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Context-dependent outcome expectation contributes to experience-based risky choice

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Abstract

Previous research has demonstrated systematic discrepancies between description- and experience-based risky choices. This *description-experience gap* has been attributed to several factors such as reliance on small samples and differential probability weighting patterns. Because context-dependent outcome expectation regarding safe options might influence experience-based risky choices, it constitutes another potential contributor to the gap. Using a free-sampling paradigm and risky options with rare outcomes that were either attractive or unattractive relative to the frequent ones, two experiments examined the existence and impact of such outcome expectation in experience-based risky choices. Both experiments had two information conditions: hint information meant to eliminate outcome expectation was provided in one condition but not the other. Experiment 1, which indicated the numbers of possible outcomes regarding both safe and risky options under the hint condition, revealed different choice behaviors regarding risky-safe trials between the two information conditions, no matter whether the rare outcome of the risky option in such a trial (i.e., the *local* context) was attractive or unattractive. However, this result provided only indirect evidence for the role of outcome expectation because it was unclear whether the hint information affected only the outcome expectation and thus evaluation of safe options or the evaluations of both safe and risky ones. With refined hint information arguably removing potential impacts on the evaluation of risky options, Experiment 2 showed that expectation of a non-existent rare outcome of safe options did contribute to experience-based risky choices. In addition, it appeared that the rare outcomes of the risky options in other decision problems presented in the same experiment (i.e., the *global* context) also affected outcome expectation. Future research could investigate how the interaction between local and global contexts determines outcome expectation to deepen our understanding of its contribution to experience-based risky choice and the description-experience gap.

Keywords: Description-experience gap, experience-based risky choice, outcome expectation, context-dependency, free-sampling

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1 Introduction

People make risky choices all the time. Some choices are made from description, such as buying a lottery ticket after learning summary information of its possible payoffs and related probabilities, whereas others are made from experience, such as choosing a particular restaurant for an important date based on previous personal experiences of the very place. A large body of research has shown that risky choices from description can be systematically different from those from experience, that is, the *description-experience gap* in risky choice (e.g., Barron & Erev, 2003; Hertwig et al., 2004; Hertwig & Erev, 2009; Weber et al., 2004; see Wulff et al., 2018 for a recent review).

Several factors have been demonstrated to contribute to the description-experience gap in risky choice, such as reliance on small samples and the resultant sampling errors (e.g., Camilleri & Newell, 2011; Fox & Hadar, 2006; Hau et al., 2008) and differential probability weighting patterns between the two learning modes (e.g., Camilleri & Newell, 2011; Frey et al., 2015; Kellen et al., 2016). Although these findings have substantially improved our understanding of how people make risky choices from experience and why such choices could differ from those from description, the puzzle has not been fully solved. For example, recent studies by Glöckner and colleagues (Glöckner et al., 2012; Glöckner et al., 2016) showed that structure of decision problem (i.e., choice between a safe and a risky option [a risky-safe trial] vs. choice between two risky options [a risky-risky trial]) had a substantial effect on the gap and might reverse the gap under some circumstances. See Wulff et al. (2018) for a recent review regarding the effect.

A cognitive mechanism based on context-dependent outcome expectation has been invoked to account for the effect of the structure of decision problem on the gap (Glöckner et al., 2016). It was argued that, while choosing between a safe and a risky option from experience, the outcome distribution of the risky option constituted a context for evaluating the safe option. Specifically, people might conjecture that the safe option had a second not-yet-sampled outcome that was similar to the sampled rare outcome of the risky option. Note that the single outcome of the safe option was always set to lie between the unattractive and attractive outcomes of the risky options to maintain similar expected values. Therefore, the conjecture of a not-yet-sampled outcome meant that participants would expect a non-existent outcome regarding the safe option that was the same as the rare outcome of the risky option in terms of attractiveness. Consider a choice between a safe option of 6 dollars and a risky option that has a probability of 0.8 to produce 7 dollars, otherwise nothing. In this case, the risky option has a rare unattractive outcome (i.e., zero), and participants might expect that the safe option also has an unattractive outcome close or equal to 0, although

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it has not been sampled due to limited sampling experience. This false expectation would decrease the evaluation of the safe option and thus increase the choice probability of the risky option, leading to apparent underweighting of the rare, unattractive outcome of the risky option. The same reasoning applies to a choice between a safe option and a risky option with an attractive rare outcome (e.g., 1 dollar for sure vs. 4 dollars with a probability of 0.2), although the false expectation of a not-yet-sampled attractive outcome would instead increase the evaluation of the safe option and thus decrease the choice probability of the risky option. Since the safe option involved in a risky choice from description would not suffer from such an expectation, the resultant information asymmetry between description and experience might be a major reason for the common finding of relative underweighting of rare outcomes in risky choices from experience when using a risky-safe decision problem. However, for a risky-risky decision problem, such an expectation would not occur as long as all outcomes of each risky option were sampled. Therefore, it was not surprising that the relative underweighting of rare outcomes in experience-based risky choices might be reduced or even reversed when risky-safe problems were replaced by risky-risky ones.

The purpose of this article is to verify the role of context-dependent outcome expectation in experience-based risky choice and thus provides an alternative explanation of the description-experience gap in risky choice. Although Glöckner et al. (2016) invoked context-dependent outcome expectation from a theoretical perspective to account for the original description-experience gap, the existence and impact of such an expectation have not been empirically established. Therefore, it is critical to perform experimental studies to provide direct evidence for this potential cognitive mechanism leading to the description-experience gap.

