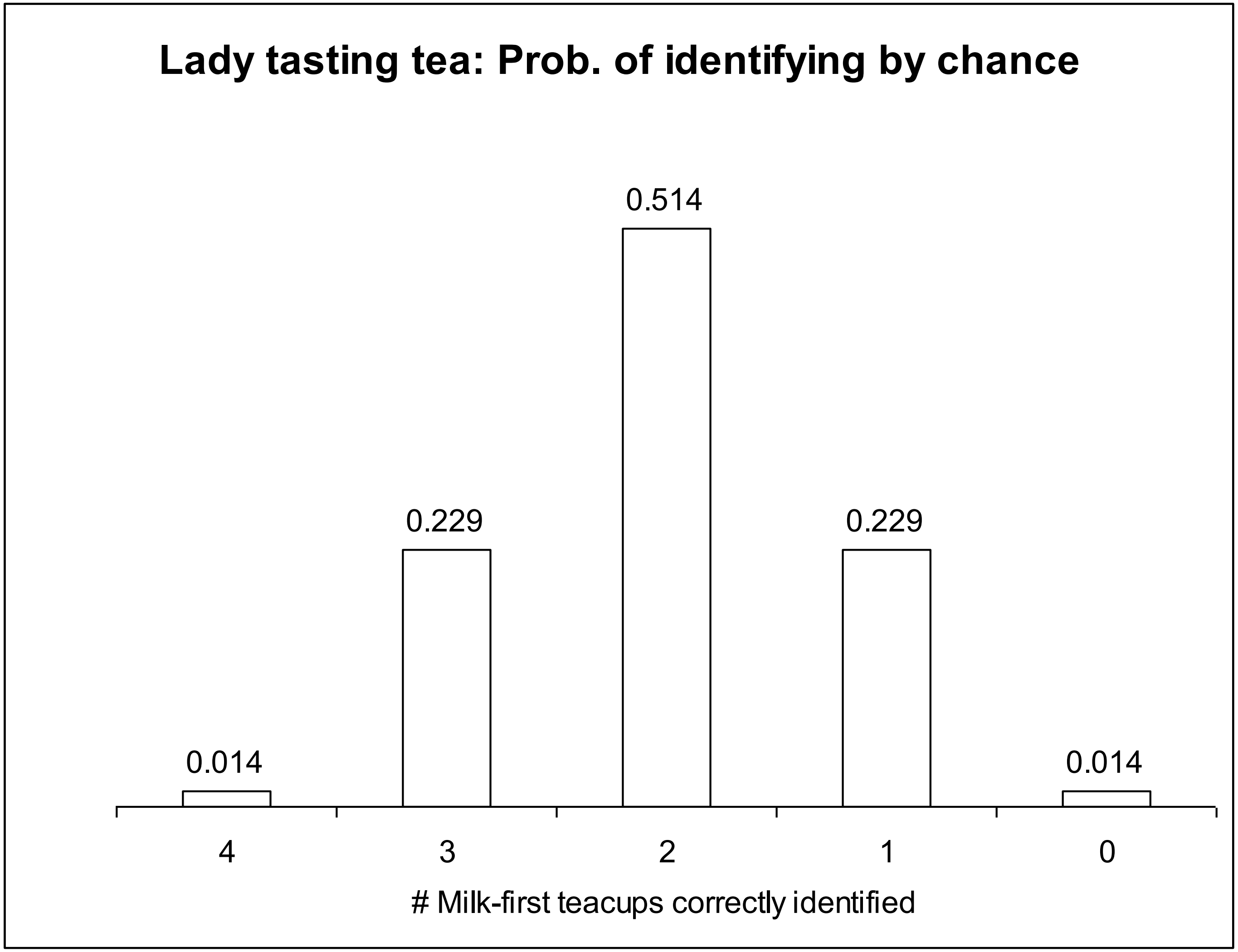
Statistical Inference

Two simple examples

- Lady tasting tea
- Human energy fields

Fisher's exact test

- A simple approach to inference
- Only applicable when outcome probabilities known
- Lady tasting tea example
  - Claims she can tell whether the milk was poured first
  - In a test, 4/8 teacups had milk poured first
  - The lady correctly detects all four
- What is the probability she did this by chance?
  - 70 ways of choosing four cups out of eight
  - How many ways can she do so correctly?


Lady tasting tea: Prob. of identifying by chance
0.514
0.229
0.229
0.014
0.014
4
3
2
1
0
Milk-first teacups correctly identified

Second simple example

Healing touch: human energy field detection

"A Close Look at Therapeutic Touch"

Linda Rosa; Emily Rosa; Larry Sarner; Stephen Barrett. 1998.

JAMA

(279: 1005 – 1010)

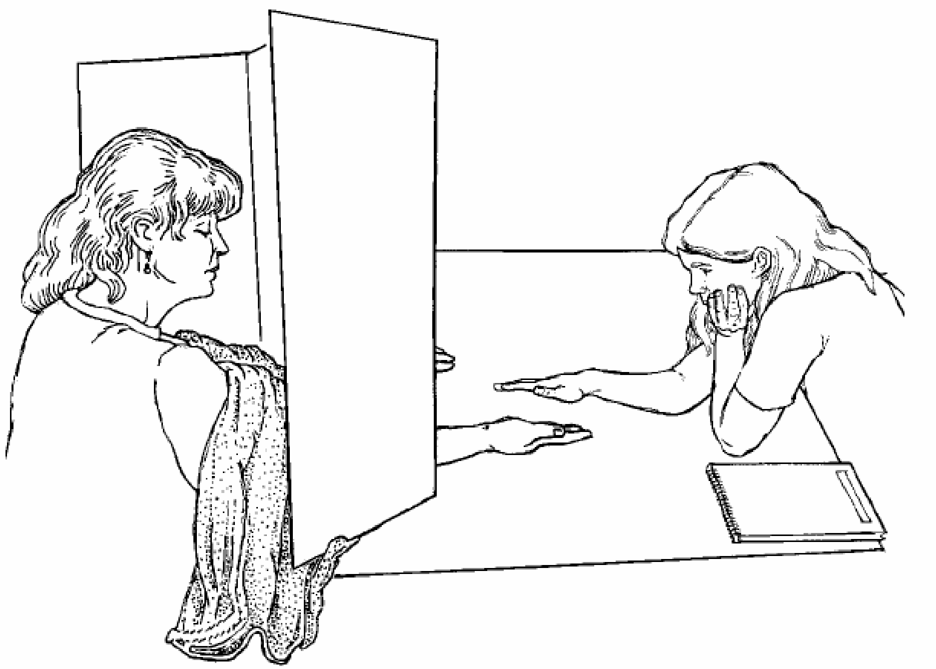
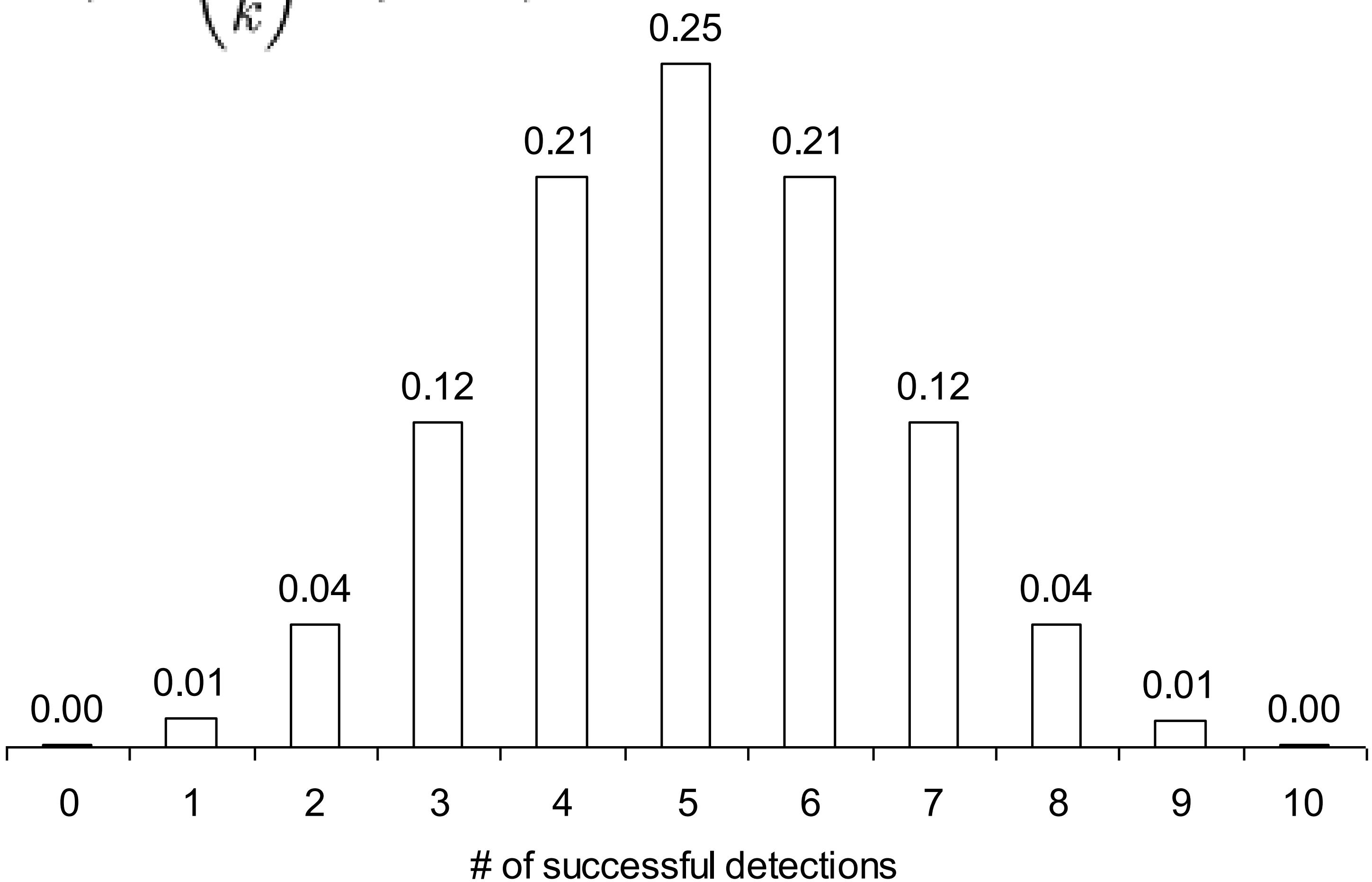
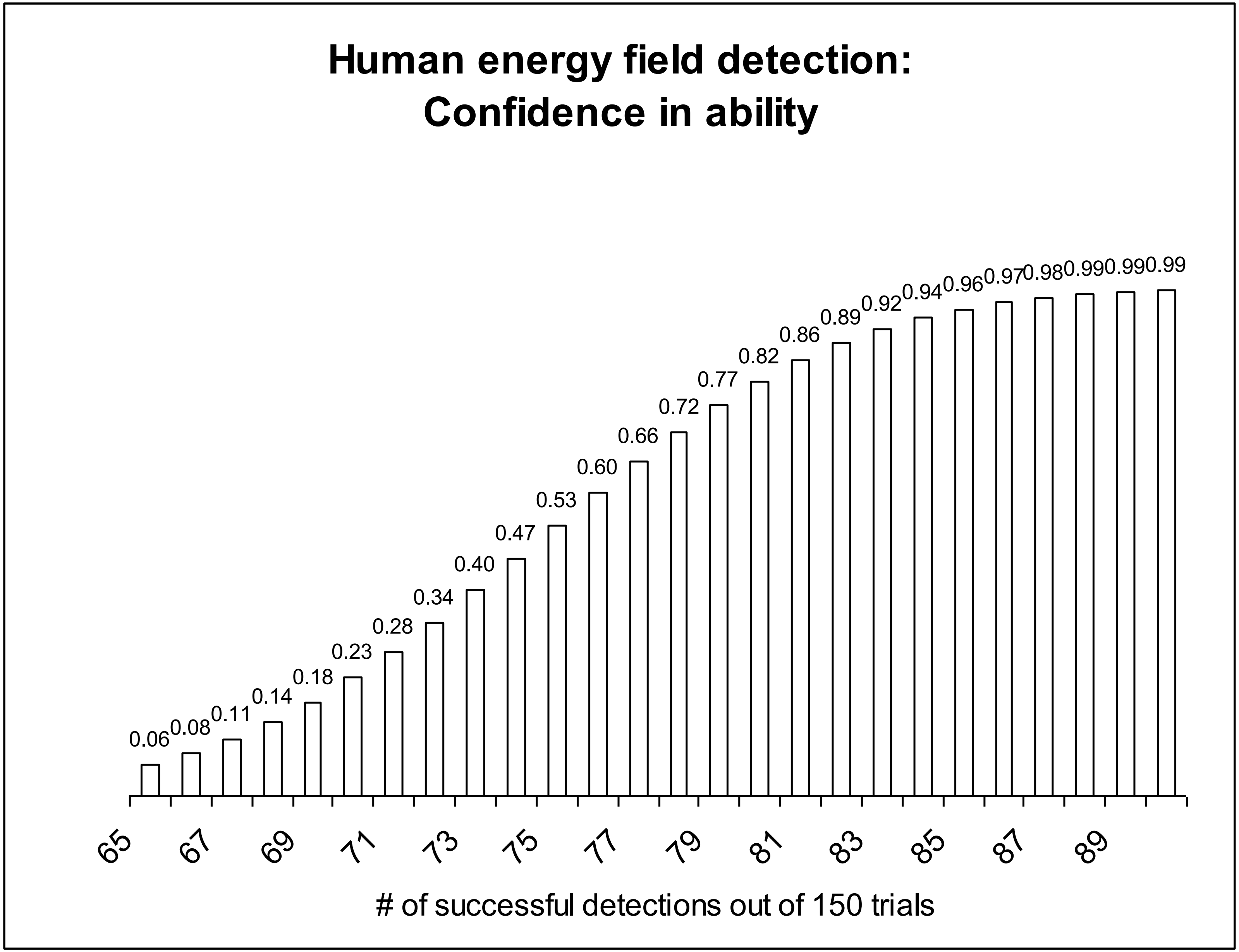


