

## 8.6: Summary

In this chapter I've covered two main topics. The first half of the chapter talks about sampling theory, and the second half talks about how we can use sampling theory to construct estimates of the population parameters. The section breakdown looks like this:

- Basic ideas about samples, sampling and populations (Section 10.1)
- Statistical theory of sampling: the law of large numbers (Section 10.2), sampling distributions and the central limit theorem (Section 10.3).
- Estimating means and standard deviations (Section 10.4)
- Estimating a confidence interval (Section 10.5)

As always, there's a lot of topics related to sampling and estimation that aren't covered in this chapter, but for an introductory psychology class this is fairly comprehensive I think. For most applied researchers you won't need much more theory than this. One big question that I haven't touched on in this chapter is what you do when you don't have a simple random sample. There is a lot of statistical theory you can draw on to handle this situation, but it's well beyond the scope of this book.

### References

Stigler, S. M. 1986. *The History of Statistics*. Cambridge, MA: Harvard University Press.

Keynes, John Maynard. 1923. *A Tract on Monetary Reform*. London: Macmillan; Company.

147. The proper mathematical definition of randomness is extraordinarily technical, and way beyond the scope of this book. We'll be non-technical here and say that a process has an element of randomness to it whenever it is possible to repeat the process and get different answers each time.
148. Nothing in life is that simple: there's not an obvious division of people into binary categories like "schizophrenic" and "not schizophrenic". But this isn't a clinical psychology text, so please forgive me a few simplifications here and there.
149. Technically, the law of large numbers pertains to any sample statistic that can be described as an average of independent quantities. That's certainly true for the sample mean. However, it's also possible to write many other sample statistics as averages of one form or another. The variance of a sample, for instance, can be rewritten as a kind of average and so is subject to the law of large numbers. The minimum value of a sample, however, cannot be written as an average of anything and is therefore not governed by the law of large numbers.
150. As usual, I'm being a bit sloppy here. The central limit theorem is a bit more general than this section implies. Like most introductory stats texts, I've discussed one situation where the central limit theorem holds: when you're taking an average across lots of independent events drawn from the same distribution. However, the central limit theorem is much broader than this. There's a whole class of things called "U-statistics" for instance, all of which satisfy the central limit theorem and therefore become normally distributed for large sample sizes. The mean is one such statistic, but it's not the only one.
151. Please note that if you were *actually* interested in this question, you would need to be a *lot* more careful than I'm being here. You *can't* just compare IQ scores in Whyalla to Port Pirie and assume that any differences are due to lead poisoning. Even if it were true that the only differences between the two towns corresponded to the different refineries (and it isn't, not by a long shot), you need to account for the fact that people already *believe* that lead pollution causes cognitive deficits: if you recall back to Chapter 2, this means that there are different demand effects for the Port Pirie sample than for the Whyalla sample. In other words, you might end up with an illusory group difference in your data, caused by the fact that people *think* that there is a real difference. I find it pretty implausible to think that the locals wouldn't be well aware of what you were trying to do if a bunch of researchers turned up in Port Pirie with lab coats and IQ tests, and even less plausible to think that a lot of people would be pretty resentful of you for doing it. Those people won't be as co-operative in the tests. Other people in Port Pirie might be *more* motivated to do well because they don't want their home town to look bad. The motivational effects that would apply in Whyalla are likely to be weaker, because people don't have any concept of "iron ore poisoning" in the same way that they have a concept for "lead poisoning". Psychology is *hard*.
152. I should note that I'm hiding something here. Unbiasedness is a desirable characteristic for an estimator, but there are other things that matter besides bias. However, it's beyond the scope of this book to discuss this in any detail. I just want to draw your attention to the fact that there's some hidden complexity here.
153. , I'm hiding something else here. In a bizarre and counterintuitive twist, since  $\hat{\sigma}^2$  is an unbiased estimator of  $\sigma^2$ , you'd assume that taking the square root would be fine, and  $\hat{\sigma}$  would be an unbiased estimator of  $\sigma$ . Right? Weirdly, it's not. There's actually a subtle, tiny bias in  $\hat{\sigma}$ . This is just bizarre:  $\hat{\sigma}^2$  is an unbiased estimate of the population variance  $\sigma^2$ , but when you take the

square root, it turns out that  $\hat{\sigma}$  is a biased estimator of the population standard deviation  $\sigma$ . Weird, weird, weird, right? So, why is  $\hat{\sigma}$  biased? The technical answer is “because non-linear transformations (e.g., the square root) don’t commute with expectation”, but that just sounds like gibberish to everyone who hasn’t taken a course in mathematical statistics. Fortunately, it doesn’t matter for practical purposes. The bias is small, and in real life everyone uses  $\hat{\sigma}$  and it works just fine. Sometimes mathematics is just annoying.

154. This quote appears on a great many t-shirts and websites, and even gets a mention in a few academic papers (e.g.,

`\url{http://www.amstat.org/publications/jse/v10n3/friedman.html}`

155. As of the current writing, these are the only arguments to the function. However, I am planning to add a bit more functionality to `ciMean()`. However, regardless of what those future changes might look like, the `x` and `conf` arguments will remain the same, and the commands used in this book will still work.

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