Statistical Literacy Textbook: Chapter 8 Slides

Statistical Literacy: Critical Thinking about Everyday Statistics

Kendall-Hunt 2023

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Randomness
Chapter 8: Table of Contents

Randomness
Chapter 8: Learning Outcomes

- Understand the good and bad of statistical significance
- Recognize how statistical significance can be influenced – from significance to insignificance or vice versa – by confounding, assembly, randomness and bias
- Compare hypothesis tests to criminal trials: type 1 and type 2 error
- Distinguish polls from surveys. Polls predict; surveys summarize.
- Estimate size of population using capture-recapture
- Identify common misunderstanding involving chance

Statistical Significance: The Idea (very abstract)

Statistically significant: statistically unlikely. The less likely the chance, the more 'significant' the result.

Examples:

- Dog that didn't bark. Sherlock Holmes, Silver Blaze
- Goldfinger meets Bond 3 times, 3 different places
- Five heads in five flips of a fair coin.

Statistically significant:

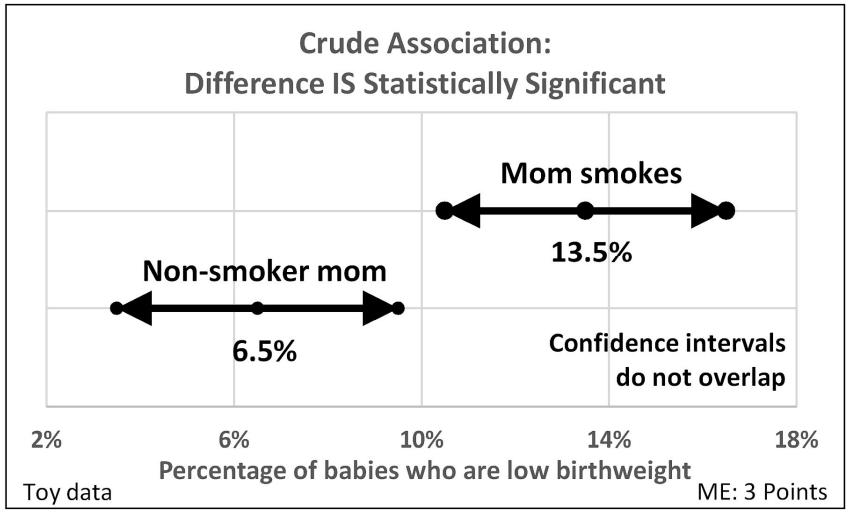
- Not necessarily important
- is arbitrary (< 1 chance in 20) but not unreasonable
- can be influenced

Statistical Significance: Influenced by Confounding

Crude: Difference is statistically significant

Young moms: smokers 50%; non-smokers 10%.

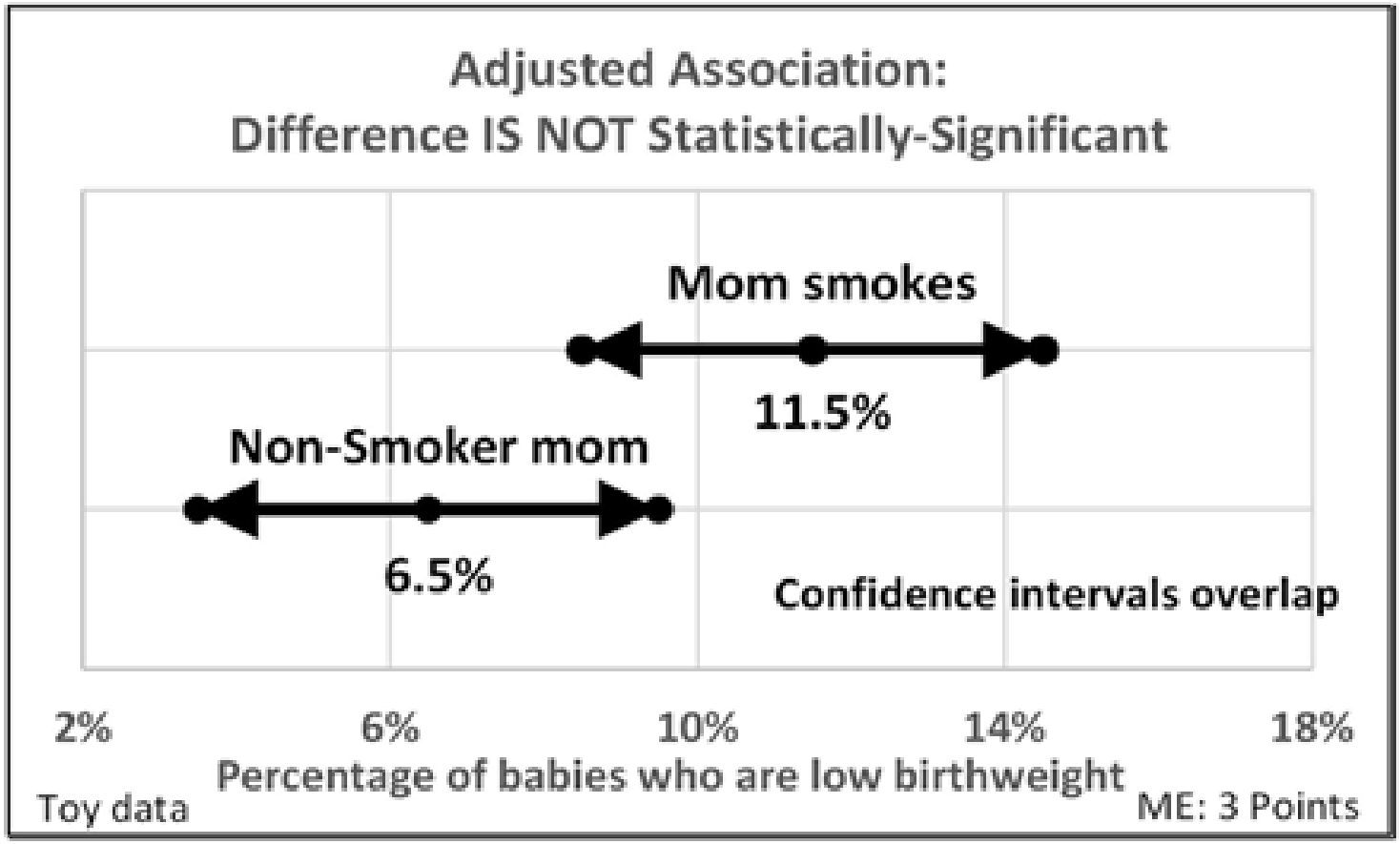
Adjust for mom's age:



