

The SPINE of statistics: Standard error and confidence intervals

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 www.youtube.com/user/ProfAndyField/

 www.discoveringstatistics.com

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The SPINE of statistics

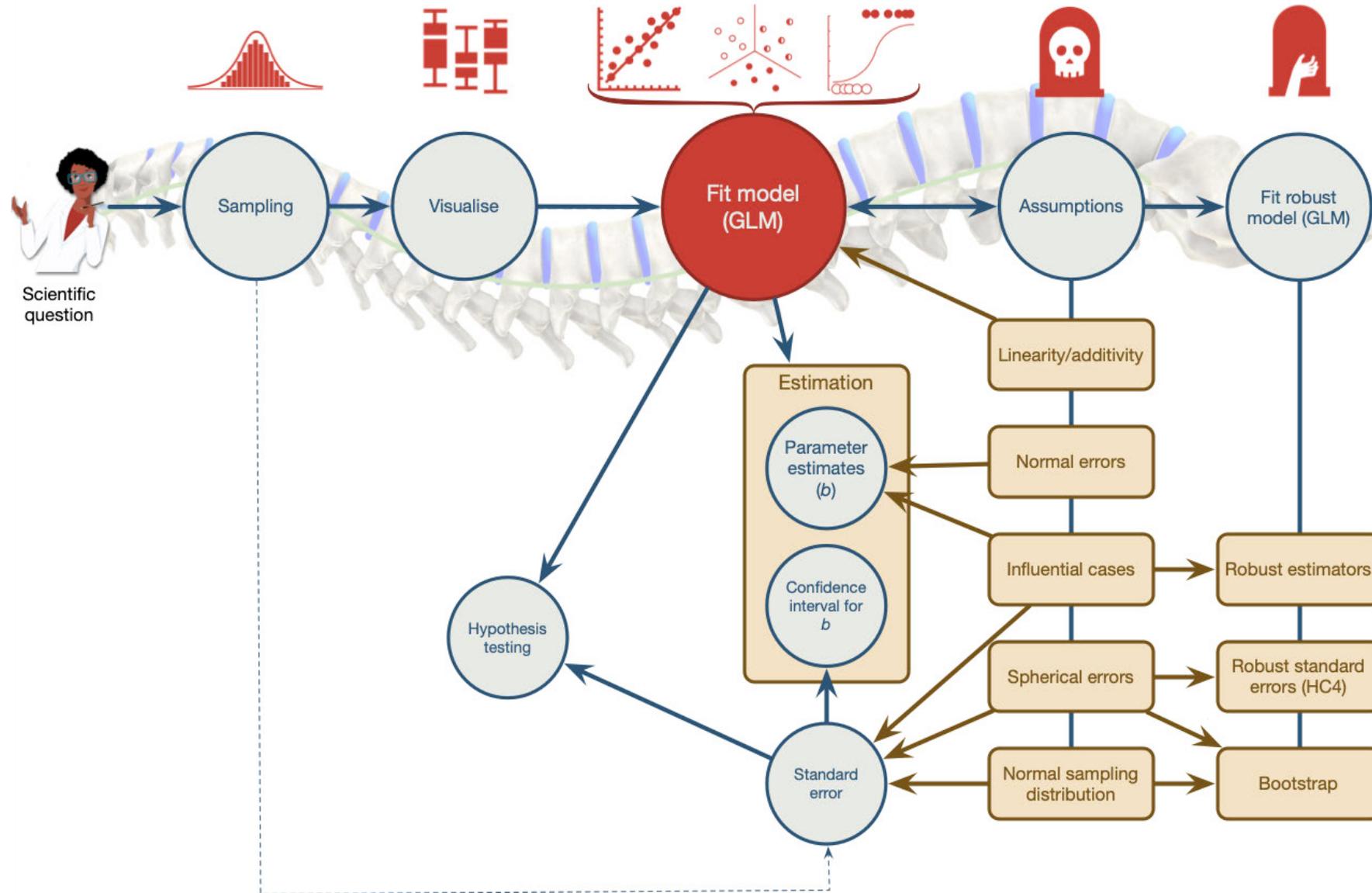
5 Key concepts

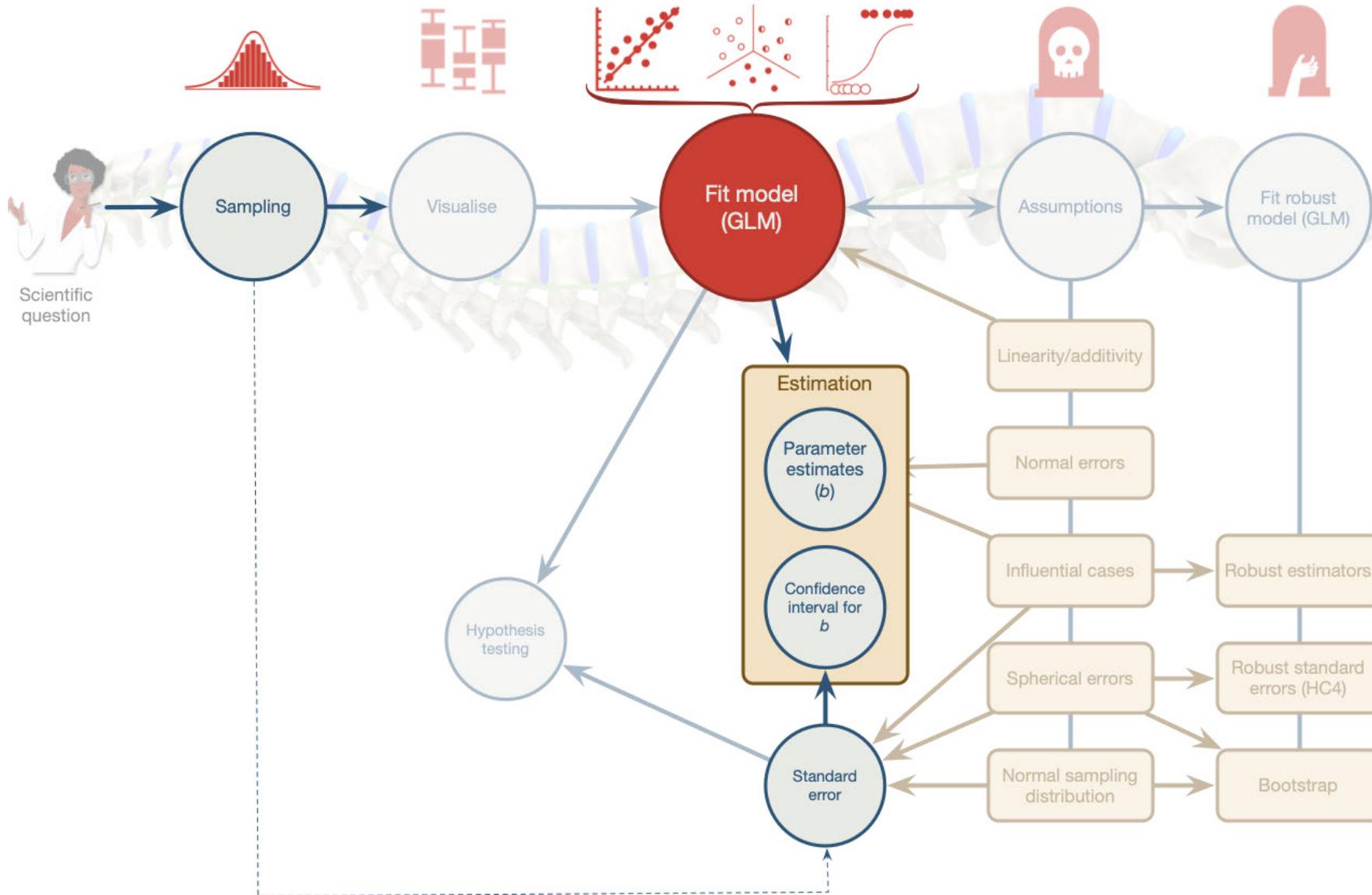
- Standard error
- Parameters
- Interval estimates
- Null hypothesis significance testing (NHST)
- Estimation