Several previous studies have produced results consistent with the hypothesized role of context-dependent outcome expectation in experience-based risky choices, but these results were accounted for by differential evaluations of risky instead of safe options. For example, Study 2 in Erev et al. (2008) investigated the *mere-presentation effect* on the impact of rare events in risky choices from experience and found that indicating all possible outcomes of each option on the corresponding button during the sampling phase (i.e., *the mere-presentation condition*) altered participants' choice behavior in a way suggesting an overweighting of rare events similar to that found in description-based risky choices. This finding was at odds with the conventional probability weighting pattern when no information about possible outcomes was explicitly labeled on each option button (i.e., *the blank condition*). This effect was interpreted as if the presentation of all possible outcomes increased the decision weight of the rare event and thus affected the evaluation of the risky option. Since the button for the safe option was also labeled with its single possible outcome, the same manipulation might eliminate any false outcome expectation regarding the safe option, leading to the same observed choice pattern. In other words, the result could also be accounted for by the hypothesized role of outcome expectation in experienced-based risky choices.

Similarly, Study 1 in Hadar and Fox (2009) showed that, indicating all possible outcomes of each option during the choice phase would also render a risky choice from experience more similar to that from description even if the rare outcome of the risky option was never sampled. The result was again interpreted as a consequence of different evaluations of risky options. Specifically, indicating all possible outcomes was argued to eliminate the information asymmetry between description and experience regarding risky options, and thus the impact of rare outcomes increased substantially although they were never sampled. However, as for Study 2 in Erev et al. (2008), the same result might be produced by an altered evaluation of safe options. Specifically, indicating all possible outcomes at the choice phase might again remove false outcome expectation regarding safe options, leading to the same observed choice pattern. Aware of this possibility, Hadar et al. conducted a second study in which a risky-safe trial was either preceded or followed by a risky-risky trial. It was hypothesized that the risky-risky trial would generate expectation of a non-existent outcome regarding the safe option in the subsequent risky-safe trial, making the order of trials matter. The result confirmed this hypothesis, suggesting that outcome expectation did exert an impact on the evaluation of the safe option. However, the study involved only two trials and thus provided just very weak evidence for the hypothesized role of outcome expectation. Therefore, we conducted two new experiments that directly manipulated context-dependent outcome expectation to provide stronger and clearer evidence for the existence and impact of outcome expectation in experience-based risky choices. Specifically, the numbers of possible outcomes regarding the safe or both options were either hinted or not. By comparing choice responses under different information conditions, we could verify the existence and impact of context-dependent outcome expectation in experience-based risky choice more straightforwardly.

2 Experiment 1

2.1 Method

2.1.1 Participants

Two-hundred and six students (141 females, M_{age} = 20.0 years, SD_{age} = 2.30 years) from a top university in China were recruited for this study. One-hundred and two participants were randomly assigned to a hint condition (72 females, M_{age} = 20.2 years, SD_{age} = 2.27 years), whereas the remaining 104 participants were assigned to a no-hint condition (69 females, M_{age} = 19.8 years, SD_{age} = 2.32 years). Each participant received 10 Chinese Yuan (CNY) as a base payment, together with a bonus contingent on his/her response in a choice trial randomly determined at the end of the experiment. The chosen option would be played out according to its objective outcome distribution and the participant would get the resultant amount of money. In addition, each participant had a chance of 20% to obtain an

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extra amount of money according to his/her response in a randomly picked evaluation trial in which the participant needed to report his/her certainty equivalent for a given gamble.

2.1.2 Materials and procedure

This study involved a between-subject factor with regard to hint information. In the *no-hint* condition, participants learned information regarding the two options in each decision problem simply via the standard free-sampling paradigm. Specifically, in each trial participants first learned the distributional information of each option by clicking the corresponding button as many times as they wanted to reveal possible outcomes of the option (i.e., the sampling phase). Afterwards, they proceeded to a choice phase when they indicated their preference between the two options. In the *hint* condition, however, participants also received information about the numbers of possible outcomes for both options in each decision problem before they started the free-sampling procedure. For a risky-safe trial, participants were told that one of the options had only one possible outcome and the other had two different outcomes. Note that participants were *not* informed of which option had only one outcome. For a risky-risky trial, participants were told that both options had two different outcomes.

Table 1 displays the 12 decision problems to which participants needed to show their preferences. Each safe option was presented in the table with its single outcome (e.g., *6* for a safe option with a single outcome of 6), whereas each risky option was presented with its nonzero outcome and the corresponding probability (for example, *7, 0.8* for a risky option with a probability of 0.8 to produce an outcome of 7, otherwise nothing). All the outcomes were in the unit of CNY. Risky option in each of the first three risky-safe trials (i.e., decision problems 1, 3, and 5) involved a rare unattractive outcome (i.e., zero), whereas risky option in each of the last three risky-safe trials (i.e., decision problems 7, 9, and 11) involved a rare attractive outcome. Hereafter we will call the first three risky-safe trials as *unattractive* risky-safe trials, whereas the last three as *attractive* risky-safe trials. The risky-risky trials (i.e., decision problems 2, 4, 6, 8, 10, and 12) were adapted from the preceding risky-safe ones by dividing the corresponding probabilities by 4 (for the unattractive trials) or 2 (for the attractive trials). Context-dependent outcome expectation in the unattractive risky-safe trials would shift preference towards the risky options, whereas that in the attractive risky-safe trials would shift preference towards the safe options. Note that, when such outcome expectations were eliminated by hint information, preferences (and thus choice patterns) should change in the opposite direction. Therefore, providing hint information would decrease the choice proportion of the risky options in unattractive risky-safe trials, but increase the choice proportion of such options in attractive risky-safe trials.

