THINKING & REASONING, 2006, 12 (2), 129–143

Psychology Press
Taylor & Francis Group

A new look at the "Asian disease" problem: A choice between the best possible outcomes or between the worst possible outcomes?

Shu Li
Institute of Psychology, Chinese Academy of Sciences, China Peking University, China

Xiaofei Xie
Peking University, Beijing, China

The "Asian disease" problem (Tversky & Kahneman, 1981) demonstrated behaviour in contradiction to the invariance axiom of EU theory. However, the risky choice behaviour was simply seen by the equate-to-differentiate model as a choice between the best possible outcomes or a choice between the worst possible outcomes. It was then argued that a way in which frame influences choice is through the perceived difference between possible outcomes. A "judgement" task was designed to examine whether the knowledge of "the value difference between each possible outcome and the certain outcome" will permit prediction of preference in the choice pattern related to the Asian disease problem. Participants were exposed to an anthrax disease problem (the original or probabilistic version of the Asian disease problem) and a SARS problem (the fuzzy version of the Asian disease problem). It was shown that the empirical evidence in relation to the Asian disease problem could be satisfactorily accounted for by the generalised weak dominance strategy revealed by the judgement results.

Correspondence should be addressed to Xiaofei Xie PhD, Department of Psychology, Peking University, Beijing 100871, China. Email: xiaofei@pku.edu.cn

The authors thank Nigel Harvey and four anonymous referees of this journal for their helpful comments on the initial version, and Ng Chor Hong, Tan Ling Chin, and Tay Mei Choo at Nanyang Technological University, and Wang Xiaolu at The Institute of Psychology, Chinese Academy of Sciences, for their help in collecting the data.

The first author initiated the research while teaching at Nanyang Technological University, and completed it while working as a visiting scholar at the Department of Psychology, Peking University.

http://www.psypress.com/tar DOI: 10.1080/13546780500145652

The Asian disease problem introduced by Tversky and Kahneman (1981) demonstrated behaviour in contradiction to the invariance axiom of EU theory. In the Asian disease problem (Tversky & Kahneman 1981), one group of subjects choose between two programmes designed to combat a disease that is expected to kill 600 people. If one programme is adopted, 200 people will be saved, and if the other programme is adopted, there is one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved. Another group of subjects choose between the programmes described in terms of lives lost. If one programme is adopted, 400 people will die, and if the other programme is adopted, there is one-third probability that nobody will die and two-thirds probability that 600 people will die. When alternative outcomes were phrased positively in terms of lives saved, subjects preferred the certain option. When outcomes were phrased negatively in term of lives lost, the risky option was preferred.

Over the past two decades, the problem has triggered numerous studies, including those in applied settings, to examine the resulting framing effect. For example, McNeil, Pauker, Sox, and Tversky (1982) found that not only laypeople but also physicians are susceptible to this framing effect. However, not everyone who looks for framing effects finds them, and there are certainly many reasons why and conditions under which the framing effect appears (see, e.g., Bohm & Lind, 1992; Christensen, Heckerling, Mackesy, Bernstein, & Elstein, 1995; Elliott & Archibald, 1989; Fagley & Miller, 1990; Fox & Dayan, 2004; Levin, Schneider, & Gaeth, 1998; Li, Fang, & Zhang, 2000; Rothman & Salovey, 1997). Based on data from 136 empirical papers that reported framing experiments with nearly 30,000 participants, a meta-analysis of the influence of framing on risky decisions (Kühberger, 1998) shows that the overall framing effect between conditions is of small to moderate size, and that profound differences exist between research designs. It is concluded that framing is a reliable phenomenon, but that outcome salience manipulations, which constitute a considerable amount of work, have to be distinguished from reference point manipulations, and that procedural features of experimental settings have a considerable effect on effect sizes in framing experiments.

