DOCUMENT RESUME

ED 471 345 TM 034 636

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TITLE Methods for Resampling Meta-Analyses with Multiple Effect Sizes.
PUB DATE 2002-11-00
NOTE 10p.; Paper presented at the Annual Meeting of the Mid-South Educational Research Association (Chattanooga, TN, November 6-8, 2002).
PUB TYPE Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS *Educational Research; *Effect Size; *Meta Analysis; *Statistical Distributions; Validity
IDENTIFIERS Independence; Nonnormal Distributions; *Resampling Techniques

ABSTRACT

During the 1990s, the use of meta-analytic methods in educational research has been widespread, and few aspects of education have escaped the meta-analytic revolution. The acceptance has not been complete, however, and several threats to validity remain. Prominent among these are the "normality" problem and the "independence" problem (whether multiple effect sizes from a single study should be analyzed independently). As a result, resampling methods have been proposed when it is assumed that distributions are nonnormal and multiple effect sizes are independent. However, resampling methods for nonnormal dependent multiple effect sizes have not been found. This paper discusses methods for resampling meta-analysis with dependent multiple effect sizes. First, the literature regarding the use of resampling for a univariate meta-analysis is reviewed. Then, a review of the independence problem (i.e., multiple effect sizes) is provided. Finally, resampling methods for countering the problems of nonnormality and nonindependence for the multivariate meta-analytic case are described. Educational researchers involved with meta-analysis are likely to find multiple effect sizes to be of issue. In most cases, if not all, multivariate methods will be preferred over univariate. Resampling methods can improve multivariate meta-analytic applications. (Contains 15 references.) (SLD)

Methods for Resampling Meta-Analyses with Multiple Effect Sizes

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Paper presented at the annual meeting of the Mid-South Educational Research Association, Chattanooga, TN, November 6, 2002.

Abstract

For the last decade, the use of meta-analytic methods in educational research has been widespread. Indeed, few aspects of education have escaped the meta-analytic revolution. However, the acceptance of findings has not been outright, as several validity threats remain debatable. Prominent among these are (a) the "normality" problem and (b) the "independence" problem (i.e., should multiple effect sizes from a single study be analyzed independently). Accordingly, resampling methods have been proposed when it is assumed that (a) distributions are non-normal and (b) multiple effect sizes are independent. Incidentally, however, resampling methods suitable for non-normal dependent multiple effect sizes have not been found. Herein, methods for resampling meta-analyses with dependent multiple effect sizes are discussed. First, the literature regarding the use of resampling for a univariate meta-analysis is reviewed. Second, a review of the "independence problem" (i.e., multiple effect sizes) is provided. Finally, resampling methods for countering the problems of "non-normality" and "non-independence" for the multivariate meta-analytic case are described. For educational researchers involved with meta-analysis, it is likely that multiple effect sizes will be of issue. In most cases (if not all), multivariate methods will be preferred over univariate. Moreover, resampling methods can improve multivariate meta-analytic applications.

Methods for Resampling Meta-Analyses with Multiple Effect Sizes

In general, a biased estimate (statistic) is undesirable because it could lead one to misconclude and subsequently make ineffective decisions. In a meta-analytic review, effect size estimates may be grouped and cumulated to yield a "grand effect size" estimate. In this case, accumulation of bias is also possible. The importance of an unbiased effect size estimate is evident when one considers that a grand effect size is intended to provide a global decision point regarding a phenomena's research base. Moreover, the scope of the meta-analytic applications (e.g., physical and social sciences) and range of interpretations (e.g., setting research priorities, establishing policies, drug certification) emphasize the need for improved bias control (modeling). Herein, resampling methods are explored as a means of controlling bias for multivariate non-normal effect size estimates.

