Statistically Speaking: *ANOVA + Tukey HSD*

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Overview

- A tale of two giants:

  Ronald A. Fisher and John W. Tukey

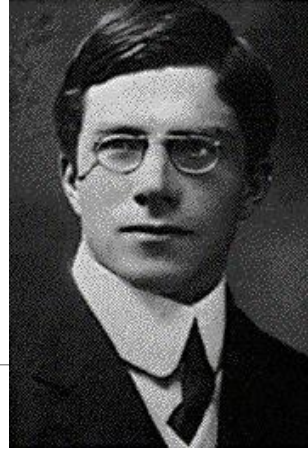
- Are they all the same?

  ANOVA and F statistic

- What changed?

  The Tukey Honestly Significant Difference

Ronald A. Fisher



Wikimedia Commons

- Born in 1890, RA Fisher was a towering statistician, and he is credited with having created the fields of experimental design and population genetics (with Haldane and Wright).
- Chronically short-sighted, he was excluded from service in World War I in 1914.
- Notable for feuds due to his quick temper.

https://www.famousscientists.org/ronald-fisher/

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Eugenics: a popular skeleton in the closet

Fully one third of Fisher's greatest work, the five concluding chapters in *Genetical Theory*, are devoted to an analysis of the "decay of civilizations" and its prevention by raising the fertility of "more prosperous" or "superior" social groups. (quote from citation below)

The image from the prior page is from the 1912 First International Eugenics Conference!

J Moore. *Stud. Hist. Philos. Biol. Biomed. Sci*. (2007) 38: 110-35

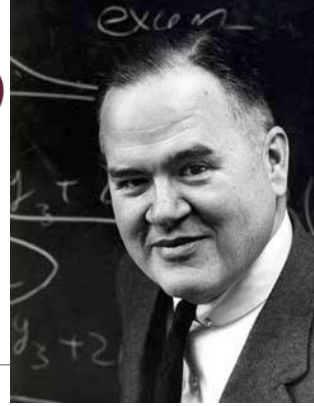
Notable and quotable

"To consult the statistician after an experiment is finished is often merely to ask him to conduct a *post mortem* examination. He can perhaps say what the experiment died of."

- Maximum likelihood
- Sample mean ≠ population mean
- Defined "variance"
- Mendel to Darwin
- ANOVA
- *Statistical Methods for Research Workers*

http://www.economics.soton.ac.uk/staff/aldrich/fisherguide/quotations.htm

John W. Tukey



- Born in 1915, Tukey was a prodigious, original researcher in statistics with a tremendous impact on telecommunications and computer science.
- He completed a Ph.D. in mathematics at Princeton in just two years and achieved the rank of full professor by age 35.

http://unbiasedresearch.blogspot.co.za/2016/04/john-wtukey-playing-in-everyones.html

Accomplishments

- Created the terms “software” and “bit” in 1958
- “The best thing about being a statistician is that you get to play in everyone’s backyard.”
- Confidence intervals for ANOVA
- Fast Fourier Transform
- Box-and-whisker plots
- Exploratory data analysis
- Robust statistical methods

https://ww2.amstat.org/about/statisticiansinhistory/index.cfm?fuseaction=biosinfo&BioID=14

One-way ANOVA

- You measure an independent variable for samples that come from more than two groups from the population. Does the independent variable reflect group identity?
- Simple example: does weight differ among apples, pears, bananas, and oranges?

Why "analysis of variance?"

- ANOVA compares variance under two different models:

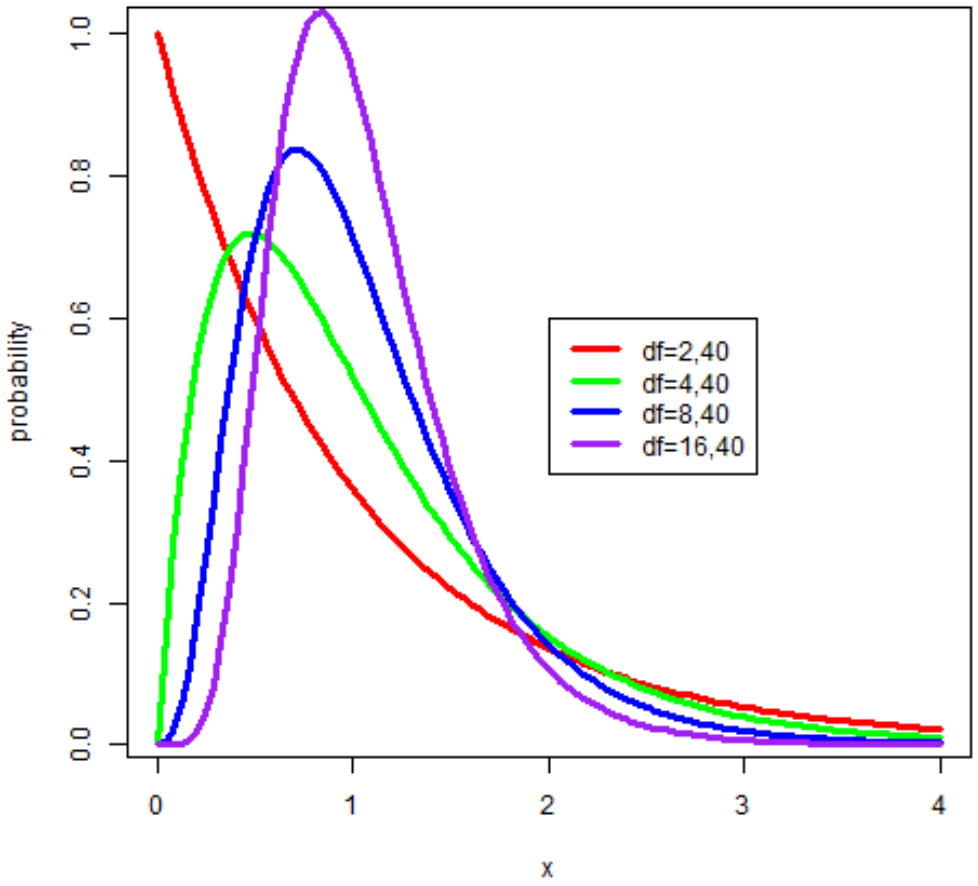
$$F = \frac{explained\ variance}{unexplained\ variance}$$ or

$$F = \frac{betweengroup\ variability}{withingroup\ variability}$$

- With two groups, $F = t^2$

http://blog.minitab.com/blog/adventures-in-statistics-2/understanding-analysis-of-variance-anova-and-the-f-test

The F distribution converts F value to a p-value



Why do we need Tukey HSD?

- One-way ANOVA will tell you a difference exists, but it won't tell you where.
- With five different groups, one would need ten different T-tests to find the differences, and the probability of falsely rejecting null would be too high!
- Tukey HSD will find the difference for us while protecting us from false positives.

http://www.statisticshowto.com/tukey-test-honest-significant-difference/

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R script to execute PlantGrowth example

```
#Use built-in data set
pg = PlantGrowth

#Fit linear model
pgmodel = aov(weight~group,data=pg)

#Compare variances
anova(pgmodel)

#Locate differences
TukeyHSD(pgmodel)
```

Takeaways

- Running a pile of T-tests is almost never the correct answer.
- In its simplest form, ANOVA helps us to ask whether any differences are present.
- TukeyHSD acts as a follow-on, should ANOVA reveal that a difference is present.