Figure 1.—Experimenter hovers hand over one of subject's hands. Draped towel prevents peeking. Drawing by Pat Linse, Skeptics Society.

Human energy field: Prob. of success by chance

$$f(k;n,p) = \binom{n}{k} p^k (1-p)^{n-k}$$




Human energy field detection:
Confidence in ability
0.06
0.08
0.11
0.14
0.18
0.23
0.28
0.34
0.40
0.47
0.53
0.60
0.66
0.72
0.77
0.82
0.86
0.89
0.92
0.94
0.96
0.97
0.98
0.99
0.99
0.99
65
67
69
71
73
75
77
79
81
83
85
87
89
# of successful detections out of 150 trials

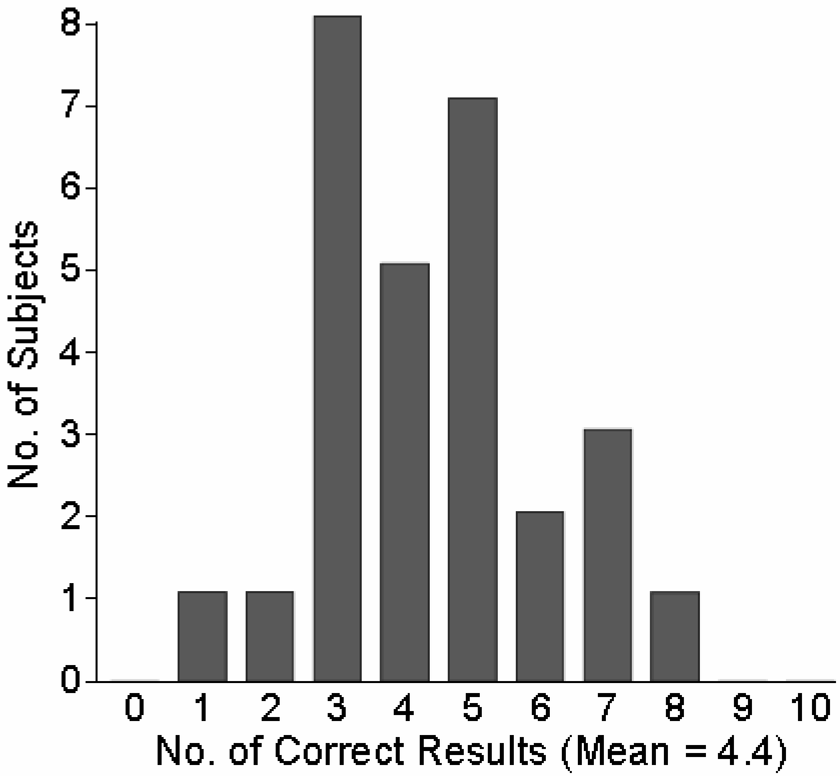


Figure 2.—Distribution of test results.

Table 2.—Statistical Analysis

Statistical Function	Initial Test (n = 15)	Follow-up Test (n = 13)
Mean (95% confidence interval)	4.67 (3.67-5.67)	4.08 (3.17-4.99)
SD	1.74	1.44
α (1-tailed test)	.05	.05
t statistic	−0.7174	−2.222
Upper critical limit of Student t distribution	1.761	1.782
Alternative hypothesis, $\mu = 6.67$	0.9559	0.9801
Alternative hypothesis, $\mu = 7.50$	0.999644	0.999953

Linda Rosa; Emily Rosa; Larry Sarner; Stephen Barrett. 1998. "A Close Look at Therapeutic Touch" JAMA, 279: 1005 - 1010.

Null hypothesis

- In both cases, we calculated the probability of making the correct choice by chance and compared it to the observed results.
- Thus, our null hypothesis was that the lady and the therapists lacked any of their claimed ability.
- What's the null hypothesis that Stata uses by default for calculating p values?
- Always consider whether other null hypotheses might be more substantively meaningful.
  - E.g., testing whether the benefits from government programs outweigh the costs.

Two types of inference

- Testing underlying traits
  - E.g., can lady detect milk-poured first?
  - E.g., does democracy improve human lives?
- Testing inferences about a population from a sample
  - What percentage of the population approves of President Bush?
  - What's average household income in the United States?

Assessing uncertainty

- Today we will cover
  - Standard error
  - Confidence intervals
  - Central limit theorem

Baseball example

- **In 2006, Manny Ramírez hit .321**
- **How certain are we that, in 2006, he was a .321 hitter?**
- **To answer this question, we need to know how precisely we have estimated his batting average**
- **The standard error gives us this information, which in general is (where *s* is the sample standard deviation)**

$$\text{std. err.} = \frac{s}{\sqrt{n}}$$

Baseball example

- The standard error (s.e.) for proportions (percentages/100) is

$$\sqrt{\frac{p(1-p)}{n}}$$

- N = 400, p = .321, s.e. = .023
- Which means, on average, the .321 estimate will be off by .023

Baseball example: postseason

- 20 at-bats
  - N = 20, p = .400, s.e. = .109
  - Which means, on average, the .400 estimate will be off by .109

- 10 at-bats
  - N = 10, p = .400, s.e. = .159
  - Which means, on average, the .400 estimate will be off by .159

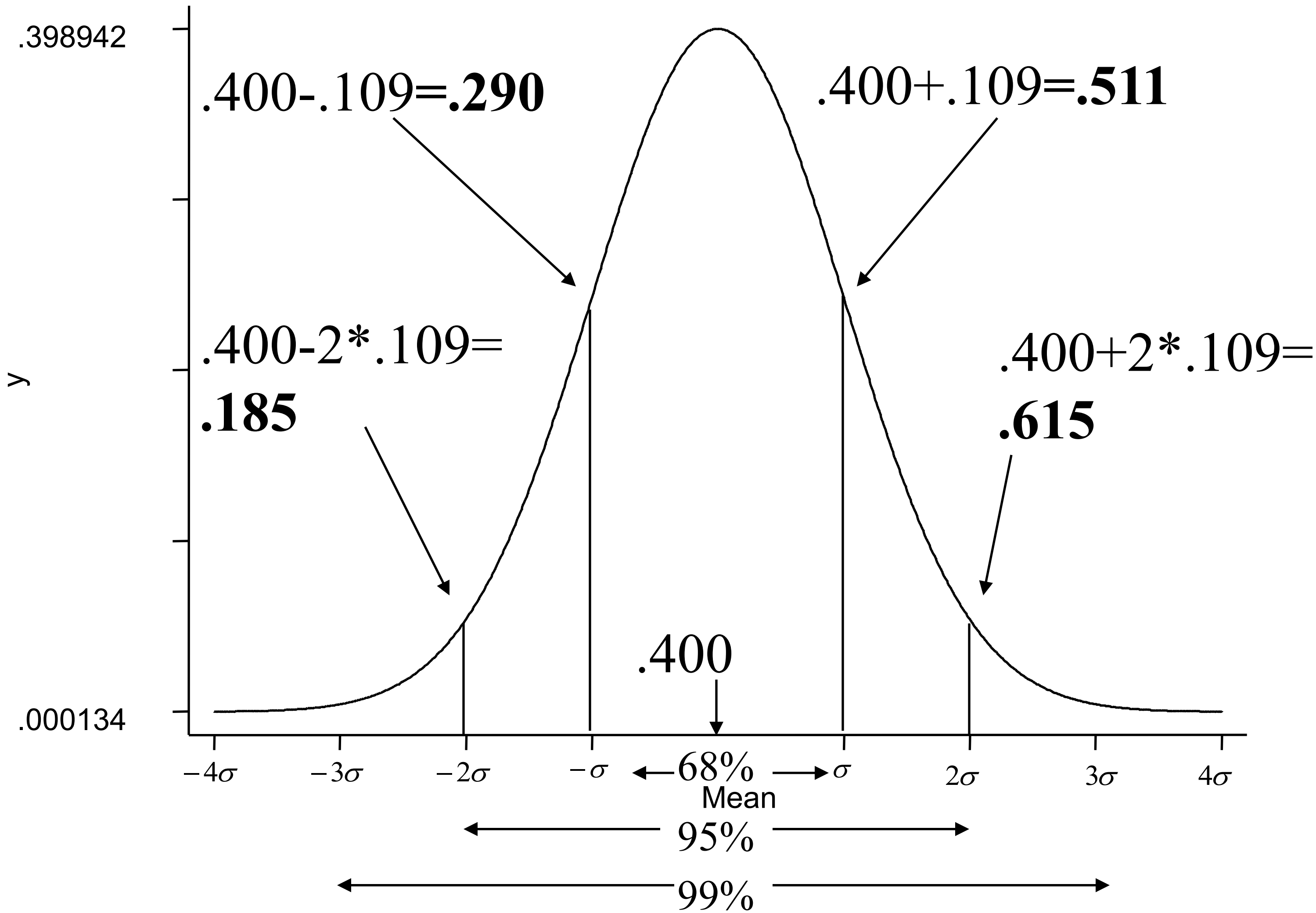
Using Standard Errors, we can construct "confidence intervals"

- **Confidence interval (ci)**: an interval between two numbers, where there is a certain specified level of confidence that a population parameter lies

