

## A Stratified Randomized Response Technique for Addressing Sensitive Questions in Survey

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### *Abstract*

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*A Stratified Randomized Response Technique (SRRT) with three randomization devices which focused on classification of respondents in a heterogeneous population into non-overlapping homogenous was developed. A simple random sampling scheme was used to select 500 students among students of Federal University of Agriculture, Abeokuta, Ogun State. These students were stratified into two homogenous strata and proportional allocation procedure was used to select 199 male students and 101 female students. An interviewer administered questionnaire was used to collect data on related sensitive questions such as sexually transmitted disease, rape, abortion, cultism, murder, stealing, examination malpractice and bribery of lecturers for marks from selected students. An estimator was proposed for estimating the proportion of students with stigmatized and sensitive behaviour and its statistical properties were examined. The proportion of male students who had contracted sexually transmitted disease, involved in rape, abortion, cultism, murder, stealing and examination malpractice is higher than that for the females. The proposed estimator showed that the variance of proportion for both male and female students involved in the sensitive and stigmatized characteristics is lower than that for the existing estimator. Hence, the proposed estimator is efficient.*

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**Keywords:** Randomize Response, Sensitive Questions, Stratified Random Sampling.

### **1.0 Introduction**

The randomized response technique (RRT) is useful for reducing response error problems when potentially sensitive questions such as the illegal use of drugs, sexual practice, illegal earning, or incidence of acts of domestic violence are included in surveys of human populations. Direct questioning of respondents about sensitive issues often results in either refusal or falsification of the answers. Social stigma and fear of reprisals sometimes result in untruthful, exaggerated, or misleading responses by respondents when approached with conventional survey methods. An ingenious method of counteracting fears in response to sensitive questions was the first to suggested by Warner [1]

Several authors had developed an efficient Randomized Response Techniques (RRTs), the developed techniques only considered a two-option of “yes” and “no” response [2]. In design, the two randomization devices are the same as that of Warner’s device but with different probabilities of choosing the stigmatize question. The basic idea behind this suggestion is to reduce considerably the suspicion among the respondents by providing them choice to randomly select the randomization device itself. Consequently, respondents may reveal their true status. As a result, a new Re-parameterized Randomized Response Technique (RRRTs) that will be based on the random use of one of the three randomization devices was proposed [3]. This work is proposing a modified Stratified Randomized Response Model based on the random use of one of the three randomization devices.

The basic idea behind this suggestion is to reduce considerably the suspicion among the respondents by providing each stratified group choice to randomly select the randomization device itself, which will increase response rate from the respondent.

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Direct interrogation about a stigmatized attribute such as induced abortion, use of drugs, tax evasion, etc. in a human population survey is a different exercise. A sampler may receive wrong answers from the survey respondent when he/she uses direct interrogating approach. Due to many reasons, information about prevalence of stigmatized attributes, in the population is essential. A complicated method of survey to gather information in relation to stigmatized attributes by ensuring confidentiality and anonymity to the respondents was proposed [1]. Up till now, a vast number of developmental improvements on Warner’s Randomized Response Techniques (RRT) have been developed by several researchers [3-10] are some of the many to be listed. In some situations, prior information about the unknown parameter may be available and can be used along with the sample auxiliary information for determination of that unknown parameter known as the Bayesian approach of estimation. Work done by researchers on Bayesian analysis of randomized response model are not very much, nonetheless, attempts have been made on the Bayesian analysis of Randomized Response techniques [2,8,11-21] are the major references on the Bayesian analysis of the Randomized Response Techniques.

