LOSS TO FOLLOW-UP ASSESSMENT: APPLICATION OF GRADE OF MEMBERSHIP METHODS TO AGED POPULATION LONGITUDINAL SAMPLE LOSS TO FOLLOW-UP IN THE NATIONAL LONG TERM CARE SURVEY

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INTRODUCTION

Panel surveys are composed of design features that allow the investigator to estimate transitions in the characteristics of a population over a specific time interval, e.g., 2-1/2 years, 7 years, etc. Unlike cross sectional surveys which generally make point prevalence estimates for very narrow time intervals, e.g., one or two weeks prior to the interval or even that day, panel studies may link together numerous point prevalence estimates over time for the same individual (Kish, 1987). The analytic strategy for the measurement of transitions is based on assumptions concerning measurable amounts of sampling error, which includes adjustment for nonresponse. Sample attrition over waves of a survey such as Survey Income and Program Participation (SIPP) or National Medical Expenditure Survey (NMES) entails a problem in weights construction that requires an adjustment for a nonresponse weighting based on the characteristics of nonrespondents, time in sample, and other criteria. Often little is known about the characteristics of nonrespondents (Groves, 1989; Kish, 1987). Further, the trend has been toward increasing rates of nonparticipants in surveys nationwide (Lepkowski, 1989; Groves, 1989; Lyberg and Lyberg, 1991).

Loss to follow-up in the panel survey context concerns the analyst's ability to appropriately measure transitions between a survey's waves as well as the ability to make appropriate point prevalence estimates. It is also concerned with sampling error in the context of response rates and adjustment for nonresponse and nonsampling error when measurement of characteristics based on adjustments for nonresponse may be an issue. In the case of panel surveys, we often have detailed information about future nonrespondents, e.g., persons who responded in earlier waves who became nonrespondents in later panel waves. We, therefore, have a greater opportunity to examine the nonresponse bias issue than is generally the case in surveys, particularly cross sectional surveys. This research represents continuing development of methods and procedures to assess nonsampling error (Corder et al., 1989, 1990a,b, 1991).

This study, like most other research in this area of survey research concentrates on the characteristics of nonrespondents, both personal and survey related (Lyberg and Lyberg, 1991). We employ both a new and useful statistical methodology (Grade of Membership) (Woodbury and Manton, 1982) and a unique data set (the National Long Term Care Survey (NLTCS)) to investigate loss to follow-up, a particular kind of nonresponse problem among the aged; a population of interest in light of generally decreasing survey participation levels over time (Manton, 1988). Since the NLTCS began in 1982 and is likely to continue to be administered for some time (the study has been completed in 1982, 1984, and 1989 and will be repeated in 1994, 1999 and 2004), this study will detail patterns of loss to follow-up with the aim of maintaining and improving response rates that have been uniformly high via examination of those patterns with a powerful analytic technique, Grade of Membership. We describe the aged population, the aged population's pattern of loss to follow-up, and identify them by reason, vital status, and temporality. The Grade of Membership methodology provides an opportunity to examine the pattern of follow-up nonresponse in a new and useful way. The method constructs a series of data profiles or ideal types, measuring the level of membership of each sample person in the pure type. We contribute to understanding the loss to follow-up problem and the manner in which a nonresponse bias is accounted for in a sampling and nonsampling error context. (It is often modeled based on logical assumptions in the former and ignored in the latter.) (Groves and Cirldini, 1991) However, if the structure of the loss to follow-up population is not reflected in the adjustment procedure, e.g., out of sample individuals, then the measurement properties of the post-stratified sample will reflect residual nonresponse bias. Further, the time trend in nonresponse may further alter our interpretation of specific population measurements. Thus, examination of loss to follow-up over an extended period should illustrate an implicit asset allocation strategy to reduce nonresponse (chargeable and nonchargeable to response rate calculations) in what is essentially a study following aged cohorts to extinction. By doing so with Grade of Membership, as opposed to tabulations on the one hand, or a response optimization routine on the other, allows us to examine multiple influences in the outcome (e.g., the participation—nonparticipation dichotomy).

