Lecture 8: Lab in Human Cognition

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Agenda for Today

- **REMEMBER:** Proposal due monday!
- Quick background on ANOVA
- How to report an ANOVA in your paper
- What to put in Lab 2 write up
- Time to work on Lab 2

First

Background on ANOVA

Variables

- **Dependent variables -** typically the one we are observing (can be continuous, multivariate, etc...)
- **Independent variable** - the ones we manipulated in the experiment (can be qualitative, continuous, or based on things like individual differences)
- **Confounding variable** - not held constant or manipulated but could also impact our dependent variable
- **Control variable** - potential nuisance, held constant

t-test revisited

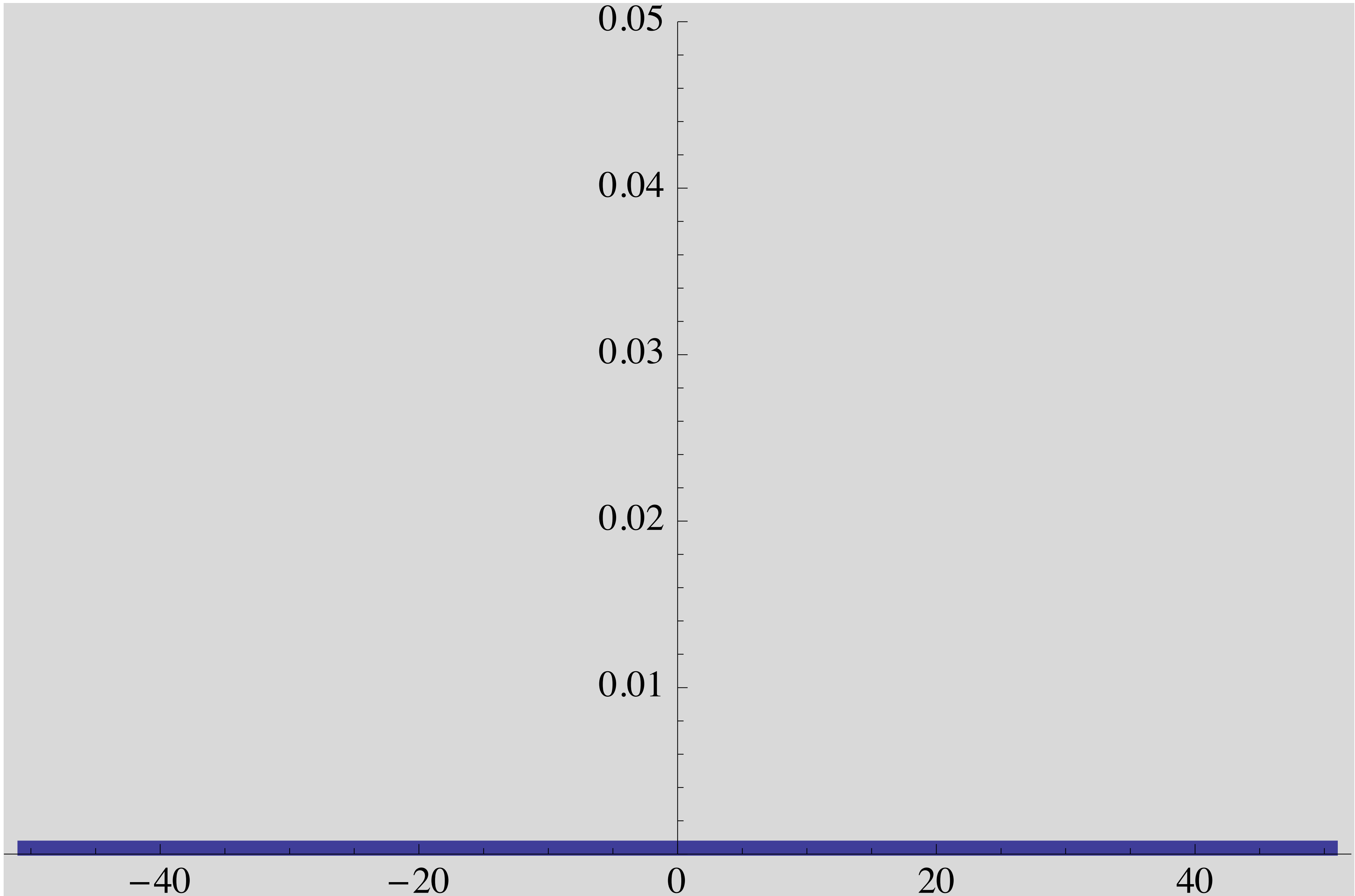
- So we discussed the t-test extensively so far
- There are three varieties of t-test:
    - One-sample
    - Two sample (paired) - really the same as one sample but on the differences
    - Two sample (independent populations)

Pooled variance two-sample t-test

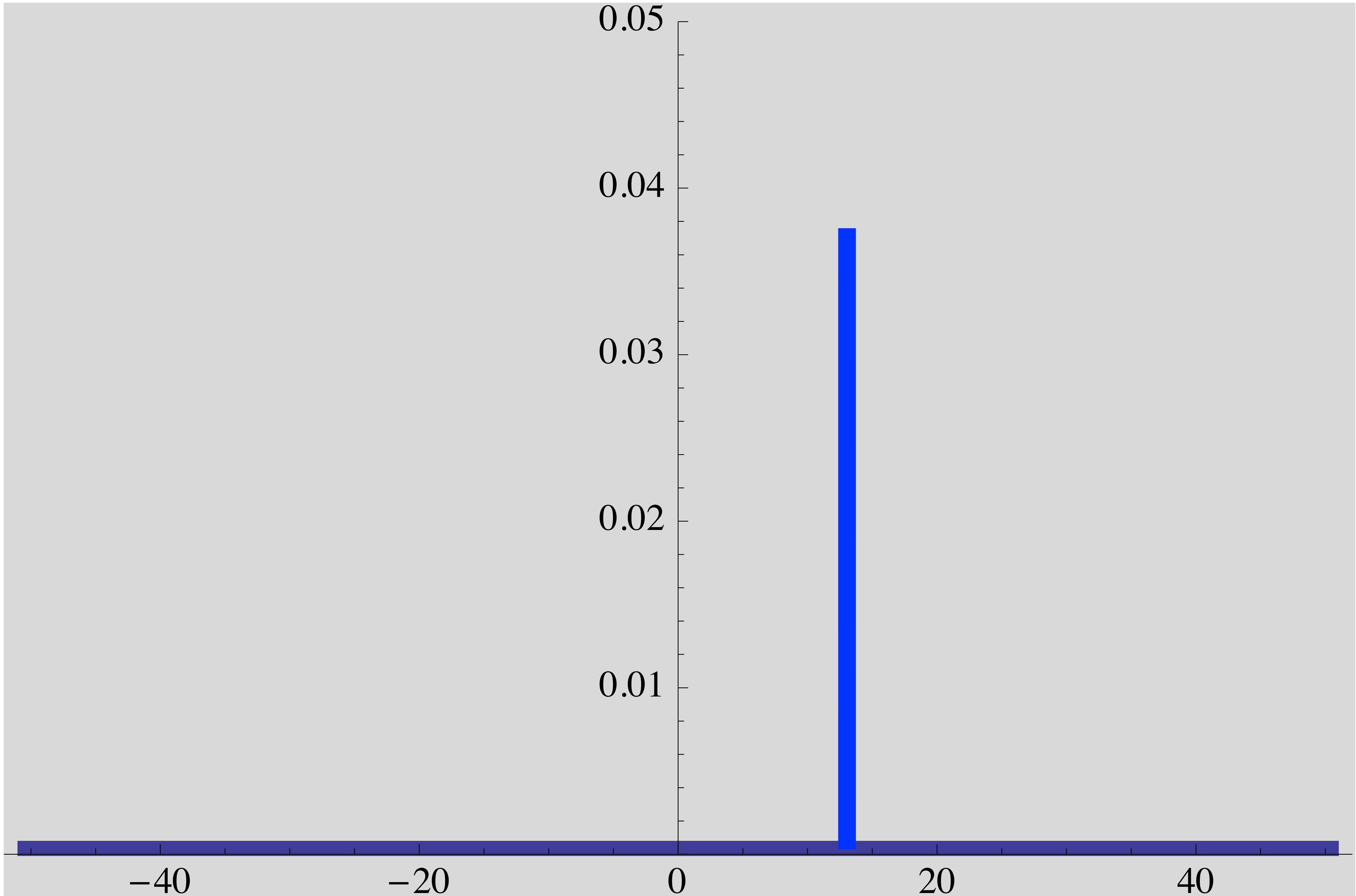
- Examples:
    - Is there a difference in the stroop effect for liberals versus conservatives?
    - Do people with Parkinson's disease learn at a lower rate in a cognitive skill learning test than do normal college undergraduates?
    - In these cases, the groups are not paired (i.e., they are not the same individual tested twice)
    - Thus, we can't just take the difference of the scores and do a one-sample t-test