Existing Reparameterized Randomized Response Model:

Despite the success achieved by many authors in developing an efficient Randomized Response Models (RRMs), the developed Models only considered a dichotomous option of “yes” and “no” response. In view of this, they propose a new Reparameterized Randomized Response Model (RRRM) that was based on the random use of one of the three randomization devices, In design, the three randomization devices are identical to that of Warner’s device but with different probabilities of selection. In addition to  $\alpha$  and  $\beta$  proposed earlier by Hussain and Shabbir, we introduce  $\delta$ , a positive real

number such that  $\frac{\alpha}{\alpha + \beta + \delta}, \alpha \neq \beta \neq \delta$  is the probability of using first randomization device which consists of the two

statements of Warner’s device and the new introduce device also with preset probabilities  $P_1, P_2$  and  $P_3$  respectively. By

using Hussain and Shabbir’s probability of a “yes” response for the  $i^{th}$  respondent, the probability of a “yes” response when the third option “undecided” is included is given by

$$\varphi = \frac{\alpha}{\alpha + \beta + \delta} [p_1\pi + (1 - p_1)(1 - \pi)] + \frac{\beta}{\alpha + \beta + \delta} [p_2\pi + (1 - p_2)(1 - \pi)] + \frac{\delta}{\alpha + \beta + \delta} [p_3\pi + (1 - p_3)(1 - \pi)]$$

The unbiased moment estimator of true probability of yes response (response rate) was given by

$$\pi = \frac{\varphi(\alpha + \beta + \delta) - [(\alpha + \beta + \delta) - p_1\alpha - p_2\beta - p_3\delta]}{2p_1\alpha + 2p_2\beta + 2p_3\delta - \alpha - \beta - \delta} \tag{1}$$

The variance of the estimator is given then by

$$V(\hat{\pi}_h)_{prop} = \frac{\pi(1 - \pi)}{n} + \frac{(p_1\alpha + p_2\beta + p_3\delta)(p_3\alpha + p_2\beta + p_1\delta)}{n[2p_1(\alpha - \delta) + 2p_2(\beta - \delta) - (\alpha + \beta - \delta)]^2(\alpha + \beta + \delta)^2}$$

## 2.0 Methodology

### 2.1 Proposed Modified Stratified Randomization Response Method

#### Theorem 1

The probability of yes  $Q(yes)$  for each stratum denoted as  $\varphi_h$  is

$$\begin{aligned} Q(yes) = \varphi_h &= \frac{\alpha_h}{\alpha_h + \beta_h + \delta_h} [p_{1h}\pi_h + (1 - p_{1h})(1 - \pi_h)] \\ &+ \frac{\beta_h}{\alpha_h + \beta_h + \delta_h} [p_{2h}\pi_h + (1 - p_{2h})(1 - \pi_h)] \\ &+ \frac{\delta_h}{\alpha_h + \beta_h + \delta_h} [p_{3h}\pi_h + (1 - p_{3h})(1 - \pi_h)] \end{aligned} \tag{2}$$

So that,

$$\hat{\varphi} = \sum W_h \varphi_h$$

Where  $W_h$  is the stratum weights and  $W_h = \frac{N_h}{N}$  for  $h=1,2,\dots,L$  so that  $W = \sum_{h=1}^L W_h = 1$  (  $N$  is the number of unit in the population and  $N_h$  is the total number of units in stratum h).

In order to ensure equal privacy protection in the three randomization devices  $X_1, X_2,$  and  $X_3,$  we put  $p_1 = 1 - p_2 - p_3$  into equation (1), to get

$$\pi_h = \frac{\varphi_h(\alpha_h + \beta_h + \delta_h) - [(\alpha_h + \beta_h + \delta_h) - p_{1h}\alpha_h - p_{2h}\beta_h - p_{3h}\delta_h]}{2p_{1h}\alpha_h + 2p_{2h}\beta_h + 2p_{3h}\delta_h - \alpha_h - \beta_h - \delta_h} \tag{3}$$

Hence, the unbiased sample estimate of  $\pi_h$  is given as

$$\hat{\pi}_h = \frac{\hat{\varphi}_h(\alpha_h + \beta_h + \delta_h) - [(\alpha_h + \beta_h + \delta_h) - p_{1h}\alpha_h - p_{2h}\beta_h - p_{3h}\delta_h]}{2p_{1h}\alpha_h + 2p_{2h}\beta_h + 2p_{3h}\delta_h - \alpha_h - \beta_h - \delta_h} \tag{4}$$

Where  $\hat{\varphi} = \frac{x}{n}$  and x is the number of respondents reporting a “yes” answer

