How Different Choice Strategies Can Affect the Risk Elicitation Process

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***Abstract*—This paper presents a study focusing on deviations from normative behavior in risk elicitation. Such deviations have implications on the process of eliciting reliable input data in applications of decision analysis. No existing elicitation method seems to be universally useful based on the findings made in this study. Since people obviously do not act in accordance with the normative rules, and different choice strategies have been identified, a prescriptive approach with individual assistance of the decision makers in the elicitation process thus seems to be necessary.**

***Index Terms*—Decision analysis, elicitation, risk behavior**

I. Introduction

Traditional decision analytic tools often presuppose that reliable input data is obtained by an exogenous process and the tools are almost exclusively based on normative rules, cf. [1, 2]. The specification and execution of the process is, though, left to the discretion of the user, which poses a problem as the applicability of computational decision methods often rests on the quality of input data. Needless to say, this causes problems when using decision analysis tools in real decision making situations. For example, since people have difficulties distinguishing between probabilities ranging from approximately 0.3 to 0.7 [3], there is reason to believe that human decision makers will face similar problems when making subjective probability estimations in an elicitation process. However, despite this, numerical probabilities and utilities are subjectively assigned by the decision maker in most decision problems [4, 5]. Subjective, in this sense, means that the values reflect the decision maker's actual beliefs and preferences. These are not necessarily logical or rational, but rather interpreted in terms of the willingness to act in a certain way [6]. Thus, individual risk attitudes affect the outcomes of such processes. The elicitation of probabilities has been studied to a greater extent than the elicitation of utilities, and recommendations as to how to elicit probabilities and problems with such assessments can be reviewed further in, e.g., [7]. The question arises as to whether or not people are able to provide the inputs which utility theory requires [8], and more specifically - how can we reduce deviations from the normative rules in elicitation processes? For example, [9] suggests modifications of normative theories to include cognitive concerns as a way of reducing discrepancies between real and idealized behaviour. Therefore, it is essential to consider human aspects on reasoning and understanding more explicitly when designing decision analysis tools. There is a need to incorporate deliberate elicitation methods that lead to higher input quality (in line with decision tool assumptions), and thus improve the usage of computer based decision making applications.

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II. The Study

In this article, we study individuals' behavior when they choose alternatives in risky prospects with respect to gains or losses. In [10], we observed that the behavior of the subjects tended to deviate more from normative rules when the probability of a gain or loss in the prospects were lower than 0.25 or higher than 0.75. Furthermore, we could observe the choices subjects made, but had no information about their strategies, that is, how they perceived the different prospects regarding the size of the probability of gain or loss and the values in consideration. Thus, in order to identify if decision makers use different strategies, it was necessary to interview some of the subjects. The focus of this study is therefore on qualitative aspects, such as risk perception and choice strategies.

III. Study Outline

This study, which follows from [10], focuses on deviations from normative behavior. The study was conducted with 252 undergraduate students, divided into 8 groups. They were asked to make choices about hypothetical gains or losses, and 12 students were also interviewed in order to identify and understand different strategies employed when making these choices. Each subject answered questions on prospects with either a chance of gain or a risk of loss. We will use the following notation for an alternative A_i in a risky prospect,

$$A_i(p, x_i)$$

where p denotes the probability of ending up with a (not necessarily positive) monetary value of x_i.

TABLE I

1	2	3	4
$A_1(0.05, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.95, x_2)$

Table 1. The probability levels of the 4 measuring points used, here presented in an *increasing probability order*. In measuring point 1, the subject is asked (given a value of x_1) at different values of x_2 about his/her preference order of A_1 and A_2.

In the current study, four so called *measuring points* were used (see Table 1). A measuring point may be considered as a risky prospect represented by a pair of alternatives $\langle A_1(p_1, x_1), A_2(p_2, x_2)\rangle$ with differing probabilities of ending up with a gain or loss such that the probability in the second alternative (A_2) is 0.1 higher or lower than in the first (A_1).