Pooled variance two-sample t-test

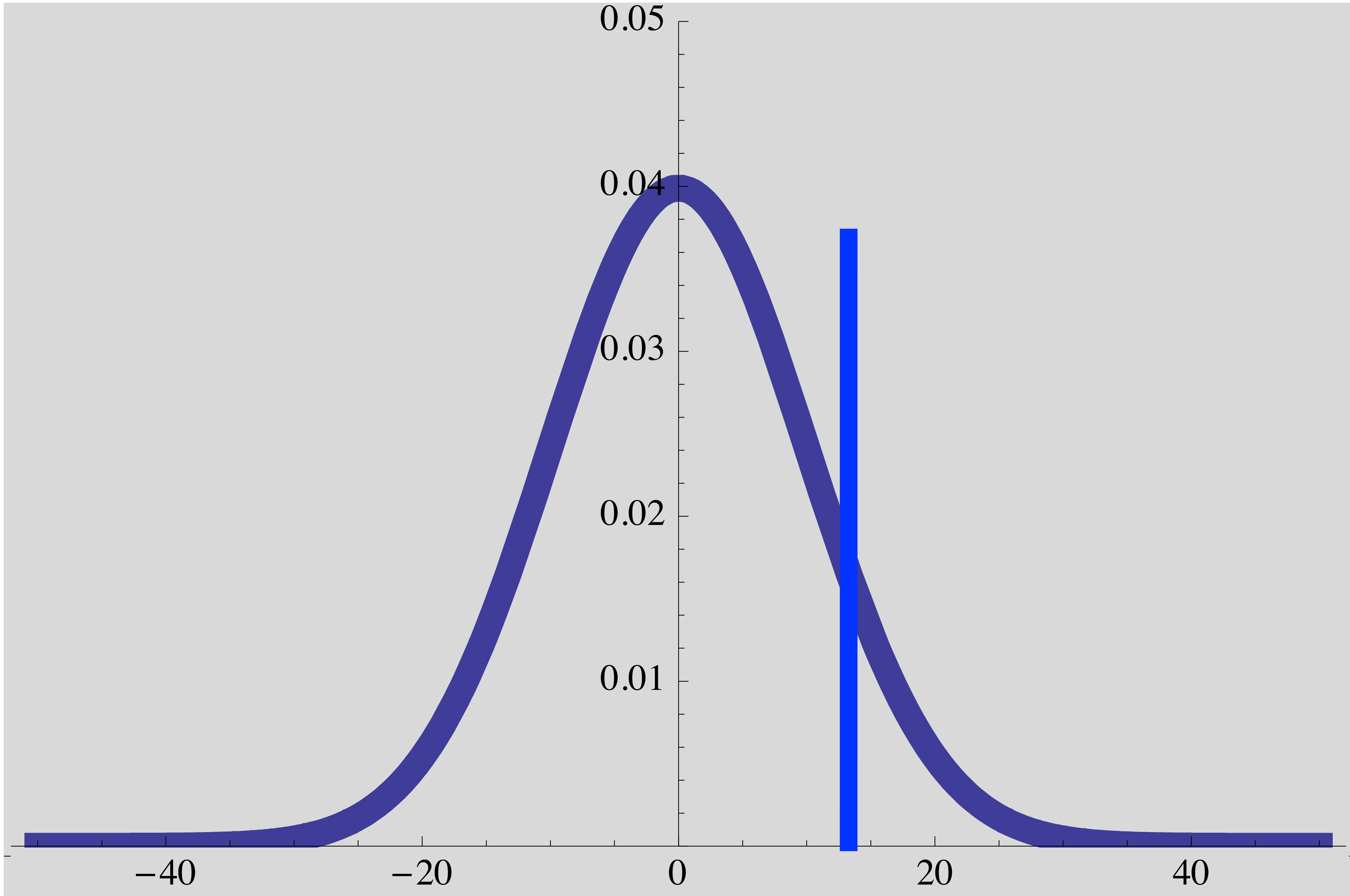
- What do we do?
- Use the logic for the original t-test
    - Compute the difference in the means of the two groups
    - Convert that to a t-value by dividing by the standard error
    - However, in this case, we use what is called a "pooled" estimate of the variance from both groups



