Modification of Value Function by incorporating Mental Account [1]

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Abstract: Depending on the prospect theory, the curve features of value function change with human's risk attitude. But, through experiments, it is verified that the wealth level of a decision maker influences his value estimation and behaviours of decision-making under uncertain circumstances. In this paper, the endurable Maximum Loss Value (MLV), which means the amount of the maximum loss in a mental account can endure, is regarded as the measurement of the decision-maker's risk-avoiding attitude to some extend and is used to qualify the code of the original value function. Hereafter, we use relatively coding method to construct the value function, which is called decision value function, under uncertain circumstances. It is found that the modified value function model which is amended by relative code well explains the experimental results of decisions under uncertainty. General speaking, the modified model has better unity and stability.

Keywords: Prospect Theory , Mental Account , Value Function , Relative Code

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1 Introduction

Prospect theory has become the most prominent alternative to expected utility theory due to the fact that it has been widely accepted, especially for the decision-making under uncertainty. And It has widely explained different anomalies such as Allais paradox、Friedman-Savage's puzzle and deposition effect (Kahneman and Tversky，1979；Camerer，1998).Actually, prospect theory is based on two main pillars: (1) a value function v (x), where x is the change of wealth (gains or losses) with respect to some reference point. The value function exhibits risk seeking behaviour for losses and risk aversion behaviour for gains. (2) A probability weighting function π (p) that transforms the given probabilities in decision weights.

The subsequent research of the prospect theory involves in different kinds: Richard Gonzalez and George Wu (1999) focused on the research of probability weight function, mainly about the forms of the weight function and its psychology foundation analyses. Kahneman and Tversky(1979)pointed out that supposition of $\pi(p) \neq p$ in the weight function of the prospect theory obviously caused a defect [2]. While Fishburn(1978)proposed that the non-linearity of $\pi(\cdot)$ had caused a serious problem, that is , the potential violation of stochastic dominance[3]. Richard Gonzales and George Wu (2003)had done some further studies on the combination rule of the value function and probability weight function. Additionally, some further studies on value function were specified on the shape, the form, and the estimation of the parameters of value function (Zank (1998),Neilson and Stowe(2001)). Levy and Levy (2002) conducted an experimental study with mixed prospects. Their experimental results led them to conclude that prospect theory might be of value only in the case of all-gains or all-losses lotteries. For mixed lotteries they argued that reversed S-shape value functions, such as proposed by Markowitz (1952), represented more consistently the observed behaviours of many individuals. They rejected the S-shaped value function,

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[2] $\pi(\cdot)$ is probability weight function. By comparing the two expectation (x,p;x,q) and (x,p';x,q'), if p+q=p'+q'<1, we can see that there will be no difference between the preferences towards these two expectations, thus $\pi(p)+\pi(q)=\pi(p')+\pi(q')$, which means that $\pi(\cdot)$ is an equal function, contrary to the defining of non-linear weight function by the prospect theory. To get more details we can refer to Literature 7.

[3] Suppose that $\pi(0.15)=0.2, \pi(0.3)=0.3$, if ε is small enough, according to $V_0(p_1,x_1;...;p_i,x_i;....;p_n,x_n)=\sum_{i=1}^{n}\pi(p_i)v(x_i)$ we can conclude that the value of （100，0.3） is less than that of（100，0.15；100-ε，0.15） which is stochastically dominated by the former. That is to say, so long as function π is not linear，stochastic dominance will inevitably be contravened.

showing that the results support for the Markowitz reversed S-shaped utility function, which is convex-concave-convex-concave utility function, in other word, being opposite to the prospect theory value function. Wakker(2003) criticized Levy and Levy (2002) and declared that the experimental results are in total accordance with cumulative prospect theory, in contrast to Levys' claims.

The value function proposed by Kahneman and Tversky(1979)is as follows(1.1):

$$V(x) = \begin{cases} x^{\alpha} & , \quad x \geq 0 \\ -\lambda \cdot (-x)^{\beta} & , \quad x < 0 \end{cases} \tag{1.1}$$

In the formula, the parameters α、$\beta < 1$ indicate the decreasing of sensitivity, $\lambda > 1$ indicates loss aversion. Many scholars have done estimation to the three parameters in this form, but got different estimated results. Meanwhile, the form and parameter of the value function is unstable in the condition of the stochastic dominance. According to Kahneman and Tversky's value function, we simulate the function with different value of three parameters, which shows the different shapes of the curves (See figure 1).

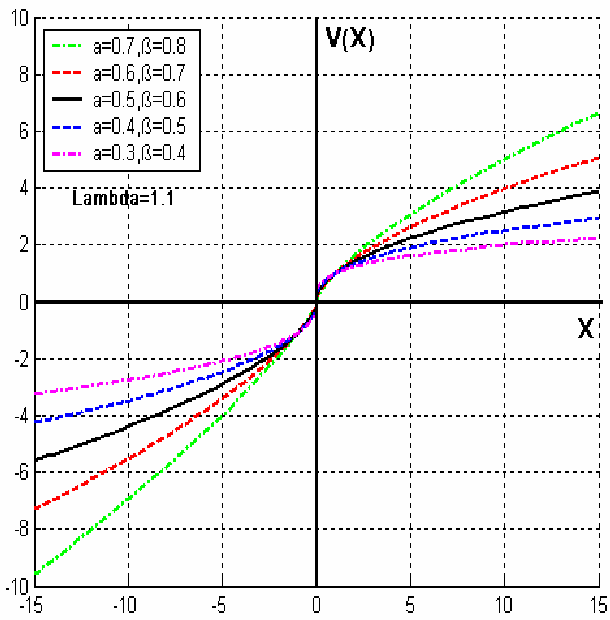

Figure1 the simulated curve of value function under different parameters

It could be easily found that with different parameters, there occur innumerable curves with different shapes. What we are interested in is what characteristics of individuals caused the different values of parameters and the different shapes of curves.

In this paper, we try to incorporate the mental account (Thaler,1985) into the value function in order to measure the characteristics of loss aversion and enhance the explanatory power of the value function. The maximum losses which could be endured by one's mental account is regarded as the measurement of the decision maker's risk-aversion level, and could be used to design a relative code for reconstructing the value function under uncertain circumstances. Thus, the differences of the value functions caused by different endurable maximum losses could be eliminated by using the relatively coding. We conduct an experimental study on decision making under uncertainties by testing two groups of people with different wealth level, and observe the difference of the shapes of value function. Then, we use the mental account to mend the code. Finally, a decision value function model with more explanatory power is offered.

The paper proceeds as follows: In Section 2, we present an experiment to test the instability of the parameters of the value function by inspecting the outcomes under uncertainty in different individuals with different wealth. In Section 3, we introduce the mental account to value function by using a relative code in accordance with the individuals' maximum endurable loss aversion. In Section 4, we give the conclusions.

2 Experiments on the instability of the parameters of the value function

2.1 Design of experiments

The purpose of this experiment is to check out whether there exist any differences among the decisions makers in different wealth level facing the same lotteries. The tested samples are selected from two totally different groups — teachers and students, which include the students of undergraduates and graduates, majored in finance, management science and engineering, etc. and teachers mainly in economical discipline. It means that all of the experiment participants obtained a basic knowledge of probability. Two groups have the systematic difference in monthly incomes and payouts. Group 1 includes 25 students whose payouts are around 300－600 Yuan per month mainly sponsored by their parents. Group 2 is related to 25 teachers whose payout are around 1000-3000 Yuan each month and income around 2000-4000 Yuan monthly.

We offered six gambles to the participants: A, B, C, D, E, and F.

Gamble A: A probability of 0.5 to win 2 Yuan, and a probability of 0.5 to lose 1 Yuan. The coding is (2，0.5；-1，0.5);

Gamble B: A probability of 0.5 to win 20 Yuan, and a probability of 0.5 to lose 10 Yuan. The coding is (20，0.5；-10，0.5);

Gamble C: A probability of 0.5 to win 200 Yuan, and a probability of 0.5 to lose 100 Yuan. The coding is (200，0.5；-100，0.5);

Gamble D: A probability of 0.5 to win 400 Yuan, and a probability of 0.5 to lose 200 Yuan. The coding is (400，0.5；-200，0.5);

Gamble E: A probability of 0.5 to win 2000 Yuan, and a probability of 0.5 to lose 1000 Yuan. The coding is (2000，0.5；-1000，0.5);

Gamble F: A probability of 0.5 to win 20000 Yuan, and a probability of 0.5 to lose 10000 Yuan. The coding is (20000，0.5；-10000，0.5).

Tversky and Kahneman (1992) declared that the result only differs slightly when there is no real money stimulation in experiment by using different ways to stimulate different participants. Since many other scholars successfully conduct the experiment by applying partially real money stimulation, So, in our experiment, we also carry out gambles experiment by paying the actual money partially as an incentive to the participants

2.2 The experimental results and the analysis

Experiment was carried out during the period from December of 2004 to May of 2005. So every participant had enough time to consider whether to take part in or not and make the decision. Thus, the descriptive statistic results of every participant's choice of the six Gambles are shown below. Tab 1 shows the percentage of these two groups who were willing to gamble. The test of validity and reliability of the results showed that the relative coefficients are high and the results are reliable (See the appendix).

Tab1 Statistics of the results of the experiment

Gambl / Proportio / Group	A	B	C	D	E	F
Students	100%	96%	60%	12%	4%	0%
Teachers	100%	100%	100%	92%	56%	8%

Note: The proportions represent the people who are willing to take gamble in every group.

From Tab 1, it is obviously shown that, as for gamble A, there exists no difference between the two groups. In gamble B, the proportion of those who were willing to take the gamble in students group is 96%, while in teachers group is still 100%. Here, the model of *Single Factor Analysis of Variance* is used to test whether there exists an obvious difference between the participation proportions between two groups or not, and the wealth level denotes the single factor. Since there are two groups and 25 samples in every subset, that is $s = 2, n_1 = n_2 = 25, n = 50$. And its F value is $F_{0.05}(1, 48)=4.04$.Under the significance level of 0.05, the hypothesis can be accepted that two groups are not influenced by wealth level. For gamble C, the proportion of those who were willing to participate in the students' group is 60%, while that in the teachers' group is 100%. The result of the significance test is $F=16>4.04=F_{0.05}(1, 48)$, which shows that there exists an obvious difference between the results, but most of the participants in the two groups were willing to participate in gamble C, because the proportions of the two groups are both greater than 50%. For gamble D, the difference reaches the greatest level, that the proportion of those who were willing to participate in the students' group is 12%, while that in the teachers' group is 92%. The result of the significance test is $F=85.71>4.04=F_{0.05}(1, 48)$.The result shows that most of the students were not willing to participate in gamble D, since the proportion in the students group is much less than 50%. Contrarily, most of the teachers were willing to participate in gamble D, since the proportion in the students' group in much greater than 50%. The two groups made an absolutely different choice. For gamble E, the proportion of those who were willing to participate in students group is 4%, while in teachers group is 56%. There also exists an obvious difference, and the result of the significance test is $F=61.9>4.04=F_{0.05}(1,48)$. For gamble F, there exists no significant difference between the two groups , the result of the significance test is $F=2.09<4.04=F_{0.05}(1, 48)$.

Figure 2 shows the differences of choice in every gamble between two groups, and the difference reached the greatest level in gamble D.

We can see that two groups made absolutely different choices in gamble D and E. In these two gambles, most of the teachers were willing to participate, but most of the students were not. It results in opposite preference between teachers and students in gamble D and E, as can be measured by the formula of expectation $V = \sum_{i=1}^{n} \pi(p_i)v(x_i)$ in the original prospect theory; we know the value expression of different groups.

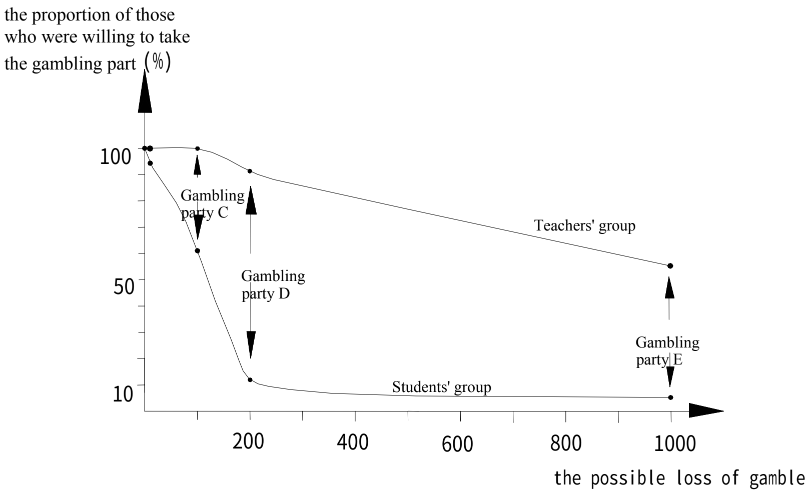

Figure2 Contrast between the two groups about proportion

From gamble D, we knew as follows:

Students group: $\pi(0.5)v(400) + \pi(0.5)v(-200) < 0$, that is, $v(400) + v(-200) < 0$.

Teachers group: $\pi(0.5)v(400) + \pi(0.5)v(-200) > 0$, that is; $v(400) + v(-200) > 0$.

From Gamble E, we knew :

Students group: $\pi(0.5)v(2000) + \pi(0.5)v(-1000) < 0$,that is, $v(2000) + v(-1000) < 0$.

Teachers group: $\pi(0.5)v(2000) + \pi(0.5)v(-1000) > 0$,that is $v(2000) + v(-1000) > 0$.

These inequalities of the expectation value is described in the form of value function curve (See figure 3). The line segment “oa” and “ob” represent the utility value of the two groups when the gain is ¥400; “oc” and “od” represent the gain of ¥2000; “oe” and “of” represent that when the loss is ¥200 ; “og” and “oh” represent that as the loss is ¥1000. According to the results of the experiments, $|oa|>|oe|$, $|ob|<|of|$, $|oc|>|og|$, $|od|<|oh|$, and the differences between the two groups are brought together on by the differences in both gain domain and loss domain. So there exists coherence[4] between the differences in gain domain and loss domain, that is $|oa| < |ob|$, $|oc| < |od|$, $|of| > |oe|$, $|oh| > |og|$.

Figure 3 indicates that two groups have different value function curves. The curve of the students group shows a stronger character of loss-aversion. Hence, the systemic differences value of the two groups determined by the participants’ different level of wealth level. So, we can conclude that the value function curve differs with the differences of wealth level among different individuals or the changes of wealth level in one’s different period of stage.

[4] Contrasting between investor A and investor B, if investor A is more risk-aversion than investor B in the gain domain, then generally investor A will be more risk-aversion than investor B.

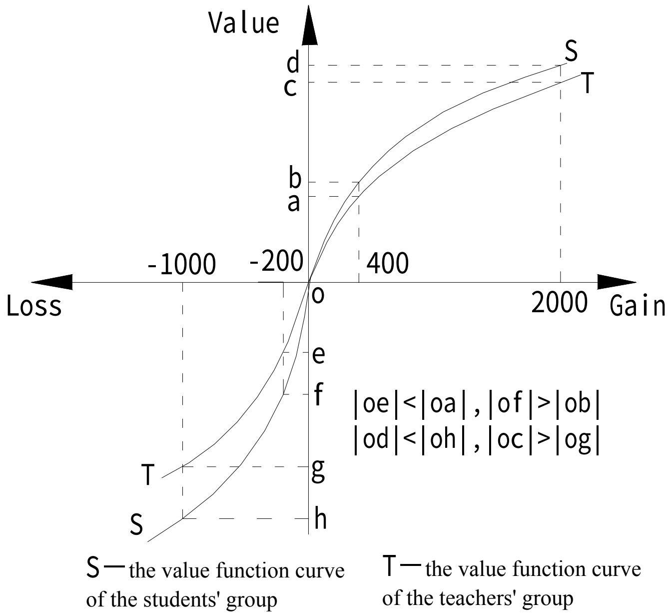

Figure3 the value function of the two groups.

3 Incorporate the mental account into value function

3.1 Relatively Coding with Mental Account

By the experimental results, it might be indicated that one's real-time wealth level obviously affects his decision-making. Mental Account, which is incorporated into for further analysis on this topic, means that humans classify their funding depending on different resources, places, usages and so on. Afterwards, different attitudes on either the return or the risk are performed. Here, we use the endurable Maximum Loss Value (MLV) in their Mental Account to represent the wealth status of decision-makers due to the fact that people will be influenced by his own wealth level during the process of his decision making. Actually, ones' own wealth level is only influenced by the cash flow which goes to the Mental Account instead of the wealth he really owns. Additionally, concerning about the human's loss aversion characteristic, the decision-maker's endurable MLV in the mental account could be a good reflection of his wealth level.

From another point of view, the process of relatively coding does not only depend on the wealth dynamic value which is mentioned in the Prospect Theory by Kahneman and Tversky , but also is affected by the endurable MLV in the Mental Account. That means, the endurable MLV is related to one's final wealth value to some extend. So, the reference system in both Expected Utility Theory and Prospect Theory are involved in the human's decision-making respectively.

Normally, two elements lead to the level of the endurable MLV in the Mental Account. One is the average general payout in a liquidated cycle period, denoted by G. The other coefficient is μ, which means the characteristics of human's risk avoidance. Here, we can see: the bigger the μ is, the higher risk-avoidance degree is; the smaller the μ is, the lower risk-avoiding degree is. In that case, the endurable MLV in the mental Account is $L = G/\mu$.

Therefore, in the light of mental account, the reason why the participators in above experiment got the different choice results through the same gamble is that, according to the different groups' decision making events, each relevant mental account has the different endurable MLV.

Next, we amend the coding process in the Prospect Theory which aims to make the value function be more practical. Thereupon, a kind of relative coding method is designed to reflect the MLV's influencing on the human's decision making.

Let x_r be the value of relative code, x is the value of primitive code and L denotes the endurable MLV in the decision makers' mental account. Then $x_r = x/L$ can be used to eliminate the factor of individual wealth level in the value function so as to strengthen the consistency. Thus, it has a better fitness.

3.2 Explanation of selective experiments and the normalization of Value function

As above experiments results are concerned, the differences of the two groups achieve the extreme value at gamble D, which possible loss is ¥200. Moreover, through further investigation, it concludes that, regarding to this kind of gambles, the students group's mental account takes about ¥200 as the endurable MLV. Meanwhile, that of the teachers' group is ¥2,000. Hence, relative codes of 6 gambles' are shown as below respectively (Table 3).

From the view of the relatively coding, the value of gamble A to student is $V_{A,S} = \pi(0.5)v(0.01) + \pi(0.5)v(-0.005)$, and the value of gamble B to teacher is $V_{B,T} = \pi(0.5)v(0.01) + \pi(0.5)v(-0.005)$. $V_{A,S} = V_{B,T}$ .Scilicet, the students facing the gamble A is equivalent to the teachers facing the gamble B. By the same token ,we can suppose that the students facing the gamble B is equivalent to the teachers facing the gamble C ;the students facing the gamble C is equivalent to the teachers facing the gamble E ;the students facing the gamble E is equivalent to the gamble F . All above suppositions are tallies with our experimental results. The percentage of the student group who are willing to participate in this gamble when facing the gamble A is 100%,

Table3 the calculate of relative code

		A	B	C	D	E	F
Primitive code		(2，0.5；-1，0.5)	(20,0.5；-10,0.5)	(200，0.5；-100，0.5)	(400，0.5，-200，0.5)	(2000，0.5；-1000，0.5)	(20000，0.5；-10000，0.5)
Group of student	the biggest tolerable loss value	200					
	Relative code	(0.01，0.5；-0.005，0.5)	(0.1，0.5；-0.050，0.5)	(1，0.5；-0.5，0.5)	(2，0.5；-1，0.5)	(10，0.5，-5，0.5)	(100，0.5，-50，0.5)
Group of teacher	the biggest tolerable loss value	2000					
	Relative code	(0.001，0.5；-0.0005，0.5)	(0.01，0.5；-0.005，0.5)	(0.1，0.5；-0.050，0.5)	(0.2，0.5；-0.1，0.5)	(1，0.5；-0.5，0.5)	(10，0.5，-5，0.5)

and the percentage of the teacher group who are willing to participate in this gamble when facing the gamble B is 100%; similarly, the percentage of the student group which is willing to participate in the gamble B is 96% and the percentage of the teacher group which is willing to participate in the gamble C is 100%, there are not obviously difference($F=1<4.04=F_{0.05}(1, 48)$)；the percentage of the student group which is willing to participate in the gamble C is 60% and the percentage of the teacher group which is willing to participate in the gamble E is 56%, they also don't have the obvious difference(all is bigger than 50%，$F=0.08<4.04=F_{0.05}(1, 48)$; finally ,the percentage of the student group which is willing to participate in the gamble E is 4% and the percentage of the teacher group which is willing to participate in the gamble F is 8%, there also do not exist the obvious difference(all is smaller than 50%，$F=0.34<4.04=F_{0.05}(1, 48)$). It indicates that the value function constructed by the relative coding might quite really reflect the choice and the decision of various decision makers.

