

Research on the measurement of general risk preference based on multivariate statistical analysis methods

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Abstract. It is of great significance to study general risk preference for different populations to take targeted interventions to reduce potentially risky behaviors. In this paper, the results of Balloon Analogue Risk Task (BART) experiment are analyzed by single factor analysis of variance. Through this analysis, it is found that there are significant differences in people's general risk preference in different situations. Then, This paper is based on BART experiment and risk propensity questions and Frequency of General Risk Propensity Scale (GRiPS), Socio-Economic Panel (SOEP) Results of three questionnaires on Risky Behaviours (FoRB) were used to measure general risk preference using exploratory factor analysis. Then, cluster analysis is used to explore the performance of different risk preferences under different characteristics. The empirical analysis shows that the group with high risk preference has larger data on the two factors of GRiPS and SOEP, while the group with moderate risk preference has more balanced values on the four factors of BART, GRiPS, SOEP and FoRB. The risk-averse group has lower scores on GRiPS, SOEP and FoRB. According to the above conclusions, for specific things, relevant targeted measures can be developed to minimize the impact of potential risks or injuries on people's personal safety and property safety.

Keywords: General Risk Preference, Factor Analysis, K-mean Clustering, ANOVA.

1. Introduction

Risk-taking behavior involves behavior that involves potential danger or harm, while also providing the opportunity for a reward [1]. Risk refers to the uncertainty of the consequences of decision [2], and the individual's attitude towards risk is called risk preference. However, there is disagreement about the concept of risk preference: is it a single structure across domains, or is it a domain-specific multi-faceted structure? If it is a stable personality trait across domains, then assessing someone's level of risk behavior in one domain can predict their performance in other domains. However, this may not be the case, and natural persons may have different preferences when faced with different types of risks, which may involve various fields such as health, finance, and occupation. For example, a person may exhibit a high risk tolerance when it comes to financial investments, be willing to take large financial losses for higher returns, and be more conservative when it comes to health, preferring to choose safer medical options rather than risk new treatments. Similarly, a person may exhibit a moderate risk attitude in the professional world, willing to accept a certain level of professional challenge and uncertainty, but may prefer stability and security in their home life.

In recent years, many scholars have conducted research on this issue. Tang Yingmei, Wang Huaiming et al. used comprehensive evaluation method to measure risk preference and found that risk preference was affected by different factors and variables [3]. Sun Wenzhang, Li Yanxi et al. explored the risk preference index of managers with a regression model, and concluded that managers present different risk preferences under different conditions [4]. Gary Charness and Nir Chemaya used the two-tail test to measure the risk preference of players in risk-motivated tasks [5]. Werner Jammernegg, Peter Kischka et al. 's Mean-CVaR model, based on popular risk measures value at risk (VaR) and conditional Value at risk (CVaR), The use of risk metrics to explore the newsstand risk preference certainty is equivalent to modeling risk aversion, risk neutrality and risk decision makers [6]. Zhai Guangyu, Wang Chao et al. used the estimation of static risk aversion coefficient and the estimation of dynamic risk aversion coefficient considering the time-varying characteristics of

population age to measure the risk preference of financial assets from multiple angles [7]. Based on the US Consumer Financial Survey (SCF) database and global panel data, Lu Yan and Li Gang found that the age structure of the population has a significant impact on risk preference, and with the increase of population age, there is an "inverted U-shaped" relationship [8]. Meng Yingying uses Multinomial Logistic multivariate regression model to analyze the relationship between risk preference of rural migrant workers in urban areas, insurance demand and wealth accumulation [9]. Guo Weilong, Zhao Yixin et al used weighted median, anti-variance weighting and Mendelian randomization-Egger method to evaluate the bidirectional relationship between risk preference and mood disorders by Mendelian randomization analysis[10].