The experiment started with two practice trials, one with a risky-safe choice between 2 and (5, 0.6) and the other with a risky-risky choice between (5, 0.4) and (4, 0.6). Afterwards, participants took the formal trials under either information condition. Both the presentation order of formal trials within each condition and the presentation positions (left or right)

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Table 1: Summary of the decision problems presented in Experiment 1, the median sample sizes of different options under the two information conditions, and the corresponding proportions of participants choosing the riskier options.

			No-hint			Hint		
Decision Problem	S	R	N(S)	N(R)	P(R)	N(S)	N(R)	P(R)
1	6	7, 0.8	10	10	18	5	7	10
2	6, 0.25	7, 0.2	10	13	55	10	11	65
3	6	8, 0.8	10	10.5	44	4	9	33
4	6, 0.25	8, 0.2	14.5	14	58	10	11	67
5	6	9, 0.8	10	11	60	6	10	46
6	6, 0.25	9, 0.2	13	13	64	10	10	75
7	1	4, 0.2	8	12	22	4	10	41
8	1, 0.5	4, 0.1	10	13	44	8.5	12	52
9	1	5, 0.2	7.5	10	38	4	11	47
10	1, 0.5	5, 0.1	10	14.5	51	8.5	13	56
11	1	6, 0.2	8	11	40	3.5	10	58
12	1, 0.5	6, 0.1	10	12	64	9	11	69

Note. S = safer option; R = riskier option; N(S) = median sample size of safer option; N(R) = median sample size of riskier option; P(R) = proportion of participants choosing the riskier option.

of the safer and riskier options in each formal trial were randomized for each participant. Finally, six evaluation trials were presented at the end of the experiment to measure the baseline risk preference of each participant, so that its impact on choice response could be taken into consideration while examining the target effect of information condition. Specifically, participants needed to report their certainty equivalents for six gambles generated by crossing over two outcomes (i.e., 11 and 13 CNY) and three probabilities (i.e., 0.7, 0.8, and 0.9). The evaluation trials were presented in a random order for each participant and the average value of the certainty equivalents would be used as a measure of baseline risk preference. To encourage participants to report their true evaluation of each gamble, a procedure adapted from the Becker-DeGroot-Marschak (BDM) mechanism (Becker et al., 1964) was implemented to determine the actual payment. See Appendix for the details of the procedure.

2.1.3 Data analysis

All analyses in this and the following study were performed using a Bayesian approach with the R software (R core team, 2020), its rstanarm package (Goodrich et al., 2020) and

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other relevant packages, and the JASP software (JASP Team, 2020). We first examined the impact of information condition on choice response to address the major research question, that is, whether outcome expectation plays a role in experience-based risky choices and thus contributes to the description-experience gap. These analyses were conducted with logistic regressions in which choice response served as the dependent variable, whereas information condition, the difference in experienced average outcome between the two options within each decision problem, and the baseline risk preference (i.e., the average value of certainty equivalents from the evaluation trials) served as the predictors. Besides the more comprehensive analyses using logistic regressions, when necessary, we also simply compared choice proportions of the riskier options under the two information conditions to provide further evidence regarding the impact of the hint information.

Since the current research focused on the role of outcome expectation in the evaluation of safe options in risky-safe trials, trials with and without safe options were analyzed separately. In addition, only trials in which all possible outcomes of any risky option were experienced were involved in the analyses. This was because, for risky-safe trials, expectation of a rare, not-yet-sampled outcome regarding the safe option was possible only when the other, risky option was actually experienced as a risky option. For trials with two risky options, this approach was adopted because experienced distributions were the direct determinant of participants' choice response, but such trials would become a risky-safe trial in terms of experienced outcomes if one or both risky options revealed only one possible outcome. Such an approach would also conduce to the control of sampling errors. Finally, risky-safe trials with risky options containing rare attractive outcomes were analyzed separately from those containing rare unattractive outcomes, since the outcome expectation had opposite impacts on choice response in respective trials.

As in most studies on experience-based decisions, we also analyzed sample sizes to provide additional evidence for the validity of the manipulation of outcome expectation as well as process information of the sampling procedure. When sample size was of concern, all trials were included in the analysis, no matter whether all outcomes of the involved risky option(s) were experienced or not. Finally, following Erev et al. (2008)'s analysis, we examined whether there was a certainty effect between risky-safe decision problems and corresponding risky-risky decision problems for either information condition using Bayesian logistic regressions. In these analyzes we considered the impact of problem type on choice response (i.e., the certainty effect), together with the influences of the difference in experienced average outcome and the baseline risk preference as in the analyses regarding the impact of information condition.