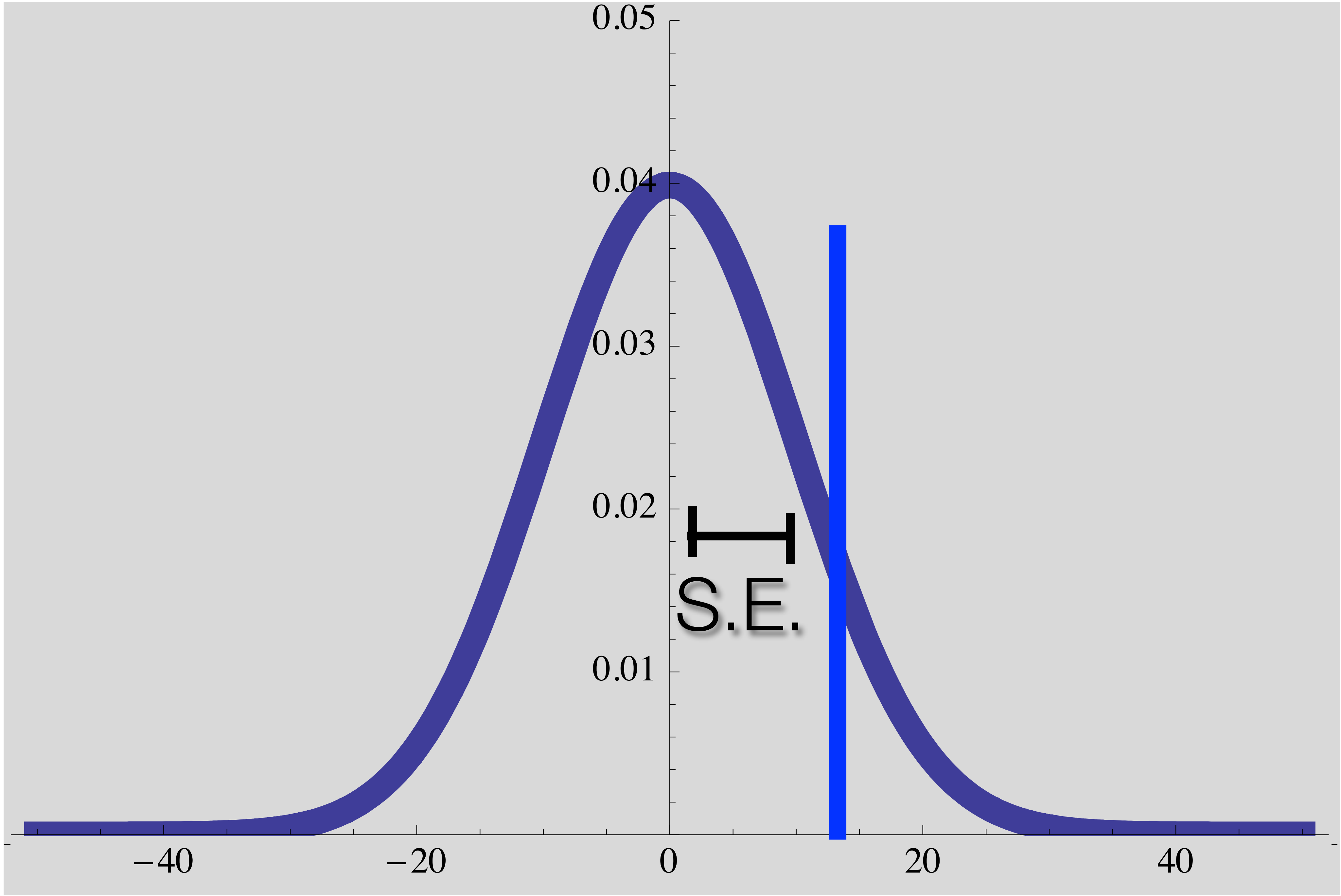
Difference in Means



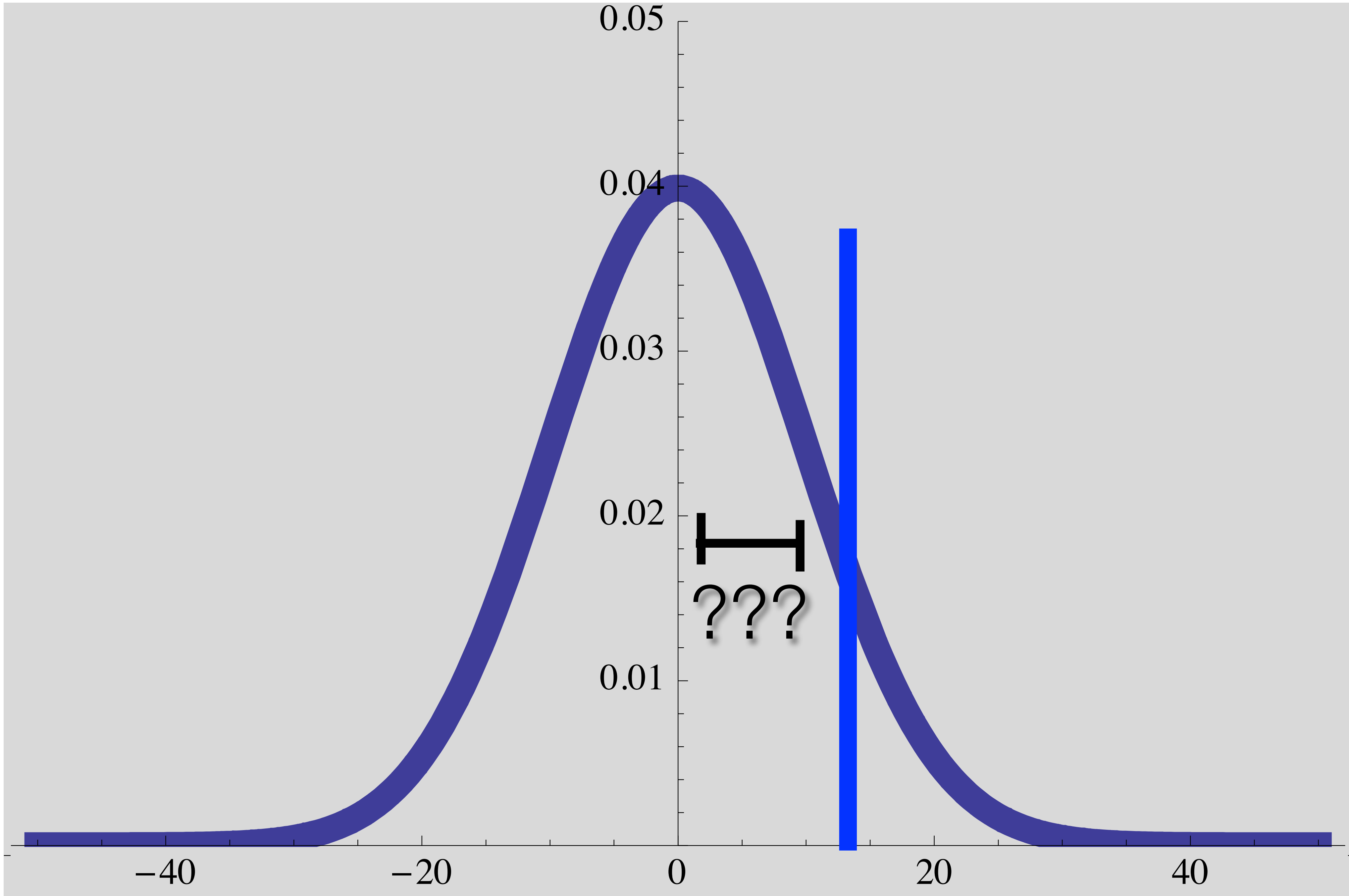
Difference in Means



Difference in Means



Difference in Means



Difference in Means

Pooling Means

Pooled Means

$$\overline{x_{12}} = \frac{n_1\,\overline{x_1} + n_2\,\overline{x_2}}{n_1 + n_2}$$

- A “weighted” average of the mean... weight by *n* of the sample

Pooled Variance

$$s_{12}^{2} = \frac{(n_1 - 1)\, s_1^{2} + (n_2 - 1)\, s_2^{2}}{(n_1 - 1) + (n_2 - 1)}$$

- A "weighted" average of the individual variances... weighted by n-1 (the degrees of freedom that go into each individual variance).

our “old” t-value calculation

$$t = \frac{\overline{x_1} - \overline{x_2}}{s/\sqrt{n}}$$

- degrees of freedom = n - 1

t-value formula in terms of variance (instead of s.d.)

$$t = \frac{\overline{x_1} - \overline{x_2}}{s_{12}\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

- degrees of freedom = n1+ n2 -2
- (assumes equal variances)

wait!
what about more than two groups?

