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The Application of the Item Response Theory in China's Public Opinion Survey Design

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Abstract

In this paper, we use the item response theory (IRT), take the public opinion poll questionnaire survey design as main lines, combine college campus life satisfaction survey, discuss the basic principle of IRT public opinion poll questionnaire survey design systematically and research key technology and method of the process specifications, survey topic choice, scheme configuration, error control and satisfaction standards definition of the public opinion poll questionnaire survey design. Studies show that this theory and method overcomes the problem, which the public opinion poll questionnaire survey design under classical test theory (CTT) can not solve it and IRT may improve the quality of the public opinion poll questionnaire survey design.

Key words: The public opinion poll survey; Questionnaire design; IRT; Survey technology research

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1. TO PRESENT A PROBLEM

Public opinion is the manifestation of social public opinion. The investigate object of public opinion poll are people's opinions, ideas, habits, behavior and attitude, scientifically and effectively collect and analyze relevant information so as to provide the process of scientific basis for the decision-making of management department.

Opinion of citizens and asks expression, is an important part of Chinese service-oriented government construction. In recent years, China has developed all kinds of polls, which include the environmental satisfaction, consumer confidence index and so on. These polls provide the scientific basis for the decision-making of governments at all levels and have gained wide social acceptance. Public opinion polls have become the focal point of current statistical investigations.

However, due to the institutionalization of public opinion polls has just begun in China, and therefore, there is a very big disparity in related research of theory and application of practice, compared with foreign other countries. At present, China's public opinion polls mainly include the democratic political class, economic (psychology) class and social public living class, etc. Its research of theory and technology mainly concentrated on assessment index system establishment of public opinion, questionnaire design, organization of survey and evaluation of survey result and so on, but the Classical Test Theory (CTT) has some shortcomings[1-4], so at present, the research of China's public opinion polls theory has some questions, which still can not be solved.

In essence, the public opinion polls is a kind of measurement of people's certain psychological traits (feelings, intend, attitude, etc.).With the development of modern measurement theory, especially the development

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of Generalization Theory (GT) and Item Response Theory (IRT)[4], these greatly promoted the development of survey theory and widened the research field of questionnaire design theory, and this has become the international trend ,which we apply the modern measurement theory to questionnaire survey.

In recent years, Chinese scholars, for example, Tu, Yu and He and so on, have a large amount of research in this aspect, but their research mainly focus on the basic theory of GT and IRT and their application in psychological evaluation, standardized tests, database construction and adaptive test, etc.

2. BASED ON THE PRINCIPLE OF IRT PUBLIC OPINION QUESTIONNAIRE DESIGN

2.1 The Basic Concepts of IRT

IRT originated in the 1950s and it was founded by Lwaley (1936), Lazarsfied (1950), A.Birnbaum (1957) and G.Rasch (1960), etc. Science 1970s, IRT had become the main research topic of the psychological measurement in most countries. IRT mainly is used for the measurement of so-called potential psychological traits in psychology and this is in accord with the goals of public opinion class survey. To take public opinion class survey for example, IRT basic idea can be expressed as: for any interviewees, whether a survey topic can be answered by the probability of affirmation or satisfaction or not, this depends on two aspects: one is subjective factors, other is the objective attributes of survey topic, which is reflected by the attributes of the difficulty and distinction. In other words, whether this survey topic can be answered by affirmation or satisfaction or not, this depends on the attitude of interviewees, difficulty and distinction of survey topic.

IRT adopts item characteristic curve (ICC) to reflect the relationship between the above. For any survey topic, we may calculate the parameters of ICC according to survey data so as to obtain a specific characteristics curve. In practice, the most common ICC is Logistic IRT model and this model mainly has single parameter, double parameters, where three parameters of IRT model are as follows:

$$P_i(\theta) = c_i + (1-c_i)\frac{\exp[Da_i(\theta-b_i)]}{1+\exp[Da_i(\theta-b_i)]} = c_i + \frac{1-c_i}{1+\exp[-Da_i(\theta-b_i)]} \quad (1)$$

Where $p_i(\theta)$ stands for the probability of satisfactory, which the interviewee of the attitude valued θ answer the i-th topic; the constant D equals to 1.7; the parameter a is the distinction of survey topic; the parameter b stands for difficulty; C is the guess parameter or pseudo- random level parameter.