	A	B	C	D		F	G	H	I
1									
2	**Low-weight birth rates: crude**					**Low-weight birth rates: mix-match**			
3	Moms	Teens	Older	ALL		Moms	Teens	Older	ALL
4	Non-Smokers	11%	6%	**6.5%**		Non-Smokers	11%	6%	6.5%
5	Smokers	16%	11%	**13.5%**		Smokers	16%	11%	**11.5%**
6	DISTRIBUTION (weights):					DISTRIBUTION (weights):			
7	Non-Smokers	10%	90%	100%		Non-Smokers	10%	90%	100%
8	Smokers	50%	50%	100%		Smokers	**10%**	**90%**	100%
	D4=B4*B7 + C4*C7	=0.11*0.10 + 0.06*0.90				I4	Same as D4		
	D5=B5*B8 + C5*C8	=0.16*0.50 + 0.11*0.50				**I5=G5*G8 + H5*H8**	**=0.16*0.10 + 0.11*0.90**		

Statistical Significance: Influenced by Confounding

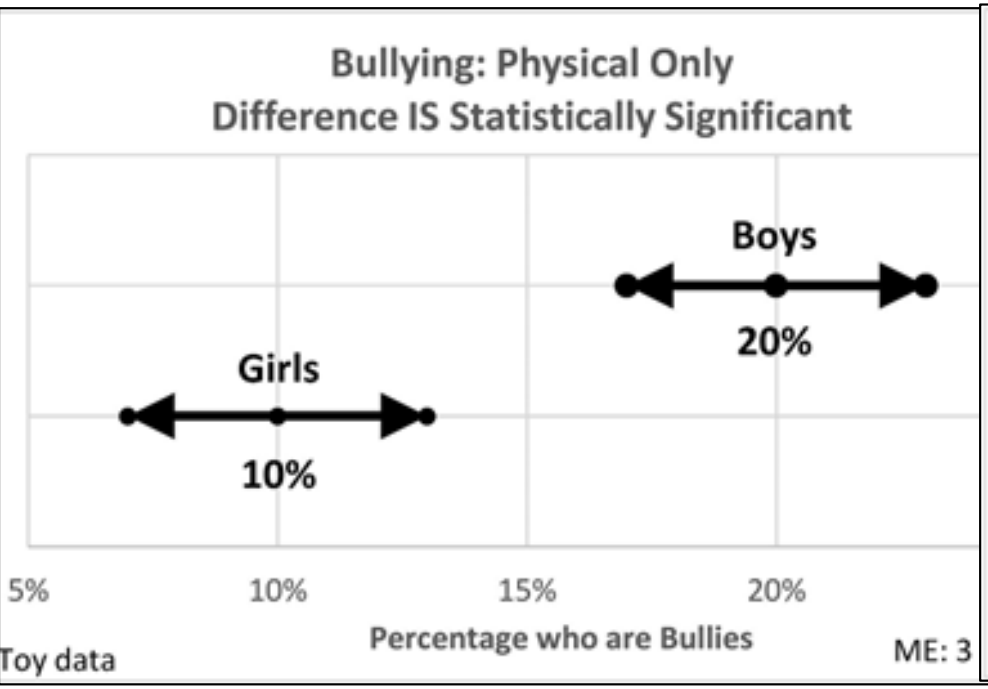
Crude Association: Difference statistically significant

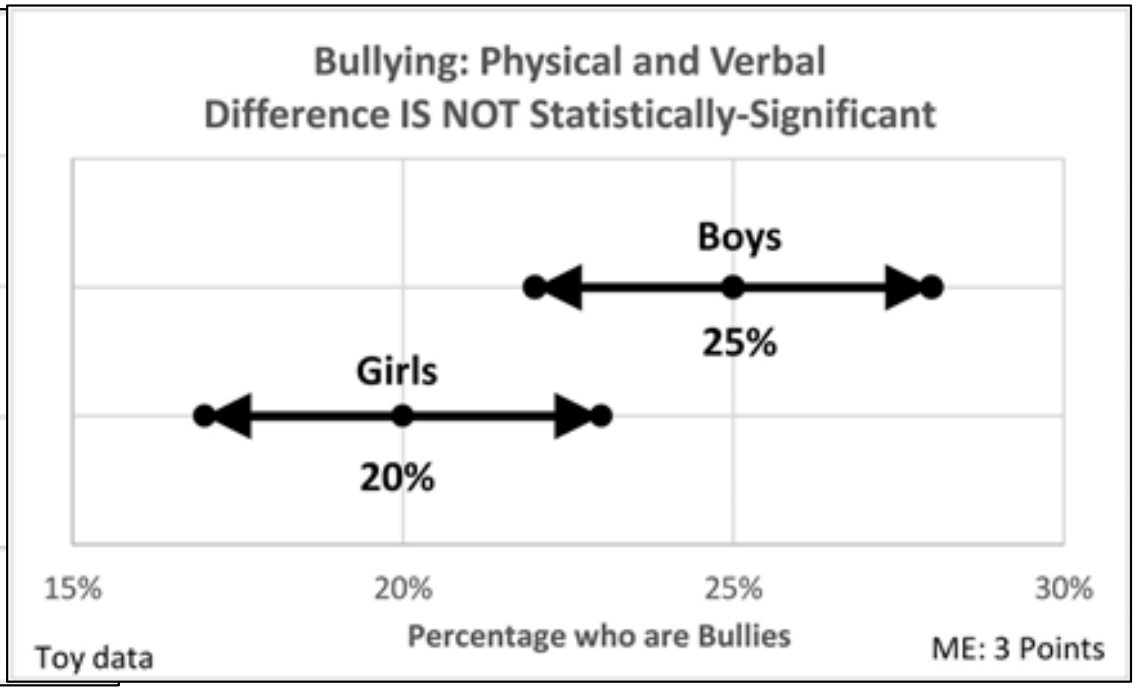


Adjusted: Difference is not statistically significant.

Statistical Significance: Influenced by Assembly

Bullying #1: physical only.

