

ANOVA Part 2

Grinnell College

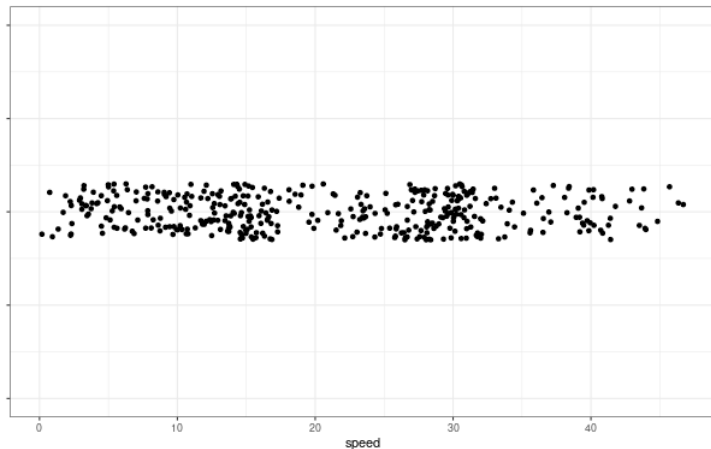
December 4, 2024

Review

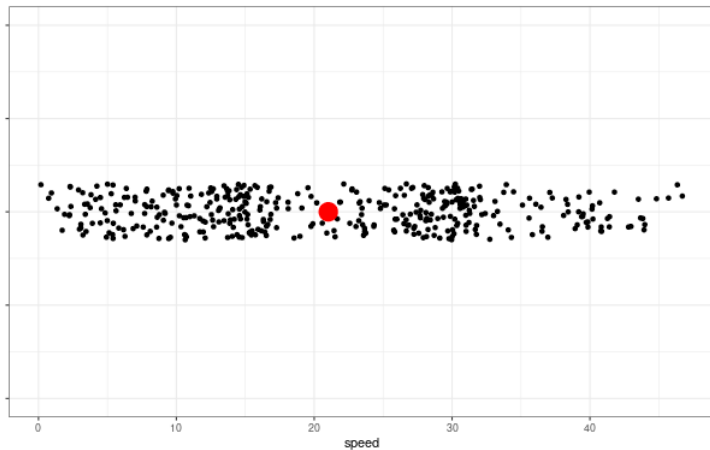
- ▶ What were we doing with ANOVA?
- ▶ What was the F-statistic representing?
- ▶ Maybe let's have fewer equations today

Speed of all dogs

Jitter Plot (better than boxplot for this example)

