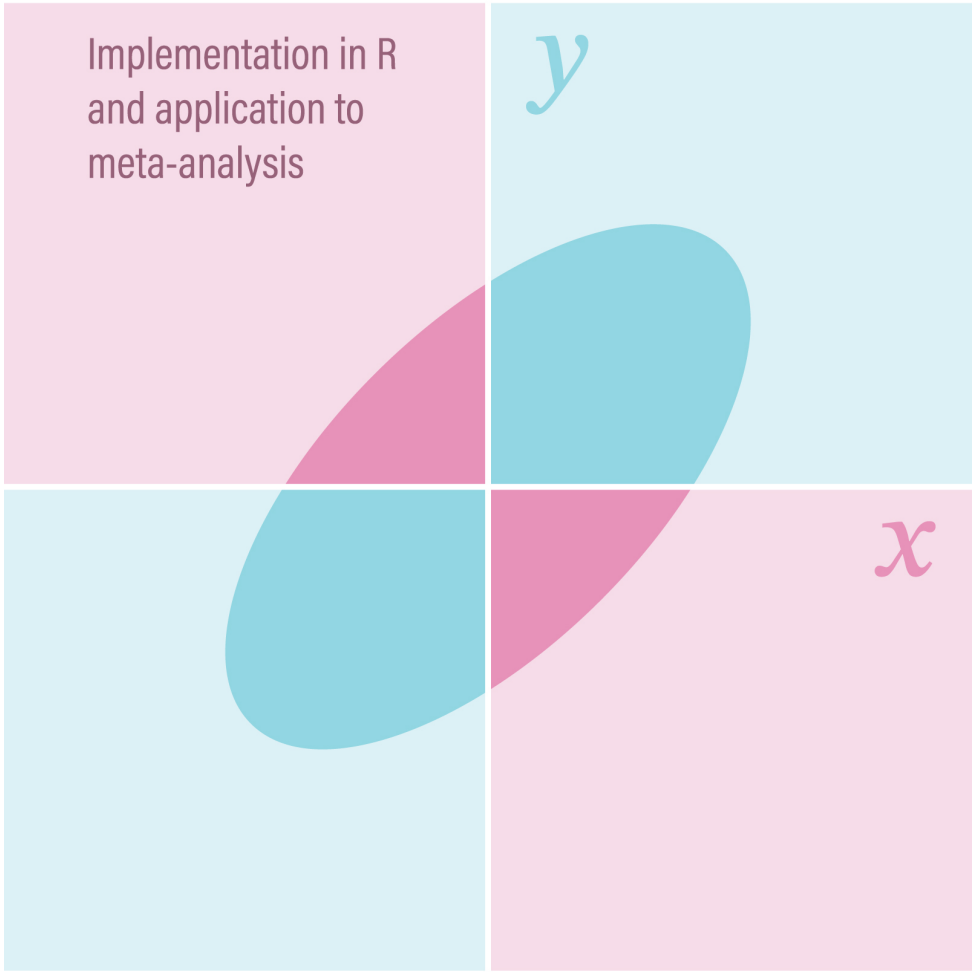
ARTIFACT CORRECTIONS

for EFFECT SIZES

Implementation in R
and application to
meta-analysis



Matthew B.
Jané

Artifact Corrections for Effect Sizes

Seeing Reality for What it is

Matthew B. Jané

2023-10-08

Table of contents

1 Greetings

Welcome to the living open source textbook ***Artifact Corrections for Effect Sizes***. This textbook covers all the essential equations and code needed to correct for biases in our effect size estimates. It will also hopefully provide readers with a deeper understanding, appreciation, and intuition for these seemingly complex formulas. It also covers how to apply these corrections to meta-analysis.

What are Statistical Artifacts?

In this book statistical artifacts will be defined broadly as **any source of contamination that induces bias in research findings**. Artifacts are present in virtually every research study, so it is crucial that we address them.

Open and Living Textbook

A living textbook is one that constantly updates with new features and is open to changes from others. This book will contain modern methods and cutting-edge techniques for artifact corrections, so in order to keep this book up-to-date it needs to grow as the research grows. New features, such as interactive figures will be added soon

It is important that this book is both open-source and open-access. All the figures, code, and documents are available in a github repository. The current maintainer of the book is Matthew B. Jané. This work is under a CC-BY license, therefore if you use any part of this work in your own work, it is important that you acknowledge it and cite it as follows:

1.0.0.0.1 * APA

Jané, M. B. (2023). Artifact Corrections for Effect Sizes: Implementation in R and Application to Meta-Analysis. (n.p.). https://matthewbjane.quarto.pub/artifact-corrections-for-effect-sizes/

1.0.0.0.2 * BibTeX

```
@book{MatthewBJane2023,
  title     = "Artifact Corrections for Effect Sizes: Implementation in R and Application
  author    = "Jané, Matthew B.",
```

```
  year      = 2023,
  publisher = "(n.p.)",
  url       = {https://matthewbjane.quarto.pub/artifact-corrections-for-effect-sizes/}
}
```

Contributions

Please feel free to contribute to this textbook, if your contribution makes it to the published version of this book, your name will be included in the contributor list below with a description of your work.