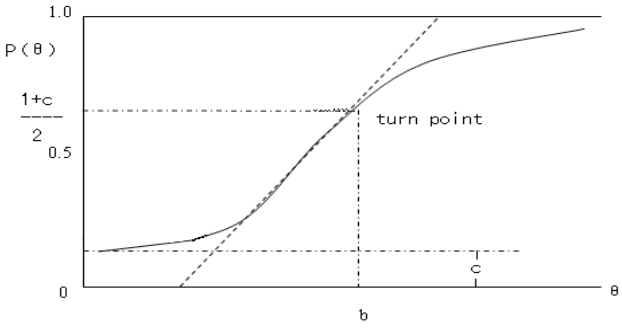

Figure 1
Three Parameters Logistic ICC

In order to reflect the survey precision, IRT use the concept of the information function, which the i-th survey topic provide the information for the interviewee of the attitude valued θ. In IRT, the information function of i-th survey topic reflects in the level of different interviewee and its computation formula is:

$$I_i(\theta) = \frac{(P')^2}{PQ} = \frac{D^2 a_i^2 (1-c_i)}{\{c_i + \exp[Da_i(\theta-b_i)]\}\{1+\exp[-Da_i(\theta-b_i)]\}^2} \quad (2)$$

IRT proves that the information function of survey is the total sum of every survey topic information function and the standard error of survey SE (θ) is the root inverse of information function, namely, the standard error of survey is as follows:

$$SE(\theta) = \frac{1}{\sqrt{\sum I_i(\theta)}} \quad (3)$$

Where, SE (θ) stands for the survey standard error of the attitude θ, n is the title number and $I_i(\theta)$ is the i-th information content.

The information function in IRT avoids the parallel test hypotheses of CTT, can give the survey precision of the different attitudes value, can also choose the most gain survey topic of different attitude estimation precision according to the size of the survey topic information content and makes the survey reach prescribed satisfactory precision. The researchers of questionnaire can use the information function and survey standard error, which are provide by IRT, so as to design more scientific and reasonable questionnaire.

2.2 Based on the Questionnaire Design Process of IRT

1st. Survey topic compilation and pre-survey. Compilation is in accord with the traditional method. According to certain survey goal, we compile the survey topic in the building of the survey index system basis and the survey topics of compilation need to be enough (at least more then 30[4]). When we do pre-survey, in order to ensure

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the accuracy of the IRT questionnaire design, usually, we accept that the number of interviewees is more than 500[4].

2nd. Hypothesis testing of single-dimension and ICC choice. So-called single-dimension, namely, one survey merely is used to measure a poll of attitude. The hypothesis testing of single-dimension often adopts the principal component analysis and general we deem that assumption is established as long as the ratio of the first and the second principal components characteristic root is more than 0.5. In ICC choice, the pubic opinion poll should be choice two parameters Logistic ICC because the interviewee, whose attitude value is low, should not be given the high evaluation.

3rd. Parameter estimation and the first choice of survey topic. According to the data of pre-survey, we may adopt all kinds of IRT software to estimate the parameters of ICC. The first choice of survey topic will remove the extreme parameter values of survey topic according to the estimated ICC parameters. Generally speaking [8], if any conditions can not be fulfilled a≤0.3 (or a≥4), b>2.95 (or b<-2.95) or c>0.4, the survey topic should be modified or remove.

4th. Determination of the target information curve (TIC). We may calculate the standard error of survey $SE(\theta)$ according to the requirement of the user so as to determine the request of the minimum needed survey information, namely TIC.

If we require ensure the reliability of 98%, the real attitude value θ1 should be fell over within the region of the attitude neutral point θ_0 ($-\theta_1 \le \theta_0 \le \theta_1$). According to the normal distribution theory, θ1 should be two standard deviation higher than θ0, namely, $\theta_1 \ge 2SE(\theta)$ then according to formula (3), we can determine that the selected survey topic, which has reached the given precision, should has the lowest information content $I(\theta)$, so as to get the TIC of the region ($-\theta_1 \le \theta_0 \le \theta_1$). In this way, the requirement of survey precision has changed the lowest information content of survey topic, namely, the determination of TIC. Obviously, the higher precision requirement, the corresponding information function value is bigger.