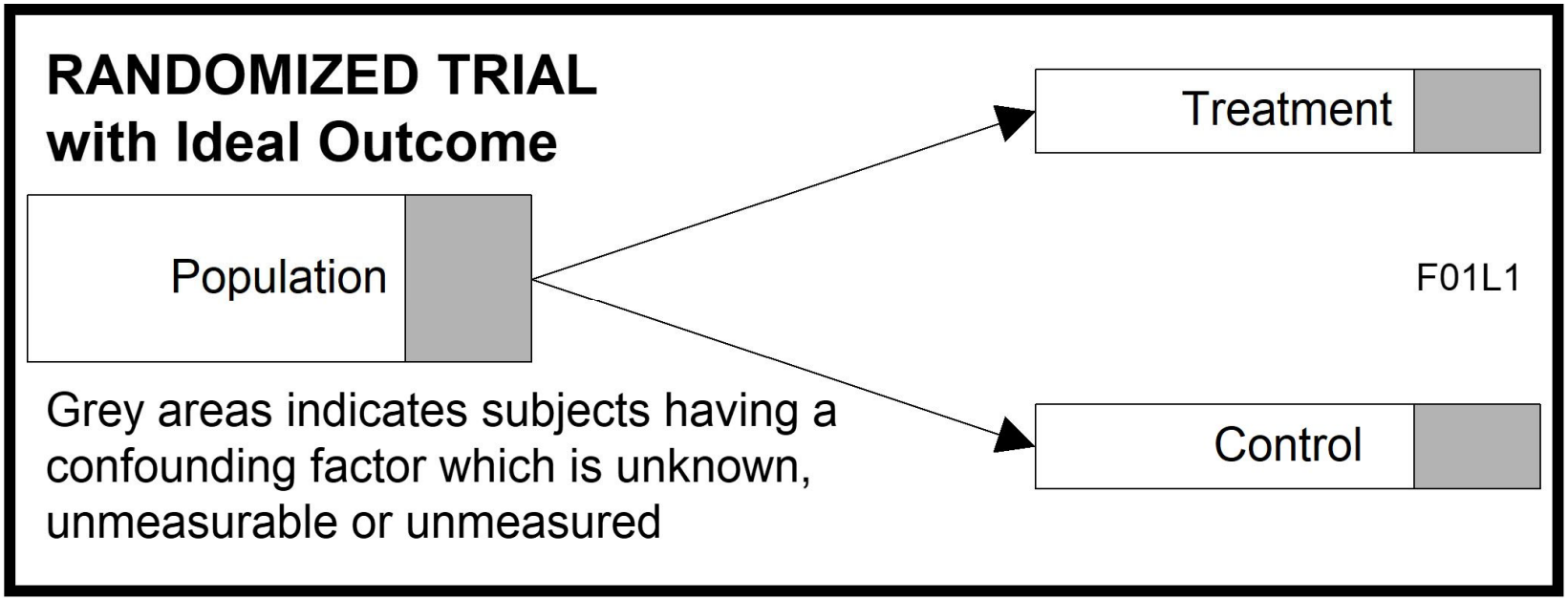




Bullying #2: physical or verbal.

Change in definition (assembly) changes statistically-significant into statistically insignificant

Statistical Significance: Influenced by Randomness



Suppose the difference between treatment sample and control sample is statistically significant.

Statistically significant: 1 chance in 20 (5%) of error

Statistical Significance: Influenced by Randomness

Suppose the treatment has no effect.
How could the difference be statistically significant?

1. One researcher: one trial repeated 20 times.
2. One researcher: one trial with 20 outcomes.
3. 20 researchers: same trial, same outcome.

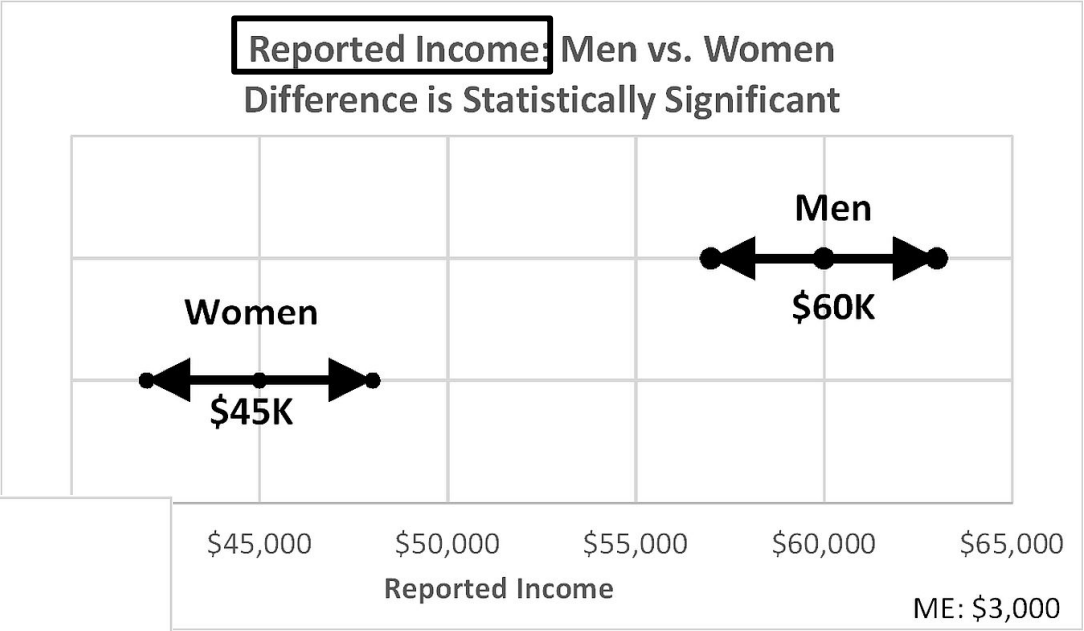
In each case, one of the 20 results is expected to be statistically-significant even though the treatment has no effect.