The precise details of the design of the present study on the Asian disease problem are based on possible tests of a choice model called the "equate-to-differentiate" theory (Li, 2003, 2004a, 2004b). This model posits that the mechanism governing human risky decision making has never been one of maximising some kind of mathematical expectation, but rather some generalisation of dominance detection. Weak dominance states that if alternative A is at least as good as alternative B on all attributes, and alternative A is definitely better than alternative B on at least one attribute, then alternative A dominates alternative B (cf. Lee, 1971; von Winterfeldt &

Edwards, 1986). When a dominant alternative exists, it is unambiguously the best alternative available and therefore no further analysis is required. The model postulates that, in order to utilise the very intuitive or compelling rule of *weak* dominance to reach a binary choice between A and B in more general cases, the final decision is based on detecting A dominating B if there exists at least one j such that $U_{Aj}(x_j) - U_{Bj}(x_j) > 0$ having subjectively treated all $U_{Aj}(x_j) - U_{Bj}(x_j) \leqslant 0$ as $U_{Aj}(x_j) - U_{Bj}(x_j) = 0$, or detecting B dominating A if there exists at least one j such that $U_{Bj}(x_j) - U_{Aj}(x_j) > 0$ having subjectively treated all $U_{Bj}(x_j) - U_{Aj}(x_j) \leqslant 0$ as $U_{Bj}(x_j) - U_{Aj}(x_j) = 0$, where x_j ($j = 1, \ldots, M$) is the objective value of each alternative on Dimension j (for an axiomatic analysis, see Li, 2001).

In searching for evidence of whether the conditions governing the framing effect can be determined, the present research began by looking into a graphical representation of the positive and negative frames of the Asian disease problem. Instead of distinguishing the value of an outcome and the likelihood of an outcome separately (i.e., to represent risky choices by using two risk dimensions, e.g., Montgomery, 1977; Ranyard, 1982; Tversky, 1969), an amount to win (x) and a chance of winning (p), assuming that values on the two dimensions can be varied independently), the proposed representation decomposes each programme into two possible outcomes (the best and the worst possible outcome dimensions), valuing each possible outcome separately, and then determines the rank ordering of each dimension on which the intra-dimensional comparison of the two programmes presumably depends. If the sure-thing option itself were seen as either the best possible outcome (when compared with the best possible outcome of the risky option) or the worst possible outcome (when compared with the worst possible outcome of the risky option), the binary choice problems can now be restated as follows: How would one of the two points in the *two*-dimensional space, as shown in Figure 1, be chosen?

With such a cognitive representation in mind, it will enable the operation of the very intuitive rule of dominance in risky situations. The equate-to-differentiate way to solve the Asian disease problem is to construct a negatively accelerated (concave) utility function (e.g., simply applying a logarithmic utility function supported by Weber-Fechner law) over the two possible outcomes, and then to determine whether the utility difference between the best possible outcomes is smaller or larger than that between the worst possible outcomes. As soon as the dimension on which the utility difference is the greatest is determined, the decision maker's objective is reduced to a choice of a better outcome along this dimension (to maximise outcomes along the best possible outcome dimension or to minimise outcomes along the worst possible outcome dimension). That is, the decision maker's task is to achieve a so-called *equated dominance*; i.e.,

