

RANDOMIZED RESPONSE TECHNIQUE IN A NATIONAL SURVEY

Iris M. Shimizu and Gordon Scott Bonham
National Center for Health Statistics

1. INTRODUCTION

Up until the Supreme Court ruling in 1973, abortions were illegal in many States and greatly restricted in most other States. Asking women to report abortions was often asking them to report illegal behavior and to potentially open themselves to criminal prosecution. Even where abortions were legal, the sensitivity of the subject led to underreporting. The importance to fertility and health research of knowing about the amount of abortion, however, was still great.

Surveys designed to measure abortions by direct questioning had been able to elicit little reporting of abortion [10]. Registration or reports of legal abortions in the United States [2, 9] did not include illegal abortions nor abortions from non-reporting jurisdictions or facilities. In addition, little information is available from registration on the characteristics of women whose abortions are reported.

Randomized response is a technique introduced by Warner [8] to obtain estimates of behavior that is normally underreported, most often because it is sensitive or may have social stigma attached to it. The randomized response technique allows the respondent to answer truthfully without the interviewer being able to know whether or not the respondent has the sensitive characteristic. Horvitz and his associates [4] found that the randomized response technique produced an estimate of illegitimacy almost as high as the known illegitimacy in the selected sample. Another North Carolina study yielded an estimate of abortions for the United States that was in line with previously hypothesized numbers, if the total United States experience was similar to that of North Carolina [1].

The randomized response technique of interviewing on sensitive topics was used by the National Survey of Family Growth (NSFG) to ascertain the incidence of abortion within a twelve month period, and yet preserve the individual respondent's complete privacy. The model chosen for the survey was the two unrelated questions model investigated by Folsom, et al [3]. The results indicate that a substantial amount of abortion was reported, even though the survey yielded divergent estimates for the amount of abortion.

2. IMPLEMENTATION OF RANDOMIZED RESPONSE MODEL

2.1 The National Survey of Family Growth

The NSFG is based on a multi-stage probability sample of women 15 to 44 years of age, living in households in the conterminous United States. To be eligible for the NSFG, a woman must be either ever married, or single (i.e., never married) with her own children living with her. The data are weighted to provide national estimates. The survey is conducted biennially by the National Center for Health Statistics. Data for the present discussion comes from the first cycle of the survey, which began in 1973.

The field work for that cycle was conducted by the National Opinion Research Center of the University of Chicago between July 1973 and February 1974. The median date of the interviews was about September 15, 1973. The NSFG measure of abortion was in reference to the 12 months preceding the date of interview. Although this measurement reflects no exact calendar time period, discussion in this paper will be made as if the twelve month incidence was congruent with the period September 16, 1972, through September 15, 1973. All figures shown are provisional.

2.2 Application in the Survey

The randomized response model employed two random half-samples. All sample households were numbered sequentially at the time the sample was drawn. If the last digit of the household number was odd, any eligible respondent interviewed in the household fell into the first half-sample. This included 4,926 respondents. During the interview, they were asked the innocuous question:

This time last year, did you live in a different county or State than this one?

(IF THE RESPONDENT NOW LIVES IN LOUISIANA, SAY: "different parish or State.")

IF R. NOW LIVES IN THE NEW ENGLAND STATES, SAY: "different township or State.")

At the end of the interview, respondents in half-sample 1 were handed a card with the questions:

[Heads] In the past 12 months, I had an abortion done to end a pregnancy.

[Tails] Was your mother born in April?

They were instructed to toss a penny and if a head showed, then the respondent was to answer the question after the head on the card. If a tail showed, then the respondent was to answer the question after the tail on the card. They were to answer only "yes" or "no".

If the last digit of the household number was even, the interviewed respondent was in half-sample 2. This half-sample included 4,871 women who were directly asked:

In what month and year was your mother born?

At the end of the interview, half-sample 2 respondents were given the same instructions as the half-sample 1 respondents and then given a card with the questions:

[Heads] In the past 12 months, I had an abortion done to end a pregnancy.

