

Strategies on Improvement of Random Experiment Validity in Statistical Teaching

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Abstract—It has become an important means of empirical research for obtaining research data through random experiments. Due to the human interference factors and the complex and changeable social psychological phenomena, it is significant to improve experimental validity. In statistics teaching, randomization and repeatability are the basic principles to be followed in randomized experiments. Correcting experimenter bias and participant bias are two important aspects to improve internal validity. Selecting sampling groups randomly and reducing demand characteristics are effective strategies to improve external validity.

Keywords—*randomized experiment; internal validity; external validity*

I. INTRODUCTION

An important task of survey research is to explore the basic pattern of complex social and economic phenomena through empirical methods and to give some kind of scientific causal explanation for this pattern. Experimental research, as an empirical method of cognition, is the most direct and important basis for the cognition of natural phenomena and constitutes the cornerstone of science. In the field of social economy, although there are many uncertainties as well as complex and changeable phenomena, the logic contained in experimental research is interlinked, and its basic elements such as structure, procedures, principles, characteristics, reliability and validity are consistent. Both experience-driven experiments based on method of difference and theory-driven experiments based on theoretical premise and for the purpose of theory testing are effective tools for empirical research, which have been widely used in the establishment of cause and effect, theory establishment, hypothesis testing etc. However, different from natural science experiments, experiments in the field of socio-economic science inevitably create social situations containing social relations, so the corresponding data conclusions are inevitably affected by human factors and limited by environmental conditions. Therefore, it is of practical significant to study how to conduct experiments under the optimal conditions of observation and measurement and reduce various influencing factors to improve research validity. At present, in the practice of statistics teaching, the common problem is insufficient attention to the validity of experiments for data acquisition, which to some extent affects the credibility and quality of research conclusions. This paper, in combination with the teaching practice, puts forwards

specific strategies to improve the validity of random experiments.

II. BASIC ELEMENTS OF RANDOM EXPERIMENTS

The randomized controlled experiment established by R. A. Fisher and the experimental research innovatively developed by his successors have greatly changed the field and scope of knowledge exploration, and become an important methodological tool for understanding laws and testing theories in various fields and the logic basis for scientific and philosophical speculation.

A. *Randomized Experiment and Its Advantages in Research*

Randomized experiment is an exploration activity, in which researchers observe and measure phenomena and behaviors under research environment they created, established and controlled in whole or in part; its characteristic is to achieve the balance of confounding variables between the experimental group and the control group by means of randomization. In the socioeconomic phenomenon research, its advantages are reflected in the following aspects: first, under the condition of random experiment, it's feasible to manipulate some variables and control the interference of external variables at the same time, so as to observe and measure the surveyed factors and process more accurately; second, it is feasible to artificially create and reproduce the initial conditions required by the theory to verify the hypotheses derived from the theory; third, it greatly improves the logical fit among theories, hypotheses and research findings, thus ensuring the strength of statistical testing effectiveness. These are difficult to achieve in the way of obtaining data based on surveys (such as questionnaire survey).

B. *Basic Principles of Randomized Experiment*

1) *Randomization*: It refers to assigning experiment participants randomly to the control group and the experimental group, which is the logic basis of applying experimental data for statistical test. Under the condition of randomization, differences in observed values can be regarded as independently randomized, at least without systematic influence on the values of dependent variables. In other words, randomization can reduce or even eliminate the influence of those additional interference factors that have not been

effectively controlled or recognized, and the statistical magnitude of the sample groups to be tested are similar. In this way, the effect of experimental treatment (intervention, arrangement) on the results can be tested.

To ensure randomization in the experiment, first, participants are selected by random selection or random sampling, so that each individual in the group has an equal chance of being selected, so as to ensure the representativeness of the sampling. It requires to avoid the use of naturally formed convenient samples as far as possible, such as a team, a workshop, a group; voluntary participants shall also be excluded. Second, to ensure individuals are assigned to experimental groups randomly, it is advisable to number the individuals randomly and then assign them uniformly, which can eliminate the possibility of influence of systematic error between participants and the experimental environment on experimental results, so that the difference in the results can be attributed to the experimental treatment. Third, in practice, to systematically control some variables that may affect the results, the experimenter may match the participants according to certain characteristics or features before assigning them to different experimental groups.