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Learning outcomes

- Understand what sampling error is
- Understand what the standard error represents
- Understand what a confidence interval represents
 - and also what it does NOT represent!
- Understand that parameter estimates are raw effect sizes
- Be able to interpret
 - Parameter estimates
 - Their confidence intervals
 - Standardized parameter estimates



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The only equation you will ever need

The General Linear Model (GLM)

$$\text{outcome}_i = (\text{model}_i) + \text{error}_i$$

$$\text{outcome}_i = \hat{b}_0 + \hat{b}_1 \text{predictor}_i + \dots + \hat{b}_n \text{predictor}_i + \text{error}_i$$

\hat{b}_n

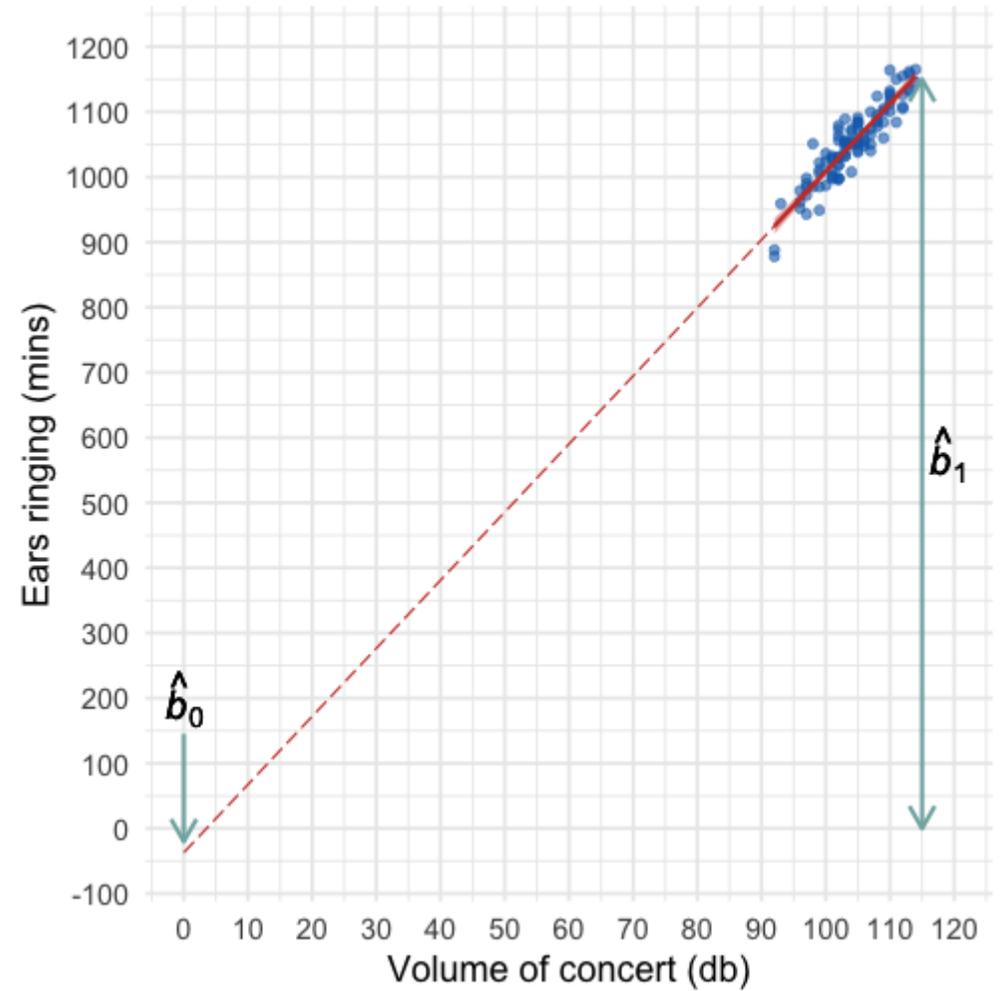
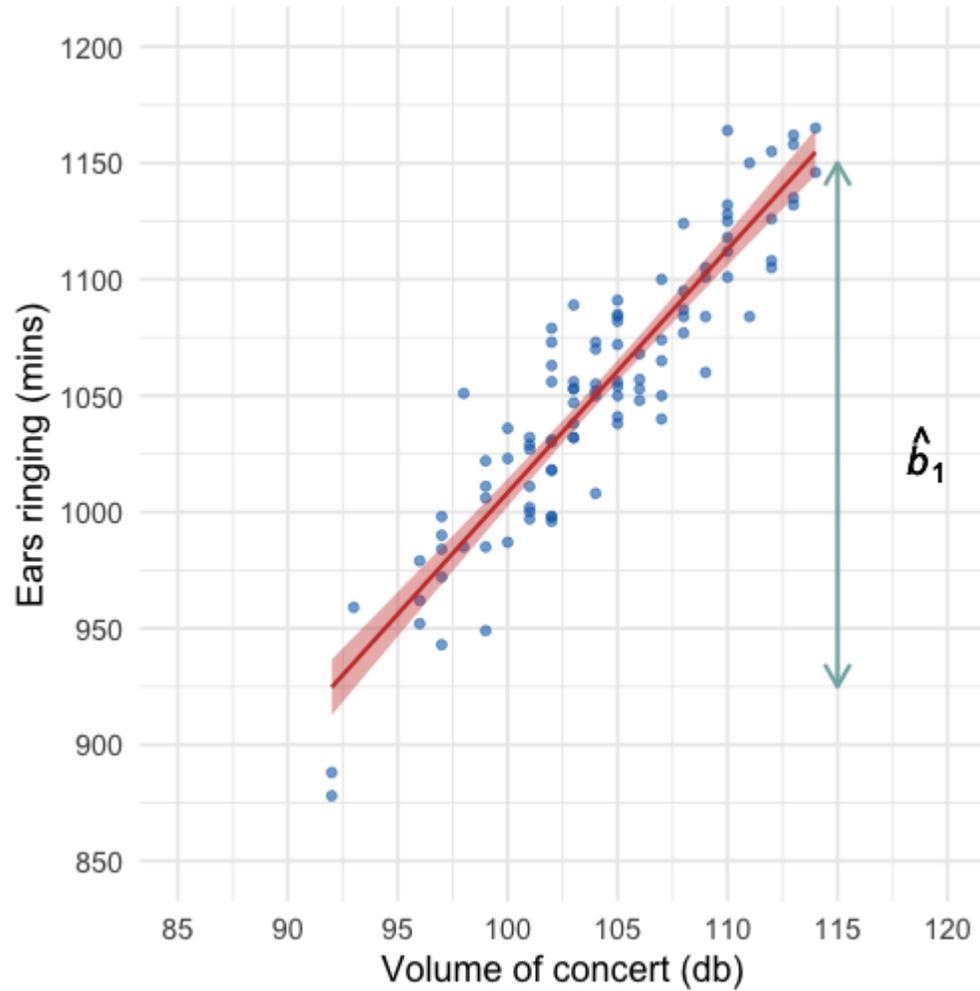
- Estimate of parameter for a predictor
 - Direction/strength of relationship/effect
 - Difference in means

