COGNITIVE ASPECTS OF RANDOMIZED RESPONSE

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KEY WORDS: sensitive questions; sample surveys; response bias

1. INTRODUCTION

The need for extensive national data on sensitive topics, such as sexual behavior and drug use, has increased dramatically since the AIDS epidemic was declared the nation's number one public health problem by the U.S. Surgeon General. To be successful, the large scale population surveys currently being undertaken or planned to collect these statistics will have to overcome the well-known reluctance of survey respondents to respond honestly to sensitive questions. Several survey techniques for enhancing the truthfulness of responses to sensitive survey questions have been proposed that involve protecting the anonymity of respondents. Perhaps, the best known of these techniques is Randomized Response (RR) - Warner (1965).

RR techniques provide anonymity of response as follows: the respondent uses a randomization device, such as a coin or a die, to select the question he answers from a set of question's (usually a pair) provided to him. When appropriately implemented, RR assures that the respondent and only the respondent knows with certainty to which question he has responded. For instance, the interviewer will not know whether his response means that the respondent has or does not have the sensitive attribute. The notions that "anonymity breeds honesty of response" is not, however, always supported by the empirical evidence. The quality of response in RR surveys has often been suspect and has varied unpredictably and inexplicably from one RR survey to another. Compared to conventional surveys that ask sensitive questions directly (i.e. without response anonymity), RR estimates invariably have larger sampling errors and sometimes have as large or even larger response error. To improve our understanding of the response error effects of data collection instruments and strategies, such as RR, the National Laboratory for Collaborative Research in Cognitive and Survey Measurement was recently established at the National Center for Health Statistics.

The National Laboratory's basic mission is to investigate the cognitive aspects of survey responses; that is the way information pertaining to survey questions is processed in the minds of survey respondents. Thus, the Laboratory is addressing an essential aspect of the response equation that is virtually always ignored in traditional studies of the response errors. At the very least, it is believed that understanding the respondent's cognitive processes will lower the risk of asking questions in ways that lead them to use cognitive strategies that are likely to "cause" response error. It might also provide a scientific foundation to questionnaire design research.

There appear to be four cognitive stages in the respondents' process of answering survey questions: (1) comprehending the question, (2) recalling events and information needed to answer the questions, (3) judging the most reasonable answer when the recalled information is incomplete, and (4) deciding whether to respond and to respond honestly to the questions. The response error effects of alternative cognitive strategies in the comprehension, memory, and judgement stages of answering survey questions were discussed in Sirken et al. (1988). It was shown that by appropriately designing the survey instruments, respondents could be induced to adopt cognitive strategies that were less prone to response errors. This paper proposes a theory of the factors affecting the cognitive strategies adopted by respondents in deciding whether to answer sensitive survey questions and whether to answer them truthfully. Although the theory is formulated in the context of RR surveys, it is also applicable to other techniques for collecting responses to sensitive survey questions including techniques that do not provide anonymity of response.

The cognitive model of survey responses to sensitive questions, described in the next section, was derived from classical utility theory. The model relates respondents' decisions on whether to respond and to respond truthfully to RR surveys to their perceptions of the *risks* of response disclosure and the *losses* that would follow such disclosure, as compared to the benefits of responding truthfully. Section 3 proposes methods for measuring respondents' perceptions of the risks and losses of having their responses disclosed in RR surveys. It also suggests ways of empirically investigating the relationship between respondents' perceptions and their decisions whether to respond and whether to respond truthfully to sensitive questions. A mathematical formulation is presented in Section 4 that illustrates how the model and empirical measurements on risks and losses might be applied to assess response biases to sensitive questions in RR surveys.

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2. THE UTILITY MODEL

The model proposed follows classical utility theory - von Neumann and Morgenstern (1944) and Pratt, Raiffa and Schlaifer (1964) - in considering decision-making as a function which defines for each possible state of nature an outcome which will result if a given course of action is taken. The decision is made on the basis of the decision-maker's personal evaluations of risk and of loss (or of gain). However, we do not necessarily assume, as is done in classical utility theory, that the decision taken is that which minimizes expected net loss and are willing to accept a more complex relationship between probability assessments, losses and decisions. Nevertheless, we still accept that the respondent's decisions are a function of his assessments of risk and of the net loss involved, that is as a result of a conjunction of the following components:

I. Respondent's perceived risk: This component measures the degree of belief that the respondent assigns to the event that he is identified as having a certain characteristic, via the survey process. For a dichotomous variable which relates to belonging to a sensitive group, A, this would just be the respondent's subjective conditional probability that the interviewer, or any other operator in the survey process, considers him as belonging to the group A (or to its complement), given his response. Obviously this component would depend on the true status of the respondent with respect to the sensitive group and, possibly, on other characteristics of the respondent. The perceived risk of disclosure will, in general, differ according to the agent to whom information is revealed - the interviewer, government agency or market researcher.

