

RANDOMIZED RESPONSE

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1. Introduction

The randomized response technique, first proposed by Warner [1965], was developed to obtain more reliable information concerning sensitive issues in sample surveys. It was hypothesized that greater respondent cooperation would be elicited through the use of a device which selects, by chance, one of two statements (or questions) to which the respondent is to reply truthfully, without revealing this selection to the interviewer. The two statements are of the form: (1) "I have (sensitive) attribute A" and (2) "I do not have attribute A." The respondent is instructed to reply only "yes" or "no" to the statement selected by the randomizing device. Because the interviewer is unaware of the statement to which the respondent is replying, confidentiality is maintained; and hence, both the respondent and the interviewer are protected from embarrassment.

Under the assumption that each respondent answers truthfully, an unbiased estimate of the population proportion with sensitive attribute A is easily obtained. Let

θ = the population proportion of yes responses;

π_A = the true proportion of the population with attribute A;

P = the (known) probability that the randomizing device selects the sensitive statement ($P \neq 1/2$).

Then

$$\theta = P\pi_A + (1-P)(1-\pi_A);$$

and the unbiased estimate resulting from this relationship is

$$\tilde{\pi}_A = [\tilde{\theta} - (1-P)]/[2P-1] \quad (1.1)$$

where $\tilde{\theta}$ is the proportion of "yes" responses from a simple random sample (with replacement) of size n. The variance of $\tilde{\pi}_A$ is:

$$\text{Var}(\tilde{\pi}_A) = \frac{\pi_A(1-\pi_A)}{n} + \frac{P(1-P)}{n(2P-1)^2}.$$

Note that the second term in this expression is the additional variance due to the randomizing device.

Numerous modifications of Warner's technique have been proposed. Horvitz, Shah and Simmons [1967] suggested that respondent cooperation might be further

increased if two unrelated statements are used. In this case, the statements are of the form: (1) "I have attribute A" and (2) "I have (nonsensitive) attribute B." If π_B , the population proportion with attribute B, is known, the estimate of π_A is:

$$\tilde{\pi}_A = [\tilde{\theta} - (1-P)\pi_B]/P; \quad (1.2)$$

where $\tilde{\theta}$ and P are as defined above.

If π_B is not known, two independent samples are required to estimate the two population proportions, π_A and π_B . Let

$\tilde{\theta}_i$ = the proportion of "yes" responses in sample i;

P_i = the (known) probability that the randomizing device selects the sensitive statement in sample i ($P_1 \neq P_2$);

n_i = the sample size for sample i.

Then (again assuming that all responses are truthful) an unbiased estimate of π_A is

$$\tilde{\pi}_A = \frac{(1-P_2)\tilde{\theta}_1 - (1-P_1)\tilde{\theta}_2}{P_1 - P_2}. \quad (1.3)$$

(Variance formulae and further properties of the estimates (1.2) and (1.3) are given by Greenberg, et al. [1969].)

Folsom, et al. [1973] modified this two sample technique further by using two nonsensitive questions. In the first sample, nonsensitive question 1 is asked directly while non-sensitive question 2 is used in the randomizing device; and in the second sample, nonsensitive question 2 is asked directly while nonsensitive question 1 is used in the randomizing device.

Greenberg, Abernathy and Horvitz [1969] and Greenberg, et al. [1971] proposed still another modification of the two sample technique to obtain quantitative data on sensitive issues. Here, the two questions might be: (1) "How much money did you earn last year?" and (2) "How much money do you think a person of your age must earn to support a family of your size?" Responses to these questions can then be used to estimate the mean income by methods analogous to those described above.

Further modifications and theoretical investigations of the properties of the randomized response techniques may be found in Abul-Ela, Greenberg and Horvitz [1967], Moors [1971], Warner [1971], Singh [1976], Tamhane [1981], and elsewhere.

The purpose of this paper is to discuss the effects of these randomized response techniques, as compared to more conventional interview techniques, on nonresponse in sample surveys. The findings of several field studies, which employed both randomized response and conventional interview methods, are reviewed in the following section. A discussion of the advantages and disadvantages of randomized response techniques is given in Section 3.

2. Literature Review: Field Studies

Krotki and Fox [1974] reported on the results of a comprehensive fertility study comparing a randomized response technique with a mail-back questionnaire and with a face-to-face interview. A stratified cluster sample of 1045 Edmonton women between 18 and 54 years of age was divided into three interpolated sub-samples. Respondents in one sub-sample were asked all fertility questions in the interview, including questions on abortion.