ANOVA - Analysis of Variance

- Situation: We control one or more independent variables
  - Also known as “factors” (see R)
  - Must contain two or more *levels* (sub categories)
- Observe an effect on the dependent variable

Randomized Design

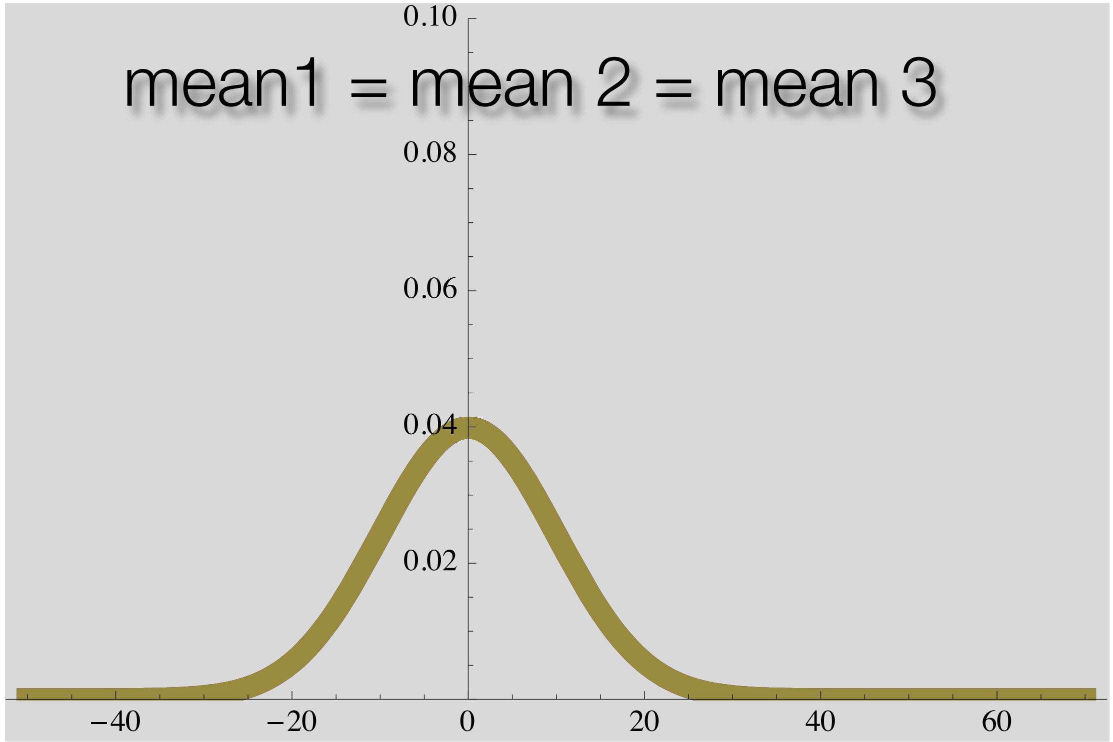
- Assign people (or trials) randomly to the treatment groups
- For example, in our experiment, trials were randomly assigned to be COLOR-UPRIGHT, COLOR-UPSIDEDOWN, etc...
- The manipulations are our factors, and the different values (e.g., “upright”, “upside down”) are the *levels*

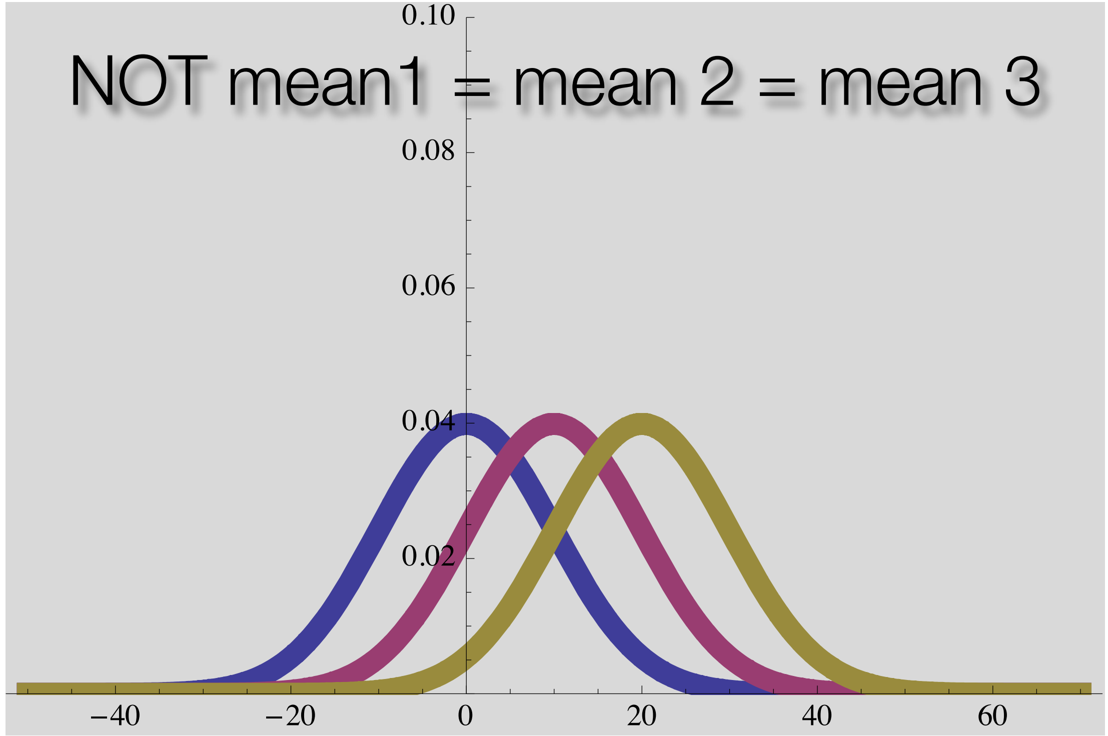
ANOVA assumptions

- **Randomized -** Samples in each treatment group are random and independent
- **Normality -** the populations follow a normal distribution (this isn’t always true, but the central limit theorem helps us)
- **Homogeneity of variance -** simply means the populations or conditions have equal variance. Harder to control.