For statistical inferences with regard to logistic regressions, we relied on both the 95% credible interval (CI) of the posterior distribution of the critical parameter (i.e., the slope regarding information condition or problem type; Lindley, 1965) and the leave-one-out cross-validation information criterion (i.e., LOOIC), a standard model comparison index for Bayesian analysis (e.g., Vehtari et al., 2017). When the credible interval of the critical

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parameter did not include the null value and the alternative model that included the critical term as a predictor had a lower LOOIC value than the null model that excluded the critical term, we would infer that there was a difference in choice response between different information conditions or problem types. When the credible interval included the null value and the null hypothesis had a lower LOOIC value than the alternative model, we would infer that there was no difference in choice response between information conditions or problem types. Otherwise, the evidence would be regarded as ambiguous and the alternative hypothesis would be neither rejected nor accepted. For analyses on sample size, we relied on appropriate Bayesian non-parametric methods (due to the nonnormality of relevant data) and the corresponding Bayes factors (BF) to make statistical inferences. Specifically, we would accept a particular hypothesis when the BF supporting the hypothesis was larger than 3 (Jeffrey, 1961). For other Bayesian analyses involved in this and the following study, we relied on BF of corresponding analyses to draw statistical inferences.

2.2 Results

The analyses on the impact of information condition revealed clear supportive evidence in risky-safe trials. Specifically, for each unattractive risky-safe decision problem, the hint condition always led to a lower sample proportion of choosing the riskier option than the no-hint condition (Table 1). The 95% CI of the slope of information condition from the relevant Bayesian logistic regression was [–0.879, –0.005] and respective values of the LOOIC index were 499.94 and 498.04 for the null and alternative models. Both the 95% CI and the LOOIC index suggested an effect of hint information on choice response. Similarly, for each attractive risky-safe decision problem, the hint condition always led to a higher sample proportion of choosing the riskier option than the no-hint condition (Table 1). The 95% CI of the slope of information condition from the relevant Bayesian logistic regression was [0.114, 0.855] and respective values of the LOOIC index were 666.09 and 661.55 for the null and alternative models. Again, both the 95% CI and the LOOIC index suggested an effect of hint information on choice response, although in the opposite direction consistent with the different context-dependent outcome expectations. Naturally, the difference in the slope of information condition between unattractive and attractive risky-safe trials was credibly below zero (95% CI = [–1.497, –0.345]).[1] See Figure 1 for a graphic demonstration of the opposite impacts of information condition on unattractive and attractive risky-safe decision problems. Finally, in both analyses, the coefficients regarding the difference in experienced average outcome and that of baseline risk preference were credibly above zero (Table 2).

For the risky-risky trials, the Bayesian logistic regression produced ambiguous evidence for the impact of information condition. The 95% CI of the relevant slope (i.e., [–0.023, 0.551]) included the null value, suggesting no impact of information condition on choice

[1]The same result held when running an interaction analysis. Specifically, the parameter for the interaction between information condition and type of rare outcome (i.e., [–1.441, –0.320]) was credibly below zero.

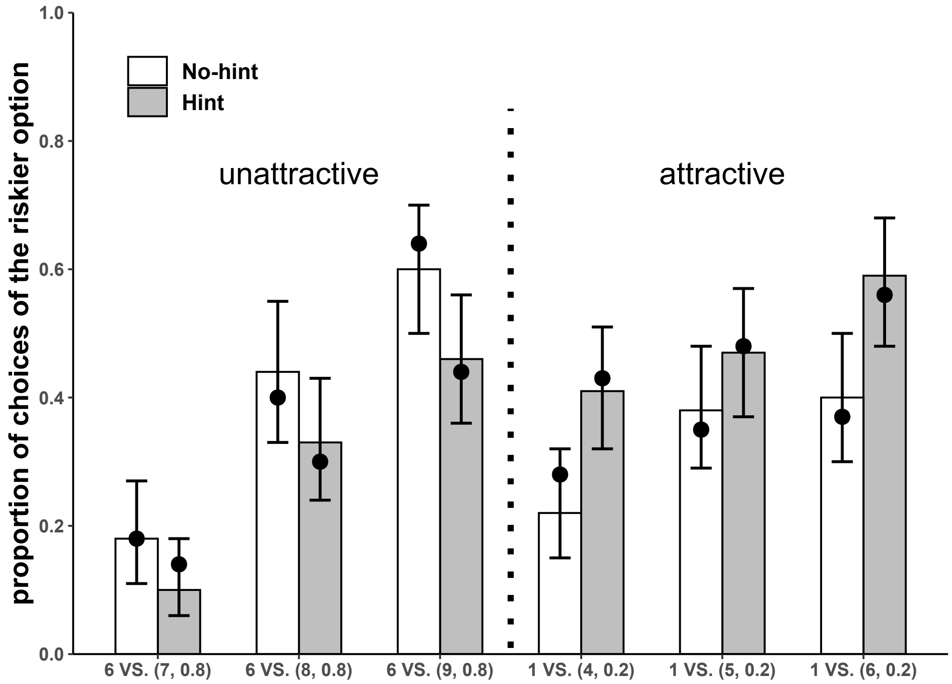

Figure 1: Choice proportion of the riskier option from risky-safe decision problems in Experiment 1. Error bars show the 95% credible intervals of the relevant proportions. Filled circles show the posterior predicted choice proportions of the Bayesian logistic regression models reported in the text.

Table 2: Results of the Bayesian logistic regressions regarding the impact of information condition on choice response in risky-safe trials of Experiment 1.