5th. Survey topic choice and form questionnaire. Survey topic choice aims to produce a group of survey topics and combine their information curves to produce a TIC, accord with or greater than TIC of the target. When we do survey topic choice, generally, in the interval of the requirements attitude value θ, according to the lowest standard of the certain chosen survey topic and the information content from large to small, we choose them.

3. BASED ON THE UNDERGRADUATE CAMPUS SATISFACTION QUESTIONNAIRE DESIGN OF IRT

3.1 The Construction of the Satisfaction Survey'S Evaluation Index System

There are a variety of measuring models of satisfaction and the most representative is the logic model of Fornell (1989), which is made of the expectation of customers, perception quality, perceptive value, customers complaints and customers loyalty and so on. For example, in the design of Chinese college students' campus life satisfaction survey questionnaire, we refer the core concept and structure of Fornell's customer satisfaction model, combine the specific conditions of Chinese higher education institution and use structural equation model theory and so on to construct the following the satisfaction appraisal model of college students' campus life (figure 2).

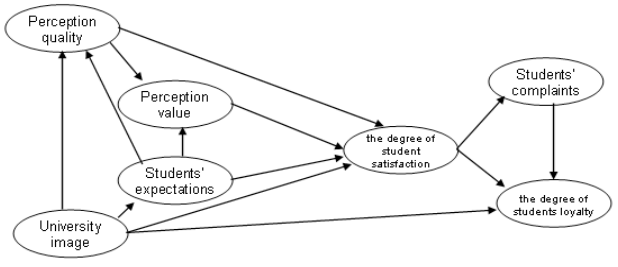

Figure 2
The Satisfaction Appraisal Model of the College Students' Campus Life

The above variables are latent variables (implicit variables), which can not be directly measured out. Therefore, according to the corresponding observable variables, which are made of the above seven latent variables, we can get the corresponding appraisal index system (table 1). Certainly, here is the key of structure, which observable variables can reveal the essential attribute of the latent variables.

Table 1
The Satisfaction Appraisal Index System of the College Students' Campus Life

The first index (latent variables)	The second index (observable variables)
University image	University social image; Professional ranks, etc.
Students' expectations	Whether the first volunteer; the interest of specialty; the scores of college entrance examination, etc.
Perception quality	Teacher's professional titles and educations; teaching facilities; the conditions of laboratories; library books; dormitory conditions; sanitation, etc.
Perception value	University spirit; study atmosphere; teaching quality; scientific research level; employment quality; awards, etc.

To be continued

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Continued

The first index (latent variables)	The second index (observable variables)
Students' satisfaction	Confidence in the future; pride; the worthy life, etc.
Students' complaints	Teaching outmoded knowledge; disjointed theory and practice; truancy; turn major; dropout; the low employment rate, etc.
Students' loyalty	Whether suggest other candidates enter this university; whether willingness to pursue this major job after graduation, etc.

3.2 Based on the Satisfaction Questionnaire Design Process of IRT

1st. The compilation of survey topic. According to the above method, which is university student campus life satisfaction evaluation index system, we may compile the corresponding initial questionnaire (including 64 topics). We make use of five Likete scale table to survey 540 university students and use isotropization and secondary sore processing to get the constitute of IRT basic data.

2nd. The single-dimension hypothesis test and model parameters estimate. We adopt the SPSS11.5 and principal component analysis to analyze the basic data. The result shows that the first factor latent root is 17.239, the second factor latent root is 3.061 and their ratio is 5.632, so we think that the hypothesis test of single-dimension is established.

We choose two parameters logistic IRT model and adopt BILOG_MG[6] soft to estimate the parameters. We obtain the ICC of every survey topic and remove the topics, which include a≤0.3or a≥4, remove the topics including b>2.95 or b<-2.95. The parameters estimated of the rest 24 topics see the table 2.

