Recent developments in measurement error modelling

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The topic Group TG4

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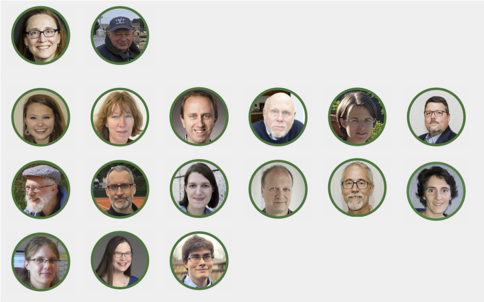
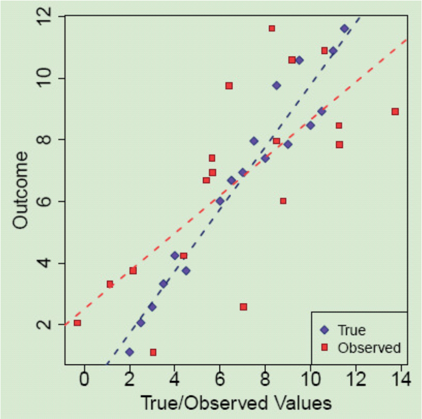


http://www.stratostg4.statistik.uni-muenchen.de/Home.html

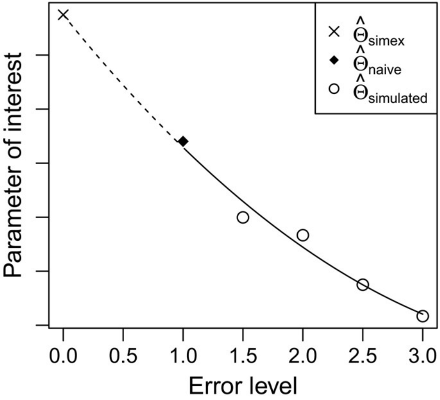
Why should we care about measurement errors ?



How should we deal with measurement errors ?

The answer: Statistical modelling

- Model relationship between bias an amount of measurement error : SIMEX



Likelihood/Bayes and Regression calibration

- General model including the measurement process

Main model	$[Y \mid X, Z, \beta]$
Error model	$[X^* \mid X, Z, \eta]$
Exposure model	$[X \mid Z, \lambda]$

  Use Maximum Likelihood or Bayes

- Measurement model: **Regression calibration**

  1. Find a model for $E(X|X^*, Z)$ by validation data or replication
  2. Replace the unobserved X by estimate $E(X|X^*, Z)$ in the main model
  3. Adjust variance estimates by bootstrap or asymptotic methods

Overview Articles

- Keogh R, Shaw P, Gustafson P, Carroll R, Deffner V, Dodd K, Küchenhoff H, Tooze J, Wallace M, Kipnis V, Freedman L (2020). *STRATOS guidance document on measurement error and misclassification of variables in observational epidemiology: Part 1 basic theory, validation studies and simple methods of adjustment*. Statistics in Medicine.
- Shaw P, Gustafson P, Carroll R, Deffner V, Keogh R, Tooze J, Kipnis V, Wallace M, Küchenhoff H, Freedman L (2020). *STRATOS guidance document on measurement error and misclassification of variables in observational epidemiology: Part 2 sample size, more complex methods of adjustment and advanced topics*. Statistics in Medicine.
- Wallace M (2020). *Analysis in an imperfect world*. Significance.

Berkson error

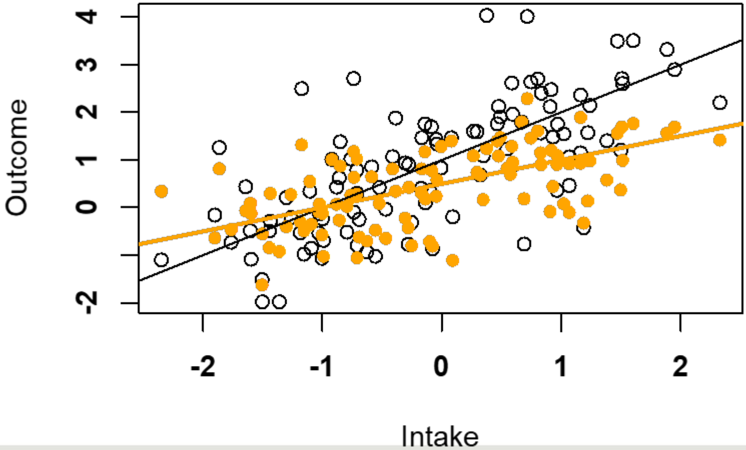
Observations X^* with Berkson eror are less variable than the true value X

$$X = X^* + error$$

Examples:

- A predicted value X^* from a regression equation has less variability than the original outcome, due to unexplained variance
- (unbiased) prediction with machine learning methods
- Regression calibration, since one uses a prediction equation for X.