			95% Credible interval	
Type of rare outcome	Effect	Posterior Median	Lower bound	Upper bound
Unattractive	CON	–0.438	–0.879	–0.005
	DEV	1.295	1.061	1.559
	BRP	0.539	0.289	0.803
Attractive	CON	0.482	0.114	0.855
	DEV	1.340	1.018	1.687
	BRP	0.266	0.072	0.465

Note: CON = information condition, DEV = difference in experienced average outcome between the two options, BRP = baseline risk preference.

response. However, the respective values of the LOOIC index were 1095.44 and 1094.24, suggesting an impact of information condition on choice response. To the contrary, sample sizes under the two conditions provided clear evidence for the impact of information con-

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dition. Specifically, sample sizes under the hint condition were always smaller than those under the no-hint condition (Table 1). This was true for both the risky-safe trials (BF_{10} = 2.15×10^9, $Md_{no\text{-}hint}$ = 20, Md_{hint} = 15) and the risky-risky trials (BF_{10} = 7683.67, $Md_{no\text{-}hint}$ = 26, Md_{hint} = 21), and when the safe and risky options in the risky-safe trials were analyzed separately (BF_{10} = 3.82×10^{16}, $Md_{no\text{-}hint}$ = 9, Md_{hint} = 4 for safe options; BF_{10} = 4980.24, $Md_{no\text{-}hint}$ = 11, Md_{hint} = 10 for risky options). The difference in sample size regarding both safe and risky options suggested that the hint information altered the evaluations of not only safe options but also risky ones. Finally, for the risky-risky decision problems, choice proportion of the riskier options was lower under the no-hint condition (i.e., 56.25%) than under the hint condition (i.e., 64.25%; change in choice proportion = 8.00%, BF_{10} = 3.97), also suggesting an impact of hint information on the evaluation of risky options. However, the impact of information condition on risky-risky trials appeared smaller than that on risky-safe trials in terms of the change in sample choice proportion. Specifically, providing hint information in risky-safe trials led to a decrease in sample choice proportion from 40.71% to 29.33% given unattractive rare outcomes (change in choice proportion = 11.38%, BF_{10} = 4.63), and an increase in sample choice proportion from 33.33% to 48.77% given attractive rare outcomes (change in choice proportion = 15.44%, BF_{10} = 92.90).

For the analyses on the certainty effect, Bayesian logistic regressions revealed supportive evidence for both information conditions (for the no-hint condition, 95% CI of the slope of problem type = [0.785, 1.391], $LOOIC_{null}$ = 1123.44, $LOOIC_{alt}$ = 1072.28; for the hint condition, 95% CI of the slope of problem type = [0.837, 1.400], $LOOIC_{null}$ = 1268.04, $LOOIC_{alt}$ = 1205.54). Table 1 shows the choice proportion of the riskier option within each decision problem and information condition. Clearly, the riskier option in each decision problem with two risky options was more likely to be chosen than that in the corresponding decision problem with a safe and a risky option under both information conditions, consistent with the certainty effect commonly found in description-based risky choices.

2.3 Discussion

By explicitly manipulating outcome expectation with information regarding the numbers of possible outcomes and examining risky-safe decision problems with risky options containing either unattractive or attractive rare outcomes, this study showed evidence for an impact of information condition on both choice response and sample size in risky-safe trials. The relevant changes were consistent with the hypothesized influence of context-dependent outcome expectation on the evaluation of safe options. However, analyses on choice responses and sample sizes of risky-risky trials also suggested an impact of information condition on the evaluation of risky options in the current study. It seemed that the hint information also inclined participants towards assigning equal weights to the two possible outcomes of a risky option. This altered evaluation of risky options could also lead to the observed change in choice response regarding risky-safe trials. Therefore, it was not clear whether the hypothesized impact of context-dependent outcome expectation on the evaluation of

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safe options was at least the major reason for the difference in choice response between the two information conditions for risky-safe trials. To provide clearer evidence for the role of outcome expectation regarding safe options in experience-based risky choices, we conducted a second experiment with different hint information regarding risky options to avoid its impact on the processing of such options.

3 Experiment 2

3.1 Method

3.1.1 Participants

Two-hundred students (136 females, M_{age} = 20.9 years, SD_{age} = 2.44 years) from a top university in China were recruited for this study. Ninety-nine participants were randomly assigned to a hint condition (67 females, M_{age} = 21.1 years, SD_{age} = 2.44 years), whereas the remaining 101 participants were assigned to a no-hint condition (69 females, M_{age} = 20.6 years, SD_{age} = 2.43 years). Each participant received 12 CNY as a base payment as well as a bonus contingent on his/her response in a randomly picked choice trial. As in Experiment 1, each participant also had a chance of 20% to obtain an extra amount of money according to his/her response in a randomly picked evaluation trial.

3.1.2 Material and procedures

This study adopted similar material and procedures as Experiment 1 with two major changes. First, in this study a different instruction regarding risky options was provided since the hint information provided in Experiment 1 appeared to affect the processing of both safe and risky options. Specifically, for risky-safe decision problems, participants under the hint condition were told that one option had only one outcome, whereas the situation of the other option was still unknown. For decision problems with two risky options, participants were told that the situation of either option was still unknown. Specifying a particular number of outcomes (i.e., 2) for a risky option might incline participants towards assigning equal weights to the outcomes and thus lead to an apparent overweighting of the rare outcome. The current instruction might at least reduce such a tendency and thus its impact on the processing of risky options. Second, the number of decision problems was doubled by adding decision problems adapted from those in Experiment 1. Specifically, the attractive outcome of the riskier option in each decision problem was increased by 10 CNY and that of the safer option was increased as well to maintain the difference in expected value between the two options. This expansion of study material would allow each participant to provide more data for a more powerful examination of the various effects. See Table 3 for the decision problems used in the current study.

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Table 3: Summary of the decision problems presented in Experiment 2, the median sample sizes of different options in the two information conditions, and the corresponding proportions of participants choosing the riskier options.