The null hypothesis in the ANOVA

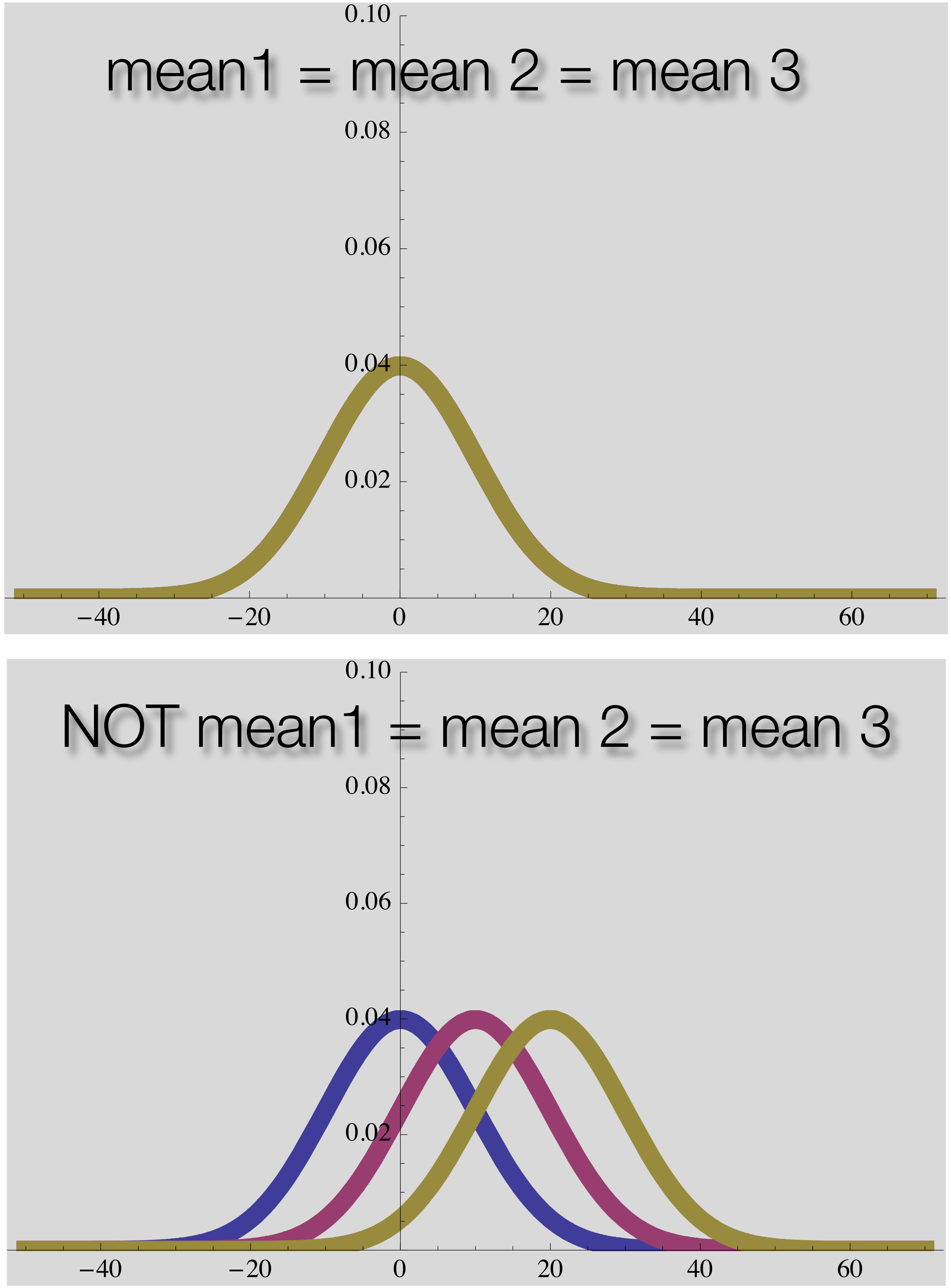
- **Null hypothesis** - the means of each group are *all* equal
- **Alternative hypothesis - ** the means are not all equal (at least 1 but maybe more are "different").