Validity Threats to Meta-Analytic Findings

Independence Problem

In the simplest, non-degenerative case of a standardized mean difference (treatment effects) meta-analysis, a study (unit of analysis) will contain one treatment group and one endpoint (measure), thereby, producing one effect size estimate (statistic). However, a study can contain multiple treatment groups for a single control group and (or) multiple endpoints (measures) for each dependent variable. In these cases, multiple estimates of effect size within a single study are possible. Consequently, to statistically combine (synthesize) effect sizes within and (or) among studies, one must decide whether the multiple effect sizes are stochastically independent Indeed, Rosenberg, Adams, and Gurevitch (2000) suggest that the assumption of independence "is an important and substantive issue for the person carrying out the analysis to think through with care" (p. 6).

Normality Problem

To date, many approaches for modeling multiple effect sizes exist (see e.g., Hedges & Olkin, 1985 chap. 10; Glass, McGaw, & Smith, 1981, chap. 6; Gleser & Olkin, 1994; Kalaian & Raudenbush, 1996; Raudenbush, Becker, & Kalaian, 1988; Raudenbush & Bryk, chap. 7; Rosenthal & Rubin, 1986; Timm, 1999a, 199b). However, current multivariate models assume that the distribution of population effect sizes is multivariate normal (parametric modeling). Accordingly, in cases where the assumption of distributional normality is not met, parametric models can produce biased results. In general, resampling schemes can be used to approximate the distributions of statistics (to include multivariate analyses) under almost no distributional assumptions (thereby reducing bias of the parametric model). Indeed, resampling schemes for *independent non-normal* meta-analytic data have been advanced (see Adams, Gurevitch, & Rosenberg, 1997; Brown, Homer, & Inman, 1998). However, resampling applications for *non-independent non-normal* cases have not been found. Consequently, the following question is of interest: Are resampling methods applicable to modeling multivariate effect sizes?

Rationale for Resampling Multiple Effect Sizes

The term "resampling", as used herein, collectively refers to (a) jackknifing, (b) bootstrapping, and (c) permuting. A review of the suitability of each method to meta-analytic data now follows:

Jackknifing

In general, the "jackknife" procedure creates new samples (i.e., resamples) by sequentially removing an observation from the original (observed) data. Glass, McGaw, and Smith (1981) proposed using the jackknife to estimate confidence intervals for the multiple effect size case.

Based on simulation results, they concluded that "the jackknife method appears to be appropriate and equal to the task of handling data sets interlaced with complicated dependencies." (p. 208).

Bootstrapping

In general, the "bootstrap" procedure creates new samples by selecting an exact size simple random sample from the original (observed) data. According to Shao and Tu (1995) "the bootstrap provides a nonparametric alternative for approximating the distributions of statistics in multivariate analysis under almost no distributional assumptions" (p. 373). Accordingly, the bootstrap would seem an useful approach for meta-analytic data. However, applications of the bootstrap to multiple effect sizes could not be found. Consequently, the author is working on a bootstrap approach for both (a) testing homogeneity of effects sizes and (b) computing class (grand) confidence intervals.

Permuting

In general, a "permutation" procedure creates a new sample by randomly assigning subjects (in our case, effect sizes) to class levels. According to Good (2000), for a permutation test to be exact and unbiased the observations must be exchangeable. Furthermore, exchangeable observations in the case of dependence must also have normally distributed random variables. Based on this constraint, permuting does not seem to be a viable resampling approach for multiple effect sizes with a non-normal distribution.

Research Agenda

To improve the resampling of multiple effect sizes the following research agenda is proposed:

1. Where applicable, do resampling methods (i.e., nonparametric approaches) offer an improvement over parametric approaches to modeling multivariate effect sizes?

2. Where more than one resampling method is applicable, how does each compare with regard to desirable modeling properties?

3. Do diagnostics techniques (e.g., double bootstrapping) and computational enhancements (e.g., Monte Carlo simulation) improve resampling methods for the *non-normal non-independent* case?

Conclusions

Today, educational researchers must engage decades of primary research that is often interdisciplinary and from fields that continue to subspecialize. Consequently, meta-analytic studies are essential for cumulating findings and revealing new research opportunities. Resampling methods can improve these efforts.

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Author Note

This paper was prepared for the annual meeting of the Mid-South Educational Research Association (MSERA), November 6-8, 2002, Chattanooga, TN.

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