[Tails] This time last year, I lived in a different county or State than this one.

The responses to the above questions were used to obtain the following estimates:

- $\hat{\lambda}_1^r$ = estimated probability of a "yes" response to the randomized question asked in the first half-sample.
- $\hat{\lambda}_1^d$ = estimated probability of a "yes" to the direct question in the first half-sample and is an estimate of the proportion of the population who lived in a different county or State last year.
- $\hat{\lambda}_2^r$ = estimated probability of a "yes" response to the randomized question in the second half-sample.
- $\hat{\lambda}_2^d$ = estimated proportion of the population whose mothers were born in April, derived from the second half-sample.

The probability of selecting the sensitive question on abortion is assumed to be $P = 1/2$, since a penny was the randomizing device. This assumption, together with the above estimates, leads to the following unbiased estimates of π_A , the

proportion of the population having abortions. That is

$$\hat{\pi}_A(1) = \frac{1}{P} \{ \hat{\lambda}_1^r - (1-P) \hat{\lambda}_2^d \} = 2\hat{\lambda}_1^r - \hat{\lambda}_2^d \quad (2.1)$$

$$\hat{\pi}_A(2) = \frac{1}{P} \{ \hat{\lambda}_2^r - (1-P) \hat{\lambda}_1^d \} = 2\hat{\lambda}_2^r - \hat{\lambda}_1^d \quad (2.2)$$

The final estimate is then the weighted average

$$\hat{\pi}_A = W \hat{\pi}_A(1) + (1-W) \hat{\pi}_A(2) \quad (2.3)$$

where W was chosen to minimize the variance of $\hat{\pi}_A$. If

$$\Sigma_1^2 = \text{Var } \hat{\pi}_A(1) \quad (2.4)$$

$$\Sigma_2^2 = \text{Var } \hat{\pi}_A(2) \quad (2.5)$$

$$\Sigma_{12} = \text{Cov}[\hat{\pi}_A(1), \hat{\pi}_A(2)] \quad (2.6)$$

then the value of W that minimizes the variance of $\hat{\pi}_A$ is

$$W_{\text{opt}} = (\Sigma_2^2 - \Sigma_{12}) / (\Sigma_1^2 + \Sigma_2^2 - 2\Sigma_{12}) \quad (2.7)$$

and the variance of $\hat{\pi}_A$ becomes

$$\text{Var}(\hat{\pi}_A) = (\Sigma_1^2 \Sigma_2^2 - \Sigma_{12}^2) / (\Sigma_1^2 + \Sigma_2^2 - 2\Sigma_{12}). \quad (2.8)$$

Estimates of the variances and covariances of $\hat{\pi}_A(1)$ and $\hat{\pi}_A(2)$ were substituted in (2.7) and

(2.8). A balanced half-sample replication procedure [5] was used to compute the variances

and covariances of $\hat{\lambda}_1^r$, $\hat{\lambda}_1^d$, $\hat{\lambda}_2^r$, and $\hat{\lambda}_2^d$, which

values were then used in the straightforward formulae for estimating the variances and covariance of $\hat{\pi}_A(1)$ and $\hat{\pi}_A(2)$.

2.3 Effectiveness of the Technique

Of the 9,797 respondents, 98.5 percent accepted the randomized response "game" and gave an answer of "yes" or "no". Seven respondents did not answer because they could not read and twenty refused to give an answer. Another 124 were not asked the question or did not give a codable answer. Of these 151, about 55% and 45% were in the odd and even samples respectively. Interviewers reported that some respondents felt flipping a coin was foolish, and immediately answered "no" to both, but no count was made of these respondents. There was no other report of adverse reactions, and the small rate of non-response on this question compares favorably with other items on the questionnaire. Non-response was actually higher for the innocuous questions when asked directly during the course of the interview than for the randomized response question itself. Of the half-sample asked when their mother was born, 8.2 percent did not know the month and an additional 3.0 percent were erroneously not asked the question. For the question on whether they lived in the same county and State last year, there were no "don't know" responses but 3.0 percent of the women were erroneously not asked the question. Most of the not ascertained cases were due to interviewer confusion--asking the wrong question for a woman in a specified half-sample, or completely missing the question. In the NSFG, missing data were imputed from similar respondents where "similar" respondents are defined to be of the same age, race, and, for migration, education.