Therefore,

$$\hat{\tau} = \sum W_h \pi_h \tag{5}$$

Where  $W_h$  is the stratum weights and  $W_h = \frac{N_h}{N}$  for  $h=1,2,\dots,L$  so that  $W = \sum_{h=1}^L W_h = 1$  (  $N$  is the number of unit in the population and  $N_h$  is the total number of units in stratum h)

Setting  $p_1 = 1 - p_2 - p_3,$  the variance of the estimator for each stratum is then given by

$$V(\hat{\pi}_h) = \frac{\left( \begin{matrix} \alpha_h + \beta_h \\ + \delta_h \end{matrix} \right)^2 \left[ \begin{matrix} \pi_h(4\alpha_h^2 p_{1h}^2 - 4\alpha_h^2 p_{1h} - 4\alpha_h \beta_h p_{1h} \\ + 8\alpha_h \beta_h p_{1h} p_{2h} - 4\alpha_h \delta_h p_{1h} + 8\alpha_h \delta_h p_{1h} p_{3h} \\ + \alpha_h^2 + 2\alpha_h \beta_h - 4\alpha_h \beta_h p_{2h} + 2\alpha_h \delta_h \\ - 4\alpha_h \delta_h p_{3h} - 4\beta_h^2 p_{2h}^2 + 4\beta_h^2 p_{2h}^2 \\ - 4\beta_h \delta_h p_{2h} + 8\beta_h \delta_h p_{2h} p_{3h} + \beta_h^2 \\ + 2\beta_h \delta_h - 4\beta_h \delta_h p_{3h} - 4\delta_h^2 p_{3h} + 4\delta_h^2 p_{3h}^2 \\ + \delta_h^2) - \pi_h^2(4\alpha_h^2 p_{1h}^2 - 4\alpha_h^2 p_{1h} \\ - 4\alpha_h \beta_h p_{1h} + 8\alpha_h \beta_h p_{1h} p_{2h} - 4\alpha_h \delta_h p_{1h} \\ + 8\alpha_h \delta_h p_{1h} p_{3h} + \alpha_h^2 + 2\alpha_h \beta_h - 4\alpha_h \beta_h p_{2h} \\ + 2\alpha_h \delta_h - 4\alpha_h \delta_h p_{3h} - 4\beta_h^2 p_{2h}^2 \\ + 4\beta_h^2 p_{2h}^2 - 4\beta_h \delta_h p_{2h} + 8\beta_h \delta_h p_{2h} p_{3h} \\ + \beta_h^2 + 2\beta_h \delta_h - 4\beta_h \delta_h p_{3h} - 4\delta_h^2 p_{3h} \\ + 4\delta_h^2 p_{3h}^2 + \delta_h^2) \end{matrix} \right] + \left[ \begin{matrix} \alpha_h^2 p_{1h} + \alpha_h \beta_h p_{2h} \\ + \alpha_h \delta_h p_{3h} - \alpha_h^2 p_{1h}^2 \\ + \alpha_h \beta_h p_{1h} - 2\alpha_h \beta_h p_{1h} p_{2h} \\ + \alpha_h \delta_h p_{1h} - 2\alpha_h \delta_h p_{1h} p_{3h} \\ + \beta_h^2 p_{2h} + \beta_h \delta_h p_{3h} \\ - \beta_h^2 p_{2h}^2 + \beta_h \delta_h p_{2h} \\ - 2\beta_h \delta_h p_{2h} p_{3h} + \delta_h^2 p_{3h} \\ - \delta_h^2 p_{3h}^2 \end{matrix} \right]}{n_h [2p_{1h}(\alpha_h - \delta_h) + 2p_{2h}(\beta_h - \delta_h) - (\alpha_h + \beta_h - \delta_h)]^2 (\alpha_h + \beta_h + \delta_h)^2}$$

On simplification, we have

$$V(\hat{\pi}_h)_{prop} = \frac{\pi_h(1 - \pi_h)}{n_h} + \frac{(p_{1h}\alpha_h + p_{2h}\beta_h + p_{3h}\delta_h)(p_{3h}\alpha_h + p_{2h}\beta_h + p_{1h}\delta_h)}{n_h [2p_{1h}(\alpha_h - \delta_h) + 2p_{2h}(\beta_h - \delta_h) - (\alpha_h + \beta_h - \delta_h)]^2 (\alpha_h + \beta_h + \delta_h)^2} \tag{6}$$