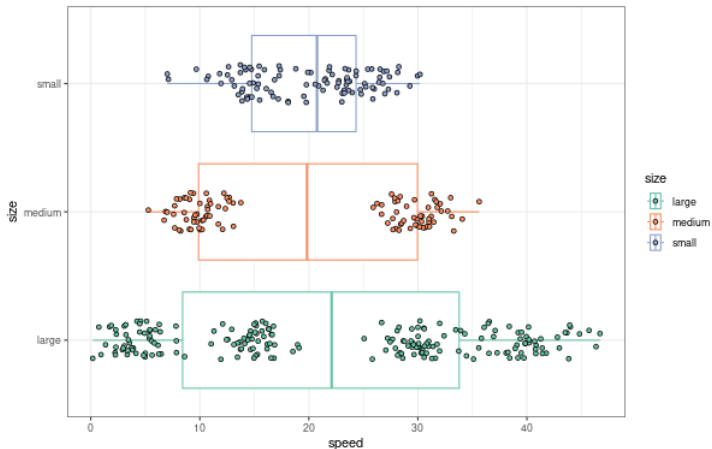


Speed of all dogs

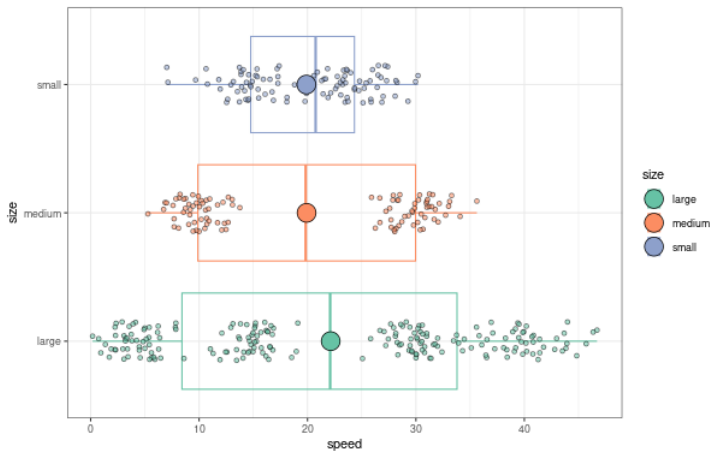


	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Residuals	399	52398	131.32		

Speed of Size dogs

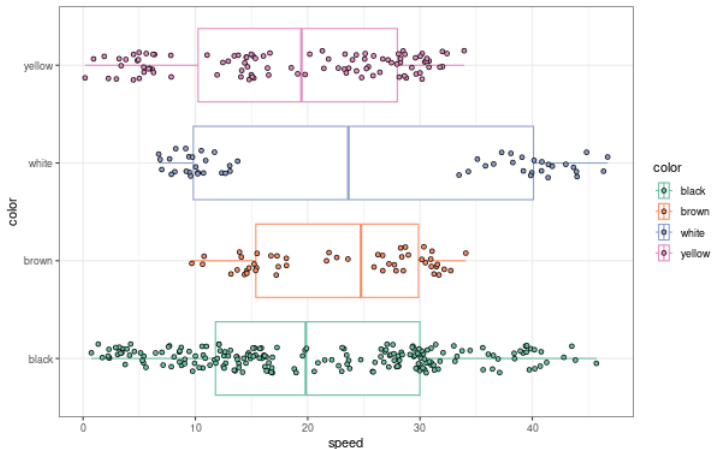


Speed of Size dogs

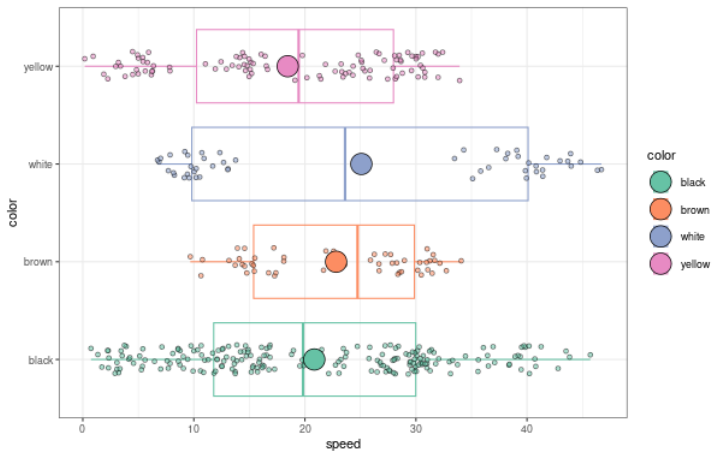


	Df	Sum Sq	Mean Sq	F value	Pr(>F)
size	2	498	248.96	1.90	0.1503
Residuals	397	51900	130.73		