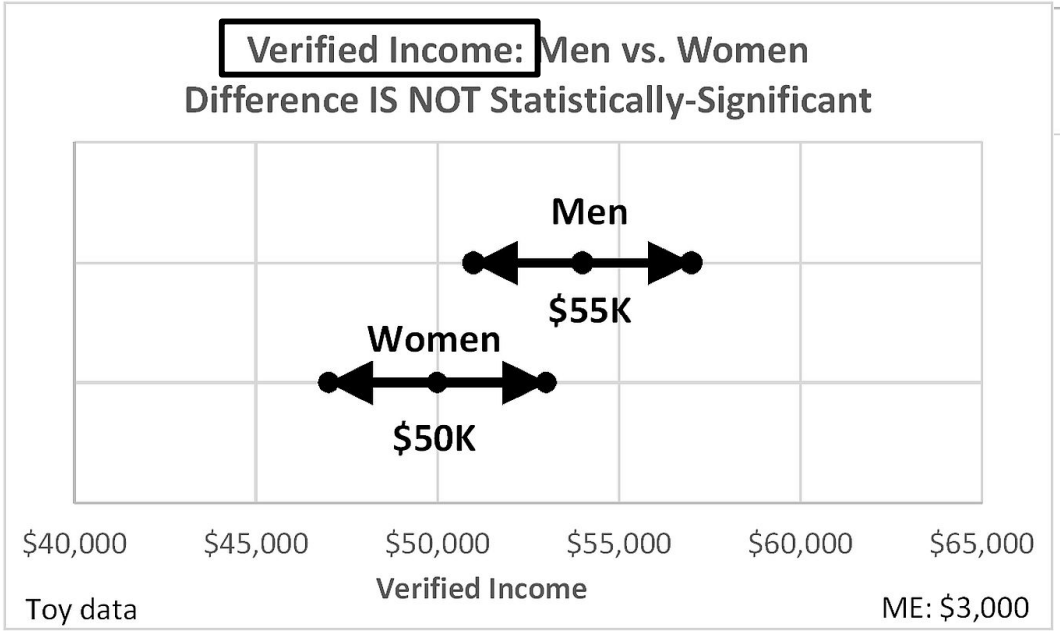
Statistical Significance: Influenced by Error/bias

Income by Sex:

Reported vs. verified.

Subject bias!





Hypothesis Tests and Criminal Trials

Criminal trial: Innocent until proved guilty
Statistical trial: No difference until proved different

Type 1: false alarm. Type 2: silent alarm

---------- Criminal Trial ----------		
	Defendant (Reality)	
Jury verdict	**INNOCENT**	Guilty
Not-guilty	OK	Type 2
Guilty BRD	**Type 1**	OK
Type 1 error: Innocent person found guilty		
Type 2 error: Guilty person found not-guilty		
Minimize Type 1 error. Presume innocent.		

---------- Hypothesis Test ----------		
	Claim (Reality)	
Statistical result	**FALSE**	True
Stat. Insignificant	OK	Type 2
Stat. Significant	**Type 1**	OK
Type 1: Statistically significant result is false		
Type 2: Statistically-insignificant result is true		
Minimize Type 1 error. Presume false		

Subtle Distinctions: Two or Three outcomes

Not guilty vs. innocent.

Jury Finding		
Found "Not-Guilty"		Found
Innocent	Don't know	"Guilty"

"Absence of evidence is not evidence of absence"

- Policy X: has *not* been found to work versus has been found to *not* work.
- Drug Y has: *not* been found to be effective versus been found to be *in*effective.

'Not been found' includes 'did not look or test'.

Political Polls

Political polls 'predict' results of a future event.
Pollsters 'adjust'. Polls are like weather forecasts.

Suppose pollsters ask, "Which of 2 candidates are you most likely to vote for: A or B?"

Q1. What are some other answers than A or B?

Q2. Why do pollsters adjust their data?

Political Polls

Political polls 'predict' results of a future event.

Pollsters 'adjust'. Polls are like weather forecasts.

Surveys 'summarize' current situation (more factual).

DIFFERENCES		SURVEYS	POLLS*
Goal or Purpose		Summarize	Predict
Adjust	Demographics	May adjust	Yes
" " " "	Vote? Undecided	Not relevant	Yes
" " " "	Candidate? Undecided	Not relevant	Yes
" " " "	3rd party: Switch?	Not relevant	Yes
" " " "	Plan to vote: No show	Not relevant	Yes
Evaluate the results		Not relevant	Yes

* Political polls generally predict; opinion polls generally don't.

Sampling: Random and Nonrandom

Random sample: sample obtained by random sampling.

SAMPLING

Random

"Simple"	Cluster
Stratified	Systematic

Non-Random

Convenience	Quota
Judgmental	Snowball

Random Sampling

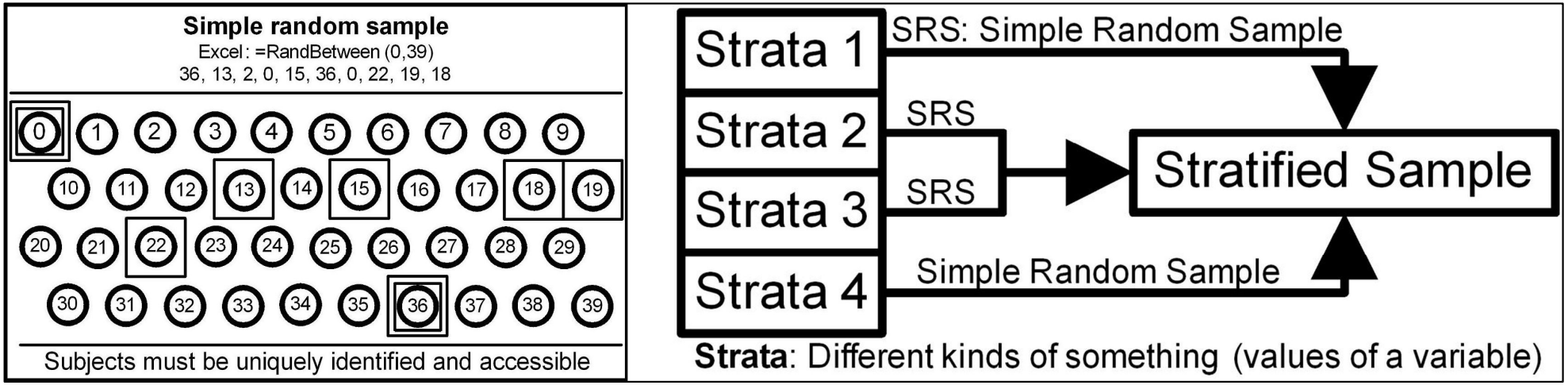
Classified

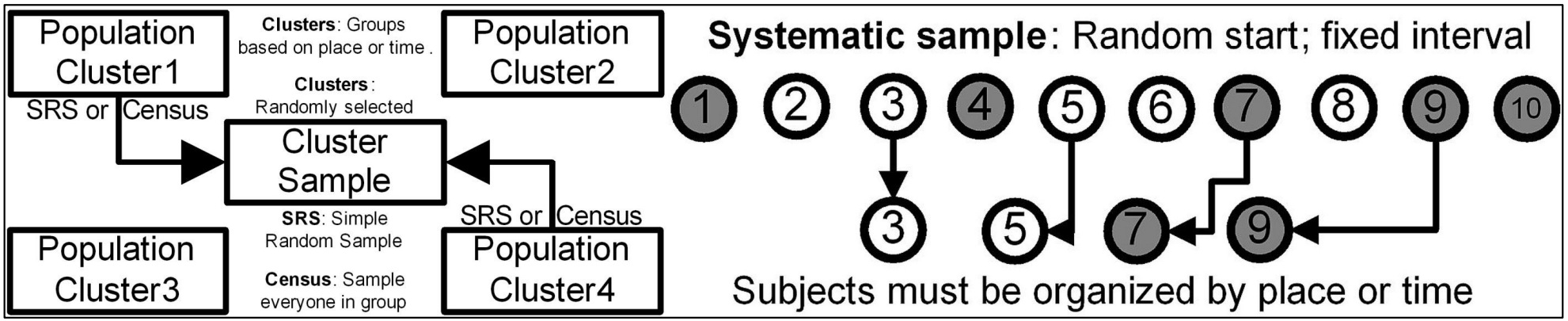
List? Yes	Place? Yes
Simple	Systematic
Stratified	Cluster

