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Estimating Response Rates in Random-Digit-Dialing Surveys That Screen for Eligible Subpopulations

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1. Introduction

Nonresponse causes bias in survey results when nonrespondents differ in important ways from respondents. This paper focuses on potential nonresponse bias in surveys that first screen a sample to determine eligibility for the study and then complete an interview with eligible respondents. Nonresponse to the screening interview may be correlated with eligibility criteria in such a way that typical response rate calculations fail to accurately represent the proportion of eligible sample members that participate in the survey.

An estimate of the eligibility rate among sample members that cannot be contacted and screened during the field data collection period is an important component of the formula used to calculate overall response rates. As suggested in recommendations published recently by the American Association for Public Opinion Research (AAPOR, 1998), if there is reason to suspect that screening respondents and nonrespondents have different eligibility rates, then it is important to use distinct final dispositions (e.g., telephone dialing outcomes or in-person contact outcomes) for screened and unscreened cases and develop separate estimates of eligibility rates.

This paper extends an approach suggested by Massey (1995) for estimating the response rate in telephone surveys with screening by using external data to estimate the percentage of eligible households. In his paper Massey used as an example the telephone call outcomes from the first three calendar quarters (April 1994-December 1994) of the National Immunization Survey (NIS), a large random-digit-dialing (RDD) telephone survey . However, the conceptual approach is applicable in any survey, regardless of data collection mode, where screening for eligibility is a design feature.

The National Immunization Survey

Currently in its sixth year of data collection (1999), the NIS, conducted by the National Center for Health Statistics, Centers for Disease Control and Prevention, measures vaccination coverage among children 19 to 35 months old nationally and in each of 78 state and local areas (the 50 states, the District of Columbia, and 27 other metropolitan areas). The quarterly random sample of telephone numbers is screened first to determine whether the number is a working household number, a working nonresidential number, or a non-working number. Households are then screened for the presence of age-eligible children. Because the target population for this RDD survey—households with children 19 to 35 months old—constitutes only about 5% of all households in the U.S., extensive screening is required to identify eligible households. Ezzati-Rice *et al.*(1995) describe the NIS sample design in some detail.

2. Eligibility and Response Rates in the National Immunization Survey

Beginning with the first quarter of the survey (April to June 1994), the observed eligibility rate has been about 1 percentage point lower than the estimated eligibility rate of 5% (based on independent estimates from other surveys). Massey (1995) suggested that the lower observed eligibility was due to underreporting of eligibility by household respondents, so that calculating response rates from the eligibility rate observed in the NIS resulted in an overestimate of response rates. Thus, he proposed an alternative definition for the overall response rate (ORR) that uses an estimate of the household eligibility rate (later designated as the eligibility benchmark) derived from sources external to the NIS. The eligibility benchmark is used to estimate the number of eligible households in each quarterly sample, nationally and in each of the 78 state and local areas, in order to calculate the ORR nationally and for each state and local area.

This paper describes how this approach has been implemented in more recent years of NIS data collection. In particular, the eligibility benchmark has been updated on an annual and quarterly basis to account for national trends in birthrates and household formation. The paper also compares ORR with other estimates of response rates to illustrate the sensitivity of response rate calculations to assumptions about the proportion of eligible households in the sample. As the survey research profession searches for standard approaches to response rate calculations for complex surveys, the method and issues discussed in this paper will have important applications.

3. Components of Estimates of Response Rates in the NIS

The following discussion relies on final dispositions in the NIS, as summarized in Table 1. The generic equation for response rate (CASRO,1982) is:

$$\text{Response Rate} = \frac{\text{Completed Interviews}}{\text{Eligible Reporting Units}} \tag{1}$$

Using the dispositions from Table 1, the number of completed interviews, L, is the numerator, and the denominator is the number of eligible households in the sample. Households screened as eligible (category K in the table) form one component of the denominator. Categories G, I, S1, and S2 may also contain numbers of eligible households that should be estimated and included in the number of eligible reporting units.