Speed of Color dogs

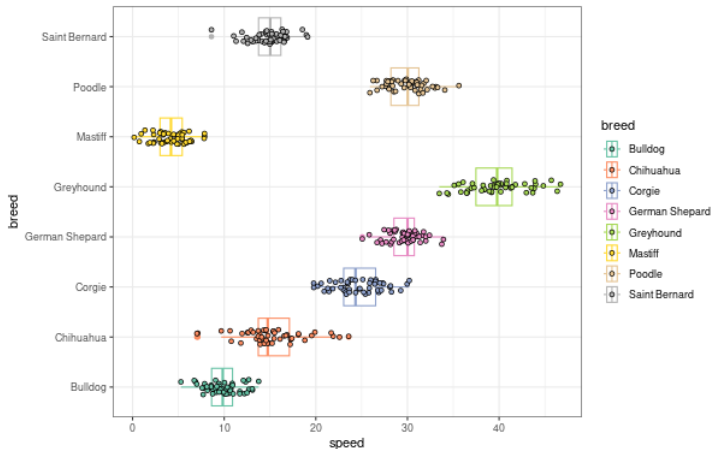


Speed of Color dogs

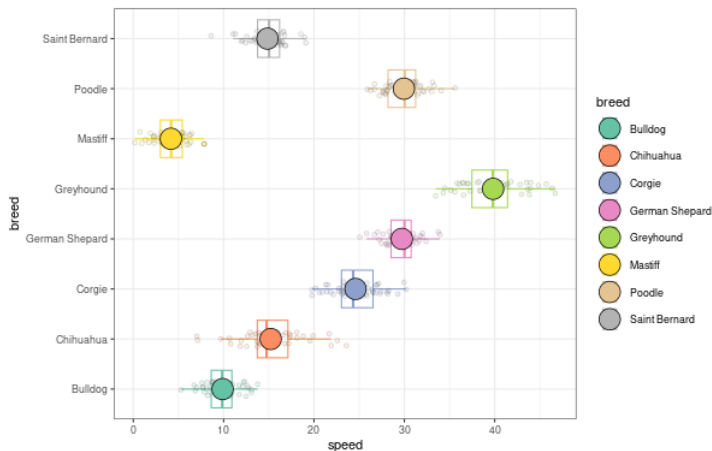


	Df	Sum Sq	Mean Sq	F value	Pr(>F)
color	3	1652	550.55	4.30	0.0053
Residuals	396	50746	128.15		

Speed of Breed dogs



Speed of Breed dogs



	Df	Sum Sq	Mean Sq	F value	Pr(>F)
breed	7	50066	7152.25	1202.16	0.0000
Residuals	392	2332	5.95		

To t or Not to t

Recall that for ANOVA we are testing the null hypothesis that *all* of our means are equal

$$H_0 : \mu_A = \mu_B = \mu_C$$

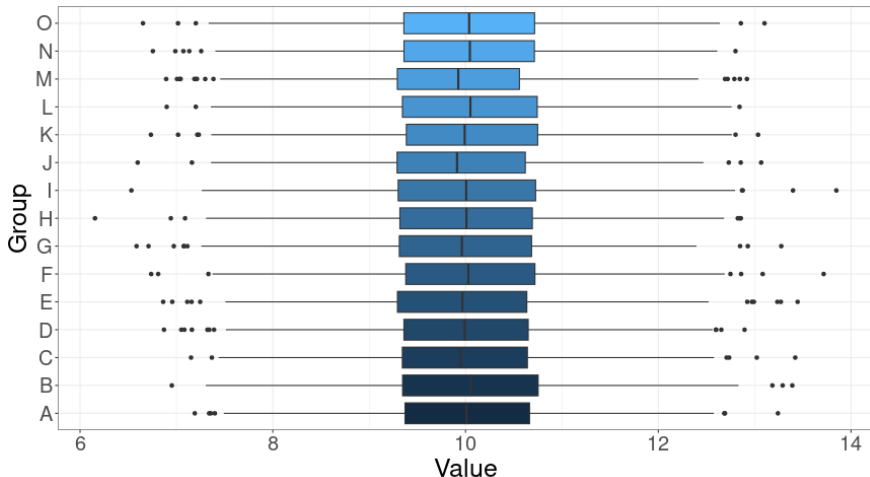
Why not instead just stick with our t-test, doing

$$H_0 : \mu_A = \mu_B, \mu_A = \mu_C, \text{ and } \mu_B = \mu_C$$

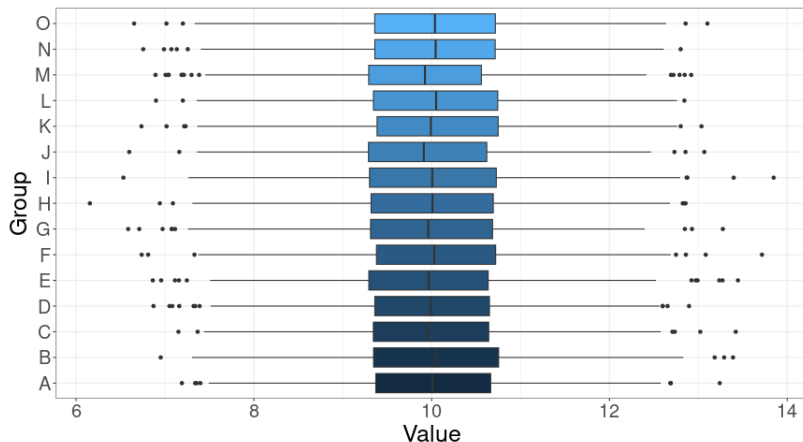
Multiple tests

15 groups, all generated with the same mean value:

- ▶ F-test (ANOVA) should not tell us there is a difference



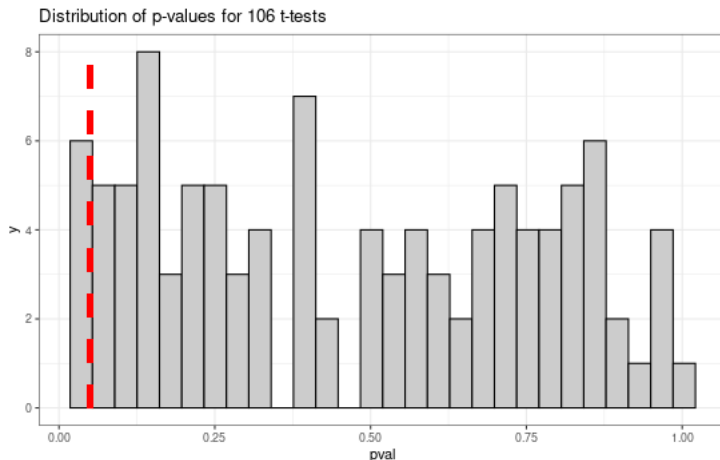
Multiple tests



	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Group	14	15.40	1.10	1.10	0.3504
Residuals	14985	14964.85	1.00		

Multiple tests

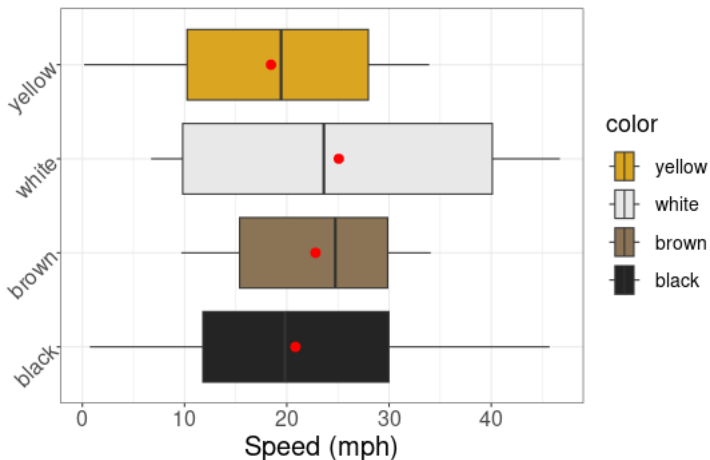
- ▶ 105 pair-wise tests
- ▶ 6 with p -value < 0.05



Post-hoc Tests

ANOVA only tells us *that* a difference exists, not where it is or to what degree

If our ANOVA test is such that we reject the null hypothesis, we can use *post-hoc* testing via the **Tukey Range Test** or the **Tukey Honest Significant Difference Test** to identify any statistically significant pair-wise differences



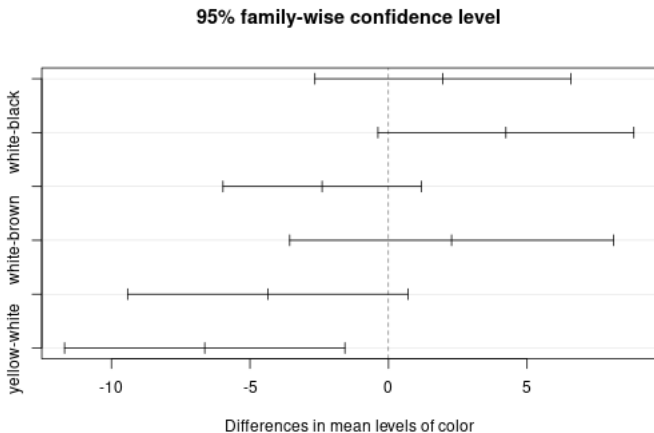
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
color	3	1651.64	550.55	4.30	0.0053
Residuals	396	50746.34	128.15		


```

1 > aov(speed ~ color, dogs) %>% TukeyHSD()
2   Tukey multiple comparisons of means
3     95% family-wise confidence level
4
5 Fit: aov(formula = speed ~ color, data = dogs)
6
7 $color
8           diff          lwr          upr    p adj
9 brown-black   1.9612   -2.65664   6.57906 0.69237
10 white-black   4.2360   -0.38182   8.85388 0.08529
11 yellow-black  -2.3968  -5.97373   1.18021 0.31012
12 white-brown    2.2748  -3.56635   8.11599 0.74672
13 yellow-brown  -4.3580  -9.41657   0.70063 0.11889
14 yellow-white  -6.6328 -11.69139  -1.57418 0.00437

```

```
1 > aov(speed ~ color, dogs) %>% TukeyHSD() %>% plot()
```



- ▶ ANOVA allows us to test equality of many means
 - ▶ By comparing ratio of between-group and within-group variance
- ▶ alleviates problem of multiple testing
- ▶ *Post-hoc* testing can be done to determine which groups are different
- ▶ Tukey Honest Statistical Difference (TukeyHSD)