Evaluated

	List? Yes		Place? Yes
B	Simple	C	Systematic
A	Stratified	C	Cluster

Random Sampling:
Simple, Stratified, Cluster, Systemic





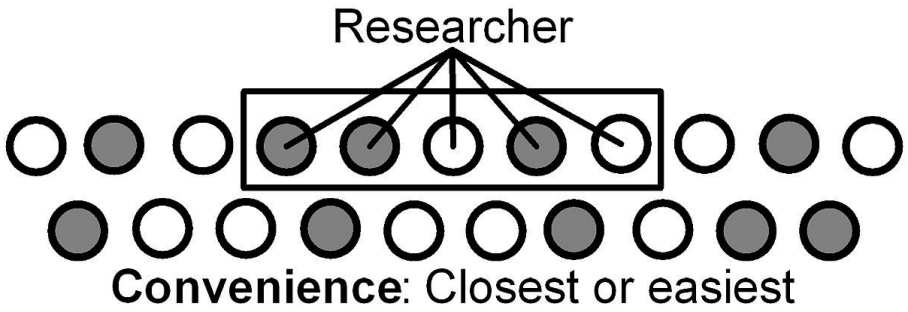
Sampling: Random and Nonrandom

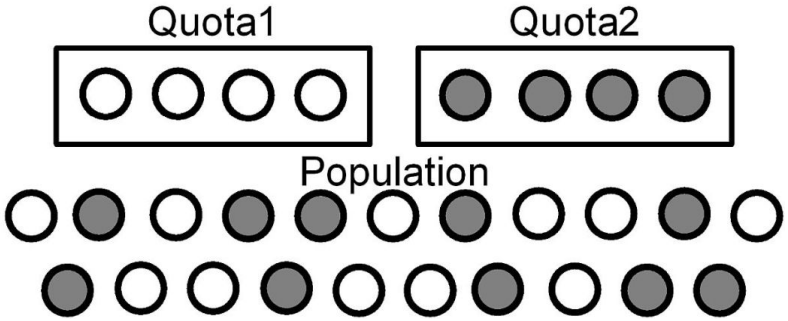
Random sample: sample obtained by random sampling.

SAMPLING			
Random		Non-Random	
"Simple"	Cluster	Convenience	Quota
Stratified	Systematic	Judgmental	Snowball

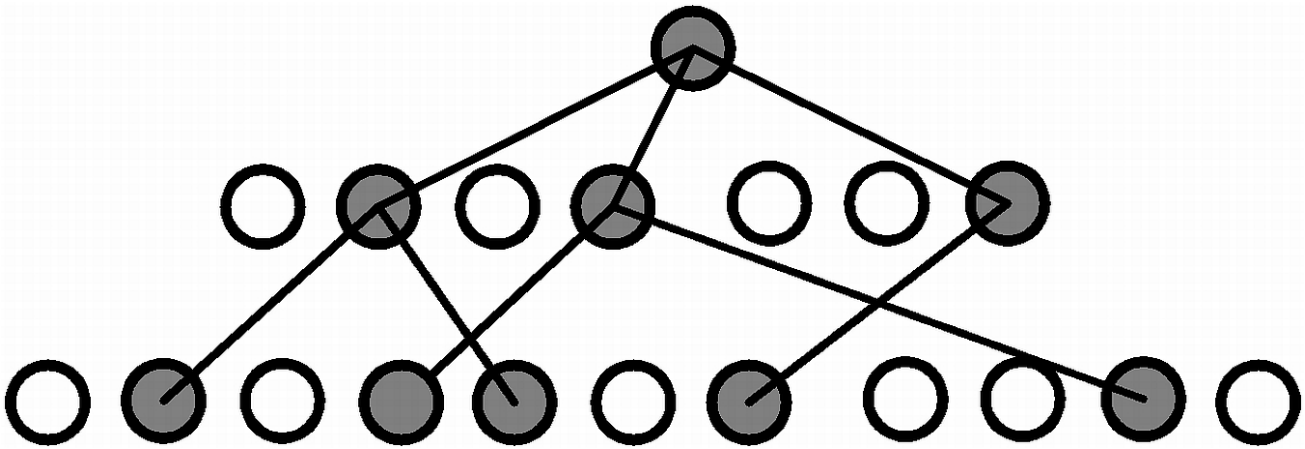
1) Why is a random sample preferred to a non-random?
2) Why is a stratified sample preferred to a 'simple'?
3) Why is a 'simple' sample preferred to a cluster?
4) When is a systematic sample the best available?

Nonrandom Sampling: Convenience, Quota & Snowball





Snowball: Contact those with similar interests



Randomness: Counting the Uncountable

1st try: Capture 200 fish. Tag each. Return to water.

2nd try: Capture 400 subjects. Count those tagged.

Four (1%) of #2 fish are tagged.

If tagged randomly mixed, then 1% of **all** fish are tagged.

200 = 1% * N, so N = 200/1% = 20,000

Fish	#1	#2
Have tags	0	4
Size	200	400
% tagged		1%

200 fish are tagged in #1

Assuming random mixing,

1% of the fish are tagged.

So, 100% equals 20,000 fish.

Chance: Evolution

Life is too complex to be due to chance alone. Agreed.

Chance of songbird: run of 1,000 ones with 10-sided die.
Expected by chance alone: one chance in $10^{1,000}$.
If 317 throws/second, (10^{10} times/year),
Expected in 10^{990} years. Age of earth: $<10^{10}$ years

Assume inheritance: Save every success.
Expected with inheritance: 10,000 tries: 10 x 1,000.
Expected in 10^{-6} years: 30 seconds.