Table 1
Counts of Final Dispositions from the *National Immunization Survey*, 1997

Label	Disposition Category	Count
TOTAL	Total selected sample in released replicates	2,118,796
F	Number of telephone numbers found to be non-working or non-residential through list-assisted and pre-CATI auto-dialing procedures	395,488
Total to CATI	All sampled telephone numbers initially loaded into the CATI Sample Management System	1,723,308
D	Non-working, out-of-scope	393,833
E	Non-residential	217,345
G	Non-contact	108,177
I	Answering machine or service (working number, household status unknown)	22,968
S1	Known household, screening for eligible child incomplete	19,506
S2	Likely household	37,151
J	Screened household, no eligible children	889,758
K	Screened household, eligible children	34,570
L	Completed interview	32,434
M+N	Eligible household, incomplete interview or refusal	2,136

Source: The National Immunization Survey, 1997

Using these terms, equation 1 can be expressed as equation 2. The denominator includes estimates of both the number of households among the telephone numbers in categories G, I, and S2 and the number of eligible households among those in category S1.

$$\text{Response Rate} = \frac{L}{K + p(r((G + I + S2) + q((S1)} \qquad (2)$$

where:

p = Estimated proportion of households among numbers not resolved as working household numbers, business numbers, or non-working numbers

r = Estimated proportion of eligible households among these households

q = Estimated proportion of eligible households among known households that could not be screened.

In the absence of other information, p can be estimated from the household working number rate, and r and q can be estimated from the eligibility rates, among screened households. For example, if

$$p = \frac{\text{Known Households}}{\text{Resolved Numbers}} = \frac{J + K + S1}{J + K + S1 + D + E + F} = 48.4\% \qquad (3)$$

and

$$r = q = \frac{\text{Eligible Households}}{\text{Screened Households}} = \frac{K}{J + K} = 3.7\% \qquad (4)$$

then

$$\text{Response Rate} = \frac{L}{K + p(r((G + I + S2) + q((S1)} = 84.6\% \qquad (5)$$

These are the equations suggested by both CASRO (1982) and AAPOR (1998) standards.

Alternatively, it can be shown that the response rate calculated using these estimates is equal to the product of the resolution rate, the screening completion rate, and the interview completion rate. The number of completed interviews is retained in the numerator. The denominator is expressed as the product of the TOTAL, p, and r:

$$\text{Response Rate} = \frac{\text{Completed Interviews}}{\text{TOTAL}(\ p(\ r} \qquad (6)$$

Algebraic rearrangement yields the product of the three rates:

$$\text{Response Rate} = \frac{\text{Completed Interviews}}{\dfrac{\text{TOTAL}(\ \text{Known Households}(\text{ Eligible Households}}{\text{Resolved Numbers}(\text{ Screened Households}}} \qquad (7)$$

$$\text{Response Rate} = \frac{\text{Resolved Numbers} (\text{ Screened Households} (\text{ Completed Interviews}}{\text{TOTAL} (\text{ Known Households} (\text{ Eligible Households}}$$

$$= \frac{\text{Resolved Numbers}}{\text{TOTAL}} \; (\; \frac{\text{Screened Households}}{\text{Known Households}} \; (\; \frac{\text{Completed Interviews}}{\text{Eligible Households}} \qquad (8)$$

This equivalence is illustrated in the following calculations with figures from Table 1:

$$\text{Response Rate} = \frac{D + E + F + S1 + J + K}{\text{TOTAL}} \; (\; \frac{J + K}{J + K + S1} \; (\; \frac{L}{K} \qquad (9)$$

$$= \quad 92.1\% \quad (\quad 97.9\% \quad (\quad 93.8\%$$

$$= \quad 84.6\%.$$

The calculations presented above use estimates of *r* and *q* (as well as *p*) that are derived from observed outcomes of the survey. Their use depends on three assumptions, that:

! *p* has the same value among resolved and unresolved numbers,

! *r* is equal to *q*, and

! *r* and *q* have the same value among screened and unscreened households.

Noting that the eligibility rate determined from the NIS data was lower than the rate expected from other data sources, Massey (1995) suggested alternative estimates of both the household working-number rate and the eligibility rate that lead to an alternative estimate of the overall response rate. He initially used a figure of 5.2%, based on the 1993 National Health Interview Survey, as the estimated eligibility rate or benchmark. The estimate was later revised to 5.08%, based on more recent data from the NHIS.

In place of the household working-number rate, *p*, Massey suggests a figure of 90% that is applied only to working telephone numbers where household status could not be determined. In the categories of Table 1, these telephone numbers are contained in categories I (answering machine or service, household status unknown) and S2 (likely household). S2 consists of numbers where a call was answered but screening for household status could not be completed, because of either refusals or language barriers. Telephone numbers in categories I and S2 are working numbers, because either an answering machine or a person was reached, and they are probably residential rather than business lines. Businesses tend to identify themselves as such, either when answering a call or in answering-machine messages. Numbers remaining in the uncontacted category (G) after repeated attempts are assumed to be non-working.

Massey's estimate of ORR uses the number of completed interviews (L) in the numerator and the estimated number of eligible households in the denominator. The denominator is calculated by applying the eligibility benchmark to all known households (that is, the sum of S1, J, and K) and to the estimated number of households in the unscreened portion of the sample (that is, 90% of the sum of I and S2). The 1994 quarters of the NIS used the following equation:

$$ORR = \frac{L}{.0508(\,(J + K + S1 + .9(\,(I + S2))} \qquad (10).$$

The eligibility benchmark of .0508 has been revised quarterly in reported estimates of ORR to take account of annual increases in the number of households and variations in the number of eligible children. Data from the *Current Population Survey*, available from the Census Web site, suggest that the number of households has grown at annual rates of 1.12%, 1.12%, and 1.08% for the years 1995 through 1997. Annual benchmarks (Table 2) have been derived from the 1994 benchmark by using this sequence of annual growth rates and the ratio of each year's number of eligible children (the average of the four quarterly totals from Vital Statistics) to the number for 1994. A similar calculation, using quarterly growth rates (derived from the annual growth rates) and quarterly numbers of eligible children, yields quarterly benchmarks (Table 3).

Table 2. Eligibility Benchmark (an estimate of the proportion of households that have a child 19 to 35 months old), Average Number of Eligible Children, and Annual Rate of Growth in the Number of Households, 1994 to 1997

Year	Eligibility Benchmark	Average Number of Eligible Children	Rate of Growth in Number of Households
1994	.0508	5,868,275	
1995	.0496	5,794,538	1.12%
1996	.0484	5,714,424	1.12%
1997	.0473	5,649,858	1.08%

Table 3. Eligibility Benchmark and Number of Eligible Children, Q2/1994 to Q4/1997

Quarter	Eligibility Benchmark	Number of Eligible Children
Q2/1994	.0508	5,941,591
Q3/1994	.0508	5,859,316
Q4/1994	.0508	5,803,917
Q1/1995	.0502	5,837,413
Q2/1995	.0502	5,852,498
Q3/1995	.0493	5,771,808
Q4/1995	.0487	5,716,432
Q1/1996	.0489	5,757,290
Q2/1996	.0489	5,773,890
Q3/1996	.0482	5,696,075
Q4/1996	.0475	5,630,440
Q1/1997	.0478	5,683,037
Q2/1997	.0479	5,715,726
Q3/1997	.0471	5,626,750
Q4/1997	.0465	5,573,920

Revising the above equation (Equation 10) following Massey's rationale and using p = .90 and q = r= .0473, the estimate of ORR for 1997 is:

$$\text{ORR} = \frac{\text{Completed Interviews}}{q(\text{ (Ineligible + Eligible + Known Households + } p(\text{ (Answering Machines + Likely Households))}} \qquad (11)$$

$$= \frac{L}{.0473((J + K + S1 + .9((I + S2))} = 68.7\%.$$

4. Comparison of Estimates of Response Rates

For each quarter from Q2/1994 to Q4/1997, Figure 1 (see Appendix) presents ORR, along with the standard unadjusted CASRO response rate, which was shown in Section 3 to be equivalent to the product of the resolution rate, the screening completion rate, and the interview completion rate (Equations 8 and 9). This graph shows that ORR is substantially lower than the CASRO rate. Except for having a higher value in Q4/1994, the the two rates follow somewhat different patterns. The unadjusted rate shows a slight decline, but the ORR has no particular pattern. The difference in the two rates range from a low of about 12 percentage points to a high of 19 percentage points. The data indicate the continued importance of estimating household eligibility from sources outside the survey itself.

To gain some insights into the potential sources of the trend in the declining unadjusted response rates in the NIS, Figure 2 (see Appendix) displays the quarterly unadjusted CASRO response rates calculated from Equation 9 and its three components (resolution rate, screening completion rate, and interview completion rate). The comparison of the components suggests that the problem of declining response rate in the NIS is due in large part to declines in the resolution rate.

5. Discussion and Implications

The recent AAPOR recommendations point to the importance of assumptions regarding eligibility rates in the unscreened portion of the sample when calculating response rates in a survey involving screening. The specific method discussed in this paper, along with the example from the NIS, provides the framework for application to any survey that screens for eligibility, including in-person as well as telephone surveys. As the example illustrates, estimates of both the household working-number rate among unresolved cases and the eligibility rate among unscreened cases can have a substantial effect on estimates of response rates. In the NIS, rather than deriving these estimates directly from the outcome of the survey, both factors have been estimated.

The eligibility rate has been estimated from external sources. The estimated percentage of households with eligible children was obtained initially from other surveys and has subsequently been adjusted to account for the growing number of households and the declining birthrate. The resulting eligibility benchmark has been used in place of separate estimates of eligibility rates for responding and nonresponding households.

Sources external to the survey can also be used to estimate the status of cases remaining unresolved at the end of a survey period. For example, information from special follow-up studies can be used to allocate unresolved lines among the categories non-working, non-residential, and residential. During a number of the earlier quarters, the NIS drew samples from different classes of unresolved numbers, such as “ring no answer to all attempts,” and calls were made to local telephone business offices to determine whether the numbers were non-working, non-residential, or residential (Shapiro *et al.*, 1995).

Because of the importance of apparent differential eligibility rates between households that do and those that do not complete the screening interview, the NIS has devoted considerable effort to evaluating estimates of the household working number rate and eligibility rate among uncontacted and unscreened sample lines. For example, Camburn and Wright (1996) showed that estimates of both rates may be confounded by the growing number of households with several telephone lines. A portion of the uncontacted numbers may be working but used as a secondary line in the household, either as a “children’s phone” or as a fax or modem line. Data presented in their paper suggest that eligibility rates estimated for household telephone *lines* in place of households may be much closer to the eligibility rates than that found among responders to the NIS screening.

The example in this paper and ongoing research on the NIS point to the difficulty in estimating eligibility rates directly in telephone surveys. However, the concern with the effects of nonresponse on estimates of eligibility rates is certainly germane to all surveys that employ screening for eligible respondents. Both the 1982 CASRO report and the 1998 AAPOR report note that other sources of information might be useful for estimating the unknown factors in the denominator of response rate formulas. However, when applied to surveys that screen for eligible respondents, the formulas presented in both reports make the implicit assumption that the eligibility rate is identical in screened and unscreened households. The difference in estimates of response rates shown in Figure 1 highlights the importance of this assumption. Differences in the eligibility rates of screened and unscreened households, due to nonresponse to the screener, could lead to misinterpretation of response rates from standard formulas.

The standard/traditional method of calculating response rates involves the product of three rates – the resolution rate, the screening completion rate, and the interview rate. Often in the past the coverage rate has been reported separately from the response rate. The method presented in this paper combines the coverage rate (population coverage) and the response rate in the calculation of the overall response rate. (Of course, one component of noncoverage is still not accounted for: noncoverage of nontelephone households.) As shown in this paper, when eligibility is built into the calculation of the overall response rate, the rate will generally differ from that calculated using the more traditional method.

Response rates have been defined in a number of ways for RDD surveys. The new approach discussed in this paper is used to track and monitor response rates in a large ongoing RDD survey, the NIS. This new refined method adds some complexities (although not extensive) to the calculation of the response rate through the need for external data and periodic adjustments. Nevertheless, the example and actual response rate calculations presented point to the need for survey researchers involved with RDD surveys to consider this new approach to the presentation of realistic response rates.