- ci = sample parameter $\pm$ multiple * sample standard error

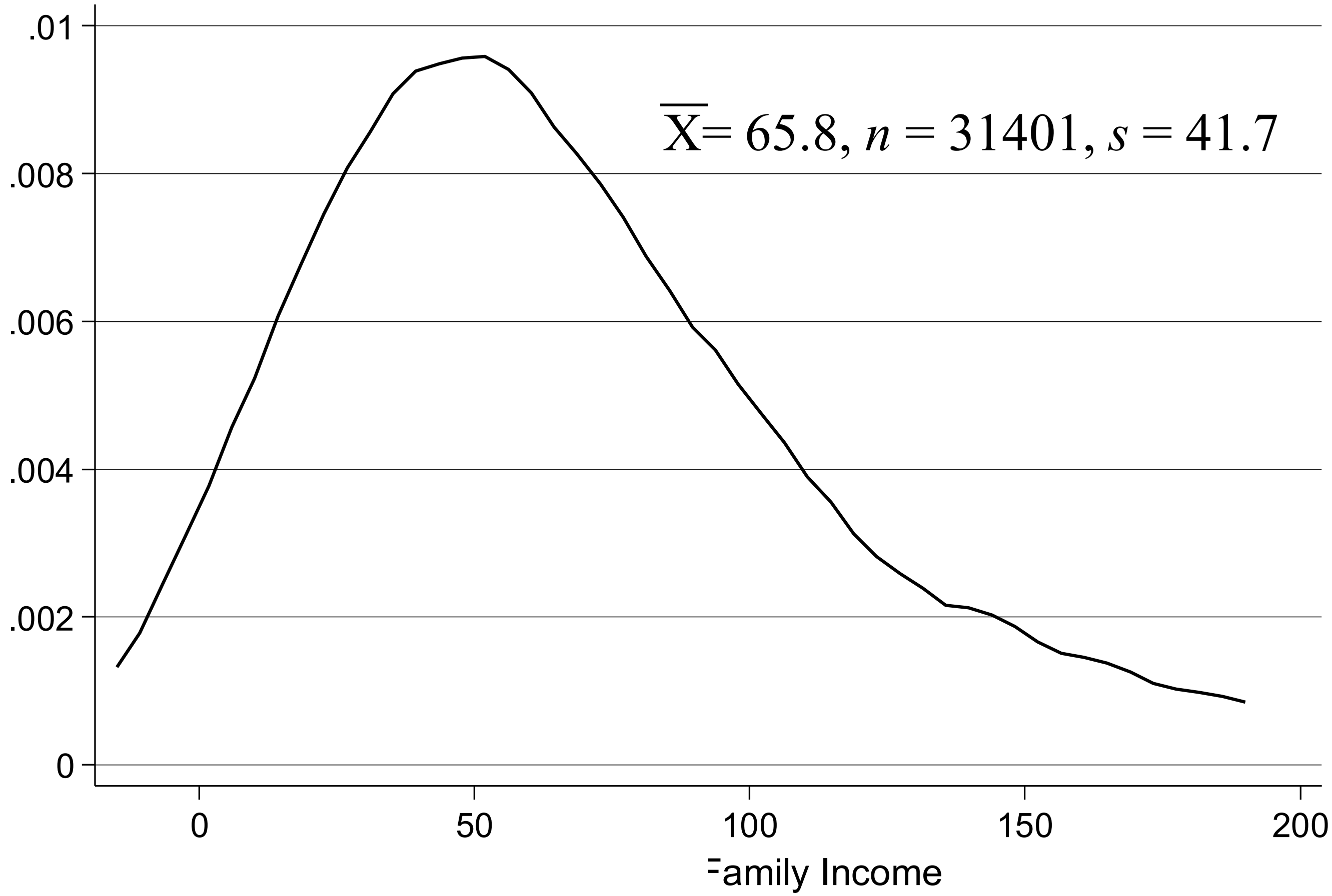
N = 20; avg. = .400; s = .489; s.e. =.109

Confidence interval



- Much of the time, we fail to realize the uncertainty in statistical estimates
  - Postseason statistics
  - Competitions

Certainty about mean of a population based on a sample: Family income in 2006



Source: 2006 CCES

Calculating the Standard Error

$$\text{std. err.} = \frac{s}{\sqrt{n}}$$

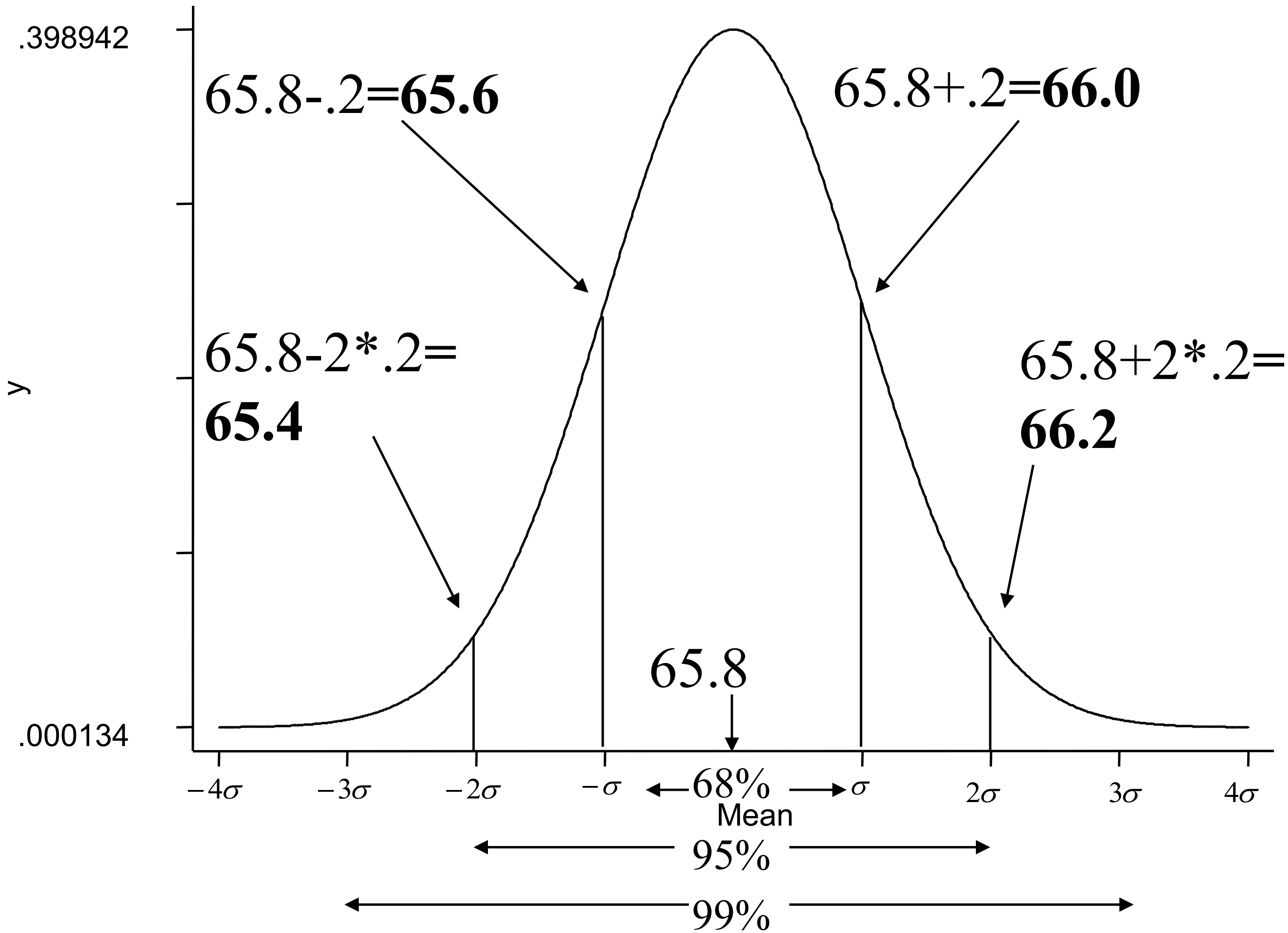
For the income example,

std. err. = 41.6/177.2 = .23

$\overline{X} = 65.8$, $n = 31401$, $s = 41.7$

N = 31401; avg. = 65.8; s = 41.6; s.e. = s/√n = .2

The Picture



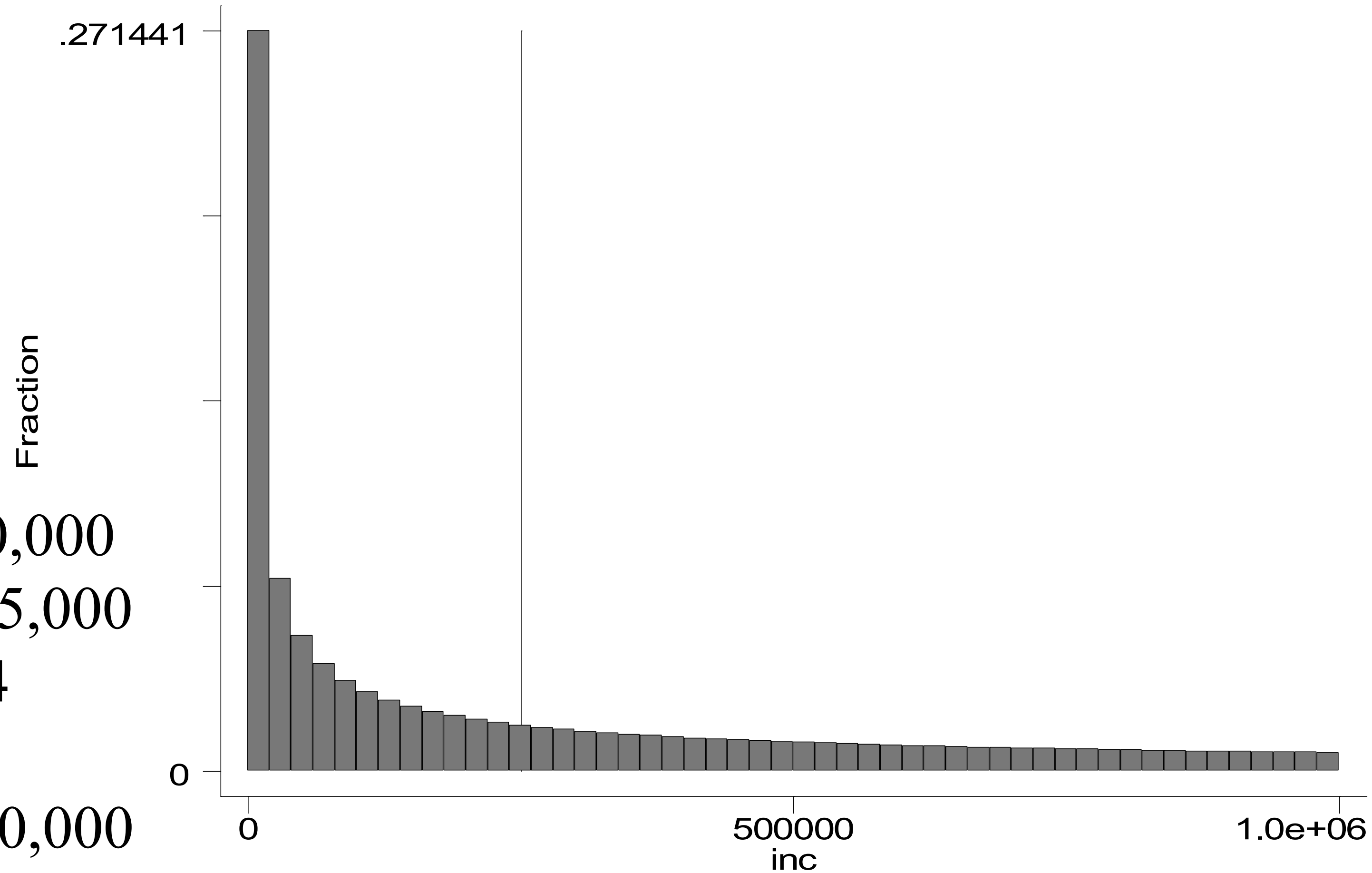
Where does the bell-shaped curve come from?

