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On the Application of Grey Relational Analysis and RIDIT Analysis to Likert Scale Surveys

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Abstract

Likert scale is one of the most frequently used measures in social sciences to gather data on attitudes, perceptions, values, intentions, habits and behaviour changes. This paper illustrates two methods, i.e. grey relational analysis and RIDIT analysis, which can be used to analyse data from Likert scale surveys. It is found that the results derived from applying the aforementioned methods are very much consistent with each other. Characteristics of the two methods and guidelines for choosing between the two for data analysis are also discussed in this paper.

Mathematics Subject Classification: 62P25

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1 Introduction

Research topics in social sciences often require collecting data on attitudes, perceptions, values, intentions, knowledge and behaviour changes. These types of data are commonly measured by Likert scales [7], [9], [19]. As such, analysing Likert scale data is a common practice in social science researches.

In general, basic statistical techniques such as frequency tabulations, means, standard deviations, t tests, chi square tests, correlation coefficients, multivariate techniques etc. are available for Likert scale data analysis [4], [8], [13], [17], [20]. However, these techniques are not suitable for generating statistics that can be used as criterion for arranging scale items in ascending or descending order. For example, questions like "what are the three most (or least) satisfied items in a proposed benefits program" can not be properly answered by using basic statistical techniques.

Grey relational analysis and RIDIT analysis are methods that can be applied to Likert scale data analysis. The results from the analysis can be used to order Likert scale items and explore the relationships among them in terms of, for example, degrees of importance or agreement. This paper explains the concepts of the methods and illustrates the computation procedures through data extracted from an actual Likert scale survey. A comparison of the two methods and guidelines for choosing a method between the two for data analysis are also discussed.

2 Likert Scale

Likert scale was developed by American educator and organisational psychologist R. Likert in the 1920's in an attempt to improve the levels of measurement in social research through the use of standardised response categories in survey questionnaires. Likert scaling presumes the existence of an underlying (or latent or natural) continuous variable whose value characterizes the respondents' attitudes and opinions [4], [14]. Although Likert scaling has been criticised for being subjective in nature, it is still one of the most frequently used measurement instruments in social sciences.

Generally speaking, in a Likert scale survey, respondents are instructed to state their levels of agreement with a series of statements. Each degree of agreement or disagreement is then given a numeric value on a predetermined scale. Likert statements are typically a five or seven-point scale. Some research designs prefer an even number of possible responses so that there is no midpoint in the scale. In such a case, the respondent is forced to make a choice that leans either to agree or disagree with the corresponding statements.

Data from a Likert scale survey is considered to be ordinal or arguably interval [4], [9], [12], [13], [16], [18], [20]. In a Likert scale survey, test of reliability and validity of the scale in the context of the research area of interest is deemed as indispensable [15]. Typical research areas that may be addressed using Likert scales include (1) customer satisfaction with products or services (2) public opinion about controversial issues (3) employees satisfaction with compensation programs, (4) perceptions on institutional image and (5) parent satisfaction with school education.

3 Methodology Review

3.1 Grey Relational Analysis

The validity of traditional statistical analysis techniques is based on assumptions such as the distribution of population and variances of samples. Nevertheless sample size will also affect the reliability and precision of the results produced by traditional statistical analysis techniques. J. Deng argued that many decision situations in real life do not conform to those assumptions, and may not be financially or pragmatically justified for the required sample size. Making decisions under uncertainty and with insufficient or limited data available for analysis is actually a norm for managers in either public or private sectors [5], [6]. To address this problem, J. Deng developed the grey system theory, which has been widely adopted for data analysis in various fields.

The grey relational analysis introduced in the following is a method in grey system theory for analyzing discrete data series. A procedure for the grey relational analysis, which is appropriate for Likert scale data analysis, consists of the following steps.

1. Generate reference data series x_0.

$$x_0 = (d_{01}, d_{02}, ..., d_{0m})$$

   where m is the number of respondents. In general, the x_0 reference data series consists of m values representing the most favoured responses.

2. Generate comparison data series x_i.

$$x_i = (d_{i1}, d_{i2}, ..., d_{im})$$

   where $i = 1, ..., k$. k is the number of scale items. So there will be k comparison data series and each comparison data series contains m values.