At each of the four measuring points, the subjects were offered a choice between two alternatives; one with a specific probability of gain or loss, another with a fixed probability and an interval within which they could pick a monetary value so that the second alternative would be preferred over the first. The probability of the second alternative was higher or lower than the first depending on whether the order of the probabilities was increasing or decreasing. In the interval of the second alternative, a value that resulted in the corresponding EMV[1] of the first alternative was always available for choice. In order to reduce monotony, the monetary values 2000 SEK[2] and 4000 SEK were alternated in the fixed alternative on the left hand side of the risky prospects. We could not observe irregularities in the subjects' choice patterns between alternatives with different amounts of gains or losses, and therefore assume that their utility perceptions within the applied monetary range were linear.

IV. RESULTS

Traditionally when describing risk behavior, people are categorized into three groups; risk-prone, risk-neutral and risk-averse [11]. Based on this division, the results from the study and interviews are here categorized into three main groups. We called the groups **A**, **B** and **C**, and the behavior of respondents in each group is described as follows:

- **A.** In this category, subjects demand a higher EMV (at least 10% higher or more) of the second alternative in order to prefer it.
- **B.** In this category, subjects prefer the second alternative with a corresponding EMV (±10%) of the first alternative.
- **C.** In this category, subjects prefer the second alternative although it has a lower EMV than the first alternative (at least 10% lower or less).

Below, the results have been divided into the three group categories for each offered choice situation, the results are depicted in Figures 1-4. In addition, significant interview results are presented for each choice situation. Note that when we refer to *subjects* below, we describe the behavior of all study participants (252 persons), whereas those referred to as *respondents* are the 12 complementary interview subjects.

A. Chance of gain

Chance of gain means that for each prospect $\langle A_1(p_1, x_1), A_2(p_2, x_2)\rangle$, the value of x_i is positive.

1) Increasing probability order

a) Choose between $A_1(0.05, x_1)$ and $A_2(0.15, x_2)$

In category **A** (7/12), the respondents perceived the chance of gain in both alternatives as very low.

In category **C** (5/12), all of the respondents perceived the chance of gain in the alternative A_2 as very small and therefore chose the second alternative to a lower EMV.

b) Choose between $A_1(0.15, x_1)$ and $A_2(0.25, x_2)$

In category **A** (6/12), a few respondents perceived the chance of gain in both alternatives as very low, although more prominent was their tendency to choose A_2 when the values of x_1 and x_2 differed with 1000 SEK.

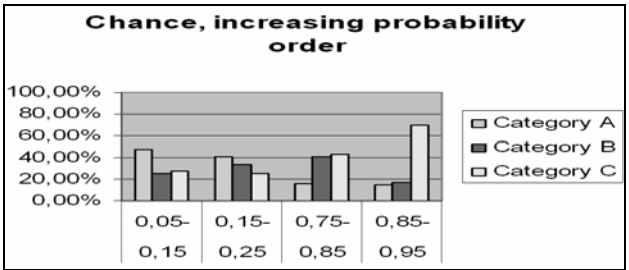
In category **C** (4/12), the respondents consider 0.25 as a much higher probability than 0.15 and therefore chose A_2 more or less immediately. One of the respondents reflects on the fact that 0.25 is one chance out of four.

c) Choose between $A_1(0.75, x_1)$ and $A_2(0.85, x_2)$

In category **A** (3/12), the respondents perceived both probabilities as high chances of gain and therefore mainly considered the values of x_1 and x_2 when evaluating the prospects.

In category **B** (3/12), the respondents perceived the probabilities as almost equal, and based their choices on a combination of probabilities and values.

In category **C** (6/12), some of the respondents explicitly stated that they perceived 0.85 as almost certain, and therefore they were prepared to choose that alternative at a much lower value of x_2 than of x_1.



	$A_1(0.05, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.95, x_2)$
A	47%	41%	16%	15%
B	26%	34%	41%	16%
C	27%	25%	43%	69%

Fig. 1. The aggregated data of all subjects, divided into the three categories **A**, **B** and **C**.

[1] Expected Monetary Value

[2] Abbreviation for the Swedish currency – Krona. 1 USD is approximately equivalent to 8 SEK.

d) Choose between $A_1(0.85, x_1)$ and $A_2(0.95, x_2)$

In category **A** (3/12), the respondents perceived 0.85 as a huge chance of winning and therefore only considered the values of x_1 and x_2.

In category **C** (6/12), the choices of the respondents varied, some felt that 0.95 was close to one, and therefore chose an alternative with a much lower EMV.