The value function revision mode constructed by the relatively coding is denoted as (3.1):

$$V_r(x_r) = \begin{cases} x_r^a, & x_r \geq 0 \\ -\lambda(-x_r)^{\beta}, & x_r < 0 \end{cases} \tag{3.1}$$

Where, $x_r = x/L = \mu x/G$.

Regarding any two investors A and B, we suppose their sensitivity decreasing parameter in the original value function respectively is α_A、β_A、α_B、β_B ,and $\alpha_A > \alpha_B$、$\beta_A > \beta_B$. Due to the above deduction, It should be concluded that investor A has a stronger risk aversion characteristic, and his individual wealth level is lower than investor B's. So, the endurable MLV in investor A's mental account is smaller than that investor B, namely $L_A < L_B$.

Being relatively coding for a random value $x > 0$, the prospect value of the wealth level of investors A and B is x/L_A、x/L_B separately, and $x/L_A > x/L_B$. We can see that the more difference exists between α_A and α_B ， the more difference are between L_A and L_B， and the more difference exists between the value of the same level of prospect to the investors A and B, and this difference can be described by using the bigger $(x/L_A)^{\alpha_B} - (x/L_B)^{\alpha_B}$ (or $(x/L_A)^{\alpha_A} - (x/L_B)^{\alpha_A}$) in the new decision value function, By doing so, the new decision value function depicts the part which only reflects the risk preference grade of the investors themselves except this influential factor of the wealth level, so,the application of the new decision value function becomes more understandable, the explanation power to the commonplace has been improved. Figure 4 shows that the investor A and B separately in F and E are in the same level of prospect x, they respectively has transferred to G and D after the relative coding. At this time，the differences of the wealth level between E and F leads to the different value in the same level of prospect, and after transformation to D and G respectively, the different value can be described by using the difference of the transformed prospect between x/L_A、x/L_B (DH segment or CG segment).

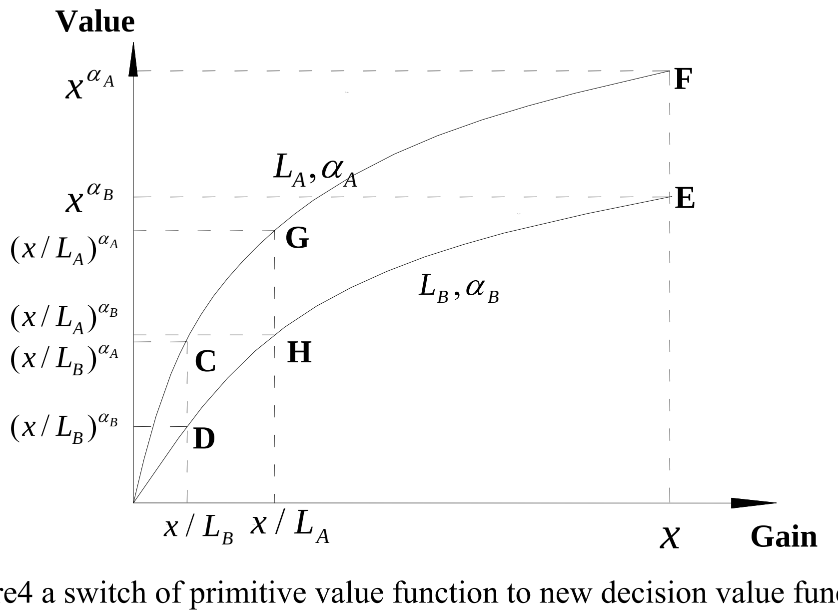

Figure4 a switch of primitive value function to new decision value function

The instance about the prospect value $x < 0$ can be similarly analyzed .Therefore, the explanation power of the new decision value function constructed by the relative coding has been strengthened. And the relative value of the wealth change became the carrier of value temporally.

4 Conclusion

The value function of the prospect theory and its amendment is mainly discussed in this paper, which shows that different curve characteristics are shown depending on the human's attitude to the risk.