3. Compute the difference data series Δ_i.

$$\Delta_{i=}(|d_{01} - d_{i1}|, |d_{02} - d_{i2}|, ..., |d_{0m} - d_{im}|)$$

4. Find the global maximum value $\Delta \max$ and minimum value $\Delta \min$ in the difference data series.

$$\Delta \max = \max_{\forall i}(\max \Delta_i)$$

$$\Delta \min = \min_{\forall i}(\min \Delta_i)$$

5. Transform each data point in each difference data series to grey relational coefficient. Let $\gamma_i(j)$ represents the grey relational coefficient of the j_{th} data point in the i_{th} difference data series, then

$$\gamma_i(j) = \frac{\Delta_{\min} + \varsigma\Delta_{\max}}{\Delta_i(j) + \varsigma\Delta_{\max}}$$

   where $\Delta_i(j)$ is the j_{th} value in Δ_i difference data series. ς is a value between 0 and 1. The coefficient ς is used to compensate the effect of $\Delta \max$ should $\Delta \max$ be an extreme value in the data series. In general the value of ς can be set to 0.5.

6. Compute grey relational grade for each difference data series. Let Γ_i represent the grey relational grade for the i_{th} scale item and assume that data points in the series are of the same weights [1], then

$$\Gamma_i = \frac{1}{m}\sum_{n=1}^{m}\gamma_i(n)$$

The magnitude of Γ_i reflects the overall degree of standardized deviance of the i_{th} original data series from the reference data series. In general, a scale item with a high value of Γ indicates that the respondents, as a whole, have a high degree of favoured consensus on the particular item.

7. Sort Γ values into either descending or ascending order to facilitate the managerial interpretation of the results.

3.2 RIDIT Analysis

RIDIT analysis was first proposed by I. Bross and has been applied to the study of automobile accidents, of cancer, of schizophrenia and of various business management and behaviour studies. RIDIT analysis is "distribution free" in the sense that it makes no assumption about the distribution of the population under study [2], [10]. Suppose that there are m items and n ordered categories listed from the most favoured to the least favoured in the scale, then RIDIT analysis goes as follows.

1. Compute ridits for the reference data set.

   (a) Select a population to serve as a reference data set. For a Likert scale survey, the reference data set can be the total responses of the survey, if the population can not be easily identified.

   (b) Compute frequency f_j for each category of responses, where $j = 1, ..., n$

   (c) Compute mid-point accumulated frequency F_j for each category of responses.

$$F_1 = \frac{1}{2}f_1$$

$$F_j = \frac{1}{2}f_j + \sum_{k=1}^{j-1} f_k \ where \ j = 2, ..., n$$

[1]If data points are of different weights, then $\Gamma_i = \sum_{n=1}^{m}(\gamma_i(n) \times \omega(n))$ subject to $\sum_{n=1}^{m}\omega(n) = 1$, $\omega(n)$ is the weight of the n_{th} data point.

(d) Compute ridit value R_j for each category of responses in the reference data set.

$$R_j = \frac{F_j}{N} \textit{ where } j = 1, ..., n$$

N is the total number of responses from the Likert scale survey of interest. By definition, the expected value of R for the reference data set is always 0.5 [1], [2].

2. Compute ridits and mean ridits for comparison data sets. Note that a comparison data set is comprised of the frequencies of responses for each category of a Likert scale item. Since there are m Likert scale items in this illustration, there will be m comparison data sets.

(a) Compute ridit value r_{ij} for each category of scale items.

$$r_{ij} = \frac{R_j \times \pi_{ij}}{\pi_i} \textit{ where } i = 1, ..., m$$

π_{ij} is the frequency of category j for the i_{th} scale item, and π_i is a short form for the summation of frequencies for scale item i across all categories, i.e.

$$\pi_i = \sum_{k=1}^{n} \pi_{ik}$$

(b) Compute mean ridit ρ_i for each Likert scale item.

$$\rho_i = \sum_{k=1}^{n} r_{ik}$$

(c) Compute confidence interval for ρ_i. When the size of the reference data set is very large relative to that of any comparison data set, the 95% confidence interval of any ρ_i is[2]:

$$\rho_i \pm \frac{1}{\sqrt{3\pi_i}}$$

(d) Test the following hypothesis using Kruskal-Wallis statistics W [3].

$$\begin{cases} H_0 : \forall i, \rho_i = 0.5 \\ H_a : \exists i, \rho_i \neq 0.5 \end{cases}$$

[2]If the reference data set is not too much larger than the comparison data set, please refer to J. Fleiss to find the standard errors of mean ridits [10].

[3]If N is not sufficient in size then

$$W = \frac{12N}{(N+1)T} \sum_{i=1}^{m} \pi_i (\rho_i - 0.5)^2 \quad \textit{where } T = 1 - \frac{\sum_{i=1}^{m} (\pi_i^3 - \pi_i)}{N^3 - N}$$

$$W = 12 \sum_{i=1}^{m} \pi_i (\rho_i - 0.5)^2$$

W follows a χ^2 distribution with *(m-1)* degree of freedom. If H_0 can not be accepted, examine the relationships among confidence intervals of ρ. The general rules for interpreting the values of ρ are shown below.

1. A scale item with its ρ_i value statistically deviate from 0.5 implies a significant difference in the response patterns between the reference data set and the comparison data set for the particular scale item. If the confidence interval of a ρ_i contains 0.5, then it is accepted that the ρ_i value is not significantly deviate from 0.5.

2. A low value of ρ_i is preferred over a high value of ρ_i because a low value of ρ_i indicates a low probability of being in a negative propensity.

3. The response patterns of scale items with overlapped confidence intervals of ρ are considered, among the respondents, to be statistically indifferent from each other.

4 An Illustrating Example

A sample data extracted from an actual Likert scale survey [18] regarding the life orientation (6 items) of respondents is used to illustrate the procedures for grey relational analysis and RIDIT analysis. Cases with missing values are not included for analysis. A brief description of the scale can be found in the appendix[4].

4.1 Procedure for Grey Relational Analysis

For ease of explanation of the computation procedure for grey relational analysis, only the first 10 cases in the data file were used for illustration. In table 1, x_0 is the reference data series. Because the life orientation scale is a five-point Likert scale, x_0 is set to contain values of 5. x_1-x_6 is the original comparison data series which contains responses of the respondents. The difference data series for Table 1 is shown in table 2. As an example,

$$\Delta_1(1) = |2 - 5| = 3$$

From table 2, it can be seen that $\Delta max = 4$ and $\Delta min = 0$. Table 2 can then be transformed to grey relational coefficients shown in table 3. $\gamma_1(1)$ and Γ_1 are calculated by the following expressions.

[4]The data file survey.sav and its codebook can be downloaded from http://www.allenandunwin.com/spss/data.htm

Table 1: Life orientation data set (10 cases)

	x_0	x_1/OP1	x_2/OP2	x_3/OP3	x_4/OP4	x_5/OP5	x_6/OP6
$d._1$	5	**2**	**4**	**2**	**4**	**3**	**4**
$d._2$	5	**4**	**5**	**4**	**5**	**5**	**5**
$d._3$	5	**2**	**3**	**4**	**3**	**5**	**2**
$d._4$	5	**3**	**3**	**4**	**5**	**5**	**3**
$d._5$	5	**3**	**4**	**4**	**4**	**4**	**3**
$d._6$	5	**2**	**4**	**5**	**4**	**4**	**4**
$d._7$	5	**1**	**3**	**1**	**2**	**1**	**1**
$d._8$	5	**3**	**3**	**3**	**3**	**4**	**4**
$d._9$	5	**4**	**5**	**4**	**4**	**5**	**5**
$d._{10}$	5	**4**	**4**	**4**	**4**	**4**	**4**

Table 2: The difference data series

$\Delta_1.$/OP1	$\Delta_2.$/OP2	$\Delta_3.$/OP3	$\Delta_4.$/OP4	$\Delta_5.$/OP5	$\Delta_6.$/OP6
3	1	3	1	2	1
1	0	1	0	0	0
3	2	1	2	0	3
2	2	1	0	0	2
2	1	1	1	1	2
3	1	0	1	1	1
4	2	4	3	4	4
2	2	2	2	1	1
1	0	1	1	0	0
1	1	1	1	1	1

$$\gamma_1(1) = (0 + 0.5 \times 4)/(3 + 0.5 \times 4) = 0.4$$
$$\Gamma_1 = (0.4 + 0.67 + 0.40 + ... + 0.67)/10 = 0.50$$

In this particular example, Γ values represent the degrees of agreement to scale items. A large Γ value represents a high degree of agreement. According to the magnitude of the Γ values of scale items shown in table 3, the scale items can be arranged in the following order.

OP5(0.75)> OP2(0.67),OP4(0.67)> OP6(0.64)> OP3(0.62)> OP1(0.50)

From this order, it can be said that, in general, the respondents as a whole expect more good things to happen. However, in reality the respondents are more pessimistic than optimistic. The Γ values calculated from the entire life orientation data set are shown below in descending order. This order is very similar to the result calculated from the first 10 cases.

OP5(0.72)> OP6(0.69)> OP2(0.68),OP4(0.68)> OP3(0.66)> OP1(0.58)

Table 3: Grey relational grades

γ_1./OP1	γ_2./OP2	γ_3./OP3	γ_4./OP4	γ_5./OP5	γ_6./OP6
0.40	0.67	0.40	0.67	0.50	0.67
0.67	1.00	0.67	1.00	1.00	1.00
0.40	0.50	0.67	0.50	1.00	0.40
0.50	0.50	0.67	1.00	1.00	0.50
0.50	0.67	0.67	0.67	0.67	0.50
0.40	0.67	1.00	0.67	0.67	0.67
0.33	0.50	0.33	0.40	0.33	0.33
0.50	0.50	0.50	0.50	0.67	0.67
0.67	1.00	0.67	0.67	1.00	1.00
0.67	0.67	0.67	0.67	0.67	0.67
0.50	0.67	0.62	0.67	0.75	0.64

4.2 Procedure for RIDIT Analysis

The first step in doing RIDIT analysis is to identify a reference data set to calculate the ridits. The key to an intelligent choice of the reference data set is to achieve the space-time stability of refined measurement system. Sometimes there is a natural choice of a reference data set. Occasionally the study series as a whole will serve as a reference data set because it is representative of some larger population. The reference data set should be representative and be large enough to ensure that the ridits of the reference data set will be stable [1], [2].

In this illustration, the whole survey data on life orientation is chosen as the reference data set. The frequencies of the responses are shown in bold figures in table 4. The last row of table 4 shows the ridits of the reference data set for each ordered category. As an example, the ridit value 0.98 for the category ”strongly disagree” is calculated by the following expression.

$$(664+915+668+274+44.5)/2610=0.98$$

The various ridits for the comparison data sets are shown in table 5 in bold figures. The ridit value 0.28 of category “undecided” for scale item OP1 is calculated by the following expression.

$$(169\times 0.73)/435=0.28$$

The mean ridit of scale item OP1 is calculated, with rounding error, by the expression that follows.

$$(0.01+0.13+0.28+0.14+0.05)=0.62$$

The Kruskal-Wallis W is calculated as follows.

$$12\times[\,435\times(0.62-0.5)^2+435\times(0.49-0.5)^2+435\times(0.50-0.5)^2+435\times(0.48-0.5)^2+435\times(0.43-0.5)^2+435\times(0.48-0.5)^2\,]$$

Since the Kruskal-Wallis $W(100.41)$ is significantly greater than $\chi^2(6-1) = 11.07$, it can be inferred that the opinions about the scale items among the respondents are statistically different somehow.

From the confidence intervals shown in table 5, it can be seen that the opinions of respondents about scale item 5 (OP5) is significantly different from scale item 1 (OP1). Compared to the reference data set, the respondents have less probability of disagreeing with scale item 5 (OP5). In other words, the respondents are more likely to expect good things to happen. On the other hand, respondents have higher probability of disagreeing with scale item 1 (OP1). That is to say, in uncertain times, the respondents are more likely to expect bad things to happen. Furthermore respondents are more agreeable

Table 4: ridits for the reference data set

	S.A.(5)	A.(4)	U.(3)	D.(2)	S.D(1)	π_i
OP1	**46**	**132**	**169**	**67**	**21**	435
OP2	**130**	**131**	**111**	**49**	**14**	435
OP3	**88**	**187**	**118**	**28**	**14**	435
OP4	**120**	**156**	**101**	**45**	**13**	435
OP5	**140**	**179**	**78**	**29**	**9**	435
OP6	**140**	**130**	**91**	**56**	**18**	435
f_j	664	915	668	274	89	2610
$1/2f_j$	332	457.5	334	137	44.5	
F_j	332	1121.5	1913	2384	2565.5	
R_j	0.13	0.43	0.73	0.91	0.98	

Note: S.A.: strongly agree. A.: agree. U.: undecided. D.: disagree. S.D.: strongly disagree.

Table 5: ridits for the comparison data sets

	S.A.	A.	U.	D.	S.D.	ρ_i	L.B.	U.B.
OP1	**0.01**	**0.13**	**0.28**	**0.14**	**0.05**	0.62	0.59	0.64
OP2	**0.04**	**0.13**	**0.19**	**0.10**	**0.03**	0.49	0.46	0.52
OP3	**0.03**	**0.18**	**0.20**	**0.06**	**0.03**	0.50	0.47	0.53
OP4	**0.04**	**0.15**	**0.17**	**0.09**	**0.03**	0.48	0.46	0.51
OP5	**0.04**	**0.18**	**0.13**	**0.06**	**0.02**	0.43	0.40	0.46
OP6	**0.04**	**0.13**	**0.15**	**0.12**	**0.04**	0.48	0.45	0.51
Kruskal-Wallis W=100.41; χ^2(6-1)=11.07								

Note: L.B.: lower bound of the 95% confidence interval of mean ridit ρ_i. U.B.: upper bound of the 95% confidence interval of mean ridit ρ_i.

to OP5 (ρ_5=0.43) than OP1 (ρ_1=0.62). Finally the opinions of respondents about OP2, OP3, OP4, OP6 are not significantly different from each other. A direct sorting of mean ridits in terms of the probability of being in agreeing propensity gives the following sequence.

OP5(0.43)> OP4(0.48),OP6(0.48)> OP2(0.49)> OP3(0.50)> OP1(0.62)

4.3 Choose a Method for Data Analysis

The two methods illustrated in this paper can be used to sort the order of the scale items in terms of the Γ (or ρ) values of scale items. Table 6 summarizes the characteristics of the two methods. Each method has its pros and cons

Table 6: Characteristics of grey relational analysis and RIDIT analysis

	Grey relational analysis	RIDIT analysis
Distribution assumption	None	None
Data type	Interval	Ordinal
Reference data set/series	Required	Required
Complexity	Less complex	Complex
Category weights	Yes	No
Propensity indicator	Grey relational grades	ridits
Meaning of output value	Relative intensities, e.g. importance/ agreement/ satisfaction, of scale items to the reference data set	Probabilities of scale items being in worse/better condition than the reference data set
Critics	Item responses are arguably interval	More difficult to interpret the meaning of ridits
Choice of reference data set/series	Reference data series can be set to consist of the most/least favoured values of each category	Requires large representative reference data set to calculate reliable ridits
Philosophy behind the method	To address decisions under uncertainty with insufficient data available for analysis	To address "borderland" response variables that may not be adequately analysed by chi-square or t-test family statistical techniques

and the choice of which method for data analysis depends on the objectives and assumptions of the research at hand. The following is a checklist that can help choose between the two methods.

1. If scale data is considered to be ordinal then select RIDIT analysis.

2. If there is a need to statistically test the differences of relative propensity indicators (Γ or ρ) among scale items then choose RIDIT analysis.

3. If it is difficult to identify a representative reference data set that is large enough in size then use grey relational analysis.
4. If it is necessary to set different weights for data in comparison data sets/series then adopt grey relational analysis.
5. If a simple and straightforward value that can reflect the degree of relative propensity of each scale item is preferred then grey relational analysis would be appropriate.

Choosing the right data analysis techniques for a research involves many factors. Guidelines listed in the checklist are not necessarily golden rules. “It is not a question of right and wrong ways to analyse data from Likert-type items. The question is more directed to answering the research questions meaningfully [4].”

5 Conclusions

This paper has presented and compared two popular methods which can be used to order scale items in terms of relative propensity represented by grey relational grades (Γ) and mean ridits (ρ). The calculation of grey relational grades (Γ) for scale items is based on the scores/numbers assigned to the categories. Assigning scores to categories can be difficult. The straightforward system of numbering assigns integers successively to the ordered categories. If an underlying logistic model may be assumed, a procedure due to J. Snell is appropriate [18]. Fuzzy transformation of ordered categories to numeric values is another option [3]. The standardised numeric grey relational grades for scale items can be used to explore the relationships among scale items.

The calculation of mean ridits (ρ) for scale items is based on the response frequencies of ordered categories from a Likert scale survey. The Kruskal-Wallis statistics W , which follows a χ^2distribution, can be used to test whether or not there exists statistically differences among the mean ridits of scale items. The relationships among scale items can further be examined by the 95% confidence intervals of mean ridits.

In this research, it is found that, for the same sample data, the managerial implications derived from the introduced methods are very much consistent with each other. As shown in table 6, each method has its own characteristics. The choice of grey relational analysis or RIDIT analysis is contingent. This paper provides guidelines that can help choose between the two methods. There is no intention to argue that one is better than the other. It is the question of which method will better answer meaningfully research questions.

Appendix

The life orientation test from J. Pallant consists of the following 6 items [18]. Respondents are directed to rate each statement using a 5-point scale. 5=strongly agree and 1=strongly disagree.

1. In uncertain times, I usually expect the best. (OP1)
2. If something can go wrong for me, it will. (OP2)
3. I'm always optimistic about my future. (OP3)
4. I hardly ever expect things to go my way. (OP4)
5. Overall I expect more good things to happen to me than bad. (OP5)
6. I rarely count on good things happening to me. (OP6)

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