2) *Decreasing probability order*

a) Choose between $A_1(0.15, x_1)$ and $A_2(0.05, x_2)$

In category **A** (4/12), all of the respondents perceived 0.05 as a very small probability of gain and therefore did not choose A_2 until its EMV was much higher than the EMV of A_1.

In category **C** (8/12), the respondents perceived the chance of gain in both alternatives as very low. They pointed out that they did not care much about the probabilities (as both were low), but rather based their choices on the values of x_1 and x_2.

b) Choose between $A_1(0.25, x_1)$ and $A_2(0.15, x_2)$

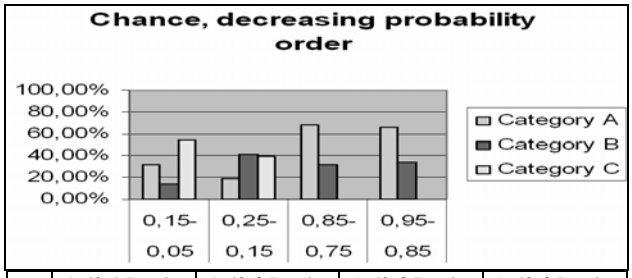
In category **A** (4/12), the respondents considered 0.25 as a much higher probability than 0.15 and therefore chose A_1 until the value of x_2 was more than twice the value of x_1.

In category **B** (5/12), the respondents did not calculate explicitly, although they considered both the values of x_1 and x_2 as well as the probabilities. When considering the alternatives, two of the respondents converted the probabilities into odds, for example, 3 out of 20 or less than 1/5 instead of 0.15.

In category **C** (3/12), the respondents perceived the chance of gain in both alternatives as quite low.

c) Choose between $A_1(0.85, x_1)$ and $A_2(0.75, x_2)$

In category **A** (6/11), the respondents perceived 0.85 as almost certain and therefore demanded a higher EMV of A_2 in order to choose it. However, one respondent pointed out that he found A_2 attractive since it is easier to recognize and deal with in terms of the odds 3 out of 4.



	$A_1(0.15, x_1)$ and $A_2(0.05, x_2)$	$A_1(0.25, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.75, x_2)$	$A_1(0.95, x_1)$ and $A_2(0.85, x_2)$
A	32%	19%	68%	66%
B	14%	41%	32%	34%
C	54%	40%	0%	0%

Fig. 2. The aggregated data of all subjects, divided into the three categories **A**, **B** and **C**.

mentioned the fact that 0.25 equals ¼, and said that since they recognized ¼ they tended to overweight it intuitively.

In category **B** (5/11), the respondents perceived both probabilities as high and felt that they did not differ to a great extent. They based their choices on a combination of the probabilities and the values of x_1 and x_2.

d) Choose between $A_1(0.95, x_1)$ and $A_2(0.85, x_2)$

In category **A** (7/11), the respondents felt that 0.95 was next to certain and therefore they were unwilling to choose an alternative with a lower probability of gain.

In category **B** (4/11), the respondents felt that the probability of gain was large in both cases.

B. *Risk of Loss*

Risk of loss means that for each prospect $\langle A_1(p_1, x_1), A_2(p_2, x_2)\rangle$, the value of x_i is negative.

1) *Increasing probability order*

a) Choose between $A_1(0.05, x_1)$ and $A_2(0.15, x_2)$

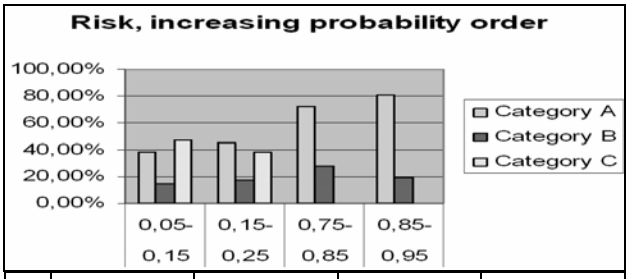
In category **A** (6/12), the respondents perceived the risk of loss in A_1 as very low, "almost safe" as several of them stated, and therefore did not choose A_2 until the EMV of that alternative was much higher.

In category **B** (4/12), the respondents perceived the risk of losing as small in A_1, but still considered the amounts they risked to lose.

In category **C** (2/12), the respondents focused more on the amounts they risked to lose than the probabilities, and considered what amounts they could afford to lose.

b) Choose between $A_1(0.15, x_1)$ and $A_2(0.25, x_2)$

In category **A** (5/12), the respondents felt that 0.25 was a much larger risk than 0.15 and were reluctant to choose A_2 until the EMV of A_2 was much higher.