The variance of the estimator  $\hat{\tau}$  is then given as;

$$V(\hat{\tau})_{prop} = \frac{1}{n} \sum_{h=1}^L W_h \left[ \pi_h(1 - \pi_h) + \frac{(p_{1h}\alpha_h + p_{2h}\beta_h + p_{3h}\delta_h)(p_{3h}\alpha_h + p_{2h}\beta_h + p_{1h}\delta_h)}{[2p_{1h}(\alpha_h - \delta_h) + 2p_{2h}(\beta_h - \delta_h) - (\alpha_h + \beta_h - \delta_h)]^2 (\alpha_h + \beta_h + \delta_h)^2} \right] \tag{7}$$

### 2.2 Sampling Strategy

For the purpose of this study, five hundred (500) questionnaires were constructed to know some of the wrong vices practiced among students in which eight different sensitive questions were administered. The students of Federal University of Agriculture, Abeokuta, (FUNAAB) Ogun state, Nigeria were considered. The questionnaire consists of two sections. Section A consists of the Socio- Demographic Data and section B consists of the some selected wrong vices practiced among

university students. Three randomization devices were used. The randomization devices used were coin, dice and deck of cards. The possible outcomes for the tossing of coins is head or tail, for the dice the possible outcome is 1, 2, 3, 4, 5 and 6 while for the deck of card which has 54 cards with 13 hearts, 13 clubs, 13 spade and 13 diamond shapes. Each student were given an opportunity of picking any of the three devices randomly. Any student who picked the coin and dice was asked to toss privately and note the outcome, while those who picked the deck of card were asked to shuffle the cards and pick their choice, this was also done privately. For those outcome of the rolling of the dice was 1, 2, 3 and 4 were required to answer the questions in the questionnaire privately and truthfully while those whose outcome of the rolling of the dice was 4 and 5 were required to tick 'yes' option for all the sensitive questions. For those whose outcome of the tossing of the coins was head were required to answer the questions privately and truthfully otherwise was required to tick 'yes' option for the questions. For those who picked the deck of cards, those whose outcome after shuffling and picking was a heart, spade and diamond were required to answer the questionnaire privately and truthfully otherwise they were instructed to tick the 'yes' option in the questionnaire. After each respondent had answered the questionnaire as applicable to him/her, they were then asked to submit the questionnaire.

### 3.0 Results and Discussion

The following section deals with the descriptive statistics of the administered sensitive questions. The first question as shown in table 1 revealed that 209(41.8%) students ticked the 'Yes', 285(57.0%) tick 'No' while 6(1.2%) tick 'undecided', second question shows that 207(41.8%) students ticked 'Yes' answers, 290(58.0%) ticked 'No' and 3(0.6%) ticked 'undecided', third question shows that 203(40.9%) students ticked 'Yes' answers, 292(58.4%) ticked 'No' and 5(1%) ticked undecided, fourth question shows that 199(39.8%) students ticked 'Yes' answers and 301(60.2%) ticked 'No', fifth question shows that 196(39.2%) students ticked 'Yes' answers, 302(60.4%) ticked 'No' and 2(0.4%) ticked undecided, sixth question shows that 200(40.0%) students ticked 'Yes' answers, 292(58.4%) ticked 'No' and 8(1.6%) ticked undecided, seventh question shows that 268(53.6%) students ticked 'Yes' answers, 225(45.0%) ticked 'No' and 7(1.4%) ticked undecided, question eight shows that 214(42.8%) students ticked 'Yes' answers, 284(56.8%) ticked 'No' and 2(0.4%) ticked undecided,

**Table 1:** Frequency of Respondents for the 500 Questionnaires

Question	Sample size	Yes		No		Undecided	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Have you contracted sexually transmitted disease before?	209	41.8	285	57.0	6	1.2	500
Have you raped or being raped before?	207	41.4	290	58.0	3	0.6	500
Have you aborted or aborted for someone before1?	203	40.9	292	58.4	5	1.0	500
Are you a member of a secret cult?	199	39.8	301	60.2	0	0	500
Have you killed before?	196	39.2	302	60.4	2	0.4	500
Have you robbed a fellow student or stole during e-examinations before?	200	40.0	292	58.4	8	1.6	500
Have you cheated during an examination in FUNAAB before?	268	53.6	225	45.0	7	1.4	500
Have you bribed a lecturer for marks before?	214	42.8	284	56.8	2	0.4	500

### 3.1 Existing Procedure

When the 300 sample was selected, to know the particular wrong vices that is been carried out by the students of FUNAAB, cheating in an examination was the question with highest percentage across the varied sample sizes.