3. FINDINGS

3.1 NSFG Estimates

The provisional estimates of women with abortions produced through the randomized response technique are shown in the table, along with all the components of the estimator. The overall estimated proportion of the ever married plus single women with their own children in the household who had abortions is 3.0 percent with a standard error of 0.8 percentage points. Based on an estimated 31,018,000 women ever married or single with their own children, an estimated 930,000 women in these categories had an abortion within the 12 month reference period with a standard error of the 248,000 assuming the randomized response procedure achieved accurate reporting.

However, there is wide variation in the half-sample estimates of abortion. According to the table, 5.3 and 0.6 percent of the women ever married or single with their own children, had abortions in half-samples 1 and 2, respectively. The difference in the two half-sample estimates is 3.0 times the standard error of the difference. This great a difference would not be expected by chance. Potential sources of error or bias are: (1) selection of the two half-samples and differential weighting; (2) the randomizing device or its application; (3) interviewers asking inappropriate questions, failing to ask appropriate questions, or incorrectly wording questions; (4) respondents failing to answer questions;

(5) respondents misunderstanding the questions; (6) respondents falsifying their answers; (7) interviewer recording, coding, or keypunch error; or (8) data editing and imputation procedures. Although all these errors probably exist in every survey, the present concern is a bias in one half-sample versus the other half-sample. The only differences between the two half-samples (other than the respondents) were the questions that appeared differently for the two sets of respondents. Hence, the difference in estimates appears to be respondent misunderstanding on these questions.

It was observed during interviewer training for the second cycle of the survey that "county" was often misread as "country". In half-sample 1, the interviewer verbally asked the innocuous question on migration. In half-sample 2, the innocuous question on migration was printed on a card for the respondent to read. The Cycle 1 trained interviewers could not have made the wording mistake often as the NSFG estimate of migration from half-sample 1 is more similar to the Census estimate of inter-county migration than of inter-state migration. However, the respondents were not trained, and might have misread the word as the untrained interviewers tended to do at first.

In view of these possible problems of respondent misunderstanding in half-sample 2, it has been suggested that the result from half-sample 2 be discarded in favor of that from half-sample 1, by itself. Since the NSFG sample was randomly divided, the first half-sample is still a probability sample.

Whether one accepts as best the weighted average of the two half-sample estimates or just the estimate based on the first half-sample, it is still likely that abortions are undercounted in the NSFG since respondents may be hesitant to report having an abortion even if they are convinced that no one will know their answer.

3.2 Comparison with Other Data

How do the findings on abortion using the randomized response compare to other measures of abortion? It was possible for women to volunteer abortions in the NSFG during the time they were asked about birth control methods. Some encouragement was given by abortion being included in a list of family planning methods handed to the respondent during this part of the interview. Relying on this volunteered information alone would have produced an estimate of only 28,000 women having abortions in the previous twelve months, or 3.0 percent of the estimate produced using randomized response techniques. In other surveys, directly asking women about abortions during interview has achieved very little reporting of abortion. The National Fertility Study, conducted in late 1970 and early 1971, found 1.5 percent of the ever married women 15-44 years old had ever had an abortion, and only 0.3 percent reported an abortion within the 12 months prior to interview.^{1/} This latter estimate is much smaller than the corresponding estimate of 2.8 percent of ever married women produced in the NSFG.

The major sources of abortion data have been

the Center for Disease Control and the Alan Guttmacher Institute. In 1973, the Center for Disease Control collected reports on 615,831 legal abortions from the central health agencies in 24 States and the District of Columbia and from hospitals and other facilities in the remaining States [2]. These reports did not cover all facilities performing legal abortions, nor did all States report for the full 12 months. Also in 1973, the Alan Guttmacher Institute surveyed health service providers and arrived at an estimate of 745,400 legal abortions with an estimated underreporting of 5-10 percent [9]. Direct comparison cannot be made between the NSFG estimates of abortion and those from the Center for Disease Control or the Alan Guttmacher Institute because the data relate to different populations of women--most notably the NSFG did not interview single women without their own children in the household.