BACKGROUND

Survey research issues concerning the aged population have not received extensive treatment in the literature until quite recently (Corder and Manton, 1991; Hertzog and Rodger, 1988). Issues associated with survey participation, proxy response, accuracy of reporting, and item consistency have dominated this small but growing literature. Studies which report estimates of aged population characteristics do not develop specific interviewing techniques for the group 65 years of age and older and may thereby encounter measurement errors than might be observed otherwise, e.g., the Health Interview Survey. Beginning in the 1980s, several major national studies concerned with the aged population were developed and fielded. Epidemiologic catchment area studies or small population based studies have been conducted for a much longer period (e.g., the Duke Longitudinal Study on Aging). Among the recent national population based surveys of the aged, the National Long Term Care Survey offers an excellent opportunity to study nonresponse bias and loss to follow-up among the aged population (target population). The NLTCS is organized around a virtually complete census of aged persons for use as a sampling frame and conducts interviews in all institutional and noninstitutional facilities and dwellings except prisons. As an improvement over area probability samples, the NLTCS is better designed to include the very sick, hospitalized, and the institutionalized across a wide variety of settings (NCHS, 1966). The NLTCS is designed to cross sectionally and longitudinally represent the entire aged United States population (Corder and Manton, 1991). However, since the target population is represented by the national Medicare list as the sampling frame, people not covered by Medicare are excluded. Approximately 97% of the aged population is covered. NLTCS is composed of several sample components. In order to maintain representativeness over time, people turning 65 years of age during the intersurvey period are sampled. Thus, the study may be used to estimate transitions for a population alive as of a certain date as well as provide population estimates for a population alive as of a certain date. The study includes the benefits of a cross sectional and longitudinal research efforts in a single effort. However, inferential power associated with both point prevalence and transition estimates in this type of study design is predicated on high response rates, low nonresponse bias, and consistent levels of nonresponse over time.

Although the NLTCS exhibits several indicators of low nonresponse bias, e.g., high response rates and low loss to follow-up as well as low inefficiency in the frame and high coverage of the target population, we may be justifiable concerned about 1) the methods employed to generate cross sectional weighting adjustments and their extension to the longitudinal weighting situation (Manton et al., 1991). The Grade of Membership analysis of the population chosen for interview in 1982 (and still alive in 1989) compared to a parallel analysis population initially interviewed in a high response rate setting who became nonrespondents at a later wave will provide us with substantial information on the loss to follow-up group. Should the profiles which emerge from the two analyses appear consistent, then we could conclude that the loss to follow-up pattern does not affect our ability to make straightforward nonresponse adjustment assumptions. Indeed, depending on the level of correspondence, measurement error issues associated with loss to follow-up could be discounted. That is, such a result would suggest that nonresponse error was not a difficulty and further that the means and methods of survey design had, in this case, hit upon an adequate theory of survey participation (Groves, 1989, 1991). If, on the other hand, we observe differences of some magnitude among the two sets of profiles, adjustment for nonresponse, measurement issues, and survey administration could be raised as issues as a model to predict nonresponse and, additionally allocate resources to optimally reduce nonresponse might be developed for aged population studies from this data and analyses (Manton et al., 1992; Manton and Stallard, 1988).