			No-hint			Hint		
Decision Problem	S	R	N(S)	N(R)	P(R)	N(S)	N(R)	P(R)
1	6	7, 0.8	9	8	14	5	6	10
2	6, 0.25	7, 0.2	12	12	61	10	11	57
3	6	8, 0.8	8	10	39	5	7	24
4	6, 0.25	8, 0.2	12	12	64	11	11	54
5	6	9, 0.8	10	9	40	4	8	35
6	6, 0.25	9, 0.2	11	12	71	11	11	66
7	14	17, 0.8	10	10	21	5	7	20
8	14, 0.25	17, 0.2	11	11	65	11	14	52
9	14	18, 0.8	9	10	29	5	10	22
10	14, 0.25	18, 0.2	11	12	53	11	12	63
11	14	19, 0.8	8	10	31	5	8	37
12	14, 0.25	19, 0.2	13	12	61	13	13	53
13	1	4, 0.2	7	10	32	4	11	30
14	1, 0.5	4, 0.1	9	13	65	8	11	60
15	1	5, 0.2	7	11	36	3	10	47
16	1, 0.5	5, 0.1	9	11	63	10	12	50
17	1	6, 0.2	7	10	45	4	9	61
18	1, 0.5	6, 0.1	10	14	58	8	11	67
19	3	14, 0.2	8	11	28	4	10	49
20	3, 0.5	14, 0.1	10	12	39	10	12	44
21	3	15, 0.2	7	10	35	4	11	35
22	3, 0.5	15, 0.1	10	12	42	9	12	49
23	3	16, 0.2	7	11	28	3	10	39
24	3, 0.5	16, 0.1	10	12	47	10	12	51

Note. S = safer option; R = riskier option; N(S) = median sample size of safer option; N(R) = median sample size of riskier option; P(R) = proportion of participants choosing the riskier option.

3.1.3 Data analysis

This study involved the same set of analyses as in Experiment 1.

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3.2 Results

The analyses on the impact of information condition revealed differential evidence for the role of outcome expectation in risky-safe trials. Specifically, for most unattractive risky-safe decision problems, the hint condition led to a lower sample proportion of choosing the riskier option than the no-hint condition (Figure 2). However, both the 95% CI of the slope of information condition from the relevant Bayesian logistic regression (i.e., [–0.497, 0.118]) and respective values of the LOOIC index for the null and alternative models (i.e., 990.97 and 991.51) suggested no effect of hint information on choice response. The simpler analysis regarding choice proportion of the riskier option also provided weak evidence that there was no credible difference between the no-hint condition (sample proportion = 29.08%) and the hint condition (sample proportion = 24.81%; $BF_{10} = 0.45$). To the contrary, for most attractive risky-safe decision problems, the hint condition led to a higher sample proportion of choosing the riskier option than the no-hint condition (Figure 3). In this case, both the 95% CI of the slope of information condition from the relevant Bayesian logistic regression (i.e., [0.153. 0.711]) and respective values of the LOOIC index for the null and alternative models (i.e., 1200.75 and 1193.51) favored a positive effect of information condition on choice response. As in Experiment 1, the difference in the slope of information condition between unattractive and attractive risky-safe trials was credibly below zero (95% CI = [–1.041, –0.197])[2]. Finally, in both analyses, the coefficients regarding the difference in experienced average outcome and those of baseline risk preference were credibly above zero (Table 4).

Table 4: Results of the Bayesian logistic regressions regarding the impact of information condition on choice response in risky-safe trials of Experiment 2

			95% Credible interval	
Type of rare outcome	Effect	Posterior Median	Lower bound	Upper bound
Unattractive	CON	–0.188	–0.497	0.118
	DEV	0.689	0.574	0.811
	BRP	0.267	0.103	0.434
Attractive	CON	0.430	0.153	0.711
	DEV	0.746	0.617	0.884
	BRP	0.217	0.079	0.356

Note: CON = information condition, DEV = difference in experienced average outcome between the two options, BRP = baseline risk preference.

For decision problems with two risky options, the results of relevant Bayesian analyses

[2]The same result held when running an interaction analysis. Specifically, the parameter for the interaction between information condition and type of rare outcome (i.e., [–1.022, -0.197]) was credibly below zero.

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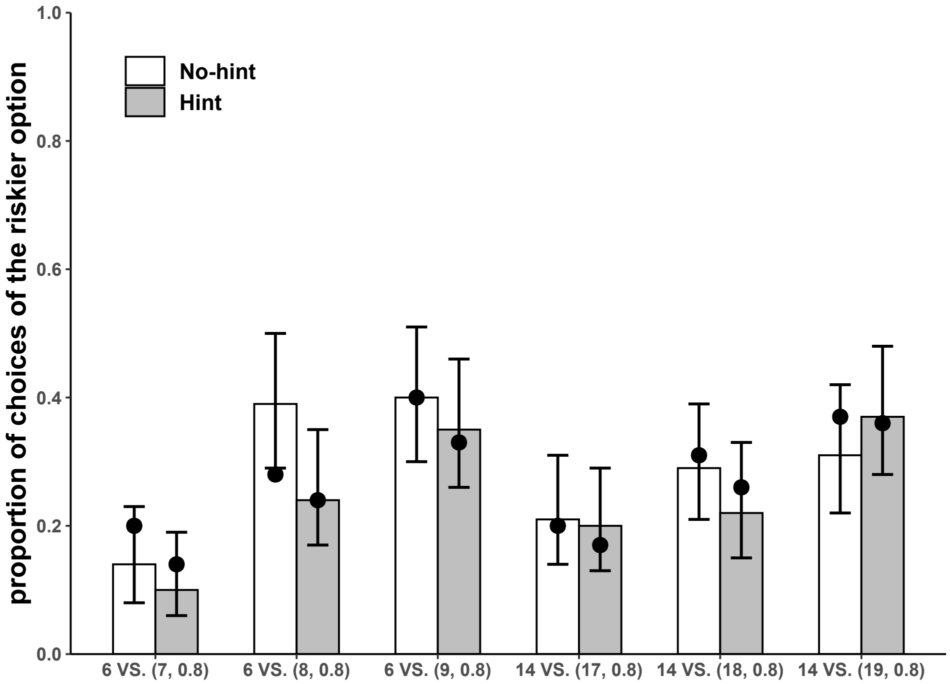