\hat{b}_0

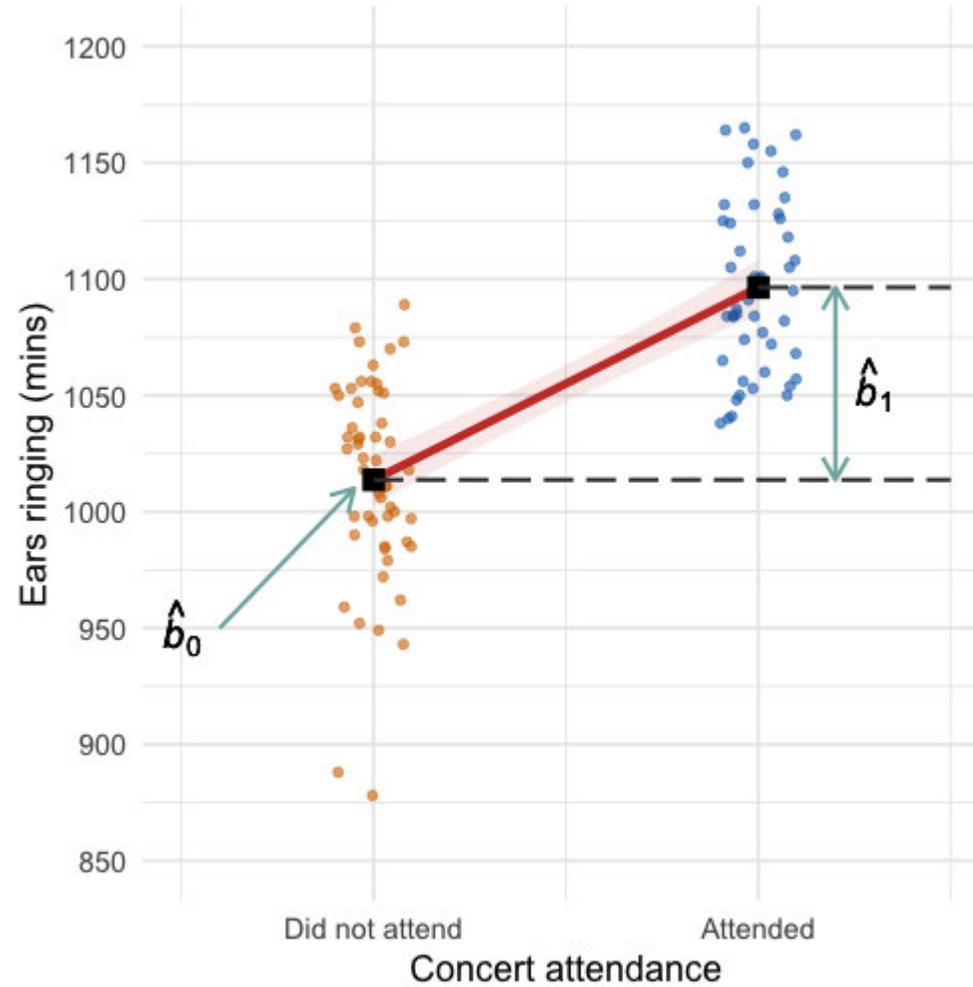
- Estimate of the value of the outcome when predictor(s) = 0 (intercept)



$$\widehat{\text{ringing}}_i = -37.12 + 10.45\text{volume}_i + e_i$$



$$\text{ringing}_i = \hat{b}_0 + \hat{b}_1 \text{attendance}_i + e_i$$

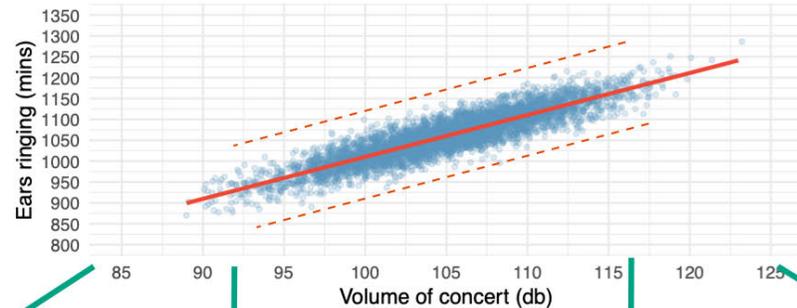




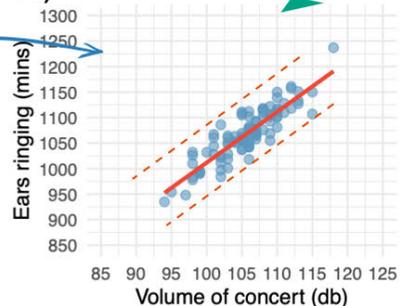
True values
(parameter)

Population

$$y_i = 5.5 + 10.05x_i + \varepsilon_i$$

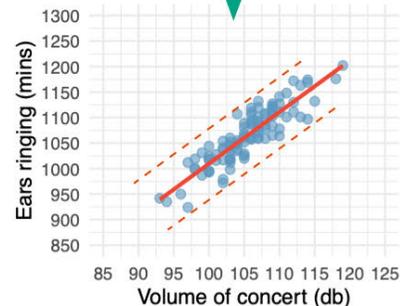


Estimates
(statistics)