To sum up, first of all, in order to explore whether general risk preference belongs to a single structure or a multi-faceted structure, this paper uses one-way ANOVA to analyze the BART experiment results, and finds that people's general risk preference has significant differences in different fields (different risk probability distributions). Then, in order to understand general risk preference more comprehensively, this paper uses three classic questionnaire experiments, Includes General Risk Propensity Scale (GRiPS), Socio-Economic Panel (SOEP) risk propensity questions and Frequency of Risky Behaviours (FoRB) and BART data were combined to measure general risk preference using exploratory factor analysis. Finally, based on the measurement results, this paper uses Kmeans cluster analysis to carry out group portraits of people with different general risk preferences. The results show that those with high risk preference have higher data on GRiPS and SOEP, those with medium risk preference have more balanced values on the four factors, while those with risk aversion have lower scores on the four factors. These results further emphasize the differences in risk preference among different groups. Based on the above research results, we can put forward some suggestions for people with different risk preferences to minimize the impact of potential risks or injuries on people's personal safety and property safety. For example, for people with high risk preference, the government can strengthen risk education and supervision to guide their behavior to be more prudent and rational; For people with moderate risk preference, risk management tools such as insurance can be promoted to help them better manage their personal risks. For the risk-averse population, it is necessary to provide more stable and reliable investment channels to meet their needs for security.

2. Theory and method

2.1. BART experiment

Participants inflated virtual balloons (30 in total) in turn, with each successful expansion bringing a reward, but once the balloon exploded, all rewards in the current trial were lost. Participants have the right to stop inflating at any time to keep the rewards they have earned, but this also means giving up the opportunity to further inflate. The timing of the balloon's explosion is random, with the probability of explosion increasing with each increase in inflation, but the participants do not know the exact probability of explosion. Participants can gradually learn by constantly inflating new balloons. At the start of the task, participants were only given the amount of money they were rewarded for each successful inflate, while once the balloon exploded, they would lose all of the proceeds from the current experiment. In addition, the balloon must not exceed the screen size, otherwise it will explode. The General Risk Propensity Scale contains eight items designed to assess an individual's risk propensity. The questionnaire was assessed based on an individual's self-assessment of their own risk propensity. Specific indicators are shown in Table 1 below:

Table.1. General Risk Propensity Scale (GRiPS)

Question	Content	Fractional Range
1	I commonly make risky decisions	1-5
2	I am attracted, rather than scared, by risk.	1-5
3	I am a believer of taking chances.	1-5
4	Taking risks makes life more fun.	1-5
5	I enjoy taking risks in most aspects of my life.	1-5
6	Taking risks in an important part of my life.	1-5
7	I would take a risk even if it meant I might get hurt.	1-5
8	My friends would say that I'm a risk taker.	1-5

The German Socio-economic Group (SOEP) is an extensive survey project designed to be representative of the German adult population. The survey contains 7 items related to risk. By analyzing the scores of the questionnaire, we can infer the risk tendency of the respondents in daily life, and classify the population according to the results, as shown in Table 2.

Table.2. Socio-Economic Panel (SOEP) risk propensity questions

Question	Content	Fractional Range
1	How would you rate your willingness to take risks during leisure and sport?	0-10
2	How would you rate your willingness to take risks regarding your health?	0-10
3	How would you rate your willingness to take risks while driving?	0-10
4	How would you rate your willingness to take risks in your occupation?	0-10
5	How would you rate your willingness to take risks regarding your faith in other people?	0-10
6	How would you rate your willingness to take risks in financial matters?	0-10
7	Are you generally a person who is willing to take risks or do you try to avoid taking risks?	0-10

The Frequency of Risky Behaviours survey asks participants to report how often they have engaged in various risky behaviours in the past year. They need to provide an average or approximation, which can be done by giving a number between 0 and 100 and an associated unit of time (such as "daily," "weekly," "monthly," or "yearly"). The average/approximation of these reports will then be converted to a frequency in units of "daily". The risk propensity of the population can be analyzed by the frequency of risky behaviors shown in the survey data, as shown in Table 3 below.