Name	Affiliation	Role
Velu Immonen, BS	Solent University	Designed cover and twitter preview.

2 Dedication

In Loving Memory of Haley Jané

My companion, whose love and presence have filled my life with joy and comfort.

3 Effect Sizes and Artifacts

3.1 What are Effect Sizes?

Effect sizes are statistics that measure the magnitude of a relationship between variables. It's important to remember that effect sizes are a valuable tool, enabling researchers to extract meaningful insights from data, rather than being the ultimate objective themselves. Effect sizes aide in researcher's ability to draw meaningful inferences from data and therefore it is crucial that they are accurate. Correlation coefficients and standardized mean differences are two of the most common effect sizes and so they will be the primary focus of this book.

3.2 Defining the Scientific Estimand

It is important to clearly define the quantity that we aim to estimate (i.e., the estimand). A clearly defined estimand not only shapes our statistical analyses but also establishes a meaningful connection between empirical observations and a theoretical quantity (Lundberg, Johnson, and Stewart 2021). A study can produce effect size estimates that do not accurately reflect the target value. Inaccuracies in effect size estimates can be due to deviations between the current study's design and the design of a technically perfect study (Rubin 1992). Obtaining a quality estimate of the target effect size requires that the study sample and the measured variables accurately reflect the population and variables of interest. We can illustrate this with the following example:

Let's say we want to know the correlation between student motivation and stress among high-school students. Suppose we conduct a study to estimate the correlation by administering a survey to a sample of senior students at a private high school. The survey consists of two questions asking student's to rate their level of motivation and stress on a scale of 1-10. Let's now compare how the target population and variables differ from the study population and variables (see Table **??**):

Table 3.1: Comparison of the target and the study.

	Target	Study	Potential sources of contamination
POPULATION	High-School Students	Seniors High-School students	**Range Restriction.** Senior student's at private universities may have a more narrow range of characteristics such as stress and motivation than other classes (e.g., freshmen) and schools (e.g., public).
VARIABLES	Motivation and Stress	Self-report questionnaire	**Measurement Error.** The measurement of the target variables of motivation and stress likely will produce errors that do not reflect the true motivation and stress of each individual.

3.3 Effect Size Errors

3.3.1 Random (Sampling) Errors

Let's start by differentiating between a population effect size and a sample estimate. The **population** effect size, characterizes the effect size among all possible observations of interest. In contrast, a **sample** effect size is an estimate of this population value, estimated by a random sample of observations. Throughout the book, population effect sizes will be denoted with Greek letters whereas sample estimates will be denoted with an English letters.

The population effect size is a constant, unchanging value that remains fixed across samples. However, if we were to take a random sample from the population and estimate an effect size we would find that the sample estimate varies from sample to sample and does not exactly reflect the population value. This is due to the fact that randomly taking a subset of the population will contain inherent variability in the composition of the sample. **Sampling errors** describe the random deviations that we observe in effect size estimates from sample to sample (Barraza et al. 2019). Sampling errors are random, however we will see in the next section that not all errors are systematic. We can quantify sampling errors by the variance of the effect size estimator. The variance of an effect size estimator tends to be some function of sample size, where large samples will show less variance compared to small samples. For an illustration of sampling error, see Figure **??**.