A detailed analysis of loss to follow-up between the 1982 and 1989 National Long Term Care Surveys is presented below. The population of interest is defined as follows; in order to be included in the analysis, a person was eligible to receive an interview in 1982, was alive at wave 2 in 1984 and was eligible to receive an interview during Wave 3 in 1989. The study's observational plan is presented in Figure 1. In the case of the analysis, interview is defined as a detailed in-person interview. The structure of the NLTCS is such that while population estimates for the entire aged population is possible, detailed estimates are available for the chronically disabled population only. Thus, everyone in our population of interest indicated a disability in a screening interview and received a more detailed interview some time later. 3,378 persons were thus subject to loss to follow-up in the 7-year interval prior to the

1989 NLTCS. Of these persons, 527 were not interviewed in 1989. The analysis follows this general outline. Rather than producing a volume of cross tabulations which, when digested would help to define the characteristics of noninterviews (in the loss to follow-up context) or producing tables for application to reinterview procedures, two common approaches to the study of nonresponse adjustment, we employ Grade of Membership techniques to alow the data itself to generate ideal types from which the correlates of nonparticipation may be measured. Comparison of the distributions of persons across variables within ideal types according to interview status provides insight into the issue of nonresponse bias among the aged and the development of plans and procedures to address it.

The two analyses each address a different aspect of the nonresponse issue area. First, we incorporate information from the 1982 and 1989 interviews for all eligible persons. Parallel variables from each year are used to form a solution and it is possible to measure change over time in health and functional status as well as interview and proxy reporting status. The 527 observed noninterview cases in the second analysis are a subgroup of the 3,378 eligible cases. It is, therefore, possible to map the changing status of nonrespondents between analyses. It includes information from both the 1982 and 1989 interviews. Again, the number of variables used to form a solution is in parallel from each year. Additional information about 1989 survey noninterview persons is also available. In this case, as in the comparison above, emergence of additional ideal types in the data would indicate additional information available to differentiate the population. Both analyses will yield information according to the interpretation of the pure types for use in adjusting survey procedures and development of a model of survey participation, e.g., prediction of nonresponse.

METHODS

Next, we briefly mention the GoM model. Let us assume that we have discrete response data, where each of i persons (i = 1, 2, 3, ..., N) has one of L_j responses for the jth variable and each such response is represented by the binary variable, y_{ijl}. The basic form of the model assumes that the probability $y_{ijl} = 1.0$ can be predicted using two types of coefficients. The first type of coefficient, g_{ik}, represents the degree or grade of membership of the ith person in the kth group (k = 1, 2, ..., K) where the coefficients are estimated under the constraints that $0 \leq g_{ik} \leq 1.0$ and $\sum_{k=1}^{K} g_{ik} = 1.0$. The second type of coefficient is written λ_{kjl} which represents the probability that a person exactly of the kth type (i.e., $g_{ik} = 1.0$) has the lth response to the jth variable. With these definitions the basic model can be written as,

$$\text{PROB}(y_{ijl} = 1.0) = \sum_{k=1}^{K} g_{ik}\, \lambda_{kjl}\,. \qquad (1)$$

The parameters used in (1) were estimated using maximum likelihood procedures. These probabilities may be used for estimation depending upon the specific structure assumed. For the basic model individual response is a conditional multinomial form or,

$$L = \prod_i \prod_j \prod_l \left(\sum_k g_{ik}\, \lambda_{kjl}\right)^{y_{ijl}}. \qquad (2)$$

A second estimation approach, which is asymptotically equivalent, but which has certain desirable numerical properties, uses a Poisson likelihood function, in which the sum of λ_{kjl} over j and l are normalized to equal the number of questions j or,

$$L = \prod_i \prod_j \exp\{-y_{ijt}\, \lambda_{ijt}\} \prod_{l=1}^{L_j} [\lambda_{ijl}]^{x_{ijl}} \qquad (3)$$

where $\lambda_{ijt} = \sum_l \lambda_{ijl}$ and $y_{ijt} = \sum_l y_{ijl}$.

In other applications it is possible to extend the structure of the model to an empirical Bayes formulation where λ_{kjl} are assumed to follow a Dirichlet distribution (producing a hypergeometric likelihood function) (Woodbury and Manton, 1991), a form which models genetic effects in twin pairs or spatial effects on disease event clustering, say, in villages is discussed in Manton and Woodbury (1990) and Woodbury and Manton (1991).