Table.3. Frequency of Risky Behaviours (FoRB)

Question	Content	Fractional Range
1	How often did you engage in gambles with real monetary bets, such as in the lottery or in a casino?	0-100
2	How many cigarettes did you smoke?	0-100
3	How many alcoholic beverages did you consume?	0-100
4	How often did you make financial investments?	0-100
5	How often did you drive faster than permitted?	0-100
6	How often did you engage in risky sports such as mountain biking, mountaineering, climbing, skydiving, combat sports or similar?	0-100

2.2. Research method

(1) One-way analysis of variance

The purpose of single-factor analysis is to test r populations in the model $N(\mu_i, \sigma^2)$, ($i = 1, 2, \dots, r$) are the mean values equal; in order to describe the data more carefully, the concept of total mean and effect is often introduced in the analysis of variance; in order to describe the data more carefully, the concept of total mean and effect is often introduced in the analysis of variance. Will

$\mu_1, \mu_2, \dots, \mu_r$ the weighted average of each mean is denoted as $\frac{1}{n} \sum_{i=1}^r n_i \mu_i$ Denote as μ , i.e

$$\mu = \frac{1}{n} \sum_{i=1}^r n_i \mu_i \quad (1)$$

among $n = \sum_{i=1}^r n_i$, let

$$\delta_i = \mu_i - \mu, \quad i = 1, 2, \dots, r \quad (2)$$

δ_i represents the difference between the mean μ_i of the population and the total mean μ at level A_i , this is called the effect of factor A at the i -th level A_i . It is easy to see that the relationship between the effects is as follows

$$\sum_{i=1}^r n_i \delta_i = \sum_{i=1}^r n_i (\mu_i - \mu) = 0, \quad (3)$$

Using the above notation, the mathematical model can be rewritten as

$$X_{ij} = \mu + \delta_i + \varepsilon_{ij}, \quad i = 1, 2, \dots, r, \quad j = 1, 2, \dots, n_r, \quad (4)$$

$$\sum_{i=1}^r n_i \delta_i = 0, \quad (5)$$

$\varepsilon_{ij} \sim N(0, \sigma^2)$, each ε_{ij} is independent of the other, μ_i and σ^2 unknown. The foregoing test hypothesis is equivalent to

$$H_0: \delta_1 = \delta_2 = \dots = \delta_r = 0, \quad (6)$$

$H_1: \delta_1, \delta_2, \dots, \delta_r$ it is not all zero. This is because if and only if $\mu_1 = \mu_2 = \dots = \mu_r, \mu_i = \mu$, i.e. $\delta_i = 0 (i = 1, 2, \dots, r)$.

The statistic of one-way ANOVA is F test statistic. This statistic is defined as

$$F = \frac{\frac{\text{Mean deviation between groups } SS_{\text{interclass}}}{\text{Degree of freedom between groups } v_{\text{interclass}}}}{\frac{\text{Deviation from the mean within the group } SS_{\text{intra-class}}}{\text{Degree of freedom within a group } v_{\text{intra-class}}}} = \frac{\text{Intergroup variation}}{\text{Intra - group variation}} \quad (7)$$

One-way analysis of variance is based on the size F of the statistic. When H_0 is true, F statistics follow the F distribution. At this time, $p \leq 0.05$, reject H_0 , accept H_1 ; otherwise, they do not refuse H_0 .

(2) Exploratory factor analysis

Factor analysis is a statistical method to simplify and analyze high dimensional data. Suppose the p -dimensional random vector $X = (X_1, X_2, \dots, X_p)^T$ is satisfied

$$X = \mu + A\vec{f} + \vec{e} \quad (8)$$

$\vec{f} = (f_1, f_2, \dots, f_q)^T$ is a q -dimensional random variable, $q \leq p$, satisfy $E\vec{f} = 0, E\vec{f}\vec{f}^T = \bar{I}_q$, its component f_i is called a common factor, it works on every component of X . $\vec{e} = (e_1, e_2, \dots, e_p)^T$ is a p -dimensional unobservable random vector, satisfied

$$E\vec{e} = 0, E\vec{e}\vec{e}^T = \text{diag}(\sigma_1^2, \sigma_2^2, \dots, \sigma_p^2) \stackrel{\text{def}}{=} \sum \quad (9)$$