2) *Repeatability*: It refers to that, in the same experimental conditions, independent repeated experiments should get similar results. Repeatability experiments are reliable. If a theory is correct, then the experiment will lead to repeatable research findings to further prove the effectiveness of the theory. Repeated experiments can estimate experimental errors and determine whether there is a statistical difference; from the perspective of statistical analysis, compared with one experiment, repeated experiments can obtain more accurate statistics of sample groups. To meet the requirements of specific confidence coefficient, repeating the experiment is also a good choice to obtain a certain amount of data.

In actual experiments, to achieve repeatability, it is necessary to ensure the definiteness of the sampling frame, the universality of the sampling method and the representativeness and generality of the participants in the sample group.

C. *Standards of Randomized Experiment*

Whether the randomized experiment can provide the observation data required or not, the experiment standard logically provides the guarantee of scientific research.

First, it is recommended to establish sample groups with same initial conditions as possible. As long as the participants are randomly assigned to the control group and the experimental group in accordance with the randomization principle, the approximate equality of all groups in the statistics, except for the random difference, can be guaranteed on the premise of exclusion of external interference factors. Second, it is recommended to introduce the difference of (manipulated) variables between different groups to limit the inferences from observed results to this difference.

III. IMPROVEMENT OF INTERNAL VALIDITY

Internal validity refers to whether the experiment has excluded other reasons for the result, that is, to what extent is it possible to confirm that the change of the dependent variable is caused by the change of the independent variable. The influencing factors mainly come from the interference of unrelated variables that have not been controlled, leading to systematic deviation of the observed results, so it is impossible to determine whether the change of dependent variables is caused by the change of independent variables.

A. *Main Influencing Factors of Internal Validity*

1) *Experimenter bias*: This mainly refers to the experimenter's influence on the behaviors of participants. In general, researchers (including their assistants) will know the research hypothesis of the experiment in advance, so during the experiment, their casual conversation, standing, walking, gestures, facial expressions and other language or behaviors will reveal the information of the hypothesis in some way, which can affect the reaction of the participants and thus cause deviation to the observation results. To verify the hypothesis, achieve statistical significance and realize research expectations, some experimenters will show bias in the encoding of subjective judgment data or use implied words in the question-answer process, and even design the questionnaire with certain directionality from the guide words to the choices, which will cause bias to the experimental results.

2) *Participant bias*: This is mainly reflected in the uncontrollable differences shown by the participants with time elapsing of the same participant or among different groups during the experiment. First, as time goes on, the body and mind of the participant may change. In addition, when an experiment requires relatively long time to complete, some factors will naturally change. Even if an experiment is completed within a few hours, the observed results will also be influenced by participants' fatigue and boredom. Second, if a test is to be administered twice or if a participant has taken a similar test before, then the results of the second test will be influenced by the learning effect of the first test experience. Third, during the experiment, some participants exit from the experiment due to some reasons or the influence of the test context, which inevitably will affect the test results. Fourth, due to subjective will or objective conditions, participants are selected differently to the experimental group and the control group. Fifth, when the participants in the experimental group and the control group are informed of different experimental treatment due to curiosity or in casual conversation, this is easy to cause psychological difference to them and thus affect their behaviors. When participants in the experimental group are ideally treated, the control group either may either reduce the difference between the groups due to being stimulated by competitive pressure; or increase the difference between the groups because of noncooperation due to dissatisfaction. All of the above factors will affect the experiment results.

B. Strategy for Improving Internal Validity

1) *Experimenter*: A main means to eliminate experimenter bias is adopting "blind experiment", in which the experimenter (including his/her assistant) does not know the experimental treatment. Where possible, researchers could adopt a more ideal variant of the "blind experiment" - "double-blind experiment", in which neither the experimenter nor the participant knows the research hypothesis and experimental treatment, which would fundamentally reduce the experimenter bias. Besides, if there is a questionnaire in the experiment, questionnaire content shall be designed scientifically and reasonably and participants should be instructed to complete the questionnaire in a standardized way. No one shall ask or incite the participants to fill in the questionnaire in a specific way.

2) *Participants*: The primary means to eliminate the participant bias is to strictly abide by the randomization principle in grouping of participants. It is advisable to employ statistical software or a random number generator to ensure that each participant included has the same chance to enter different groups. In addition, if two related tests are required on the experimental group, a control group can be introduced to eliminate the interference of external factors and highlight the results of experimental treatment. Moreover, it is necessary to re-predict the characteristics of participants to reduce the loss of participants during the experiment; besides, it is advisable to, before the experiment, explain the purpose and significance of the research and the importance of completing the experiment, emphasize the randomness of selection, the anonymity of experimental results and the legitimacy of experiment organization, and encourage participants to recognize the experiment correctly, actively cooperate with the experiment, and finish the experiment carefully from beginning to end. Besides, it is necessary to limit the contact and communication between the experimental sample groups as far as possible to avoid result bias caused by joint decision-making after information exchange.