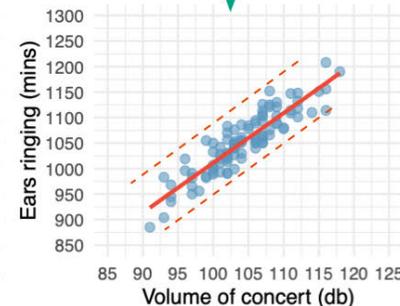


$$\hat{y}_i = 18.06 + 9.94x_i + e_i$$

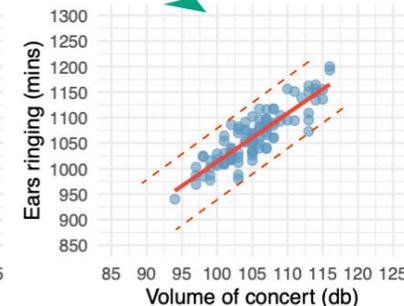
Our sample



$$\hat{y}_i = -0.32 + 10.10x_i + e_i$$



$$\hat{y}_i = 34.73 + 9.76x_i + e_i$$



$$\hat{y}_i = 65.26 + 9.48x_i + e_i$$

Other potential samples



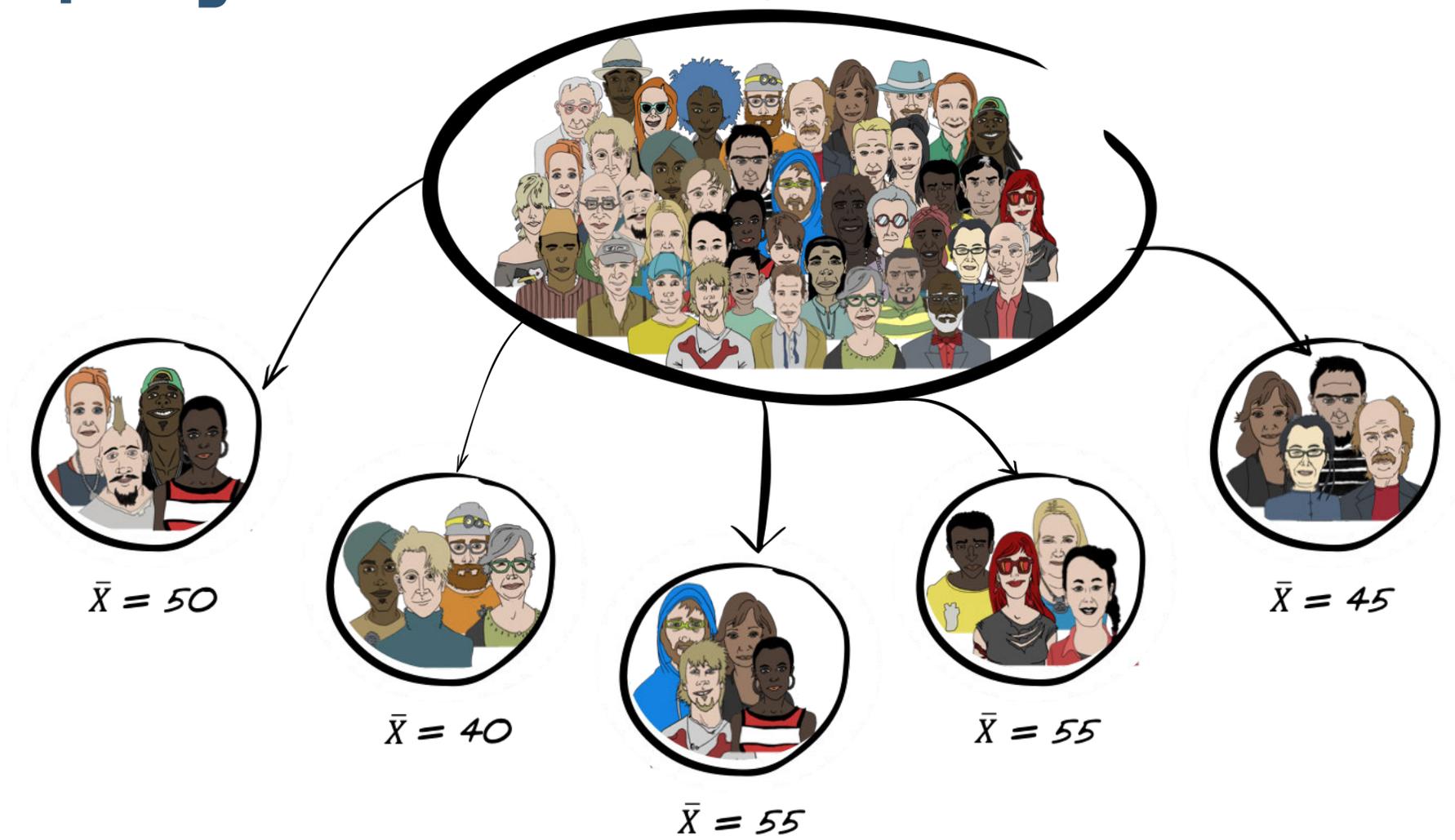
A test-y example

$$\text{accuracy}_i = \hat{b}_0 + e_i$$

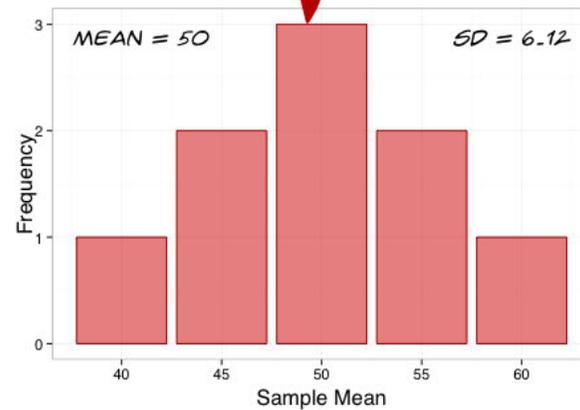
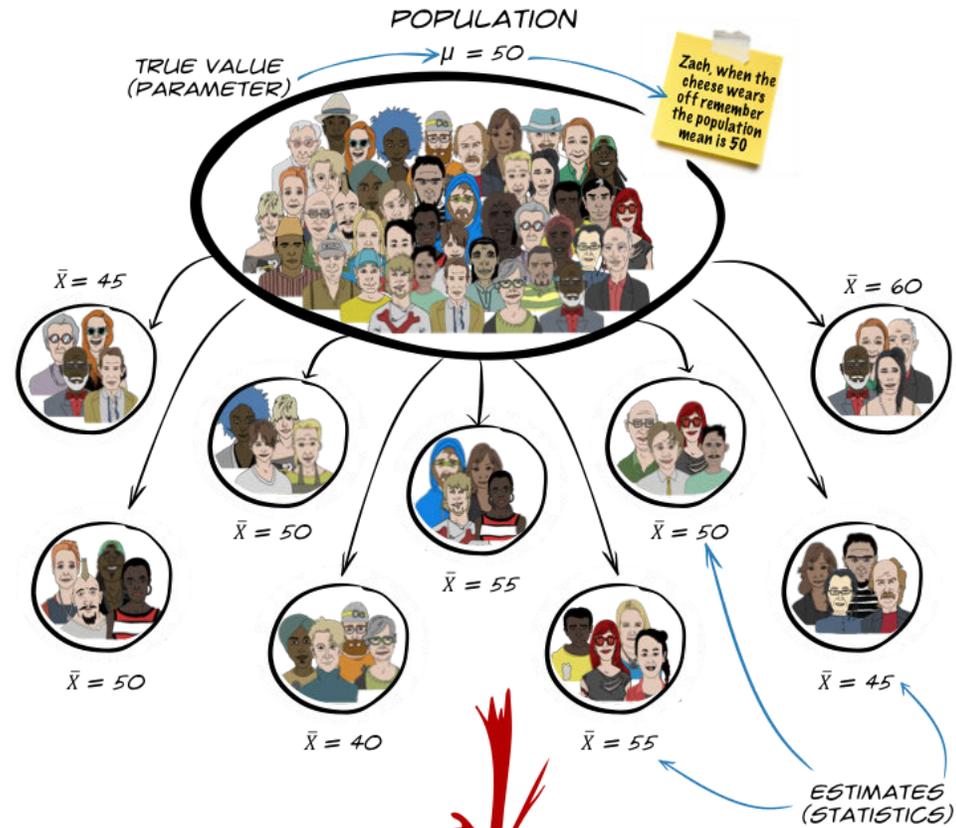


