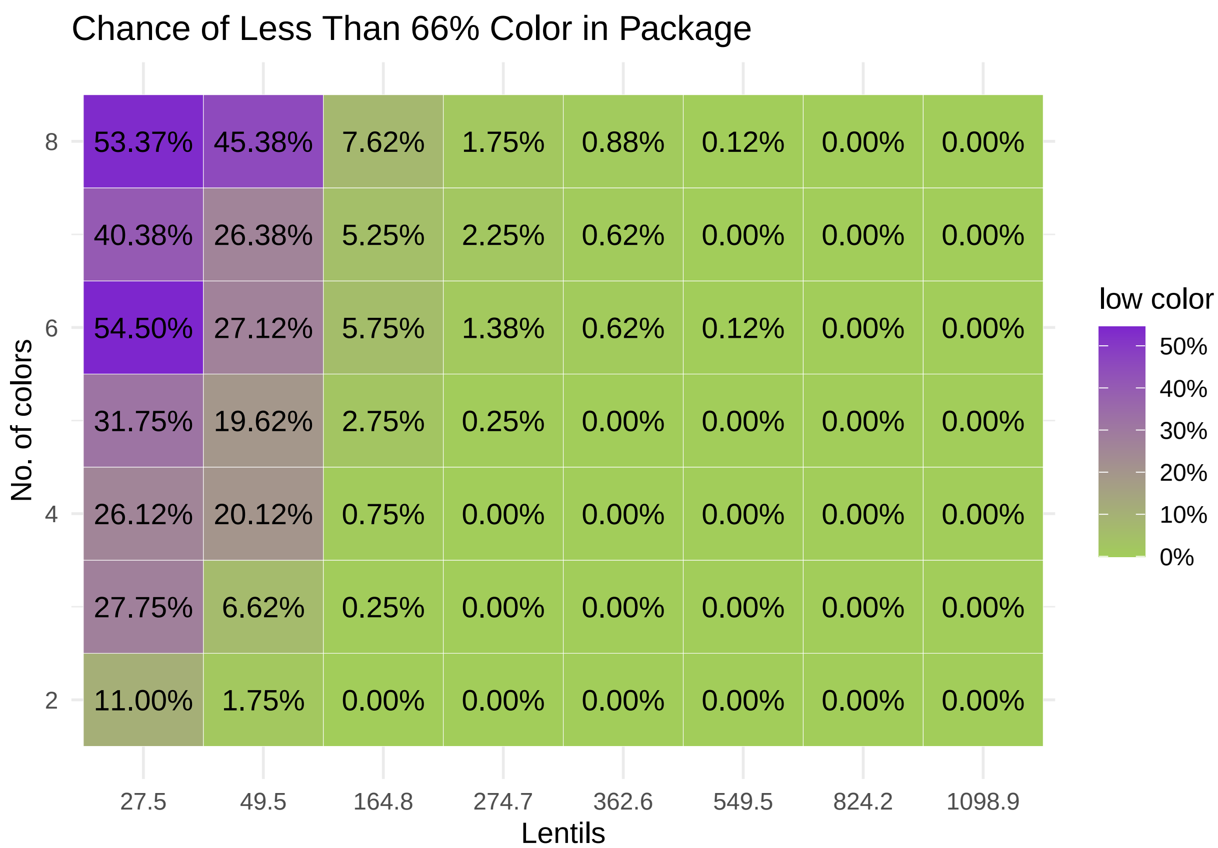




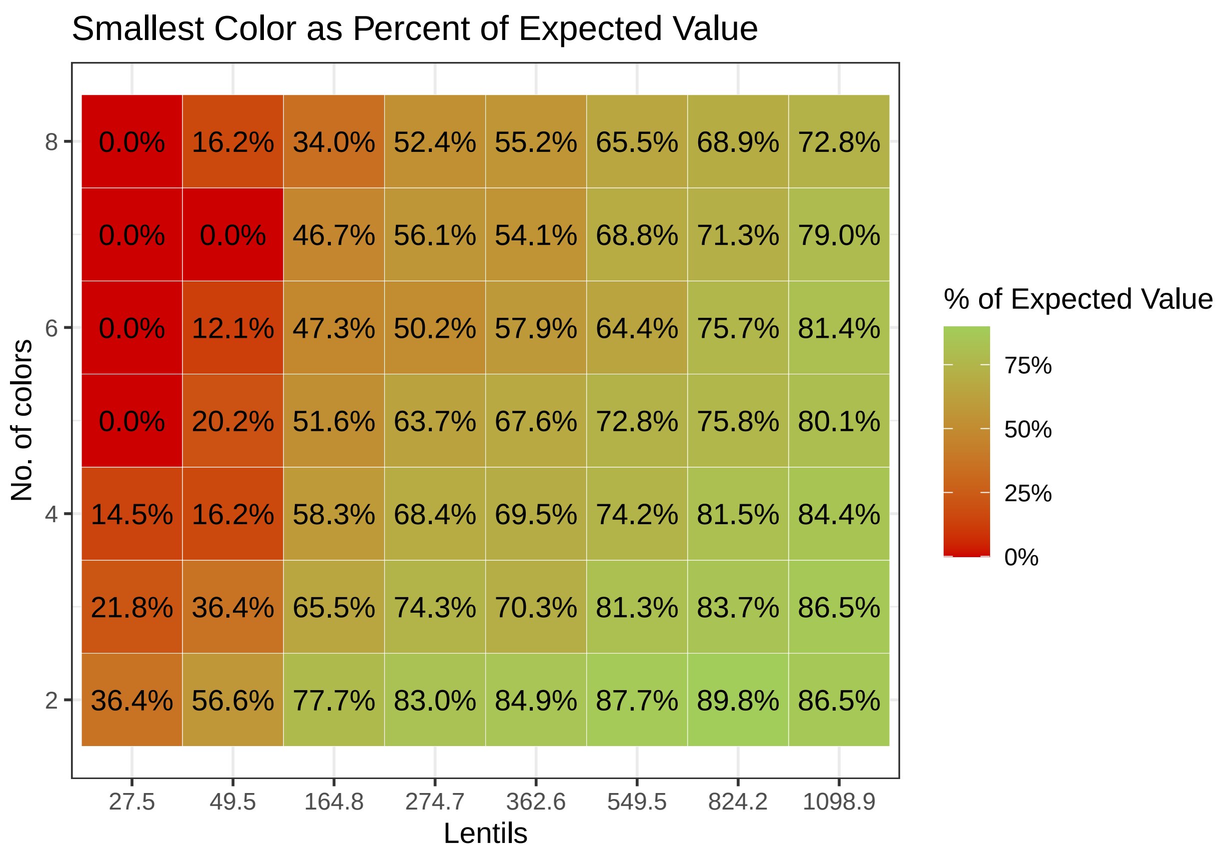
Here is probability of all even, and whether there is pattern.

```
## <Guides[1] ggproto object>
##
## colour : "none"
```


Were all Colors Evens
No. of colors
8
6
4
2
Lentils
27.5
49.5
164.8
274.7
362.6
549.5
824.2
1098.9
all even
0.2
0.1
0.2% 0.8% 0.2% 0.8% 0.5% 0.4% 0.2% 0.5%
0.4% 0.9% 0.4% 1.0% 0.6% 0.6% 1.0% 1.0%
2.2% 2.8% 1.0% 1.8% 1.2% 1.5% 2.5% 1.6%
3.8% 2.9% 2.8% 3.2% 4.1% 3.1% 3.1% 2.8%
7.0% 6.2% 5.4% 8.9% 6.8% 7.4% 7.5% 5.9%
13.5% 12.2% 11.6% 11.1% 14.4% 12.6% 14.1% 10.8%
26.8% 21.6% 28.1% 25.4% 25.1% 23.4% 24.5% 24.1%



Here we can see the smallest % of Lentils in one color as seen in my sample:



As we can see, only the small package (less than 50 lentils) have high probability of at least one color to appear severely lower.