	$A_1(0.05, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.95, x_2)$
A	38%	45%	73%	81%
B	15%	17%	27%	19%
C	47%	38%	0%	0%

Fig. 3. The aggregated data of all subjects, divided into the three categories **A**, **B** and **C**.

In category **C** (4/12), the respondents chose A_2 when the values of x_1 and x_2 differed with 1000 SEK.

c) Choose between $A_1(0.75, x_1)$ and $A_2(0.85, x_2)$

In category **A** (11/12), the respondents perceived 0.85 as much higher than 0.75 and were reluctant to choose A_2 until the EMV was much higher. Three of them said that 0.85 felt like a sure loss. Six of the respondents chose the alternative with a higher probability when the values of x_1 and x_2 differed with 1000 SEK, which some explicitly pointed at. One person said that he looked solely on the magnitudes of the probabilities and disregarded the values.

In category **B** (1/12), the respondent perceived the probabilities as relatively equal and did not want to increase the EMV of a possible loss.

d) Choose between $A_1(0.85, x_1)$ and $A_2(0.95, x_2)$

In category **A** (12/12), the respondents perceived 0.95 as a sure loss and were reluctant to choose A_2 although the EMV was higher than for A_1. A couple of them did not calculate on the risk of loss, but instead looked at the chance of not losing anything, that is, they compared a 0.15 chance with a 0.05 chance to end up with no loss.

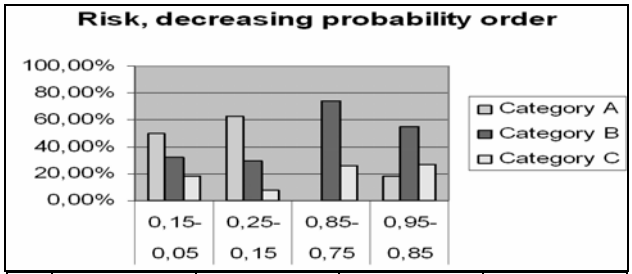
2) Decreasing probability order

a) Choose between $A_1(0.15, x_1)$ and $A_2(0.05, x_2)$

In category **A** (10/12), the respondents perceived both probabilities as relatively low and mainly considered what amounts they could afford to lose.

In category **B** (1/12), the respondent felt that 0.05 was a very small risk and chose that alternative when the value of x_2 was an acceptable potential loss to him.

In category **C** (1/12), the respondent felt that 0.05 was next to nothing and chose that alternative no matter the value of x_2, i.e., what he risked losing.



	$A_1(0.15, x_1)$ and $A_2(0.05, x_2)$	$A_1(0.25, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.75, x_2)$	$A_1(0.95, x_1)$ and $A_2(0.85, x_2)$
A	49%	62%	0%	18%
B	32%	30%	74%	55%
C	19%	8%	26%	27%

Fig. 4. The aggregated data of all subjects, divided into the three categories, A, B and C.

b) Choose between $A_1(0.25, x_1)$ and $A_2(0.15, x_2)$

In category **A** (10/12), half of the respondents only considered the values as they perceived the probabilities as relatively equal, whereas the others perceived 0.25 as much higher than 0.15. Three respondents from the latter group

In category **B** (1/12), the respondent said that for a lower probability he could accept to risk a higher value and combined the sizes of the probabilities and the values when he made his choice.

In category **C** (1/12), the respondent perceived 0.15 as a much smaller risk and chose that alternative immediately. He did not consider the size of potential loss.

c) Choose between $A_1(0.85, x_1)$ and $A_2(0.75, x_2)$

In category **B** (9/12), the respondents perceived the probabilities as relatively equal. One person mentioned the fact that he did not want to increase the possible loss with more than 1000 SEK and based his choice on this criterion. Five others made the same choice and one of them said that it was worth the risk of losing 1000 SEK more for a probability reduced with 0.1.

In category **C** (3/12), one respondent said that 0.85 was much higher than 0.75 and therefore chose A_2 no matter the value of x_2 in order to increase his chance of no loss.

d) Choose between $A_1(0.95, x_1)$ and $A_2(0.85, x_2)$

In category **A** (5/12), the respondents perceived both probabilities as very high, almost sure losses, and therefore did not want to increase the amount they risked to lose.