Chance alone? No! Chance with inheritance? Maybe.

Chance: Common Misunderstandings

1. If two outcomes, then 50% chance of either. Maybe.
2. If 90% chance of rain and no rain, forecast was wrong. Maybe. Can't tell from a single event.
3. If excess from expected, offset is predicted.
   No. Dilution is slower but maintains independence.
4. If medical test is 99% accurate and result is positive, then 99% chance that patient has disease. Maybe.
5. The more unlikely the outcome, the more likely it is causal. Maybe. Unlikely sometime, somewhere or unlikely then, there?

Chapter 8 Summary

1. Statistical significance can be influenced
2. Political polls are different from surveys
3. Random sampling is better than non-random.
4. Stratified sampling is better than simple.
5. Simple random is better than cluster or systematic.
6. Uncounted can be estimated if random.

Chapter 8 Randomness: Key Words, Phrases and Ideas (12)			
Statistical significance (SS)	SS: confounder influence	SS: assembly influence	SS: bias influence
Research hypothesis (RH)	Chance RH is True	RH: more likely than not	RH: unlikely
Random samples	Survey margin of error	Margin Error subgroup	Poll vs. Survey

Interpreting Statistical Significance Bayesian Medical Tests (>50%)

Shift from confirmation (column %) to prediction (row %).

---------- Medical Test ----------			
People	*Has the diesease (Reality)*		
Test result	**No**	Yes	TOTAL
Negative	# OK	# Type 2	Sum(Row1)
Positive	**# Type 1**	# OK	Sum(Row2)
TOTAL	Sum(No)	Sum(Yes)	SUM
Type 1 error: Disease-free person tests positive			
Type 2 error: Diseased person tests negative			

---------- Hypothesis Test ----------			
Samples	*Real difference (Population)*		
Test result	**FALSE**	True	TOTAL
Stat. Insignificant	# OK	# Type 2	Sum(Row1)
Stat. Significant	**# Type 1**	# OK	Sum(Row2)
TOTAL	Sum(False)	Sum(True)	SUM
Type 1 error: Statistically-significant result is false			
Type 2 error: Statistically-insignificant result is true			

If research hypothesis (RH) is more likely than not (prior) and result is statistically significant, 95% chance RH is true.

Medical test	DISEASED		
Result	No	Yes	Total
Negative	95	5	100
Positive	5	95	100
Total	100	100	200

50% are diseased; 95% confirmation accuracy

Hypothesis test	Research Hypothesis (RH)		
Result	FALSE	TRUE	Total
Not Stat Sig	95	5	100
Stat. Signif.	5	95	100
Total	100	100	200

50% chance RH is true; 95% confirmation accuracy

Interpreting Statistical Significance Bayesian Medical Tests (5%)

Unlikely to be true in reality:

- Group: prone to heart attacks on 4th day of the month
- Women who eat cereal are more likely to have boys.
- Hurricanes with female names are deadlier.

Extraordinary claims require extraordinary evidence (Ecree)

Medical test	DISEASED		
Result	No	Yes	Total
Negative	1,805	5	1,810
Positive	95	95	190
Total	1,900	100	2,000

5% are diseased; 95% confirmation accuracy

Hypothesis test	Research Hypothesis (RH)		
Result	FALSE	TRUE	Total
Not Stat. Signif.	1,805	5	1,810
Stat. Signif.	95	95	190
Total	1,900	100	2,000

5% chance RH is True; 95% confirmation accuracy

Interpreting Statistical Significance
Bayesian Medical Tests

Let R = Prior chance the research hypothesis (RH) is true.
Let P-value = confirmation error: P(T1|Null=True).
Let Q = Posterior chance that the research hypothesis is true.

If R < 50% and the result of the hypothesis test is positive (Bayesian significant), then the P-value must be:

1. the same as R to give a 50% chance that Q is true.
2. a tenth of R to give a 90% chance that Q is true.
3. a twentieth of R to give a 95% chance that Q is true.
   See Schield (2026).

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1

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- Compare hypothesis tests to criminal trials: type 1 and type 2 error
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- Estimate size of population using capture-recapture
- Identify common misunderstanding involving chance

3

Statistical Significance:
The Idea (very abstract)

Statistically significant: statistically unlikely. The less likely the chance, the more 'significant' the result.

Examples:
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- Goldfinger meets Bond 3 times, 3 different places
- Five heads in five flips of a fair coin.

Statistically significant:
- Not necessarily important
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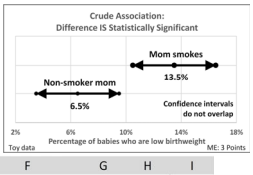
4

Statistical Significance:
Influenced by Confounding

Crude: Difference is statistically significant

Young moms: smokers 50%; non-smokers 10%.

Adjust for mom's age:



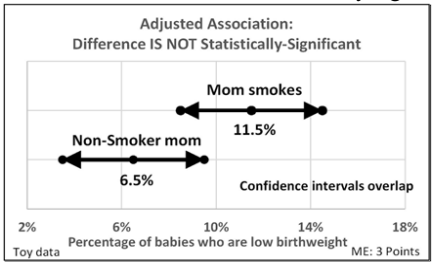
	A	B	C	D
1	**Low-weight birth rates: crude**			
	Moms	Teens	Older	ALL
4	Non-Smokers	11%	6%	**6.5%**
5	Smokers	16%	11%	**13.5%**
6	DISTRIBUTION (weights):			
7	Non-Smokers	10%	90%	100%
8	Smokers	50%	50%	100%
	D4=B4*B7 + C4*C7 =0.11*0.10 + 0.06*0.90			
	D5=B5*B8 + C5*C8 =0.16*0.50 + 0.11*0.50			

	F	G	H	I
2	**Low-weight birth rates: mix-match**			
3	Moms	Teens	Older	ALL
4	Non-Smokers	11%	6%	6.5%
5	Smokers	16%	11%	**11.5%**
6	DISTRIBUTION (weights):			
7	Non-Smokers	10%	90%	100%
8	Smokers	**10%**	**90%**	100%
	I4 Same as D4			
	I5=G5*G8 + H5*H8 =0.16*0.10 + 0.11*0.90			

5

Statistical Significance:
Influenced by Confounding

Crude Association: Difference statistically significant



Adjusted: Difference is not statistically significant.