Sampling error

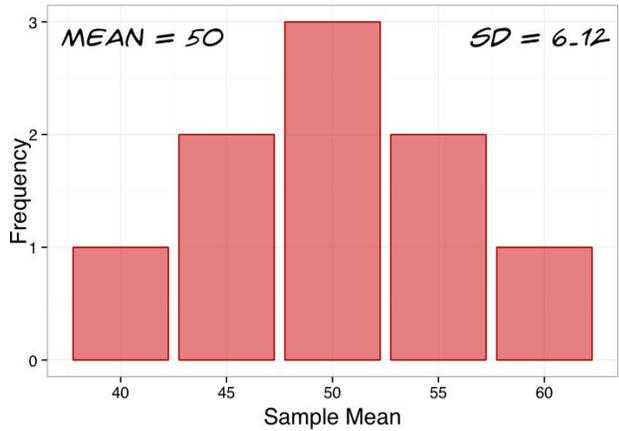
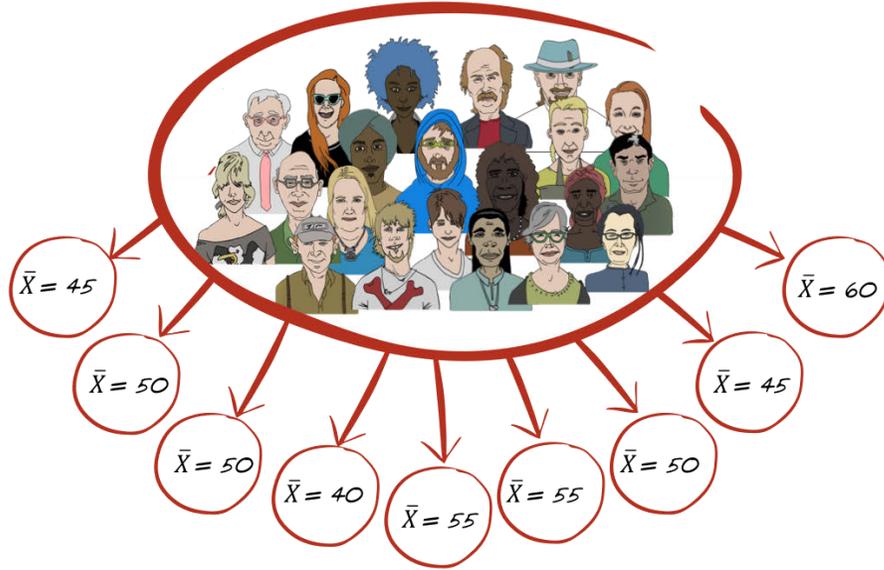
POPULATION
 $\mu = 50$



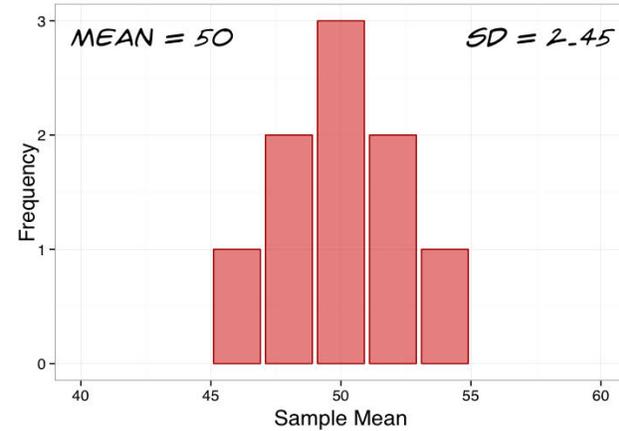
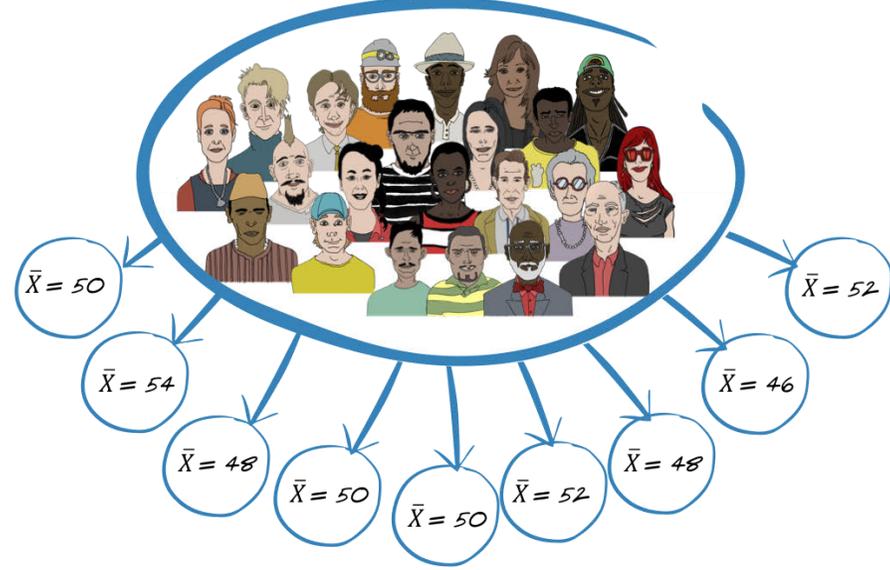
Standard error