RESULTS

This analysis is designed to examine specfic research questions: Is the pattern on noninterview case characteristics (loss to follow-up cases) sufficiently different from the overall pattern of eligible case characteristics to introduce bias into survey estimates when standard nonresponse adjustment methods are employed? First, we examine the pattern of noninterviews among those eligible for interviews in the 1982 NLTCS (aged disabled individuals). This analysis is organized around the longitudinal population's health and functional status. 8,485 persons were initially eligible for interviews in 1982. Persons identified as alive in 1982 and 1984 and eligible for interview in 1989 totaled 3,378. Of these, 2,789 were interviewed in each year, 499 were interviewed in 1982 but not in 1989, 48 were not interviewed in 1982 but were in 1989, and 27 were not interviewed in either year. We define the loss to follow-up as those not interviewed in 1989 (n = 527) 28 variables were identified that are consistent across survey years and describe health, functioning, and noninterview case status relevant to our interest in noninterview case status and nonresponse bias. Analyses of the 28 health, functional, and noninterview status variables for both eligibles (n = 3,378) and noninterviews (n = 527) were conducted using 3, 4, 5, 6, and 7 pure types (Table 1[1]). Difference in the likelihood statistics between models, each of which specified and increased the number of pure types, were examined. We found a four pure type solution for noninterviews and a five pure type solution for eligibles. The difference between a five pure type solution for the eligible for follow-up group and the loss to follow-up's four pure type solution may be attributable to the way individual's map from the four to the five pure type solution. A mapping of g_{ik}s for individuals from the two analyses is presented below. (in Table 4)

Two sets of tables representing the separate data grouping were produced. The first contains the health, functional, and noninterview status of the entire eligible population. The table includes internal and external variables. The λ_{kjl}s are estimated based on the internal variables only and the external variables are estimated contingent on that solution. A parallel analysis (same variables) is conducted for noninterviews. Although Medicare administrative records were checked, to eliminate ineligible decedents, the actual interview experience in the 1989 NLTCS produced additional decedents not previously identified. They comprise the largest noninterview group in the table. These two detailed tables present all the grade of membership information necessary to evaluate the research question. However, the volume of material remains cumbersome. For this reason, several variables important to the analysis are extracted and summarized in Table 3.

In each of the tables, the first column is the variable name along with its categories. For example, in Table 3a, a variable is "noninterview." This is a 1982 variable. The responses for each category of this variable are "yes" and "no." To conserve space and simplify the visual presentation, only the yes response is included in the table. The second column, labeled frequency, is the percent of survey population from that year excluding missing who answered yes to that question in 1982. Thus, 9.23% answered yes for refusal in 1982 and 18.79% in 1989. The next five columns represent the five pure types. The row for the answer "yes" represents the probability that someone who is 100% like a given type will have this response to a question. We observe that a yes answer is a property of pure type three. Persons who are 100% like this type in 1982 have a 65.35% probability of responding "yes" to this question, while this probability for the remaining types is zero. In the case of "refusal," the probability clearly indicates that anyone who answers yes to this question must be a member of pure type three as it is the only non-zero probability and that this observation could not be a 100% member of one of the other types though the observation could have a high grade of membership score for one or more of these other types for different reasons. The variables in the tables all follow this interpretation and format.

The characterization of the pure types is aided by the representation of the λ_{ijk}s for each category of each variable, enabling the evaluation of the relative importance of each variable category to each pure type. Detailed examination of the two tables is summarized in the following discussion where a brief label is applied to each pure type and its main characteristics are highlighted for important internal and external variables.