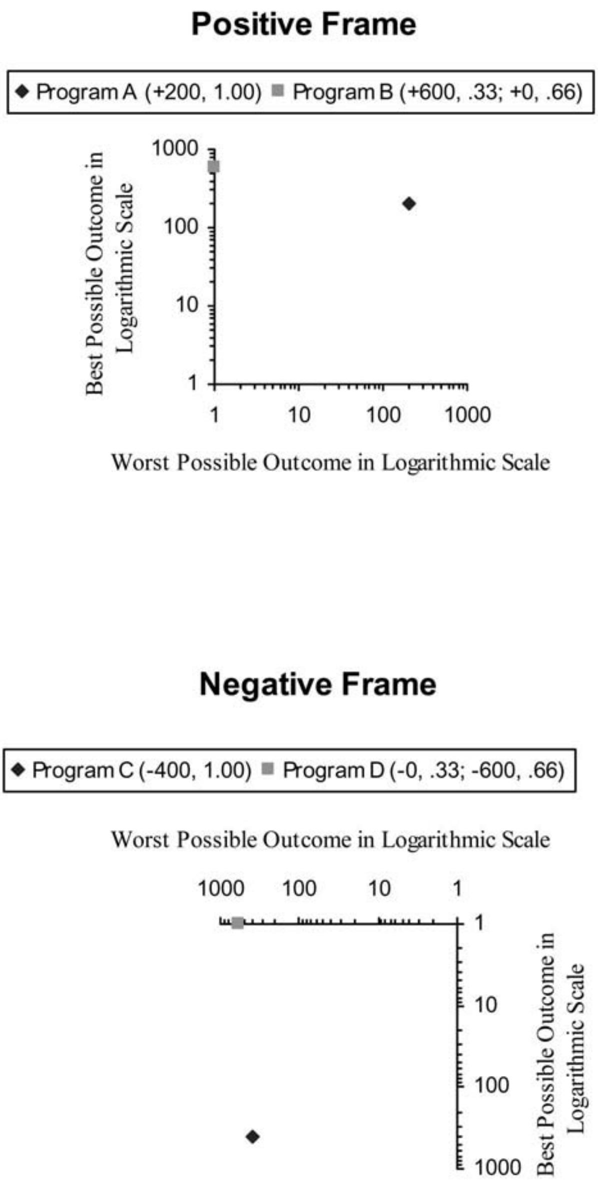

Figure 1. The representation of the Asian disease problem by applying a logarithmic utility function

Programme A (B) dominates Programme B (A), having treated the smaller dimensional difference that Programme B (A) is better than Programme A (B) as subjectively equal. A similar analysis for choice involving losses leads to the prediction that Programme D (C) will be chosen when the worst (best) possible outcomes between the two programmes are treated as equal.

Such a decision process with the detailed likelihood of an outcome being absent in making an objectively nondominated alternative subjectively dominated is somewhat similar to what the fuzzy-trace theory (Reyna & Brainerd, 1995) suggested. The fuzzy-trace theory proposes that detailed nuances of problem information are presumably not central to reasoning, and that reasoners tend to operate on representations that are at the lowest level of precision (e.g., the probability is represented categorically as either *certain* or *uncertain*) that permits a task-relevant response. According to Reyna and Brainerd (1995), removing all of the numbers from the Asian disease problems, and replacing them with vague phrases, did not eliminate the framing effect. In fact, framing effects were not only detected but they were larger in magnitude when the numbers were absent than when they were present. This suggests that numerical information was not only unnecessary for framing effects, but it tended to mask rather than amplify the effect. Instead of searching for a psychophysical function for quantities, this "fuzzy-trace" way of thinking (Reyna & Brainerd, 1995) has assumed as a key principle that reasoning prefers to operate on simple gist, as opposed to exact details.

The "simple gist" account for the framing effect was supported in some way by the findings of Kühberger (1995) and Mandel (2001). Those findings strongly suggest that framing effects in the disease problem may be due to missing information. Kühberger (1995) first notes that outcomes in the Asian disease problem are inadequately specified; knowing that 200 people will be saved does not tell us explicitly what will happen to the other 400 people. When Kühberger makes outcomes explicit (e.g., filling in the missing information for the certain prospects by stating that 200 will be saved and 400 will die) by using what Mandel (2001) called the *additive method*, "framing" effects vanish.

Be that as it may, it appears that the explanation for the "true" or "larger" framing effect in the disease problem should be the one that is able to apply to the choices with absent numbers, where, as Reyna and Brainerd (1995) suggested, the outcome value is represented nominally as whether *some* lives are saved (lost) or *no* lives are saved (lost), while the probability is represented categorically as either *certain* or *uncertain*, or correspondingly. The supposed choice with absent probabilities is interesting and worth more exploration, because it casts doubt on the role of the probability-weighting function that is derived by a deductive process which assumes that the option chosen by a decision maker is the one that maximises the overall worth of a option (for more detailed arguments, see Li, 1995, 1996).