FIGURE 2: Choice proportion of the riskier option from unattractive risky-safe decision problems in Experiment 2. Error bars show the 95% credible intervals of the relevant proportions. Filled circles show the posterior predicted choice proportions of the Bayesian logistic regression models reported in the text.

suggested that providing hint information did not change how participants evaluated risky options. The 95% CI of the slope of information condition from the relevant logistic regression was [–0.346, 0.084], and the respective values of the LOOIC index were 1932.80 and 1933.33 for the models excluding and including the term of information condition. Both the 95% CI and LOOIC index suggested no impact of information condition on the evaluation of risky options. Furthermore, there was no credible difference in choice proportion of the riskier options between the no-hint condition (sample proportion = 57.99%) and the hint condition (sample proportion = 55.49%; BF_{10} = 0.15), again suggesting no impact of the hint information on the evaluation of risky options. Similarly, sample sizes for the decision problems with two risky options did not differ between the two information conditions (BF_{10} = 0.095, Md_{hint} = 22, $Md_{no\text{-}hint}$ = 23), also favoring no impact of the hint information.[3] Finally, as in Experiment 1, Bayesian logistic regressions revealed a certainty effect under both information conditions (for the no-hint condition, 95% CI of the slope of problem type = [1.022, 1.444], $LOOIC_{null}$ = 2270.54, $LOOIC_{alt}$ = 2133.72; for the hint condition, 95% CI of the slope of problem type = [0.731, 1.148], $LOOIC_{null}$ = 2149.92, $LOOIC_{alt}$ = 2074.15).

[3]The sample sizes of the risky options in risky-safe trials still differed between the two information conditions. However, the evidence for the difference was much weaker than that in Experiment 1, and the distributions of sample size were similar between the two conditions (BF_{10} = 24.67, Md_{hint} = 9, M_{hint} = 11.75, $Md_{no\text{-}hint}$ = 10, $M_{no\text{-}hint}$ = 11.72). To the contrary, the evidence for the difference in sample size of safe options was still decisively strong ($BF_{10} = 1.98\times10^{18}$, Md_{hint} = 4, M_{hint} = 5.27, $Md_{no\text{-}hint}$ = 8, $M_{no\text{-}hint}$ = 9.08).

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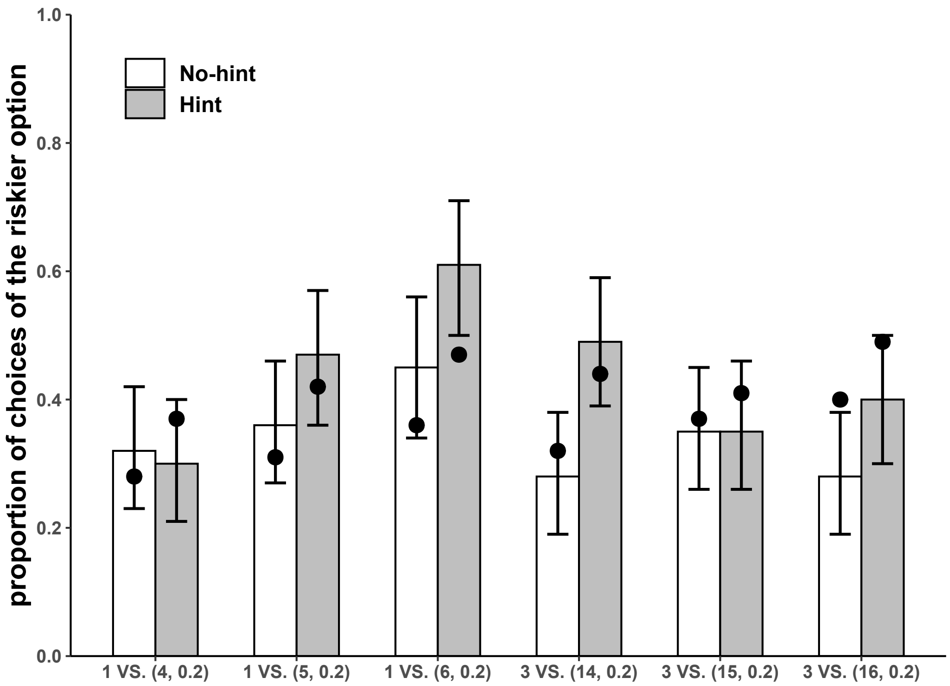

FIGURE 3: Choice proportion of the riskier option from attractive risky-safe decision problems in Experiment 2. Error bars show the 95% credible intervals of the relevant proportions. Filled circles show the posterior predicted choice proportions of the Bayesian logistic regression models reported in the text.