- **Central limit theorem**

Central Limit Theorem

As the sample size *n* increases, the distribution of the mean $\overline{X}$ of a random sample taken from **practically any population** approaches a *normal* distribution, with mean μ and standard deviation $\sigma / \sqrt{n}$

Illustration of Central Limit Theorem:
Exponential Distribution



Mean = 250,000

Median=125,000

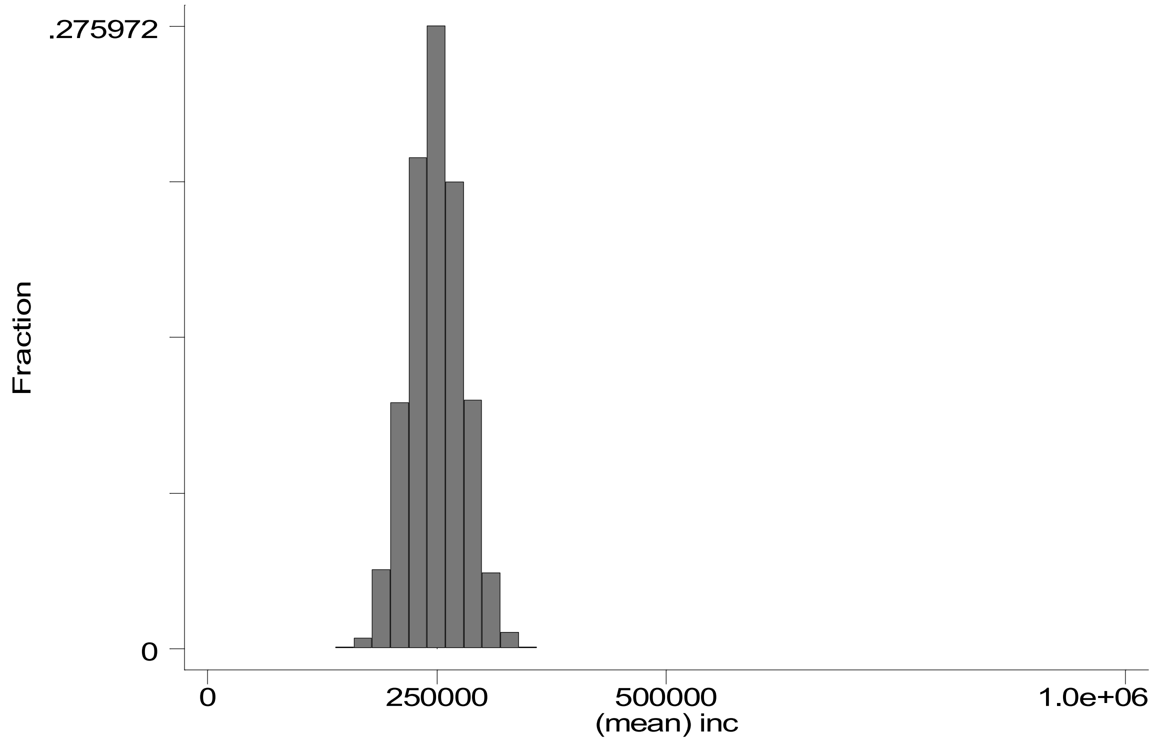
σ = 283,474

Min = 0

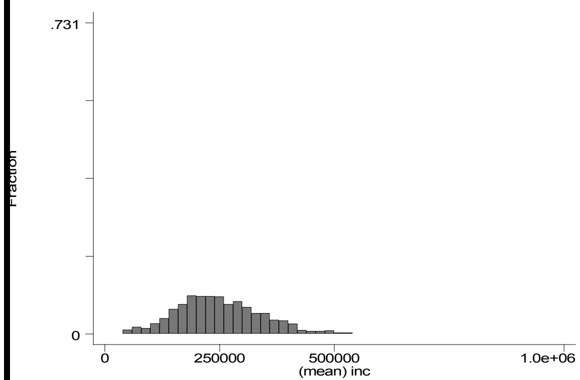
Max = 1,000,000

Consider 10,000 samples of *n* = 100

N = 10,000
Mean = 249,993
s = 28,559



Consider 1,000 samples of various sizes

<table>
<tr><th>10</th><th>100</th><th>1000</th></tr>
<tr>
<td>
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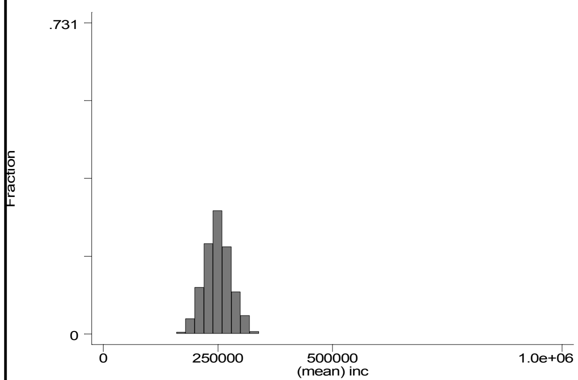
<td>
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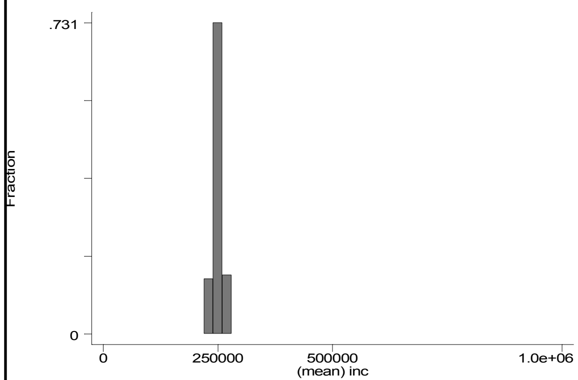
<td>
</td>
</tr>
<tr>
<td>Mean =250,105
s = 90,891</td>
<td>Mean = 250,498
s = 28,297</td>
<td>Mean = 249,938
s = 9,376</td>
</tr>
</table>

Play with some simulations

- http://www.ruf.rice.edu/~lane/stat_sim/sampling_dist/index.html
- http://www.kuleuven.ac.be/ucs/java/index.htm

Most important standard errors

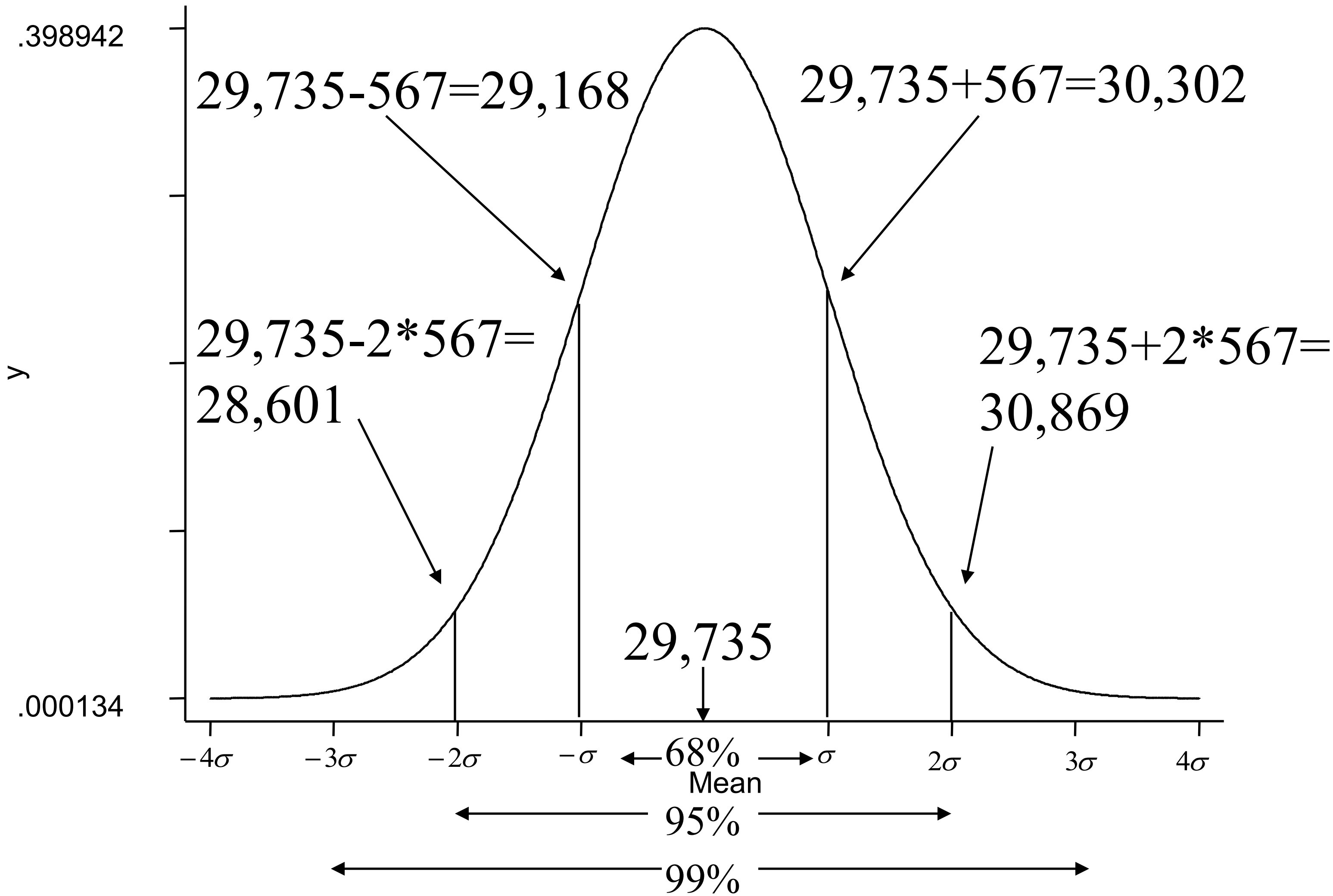
Mean	$\frac{s}{\sqrt{n}}$
Proportion	$\sqrt{\frac{p(1-p)}{n}}$
Diff. of 2 means	$\sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}}$
Diff. of 2 proportions	$\sqrt{\frac{p_1(1-p_1)}{n_1}+\frac{p_2(1-p_2)}{n_2}}$
Diff of 2 means (paired data)	$\frac{s_d}{\sqrt{n}}$
Regression (slope) coeff.	$\frac{s.e.r.}{\sqrt{n-1}}\times\frac{1}{s_x}$

Another example

- Let’s say we draw a sample of tuitions from 15 private universities. Can we estimate what the average of all private university tuitions is?
- N = 15
- Average = 29,735
- s = 2,196
- s.e. = $\dfrac{s}{\sqrt{n}} = \dfrac{2{,}196}{\sqrt{15}} = 567$

N = 15; avg. = 29,735; s = 2,196; s.e. = s/√n = 567

The Picture



Confidence Intervals for Tuition Example

- 68% confidence interval = 29,735±567 = [29,168 to 30,302]
- 95% confidence interval = 29,735±2*567 = [28,601 to 30,869]
- 99% confidence interval = 29,735±3*567 = [28,034 to 31,436]

What if someone (ahead of time) had said, "I think the average tuition of major research universities is $25k"?

