

Applied Psychological
Measurement

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in Complex Surveys**

Journal:	<i>Applied Psychological Measurement</i>
Manuscript ID:	APM-15-06-083.R2
Manuscript Type:	Computer Program Exchange
Keywords:	Computer program, Surveys, Statistics

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RRTCS: An R package for Randomized Response Techniques in Complex Surveys

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Randomized response (RR) techniques may be used to compile more reliable data, to protect the respondent's confidentiality and to avoid an unacceptable rate of nonresponse when the information requested is sensitive (for example, concerning racism, drug use, abortion, delinquency, AIDS or academic cheating). Standard RR methods are used primarily in surveys which require a binary response to a sensitive question, and seek to estimate the proportion of people presenting a given (sensitive) characteristic. Nevertheless, some studies have addressed situations in which the response to a sensitive question results in a quantitative variable. RR methods are usually developed assuming that the sample is obtained using simple random sampling. However, in practice most surveys are complex and involve stratification, clustering and an unequal probability of selection of the sample. Data from complex survey designs require special consideration with regard to the estimation of finite population parameters and to the corresponding variance estimation procedures, due to the reality of significant departures from the simple random sampling assumption. In such a complex survey design, unbiased variance estimation is not easy to calculate, because of clustering and the involvement of (generally complex) second-order inclusion probabilities. In view of these considerations, a new computer program has been developed to provide a method for estimating the parameters of sensitive characteristics under a variety of complex sampling designs.

Program Description

RRTCS is a new R package to perform the point and interval estimation of linear parameters using data obtained from RR surveys under complex sampling designs. The package works with a wide range of sampling designs, including stratified sampling, cluster sampling, unequal probabilities sampling and any combination of these. The package consists of 21 main functions, each of which implements one of the following RR procedures for complex surveys:

- *RR procedures to estimate parameters of a qualitative sensitive characteristic*: Christofides model (Christofides 2003), Devore model (Devore 1977), Forced Response model (Boruch 1972), Horvitz model (Greenberg et al. 1969), Horvitz model with unknown B (Chaudhuri 2011, page 42), Kuk model (Kuk 1990), Mangat model (Mangat 1992), Mangat model with unknown B (Chaudhuri 2011, page 53), Mangat and Singh model (Mangat and Singh 1990), Mangat, Singh and Singh model (Mangat, Singh and Singh 1992), Mangat, Singh and Singh model with unknown B (Chaudhuri 2011, page 54), Singh and Joarder model (Singh and Joarder 1997), Soberanis-Cruz model (Soberanis-Cruz et al. 2008) and Warner model (Warner 1965).

- *RR procedures to estimate parameters of a quantitative sensitive characteristic*: Bar-Lev model (Bar-Lev et al. 2004), Chaudhuri and Christofides model (Chaudhuri and Christofides 2013, page 97), Diana and Perri 1 model (Diana and Perri 2010, page 1877), Diana and Perri 2 model (Diana and Perri 2010, page 1879), Eichhorn and Hayre model (Eichhorn and Hayre 1983), Eriksson model (Eriksson 1973) and Saha model (Saha 2007).

The package includes an additional function which provides variance estimates of the RR estimators using resampling methods (Wolter 2007) under stratified, cluster and unequal

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probabilities sampling. These include the jackknife method (Quenouille 1949), the Escobar-Berger method (Escobar and Berger 2013) and the Campbell-Berger-Skinner method (Berger and Skinner 2005). Finally, the package includes 20 datasets with observations from different surveys conducted in real and simulated populations using different RR techniques.

Availability, Documentation and Distribution

The *RRTCS* package is available free of charge from the website <http://www.r-project.org> and works under Windows, Linux and MacOS. A reference manual (in PDF format) is also available from the same website. Some examples to illustrate its use in real surveys related to sensitive issues are included in this manual on CRAN. The current version of *RRTCS* is 0.0.1. Version 3.1.3 (or later) of the R software should be installed for optimal functioning of *RRTCS*.

Declaration of Conflicting Interests

The author(s) declare they have no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author(s) disclose receipt of the following financial support for the research, authorship and/or publication of this article: the development of the *RRTCS* package was partly funded by Ministerio de Educación, Cultura y Deporte (grant MTM2012-35650 and FPU grant programme, Spain) and by Consejería de Economía, Innovación, Ciencia y Empleo (grant SEJ2954, Junta de Andalucía, Spain).

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