With respect to the use of RR, two variants of this component will be considered. The first measures the a-priori risk, which relates to the situation before the randomizing device is actually used (but after the questions are made known to the respondent and the procedure is explained). This will be the variant of the component which is primarily relevant to the respondent's decision whether to cooperate in the RR process or whether to refuse. However, it could also relate to the respondent's decision at this stage to answer untruthfully no matter what the outcome of the randomization device is.

The second variant measures the a-posteriori risk, which relates to the situation after the outcome of the randomizing process is known to the respondent (i.e. when he knows which question he should answer). This variant of the component will obviously depend on the outcome of the randomization procedure and is primarily relevant to the respondent's decision on whether to answer truthfully or not (though he could also refuse to answer at this stage). Both variants of this component will, in general, depend on the the survey process and, in particular, on the method of RR and on its parameters. It might also depend on the randomizing device used, on the characteristics of the interviewer (e.g. whether he instills confidence) and of the survey sponsor or of the collection agency, as well as on the phrasing of the RR instructions. By definition, this component should be independent of the subject-matter, the sensitivity of the question, or the phrasing of the question itself, all of which relate to the respondent's perceived loss due to having information about him divulged.

Several objective or normative measures have been proposed for the degree to which protection of privacy is attained or for it's complement, the risk of having information divulged - Lanke (1975), Leysieffer and Warner (1976), Warner (1976) and Greenberg et al. (1977). Although these measures relate to the protection of the individual, they do so, primarily, from the point of view of the data collecting agency, rather than that of the respondent. Thus, as pointed out by Leysieffer and Warner (1976), they could be considered as relating to the case where data have already been collected by direct questioning and randomization is carried out a-posteriori to protect privacy.

Although normative measures of risk are important conceptually, the respondent's decisions on whether to participate and whether to answer truthfully ultimately depend on his personal subjective assessment of the risk of having information divulged, together with the loss that this involves, compared to the benefits of responding truthfully. Thus, subjective measures of respondents' risks would seem to be a determinant factor in assessing the success of a RR method, for comparing different RR methods and for determining optimal values of their design parameters, rather than the objective measures of jeopardy.

II. Respondent's perceived loss: This component measures the loss (or negative utility) that the respondent assigns to the event that he is identified as having a certain characteristic, via the survey process. For a dichotomous variable which relates to belonging to a sensitive group, A, this would be the respondent's assessment of the loss to him which would be caused if the interviewer, or any other operator in the survey process to whom information is disclosed, were to consider him as belonging to the group A. Similarly to perceived risk, this component would depend on the true status of the respondent, with respect to the sensitive group, and, possibly, on other characteristics of the respondent. It would, generally, differ according to the agent or agency to whom the information is given - the interviewer, government agency or private researcher. Thus, with respect to the interviewer, it might also depend on his characteristics (e.g. his social status relative to that of the respondent) or on the survey process. By definition, this component would, in general, depend on the subject-matter, on the sensitivity of the question, and,

possibly, on its phrasing. However it should be independent of the method of RR and its parameters, of the randomizing device used, and of the phrasing of the RR instructions, since all of these relate only to the perception of probabilities inherent in the RR process, i.e. to the risk component.

III. Respondent's decision function: This component defines the way in which the two components defined above - the risk and the loss - combine, together with other factors, to determine the respondent's decision with respect to two aspects of the survey process - whether to respond at all and, if he responds, whether to respond truthfully or not (we assume that the respondent knows the truth, or else we consider his perceived truth as true). In general, this decision function could depend in a complex way, not only on the respondent's perceived risk and loss, relating to the disclosure of his identity, as determined above, but also on his perceptions of the benefits resulting from his decisions. The benefits (or negative loss) of responding honestly could relate to the respondent's view on the general benefits of the data to society (his "altruism"), to the benefit of positive social contact with the interviewer or to his fear of discovery if he does not answer truthfully. The decision may depend only on the expected net loss (i.e. expected loss less gain), or on some other function of loss and of gain. It may be a deterministic one (e.g. not to participate if the expected loss exceeds the benefit), or it may be a probabilistic decision (e.g. the probability of answering truthfully is a decreasing function of the expected net loss).