Using equation 1, when  $\alpha = 20$ ,  $\beta = 11$  and  $\delta = 2$ , an estimate and the mean square error(MSE) of true proportion of students who engaged in some of the wrong vices using existing procedure are as shown in table 2. The table shows that for 300 sample size, question 7 which talks about examination malpractice has the highest proportion among all other vices in which FUNAAB students do engage in.

**Table 2:** Proportion of Students who engaged in Wrong Vices and its Variance using existing procedure.

Sample size	Question	Proportion of students with the stigmatized or sensitive behavior ( $\pi$ )	Variance of ( $\pi$ )
300	1	0.41073	0.000819
	2	0.390893	0.000806
	3	0.380974	0.000799
	4	0.376014	0.000795
	5	0.366096	0.000786
	6	0.371055	0.000791
	7	0.891794	0.000334
	8	0.400812	0.000813

### 3.2 Proposed Procedure

A simple random sampling scheme was used to select 500 students which comprised of 332 males and 168 females among students of Federal University of Agriculture, Abeokuta, Ogun State. These students were stratified into two strata using gender as stratifying factor and proportional allocation procedure was used to select 199 male students and 101 female students randomly. For  $\alpha = 20$ ,  $\beta = 11$  and  $\delta = 2$ , an estimate and the mean square error(MSE) of true proportion of male students and female students who engaged in some of the wrong vices are as shown in table 6 and 7 respectively. From the tables it can be seen that question 7 which talks about examination malpractice has the highest proportion among all other vices in which FUNAAB students engage in. For male, for the sample size of 300, question 7 is the highest proportion among all vices, while all other questions have the same proportion of male students who engage in wrong vices. An estimate and the mean square error(MSE) of true proportion of female students who engaged in some of the wrong vices are as shown in table 7. From the table it can be seen that question 7 has the highest proportion among all vices, followed by question 8, while all other questions has the same proportion of male students who engage in wrong vices.

**Table 3:** Frequency of Male Respondents

Question	Sample size	Yes		No		Undecided	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Have you contracted sexually transmitted disease before?	199	79	39.7	117	58.8	3	1.5
Have you raped or being raped before?	199	77	38.7	120	60.3	2	1.0
Have you aborted or aborted for someone before?	199	76	38.2	118	59.3	5	2.6
Are you a member of a secret cult?	199	79	39.7	120	60.3	0	0
Have you killed before?	199	75	37.7	123	61.8	1	0.5
Have you robbed a fellow student or stole during e-examinations before?	199	77	38.7	118	59.3	4	2.0
Have you cheated during an examination in FUNAAB before?	199	100	50.3	95	47.7	4	2.0
Have you bribed a lecturer for marks before?	199	77	38.7	120	60.3	2	1.0

**Table 4:** Frequency of Female Respondents

Question	Sample size	Yes		No		Undecided	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Have you contracted sexually transmitted disease before?	101	40	39.6	60	59.4	1	1.0
Have you raped or being raped before?	101	41	40.6	60	59.4	0	0
Have you aborted or aborted for someone before?	101	42	41.6	59	58.4	0	0
Are you a member of a secret cult?	101	38	37.6	63	62.4	0	0
Have you killed before?	101	38	37.6	63	62.4	0	0
Have you robbed a fellow student or stole during e-examinations before?	101	41	40.6	58	57.4	2	2.0
Have you cheated during an examination in FUNAAB before?	101	54	53.5	46	45.5	1	1.0
Have you bribed a lecturer for marks before?	101	45	44.6	56	55.4	0	0