Inspection of Figure 1 sheds some light on the effect of the semantic wording of options. It can be seen from Figure 1 that the construction of the problem, plotted on a logarithmic scale, will render the equating of difference on the "best possible outcome" dimension easier than that on the "worst possible outcome" dimension for the positive frame, but vice versa for the negative frame. In other words, regardless of the fact that the two problems are re-descriptions of each other, and that Programme A maps to Programme C rather than D, the choice parameters are designed so that the difference between the null outcome (the *worst* possible outcome) of Programme B and the certain outcome (200 will live) of Programme A is too significant in the positive frame, whereas the difference between the null outcome (the *best* possible outcome) of Programme D and the certain outcome (400 will die) of Programme C is too significant in the negative frame (see also Table 1). If we are indeed guided by the weak dominance rule in making our choices, quite possibly the decision outcome is then reached by seeing the best possible outcomes to be equal in the positive frame while seeing the worst possible outcomes to be equal in the negative frame. The violation of the invariance axiom arises because the dimension on which a weak dominance relationship is detected and determined is slyly switched from the worst possible outcome dimension in the positive frame to the best possible outcome dimension in the negative frame.

It was therefore reasoned that differences in possible outcomes are the driving force behind differences in risk preference. That is, in the gain (positive) condition, the smaller the difference between the null outcome and the certain outcome is perceived to be, the easier it is for the risky option weakly to dominate the sure-gain option, having seen the two options as equally good on the *worst* possible outcome dimension. In the loss (negative) condition, on the contrary, the smaller difference between the null outcome and the certain outcome is perceived, the easier it is for the sure-loss option weakly to dominate the risky option, having seen the two options as equally good on the *best* possible outcome dimension.

If the larger difference alluded to were able to be diminished either objectively or subjectively, and thus to be treated as equal, another way around the risk-seeking and risk-averse behaviour could be generated by applying the weak dominance rule. It can be seen that, when an effort is made to reverse the dimensional differences offered by the disease problem, it is possible to generate counterexamples to the common pattern of the framing effect even if the experiments retain the same way of shifting wording (Li & Adams, 1995) as well as the same scenario

TABLE 1

The intra-dimensional evaluations of the programmes offered in the Asian disease problem

Positive frame			*Negative frame*		
Programme	*Best outcome*	*Worst outcome*	*Programme*	*Best outcome*	*Worst outcome*
A	200 saved	200 saved	C	400 die	400 die
B	600 saved	0 saved	D	0 die	600 die
Difference (A-B)	– 400 saved	+ 200 saved	Difference (C-D)	+ 400 die	– 200 die
Utility difference lg(A)-lg(B)	– 0.477 (smallest)	> 2.301 (largest)	Utility Difference lg(C)-lg(D)	> 2.602 (largest)	– 0.176 (smallest)
Utility difference ln(A)-ln(B)	– 1.099 (smallest)	> 5.298 (largest)	Utility Difference ln(C)-ln(D)	> 5.991 (largest)	– 0.405 (smallest)

(Li, 1998). All of these can be done without turning to a nonlinear weighing function [e.g., $w(p) = p^\gamma / [p^\gamma + (1 - p)^\gamma]^{1/\gamma}$] as well as an S-shaped value function (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). Take Li's (1998) experiment for example. The proportion of survival and mortality was changed from 200 will live and 400 will die, to the more asymmetrical one of 20 will live and 580 will die. This change was to make the differences between the null outcome and the certain outcome less differentiable (i.e., 20 lives is close to 0 lives when compared with the total of 600 lives). The corresponding probability of gain or loss is reduced from the original 1/3 to 1/30 to ensure that expected values remain exactly the same. As a result, the difference between the null outcome and the certain outcome appears to be *smaller* when the options are positively framed, whereas the difference between the null outcome and the certain outcome appears to be *greater* when the options are negatively framed, when compared with the original Asian disease problem. The consequence of this is that the participants became risk seeking (65%) in the positive frame while remaining risk seeking (72%) in the negative frame. Hence the virtually identical responses in the two framing conditions were observed. In such a case, framing accounted for 0.6% of the variance in choice, in contrast to the 25% of the variance found in the original problem by Tversky and Kahneman (1981).

Guided by such thinking, the following experiments were designed to examine in further detail whether the knowledge of "the value difference between each possible outcome and the certain outcome" will permit prediction of preference in the Asian disease problem. In particular, it was hypothesised that:

> *H1: The framing effect on individual risk preference will be mediated by individuals' judged value difference between the possible outcome and the certain outcome.*

EXPERIMENT 1

Method

Participants. A total of 141 students from Nanyang Technological University and National University of Singapore, 30 students from Temasek Polytechnic, and 130 students from the Institute of Technical Education (East Tampines) in Singapore participated as volunteers. None had any formal knowledge of decision theory.