Also $E\vec{f}\vec{e}^T = 0$, component \vec{e}_i of e is called a special factor, it only works on the \bar{X}_i component of X . μ and A are parameter matrices. If X satisfies the above formula, then the random vector X is said to have a factor structure. Now, it's easy to calculate:

$$Var(X) = \bar{A}\bar{A}^T + \Sigma \tag{10}$$

Matrix A is called factor load, its element a_{ij} is the load of the i -th component \bar{X}_i on the j -th factor f_j . Be written as $h_i^2 = \sum_{j=1}^q a_{ij}^2$, so that

$$Val(X_i) = h_i^2 + \sigma_i^2 \tag{11}$$

It can be seen that, h_i^2 reflects the effect of common factors on \bar{X}_i , this is called the "contribution" of the common factor to \bar{X}_i . When $h_i^2 \geq \sigma_i^2$, indicating that the influence of common factor on \bar{X}_i is greater than that of special factor \vec{e}_i . It can also be seen that h_i^2 reflects the degree of dependence of component \bar{X}_i on the common factor f_j . On the other hand, for a specified common factor f_j , be written as $g_j^2 = \sum_{i=1}^p a_{ij}^2$, called the contribution of the common factor f_j to X . The greater the value of g_j^2 , the greater the influence of the common factor f_j on X , so g_j^2 is a measure of the importance of the common factor. At the same time, it can also be simplified as:

$$\begin{aligned} X_1 &= \alpha_1 F_1 + \alpha_2 F_2 + \alpha_3 F_3 + \dots + \alpha_m F_m \\ X_2 &= \beta_1 F_1 + \beta_2 F_2 + \beta_3 F_3 + \dots + \beta_m F_m \\ X_3 &= \gamma_1 F_1 + \gamma_2 F_2 + \gamma_3 F_3 + \dots + \gamma_m F_m \\ &\dots \\ X_n &= \delta_1 F_1 + \delta_2 F_2 + \delta_3 F_3 + \dots + \delta_m F_m \end{aligned} \tag{12}$$

(3) Cluster Analysis

K-Means algorithm is a widely used basic clustering algorithm. Specifically, the original dataset has N samples, initially given k center points. By calculating the similarity between samples, the ones with high similarity are divided into a category. The size of the similarity between samples is measured as the Euclidean distance,

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{13}$$

Divide the sample into two clusters and calculate the mean of the sample points in each cluster as the new center point. The calculation formula is as follows:

$$a_j = \frac{1}{N(c_j)} \sum_{i \in c_j} x_i \tag{14}$$

The K-Means construction steps are as follows:

1. Assume that the input sample is $T = X_1, X_2, \dots, X_m$; the algorithm steps are as follows (using Euclidean distance formula).
2. Select the initialized k category center a_1, a_2, \dots, a_k .
3. For each sample X_i , label it as the class j closest to the class center a_j .
4. Update the center point a_j of each category to the mean of all samples for that category.

5. Repeat the preceding two steps until a certain termination condition is reached.
Termination conditions: iteration number, least square error MSE, cluster center point change rate.

3. Empirical analysis

3.1. Data sources and descriptive statistical analysis

This article are based on data from: <https://openneuro.org/datasets/> and <https://github.com/xinyuli11>. The experiment is implemented based on R language. Before measuring and analyzing the general risk preference, descriptive statistical analysis was conducted on the samples in this paper, as shown below: The data set contains 700 data, among which the age group is mainly between 30 and 40 years old, and there are few people under 20 years old or over 70 years old. There were 372 males and 328 females in the dataset, with a male-to-female ratio of 1.1341. The association between gender and risk behavior was analyzed by one-way ANOVA. The results show that its p-value is $5.95e-06$, indicating a strong correlation. Therefore, we can conclude that the difference in risk preference in the population is related to the difference in gender in the population. Among these groups, the number of people with bachelor's degree is the largest, followed by high school education, and the least is primary school education. Among men, the average adjusted BART score was 20.402 and 19.94 for women. The variances are 36.0941 and 32.4732, respectively. It shows that risk-taking behavior is more common in men, which leads to the gap in BART scores, while women are more risk-averse, which leads to a similar score. Of this group, 579 people are working, 76 are not working, 24 are students, and 21 are retired. According to the results of one-way ANOVA on the work situation and risk-taking behavior of the population, risk-taking behavior is more relevant to people who are working, and has a certain correlation. In general, the relationship between work status and risk behavior is not obvious. This may be related to the habits of different groups of people in their daily lives or external factors.

3.2. Difference test

The differences in BART scores under four different explosion points can be viewed by using box plots, as shown in Figure 1. It can be clearly observed from the figure that there are significant differences in the adjusted BART scores in the four situations. We then used a robust one-way analysis of variance to examine the effect of this condition on the adjusted BART score. The result shows that the F statistic is 49.42 and the p value is less than 0.001. These results suggest that the probability distribution of the balloon's burst point does have an effect on the risk-taking behavior BART measures. When faced with different situations, people show different risk preferences.