In the second sub-sample, "sensitive" questions were asked using the following randomized response procedure: Respondents were given a plastic box containing 35 blue and 15 red balls, together with a card containing seven pairs of sensitive and unrelated statements. Respondents were instructed to shake the box and to answer the question indicated by the color of the ball appearing in a window in the box. The sensitive issues included questions pertaining to premarital abortions, lifetime abortions, and abortions within the previous year. The population proportions of the incidences of the unrelated questions were estimated either from census data or data obtained in the survey itself.

Respondents in the third sub-sample were given an anonymous mail-back questionnaire containing questions identical to those asked in the randomized response sub-sample.

The authors concluded that the response rates for the randomized response method (97 and 95 percent) were substantially higher than those for the mail-back questionnaire (73 percent). No response rate was given for the direct inquiry method.

Further, comparisons of estimated incidence rates revealed a greater tendency for respondents to report "sensitive" events if the randomized response procedure was used than if the questions were part of a self-administered questionnaire, and a greater tendency in both of these methods than in the direct inquiry method.

The authors note, however, that a high proportion of respondents said that their friends would answer a direct question concerning abortion; and a sizable proportion doubted the privacy guaranteed

by the randomized response method. Hence, the need for the randomized response technique in this survey may be questioned.

In a study of illicit drug use in the Army, Brown [1975] compared a mail-back version of the randomized response technique with a conventional mail questionnaire. The randomized response questionnaire consisted of two sets of questions: Set A consisted of five nonsensitive questions while set B contained five drug questions. The nonsensitive questions pertained to characteristics possessed by known proportions of the target subjects. The randomizing device was based on census data which indicate that almost exactly eight percent of all births each year take place in November. The respondents were directed to answer the sensitive questions if their mother was not born in November; and hence, a known percentage of all respondents answered the sensitive questions.

The results of the study indicated a superiority of the conventional questionnaire. The return rate was significantly higher for the conventional questionnaire (48 percent) than for the randomized response questionnaire (31 percent); while reported drug-use rates were not significantly related to the method used.

Goodstadt and Gruson [1975] used the quantitative-data randomized response model of Greenberg, et al. [1971] to compare drug-use estimates derived from either direct questioning or the randomized response procedure. Packages of questionnaires were randomly distributed to 854 Ontario high school students. Two hundred nine of these received a standard set of six questions pertaining to previous and future use of a number of drugs. One of the six questions required subjects to indicate the number of times that they had used each of six drugs (alcohol, cannabis, hallucinogens, amphetamines, tranquilizers and heroin) during the previous three months. Two hundred fourteen students were asked to answer this same drug-use question; however this was the only drug-use question asked of these students.

The remaining students comprised the two independent samples required for the randomized response procedure. Students in the first randomized response group ($n = 218$) answered either the drug-use question or a nonsensitive question concerning entertainment during the previous three months. (The six categories of entertainment, corresponding to the six categories of drugs, referred to watching T.V., visiting a library, visiting a museum, attending a play, attending a rock concert, and attending a classical concert.) Students in this group were instructed to answer the drug-use question if their telephone

numbers ended in the digits 0, 1 or 2; and to answer the entertainment question otherwise. The procedure for the second randomized response group (n = 213) was identical, except that the instructions for responding to the two types of questions were reversed.

The criterion for satisfactory completion of a questionnaire was any numerical answer indicating drug use. Employing this criterion, the authors found a significantly greater completion rate for the randomized response method than for the direct questioning methods. An overall average of 13.3 percent of the students in the two direct methods groups failed to complete the drug-use question, compared to 5.5 percent of the students in the randomized response groups ($p < .001$). This overall difference in completion rates was significant for each of the six drug categories investigated.

Further, comparisons of mean drug use revealed that students in the randomized response groups reported significantly more drug use than did students in the direct questioning groups. This applied to all drug categories except hallucinogens. There was no evidence, however, that the randomized response procedure was more effective with respect to the more socially sensitive drug categories.

Four interview techniques were compared by Locander, Sudman and Bradburn [1976] in a study carried out in Chicago. The four techniques were personal interview, telephone interview, self-administered questionnaire, and the unrelated question randomized response technique. Further, to examine the joint effect of interview technique and question threat on response rate and response bias, four "threatening" topics were chosen for study. The four topics included questions about ownership of a Chicago Public Library card, voter registration and voting behavior, involvement in bankruptcy, and being charged with drunken driving.

These four topics were chosen because, a priori, the authors felt that the level of "threat" would increase as one goes from a question concerning ownership of a library card to one on being charged with drunken driving; and because results could be validated using public records. (The respondents in the library card and voting behavior categories were drawn from a household probability sample; and responses were validated from Chicago Public Library and city voting records. The respondents in the bankruptcy category had all declared bankruptcy in the recent past. The respondents in the drunken driving category had all been recently charged with drunken driving.)