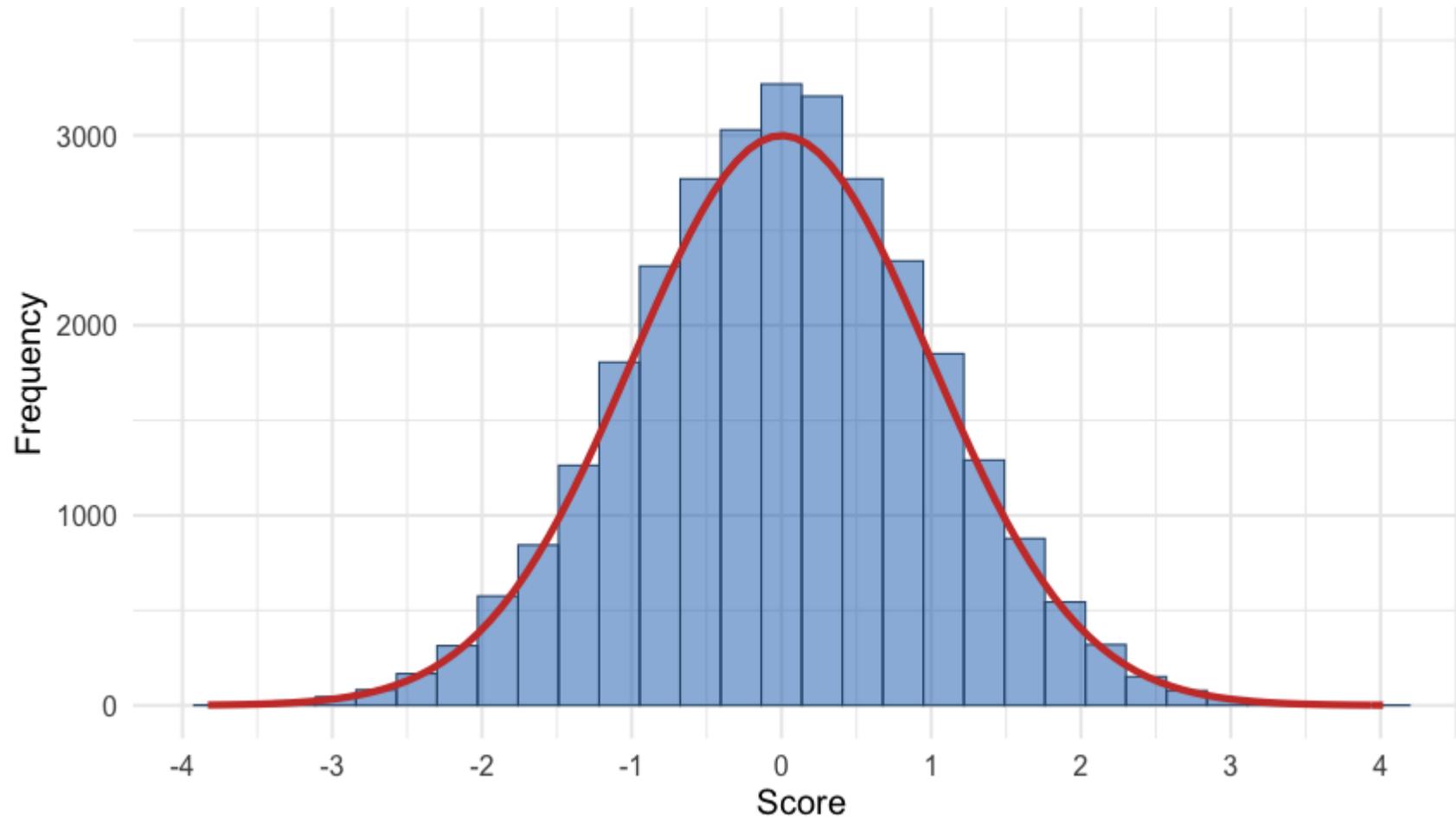
POPULATION
 $\mu = 50$



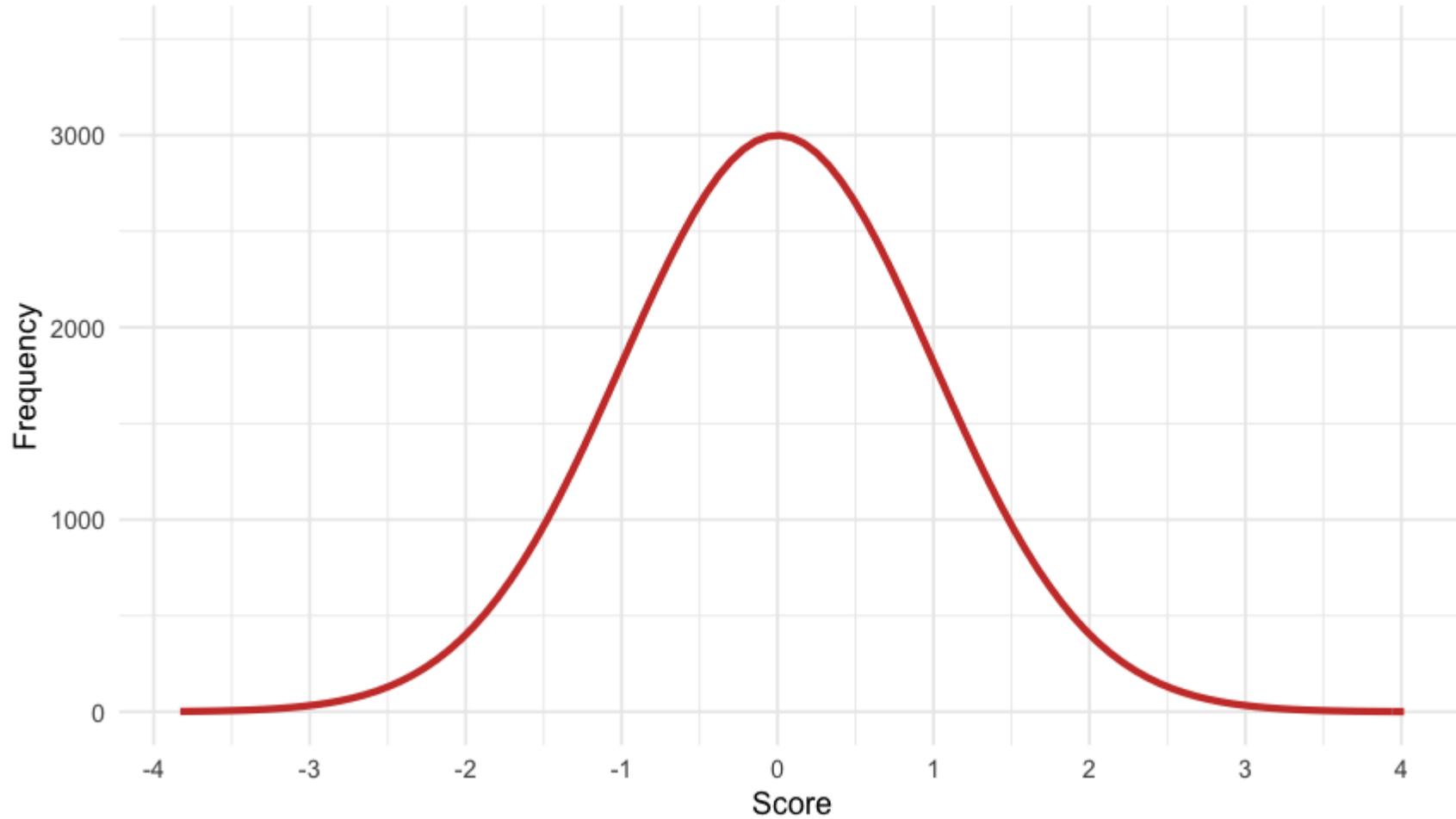
POPULATION
 $\mu = 50$



The Central Limit Theorem (CLT)



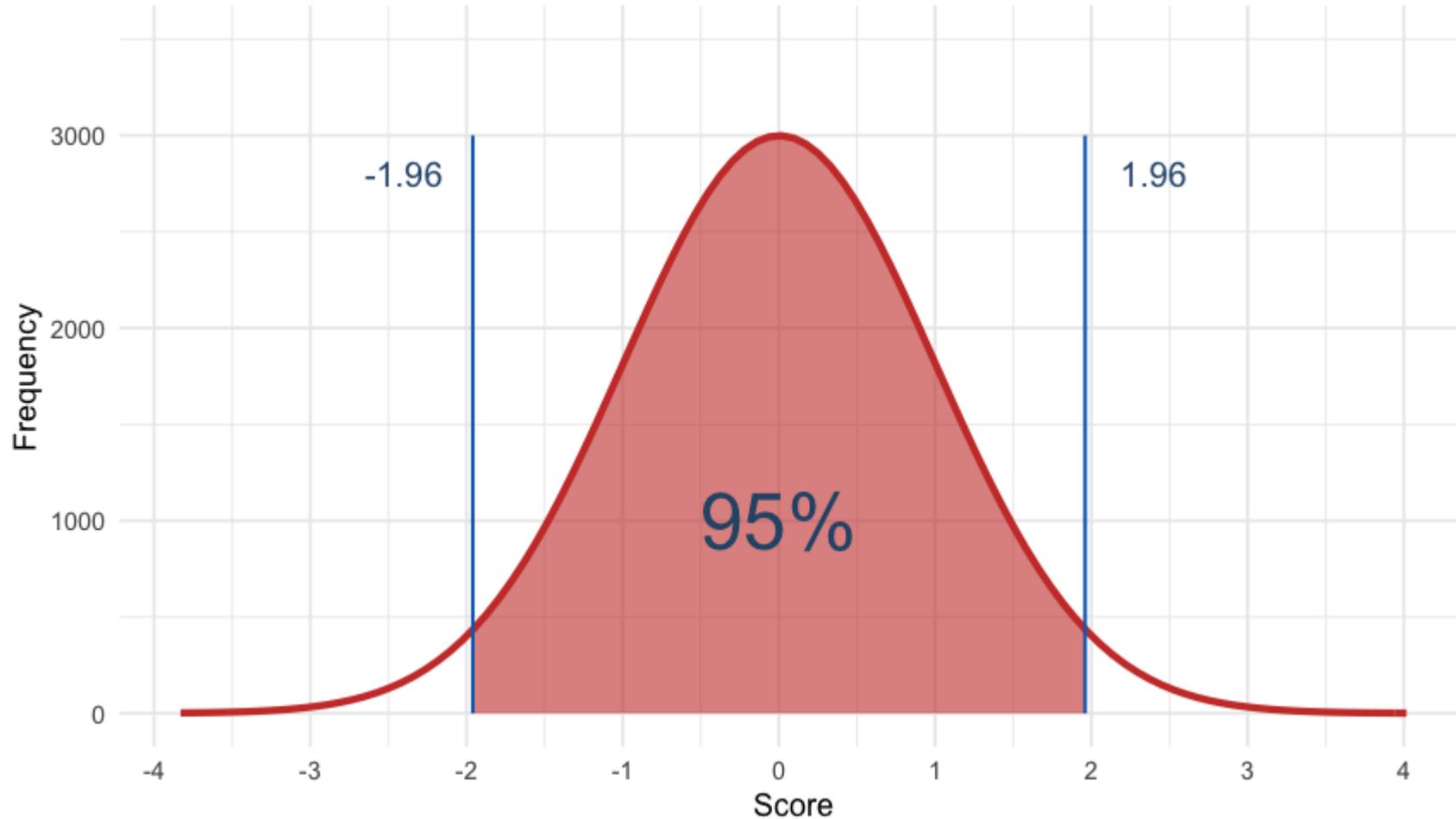
The Central Limit Theorem (CLT)