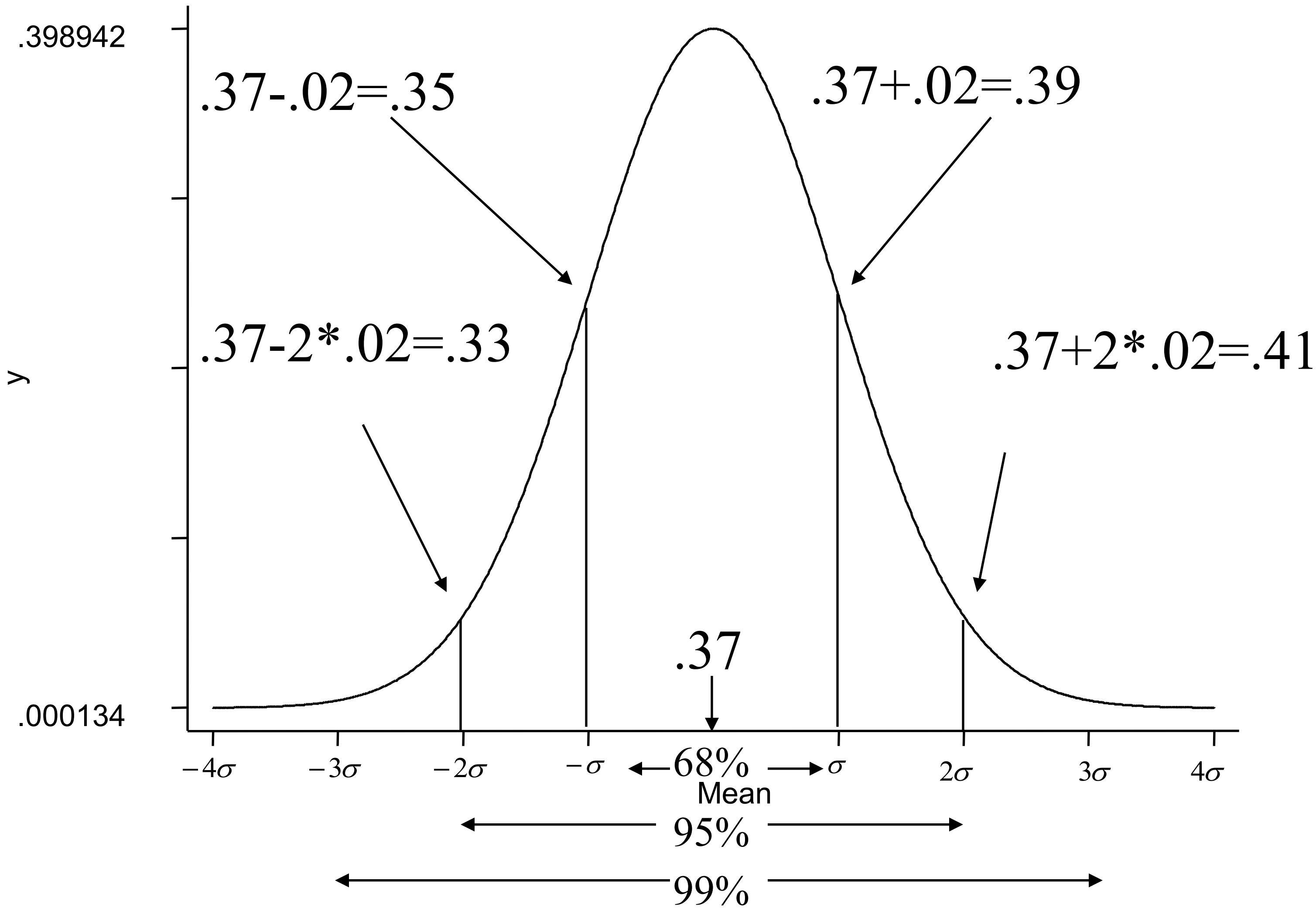
- Note that $25,000 is well out of the 99% confidence interval, [28,034 to 31,436]
- Q: How far away is the $25k estimate from the sample mean?
  - A: Do it in *z*-scores: (29,735-25,000)/567 = 8.35

Constructing confidence intervals of proportions

- Let us say we drew a sample of 1,000 adults and asked them if they approved of the way George Bush was handling his job as president. (March 13-16, 2006 Gallup Poll) Can we estimate the % of all American adults who approve?
- N = 1000
- p = .37
- s.e. = $\sqrt{\frac{p(1-p)}{n}} = \sqrt{\frac{.37(1-.37)}{1000}} = 0.02$

N = 1,000; p. = .37; s.e. = $\sqrt{p(1-p)/n}$ = .02

The Picture



Confidence Intervals for Bush approval example

- 68% confidence interval = $.37 \pm .02$ = [.35 to .39]
- 95% confidence interval = $.37 \pm 2*.02$ = [.33 to .41]
- 99% confidence interval = $.37 \pm 3*.02$ = [.31 to .43]

What if someone (ahead of time) had said, "I think Americans are equally divided in how they think about Bush."

- Note that 50% is well out of the 99% confidence interval, [31% to 43%]
- Q: How far away is the 50% estimate from the sample proportion?
  - A: Do it in *z*-scores: (.37-.5)/.02 = -6.5 [-8.7 if we divide by 0.15]

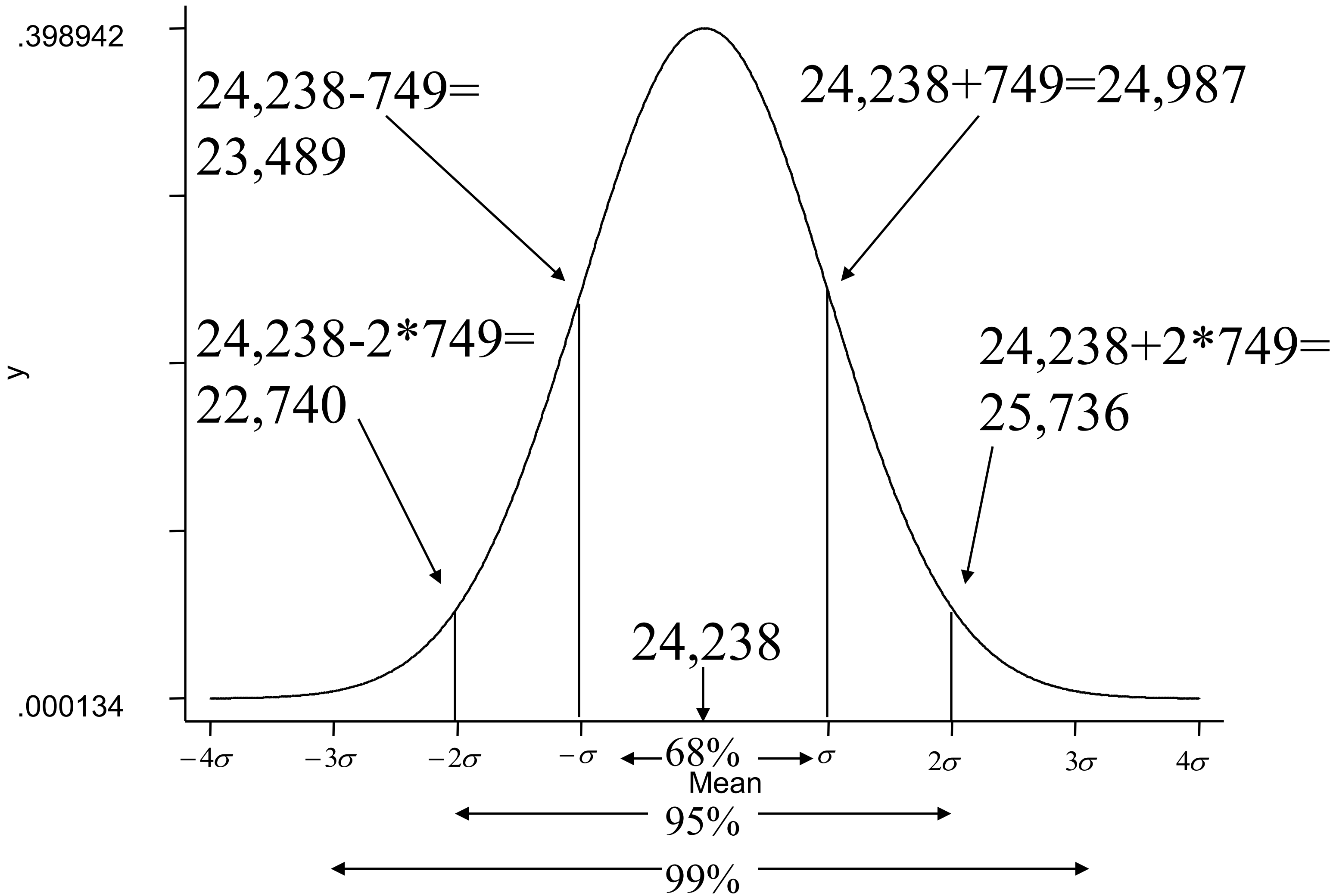
Constructing confidence intervals of differences of means

- Let's say we draw a sample of tuitions from 15 private and public universities. Can we estimate what the difference in average tuitions is between the two types of universities?

- N = 15 in both cases
- Average = 29,735 (private); 5,498 (public); diff = 24,238
- s = 2,196 (private); 1,894 (public)
- s.e. = $\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{4,822,416}{15} + \frac{3,587,236}{15}} = 749$

N = 15 twice; diff = 24,238; s.e. = 749

The Picture



Confidence Intervals for difference of tuition means example

- 68% confidence interval = 24,238±749 =

[23,489 to 24,987]

- 95% confidence interval = 24,238±2*749 = [22,740 to 25,736]
- 99% confidence interval =24,238±3*749 =
- [21,991 to 26,485]

What if someone (ahead of time) had said, "Private universities are no more expensive than public universities"

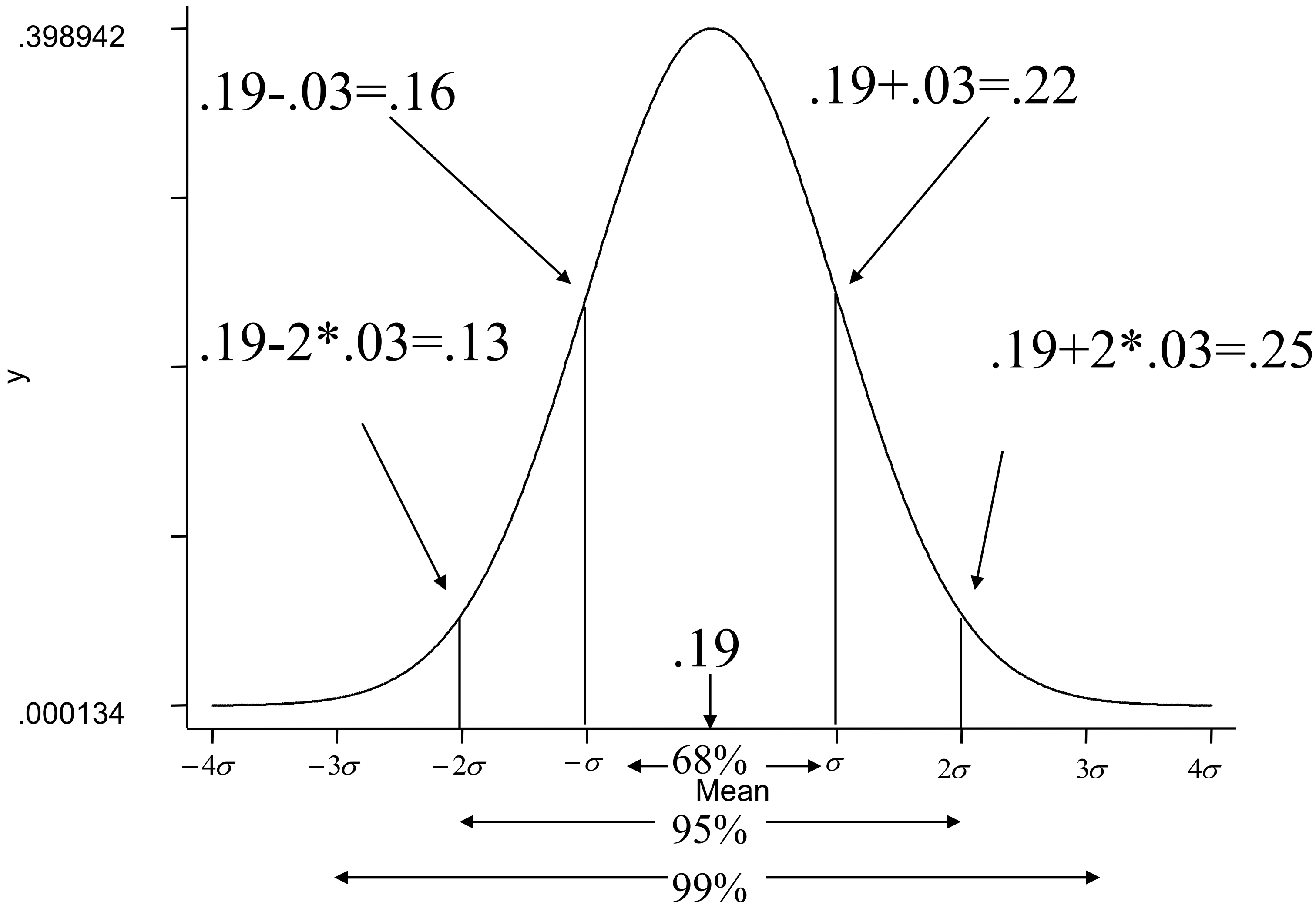
- Note that \$0 is well out of the 99% confidence interval, [\$21,991 to \$26,485]
- Q: How far away is the \$0 estimate from the sample proportion?
  - A: Do it in *z*-scores: (24,238-0)/749 = 32.4