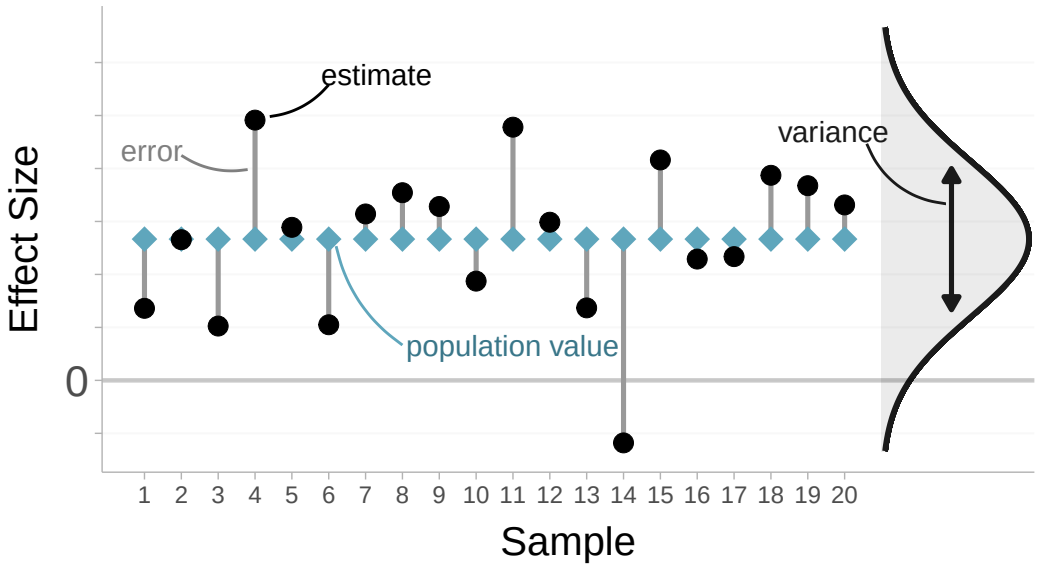


Figure 3.1: This figure shows the distribution of sample estimates. The blue diamonds denotes the population effect size, which stays constant across samples. The black dots denote the sample effect size estimate. The grey lines denote random sampling errors, which represent the difference between the estimates and the population value. The sampling distribution on the right shows the probability distribution of estimates across repeated samples, the width of this distribution is described by the variance of the estimator. Note the illustration shows a normally distributed estimator, but this is not a requirement.

3.3.2 Systematic Errors

Sampling errors produce random errors in effect sizes, however, we can also observe systematic errors. **Systematic errors** are deviations from the target population value that are consistent across samples and produce bias in effect size estimates. In other words, effect size estimates will be *on average* larger or smaller than the target population value (Barraza et al. 2019). Random sampling errors, on the other hand, will be larger or smaller than the target population value only by chance. **Attenuation** describes a type of systematic error where the effect size estimates are *smaller* than the target population value on average. **Inflation** on the other hand, is a type of bias that produce effect size estimates that are *larger* on average. An **unbiased** effect size would be one where there is no systematic errors and therefore, on average, it is equal to the population effect size. As we will see in future chapters, study artifacts such as selection effects and measurement error can produce effect sizes that contain systematic errors.

We can see in Figure **??** that the sampling distribution does not become wider or smaller with systematic errors (this may occur indirectly if the sampling variance depends on the effect size itself), instead the whole sampling distribution shifts downward or upward depending on whether the effect size estimates are attenuated or inflated, respectively.

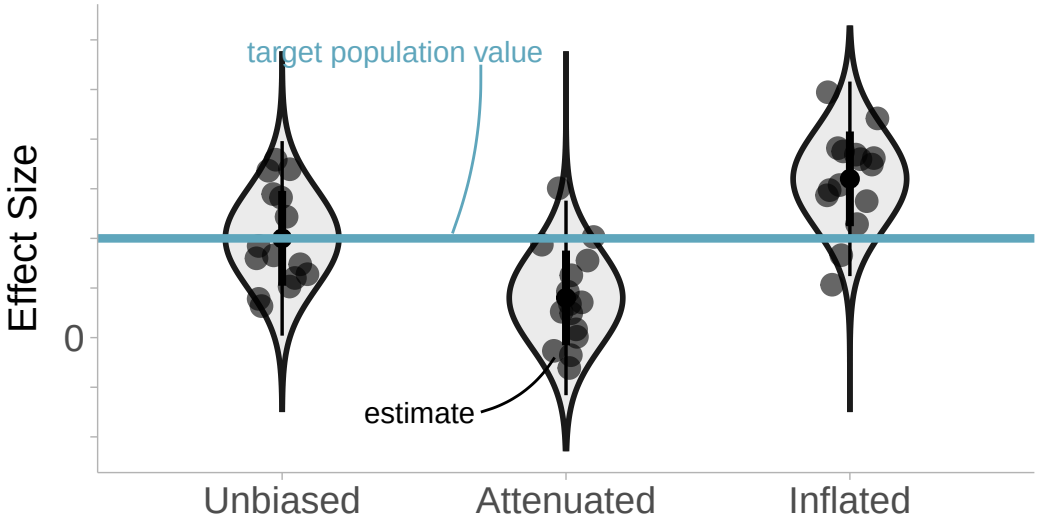


Figure 3.2: Three sampling distributions representing estimators that are unbiased, attenuated, and inflated. The blue line indicates the the location of the target population effect size, whereas the black dots show the effect size estimates.

3.4 Modeling Observed Effect Sizes

We can think of an observed effect size estimate as having three components: