MULTIPLICITY SAMPLING IN AN RDD TELEPHONE SURVEY

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1.0 Introduction

In the fall of 1989 Westat, Inc. conducted a field test for a random digit dialing (RDD) telephone survey for the National Center for Education Statistics (NCES). The primary purpose of the test was to examine methodological issues with respect to two education topics. The education topics were the early childhood education characteristics of 3- to 5-year-olds and the educational status of 14- to 21-year-olds, with a special focus on those who dropped out of school.

One of the methodological issues investigated in the field test was the use of multiplicity sampling (Kalton and Anderson (1986)) to increase the number of dropouts included in the sample and to reduce the bias associated with telephone coverage. A sample of 25 percent of the households was randomly selected to test the use of multiplicity sampling in a telephone survey. All women between the ages of 28 and 65 in the randomly subsampled households were asked about their children who did not currently live with the mother. The mothers were asked to complete an interview for each of these "out-of-household" youths, and the youths themselves were eligible for sampling to complete an extended interview.

In this paper the effectiveness of multiplicity sampling for increasing the sample size of targeted groups and for reducing the undercoverage bias associated with persons living in households without telephones is examined. The next section describes some of the salient aspects of the sample design of the field test. The subsequent sections describe various aspects of the effectiveness of the multiplicity sampling procedures.

2.0 Design and Estimation Issues

The NHES field test consisted of a series of related interviews. The first interview was the Screener, which was conducted with an adult household member. If the household contained any 14- to 21-year-olds, then a Household Respondent Interview (HRI) was attempted for each of these members. The HRI could be completed by any adult household member who knew about the educational activities of the youth. A Youth Interview was then attempted for a subsample of the 14- to 21-year-olds in the household. All 14- to 21-year-olds classified as potential dropouts based on the HRI data were selected for the Youth Interview. In addition, a subsample of about 20 percent of all other 14- to 21-year-olds was selected for the Youth Interview. A random sample of 25 percent of all households was selected to participate in the multiplicity sample experiment. In these households, all females aged 28 to 65 years were asked to enumerate and complete an HRI for each of their 14- to 21-year-old children who did not currently live in their household. Youths who were living away from home in student housing were classified as in-household members. All other eligible (i.e., civilian and noninstitutionalized) 14- to 21-year-olds identified in this process were considered "out-of-household" members.

One of the goals of the experiment was to increase the sample size for 14- to 21-year-olds, especially for dropouts. The other goal was to improve the coverage of the 14- to 21-year-old population by including youths who live in a household without a telephone but have a mother living in a telephone household. Of course, there are still youths who are not covered in a telephone survey even with the multiplicity sample. For example, youths who live with their mothers in nontelephone households are still not covered.

The population of 14- to 21-year-olds is represented in Figure 1. This figure shows the domains for which estimates are desired. Domains A and B are not affected by the multiplicity sample because the youths can only be sampled through one telephone number (the telephone number of the household in which they live). Since the NHES is a telephone sample, domains D and E are excluded by design even with multiplicity sampling. The multiplicity sample impacts on estimates for domains C and F. The use of the multiplicity sample makes it possible to cover and produce estimates for youths from domain F. It also makes it possible to produce two estimates for domain C, since a youth in this domain could be sampled in two ways.

Procedures were developed to incorporate the out-of-household sample in the estimation process. Two methods were considered for the weighting. A dual frame approach (Hartley (1974)) makes use of the fact that a particular domain of persons can be estimated in two ways. The other method of estimation is the network sampling approach (Sirken (1970)). It is based upon the determination of the overall probability that a youth had of being included in the sample. These two approaches result in identical weights.

The estimation procedure included several stages of weighting and adjustments, such as the inverse of the probability of selection and nonresponse adjustments. These parts of the estimation process are not discussed here because they are not affected by the multiplicity sample. Those aspects of estimation which are related to the multiplicity sample are described below.

Weighting the sample to take account of multiplicity sampling can be done by introducing adjustment factors, which are modifications to the standard weights for youths. For completeness, we indicate the factors associated with each of the domains, even though some of the domains are not affected by the multiplicity sample. Let

- S = 1 if the youth is in domain A or B;
- S = 4 if the youth is in domain F;
- S = 0.8 if the youth is **not** an out-of-household youth in domain C; and
- S = 0.8 (.2 × 4) if the youth is an out-of-household youth in domain C.

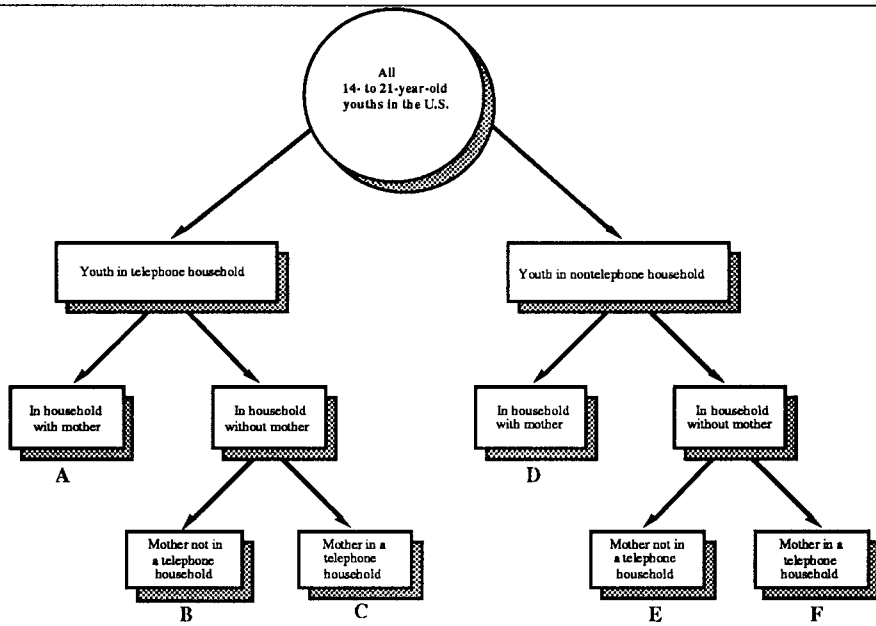

Figure 1. Domains of 14- to 21-year-olds for NHES sampling

The value of S for youths in domain C is derived by averaging the two estimates for this domain. The estimate based upon the youth sampled from their own household is given an adjustment factor of .8, and the estimate based upon the out-of-household youth is given an adjustment factor of .2. The adjustment factor for the estimate for the out-of-household youths is multiplied by four since the households were subsampled at a rate of one in four. Therefore, the total adjustment for out-of-household youth is .8. These adjustment factors approximate the optimal factors which are proportional to the sample sizes[1].

3.0 Sample Yields and Characteristics of Out-of-Household Youth

In this section, the completion rates from the field test data for the HRI and the Youth Interview are examined and the size of the sample arising from the use of multiplicity sampling is investigated. One of the goals of the field test was to examine the increase in the sample size for 14- to 21-year-olds as a result of the use of the multiplicity sample. This can be evaluated by looking at the number of cases and the completion rates by household status (in-household or out-of-household).

The HRI was completed for nearly all youths regardless of the household status. The completion rate for the in-household youths was 97 percent, and for the out-of-households youths it was 96 percent. These results indicate that there is no appreciable difference in response patterns by household status for the HRI. The subsequent analysis of the multiplicity sampling is based upon the completed HRI's.

The multiplicity sample resulted in the inclusion of 192 youths with completed HRI's who would not have been included otherwise. Since the multiplicity sample was only used in one-fourth of the sample households, we can estimate that the sample size would have been about 770 out-of-households youths if a multiplicity sample were used in all 15,000 households. This amounts to about 16 percent of all the 14- to 21-year-olds identified in a survey with 15,000 screened households.

Since the multiplicity sample was implemented with the hope of increasing the sample size for certain youth (dropouts and those without telephones), the characteristics of the out-of-household youths are important indicators of the success of the procedure. Table 1 shows the estimated number of youths by several characteristics and household status.

The percent of 14- to 21-year-olds who are classified as out-of-household is estimated to be 7.7 percent. This is an estimate of the number of 14- to 21-year-olds not currently living with their mother who would be identified through the mother's household. Note that this differs from the estimated 16 percent of the sample that are out-of-household because of differential weights, due primarily to the application of a factor[2] (S) for youths in domain C.

Comparing the two columns of percents in Table 1 for a particular characteristic provides a good summary of the prevalence of out-of-household youth. For example, youths 14 and 15 years old account for less than 5 percent of the out-of-household sample but for 25 percent of the in-household youth. The opposite is true for older youth. Over 50 percent of the out-of-household youths are over 19 years old, while less than 25 percent of the in-household youths are over 19 years old. This result indicates that the multiplicity sampling is likely to increase the sample size for older youths more than for younger ones. The same type of analysis reveals that the multiplicity sample is also effective for increasing the sample size for those not currently enrolled in elementary or secondary school.

Examination of dropout status[3] indicates that although the multiplicity sample is effective for status dropouts, this pattern does not hold for the event dropouts. Another way of looking at this relationship is to compare

Table 1. Estimated number of 14- to 21-year-olds, by household status and selected characteristics

Selected characteristics	Total (thousands)	Household status			
		Number (thousands)	Percent	Number (thousands)	Percent
Total	27,697	25,552	100.0%	2,145	100.0%
Age					
14 to15 years	6,571	6,471	25.3	100	4.7
16 to 17 years	6,767	6,587	25.8	179	8.4
18 to 19 years	7,385	6,732	26.3	653	30.4
20 to 21 years	6,974	5,761	22.5	1,213	56.5
Race/ethnicity					
Hispanic	2,784	2,588	10.1	196	9.1
Black, nonHispanic	4,060	3,709	14.5	351	16.4
Nonblack, nonHispanic	20,736	19,147	74.9	1,589	74.1
Gender					
Male	13,897	12,920	50.6	977	45.5
Female	13,800	12,632	49.4	1,168	54.5
Elementary/secondary enrollment					
Currently enrolled	13,477	13,204	51.7	273	12.7
Currently not enrolled	14,220	12,348	48.3	1,872	87.3
Status dropouts					
Yes	2,323	1,910	7.5	413	19.3
No	25,374	23,642	92.5	1,732	80.7
Event Dropouts					
Yes	587	556	2.2	31	1.5
No	27,110	24,996	97.8	2,114	98.5

Source: 1989 National Household Education Survey Field Test

the percent of all status dropouts who are out-of-household youths to the percent of all event dropouts who are out-of-household youths. Figure 2 shows these percents with approximate 95 percent confidence intervals about the estimated percents. The relative usefulness of the multiplicity sampling for status dropouts is evident in this figure.

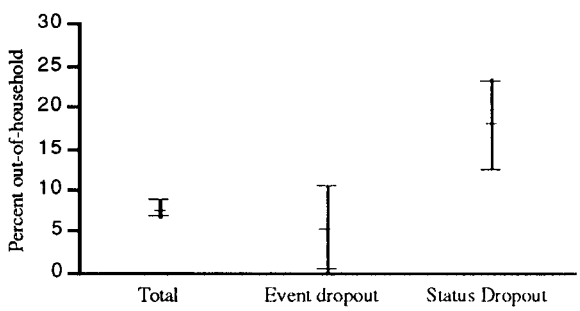

Figure 2. Estimated 95 percent confidence interval for percent out-of-household, by dropout status

These findings suggest that multiplicity sampling for 14- to 21-year-olds is reasonably effective in increasing the sample size for older youths and those who are not currently enrolled in elementary or secondary school. The increase in sample size is large for status dropouts but not for event dropouts. These findings are consistent with the expected benefits of multiplicity sampling.

Another important question that arises with multiplicity sampling is the ability to interview those sampled in this fashion. Table 2 shows the number sampled for the Youth Interview and the percent responding and not responding for selected characteristics from the HRI. The most striking result is that the overall completion rate for the in-household youths is much greater (89 percent) than the rate for the out-of-household youths (51 percent).

The vast majority of the nonresponses are the "other nonresponse" category. This category includes youth who could not be reached by telephone and those for whom the household respondent did not provide locating information. Nearly half (26) of the 55 cases of "other nonresponse" are youths who did not live in telephone households. In fact, it is somewhat remarkable that complete Youth Interviews were obtained for 41 percent of the youths who did not live in telephone households[4] (not shown in table).

The characteristics of in-household and out-of-household youth are also shown in the table. There is not very much variability with respect to response status for the in-household youth. The completion rates for out-of-household youth also reveal little substantial variability.

The findings indicate that there are significant problems associated with locating and obtaining completed interviews for out-of-household youth. These results should be considered in conjunction with the comparison of the dropout reporting in the HRI and Youth Interview (Mohadjer and Brick (1990)). That comparison indicated that the classification of youths as status dropouts from the HRI corresponded well with the classification based on the Youth Interview responses. Since the vast majority of the out-of-household youth are status dropouts rather than event dropouts, these results suggest that the multiplicity sample is useful for enlarging the sample of status dropouts and the HRI is sufficient for these persons.

The results do cast doubt about the usefulness of trying to conduct an extended telephone interview with out-of-household youth. If data from the youth are necessary, then significant additional resources (locating resources and personal interview resources) may be needed to obtain an acceptable completion rate.

Table 2. Number of Youth Interviews, by household status, response status and selected characteristics

Selected characteristics	Household status									
	In-household					Out-of-household				
			Nonresponse					Nonresponse		
	Number	Completes	Total	Refusals	Other	Number	Completes	Total	Refusals	Other
Total	1,721	89.3%	10.7%	4.4%	6.3%	131	51.1%	48.9%	6.9%	42.0%
Age										
14 to15 years	217	92.6	7.4	2.8	4.6	1	100.0	0.0	0.0	0.0
16 to 17 years	302	89.4	10.6	4.6	6.0	5	40.0	60.0	20.0	40.0
18 to 19 years	576	88.0	12.0	4.5	7.5	41	51.2	48.8	2.4	46.3
20 to 21 years	626	89.3	10.7	4.8	5.9	84	51.2	48.8	8.3	40.5
Race/ethnicity										
Hispanic	194	86.6	13.4	5.7	7.7	11	27.3	72.7	18.2	54.5
Black, nonHispanic	240	90.0	10.0	3.8	6.3	12	33.3	66.7	0.0	66.7
Nonblack, nonHispanic	1,278	89.6	10.4	4.3	6.1	105	55.2	44.8	6.7	38.1
Gender										
Male	846	88.1	11.9	4.5	7.4	62	58.1	41.9	3.2	38.7
Female	875	90.5	9.5	4.3	5.1	69	44.9	55.1	10.1	44.9
Elementary/secondary enrollment										
Currently enrolled	463	91.4	8.6	3.7	5.0	4	100.0	0.0	0.0	0.0
Currently not enrolled	1,258	88.6	11.4	4.7	6.8	127	49.6	50.4	7.1	43.3
Status dropouts										
Yes	275	87.3	12.7	6.2	6.5	31	38.7	61.3	9.7	51.6
No	1,446	89.7	10.3	4.1	6.2	100	55.0	45.0	6.0	39.0
Event Dropouts										
Yes	79	86.1	13.9	3.8	10.1	2	0.0	100.0	0.0	100.0
No	1,642	89.5	10.5	4.4	6.1	129	51.9	48.1	7.0	41.1

Source: 1989 National Household Education Survey Field Test

4.0 Estimates of Increased Coverage

The second objective of the multiplicity sample was to increase the coverage of the population of 14- to 21-year-olds. The increased coverage is obtained because the multiplicity sample provides estimates for youths living in nontelephone households if their mothers live in a telephone household (domain F in Figure 1). As noted previously, the multiplicity sample does not eliminate undercoverage bias completely.

Table 3 shows the estimated number of 14- to 21-year-olds by household status and, for the out-of-household youth, by presence of a telephone in the youth's household. The last column of this table shows the estimated percent of youth who are covered in NHES only because of the use of the multiplicity sample (domain F). The estimated percent is an indicator of the reduction in the undercoverage bias due to the multiplicity sample.

Technically, the percent bias is the estimated number of persons in domain F divided by the estimated aggregate number of persons in all domains. Because the NHES field test was weighted up to the total number of 14- to 21-year-olds in the U.S., the cases in domain F and the other domains were subjected to differential adjustments. These adjustments were introduced to partially reduce the impact of the undercoverage bias. Therefore, the estimated percent without telephones in Table 3 is only an approximation of the actual bias reduction from multiplicity sampling.

To provide a better estimate of the bias, estimates were computed using the weights prior to the introduction of poststratification and bias reduction adjustments. The estimates of the percent bias using the unadjusted weights are given in the first column of Table 4.

We begin the examination of the reduction in the undercoverage bias by looking at estimates of all youths. An estimated 5 percent of the 27.7 million youth are out-of-household youth without telephones. These youth are only covered because of the multiplicity sample. Since 92 percent of all 14- to 21-year-olds live in telephone households (Brick and Burke (1990)), the multiplicity sample accounts for approximately half of the undercoverage bias for estimates of all youths.

Multiplicity sampling was considered for the NHES primarily because dropouts were subject to much higher undercoverage rates. Status dropouts have a telephone coverage rate of only about 70 percent and event dropouts coverage rate of about 75 percent. The estimates in Table 4 show the percent bias for status dropouts is estimated at 15 percent and for event dropouts at only 4 percent. Even though the estimated 15 percent bias for status dropouts is larger than the 5 percent for all youth, it still only represents half of the undercoverage bias. The formulation of the mean square errors for the two estimates is given.

The estimated percent bias for 20- to 21-year-olds is larger than that of any subdomain except status dropouts. This result suggests that multiplicity sampling may be useful for persons in this age group for topics other than dropouts.

5.0 Mean Square Errors of Estimates

The mean square errors are needed for estimates without the multiplicity sample and for estimates with the multiplicity sample. The mean square errors of these two estimates contain some identical bias contributions coming from the bias associated with domains D and E in Figure 1. Before discussing this common component, the formulation of the mean square errors for the two estimates is given.

The mean square error for an estimate can be written as

$$MSE(z') = V(z') + B^2(z')$$

Table 3. Estimated number of 14- to 21-year-olds, by household status, telephone presence and selected characteristics

Selected characteristics	Total (thousands)	In-household total (thousands)	Out-of-household		Percent of 14- to 21-year-olds without phones
			With phones (thousands)	Without phones (thousands)	
Total	27,697	25,552	786	1,359	4.9%
Age					
14 to15 years	6,571	6,471	16	84	1.3
16 to 17 years	6,767	6,587	81	98	1.5
18 to 19 years	7,385	6,732	238	414	5.6
20 to 21 years	6,974	5,761	450	762	10.9
Race/ethnicity					
Hispanic	2,784	2,588	56	139	5.0
Black, nonHispanic	4,060	3,709	68	283	7.0
Nonblack, nonHispanic	20,736	19,147	652	937	4.5
Gender					
Male	13,897	12,920	338	639	4.6
Female	13,800	12,632	448	720	5.2
Elementary/secondary enrollment					
Currently enrolled	13,477	13,204	102	171	1.3
Currently not enrolled	14,220	12,348	684	1,188	8.4
Status dropouts					
Yes	2,323	1,910	114	299	12.9
No	25,374	23,642	672	1,060	4.2
Event Dropouts					
Yes	587	556	9	22	3.8
No	27,110	24,996	777	1,337	4.9

Source: 1989 National Household Education Survey Field Test

where V(z') is the variance of z' and B(z') is the bias of z'.

An unbiased estimate of the mean square error from a sample can be found by replacing the variance and bias squared terms with unbiased estimates. This can be written as

$$\widehat{MSE}(z') = s^2_{z'} + \hat{b}^2_{z'} - s^2_b$$

where the first term on the right-hand side is the estimate of the variance of the z', the second term is the estimate of the bias of the z' squared, and the third term is the estimate of the variance of the bias estimate. If the sum of the last two terms is negative (which can happen for small bias estimates and relatively small sample sizes), then the MSE is estimated by setting the last two terms to zero.

Let x' be the estimate from the sample excluding the multiplicity sample and y' be the estimate of the sample including the multiplicity sample. The estimate y' contains a component for domain F, but neither x' nor y' estimate the component of the bias associated with undercoverage in domains D and E. These components cannot be estimated from NHES data. Therefore, for comparing these two estimators, the component of the bias associated with domains D and E is ignored.

Now, the estimators of MSE for x' and y' can be written. For y', the estimator can be approximated by

$$\widehat{MSE}(y') = s^2_{y'} = \frac{D_1 s^2}{n_y}$$

where D_1 is the design effect, s^2 is the unit variance of the estimate and n_y is the sample size for this estimate. Note that there are no bias terms in this estimator.

The estimator for x' is approximated by

$$\widehat{MSE}(x') = s^2_{x'} + \hat{b}^2 - s^2_b = \frac{D_2 s^2}{n_x} + (y' - x')^2 - \frac{s^2_b}{n_b}$$

where the terms are defined as before and the last term on the right-hand side of the equation is the estimate of the variance of the bias estimate. The sample size for the estimated bias, n_b, is the number of cases in domain F. Note that in this formulation the population variances are assumed to be equal.

The formulas for the estimated MSE for x' and y' have provisions for different design effects, D_1 and D_2. From the field test we estimate that the approximate value of D_1 is 1.6 and the approximate value of D_2 is 1.5. The other quantities needed to estimate the MSE of x' and y' can also be estimated from the field test. If we assume that 60,000 households are screened, then about 19,600 youths are expected (n_y) if multiplicity sampling is used in all households. If it is not used, then the expected sample size is about 17,000 (n_x). The sample size for domain F (n_b) is approximately 220 in this scenario.

