Quantitative Measurement Error Bias and Correction

Understanding and Correcting Misclassification Bias

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Outline

What is Misclassification Bias?

Definition

Misclassification bias occurs when measurement error leads to incorrect categorisation of study participants.

- Common in psychological research
- Affects self-report measures
- Impacts diagnostic categories
- Usually biases toward null if error is not systematic (but not always!)

Types

1. **Non-differential**: Error independent of other variables
2. **Differential**: Error varies by group

Key Point: Even random error causes systematic bias!

Example: True Association

True Association (No Misclassification)

	Disease +	Disease −	Total
Exposed	80	20	100
Unexposed	20	80	100
Total	100	100	200

$$\textbf{Risk Ratio} = \frac{80/100}{20/100} = 4.0$$

Example: With Misclassification

With 20% Non-Differential Misclassification

	Disease $+$	Disease $-$	Total
Exposed	68	32	100
Unexposed	32	68	100
Total	100	100	200

Observed Risk Ratio $= \frac{68/100}{32/100} = 2.125$

True effect attenuated from 4.0 to 2.125 (47% reduction)

Impact on Research

Consequences

- Underestimated effect sizes
- Reduced statistical power
- Failed replications
- False null findings

Common in Psychology

- Depression screening (PHQ-9)
- Self-reported behaviours
- Cognitive assessments
- Diagnostic interviews

Critical Insight

Many "null" findings in psychology may actually reflect measurement error rather than absence of true effects!

Core Correction Formula

Mathematical Foundation

For non-differential misclassification of exposure:

$$P_{\text{true}} = \frac{P_{\text{observed}} - (1 - \text{Specificity})}{\text{Sensitivity} + \text{Specificity} - 1} \tag{1}$$

Where:

- P_{true} = True prevalence
- P_{observed} = Observed prevalence

Requirements:

- Known sensitivity
- Known specificity
- From validation study

Correction Process Step-by-Step

Given Parameters

Parameter	Value
Sensitivity	0.80 (80%)
Specificity	0.80 (80%)
Total with disease	100
Total without disease	100

Observed Data

	Disease +	Disease −	Total
Exposed	68	32	100
Unexposed	32	68	100

Applying the Correction

Step 1: Calculate observed exposure prevalence

$$P_{\text{obs}}(\text{Exposed}|\text{Disease}+) = \frac{68}{100} = 0.68$$
$$P_{\text{obs}}(\text{Exposed}|\text{Disease}-) = \frac{32}{100} = 0.32$$

Step 2: Apply correction formula

$$P_{\text{true}}(\text{Exposed}|\text{Disease}+) = \frac{0.68 - 0.20}{0.60} = 0.80$$
$$P_{\text{true}}(\text{Exposed}|\text{Disease}-) = \frac{0.32 - 0.20}{0.60} = 0.20$$

Results of Correction

Step 3: Calculate corrected cell counts

- True Exposed & Disease+ $= 0.80 \times 100 = 80$
- True Unexposed & Disease+ $= 0.20 \times 100 = 20$
- True Exposed & Disease- $= 0.20 \times 100 = 20$
- True Unexposed & Disease- $= 0.80 \times 100 = 80$

Corrected Data

	Disease $+$	Disease $-$
Exposed	80	20
Unexposed	20	80

Risk Ratio

Observed: 2.125

Corrected: 4.00

When to Use Bias Correction

Good Candidates

- Dichotomised continuous variables
- Self-report measures with known validity
- Diagnostic categories
- Screening tools

Requirements

- Validation data available
- Non-differential assumption reasonable
- Measurement properties stable
- Same population

Important Assumptions

- Misclassification is independent of other variables
- Sensitivity/specificity are accurately estimated
- The same error rates apply across all participants

R Implementation

Simple R Code for Correction

```
# function to correct for misclassification
correct_prevalence <- function(p_obs, sens, spec) {
p_true <- (p_obs - (1 - spec)) / (sens + spec - 1)
return(p_true)
}

# apply to diseased group
p_true_diseased <- correct_prevalence(0.68, 0.8, 0.8)
# returns: 0.80
```

See also: `episensr` package for comprehensive bias analysis

Examples in Psychology

Measure	Sensitivity	Specificity	Expected Bias
PHQ-9 Depression	0.88	0.88	-19%
Self-report Cannabis	0.70	0.95	-31%
ADHD Parent Rating	0.78	0.87	-29%
Memory Test (MCI)	0.85	0.80	-28%

Interpretation

If true RR = 3.0, observed RRs would be:

- PHQ-9: 2.43 (19% attenuation)
- Cannabis use: 2.07 (31% attenuation)
- ADHD rating: 2.13 (29% attenuation)

Key Takeaways

1. **Measurement error is ubiquitous**
   - All psychological measures have error
   - Even "gold standards" aren't perfect

2. **Random error causes systematic bias**
   - Always toward the null
   - Can be substantial (often 20-50%)

3. **Correction is possible**
   - Requires validation data
   - Simple mathematical approach
   - Can recover true effects

4. **Implications for psychology**
   - Many null findings may be false
   - Replication "failures" may reflect measurement
   - Power calculations should account for error

References and Resources

Primary References in This Lecture

Fox, M. P., MacLehose, R. F., & Lash, T. L. (2021). *Applying quantitative bias analysis to epidemiologic data*. New York: Springer.

Full text: https://link.springer.com/content/pdf/10.1007/978-3-030-82673-4.pdf

Lash, T. L., VanderWeele, T. J., Haneuse, S., & Rothman, K. J. (2021). *Modern Epidemiology* (4th ed.). Philadelphia: Wolters Kluwer.

Additional Resources

- R package: `episensr` for sensitivity analysis
- R package: `quantbias` for quantitative bias analysis
- Online tools and tutorials at https://sites.google.com/site/biasanalysis/

Thank You!

Questions?