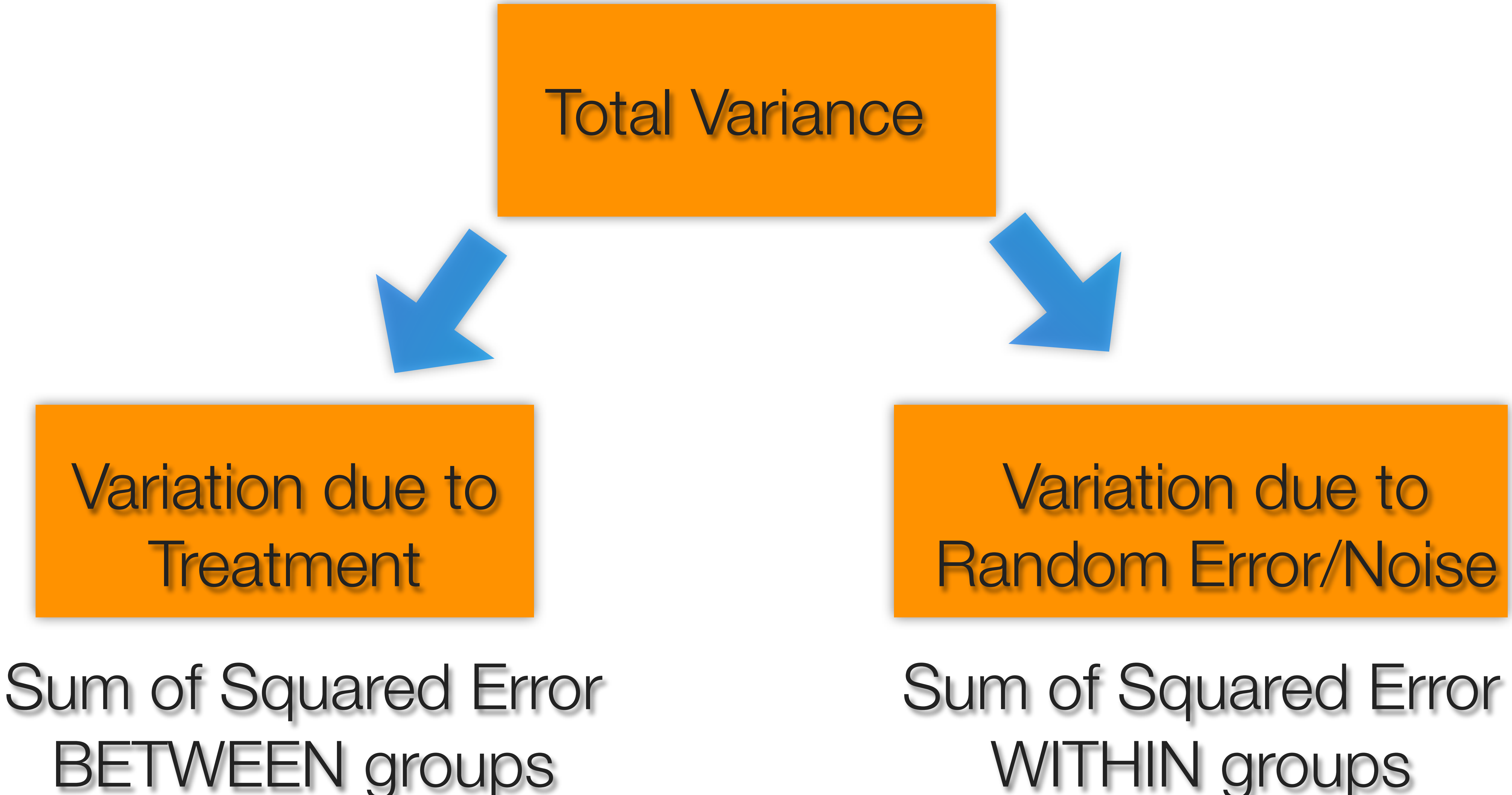


The basic idea

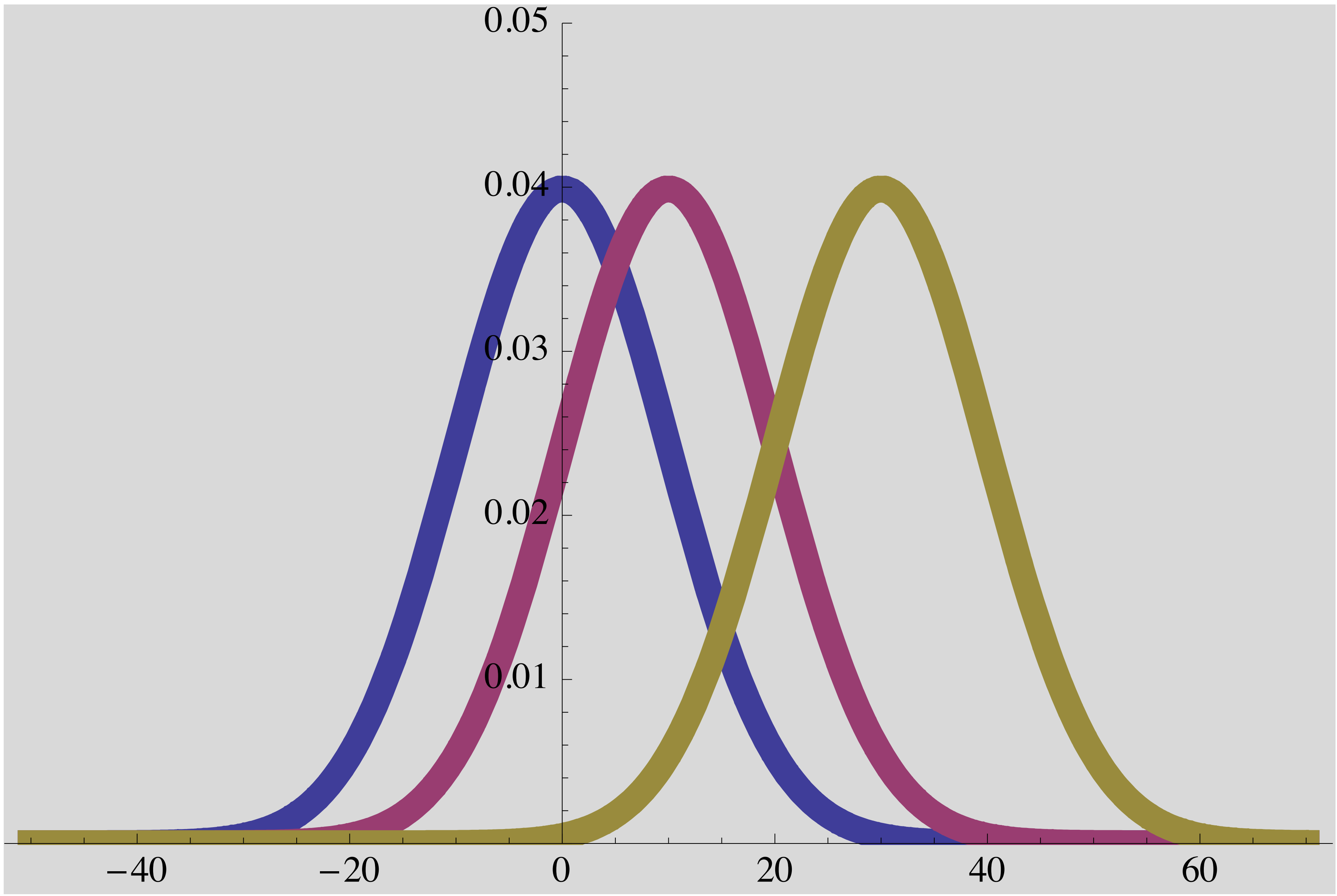
- Compare 2 types of variation to test the equality of means
- **Ratio of variances**
- If the variance between the different treatment groups is greater than the (assumed) random variation within each group, then we conclude the means are not equal
- The variance that go into this are computed by “partitioning” total variation into subsets