Materials and procedure. Booklets that contained choice and judgement tasks with regard to the modified Asian disease problem, the anthrax disease problem, were administered to 301 student participants as follows:

Anthrax Disease Problem
Imagine that our South East Asia region is preparing for the outbreak of an unusual anthrax disease, which is expected to kill 600 people. Two alternative programmes to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programmes are as follows:

Positive Frame:
If Programme A is adopted, 200 people will be saved.
If Programme B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

Please indicate your choice by circling on the 7-point scale below.

1	2	3	4	5	6	7
Definitely choosing Programme A						Definitely choosing Programme B

Judgement 1. From the previous choice, consider if you see any difference between "*200 people will be* saved" in Programme A and "*1/3 probability that 600 people will be saved"* in Programme B.

"200 people will be saved" vs "1/3 probability that 600 people will be saved"

Please indicate your choice by circling on the 7-point scale below.

1	2	3	4	5	6	7
I see little difference						I see a huge difference

Judgement 2. From the previous choice, consider if you see any difference between "*200 people will be saved*" in Programme A and "*2/3 probability that no people will be saved*" in Programme B.

"200 people will be saved" vs "2/3 probability that no people will be saved"

Please indicate your choice by circling on the 7-point scale below.

1	2	3	4	5	6	7
I see little difference						I see a huge difference

Negative Frame:
If Programme C is adopted, 400 people will die.
If Programme D is adopted, there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

Please indicate your choice by circling on the 7-point scale below.

1	2	3	4	5	6	7
Definitely choosing Programme C						Definitely choosing Programme D

Judgement 1. From the previous choice, consider if you see any difference between "*400 people will die*" in Programme C and "*1/3 probability that nobody will die*" in Programme D.

"400 people will die" vs "1/3 probability that nobody will die"

Please indicate your choice by circling on the 7-point scale below.

1	2	3	4	5	6	7
I see little difference						I see a huge difference

Judgement 2. From the previous choice, consider if you see any difference between "*400 people will die*" in Programme C and "*2/3 probability that 600 people will die*" in Programme D.

"400 people will die" vs "2/3 probability that 600 people will die"

Please indicate your choice by circling on the 7-point scale below.

1	2	3	4	5	6	7
I see little difference						I see a huge difference

The anthrax disease problem was presented to participants in two different versions, which counterbalanced the order of the two frames presented.

Results and discussion

To examine the mediating effect of personal judged dimensional difference between frame and individual risk preference, the three-step mediation analysis suggested by Baron and Kenny (1986) was performed. In step 1, a one-way ANOVA was conducted. In step 2, two regression analyses (one with frame as IV, and the two types of judged dimensional difference as DVs; the other with judged dimensional difference as IV, and the individual risk preference as DV) were performed. In step 3, an ANCOVA with two within-subjects covariates (two types of judged dimensional difference) was conducted. The analyses revealed that: (1) frame, on a within-subjects basis, had a marginal main effect (eta squared = .01) on participants' choice behaviour [$F(1, 300) = 3.29$, $p = .071$] with participants being more risk-averse in the positive frame ($M = 3.72$) than in the negative frame ($M = 3.96$); (2) frame was a predictor of two types of judged dimensional difference (i.e., the difference between the *best* possible outcomes and the difference between the *worst* possible outcomes) ($\beta = -.28$ and .41, respectively, $p < .01$), and the two types of judged dimensional difference were predictors of the risk preference ($\beta = .26$ and $-.09$ respectively, $p < .05$), where the greater judged difference between paired possible outcomes was in fact switched from the *worst* possible outcome dimension in the positive frame [$M_{best} = 4.22 < M_{worst} = 4.99$, $t(300) = -6.67$, $p < .001$] to the *best* possible outcome dimension in the negative frame

[$M_{best} = 4.77 > M_{worst} = 4.17$, $t(300) = 4.98$, $p < .001$]; and (3) when the judged dimensional difference variables were entered as within-subjects covariates, the effect of frame drops in significance [$F(1, 298) = 0.36$, $p = .55$], whereas the effects of the judged dimensional differences remained significant [$F(1, 298) = 8.71$, $p < .01$ and $F(1, 298) = 7.33$, $p < .01$ respectively]. A closer examination of the β weights of the judged *best* possible outcome dimensional difference ($\beta = .26$, $p < .01$) and the judged *worst* possible outcome dimensional difference ($\beta = -.09$, $p < .05$) indicates that, as expected, these two different judged dimensional differences predict the individuals' risk preference in the opposite direction. These results suggest that the two types of judged dimensional difference were full mediators between frame and individual risk preference. These results provide considerable support for the present hypothesis (H1) that *the framing effect on individual risk preference will be mediated by individuals' judged value difference between the possible outcome and the certain outcome*.

EXPERIMENT 2

The framing effect detected in Experiment 1 was marginally significant and relatively small (eta squared = .01) when compared with Tversky and Kahneman's (1981) original findings. This is possibly due in part to the fact that a within-subjects rather than a between-subjects manipulation of frame was used in Experiment 1. To further explore whether the mediating effect tested is robust enough to survive in a situation where the framing effects are large in magnitude, the present experiment tested the framing effect by using a fuzzy version of the disease problem and a between-subjects manipulation of frame.

Method

Participants. A total of 285 undergraduate students from Hwa Nan Women's College and 61 postgraduate students from Peking University and from the Institute of Psychology, Chinese Academy of Sciences participated as volunteers.

Materials and procedure. The materials were largely the same as in Experiment 1. However, they differed in that the disease of anthrax was placed with SARS (severe acute respiratory syndrome) and the stated probabilities "1/3 probability" and "2/3 probability" were replaced with "some probability" and "a higher probability" respectively. It was expected that such a fuzzy version would amplify the framing effect, as Reyna and Brainerd (1995) suggested.

About half of the participants responded to the positive frame (142 undergraduates and 30 postgraduates) and the other half the negative frame (143 undergraduates and 31 postgraduates). Participants were urged to give the problem a few minutes' thought prior to responding. Participants were also instructed that there were no right or wrong answers, and that the experimenters were interested in the participant's own thoughtful answer. When the completed questionnaires were collected, the participants were then debriefed.

Results and discussion

The choices and judgements of participants assigned to the two framing conditions were also analysed using the three-step mediation analysis suggested by Baron and Kenny (1986). The analyses revealed that: (1) frame, on a between-subjects basis with absent numbers, had a significant main effect (eta squared = .14) on participants' choice behaviour [$F(1, 344) = 55.09$, $p < .001$] with participants being more risk averse in the positive frame ($M = 3.55$) than in the negative frame ($M = 5.09$); (2) frame was a predictor of two types of judged dimensional difference (i.e., the difference between the *best* possible outcomes and the difference between the *worst* possible outcomes) ($\beta = .35$ and $-.15$, respectively, $p < .01$), and the two types of judged dimensional difference were predictors of the risk preference ($\beta = .22$ and $-.29$ respectively, $p < .01$, indicating that they predict the individuals' risk preference in the opposite direction), where the greater judged difference between paired possible outcomes was indeed switched from the *worst* possible outcome dimension in the positive frame [$M_{best} = 5.15 < M_{worst} = 5.55$, $t(171) = -1.96$, $p = .052$] to the *best* possible outcome dimension in the negative frame [$M_{best} = 5.70 > M_{worst} = 4.15$, $t(173) = 9.81$, $p < .001$]; and (3) when the judged dimensional difference variables were entered as covariates, the effect of frame dropped in size (eta squared = .075) and *F* value [$F(1, 342) = 27.71$, $p < .01$] although it was not fully eliminated, whereas the effects of the judged dimensional differences remained significant [$F(1, 342) = 11.91$, $p < .01$ and $F(1, 342) = 13.24$, $p < .01$ respectively]. These results show that, as expected, a larger framing effect was detected in the non-numerical version of the disease problem (eta squared = .14) than in the numerical version of the disease problem (eta squared = .01) and that, as in Experiment 1, the two types of judged dimensional difference were also mediators between frame and individual risk preference. These findings provide empirical evidence that the knowledge of "the value difference between the possible outcome and the certain outcome" is able to permit prediction of preference in the choice pattern related to the Asian disease problem. Especially, the determining "gist" is the value difference but not the likelihood information.