By experiments, we found that the wealth level of the decision maker is affecting both the human's individual value assessment and his decision under uncertainty. By classifying our objects into two groups in the gambling experiments — the students group and the teachers group, we investigated their behaviours and verified that the difference between percentages of the two gambling participates groups goes synchronously with their output. But, as the output reach a certain extent; this difference of two groups reduces gradual. The reason is that the wealth level of the decision-maker influences his decision-making behaviour.

In this paper, the endurable *Maximum Loss Value* is incorporated to be as an index of the risk-avoidance and to amend the originally value function code, because the endurable MLV is able to reflect the wealth level of a decision-maker. Meanwhile, the relatively coding methods being utilized in value function can provide a better explanation for the experimental data as well.

In academic view, the value function which is involved in the relative coding is really a better way to assessing the wealth level and explains the decision-making behaviours of the different types of the decision makers.

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APPENDIX

Test on the reliability and validity of experimental result

Reliability test

Here we have randomly drawn the choices made by the first group students in gamble C as sample to do experiments twice, and the interval between two experiments was 30 days, then we calculated the retest reliability to test the reliability.

Table 2 Option statistical table of the sample taken from student group's gamble C

Test	Participants												
	1	2	3	4	5	6	7	8	9	10	11	12	13
X_1	1	1	0	0	1	1	0	0	1	1	1	0	1
X_2	1	1	0	0	1	0	0	0	1	1	1	0	1

Test	Participants											
	14	15	16	17	18	19	20	21	22	23	24	25
X_1	0	0	1	1	0	1	1	0	1	0	1	1
X_2	0	0	1	1	0	1	1	0	1	0	1	1

Note: In the table, X_i value represents participators' option in the i^{th} test. 1 indicates that the participator is willing to participate in the gamble, 0 represents participator is not willing to participate in the gamble.

$$\sum X_1X_2 = 14, \sum X_1 = 15, \sum X_2 = 14, \sum X_1^2 = 15, \sum X_2^2 = 14 \text{,}$$

So the retest reliability coefficient is

$$r_{tt} = \frac{\sum X_1X_2 - \sum X_1 \sum X_2 / n}{\sqrt{\sum X_1^2 - (\sum X_1)^2 / n}\sqrt{\sum X_2^2 - (\sum X_2)^2 / n}} = \frac{14 - 15*14/25}{\sqrt{15\text{-}15^2/25}\sqrt{14 - 14^2/25}} = 0.9211$$

What needs to be explained is that the request of reliability in this kind of experiment is not very strict, mainly because many factors have an effect on individual's decision making, such as individual wealth level mentioned in this paper, and person's mood, individual sober conditions, and so on. Therefore, people are allowed to make different choices in different situation, and what our experimental outcome needs to provide is only a kind of overall data tendency.

Validity test

This paper is analyzed mainly from a construct validity aspect. First, Etchart's (2,004) study on the sensitivity of weighting function to the absolute magnitude output of the gamble discovered that: only in the small probability event, the absolute magnitude output has the significant influence on the weighting function, because in the above experiments our gamble probabilities are all 0.5, which do not belong to the small probability event, it can be drawn that every participator has the same weighting function in each gamble; Next, Eduard Brandstätter and Anton Kühberger (2,004) ‘s study indicated that sometimes decision making was merely influenced by the outcome, and had noting to do with the probability. So, the result is the most basic dimension of the risky gamble, and the probability is only the additional and secondary one. Generally speaking, these two dimension‘s data can be all obtained, but outcome dimension may be processed more easily, so we called this situation as "standard format".

In this pattern, the monetary outcome and the probability are all numerical, but the outcome actually has some superiority compared to the probability; in the daily life, people often deal with the numerical outcome. For example, in the supermarket people calculate their wage according to the commodity price. Therefore, people are professional in dealing with these numerals which are abstract and represent different quantity money. By contrast, people are not good at dealing with these abstract numerals which represent different probability levels, because probability seldom appears as the abstract and precise digitals in the real life. As a result, in standard format, people always feel much simpler in processing outcome than in processing probability. Finally, the monetary outcomes are modelled remarkably in the process. People’s character that attends to outcome refers to “outcome priority". Therefore, the standard format implies a biased informational input, and may be used to explain why people seek for the low probability income risk and are averse to the high probability risk in the decision-making process.

Therefore, according to the computation principle of prospect theory, this experiment can measure participator’s value estimate effectively.