The randomized response technique achieved interview completion rates similar to personal interviewing for each of the "threatening" topics considered. The total completion rate for the randomized response technique was 70

percent (standard error = 3.0); and 69.8 percent of the personal interviews were completed (standard error = 2.95). Neither of these techniques did as well as the telephone interview, which achieved a total completion rate of 81 percent (standard error = 2.58). The self-administered questionnaire had the lowest completion rate for each topic.

The superiority of the telephone interview technique was most striking for the drunken driving topic: 77.8 percent of the interviews were completed, as compared to 57.1 percent of the personal interviews and 58.1 percent for the randomized response technique.

The authors also compared the techniques with respect to response bias. By validating the responses using public records, the proportion of respondents who gave incorrect answers was computed for each interview technique by "threatening" topic category.

The randomized response method achieved the lowest rate of incorrect response for both the drunken driving and bankruptcy topics. However, the method had the highest rate of incorrect response for the library card ownership topic, and for a question concerning voting in a recent primary election.

One way of looking at these results, as suggested by the authors, is to note that response errors may be due either to over-reporting a socially desirable act, or to under-reporting a socially undesirable act. The authors concluded that randomized response procedures are least effective in reducing the first type of response error, and most effective in reducing the second type.

Zdep and Rhodes [1976], in a study concerning child abuse, compared the randomized response technique of Folsom, et al. [1973] to two self-administered questionnaire methods. Two national probability samples of adults aged eighteen or older were used. The first sample was screened for the presence of children in the household; and the screened sample was randomly divided into halves. In the first sub-sample, subjects responded to the randomizing device (a coin) by answering either the child abuse question or one of two nonsensitive questions. In the second sub-sample, subjects answered either the child abuse question or the other nonsensitive question. Each sub-sample was also asked directly the nonsensitive question used in the randomizing device of the alternate sample.

The results of this survey were compared to the results of a second national probability sample conducted eight weeks later. In this latter survey, the child abuse question was asked directly of all respondents. A split sample was used in which half of the respondents marked their answers on a form given to them by an interviewer,

sealed it in an envelope, and then returned it to the interviewer. The other half responded in a similar manner, but returned the envelope by mail.

The response rates for the two randomized response groups were 98 percent (n = 515) and 99 percent (n = 480), respectively. The response rate for the sample required to return the questionnaire to the interviewer was 88 percent (n = 538); and for the mail-back questionnaire sample, the response rate was 75 percent (n = 465). Thus, the randomized response technique greatly improved the response rate, as compared with either of the self-administered techniques.

Further, estimates of the proportion of households having engaged in child abuse indicated that the randomized response method was more successful in getting people to respond affirmatively than were the self-administered methods. The estimates for the two randomized response samples were 15 percent and 16 percent; while the two self-administered questionnaire techniques gave estimates of three percent and four percent, respectively. As the authors point out, for each of the self-administered surveys, the estimates did not differ appreciably from zero, indicating that the subject matter was highly sensitive.

3. Discussion

The results of the studies discussed in Section 2 indicate that randomized response techniques can increase response rates substantially, as compared with other interview methods. It is apparent that the techniques become increasingly appropriate as the sensitivity of the topic (and hence, the likelihood of nonresponse) increases.

These studies also indicate that randomized response procedures can reduce response bias due to under-reporting socially sensitive acts such as drug-use, child abuse, and abortion.

A third advantage of randomized response procedures is that the interviewer, as well as the respondent, is protected from embarrassment and legal actions which might result from surveys concerning illegal activities.

Of course, randomized response procedures also have several disadvantages which should be considered. Interviews using randomized response techniques require more time to complete than do other types of interviews, because the relatively complex procedures must be explained. This may cause higher nonresponse rates than would have occurred had the question been asked directly.

Other disadvantages of the technique are noted by Berman, McCombs and Boruch [1977]. The authors report on a study in which 72 percent of the respondents felt, to some degree, that the technique made

telling the truth less important, since random errors are already part of the procedure. Further, the authors hypothesized that the very use of the method suggests to the respondent that the subject matter of the question is highly personal, even though the respondent might not have felt so had he been asked the question directly. The authors commented that in either case, response error would likely increase, nullifying the positive aspects of the technique.

Hence, randomized response techniques may actually result in increased nonresponse rates and response bias when the subject matter is only slightly sensitive or socially desirable. The results of the study by Locander et al. [1976], discussed in Section 2, also support this conjecture.

In summary, the randomized response procedure is a useful method for reducing both nonresponse rates and response bias in sample surveys concerning highly sensitive issues. However, use of the procedure in surveys involving nonsensitive issues may be questionable.

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