3. PROPOSALS FOR MEASUREMENT OF MODEL COMPONENTS

Overall assessments of response rates and of response errors have been reported for a wide range of empirical studies on sensitive topics - e.g. Brewer (1981); Brown and Harding (1973); Chi, Chow and Rider (1972); Goodstadt and Gruson (1975); Krotki and Fox (1974); Locander, Sudman and Bradburn (1976); Zdep and Rhodes (1976). However the multitude of factors which affect response quality makes it very difficult to draw general conclusions from these studies and to apply their results to other cases. Therefore we should attempt to assess each of the components separately and find out how they combine to determine response characteristics, i.e. to study separately the effects of changes in RR procedures or parameters (affecting only respondents' perceptions of risk) and the effects of different sensitive topics (relating only to respondents' perceived losses and benefits).

Each of the components and the final decision-making process itself are obviously the results of complex cognitive processes about which very little is known and which themselves present difficult measurement problems. Even large-scale field experimentation for measuring these components can only provide information of limited utility and generality. Before embarking on field tests, it would be necessary to carry out a series of relatively small scale laboratory experiments to investigate the cognitive processes used by respondents in deciding whether to answer the sensitive question and whether to answer honestly. As a preliminary attempt, volunteers could be investigated, in a laboratory setting, to find out what are the determining factors in making these decisions. This could be done via a focus group or via one-on-one interviews, incorporating "think aloud" modes and protocol analysis. Three types of laboratory experiments with volunteer subjects are proposed, in the following, in order to directly assess respondents' measures of risk and loss and their decision process.

I. Measurement of perceived risk: Although much of the work in RR has made some reference to the problems of the respondents' perceptions of risk, only a few - Moriarty and Wiseman (1976) and Soeken and Macready (1982) have actually tried to obtain measurements of these perceptions and to apply them to the problem of deciding about the RR procedure.

A series of experiments is required to assess the risk of having information about the respondent transferred elsewhere, as perceived by the respondent himself. The perceptions of risks have to be measured separately with respect to the transfer of information to the interviewer, to the collecting agency, to other government or non-government agencies and to friends or relatives. In each experiment the survey conditions would be varied, in order to assess the effects of different RR designs, of assurances of confidentiality and anonymity and of other survey conditions on the assessment of risk. For each condition respondents would be asked to assess directly (say on a scale of 1 to 100) how likely they regard the given type of disclosure to occur.

An attempt should be made to verify whether the basic assumption on the independence between the respondent's perception of risk and the sensitivity of the topic indeed holds. This could be achieved by asking for assessments of risk by the same respondent for several sensitive questions of different degrees of sensitivity. However in order to eliminate possible dependence between responses by the same respondent, random sub-samples of respondents could be assessed for different topics.

Both a-priori and a-posteriori components of risk should be measured (and compared) by asking respondents for their perceived risks both before the randomizing device is activated and after they have participated in the RR interview. For the latter component, assessment of respondents' perceptions of risk should be obtained separately for positive and for

negative responses. If some validation is possible, the assessment of risk for those belonging to the sensitive group should be compared with that for those not belonging. The effect of other covariates (such as age, education and socio-economic status) could also be studied if the experiment were large enough.

II. Measurement of perceived loss: The evaluation of respondents' perceptions of loss must relate to the different areas of concern that respondents may have with respect to the disclosure of personal information about them. Thus a series of experiments is required to assess the respondent's perceptions of loss of having information about him disclosed, with respect to his economic well-being (job status, taxation, credit standing etc.), his legal status (disclosure about illegal or semi-legal activities), his social status (among friends, family and colleagues) and his personal feelings (embarrassment, self-appraisal, paranoia etc.). The losses have to be assessed with respect to different questions of varying degrees of sensitivity, which must be regarded as the prime independent variable relevant to the assessment of losses.

Since it is very likely that the perceived loss would be not be the same for persons having a sensitive characteristic as for those not having it (for whom the loss would result from a false assignment to the sensitive group), measurement should be made on the basis of the knowledge about the respondent's true status. The assessment could be carried out by asking , for a series of dichotomous questions of varying sensitivity, what the respondent would be willing to pay so as to ensure that the information on his response would not be divulged to different recipients (interviewer, collecting agency, other agencies, friends, relatives or colleagues). Alternatively (or additionally), respondents may be asked what remuneration they would have to receive in order to allow the given type of information transfer. The evaluation of loss may have to be carried out on an ordinal scale, or at most on a ratio scale, rather than on an interval scale. Again the effects of covariates could be investigated. The assessment of losses should, by definition, be carried out without recourse to any RR method, although it might be useful to check that the assessment of loss is indeed independent of the method proposed to obtain the information.