CONCLUDING REMARKS

An essential condition for a theory of choice that claims normative status is the principle of invariance: equivalent formulations of a choice problem should give rise to the same preference order (Arrow, 1982). Because invariance is normatively indispensable, no adequate prescriptive theory should permit its violation. However, with their Asian disease problem, Tversky and Kahneman (1981) showed that a choice between two essentially identical options is affected by the phrasing of the options. They point out that the evaluation of an outcome as a gain or a loss depends on a somewhat arbitrary reference point. By manipulating the reference point, it may be possible to reverse an individual's preferences. Prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992) has provided the main theoretical framework for explaining the framing effect, and the reflection effect on which the framing effect presumably depends.

An alternative way of seeing the framing effect has been developed by a generalised *weak dominance* approach, the equate-to-differentiate approach (Li, 2003, 2004a, 2004b). The equate-to-differentiate way of seeing the framing effect is quite simple. Instead of accounting for the framing effect by assuming an S-shaped value function together with the overweighting of certainty due to a nonlinear weighting function (Kahneman & Tversky, 1982), it simply depends on the occurrence of changes in value difference between the possible outcome and the certain outcome as a result of different descriptions of the same (gamble) problem. An analysis applied to the pattern related to the framing effect would suggest that the risk aversion for gains and risk seeking for losses is a consequence of the fact that the difference between the possible null outcome and the sure-thing outcome is too great to be equated, assuming a concave utility function. It was therefore expected that the violation of the invariance principle and the other perplexing paradoxical patterns of behaviours would be observed in fact when people's equate-to-differentiate strategy (deciding which dimensional difference is to be equated and which is to be differentiated) is caused to change by the experimental conditions applied, but not otherwise.

Such a "third variable" account is supported by the observed effect that judgement data could satisfactorily account for the variance in choice in both the original (or probabilistic) version of the Asian disease problem and the fuzzy version of the disease problem. Both the anthrax disease problem and the SARS problem revealed that the judged difference between the *best* possible outcomes and the judged difference between the *worst* possible outcomes mediated the relationship between frame conditions and the changes in responses. This is true regardless of whether the framing effects were large (eta squared = .14) or small (eta squared = .01) in magnitude.

The mediating effect corroborates the equate-to-differentiate line of reasoning, which simply sees risky choice behaviour as a choice between the best (the worst) possible outcomes, having treated the worst (the best) possible outcomes as subjectively equal.

The present study makes a further contribution to the understanding of how the perceived difference between the possible outcomes exerts influence on individuals' risk preference. Had we not adopted this theoretical framework, we would have been unlikely to uncover the underlying mechanisms for the observed change in the effect sizes of framing with parameter modifications on both the best possible and the worst possible outcome dimensions. For example, the framing effect that Bohm and Lind (1992) reported was smaller than in Tversky and Kahneman's study when the gamble parameter is re-examined by scaling down the size to one tenth of the original size (from 600 to 60, which is considered to be appropriate for Swedish conditions). Chiu (2003) found that participants tended to be risk seeking when the disease problem was described in a 6-million-people city (i.e., *relatively* scaling down the dimensional difference), and risk averse or neutral when the disease problem was described in a 600-people village. It is the present contention that violation of the invariance principle does not necessarily depend on the semantic wording of options. If and only if framing or wording can change the perceived value difference between the possible outcome and the certain outcome across different frame conditions, can the framing effect be produced. Otherwise, the invariance principle will be satisfied regardless of whether the problem is differently framed.

Manuscript received 4 April 2003
Revised manuscript received 11 November 2004

REFERENCES

Arrow, K. J. (1982). Risk perception in psychology and economics. *Economic Inquiry*, *20*, 1–9.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology*, *51*, 1173–1182.

Bohm, P., & Lind, H. (1992). A note on the robustness of a classical framing result. *Journal of Economic Psychology*, *13*, 355–361.

Chiu, Y. C. (2003). Is there a framing effect? The asset effect in decision-making under risk. *Chinese Journal of Psychology*, *45*, 171–182.