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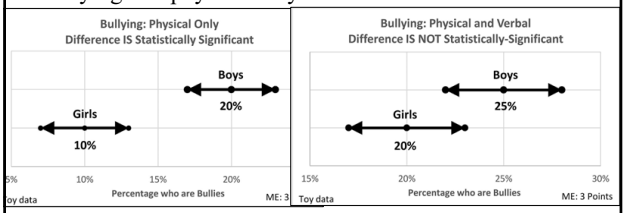
8.4.2; P 326 StatLit Textbook 2023 Chapter 8 Slides 7 V0C

Statistical Significance: Influenced by Assembly

Bullying #1: physical only.



Bullying #2: physical or verbal.
Change in definition (assembly) changes statistically-significant into statistically insignificant

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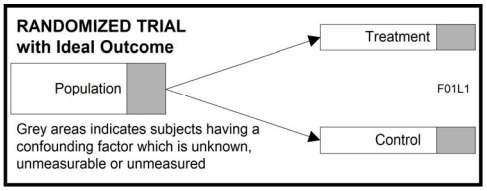
8.4.3, P 327 StatLit Textbook 2023 Chapter 8 Slides 8 V0C

Statistical Significance: Influenced by Randomness



Suppose the difference between treatment sample and control sample is statistically significant.

Statistically significant: 1 chance in 20 (5%) of error

8

8.4.3, P 327 StatLit Textbook 2023 Chapter 8 Slides 9 V0C

Statistical Significance: Influenced by Randomness

Suppose the treatment has no effect.
How could the difference be statistically significant?

1. One researcher: one trial repeated 20 times.
2. One researcher: one trial with 20 outcomes.
3. 20 researchers: same trial, same outcome.

In each case, one of the 20 results is expected to be statistically-significant even though the treatment has no effect.

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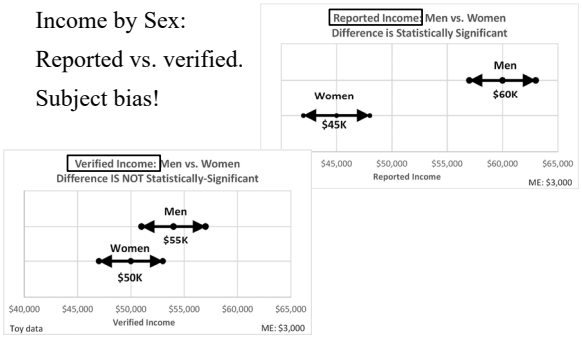
8.4.4, P 328 StatLit Textbook 2023 Chapter 8 Slides 10 V0C

Statistical Significance: Influenced by Error/bias

Income by Sex:

Reported vs. verified.

Subject bias!



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8.5, P 329 StatLit Textbook 2023 Chapter 8 Slides 11 V0C

Hypothesis Tests and Criminal Trials

Criminal trial: Innocent until proved guilty
Statistical trial: No difference until proved different

Type 1: false alarm. Type 2: silent alarm

Criminal Trial		
	Defendant (Reality)	
Jury verdict	**INNOCENT**	Guilty
Not-guilty	OK	Type 2
Guilty BRD	**Type 1**	OK
Type 1 error: Innocent person found guilty		
Type 2 error: Guilty person found not-guilty		
Minimize Type 1 error. Presume innocent.		

Hypothesis Test		
	Claim (Reality)	
Statistical result	**FALSE**	True
Stat. Insignificant	OK	Type 2
Stat. Significant	**Type 1**	OK
Type 1: Statistically significant result is false		
Type 2: Statistically-insignificant result is true		
Minimize Type 1 error. Presume false		

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8.3.3; P 330 StatLit Textbook 2023 Chapter 8 Slides 12 V0C

Subtle Distinctions: Two or Three outcomes

Not guilty vs. innocent.

Jury Finding		
Found "Not-Guilty"		Found
Innocent	Don't know	"Guilty"

"Absence of evidence is not evidence of absence"

- Policy X: has *not* been found to work versus has been found to *not* work.
- Drug Y has: *not* been found to be effective versus been found to be *in*effective.

'Not been found' includes 'did not look or test'.

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8.6; P 331 StatLit Textbook 2023 Chapter 8 Slides **13** V0C

Political Polls

Political polls 'predict' results of a future event.
Pollsters 'adjust'. Polls are like weather forecasts.

Suppose pollsters ask, "Which of 2 candidates are you most likely to vote for: A or B?"

Q1. What are some other answers than A or B?

Q2. Why do pollsters adjust their data?

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8.6; P 331 StatLit Textbook 2023 Chapter 8 Slides **14** V0C

Political Polls

Political polls 'predict' results of a future event.
Pollsters 'adjust'. Polls are like weather forecasts.

Surveys 'summarize' current situation (more factual).

DIFFERENCES		SURVEYS	POLLS*
Goal or Purpose		Summarize	Predict
Adjust	Demographics	May adjust	Yes
" " " "	Vote? Undecided	Not relevant	Yes
" " " "	Candidate? Undecided	Not relevant	Yes
" " " "	3rd party: Switch?	Not relevant	Yes
" " " "	Plan to vote: No show	Not relevant	Yes
Evaluate the results		Not relevant	Yes

* Political polls generally predict; opinion polls generally don't.

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8.7; P 333 StatLit Textbook 2023 Chapter 8 Slides **15** V0C

Sampling: Random and Nonrandom

Random sample: sample obtained by random sampling.

SAMPLING

Random		Non-Random	
"Simple"	Cluster	Convenience	Quota
Stratified	Systematic	Judgmental	Snowball

Random Sampling

Classified		Evaluated			
List? Yes	Place? Yes		List? Yes		Place? Yes
Simple	Systematic	B	Simple	C	Systematic
Stratified	Cluster	A	Stratified	C	Cluster

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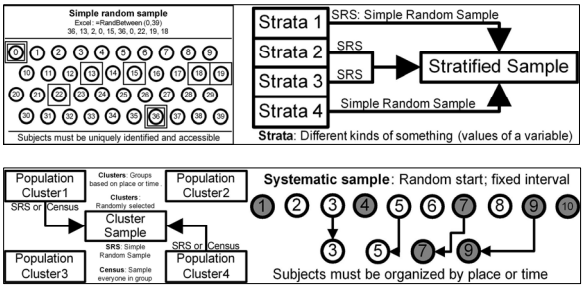
8.7.1; P 334 StatLit Textbook 2023 Chapter 8 Slides **16** V0C

Random Sampling: Simple, Stratified, Cluster, Systemic



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8.7; P 333 StatLit Textbook 2023 Chapter 8 Slides **17** V0C

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Random sample: sample obtained by random sampling.