Table 2
The Parameters Estimated of University Students Campus Life Satisfaction Survey's Two Parameters Logistic Model

Item	a discrimination	b difficulty	θ=-0.8 information	θ=+0.8 information	Item	a discrimination	b difficulty	θ=-0.8 information	θ=+0.8 information
1	0.632	0.302	0.20	0.22	13	1.006	0.049	0.30	0.30
2	1.028	-0.021	0.30	0.32	14	1.008	-0.006	0.31	0.31
3	0.676	0.051	0.20	0.20	15	0.778	0.084	0.20	0.20
4	0.377	0.217	0.10	0.10	16	1.358	0.139	0.30	0.30
5	1.093	0.008	0.30	0.30	17	1.156	-0.232	0.50	0.30
6	0.808	0.072	0.20	0.20	18	0.980	-0.024	0.40	0.40
7	1.502	-0.194	0.40	0.50	19	1.169	-0.011	0.40	0.40
8	0.633	0.223	0.20	0.20	20	0.781	0.068	0.25	0.25
9	0.401	-0.050	0.10	0.10	21	1.419	-0.031	0.40	0.40
10	0.597	0.272	0.15	0.15	22	0.873	0.187	0.30	0.40
11	0.862	-0.288	0.35	0.20	23	1.571	-0.144	0.50	0.30
12	1.368	-0.257	0.51	0.51	24	1.022	0.074	0.30	0.40

The general information function curve, which is created by BLOG_MG, is showed by figure 3. From figure 3, we can see that the university students satisfaction degree of this survey scheme if from -0.8 to+0.8 (this means that the answer of the satisfaction topics is between 4 and 21 after we deal with equivalence.) and this survey is effective. When the satisfaction degree of the university students is 0.0 (this means that the answer of the satisfaction have 12 topics, when all topics is 24), this survey is the most precise (the information contents are maximum). After that, with the attitude scale table reduces or strengthens, the survey will gradually lose its identification function.

3rd. Determined the TIC. Assuming the confidence of the confidence interval $|\theta_0 - \theta_1| = 0.8$ is 98%, then, $|\theta_0 - \theta_1| \geq 2SE(\theta)$ is established, so we have $SE(\theta) = 0.4$. According to the following formula, we can calculate $I(\theta)$.

$$I(\theta) = [\frac{1}{SE(\theta)}]^2 = (\frac{1}{0.4})^2 = 6.25$$

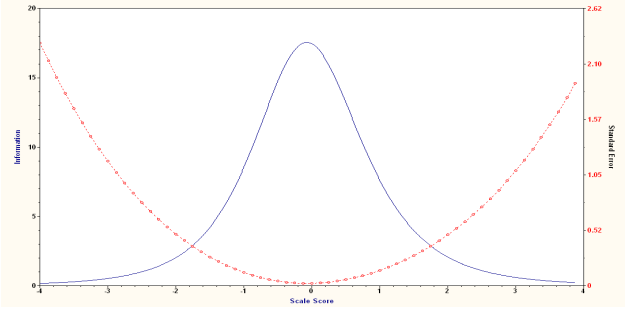

Figure 3
The Information Curve of the University Student Life Campus Satisfaction Degree's Survey

Result shows that the information function accumulative value of all survey topics should be bigger or equal to 6.25 in this scheme and this is the lowest information requirements.

4th. Survey topics choice and produce the survey scheme. According to the information, which we have calculated in -0.8 and +0.8 place, we array them from big

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to small (see table 3).

Table 3
The Sort of Every Survey Topic Measurement Precision (Information Contents)

item	θ=-0.8 information	item	θ=+0.8 information	item	θ=-0.8 information	item	θ=+0.8 information
12	0.51	12	0.51	16	0.30	13	0.30
17	0.50	7	0.50	22	0.30	16	0.30
23	0.50	18	0.40	24	0.30	20	0.25
7	0.40	19	0.40	20	0.25	1	0.22
18	0.40	21	0.40	1	0.20	11	0.20
19	0.40	22	0.40	3	0.20	3	0.20
21	0.40	24	0.40	6	0.20	6	0.20
11	0.35	2	0.32	8		8	0.20
14	0.31	14	0.31	15		15	
2	0.30	17	0.30	10		10	
5	0.30	23	0.30	4		4	
13	0.30	5	0.30	9		9	
				total	6.42		6.61

From table 3, we pick up the survey topic according to the information, which is from big to small, until the lowest cumulative information value is 6.25, and then generate the final survey scheme (including 19 survey topics). Figure 4 shows the TIC and the survey information curve of scheme. From this, we can see that the measurement error of this scheme completely satisfies the requirement of precision.