In category **B** (6/12), the respondents made a trade-off between probabilities and amounts. Initially, they considered the sizes of the probabilities, but as the values increased negatively in size, they weighted what amount they could afford to lose.

In category **C** (1/12), the respondent perceived 0.85 as a much smaller risk and therefore chose that alternative although the EMV was much lower.

V. Analysis

In this study, we have observed that people's behavior deviates from normative rules in different ways when choosing between alternatives in risky prospects where the probabilities of gains or losses are in the ranges 0.05-0.25 and 0.75-0.95. Two factors that we have identified as having significant effects on people's behavior are the size of the probability mass on a gain or loss, and more notably, the order in which the two alternatives having differing probabilities of gain or loss are presented.

A. Chance of gain, increasing probability order

When offered prospects with low probabilities, and comparing a probability of 0.05 of a gain to a probability of 0.15 of gain[3], the majority of the subjects is in category **A** and, thus, demands a higher EMV of the alternative with a higher

[3] Henceforth, we will simply write, e.g., "0.05 to 0.15" when referring to such a situation (measuring point).

probability in order to choose it. In both prospects, the respondents perceived the probabilities in the two alternatives as more or less equal and therefore mainly considered the sizes of the values involved. In the prospects with probabilities 0.15 to 0.25, we can see an increased tendency to choose according to the EMV, and the number of subjects in category **B** increase.

When offered prospects with high probabilities, we can observe a willingness to choose alternatives with higher probabilities and lower EMV, which is more evident in the probability range 0.85 to 0.95. Several of the respondents stated that they perceived a probability of 0.95 as next to certain, which we will call the "close to 100% effect".

B. Chance of gain, decreasing probability order

Subjects have two main strategies when we look at their choices of prospects with low probabilities, 0.15 to 0.05. The dominant group is category **C**, in which respondents did not pay that much attention to the probabilities (as they perceived them as low and moderately equal), but based their choice on the sizes of the values. Respondents with the other strategy perceived the probability of 0.05 as very low, and therefore demanded a much higher EMV in order to choose that alternative. In the other low probability range, 0.25 to 0.15, the number of members in both category **A** and **C** decrease considerably, and we can observe that more subjects make choices more in line with normative rules.

When offered prospects with high probabilities, the dominant strategy was in both cases category **A,** (0.85 to 0.75 and 0.95 to 0.85). None of the subjects was placed in category **C**, that is, no one was willing to choose an alternative with a lower EMV.

C. Risk of loss, increasing probability order

For low probabilities, most subjects make choices that fall under strategies **A** or **C**. Regarding prospects with probabilities 0.05 to 0.15, respondents in the first group perceived 0.05 as a very low risk, almost safe as they stated, whereas the respondents in the other group mainly focused on the values and calculated on how much they could afford to lose. For probabilities 0.15 to 0.25, more subjects demand a higher EMV in order to choose the 0.25-alternative and the respondents explained their behavior by stating that they perceived 0.25 as a much higher probability than 0.15 in a risk of loss situation. Several of the respondents reflected about the fact that 0.25 equals ¼ and that they may overweight it due to this ease of conversion to something more recognizable.

For high probabilities, the majority of subjects fall within category **A**. When choosing between alternatives in prospects with the probabilities 0.75-0.85, the respondents perceived 0.85 as a much larger risk. This tendency was even more noteworthy for prospects with probabilities 0.85-0.95. Most respondents perceived a probability of 0.95 as an almost certain loss, although a few said that they preferred to know exactly what they would lose. Furthermore, some said that they calculated their chances of losing nothing instead, that is, they compared a probability of 0.15 to a 0.05 probability of no loss instead of comparing a probability of 0.85 to a 0.95 probability of loss.

D. Risk of loss, decreasing probability order

Almost half of the subjects fall within category **A** when choosing between alternatives with probabilities 0.15 to 0.05. The respondents explained their behavior by saying that they perceived the probabilities as almost equal and did not want to face the risk of losing a much higher amount even though the probability of losing in the second alternative was only ⅓ of the first (0.15 to 0.05). The respondent in category **C** felt that a probability of 0.05 was close to no risk at all and therefore chose that alternative regardless of the values involved. Concerning alternatives with probabilities 0.25 to 0.15 of a loss, we note an increase of subjects that fall within category **A**. Half of the respondents state that they perceive the probabilities as relatively equal and therefore only consider the amounts, whereas some perceive 0.25 as much larger than 0.15 (although their choices did not correspond with this statement). Very few choose according to strategy **C**.