The size of the bias depends upon the characteristic being estimated. Estimates of the percent bias for various characteristics are shown in Table 4. These can be converted to totals by multiplying by the appropriate totals given in Table 4. For example, the estimated bias for status dropouts is 346,000 youths (.149 times 2,323,000 status dropouts).

The ratios of the estimated MSE's are large when either the estimated percent bias is larger than average, or when the estimate is a large percent of the total. The first condition arises because of the dominance of the bias term for some statistics. The second condition arises because the variance of a percent (P) approaches zero as P approaches either zero or one. When the variance approaches zero the bias again becomes the dominant term in the estimate of the MSE.

Table 4. Estimated bias, mean square errors and relative errors for estimators, by selected characteristics

Selected characteristics	Estimated percent bias	Estimated MSE(x')[1] without multiplicity sample (millionths)	Estimated MSE(y')[1] with multiplicity sample (millionths)	MSE(x')/MSE(y')
Age				
14 to15 years	0.9%	16.0	14.5	1.1
16 to 17 years	1.6	16.3	14.8	1.1
18 to 19 years	5.5	174.2	15.6	11.1
20 to 21 years	11.0	652.6	15.1	43.3
Race/ethnicity				
Hispanic	6.5	10.5	7.2	1.5
Black, nonHispanic	7.3	69.6	10.0	6.9
Nonblack, nonHispanic	4.6	1011.6	15.1	67.2
Gender				
Male	4.9	451.6	20.0	22.6
Female	5.1	583.1	20.0	29.2
Elementary/secondary enrollment				
Currently enrolled	1.2	32.2	20.0	1.6
Currently not enrolled	8.4	1675.7	20.0	83.8
Status dropouts				
Yes	14.9	74.8	6.1	12.2
No	4.2	1304.0	6.1	212.1
Event Dropouts				
Yes	4.4	1.8	1.7	1.1
No	5.0	2123.2	1.7	1280.1

[1] The estimated MSE's exclude the bias associated with youths having mothers not living in telephone households.

Source: 1989 National Household Education Survey Field Test

The ratios (last column in Table 4) show that the multiplicity sample has a significant positive impact on estimates of older youths, but very little impact on estimates of younger youths. The multiplicity sample is effective in improving the accuracy of the estimates of status dropouts, but for event dropouts it has very little impact. These results are consistent with those reported earlier and with the expected benefits of multiplicity sampling in this population.

6.0 Summary

The analysis of the field test data indicates that the multiplicity sample is effective in increasing the sample size for certain segments of the 14- to 21-year-old population. Multiplicity sampling results in larger samples for older youths and status dropouts, but does little to add to the sample size of the younger youths and the event dropouts.

The completion rates for the HRI and Youth Interview reveal that mothers are willing to provide the information for the youths who no longer reside in their households, but it is difficult to contact these youths for extended interviews. The primary difficulty in obtaining extended interviews is that many of the youths do not have telephones in their homes.

The data from the field test also show that the multiplicity sample is effective in reducing the undercoverage bias for some statistics, but not for others. The procedure is most effective for status dropouts, older youths, and youths not currently enrolled in elementary or secondary schools. In these cases the bias is approximately halved. On the other hand, for younger youths and event dropouts the procedure does not significantly reduce the undercoverage bias. The estimated mean square errors confirm these findings.

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[1] About 80 percent of the sample of youths from domain C should have been derived from the in-household sample because of the one-in-four sampling of households for the multiplicity sample. This is how the original factors of .8 for the in-household sample and .2 for the out-of-household sample were derived.

[2] The effective value of S for all youths in domain C is .5, since these youths have a chance of being sampled from two households.

[3] A status dropout is defined as a 14- to 21-year-old who was not enrolled in October of the current year and did not have a high school diploma or equivalent. Event dropouts are defined as the subset of status dropouts who were enrolled in school in October of the previous year. In other words, a status dropout is someone who is not currently enrolled and does not have a diploma or equivalent, and an event dropout is a someone who left school within the last year.

[4] Interviews with youths who do not live in telephone households were accomplished by obtaining work telephone numbers, or telephone numbers of friends whom they frequently visit. In addition, telephone calls to the mothers' households were attempted during the Thanksgiving weekend to interview the youths at that location.