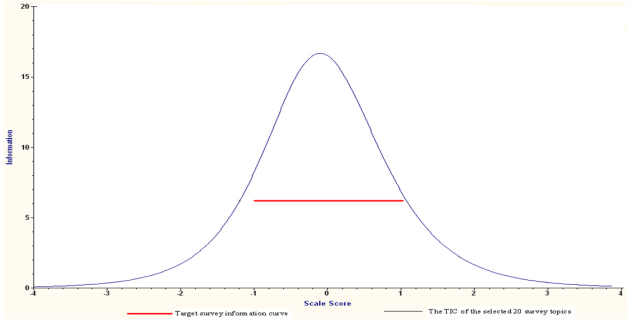

Figure 4
The Information Curve of Eventually Generated University Student Campus Life Satisfaction Degree Survey Scheme

3.3 Based on the Partition of IRT Satisfaction Degree Qualified Line

For public satisfaction survey speaking, how to scientifically and accurately differentiate satisfaction qualified line is a difficulty. Based on the information function, IRT provides the relatively accurate and complete qualified line dividing method for it. If a survey can better measure the actual situation of the satisfaction, the ratio of satisfaction answer should be averages of the whole survey topics expectation, and the approximate formula of calculation is[9]:

$$\pi \approx \frac{1}{n}\sum P_i(\theta) \tag{5}$$

Where, n is the number of survey topics, $P_i(\theta)$ is the probability, which the interviewee θ satisfactorily answers the i-th survey topic. According to the research of the actual and authoritative experts assessment team, we determine that the satisfaction qualified line should be at least achieve satisfaction percentage π1, and then according to the calculating formula of $P_i(\theta)$, which is calculated by the selection IRT model. The formula (5) only has a parameter θ and we adopt Newton iterative method to solve value of the satisfied equation (5)θ_π. This is the standard of the corresponding satisfaction qualified line. Obviously, we also may adopt the equivalent processes, and then θ_π is converted to survey topic of answer satisfaction.

CONCLUSION AND DISCUSS

This paper systematically discusses the basic principle of IRT public opinion class questionnaire design and studies the key technologies, which are the process of questionnaire design, survey topic choice, the configuration of scheme, control of error and determination of satisfaction degree standard and so on, and combines the satisfaction degree survey to discusses its realization process in detail.

Research shows that IRT method allows the designer of the scheme to compile the corresponding psychological satisfaction scale table according to the specified TIC. Scheme design precision can be strictly controlled in some points and interval of the interviewee satisfaction degree θ. Meanwhile, the division of satisfaction qualified line's standard is more scientific and reasonable. IRT has remarkable effect in the optimized allocation of survey topic, the control of the survey error precision, the determination of the satisfaction degree quailed standard, and overcome the some problem, which can not be solved by the questionnaire design technology of CTT, so IRT is the important method, which can improve the quality of public opinion class questionnaire design.

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REFERENCES

[1] WEI H-Z. (2006). *Education Statistics and Measurement*. Liaoning: Liaoning Normal University Press.

[2] KE H-X, & ZHU J-H. (2003). *Spread Statistical Chemical.* Beijing: Beijing Broadcasting Institute press.

[3] TU R-T. (2008). The Discuss of Customer Satisfaction Degree Measurement: Scale Design, Reliability and Validity. *Journal of Management.*

[4] YU, J-Y. (1992). *Item Response Theory and Its Application*. Jiangsu: Jiangsu education press.

[5] TU, S-Q. (1998). *The Modern Education and Psychometric Principle.* Beijing: Higher Education Press.

[6] Robert J. Mislevy (1990). *Bilog3, R. Darrell Bock*. Chicago: Chicago University.

[7] XU, J, MA, S-H., & He, X-Q. (2004). The Evaluation of Standardized and the Application of IRT Model. *Test Research*.

[8] KONG, Y., & ZHANG, F. (2009). Based on Chinese Citizens Scientific Literacy Assessment Method Research of the Item Response Theory. *Science and Management Research, 4*.

[9] YANG, Y-B. etc. (2008). Application of the Item Theory about the Item Analysis of Chinese Soldiers Personality Questionnaire. *Journal of Psychology, 5*.

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