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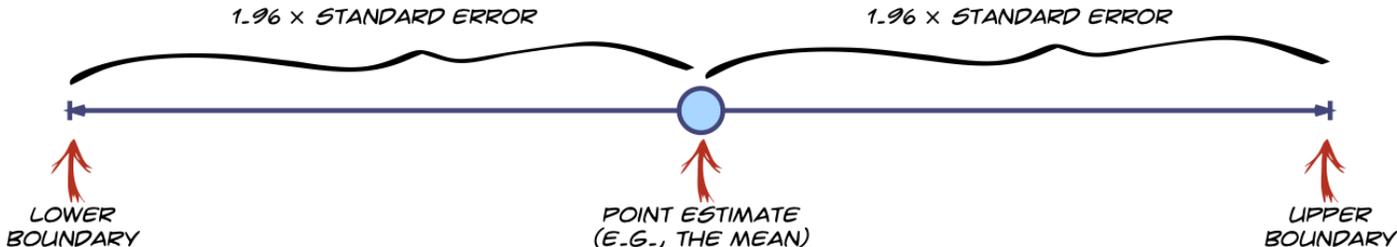
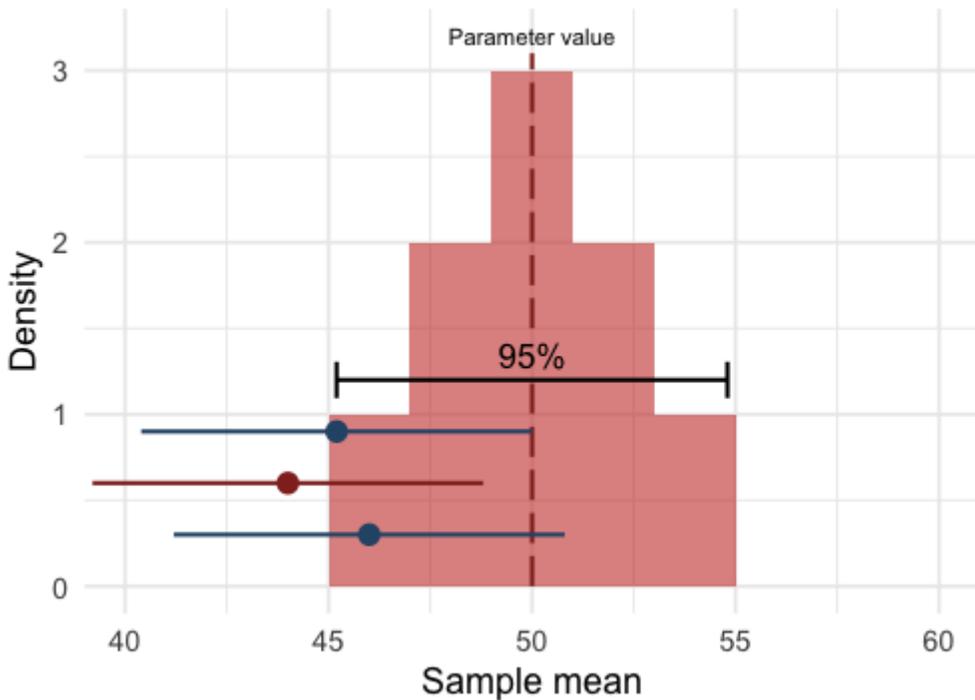
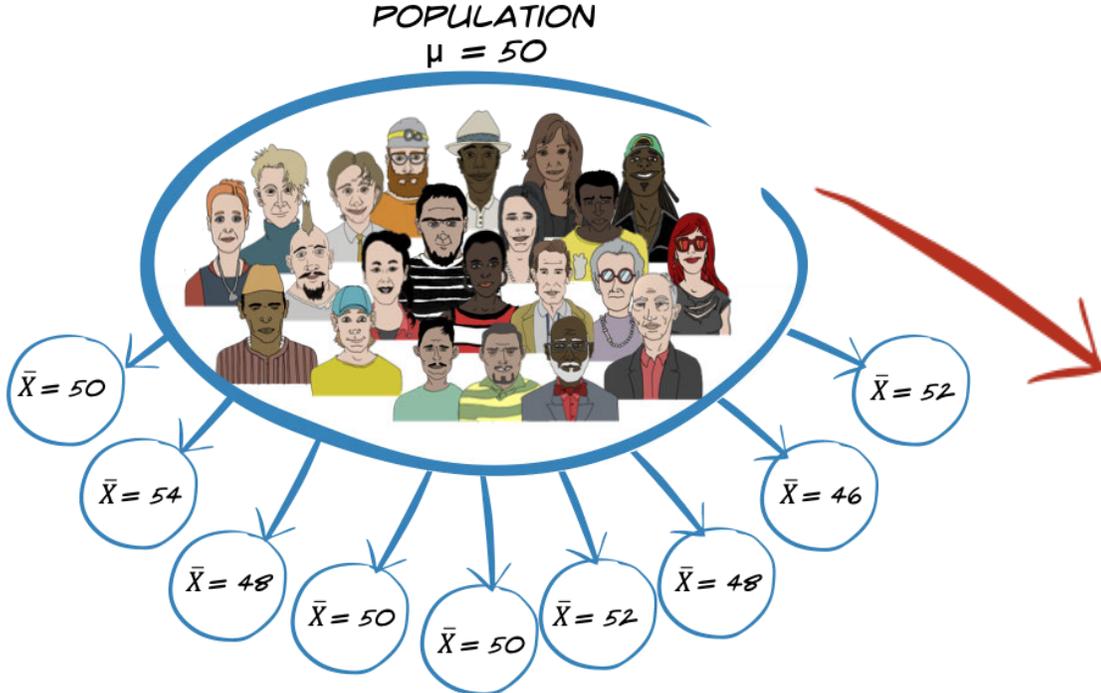
The Central Limit Theorem (CLT)



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Confidence interval



Confidence intervals



What they are:

- Intervals that contain the 'true' population value of the parameter in 95% of samples.



What they are not:

- There is not a 95% probability that a given interval contains the population value.
 - It is $p = 0$ or $p = 1$, but you can't know which!
- They do not reflect confidence in the value of the population parameter.