Comparison of the Two Sets of Pure Types

The five pure type solution for the "eligible for follow-up" population and the four pure type solution for the population "lost to follow-up" are very similar (Tables 1 and 2). The more highly differentiated or heterogeneous "eligible for follow-up" population represents the spectrum of disabled population in community and institutions. The diversity of patterns of illness and adaption to it is evident in both analyses and a great deal of correspondence is apparent between them. "Loss to follow-up analyses" included decedents who were not identified prior to the 1989 NLTCS screening and interview process. They comprise the bulk of pure types three and four among the nonrespondents and these pure types show substantial correspondence to pure types four and five among the eligible for longitudinal follow-up groups. In addition, pure types one and two show surprising similarities across the two analyses. We suspect nonresponse pure type 2 fuels "refusal" rates in follow-up analysis pure type 3 and that nonresponse pure type 3 "not available for interview" levels increase those in the follow-up group's pure type 2.

The mapping of the g_{ik}s from the four to the five pure type solution illustrates the correspondence between the pure types in the two analyses. (Table 4) A very high level of mapping occurs between the two younger and healthy pure types (pure type 1). Further substantial mapping occurs between the more severely disabled groups (pure type 4 and pure type 5) in the "loss to follow-up" and "eligible for follow-up" analyses, respectively. Pure types 2 and 3 in the four pure type solution (moderately disabled and mixed disability, respectively) switched pure types in the eligible for follow-up group. That is, pure type 2 migrated to pure type 3 and pure type 3 migrated to pure type 2 and 4. We think declines in ADL score and pattern of nonresponse (absent to refusal) account for the type 2 to type 3 shift while

$$L=\prod_{i}\prod_{j}\prod_{t}\prod_{e}\left(\sum_{k} g_{ik\cdot t\cdot e}\,\lambda_{kjl\cdot t\cdot e}\right)^{y_{ijl\cdot t\cdot e}} . \quad (5)$$

improvements and declines in ADL score and transition from refusals to absent may account for the shift from pure type 3 to pure type 2 and 4.

Generally, examination of the g_{ik}s (people) (Table 4) and the λ_{ijk}s (variables) (Tables 1 and 2) provide the same impression. That is, substantial correspondence exists between the structure of the loss to follow-up and the eligible for follow-up population. In short, the use of the grade of membership analysis methodology as an analysis and data reduction technique allows the examination of the correlates of nonresponse by identifying pure types among health functional, nonresponse variables in a loss to follow-up context where differences between respondents and nonrespondents influence nonresponse adjustment strategies as well as strategies to maintain cohort representativeness via field procedures.

DISCUSSION

Our detailed examination of noninterviews is based on an initial sample population of 8,485 persons disabled or institutionalized in 1982. Of these, 3,378 survived to be selection stage for the 1989 NLTCS interview. The surprisingly high mortality in the cohort (59.7% over 7 years) is explained by the disability criteria for sample selection. In addition, 328 additional deaths were noted during the 1989 interview. The remaining 199 noninterviews constitutes 2.4% of the starting cohort and 5.9% of the group eligible for the 1989 interview. Although noninterviews accumulate in the NLTCS design, they are small by any standard and appear to reflect the eligible follow-up population to a great degree. While careful study of the noninterview characteristics developed in Table 1, 2, and 4, will aid in capturing additional interviews, there is little evidence to suggest that nonresponse cannot be accounted for in standard ways as representativeness of the surviving numbers of the cohort was maintained in the sample survey follow-up of the disabled aged in the NLTCS.

[1]Due to space limitations, Tables 1-3 , an expanded Methods section, and References, are available from the authors.

Table 4: Cross-tabulated g_{ik} Sums for the Eligible for Follow-up Population (n = 3,378) and the Loss to Follow-up Population (n = 527)

Eligible for Follow-up Population (n = 3,378) (K = 5)	Loss to Follow-up Population (n = 527) (K = 4)				
	1	2	3	4	5
1	94.1	12.0	18.9	8.1	998.3
2	4.4	22.3	38.0	16.5	363.2
3	10.5	45.0	9.3	2.8	347.3
4	18.0	7.2	58.0	19.8	626.9
5	2.4	6.0	11.1	122.8	515.2

Dashed box: Loss to follow-up population

Solid box: Eligible for follow-up population

Underline: High frequency column cell