SAMPLING

Random		Non-Random	
"Simple"	Cluster	Convenience	Quota
Stratified	Systematic	Judgmental	Snowball

1) Why is a random sample preferred to a non-random?
2) Why is a stratified sample preferred to a 'simple'?
3) Why is a 'simple' sample preferred to a cluster?
4) When is a systematic sample the best available?

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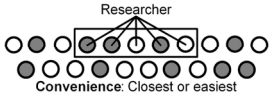
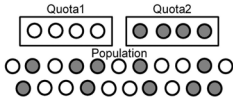
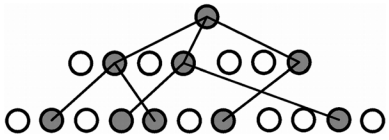
8.7.2; P 335 StatLit Textbook 2023 Chapter 8 Slides **18** V0C

Nonrandom Sampling: Convenience, Quota & Snowball





Snowball: Contact those with similar interests



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8.7.3, P 336 StatLit Textbook 2023 Chapter 8 Slides **19** V0C

Randomness: Counting the Uncountable

1st try: Capture 200 fish. Tag each. Return to water.

2nd try: Capture 400 subjects. Count those tagged.

Four (1%) of #2 fish are tagged.

If tagged randomly mixed, then 1% of **all** fish are tagged.

200 = 1% * N, so N = 200/1% = 20,000

Fish	#1	#2	200 fish are tagged in #1
Have tags	0	4	Assuming random mixing,
Size	200	400	1% of the fish are tagged.
% tagged		1%	So, 100% equals 20,000 fish.

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8.9, P 340 StatLit Textbook 2023 Chapter 8 Slides **20** V0C

Chance: Evolution

Life is too complex to be due to chance alone. Agreed.

Chance of songbird: run of 1,000 ones with 10-sided die.
Expected by chance alone: one chance in $10^{1,000}$.
If 317 throws/second, (10^{10} times/year),
Expected in 10^{990} years. Age of earth: $<10^{10}$ years

Assume inheritance: Save every success.
Expected with inheritance: 10,000 tries: 10 x 1,000.
Expected in 10^{-6} years: 30 seconds.

Chance alone? No! Chance with inheritance? Maybe.

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8.10, P 341 StatLit Textbook 2023 Chapter 8 Slides **21** V0C

Chance: Common Misunderstandings

1. If two outcomes, then 50% chance of either. Maybe.
2. If 90% chance of rain and no rain, forecast was wrong. Maybe. Can't tell from a single event.
3. If excess from expected, offset is predicted. No. Dilution is slower but maintains independence.
4. If medical test is 99% accurate and result is positive, then 99% chance that patient has disease. Maybe.
5. The more unlikely the outcome, the more likely it is causal. Maybe. Unlikely sometime, somewhere or unlikely then, there?

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8.11, P 342 StatLit Textbook 2023 Chapter 8 Slides **22** V0C

Chapter 8 Summary

1. Statistical significance can be influenced
2. Political polls are different from surveys
3. Random sampling is better than non-random.
4. Stratified sampling is better than simple.
5. Simple random is better than cluster or systematic.
6. Uncounted can be estimated if random.

Chapter 8 Randomness: Key Words, Phrases and Ideas (12)			
Statistical significance (SS)	SS: confounder influence	SS: assembly influence	SS: bias influence
Research hypothesis (RH)	Chance RH is True	RH: more likely than not	RH: unlikely
Random samples	Survey margin of error	Margin Error subgroup	Poll vs. Survey

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8.12.1, P 343 StatLit Textbook 2023 Chapter 8 Slides **23** V0C

Interpreting Statistical Significance Bayesian Medical Tests (>50%)

Shift from confirmation (column %) to prediction (row %).

---------- Medical Test ----------			
People	*Has the diesease (Reality)*		
Test result	**No**	Yes	TOTAL
Negative	# OK	# Type 2	Sum(Row1)
Positive	**# Type 1**	# OK	Sum(Row2)
TOTAL	Sum(No)	Sum(Yes)	SUM
Type 1 error: Disease-free person tests positive			
Type 2 error: Diseased person tests negative			

---------- Hypothesis Test ----------			
Samples	*Real difference (Population)*		
Test result	**FALSE**	True	TOTAL
Stat. Insignificant	# OK	# Type 2	Sum(Row1)
Stat. Significant	**# Type 1**	# OK	Sum(Row2)
TOTAL	Sum(False)	Sum(True)	SUM
Type 1 error: Statistically-significant result is false			
Type 2 error: Statistically-insignificant result is true			

If research hypothesis (RH) is more likely than not (prior) and result is statistically significant, 95% chance RH is true.

Medical test	DISEASED		
Result	No	Yes	Total
Negative	95	5	100
Positive	5 ↑	95 ↑	100
Total	100 ↑	100 ←	200

50% are diseased; 95% confirmation accuracy

Hypothesis test	Research Hypothesis (RH)		
Result	FALSE	TRUE	Total
Not Stat Sig	95	5	100
Stat. Signif.	5 ↑	95 ↑	100
Total	100 ↑	100 ←	200

50% chance RH is true; 95% confirmation accuracy

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8.12.1, P 345, 346 StatLit Textbook 2023 Chapter 8 Slides **24** V0C

Interpreting Statistical Significance Bayesian Medical Tests (5%)

Unlikely to be true in reality:

- Group: prone to heart attacks on 4th day of the month
- Women who eat cereal are more likely to have boys.
- Hurricanes with female names are deadlier.

Extraordinary claims require extraordinary evidence (Ecree)

Medical test	DISEASED		
Result	No	Yes	Total
Negative	1,805	5	1,810
Positive	95 ↑	95 ↑	190
Total	1,900 ↑	100 ←	2,000

5% are diseased; 95% confirmation accuracy

Hypothesis test	Research Hypothesis (RH)		
Result	FALSE	TRUE	Total
Not Stat. Signif.	1,805	5	1,810
Stat. Signif.	95 ↑	95 ↑	190
Total	1,900 ↑	100 ←	2,000

5% chance RH is True; 95% confirmation accuracy

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Interpreting Statistical Significance
Bayesian Medical Tests

Let R = Prior chance the research hypothesis (RH) is true.
Let P-value = confirmation error: P(T1|Null=True).
Let Q = Posterior chance that the research hypothesis is true.

If R < 50% and the result of the hypothesis test is positive (Bayesian significant), then the P-value must be:

1. the same as R to give a 50% chance that Q is true.
2. a tenth of R to give a 90% chance that Q is true.
3. a twentieth of R to give a 95% chance that Q is true.
   See Schield (2026).

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