Constructing confidence intervals of difference of proportions

- Let us say we drew a sample of 1,000 adults and asked them if they approved of the way George Bush was handling his job as president. (March 13-16, 2006 Gallup Poll). We focus on the 600 who are either independents or Democrats. Can we estimate whether independents and Democrats view Bush differently?
- N = 300 ind; 300 Dem.
- p = .29 (ind.); .10 (Dem.); diff = .19
- s.e. = $\sqrt{\frac{p_1(1-p_1)}{n_1}+\frac{p_2(1-p_2)}{n_2}}=\sqrt{\frac{.29(1-.29)}{300}+\frac{.10(1-.10)}{300}}=.03$

diff. p. = .19; s.e. = .03

The Picture



Confidence Intervals for Bush Ind/Dem approval example

- 68% confidence interval = .19±.03 = [.16 to .22]
- 95% confidence interval = .19±2*.03 = [.13 to .25]
- 99% confidence interval = .19±3*.03 = [.10 to .28]

What if someone (ahead of time) had said, “I think Democrats and Independents are equally unsupportive of Bush”?

- Note that 0% is well out of the 99% confidence interval, [10% to 28%]
- Q: How far away is the 0% estimate from the sample proportion?
  - A: Do it in *z*-scores: (.19-0)/.03 = 6.33

What if someone (ahead of time) had said, “Private university tuitions did not grow from 2003 to 2004”

- Stata command `ttest`
- Note that $0 is well out of the 95% confidence interval, [$1,141 to $2,122]
- Q: How far away is the $0 estimate from the sample proportion?
  - A: Do it in *z*-scores: (1,632-0)/229 = 7.13

The Stata output

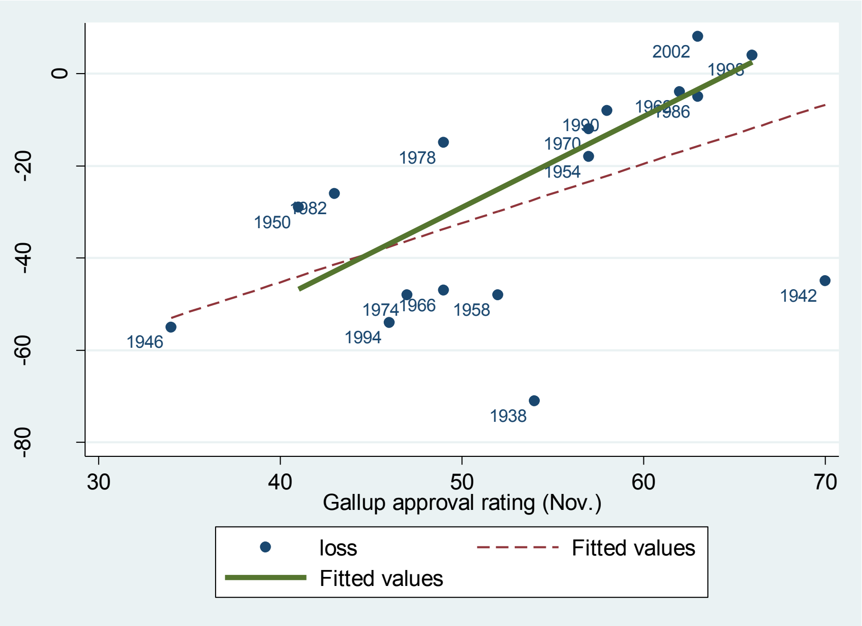
```
. gen difftuition=tuition2004-tuition2003
. ttest diff=0 in 1/15

One-sample t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
difftu~n |      15      1631.6    228.6886     885.707    1141.112    2122.088
------------------------------------------------------------------------------
    mean = mean(difftuition)                                      t =   7.1346
Ho: mean = 0                                     degrees of freedom =       14

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

Constructing confidence intervals of regression coefficients

- Let's look at the relationship between the mid-term seat loss by the President's party at midterm and the President's Gallup poll rating



Slope = 1.97

N = 14

s.e.r. = 13.8

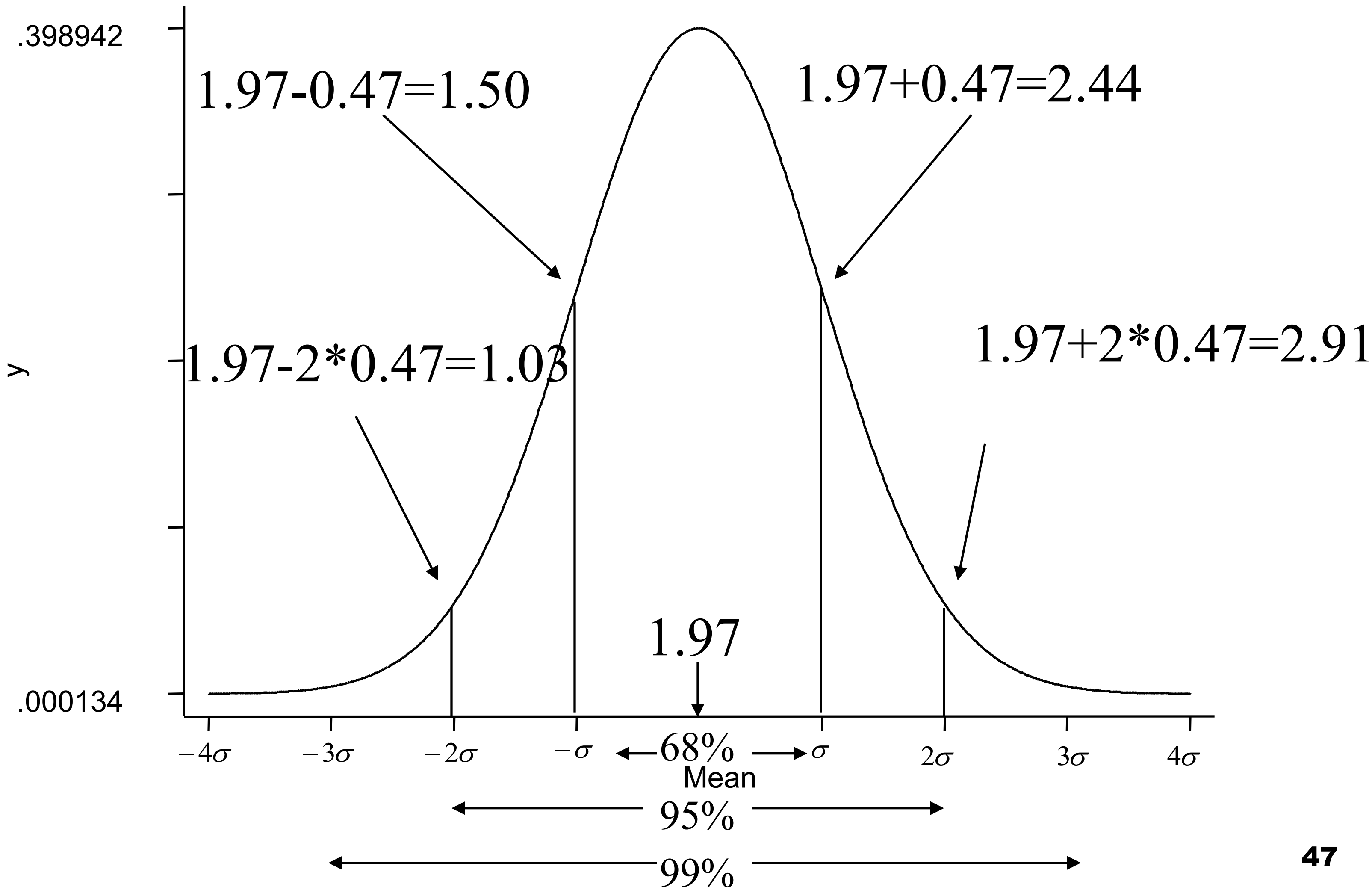
$s_x = 8.14$

$s.e._{slope} =$

$$\frac{s.e.r.}{\sqrt{n-1}} \times \frac{1}{s_x} = \frac{13.8}{\sqrt{13}} \times \frac{1}{8.14} = 0.47$$

N = 14; slope=1.97; s.e. = 0.45

The Picture



Confidence Intervals for regression example

- 68% confidence interval = 1.97± 0.47= [1.50 to 2.44]
- 95% confidence interval = 1.97± 2*0.47 = [1.03 to 2.91]
- 99% confidence interval = 1.97±3*0.47 = [0.62 to 3.32]

What if someone (ahead of time) had said, “There is no relationship between the president’s popularity and how his party’s House members do at midterm”?

- Note that 0 is well out of the 99% confidence interval, [0.62 to 3.32]
- Q: How far away is the 0 estimate from the sample proportion?
  - A: Do it in *z*-scores: (1.97-0)/0.47 = 4.19

The Stata output

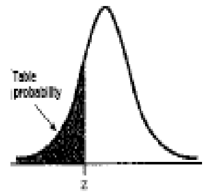
```
. reg loss gallup if year>1948

      Source |       SS       df       MS              Number of obs =      14
-------------+------------------------------           F(  1,    12) =   17.53
       Model |  3332.58872     1  3332.58872           Prob > F      =  0.0013
    Residual |  2280.83985    12  190.069988           R-squared     =  0.5937
-------------+------------------------------           Adj R-squared =  0.5598
       Total |  5613.42857    13  431.802198           Root MSE      =  13.787