Impact on Berkson error in outcome Variable Y



Predicted values in epidemiology

- There is increasing use of prediction and calibration equations in medicine
- Naïve analyses with predicted outcomes are subject to multiple biases
- Distributional summaries are biased, quantiles appear less extreme
- Regressions reliant on predicted outcomes will have biased coefficients
- Regressions reliant on predicted exposures need SE adjustment
- Awareness of the effects of Berkson error and methods to adjust for it need more attention

Regression calibration

Boe LA, Shaw PA et al. (2023) *Issues in Implementing Regression Calibration Analyses.* Am J Epidemiol.

1. To avoid bias, the calibration equation should include all confounders included in the outcome model.
2. a validation study should be conducted internally.
3. The validation study should be large enough
4. Same functional form of the exposure in main model and calibration model outcome model.
5. When regression calibration is used, SEs must be adjusted to account for the uncertainty in the estimation of the calibration equation.
6. When a calibration model covariate mediates the exposure-outcome relationship, special methods should be used.

Time-varying exposures prone to measurement error in survival analyses.

Work in progress by Cécile Proust-Lima, Viviane Philipps, Veronika Deffner, Hendrieke Boshuizen, Laurence Freedman, Anne Thiébaut

- Association between a time-varying exposure and a time to event:
- Measures of an underlying continuous-time process are measured with error and/or measured at sparse and irregular times

Methods:

- Last Value Carried Forward (LOCF)
- Regression calibration
- multiple imputation
- Joint modelling

Results

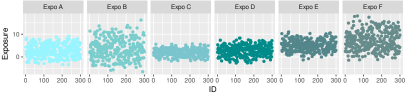
- LOCF may give strong biased estimates
- Approximations with Two-stage methods are valid if they account for early truncation by the event: using data available after the event if external (Regression Calibration) incorporating information on the event (Multiple Imputation)
- Joined model works very well (expected as the generation model) Results obtained under correct specification!
- Variance estimation with RC and MI using Rubins rule

Methods for handling misclassification in variables which are an outcome of latent class analyses

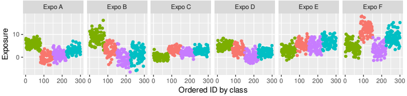
Proust-Lima C, Saulnier T, Philipps V, et al. (2023) *Describing complex disease progression using joint latent class models for multivariate longitudinal markers and clinical endpoints.* Statistics in Medicine.

Latent class Strategy

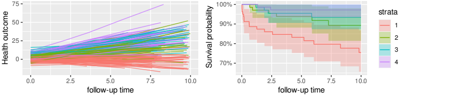
1. Estimate a latent class model on the exposure data:



2. Create a classification by assigning each subject to a fitted class:



3. Use this assignment in subsequent analyses



Main results

Latent class analysis:

- easy and graphical interpretation but inherent error of classification generally ignored
- induces incorrect interpretations especially when classes are not well separated

Methods:

- two effective methods of correction: conditional regression or two-stage
- may apply to any type of data
- require specific computation of the variance (bootstrap or analytical)
- rely on the assumptions of the model used Software: Mplus and Latent Gold (correction, conditional) R package lcmm (conditional, two-stage)

Machine learning and Measurement error

Guenther F, Brandl C, Winkler TW, et al. (2020) *Chances and challenges of machine learning-based disease classification in genetic association studies illustrated on age-related macular degeneration* Genetic Epidemiology.
Gustafson, P. (2021) Invited Commentary: Quantitative Bias Analysis Can See the Forest for the Trees Comment. AMERICAN JOURNAL OF EPIDEMIOLOGY

- machine learning algorithms estimate amount of misclassification and Measurement error
- integration in epidemiologic models via SIMEX, ML and Bayes possible
- methods for assessing measurement error (label noise in Machine learning literature) effects and correction methods are a current issue of research.