While the Center for Disease Control did not tabulate data on abortions separately for widowed, divorced, and separated women or for never married women, it does report that 27.4 percent of the legal abortions in the 24 States reporting marital status were to currently married women.^{2/} If this percentage applied to all conterminous States, 167,000 of the legal abortions reported to the Center for Disease Control and 203,000 of the legal abortions reported to the Alan Guttmacher Institute would be to currently married women.

Additional adjustments would be needed to restrict the data from the Center for Disease Control and the Alan Guttmacher Institute to produce estimates that are comparable to the estimates from the NSFG. However, this would require data on how many of the reported abortions occurred to currently married women below age 15 or above age 44, and how many of the reported abortions were the second, third, etc., to an individual woman during 1973. In addition, abortions occurring in the last quarter of 1973, well after the Supreme Court ruling on abortions, would need to be deleted and abortions occurring in the last quarter of 1972, before the ruling, would need to be added. All of these adjustments would further reduce the number of reported abortions in the Center for Disease Control and the Alan Guttmacher Institute data. Therefore, failure to make these adjustments should result in an underestimate of the difference between the magnitude of abortion measured in the NSFG and the magnitude of legal abortion reported to the Center for Disease Control and the Alan Guttmacher Institute.

7. CONCLUSION

The use of the randomized response method of obtaining information on sensitive, and therefore underreported, behavior has produced higher estimates of abortion than have previously been achieved. Its use in the National Survey of Family Growth was therefore valuable. Great confidence cannot be placed in any single estimate of abortion, however, because of apparent problems in questionnaire design and the additional variance introduced by the randomized response technique. The survey produces an estimate of

3.0 percent of the surveyed women, who include both ever married women and single women if their own children live with them, having had an abortion within the preceeding 12 months. It is possible, however, that an estimate slightly greater than 5.0 percent is more appropriate. This indicates that between 3 and 8 times as many abortions were performed in 1973 as were obtained through the present abortion reporting systems.

The second cycle of the National Survey of Family Growth, with fieldwork scheduled during the first half of 1976, should provide further estimates on abortion and further testing of this application of the randomized response technique. Three changes have been made for the second cycle: (1) the way a pregnancy ended is asked directly as well as questions about abortions by the randomized response method, (2) a question on being the only child replaces the question on whether the mother was born in April, the latter having had high rates of "don't know" in Cycle I, and (3) the card handed to the respondent in half-sample 2 reads:

This time last year, I lived in a different county in this State--or a different State--than this one.

Although the randomized response models have been used for at least ten years, there is still need for work on the Field Administration and subsequent analysis of these models. This analysis is but a first step in the investigation of the technique, especially as it relates to measuring the incidence of abortion. Additional analysis can and will be made using the NSFG data from Cycle I, with further clarifications being made once the Cycle II data are available.

FOOTNOTES

1/ Tabulations made by the authors from the 1970 National Fertility Study data file obtained from the Data and Program Library Service and Larry Bumpass, Department of Sociology, at the University of Wisconsin. The survey was conducted by Norman B. Ryder and Charles F. Westoff, Office of Population Research, Princeton University. See [10] for a discussion on the abortion findings.

2/ This is not too different from results found in 1970 where 29.9 percent of the abortions were to currently married women, 14.2 percent to widowed, divorced, or separated women, and 55.9 percent to single women [6].

REFERENCES

- [1] Abernathy, James R., Bernard G. Greenberg and Daniel G. Horvitz, "Estimates of Induced Abortion in Urban North Carolina," Demography 7 (February 1970), 19-29.
- [2] Center for Disease Control, Abortion Surveillance: 1973, (May 1975).