------------------------------------------------------------------------------
        loss |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      gallup |    1.96812   .4700211     4.19   0.001     .9440315    2.992208
       _cons |  -127.4281   25.54753    -4.99   0.000    -183.0914   -71.76486
------------------------------------------------------------------------------
```

Reading a *z* table

Standard Normal Probabilities (for $z < 0$)



z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
-3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
-3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
-2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
-2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
-2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
-2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
-2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
-2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
-2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
-1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
-1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
-1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
-1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
-1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
-1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
-1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
-1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
-1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
-0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
-0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
- 0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
- 0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
-0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
- 0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
-0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
-0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

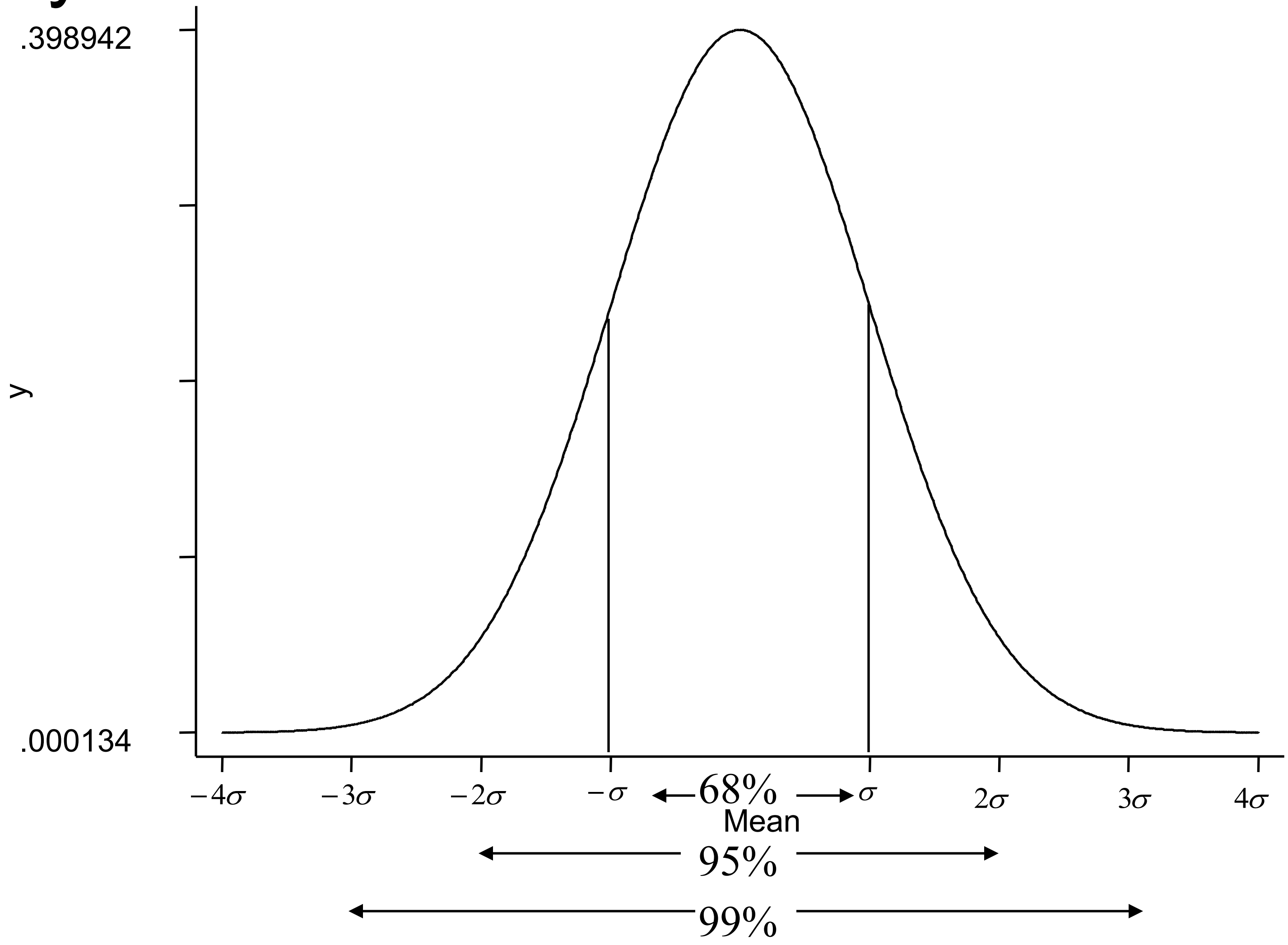
In the Extreme(for z<0)

	-3.09	-3.72	-4.26	-4.75	-5.20	-5.61	-6.00
Probability	.001	.0001	.00001	.000001	.0000001	.00000001	.000000001

SPLUS was used to determine information for the "In the Extreme" portion of the table.

z vs. *t*

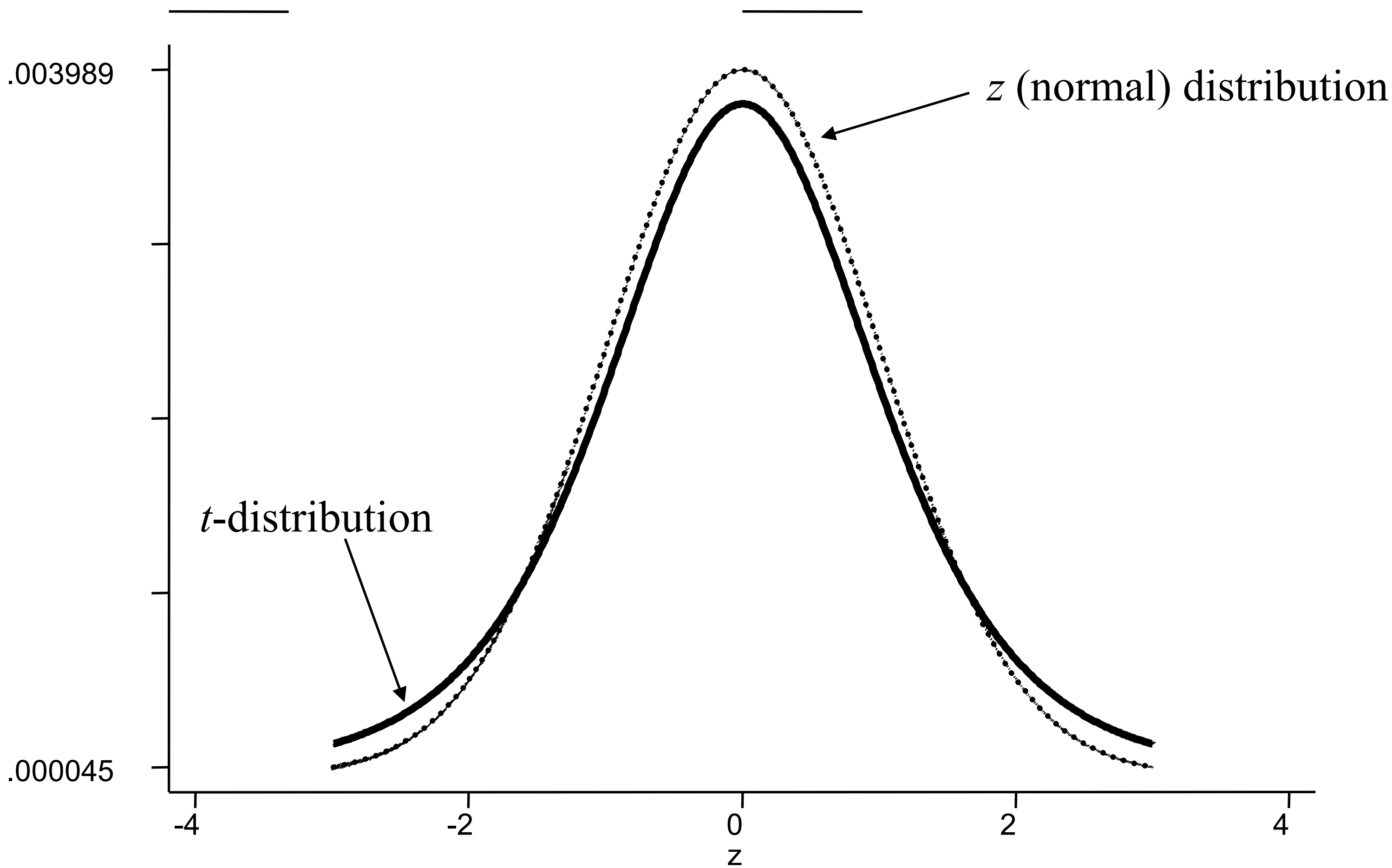
If *n* is sufficiently large, we know the distribution of sample means/coeffs. will obey the normal curve



- When the sample size is large (i.e., > 150), convert the difference into *z* units and consult a *z* table

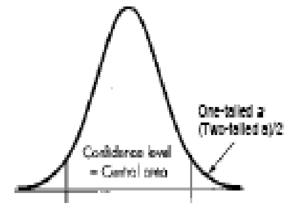
$$Z = (H_1 - H_0) / s.e.$$

t
(when the sample is small)



Reading a *t* table

t* Multipliers for Confidence Intervals and Rejection Region Critical Values



	Confidence Level						
df	*.80*	*.90*	*.95*	*.98*	*.99*	*.998*	*.999*
1	3.08	6.31	12.71	31.82	63.66	318.31	636.62
2	1.89	2.92	4.30	6.96	9.92	22.33	31.60
3	1.64	2.35	3.18	4.54	5.84	10.21	12.92
4	1.53	2.13	2.78	3.75	4.60	7.17	8.61
5	1.48	2.02	2.57	3.36	4.03	5.89	6.87
6	1.44	1.94	2.45	3.14	3.71	5.21	5.96
7	1.41	1.89	2.36	3.00	3.50	4.79	5.41
8	1.40	1.86	2.31	2.90	3.36	4.50	5.04
9	1.38	1.83	2.26	2.82	3.25	4.30	4.78
10	1.37	1.81	2.23	2.76	3.17	4.14	4.59
11	1.36	1.80	2.20	2.72	3.11	4.02	4.44
12	1.36	1.78	2.18	2.68	3.05	3.93	4.32
13	1.35	1.77	2.16	2.65	3.01	3.85	4.22
14	1.35	1.76	2.14	2.62	2.98	3.79	4.14
15	1.34	1.75	2.13	2.60	2.95	3.73	4.07
16	1.34	1.75	2.12	2.58	2.92	3.69	4.01
17	1.33	1.74	2.11	2.57	2.90	3.65	3.97
18	1.33	1.73	2.10	2.55	2.88	3.61	3.92
19	1.33	1.73	2.09	2.54	2.86	3.58	3.88
20	1.33	1.72	2.09	2.53	2.85	3.55	3.85
21	1.32	1.72	2.08	2.52	2.83	3.53	3.82
22	1.32	1.72	2.07	2.51	2.82	3.50	3.79
23	1.32	1.71	2.07	2.50	2.81	3.48	3.77
24	1.32	1.71	2.06	2.49	2.80	3.47	3.75
25	1.32	1.71	2.06	2.49	2.79	3.45	3.73
26	1.31	1.71	2.06	2.48	2.78	3.43	3.71
27	1.31	1.70	2.05	2.47	2.77	3.42	3.69
28	1.31	1.70	2.05	2.47	2.76	3.41	3.67
29	1.31	1.70	2.05	2.46	2.76	3.40	3.66
30	1.31	1.70	2.04	2.46	2.75	3.39	3.65
40	1.30	1.68	2.02	2.42	2.70	3.31	3.55
50	1.30	1.68	2.01	2.40	2.68	3.26	3.50
60	1.30	1.67	2.00	2.39	2.66	3.23	3.46
70	1.29	1.67	1.99	2.38	2.65	3.21	3.44