None of the subjects choose according to strategy **A** for alternatives with probabilities 0.85 to 0.75, and the majority belongs to category **B**. In category **B**, the respondents perceive the probabilities as relatively equal, and therefore make a trade-off between the differences in the amounts of the two alternatives when making their choice. As opposed to the case with probabilities 0.85 to 0.75, we find a group belonging to category **A** in the 0.95 to 0.85 case. These respondents perceived both probabilities as large, almost certain losses, and did not want to risk losing a larger amount with a lower probability. The majority in this case still belong to category **B**.

VI. CONCLUSIONS

From the results in a previous study, [10], it was not possible to explain how the subjects made their choices, that is, what strategies the subjects used and how they perceived the prospects. In this study, we focused on prospects having uncertain outcomes with lower or higher probabilities of either a gain or loss, since deviations observed in the first study were increasing at these levels. We have identified three main strategies that the subjects (in groups **A**, **B** and **C**) used when choosing among the alternatives in the offered prospects. As can be seen in the previous section, the behavior differs in these categories depending on whether probabilities are high or low, chance or risk domains, and the order of the probabilities. The main characteristics that were identified in the respondents' choice behavior are:

- They more often perceive the low probabilities as more or less equal, which is not the case to the same extent concerning the higher probabilities. This is particularly true regarding the chance prospects.
- For prospects with higher probabilities the respondents were keener to choose an alternative with a probability closer to 1 for a lower amount and did, in such cases, mainly focus on the probabilities.
- In the risk prospects, on the other hand, the respondents based their strategy for both lower and higher probabilities on how much they could afford to lose.
- In both chance and risk prospects we noticed the "close to 100% effect". The subjects' willingness to choose a

chance alternative with a lower EMV increased when the probability of gain approached 1. We also noted an aversion to choose alternatives in risk prospects that were almost certain losses.

- Many of the respondents expressed their evaluation strategy in terms of converting probabilities expressed as percentages into odds, e.g., 1 out of 4 instead of 0.25. Several of the respondents return to the fact that they find some probabilities such as 0.25 and 0.75 more familiar and, perhaps, therefore overweight them.
- Another tendency we observed was that some of the respondents intuitively recalculated the chance of losing into a chance of not losing at all.
- A clear tendency was that many of the respondents, irrespective of the probabilities, chose the second alternative when the difference of the values between the first and second alternative was approximately 1000 SEK. Many respondents explicitly stressed the fact that 1000 SEK in many situations corresponded to a 0.1 probability, that is, they were willing to pay that amount in order to increase the chance or to reduce the risk. This tendency is an important observation of erratic behavior as the impact of an increased/decreased chance or risk of 0.1 differs considerably depending on the sizes of the values.

VII. DISCUSSION

The findings of this study have implications on the process of eliciting reliable input data to decision analysis tools. If the elicitation process is incorporated in tools, it needs to be more flexible, since some people may prefer to have prospects presented in other forms than the traditional methods of using single-event probabilities to represent uncertainty. Cognitive research has shown that the human mind does not process such probabilities effectively and that even experienced statisticians make errors when reasoning about them [12]. Furthermore, using a single number to represent an uncertain quantity can confuse a person's judgment about uncertainties with the desirability of various outcomes [13]. Examples on alternative representations of uncertainties are presentation formats such as odds, probability wheels, and probabilities in intervals. The latter approach relaxes the need for precise data, which is not available in many cases of real life decision making. Furthermore, the elicitation part should be designed so that it can more easily be adjusted to different types of behaviors, depending on what strategies people display.

No existing elicitation method seems to be universally useful based on the findings made in this study. Since people obviously do not act in accordance with the normative rules, and different choice strategies have been identified, a prescriptive approach with individual assistance of the decision makers in the elicitation process thus seems to be necessary. This is a different approach in comparison to approaches of, e.g., normative theories which suggests rules for whole classes of problems. However, a functional prescriptive aid is a difficult task to accomplish. It demands a lot from the decision analyst and the toolbox of methods he intends use.

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