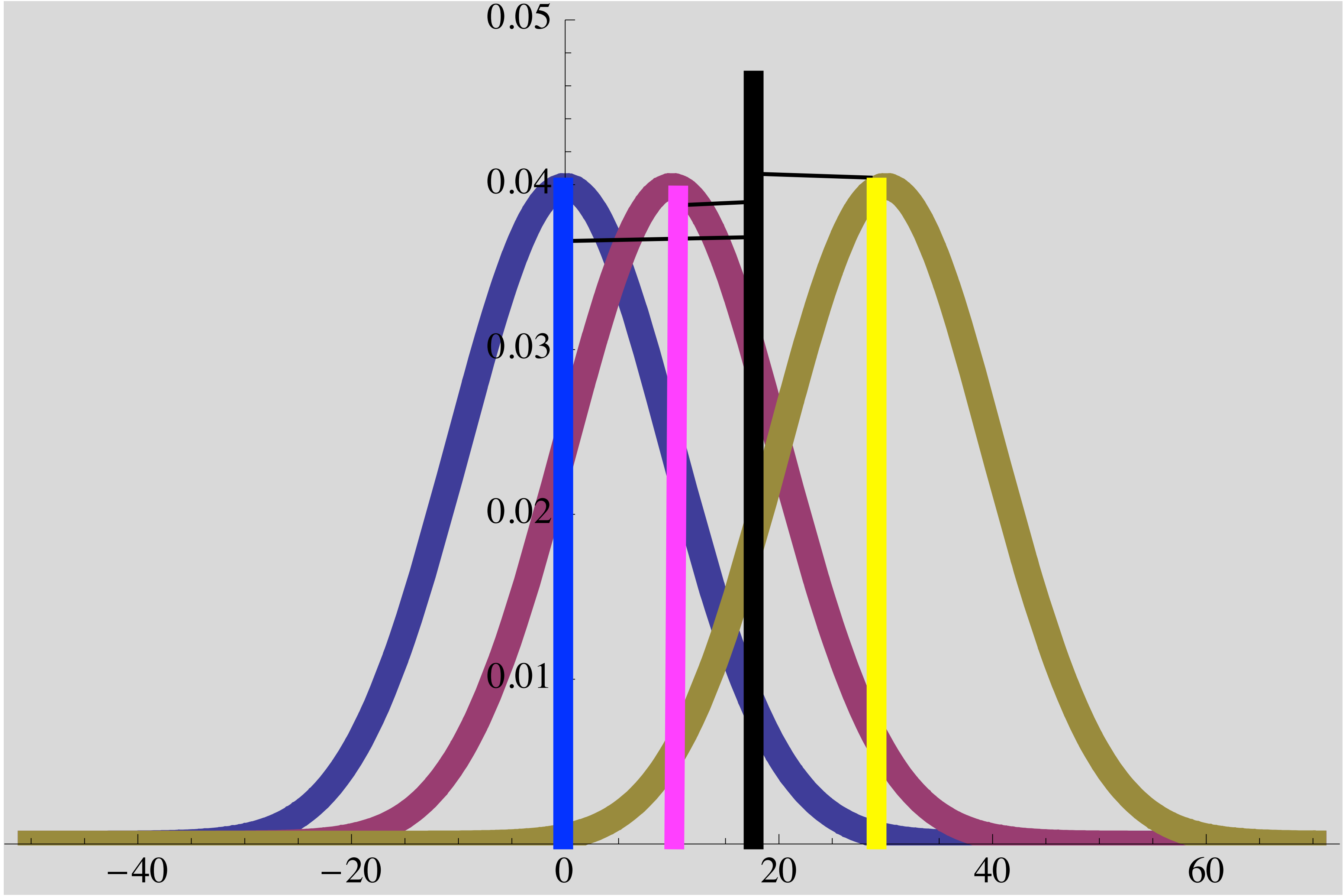
Partitioned Variance Idea



Partitioned Variance Idea

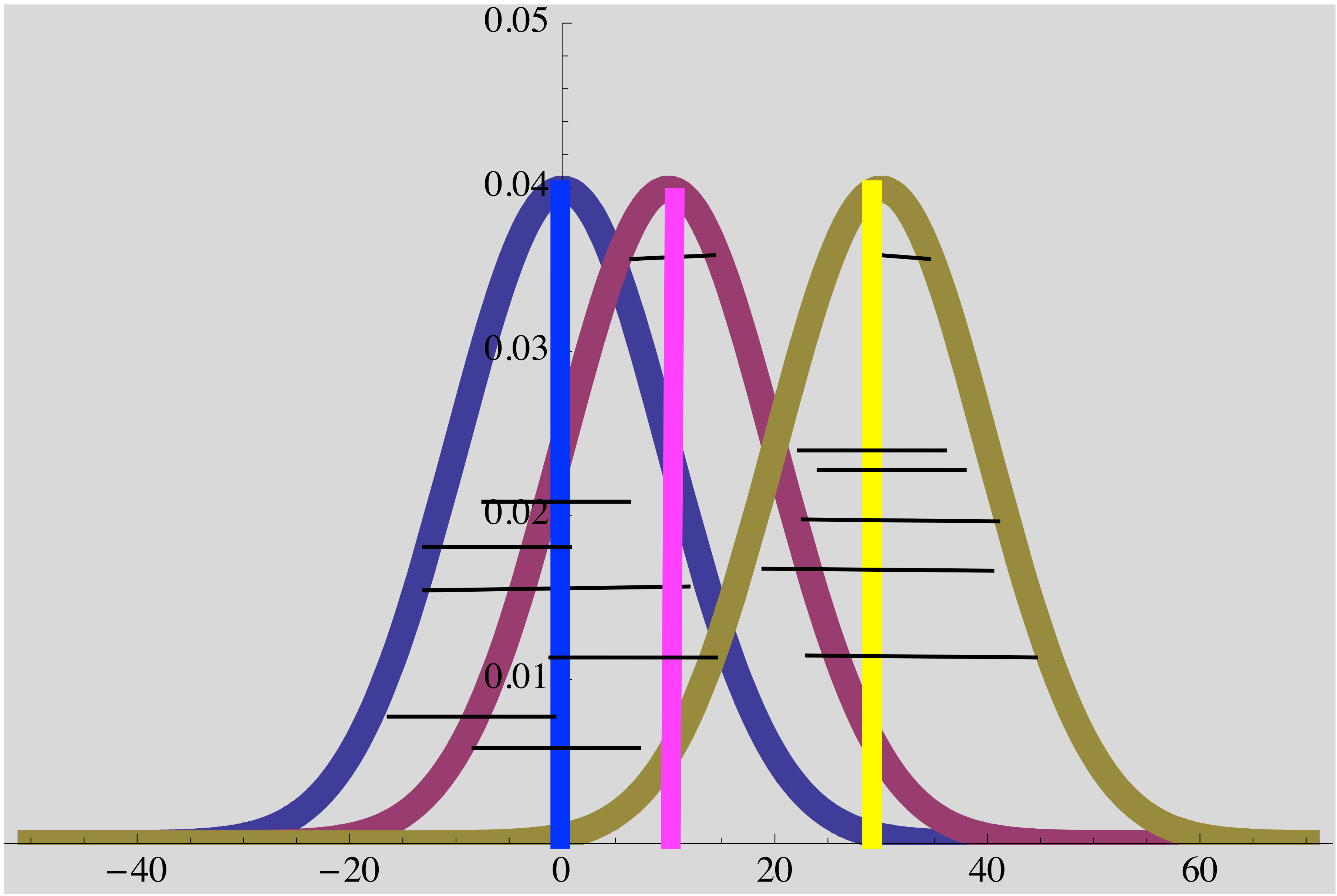


Partitioned Variance Idea



Between-group variance

Partitioned Variance Idea



Between-group variance

ANOVA

$$F = \mathrm{MSB} \,/\, \mathrm{MSW}$$

MSB = mean squared error between

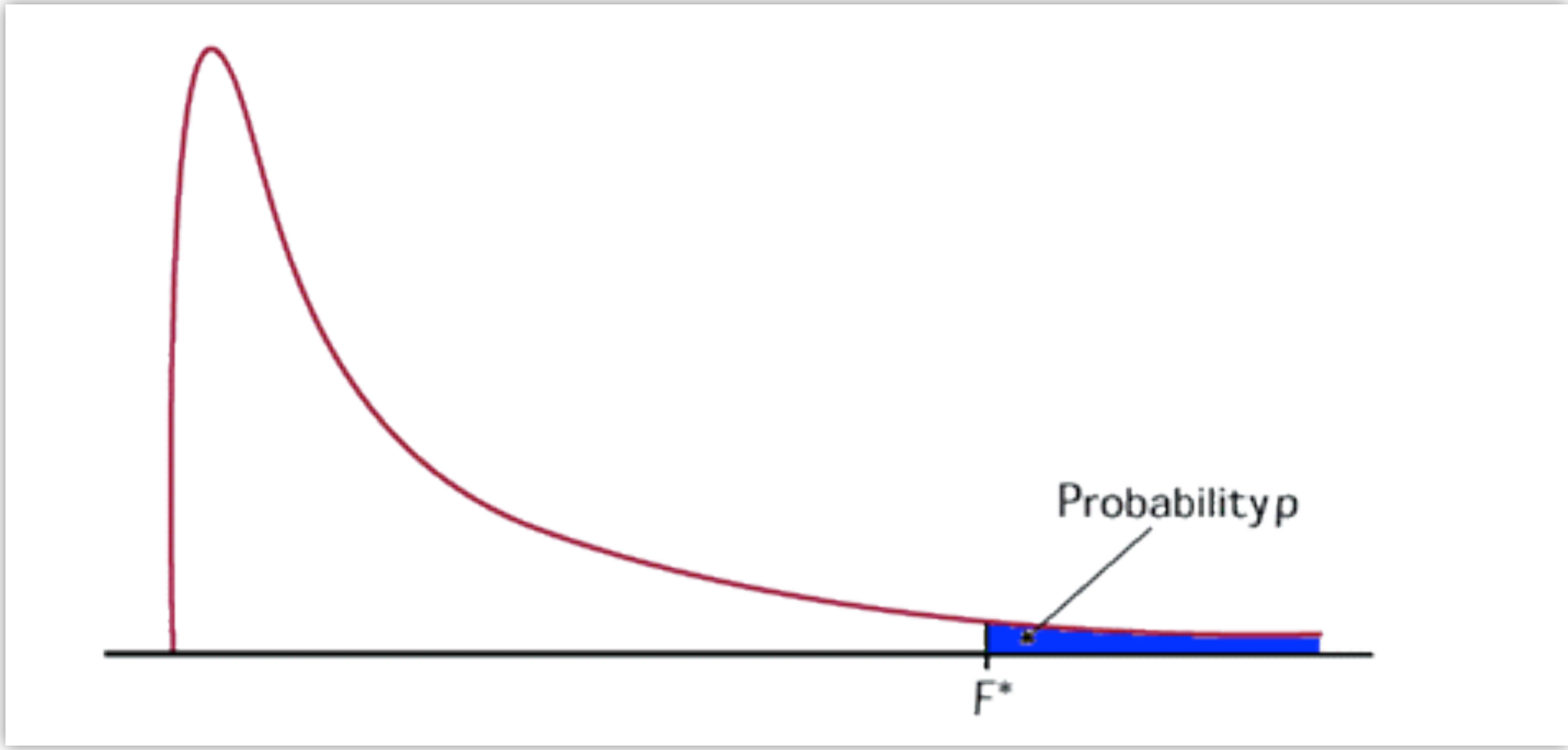
MSW = mean squared error within

df of MSB is # of groups - 1

df of MSW is # of samples - # of groups

ANOVA

$$F = \mathrm{MSB} \,/\, \mathrm{MSW}$$



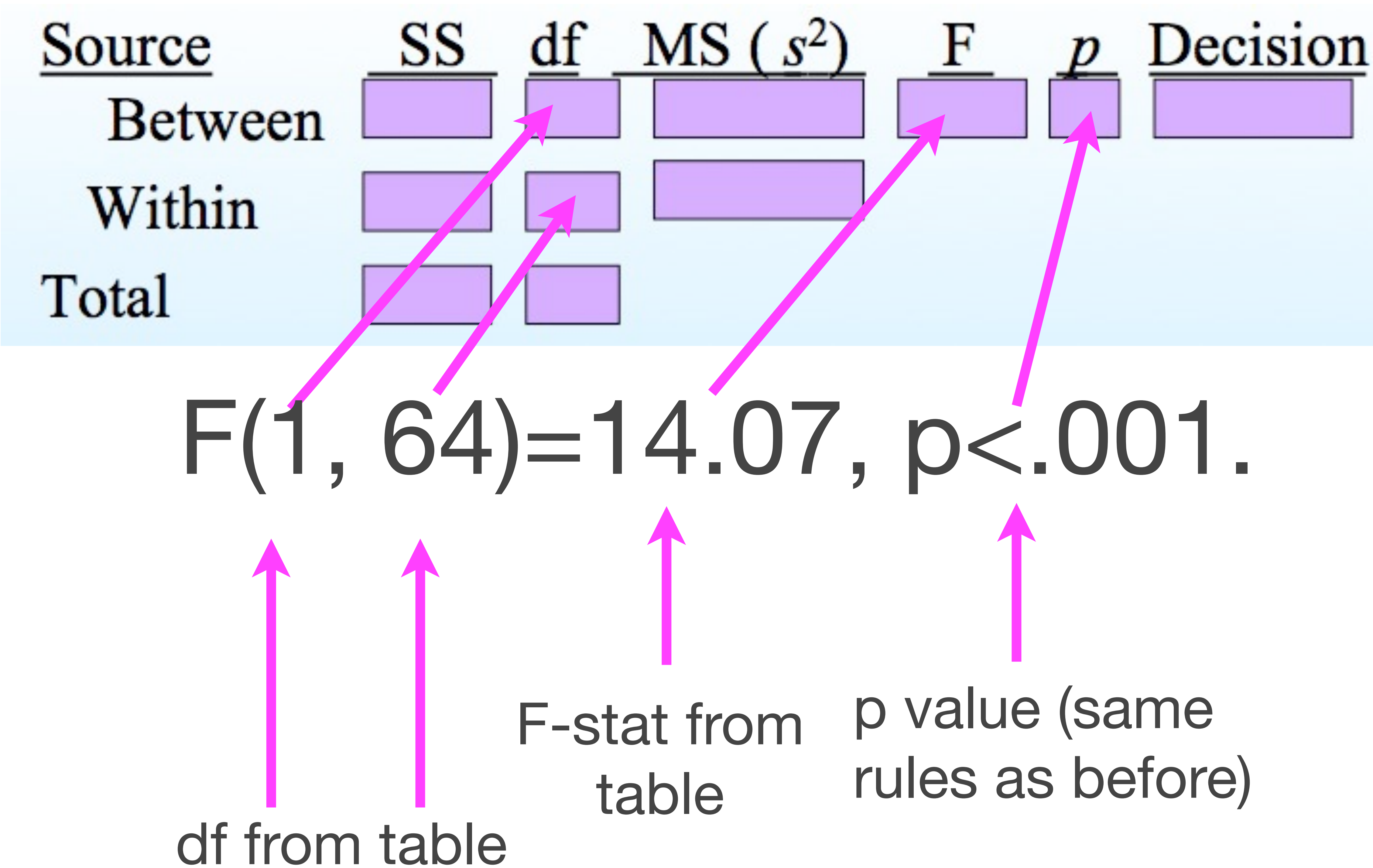
ANOVA

Source	SS	df	MS (s^2)	F	p	Decision
Between						
Within						
Total						

How to report

A one-way (repeated measures) ANOVA on trial type revealed a significant effect the presented stimulus on participant's reaction time, $F(1, 64)=14.07$, $p<.001$.

How to report



How to report

```
> myaov=aov(byslot$rt~byslot$cond)
> summary(myaov)
            Df Sum Sq Mean Sq F value   Pr(>F)
byslot$cond  2 165803   82902  6.9621 0.002779 **
Residuals   36 428672   11908
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

$F(2, 36)=6.96, p<.001.$

How to report

```
> summary(myaov)

Error: byslot$subj
          Df Sum Sq Mean Sq F value Pr(>F)
Residuals 12 374819   31235

Error: Within
             Df Sum Sq Mean Sq F value    Pr(>F)
byslot$cond   2 165803   82902  36.946 4.716e-08 ***
Residuals    24  53853    2244
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

$F(2, 24)=36.96$, $p<.001$.

How to report

Between-subject SSE

```
> summary(myaov)

Error: byslot$subj
          Df Sum Sq Mean Sq F value Pr(>F)
Residuals 12 374819   31235

Error: Within
            Df Sum Sq Mean Sq F value    Pr(>F)
byslot$cond  2 165803   82902  36.946 4.716e-08 ***
Residuals   24  53853    2244
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

$F(2, 24)=36.96$, $p<.001$.