IV. IMPROVEMENT OF EXTERNAL VALIDITY

External validity means to what extent the result of an experimental can be extended from its own participants and experimental environments to other participants and experimental environments, which can indicate the ability of the research results to be generalized at different times, places, or among different participants.

A. Main Influencing Factors of External Validity

1) *Sample bias*: If the participants selected are different from the group in which the researcher hopes to generalize the results. That is, the participants selected cannot represent the target population, which forms the sample bias. The interaction between biased samples and independent variables fundamentally reduces the external validity, which is a big taboo of sampling. For example, college students are selected

as participants. Although it is convenient, economical and time-flexible, using them to represent general consumers, employee groups or business executives lacks sufficient external validity.

2) *Demand characteristics*: If participants know they are participating in an experiment, they will show a reaction tendency to naturally guess the intentions of the experimenter and the hypothesis to be tested. All the clues leading participants to make guesses are called demand characteristics, which are all the hints inadvertently leaked to the participants to guess the hypothesis in some link or step of the experiment. When the experimental group is treated, different participants will have different ideas. For example, some motivated or rewarded will act on the experimenter's expectations as they guessed; some reluctant or bored by such experiments may try to produce the opposite result based on the experimental hypothesis they speculated. In this case, regardless of whether the speculated experimental hypothesis is correct or not, participants acting on the demand characteristics will intentionally or unintentionally bias the research results. Sometimes demand characteristics may produce severely distorted results, even overwhelming the experimental control results, resulting in a huge bias in the conclusion.

B. Strategy to Improve External Validity

1) *Selecting unbiased samples*: Firstly, it is necessary to clarify the scope and characteristics of the target objects (population) to be studied, determine the sampling frame, and then consider adopting simple random sampling, stratified sampling, mechanical sampling, cluster sampling or staged combination sampling after the sample size is determined, so that the samples should be representative. Biased sampling such as convenient sampling and snowball sampling should be avoided.

2) *Reducing demand characteristics*: Because the experimenter cannot control the participants' interest points and curiosity in the experiment, demand characteristics cannot be completely eliminated. Therefore, before the experiment, it is necessary to carefully design the experiment and try to hide the real intention of the experiment to prevent the subjects from discovering the research hypothesis and the items to be tested, and to prevent the participants from deliberately adjusting their personal behaviors, so as to reduce the influence of demand characteristics. To achieve this purpose, the following measures can be taken. First, for well-intentioned camouflage of experiment, it is feasible to tell participants false hypothesis or intention of the experiment. Placebo often used in experiments is a false experimental treatment, which has a psychological effect on participants, and shall be given as the real experiment treatment to avoid operation different, so as to observe the differences between the experimental group and the control group and further evaluate the real effect of the control variable. Second, it is feasible to hire an unwitting experimenter to complete the experiment. If the experimenter does not know the intention

of the experiment, he/she will not give a hint that will cause demand effect, and this can bring a "double blind" effect. Third, it is recommended to give experimental treatment on one item to each participant group, which can avoid the possibility of participants guessing the experimental hypothesis after they know there are different experimental treatments. Fourth, the experimenter shall avoid the participants knowing that they are being observed, and make them feel normal like in a normal environment, so as to eliminate psychological differences among participants.

V. CONCLUSION

The validity of randomized experiments determines the quality of data, and high-quality data are playing a significant role in discovering relationships between phenomena. As a tool to explore cause and effect, randomized experiments can effectively control the process and factors, exclude external interference factors to a large extent, and effectively deduce the relationship between variables. In teaching experiment, it is necessary to understand the logical structure of the experiment and strictly follow the experimental standards and basic principles, which is the fundamental guarantee to improve the experimental validity; besides, carefully controlling the selection of sample group, experimenter bias and demand characteristics, and conducting pre-test experiment to further optimize the design when necessary both are effective measures to improve experimental validity and reduce human factors.

An ideal randomized experiment has both high internal and external validity. However, in real experiments, it is difficult to have the both, because when measures are taken to improve a kind of validity, the other validity is often reduced. Therefore, a compromise strategy is often adopted in experiments. Especially, when a research focuses on testing theoretical ideas, internal validity should be paid more attention; when the research result remains to be popularized for application, improving external validity is more important.

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