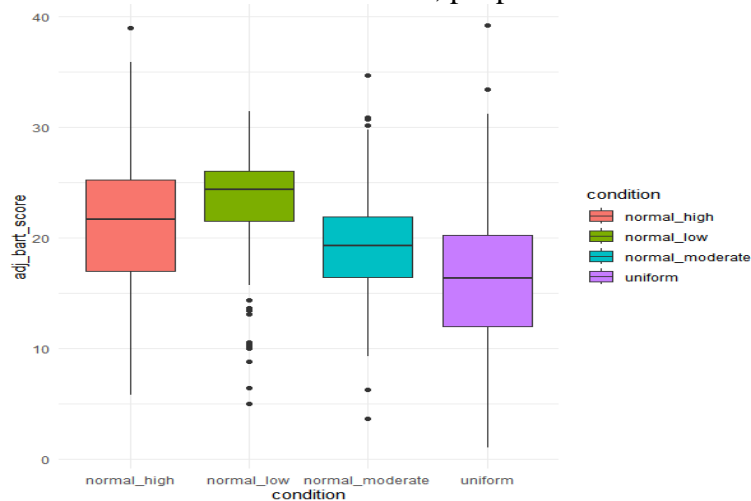


Figure 1. Box plot of BART score distribution under four different explosion points

3.3. General risk preference measure results

As can be seen from the rubble Figure 2, the cumulative contribution rate of the first four factors selected exceeds 85%, so we suggest retaining the first four factors to establish the factor load matrix. General risk preference = $W1*BART+W2*GRiPS+W3*SOEP+W4*FoRB$, where the values of $W1, W2, W3, W4$ are obtained according to the ordinate of the first four factors in the scree plots, and BART, GRiPS, SOEP, FoRB are the names of the four factors for selecting measurement dimensions. We conducted a preliminary test of the factor analysis to ensure that the factor analysis method was applicable to the data. Bartlett's sphericity test results show that its p value is less than 0.01, which meets the use conditions of factor analysis. In addition, KMO value is an indicator to measure the correlation between variables and is usually used to evaluate the applicability of factor analysis. The greater the value, the higher the applicability. The KMO value under this experimental data is 0.93, which is very suitable for factor analysis.

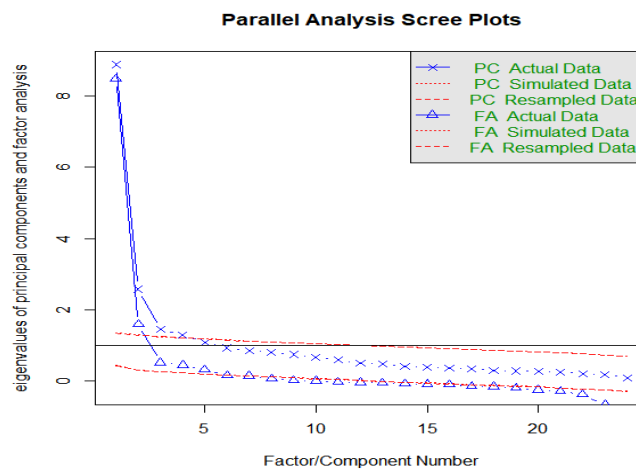


Figure 2. Scree plots of factor analysis

From the above Figure 2, a factor analysis model for measuring the general risk preference of the population can be obtained:

$$adj_bart_score_early = 0.791 * MR2 \quad (15)$$

$$grips_commonly = 0.795 * MR1 + 0.199 * MR4 \quad (16)$$

$$soep_leisure = 0.716 * MR1 + 0.169 * MR4 + 0.124 * MR3 \quad (17)$$

$$forb_gamble = 0.113 * MR1 + 0.198 * MR4 + 0.421 * MR3 \quad (18)$$

According to the factor analysis model, the first factor MR1 is mainly determined by, grips_enjoy, soep_general, grips_friends and other indicators, which represents the risk tendency of people and the degree of enjoyment in the process of taking risks. soep_general contributes the most to MR1, suggesting that people's willingness to take risks is an important indicator in factor MR1. The second factor, MR2, is mainly determined by the adjusted BART score. In the case of adj_bart_score_middle, participants can better learn risks and thus more accurately observe their potential risk preference from their behavior. The third factor, MR4, mainly reflects people's willingness to take risks in daily life. We can use people's willingness to take risks as an indicator to make a more accurate division of people's risk preference. The fourth factor, MR3, mainly reflects the frequency of risk-taking behavior in the population. According to the frequency of risky behavior of different groups, we can judge the risk preference of people.

Each variable can find its corresponding factor. In Table 4, under the same variable, the absolute value of MR1, MR2, MR4 and MR3 is the largest, which means that the variable can be divided into the factor with the largest absolute value. "—" indicates that the value of the corresponding position is relatively small compared with other values in the same row and can be omitted. First of all, in the

upper right of the three subgraphs are those who like risk. The BART experiment and GRiPS questionnaire have higher values, indicating that they are more inclined to take risks in life.

Table.4. Factor analysis load matrix

variable	MR1	MR2	MR4	MR3
adj_bart_score_early	—	0.791	—	—
adj_bart_score_middle	—	1.000	—	—
adj_bart_score_late	—	0.844	—	—
grips_commonly	0.795	—	0.199	—
grips_attracted	0.825	—	0.102	—
grips_chances	0.803	—	—	—
grips_fun	0.795	—	—	0.134
grips_enjoy	0.838	—	0.119	—
grips_part	0.802	—	—	0.101
grips_hurt	0.755	—	0.181	—
grips_friends	0.825	—	0.131	—
soep_leisure	0.716	—	0.169	0.124
soep_health	0.434	—	0.552	-0.115
soep_driving	0.526	—	0.412	—
soep_occupation	0.668	—	0.105	0.116
soep_faith	0.366	—	0.110	—
soep_finance	0.682	—	0.196	0.114
soep_general	0.845	—	0.184	0.134
forb_gamble	0.113	—	0.198	0.421
forb_sport	0.118	—	0.110	0.619
forb_cigarettes	—	—	0.259	—
forb_invest	—	—	—	0.485
forb_speed	—	—	0.103	—
forb_drink	—	—	0.322	0.117
SS loadings	7.975	2.370	0.964	0.947
Proportion Var	0.332	0.099	0.040	0.039
Cumulative Var	0.332	0.431	0.471	0.511

Risk-neutral groups are located in the equilibrium position of the three subgraphs (shown in Figure 3 below), and the GRiPS are close to 0, indicating that they have a risk-neutral attitude. Risk-averse people are located at the lower left of the three subgraphs. The GRiPS of these people are basically negative. The GriPS of BART test have the lowest value, indicating that they tend to be more secure in life and do not like taking risks. The risk-loving group at the top right of the picture has a higher FORB and GRiPS index, indicating that they are more inclined to take risks and have more risky behaviors in their lives. Risk-neutral people have a FORB and GRiPS index around 0, with little risk-taking behavior or risk-taking tendencies. Risk-averse people are located at the bottom left of the image, and their FORB and GRiPS index is below 0, indicating that they rarely take risks in their lives, and the frequency of taking risks is very low. Those who like risk are on the right side of the picture. The GRiPS are high, and the SOEP is high with extreme points, indicating that they are very willing to take risks and have a strong tendency to take risks. Risk-neutral people are in the equilibrium position in the graph, and the GRiPS and SOEP values are close to 0, indicating that they have a lower risk propensity and less usual risk taking behavior. Risk-averse people are located on the left side of the figure, and their GRiPS and SOEP values are basically less than 0, indicating that they are unwilling to take risks and have a very low risk tendency.