Interpreting parameter estimates

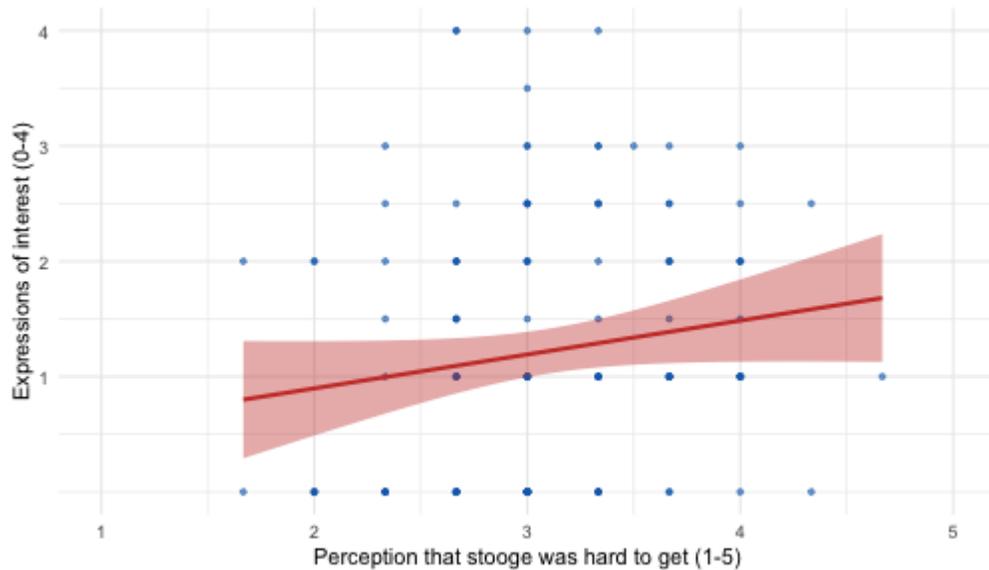
Raw effect size (b)



- Does playing hard to get work?¹
- Heterosexual participants conversed with an opposite-sex confederate over Instant Messenger for 8 mins
- **Interest**: Final message coded for the number of expressions of romantic interest (range 0 to 4)
- **Hard to get**: 3 items rated 1 (not at all) and 5 (very much so)
 - *The other participant is hard to get*
- **Mate value**: 4 items rated 1 (not at all) and 5 (very much so)
 - *I perceive the other participant as a valued mate*

[1] Birnbaum et al. (2020). *Journal of Social and Personal Relationships*. Study 3.

$$\text{interest}_i = \hat{b}_0 + \hat{b}_1 \text{hard to get}_i + e_i$$



term	estimate	std.error	statistic	p.value
(Intercept)	0.310	0.524	0.591	0.556
hard_to_get	0.294	0.167	1.765	0.080

- As the perception that the other person was hard to get increased by 1 (on a scale from 1-5), **0.294** more expressions of interest were made.
- You'd need perceptions of 'hard to get' to increase by $\frac{1}{0.294} = 3.4$ on a 5-point scale to get 1 additional expression of interest.

Parameter estimates: 95% confidence interval

$$\text{interest}_i = \hat{b}_0 + \hat{b}_1 \text{hard to get}_i + e_i$$

term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	0.310	0.524	0.591	0.556	-0.728	1.347
hard_to_get	0.294	0.167	1.765	0.080	-0.036	0.624

- Assuming that this sample is one of the 95% that yields a confidence interval containing the true value of the parameter ...
- As the perception that the other person was hard to get increases by 1, the corresponding change in the number of expressions made could be as small as **-0.036**. In other words, there are *fewer* expressions of interest.
- As the perception that the other person was hard to get increases by 1, the corresponding change in the number of expressions made could be as large as **0.624**. In other words, there are *more* expressions of interest.
- It's plausible that as the perception that the other person was hard to get increases by 1, there is *no change* in expressions of interest ($b = 0$).
- **The assumption at the start might be false.**

Interpreting parameter estimates

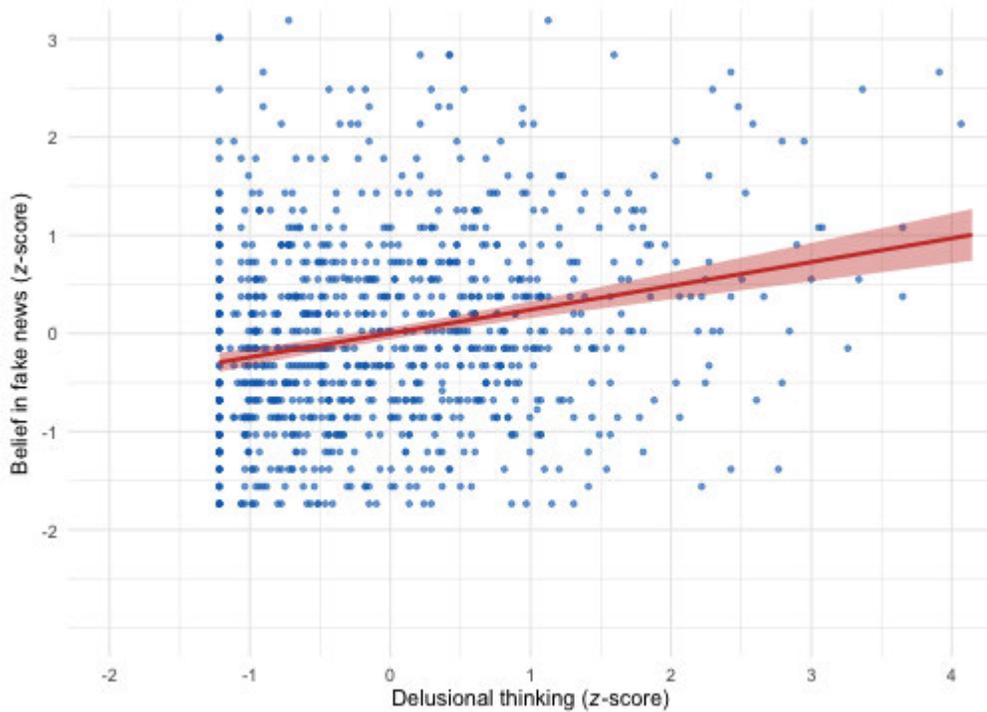
Standardized effect size β

- Who believes fake news?¹
- **fake_newz**: Belief in fake news
 - Average rating of 12 fake news items (1 = Not at all accurate, 4 = Very accurate)
- **delusionz**: Peter's delusion inventory
 - *Do you ever feel as if there is a conspiracy against you?*
- **crit_thinkz**: Critical thinking
 - 7 problems that have intuitive-but-incorrect responses that must be overridden to arrive at the correct answer
 - *How many cubic feet of dirt are there in a hole that is 3 feet deep by 3 feet wide by 3 feet long?*



[1] Bronstein et al. (2019). *Journal of Applied Research in Memory and Cognition*.

$$\text{fake news beliefs}_i = \hat{b}_0 + \hat{b}_1 \text{delusion}_i + e_i$$



term	estimate	std.error	statistic	p.value
(Intercept)	0.000	0.032	0.000	1
delusionz	0.242	0.032	7.676	0

- For every standard deviation change in delusion proneness, belief in fake news increases by **0.242** standard deviations.



Summary

You can understand most psychological statistics with 5 concepts

1. Parameters define the model and represent hypotheses of interest
2. Estimation (parameters are estimated based on sample data)
3. NHST (next lecture)
4. Interval estimates
 - All parameters have one
 - Confidence intervals might tell us something about the true value of the parameter
5. Standard Error (of a parameter)
 - Tells us about the variability in parameter estimates from sample to sample
 - Significance tests and confidence intervals rely on the standard error