Christensen, C., Heckerling, P., Mackesy, M. E., Bernstein, L. M., & Elstein, A. S. (1995). Pervasiveness of framing effects in clinical decision making. *Journal of Behavioural Decision Making*, *8*, 169–180.

Elliott, C. S., & Archibald, R. B. (1989). Subjective framing and attitudes toward risk. *Journal of Economic Psychology*, *10*, 321–328.

Fagley, N. S., & Miller, P. M. (1990). The effect of framing on choice: Interactions with risk-taking propensity, cognitive style, and sex. *Personality and Social Psychology Bulletin*, *16*, 496–510.

Fox, S., & Dayan, K. (2004) Framing and risky choice as influenced by comparison of one's achievements with others: The case of investment in the stock exchange. *Journal of Business and Psychology*, *18*, 301 – 321.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*, 263 – 291.

Kahneman, D., & Tversky, A. (1982). The psychology of preferences. *Scientific American*, *246*, 136 – 142.

Kühberger, A. (1995). The framing of decisions: A new look at old problems. *Organizational Behaviour and Human Decision Processes*, *62*, 230 – 240.

Kühberger, A. (1998). The influence of framing on risky decisions: A meta-analysis. *Organizational Behaviour and Human Decision Processes*, *75*, 23 – 55.

Lee, W. (1971). *Decision theory and human behaviour*. New York: Wiley.

Levin, I. P., Schneider, S., & Gaeth, G. J. (1998). All frames are not created equal: A typology and critical analysis of framing effects. *Organizational Behaviour and Human Decision Processes*, *76*, 149 – 188.

Li, S. (1995). Is there a decision weight π? *Journal of Economic Behaviour and Organization*, *27*, 453 – 463.

Li, S. (1996). What is the price for utilizing deductive reasoning? A reply to generalised expectation maximizers. *Journal of Economic Behaviour and Organization*, *29*, 355 – 358.

Li, S. (1998). Can the conditions governing the framing effect be determined? *Journal of Economic Psychology*, *19*, 133 – 153.

Li, S. (2001). Extended research on dominance violations in similarity judgments: The equate-to-differentiate interpretation. *Korean Journal of Thinking and Problem Solving*, *11*, 13 – 38.

Li, S. (2003). Violations of conjoint independence in binary choices: The equate-to-differentiate interpretation. *European Journal of Operational Research*, *148*, 65 – 79.

Li, S. (2004a). A behavioural choice model when computational ability matters. *Applied Intelligence*, *20*, 147 – 163.

Li, S. (2004b). Equate-to-differentiate approach: An application in binary choice under uncertainty. *Central European Journal of Operations Research*, *12*(3), 269 – 295.

Li, S., & Adams, A. S. (1995). Is there something more important behind framing? *Organizational Behaviour and Human Decision Processes*, *62*, 216 – 219.

Li, S., Fang, Y., & Zhang, M. (2000). What makes frames work? *Acta Psychologica Sinica*, 32, 229 – 234.

Mandel, D. R. (2001). Gain – loss framing and choice: Separating outcome formulations from descriptor formulations. *Organizational Behaviour and Human Decision Processes*, *85*, 56 – 76.

McNeil, B. J., Pauker, S. G., Sox, H. C., & Tversky, A. (1982). On the elicitation of preferences for alternative therapies. *New England Journal of Medicine*, *306*, 1259 – 1262.

Montgomery, H. (1977). A study of intransitive preferences using a think aloud procedure. In H. Jungermann & G. de Zeeuw (Eds.), *Decision making and change in human affairs* (pp. 347 – 362). Dordrecht, the Netherlands: Reidel.

Ranyard, R. (1982). Binary choice patterns and reasons given for simple risky choice. *Acta Psychologica*, *52*, 125 – 135.

Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences*, *7*, 1 – 75.

Rothman, A. J., & Salovey, P. (1997). Shaping perceptions to motivate healthy behaviour: The role of message framing. *Psychological Bulletin*, *121*, 3 – 19.

Tversky, A. (1969). Intransitivity of preferences. *Psychological Review*, *76*, 31 – 48.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, *211*, 453 – 458.

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, *5*, 297 – 323.

von Winterfeldt, D., & Edwards, W. (1986). *Decision analysis and behavioural research.* Cambridge: Cambridge University Press.