III. Assessment of decision function: The most difficult part of the assessment procedure is, no doubt, the synthesis required in order to relate the measures of the two components discussed above and of the respondent's assessment of gain to the actual decision of the respondent on whether to participate and on whether to answer truthfully. An indirect assessment, proposed by Moriarty and Wiseman (1976), relies on a rather simplistic assumption which is not supported by empirical evidence. There seems to be no alternative but to ask respondents, directly, whether they would be willing to respond truthfully to questions of varying degrees of sensitivity for different variants of RR procedures. This could be done together with the assessment of the respondents' perceptions of benefit or gain which they ascribe to their participation in the survey and to their answering truthfully. The assumption here is that the respondent reaches his decision by weighing the losses and associated risks of having information about him divulged against the perceived benefits of his participation in the survey process. The detailed design of this final series of experiments would have to be carried out on the basis of the results of the previous series of experiments, in order to ensure that the factors which influence assessments of risks and of losses are included.

The above are rather general ideas on the possibilities for conducting experiments to measure respondents' perceptions of risks and of losses and to assess their decision-making processes, based on these perceptions. In order to make them useful, complete specifications for a series of well-designed experiments on a fairly large scale would have to be prepared. The detailed design of these assessment procedures would benefit, as pointed out above, from laboratory probes to reach better understanding of the cognitive processes involved in respondents' assessment of risks and of losses and in their decision-making. Also, experience gained in similar assessments in other fields needs to be studied and applied, if appropriate.

4. EFFECT OF MODEL COMPONENTS ON RESPONSE BIAS

In order to consider the possible use of the proposed conceptual model and assessment of its components, the following mathematical formulation of the effect of the components on the bias of the estimator of a proportion may be useful.

We consider a single dichotomous variable, where A denotes the sensitive group and A* its complement, with true probabilities of π_A and $1-\pi_A$, respectively. The unrelated question procedure - Horvitz, Shah and Simmons (1967) - is assumed, with Y denoting the group having the unrelated characteristic, with probability π_Y, and p denoting the probability that the randomizing device designates the sensitive question as the one to be answered. For each individual in the population, i, let H_i be the perceived risk and L_i the perceived loss for that individual. The decision functions for the i-th individual are defined by:

$$R_i(H_i, L_i) = \Pr(\text{i agrees to participate})$$

$$D_i(H_i, L_i \mid Q) = \Pr(\text{i answers truthfully} \mid Q),$$

where Q denotes the condition that i agrees to participate and that the randomizing device

designates question Q (Q=s for the sensitive question and Q=u for the unrelated question).

Note that R_i is determined before the randomizing device is used. We shall also assume that this decision does not depend on whether the individual belongs to the group Y or not, although it might well depend on whether he belongs to A or not. We therefore consider the expected values of $R_i(H_i, L_i)$, separately for A and for A*:

$$P_R(A) = E[R_i(H_i, L_i) \mid i \in A]$$

and $$P_R(A^*) = E[R_i(H_i, L_i) \mid i \in A^*],$$

which are the probabilities of participating for members of A and of A*, respectively.

The expected values of D_i are assumed to depend both on whether the individual belongs to A and on whether he belongs to Y. We denote the expected values of D_i over the relevant sub-populations by $P_D(A,Y,Q)$, $P_D(A,Y^*,Q)$, $P_D(A^*,Y,Q)$ and $P_D(A^*,Y^*,Q)$, for Q=s and Q=u.

In general we may assume that the respondent misreports only when the correct answer to the designated question is "yes", since no loss can be conceived if the individual answers "no", [see for instance Bourke and Dalenius (1974)]. This implies that:

$$P_D(A,Y^*,u) = P_D(A^*,Y,s) = P_D(A^*,Y^*,s) = P_D(A^*,Y^*,u) = 1.$$

Similarly we may assume that for those who belong to A, whether they belong to Y or not is irrelevant to their decision, so that:

$$P_D(A,Y,s) = P_D(A,Y^*,s).$$

If λ is the proportion of positive answers, among those that participate, then the estimator of π_A is:

$$\hat{\pi}_A = [\lambda - (1-p)\pi_Y]/p$$

and its bias can be shown to be:

$$B(\hat{\pi}_A) = \Big[P_R(A)\pi_A\{pP_D(A,Y,s) - \pi_Y(1-p)[1-P_D(A,Y,u)]\} - P_R(A^*)(1-\pi_A)\pi_Y(1-p)[1-P_D(A^*,Y,u)]\Big] / \{P_R(A)\pi_A + P_R(A^*)(1-\pi_A)\}.$$

Assuming that assessments of the parameters are available, the above model allows the evaluation of the bias and its behavior as a function of changes in the design parameters.

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