Clearly, in order to compare response rates among surveys, it is crucial to understand the methods used by various agencies and survey organizations to calculate their survey response rates and in particular what final dispositions comprise the numerator and denominator of the rates. In addition, we urge that presentations of response rate calculations include explicit discussions concerning assumptions about eligibility rates in un-screened portions of the total sample. The method used in the NIS provides a framework for other RDD surveys. The inclusion of a coverage component in the response rate will make comparison of response rates among surveys somewhat more complex. But it probably should still be done. This new method, though not restricted to RDD surveys, may be more difficult to implement for surveys using other modes of data collection.

In summary, the evaluation of the level of nonresponse in surveys and the impact of that nonresponse on the survey estimates is an important issue in survey research. It is important to apply the most accurate method of calculating response rates in order to understand the components of nonresponse and to be in a better position to incorporate modifications in the survey procedures as necessary and feasible. The method discussed in this paper provides researchers and survey organizations with an additional, if not a more rigorous, method for the calculation of response rates for surveys involving screening. It is hoped that the method and example will encourage other applications.

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APPENDIX

Figure 1: Unadjusted Response Rate and ORR for Q1/1994 to Q4/1997
National Immunization Survey

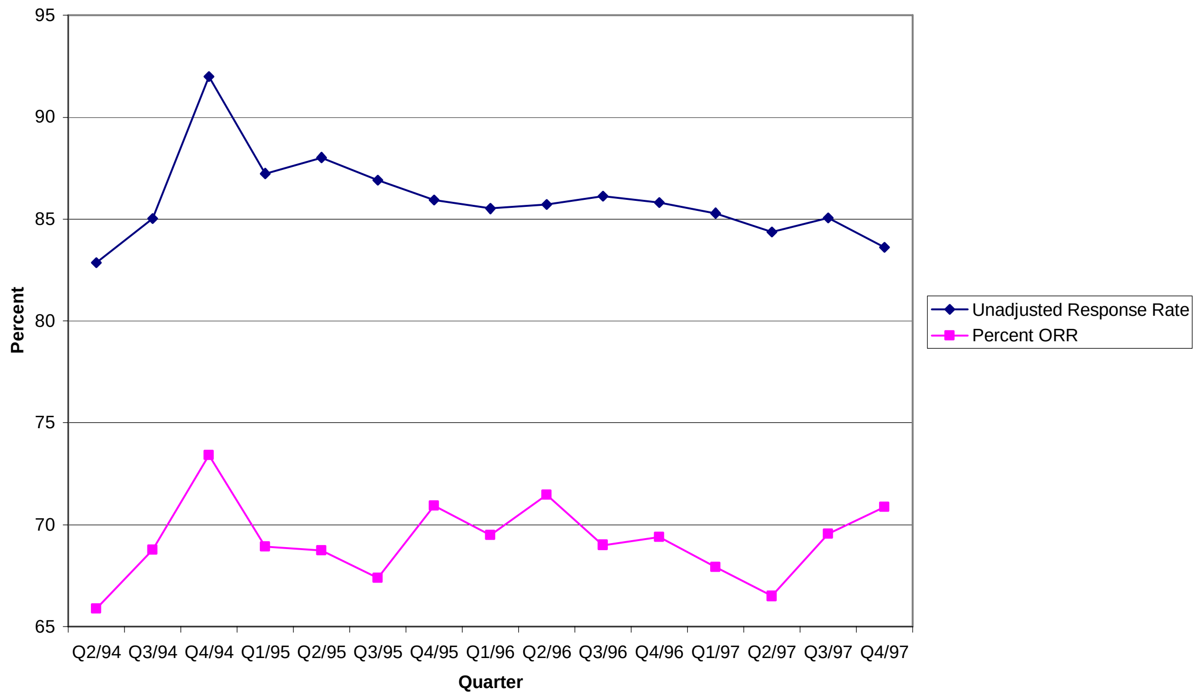

Figure 2: Unadjusted Response, Resolution, Screening Completion, and Interview Completion for Q1/1994 to Q4/1997 National Immunization Survey