80	1.29	1.66	1.99	2.37	2.64	3.20	3.42
90	1.29	1.66	1.99	2.37	2.63	3.18	3.40
100	1.29	1.66	1.98	2.36	2.63	3.17	3.39
1000	1.282	1.646	1.962	2.330	2.581	3.098	3.300
Infinite	1.281	1.645	1.960	2.326	2.576	3.090	3.291
Two-tailed α	.20	.10	.05	.02	.01	.002	.001
One-tailed α	.10	.05	.025	.01	.005	.001	.0005

Note that the t-distribution with infinite df is the standard normal distribution.

- When the sample size is small (i.e., <150), convert the difference into *t* units and consult a *t* table

$$t = (H_1 - H_0) / \text{s.e.}$$

A word about standard errors and collinearity

- The problem: if X_1 and X_2 are highly correlated, then it will be difficult to precisely estimate the effect of either one of these variables on Y

Example: Effect of party, ideology, and religiosity on feelings toward Bush

	Bush Feelings	Conserv.	Repub.	Religious
Bush Feelings	1.0	.39	.57	.16
Conserv.		1.0	.46	.18
Repub.			1.0	.06
Relig.				1.0

Regression table

	(1)	(2)	(3)	(4)
Intercept	32.7 (0.85)	32.9 (1.08)	32.6 (1.20)	29.3 (1.31)
Repub.	6.73 (0.244)	5.86 (0.27)	6.64 (0.241)	5.88 (0.27)
Conserv.	---	2.11 (0.30)	---	1.87 (0.30)
Relig.	---	---	7.92 (1.18)	5.78 (1.19)
N	1575	1575	1575	1575
R^2	.32	.35	.35	.36

How does having another *collinear* independent variable affect standard errors?

$$s.e.(\hat{\beta}_1) = \sqrt{\frac{1}{N-n-1}\frac{S_Y^2}{S_{X_1}^2}\frac{1-R_Y^2}{1-R_{X_1}^2}}$$

R^2 of the "auxiliary regression" of X_1 on all the other independent variables

Pathologies of statistical significance

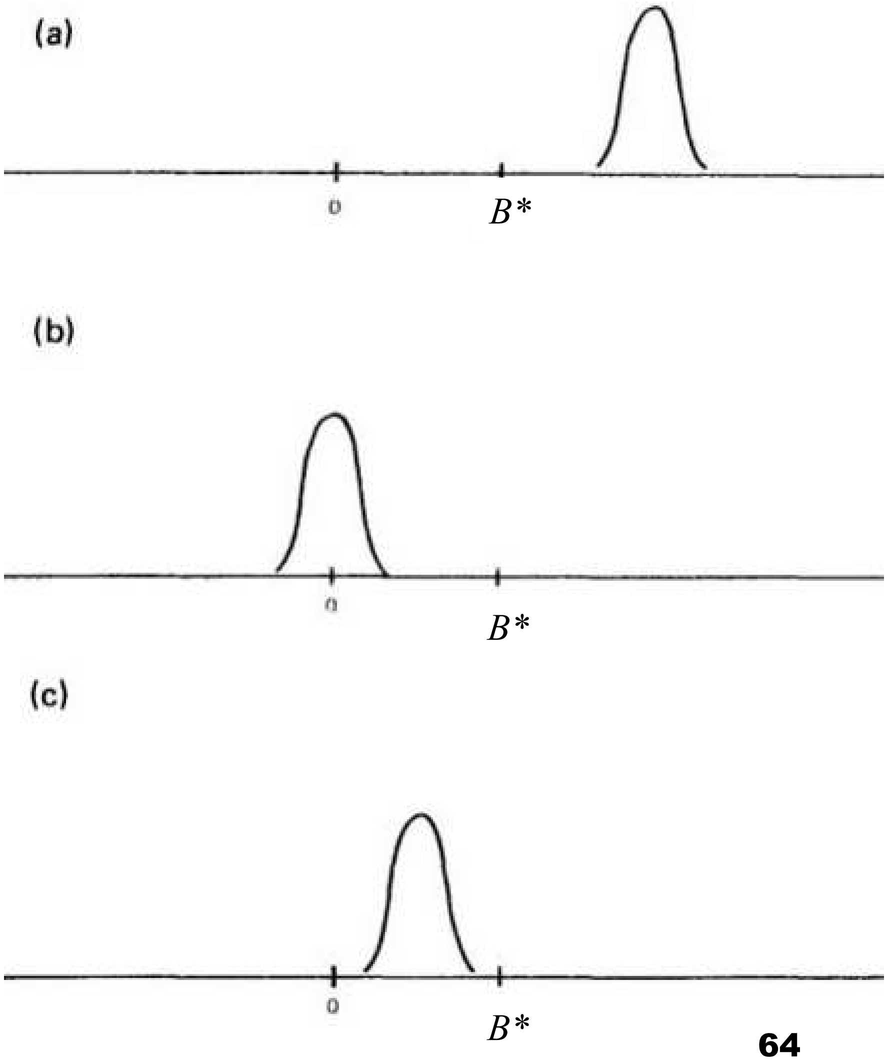
Understanding "significance"

- Which variable is more statistically significant?
- X_1
- Which variable is more important?
- X_2
- Importance is often more relevant

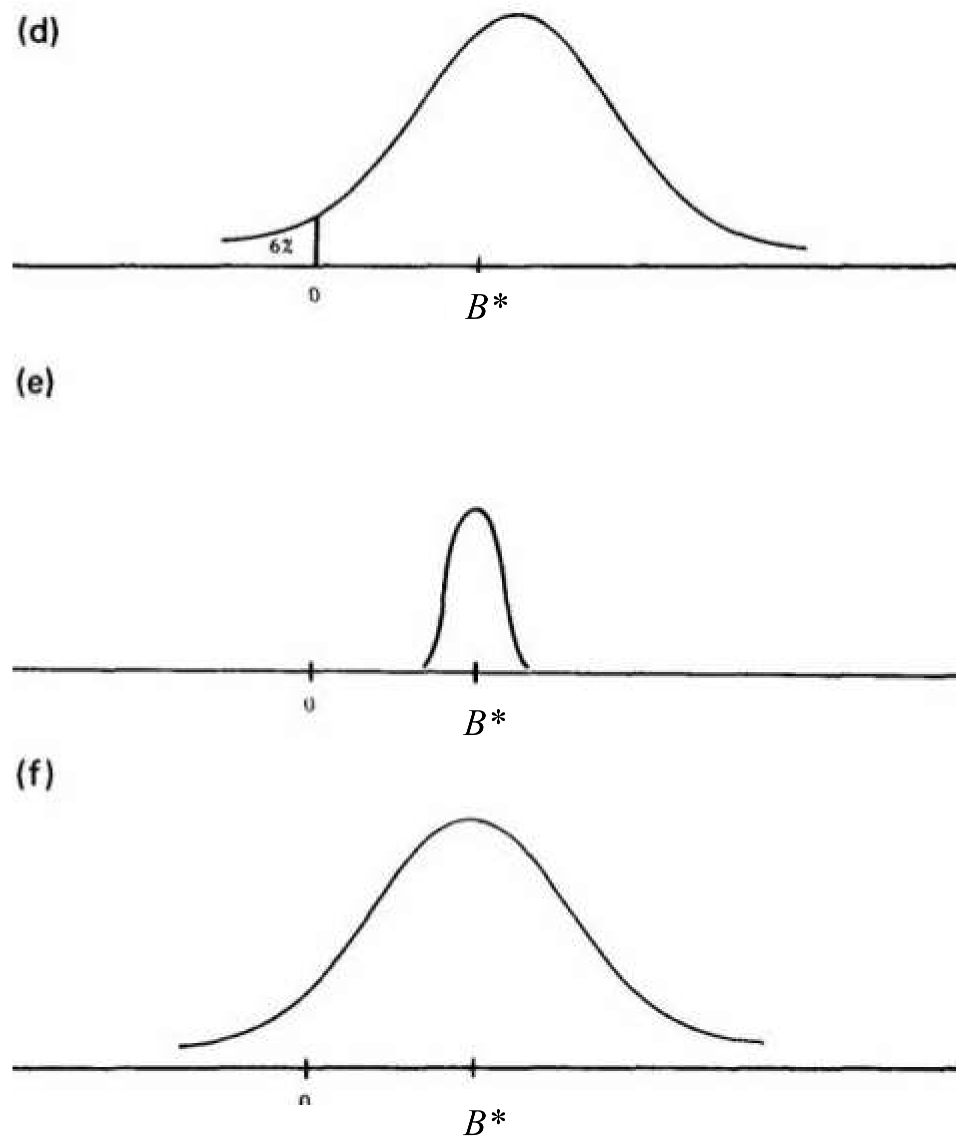
	(1)	(2)
Intercept	0.002 (0.005)	0.003 (0.008)
X_1	0.500* (0.244)	0.055** (0.001)
X_2	0.600 (0.305)	0.600 (0.305)
N	1000	1000
R^2	.32	.20
*p<.05, **p <.01		

Substantive versus statistical significance

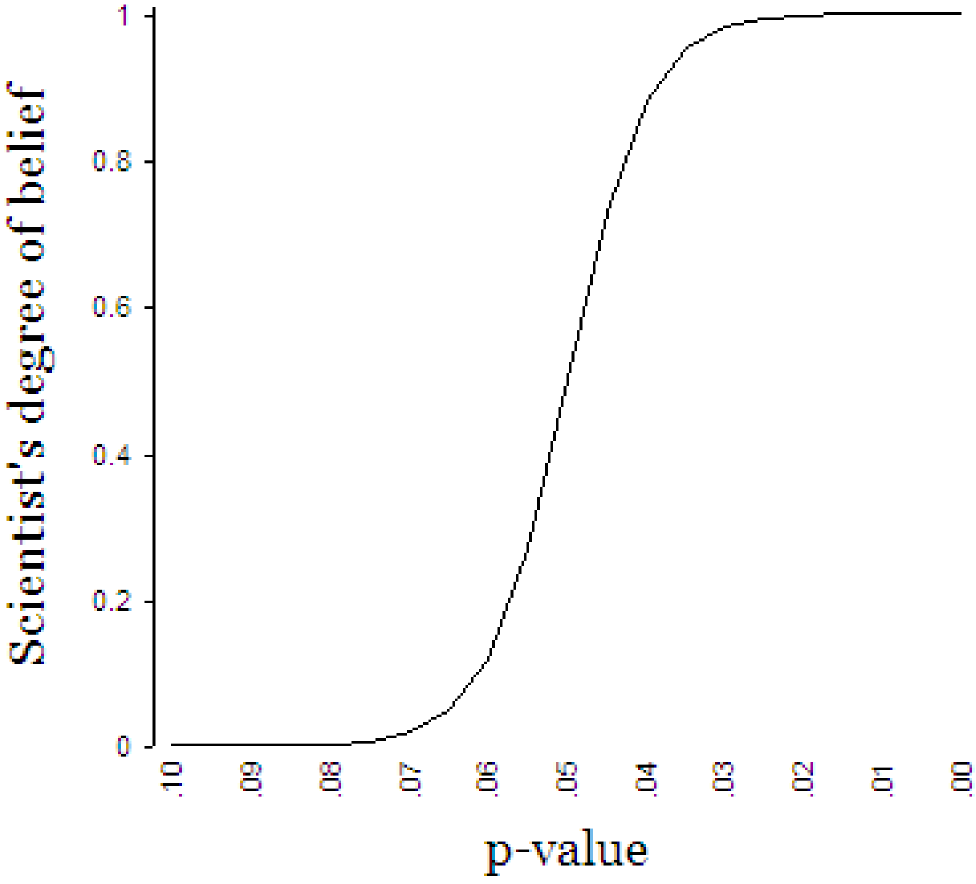
- Think about point estimates, such as means or regression coefficients, as the center of distributions
- Let B^* be of value of a regression coefficient that is large enough for substantive significance
- Which is significant?
- (a)



- Which is more substantively significant?
- Answer: depends, but probably (d)



Don’t make this mistake



What to report

- Standard error
- t-value
- p-value
- Stars
- Combinations?

TABLE 1. Explaining Democratic Lower House Seat Shares, 1946–90: Is the Nation Homogeneous?

Variable	Main Effects		Southern Interactions		Border Interactions	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
South	242.120	2.14	—		—	
Border	262.120	1.32	—		—	
Year	.032	.91	−.151	−2.28*	−.142	−1.31
Democrats (*t* − 1)	.508	20.10**	.435	7.70**	−.067	−.52
Compensation	.007	2.08*	−.005	−1.03	−.007	−.59
Presidential year	−27.079	−11.10**	22.778	6.19**	11.520	1.35
Presidential vote	.498	9.40**	−.452	5.85**	−.234	−1.39
Gubernatorial year	−.18.540	−7.86**	15.111	4.08**	−.440	−.04
Gubernatorial vote	.364	8.10**	−.328	−5.52**	−.044	−.20
Off year	−10.042	−10.62**	6.800	3.80**	2.818	.82
GNP growth	.149	2.74**	−.157	−1.49	−.148	−.79

Note: Thirty-one state intercepts not shown. Coefficients are unstandardized.
n = 1,035, adjusted R^2 = .89, *SEE* = 7.94
*$p < .05$; **$p < .01$

Specification searches
(tricks to get p <.05)

- Reporting one of many dependent variables or dependent variable scales
  - Healing-with-prayer studies
  - Psychology lab studies
- Repeating an experiment until, by chance, the result is significant
  - Drug trials
  - Called file-drawer problem

Specification searches
(tricks to get $p < .05$)

- **Adding and removing control variables until, by chance, the result is significant**
  - **Exceedingly common**

Solutions

- With many dependent variables, use a simple unweighted average
- Bonferroni correction
  - If testing *n* independent hypotheses adjusts the significance level by 1/*n* times what it would be if only one hypothesis were tested
- Show bivariate results
- Show many specifications
- Model averaging