- [3] Folsom, Ralph E., Bernard G. Greenberg, Daniel G. Horvitz, and James R. Abernathy, "The Two Alternate Questions Randomized Response Model for Human Surveys," Journal of the American Statistical Association, 68, (September 1973), 525-30.
- [4] Horvitz, Daniel G., B. V. Shah, and Walt R. Simmons, "The Unrelated Question Randomized Response Model," Proceedings of the Social Statistics Section, American Statistical Association, 1967, 65-72.
- [5] National Center for Health Statistics, "Replication, An Approach to the Analysis of Data from Complex Surveys," Vital and Health Statistics, PHS Pub. No. 1000 - Series 2 - No. 14. Public Health Service, Washington, D.C., United States Government Printing Office, April 1966.
- [6] Tietze, Christopher and Sarah Lewit, "Joint Program for the Study of Abortion (JPSA): Early Medical Complications of Legal Abortion," Studies in Family Planning, 3, (June 1972), 97-122.
- [7] United States Bureau of the Census, "Mobility of the Population of the United States: March 1970 to March 1971," Current Population Report, Series P-20, No. 235, (April 1972), Table 7.
- [8] Warner, Stanley L., "Randomized Response: A Survey Technique for Eliminating Evasive Answer Bias," Journal of the American Statistical Association, 60, (March 1965), 63-9.
- [9] Weinstock, Edward, Christopher Tietze, Frederick S. Jaffe, and Joy G. Dryfoos, "Legal Abortions in the United States Since the 1973 Supreme Court Decisions," Family Planning Perspectives, 7, (January/February 1975), 23-31.
- [10] Westoff, Charles F. "The Yield of the Imperfect: The 1970 National Fertility Study," Demography, 12, (November 1975), 573-80.

Provisional Estimates for Number and Percent of Women 15 to 44 Years Old Who had
Abortion in the 12 Months Prior to Interview, by Marital Status: United States 1973.
(Standard Error of Estimates Shown in Parentheses)

	Total	Single with Children	Ever Married	Marital Status	
				Currently married	Widowed divorced, separated
Total number of women (thousands)	31,018 (395)	771 (59)	30,247 (390)	26,646 (364)	3,601 (128)
Number of women with an abortion in 12 months (thousands)	930* (248)	77* (29)	847* (242)	693* (213)	194* (61)
<u>Percent</u>					
$\hat{\pi}_A$ - Women with an abortion in 12 months, combined	3.0* (0.8)	10.0* (3.7)	2.8* (0.8)	2.6* (0.8)	5.4* (1.7)
$\hat{\pi}_A(1)$ - Women with an abortion in 12 months, half-sample 1	5.3 (1.1)	9.0* (4.8)	5.3 (1.1)	5.1 (1.1)	6.4* (2.3)
$\hat{\pi}_A(2)$ - Women with an abortion in 12 months, half-sample 2	0.6* (1.1)	11.4* (5.6)	0.3* (1.1)	-0.2* (1.1)	4.0* (2.7)
$\hat{\lambda}_1^r$ - Yes to randomized question, half-sample 1	7.0 (0.5)	7.6 (2.3)	7.0 (0.5)	6.8 (0.5)	8.0 (1.0)
$\hat{\lambda}_1^d$ - Migrated during 12 months, half-sample 1	12.0 (0.6)	5.4 (1.8)	12.2 (0.6)	12.7 (0.7)	8.4 (1.2)
$\hat{\lambda}_2^r$ - Yes to randomized question, half-sample 2	6.3 (0.4)	8.4 (2.7)	6.2 (0.4)	6.3 (0.5)	6.2 (1.2)
$\hat{\lambda}_2^d$ - Mother was born in April, half-sample 2	8.6 (0.5)	6.3 (1.4)	8.7 (0.5)	8.6 (0.5)	9.6 (1.1)
$\text{Cov}[\hat{\pi}_A(1), \hat{\pi}_A(2)]$	0.2	0.4	0.1	0.2	0.1

*Relative standard error greater than 25.0 percent