Therefore, splitting package by color on the big ones should be relatively even.

using regression for correlation check

```
##
## Call:
## lm(formula = mega_snack_2$even_count ~ mega_snack_2$n_color +
##     mega_snack_2$n_unit)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.52418 -0.16232 -0.00384  0.16071  0.50435
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)           5.113e-01  2.159e-02  23.681   <2e-16 ***
## mega_snack_2$n_color -3.433e-03  3.676e-03  -0.934    0.351
## mega_snack_2$n_unit   1.796e-05  2.057e-05   0.873    0.383
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2461 on 1117 degrees of freedom
## Multiple R-squared:  0.001461,   Adjusted R-squared:  -0.0003271
```

```
## F-statistic: 0.8171 on 2 and 1117 DF,  p-value: 0.442
```

```
##
## Call:
## lm(formula = mega_snack_2$all_even ~ mega_snack_2$n_color + mega_snack_2$n_unit +
##     mega_snack_2$color_No2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.15844 -0.06246 -0.03335  0.01850  0.85488
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 1.492e-01  1.702e-02   8.764  < 2e-16 ***
## mega_snack_2$n_color       -2.879e-02  2.697e-03 -10.675  < 2e-16 ***
## mega_snack_2$n_unit        -1.243e-05  1.509e-05  -0.824     0.41
## mega_snack_2$color_No2TRUE  6.719e-02  1.090e-02   6.163 9.93e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1805 on 1116 degrees of freedom
## Multiple R-squared:  0.1203, Adjusted R-squared:  0.1179
## F-statistic: 50.88 on 3 and 1116 DF,  p-value: < 2.2e-16
```

Seeing the 2_{nd} regression we can suggest that more colors is correlated with 3.3% less probability of all colors even, while even numbers of colors is correlated with 7.7% more probability of all colors eve, regardless of any package size.

Conclusions

Data Structure

The simulation created a random samples of snack packs, which was proven to be statistically random with known μ and σ^2. I created one sample with specific size and numbers of colors using "sample_MnM", and costume multiple samples using "mega_snack". Then, I check the relevand indicators fot this project.

I found out that:

- Small packages often lack at least one color, and sometimes contain only one color.
- As the number of colors increases, the chance that all colors have even counts drops significantly.
- For medium to large packages, the probability of any one color being significantly underrepresented (less than $\frac{2}{3}$ of its expected amount) is near zero.

suggestion for any random sampler factory (like candies, lego, toys):

1. Smaller packages need more diversity check
2. Althernatively, I would recomand calculate the amount of each type in small packages

Main Q: Eating M&M by Two

Although there is no clear pattern to the right M&M package for all the colors to have even count, different approach might find a clear reason for more or less couples of M&M. Here is what I did found:

The general probability of all colors to be even in 6 colored pack is 1.5% for small 50g package 2.1% for big 1000g package, and overall 1.5%, which is more than I expected.

For 5 colored pack like Skittles the average is about 2.9%

For 2 colored pack the average is 24.5%, so for 2 colored marshmallow bag this will be the statistics.

See all here:

Table 4: Probability of All Colors Even by Pack Colors Number

Colors	All Even Percent
2	24.88
3	12.55
4	6.88
5	3.22
6	1.83
7	0.73
8	0.45

Summary

To sum it up, for each medium pack the probability of all even colors is 1.4%, or 1 in a 73 packs of 250g. So I might need to change my snack preference to marshmallow if I want to keep this method.

This project allowed me to implement simulation methods in response to a real (albeit silly) question, and evaluate it statistically from end to end..

I applied:

- Simulation logic
- Exploratory analysis
- Hypothesis testing
- Distribution checks
- Outlier detection
- Visualization using R

In addition, I created the infrastructure for similar questions with different parameters to be checked in a reusable, structured way.