**Table 5:** Proportion of Male Students who engage in Wrong Vices and its Variance

Sample size	Question	proportion of students with the stigmatized or sensitive behavior ( $\pi$ )	Variance of ( $\pi$ )
300	1	0.346731	0.001157
	2	0.331778	0.001133
	3	0.324302	0.00112
	4	0.346731	0.001157
	5	0.316825	0.001107
	6	0.331778	0.001133
	7	0.944853	0.000281
	8	0.331778	0.001133

**Table 6:** Proportion of Female Students who engaged in Wrong Vices and its Variance

Sample size	Question	proportion of students with the stigmatized or sensitive behavior ( $\pi$ )	Variance of ( $\pi$ )
300	1	0.345325	0.002276
	2	0.360056	0.002319
	3	0.374787	0.002358
	4	0.315863	0.002177
	5	0.315863	0.002177
	6	0.360056	0.002319
	7	0.964025	0.000381
	8	0.41898	0.002448

When  $\alpha = 20$ ,  $\beta = 11$  and  $\delta = 2$ , the combined estimate and the mean square error(MSE) of true proportion of students who engaged in some of the wrong vices are as shown in table 8. From table 9, it can be seen that across the entire selected sensitive question, the proposed procedure with stratification is more efficient than the existing without stratification. This is represented in the line graph below. It should be noted that the proportion of students who cheats in an examination is the highest among all other vices. This suggests that the higher the proportion of people with stigmatized behavior the lower the variances.

**Table 7:** Proportion of Students who engaged in Wrong Vices and its Variance Using the Proposed Procedure

Sample size	Question	proportion of students with the stigmatized or sensitive behavior ( $\pi$ )	Variance of ( $\pi$ )
300	1	0.346259	0.000767
	2	0.34128	0.000761
	3	0.341265	0.00076
	4	0.33636	0.000756
	5	0.316502	0.000734
	6	0.34128	0.000761
	7	0.951295	0.000166
	8	0.361078	0.000776

**Table 8:** Efficiency of the Proposed Procedure over the Existing Procedure

Sample size	Question	Variance of ( $\pi$ )		Efficiency
		Proposed	Existing	
300	1	0.000767	0.000819	1.067797
	2	0.000761	0.000806	1.059133
	3	0.00076	0.000799	1.051316
	4	0.000756	0.000795	1.051587
	5	0.000734	0.000786	1.070845
	6	0.000761	0.000791	1.039422
	7	0.000166	0.000334	2.012048
	8	0.000776	0.000813	1.04768

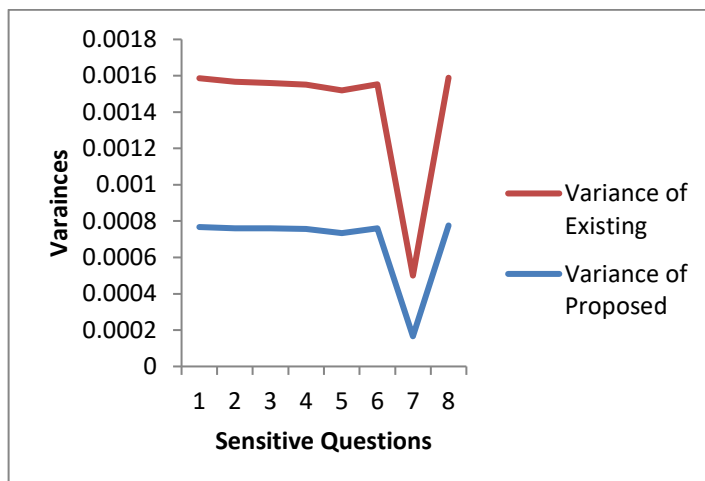


Figure 1: Efficiency of the Proposed Procedure over the Existing Procedure

#### 4.0 Conclusion

The proportion of male students who had contracted sexually transmitted disease, involved in rape, abortion, cultism, murder, stealing and examination malpractice is higher than that for the females. The proposed estimator showed that the variance of proportion for both male and female students involved in the sensitive and stigmatized characteristics is lower than that for the existing estimator. Hence, the proposed estimator is efficient.

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