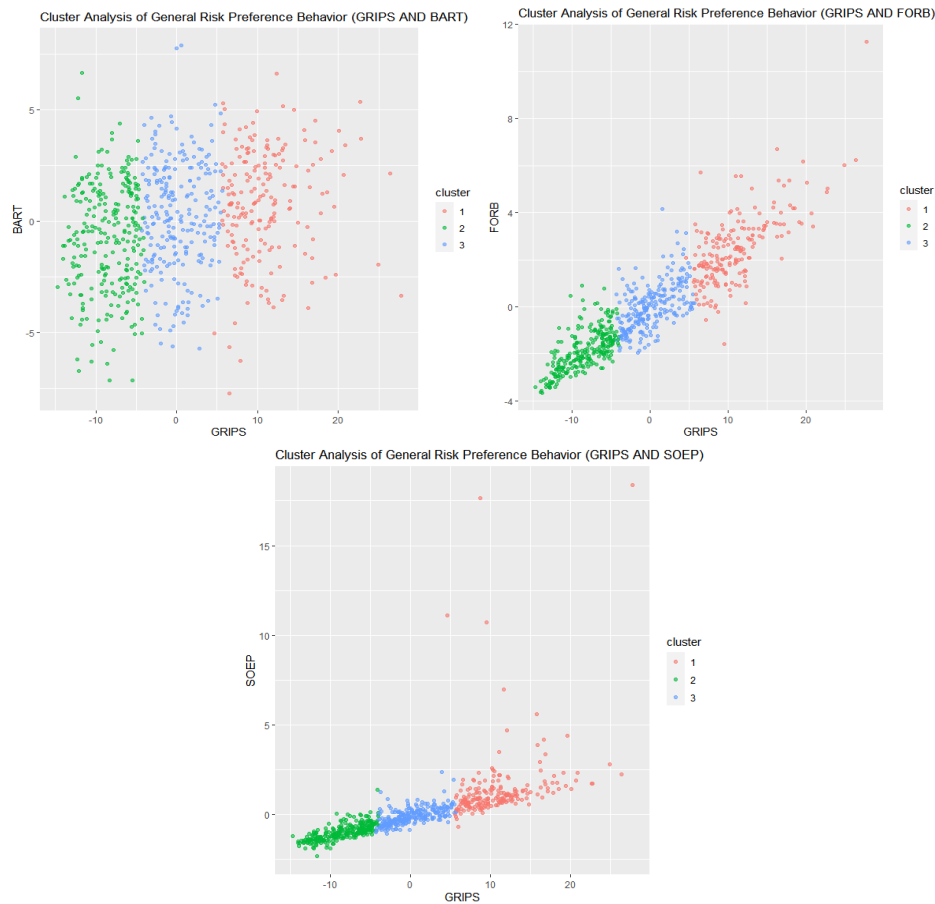


Figure 3. Portrait of different risk groups under different factors

4. Conclusions and suggestion

Based on the experiment, the following conclusions can be drawn: first of all, this paper makes an empirical analysis on whether the general risk preference is a multi-faceted structure or a single structure, and measures the general risk preference and explores the characteristic differences of different risk preference groups (See 3.2 and 3.3). And then the empirical results show that, on the one hand, people have different risk preferences in the face of different events(See 3.2 Figure 1). On the other hand, after measuring the general risk preference, it can be found that the general risk preference can be measured by BART, GRiPS, SOEP and FORB experiments(See 3.3 Figure 2). Because according to the data results of factor analysis, the cumulative contribution of the first four factors is more than 85%, so it is appropriate to divide the general risk preference into four factors. In addition, according to the data results, people with different risk preferences can be divided, and different types of people have different characteristics in the degree of risk preferences(See Figure 3).

Therefore, according to the experimental results, the following targeted suggestions can be put forward: when formulating policies, policies cannot be formulated indiscriminately, and targeted policies need to be formulated according to the risk preference of different groups.

According to different characteristics, when formulating policies or measures to face risks, a compromise can be chosen according to the performance of different groups to minimize the risk, so as to more effectively protect people's lives and property safety. For example, first, policymakers should tailor their policies to the degree of risk preference of different populations. For people who like risk, it can provide more venture capital and entrepreneurship opportunities; For risk-neutral people, more balanced investment choices should be provided; For risk-averse people, it is necessary to provide more stable and conservative investment channels. Secondly, for people with different risk preferences, different risk education and training programs can be designed to help them better understand risks and avoid risks. In addition, a risk management mechanism can be established to

detect and respond to various potential risks in a timely manner through risk assessment and monitoring to ensure the safety of people's lives and property. Finally, the government and society should encourage more research on the field of risk preference, so as to promote the development of the field of risk management and decision-making, and make greater contributions to social and economic stability.

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