3.3 Discussion

By adopting different hint information regarding risky options, the current study effectively eliminated the impact of hint information on the processing of risky options. This was evident in both choice response and sample size of trials with two risky options. The elimination of such an impact paved a solid foundation for interpreting the difference in choice response in risky-safe trials between the two information conditions. It ended up that, when the rare outcome in a risky-safe decision problem was attractive, explicitly stating that one option had only one outcome altered the processing of such an option, leading to different choice proportions of the safe options between the two information conditions. When the rare outcome in a risky-safe decision problem was unattractive, however, the same hint information did not appear to alter choice responses. Nevertheless, the credible difference in the slope of information condition between unattractive and attractive risky-safe trials still supported the existence of context-dependent outcome expectation and its impact on the evaluation of safe options in experience-based risky choices.

In both reported studies, a certainty effect was also found under not only the hint condition but also the no-hint condition. The latter result appeared to contradict the common finding of a reversed certainty effect in experience-based risky choices (e.g., the results under the blank condition in Study 2 of Erev et al. 2008). However, the very result could be well explained by invoking the notion of regressive probability estimation in risky choice under experience (e.g., Glöckner et al., 2016). According to this notion, subjective probabilities estimated from experience are inclined to regress to the mean (i.e., 50%) due to the decreased evaluability and increased noise in such a task. Such a tendency would more or less equalize the riskier options in a matched pair of risky-safe and risky-risky decision problems, whereas the difference between the safer options (i.e., between the safe option in the risky-safe decision problem and the less risky option in the risky-risky decision problem) would favor the safer option in the risky-safe decision problem. Consequently, the probability of choosing the safer option in the risky-safe decision problem would be relatively higher than that of choosing the safer option in the corresponding risky-risky decision problem, leading to the conventional certainty effect. Note that, although Study 2 of Erev. et al. (2008) showed overall evidence for a reversed certainty effect, only 2 out of the 3 pairs of decision problems in the study produced a difference in choice proportion that was consistent with the overall pattern. In summary, the current result regarding the certainty effect provides further evidence for the regressive probability estimation in risky choice under experience, another critical building block of a systematic account of the description-experience gap in risky choice and its potential reversal.

4 General Discussion

The description-experience gap in risky choice was a well-established phenomenon, although recent studies showed that the gap might be reduced or even reversed when a risky choice involved two risky options (i.e., a risky-risky task) instead of a safe and a risky option (i.e., a risky-safe task; e.g., Glöckner et al., 2016; Wulff, Mergenthaler-Canseco, & Hertwig, 2018). To provide a systematic explanation for both the original gap and its potential reversal, Glöckner et al. (2016) proposed a mechanism based on context-dependent outcome expectation to account for the original gap in which rare outcomes appeared to be relatively underweighted under experience than under description. Despite its critical position in the systematic account of the gap, the mechanism has not been directly investigated. Therefore, the current research attempted to empirically establish the existence of context-dependent outcome expectation in experience-based risky choice as well as its impact on such choice. Specifically, we tested the mechanism using instructions that could purportedly remove context-dependent outcome expectation. Most results regarding the impact of information condition provided supportive evidence for this mechanism in that the no-hint condition tended to produce different choice responses than the hint condition in a way consistent with the impact of context-dependent outcome expectation. Consequently, it appeared that context-dependent outcome expectation under experience did influence the evaluation of safe options and thus played a role in experience-based risky choice. In turn, such expectation might contribute to the description-experience gap in risky choices between safe and risky options.

4.1 Limitations and future research

Despite the overall supportive results for the role of outcome expectation in experience-based risky choice, data from the unattractive risky-safe trials in Experiment 2 seemed to speak against such a role. Specifically, results of both Bayesian logistic regression and proportion test suggested no impact of information condition on choice response. One possible explanation for these results was that outcome expectation regarding a safe option came from not only the risky option in the same decision problem but also risky options in other decision problems in the same experiment, since such options could contribute to a general impression of how options in a study look like. To distinguish between impacts of different risky options on the evaluation of a safe option, we will hereafter refer to the risky option in the same risky-safe trial as the *local* context, whereas the risky options in all other decision problems from the study as the *global* context. Specifically, while evaluating the safe option in a risky-safe decision problem, participants might also project the type of rare outcomes (i.e., whether they were relatively attractive or unattractive compared with the corresponding frequent outcomes) commonly observed in the global context to the safe option. In both reported experiments, about 2/3 of the risky options in the global context for a safe option had attractive rare outcomes due to the specific way we adopted to generate risky-risky trials. Therefore, the global context might make participants conjecture that the safe option also had a not-yet-sampled outcome that was attractive relative to the experienced one. For attractive risky-safe trials (e.g., 1 vs. [4, 0.2]), such an expectation was consistent with the outcome expectation produced by the local context. For unattractive risky-safe trials (e.g., 6 vs. [7, 0.8]), however, the expectation from the global context might counteract that from the local context, potentially leading to a reduced or nullified effect. Note that the global context was not merely an artifact produced by a controlled experiment but also an analogy to all other risky options one encounters in everyday life beyond the risky choice at hand.

Another possibility regarding the impact of the global context was that it produced a general expectation of a zero outcome. This expectation was conceivable considering that zero outcomes frequently occurred in both laboratory studies (as in the current experiments) and in real life. The current data, however, appeared to speak against such an expectation. Specifically, if the global context produced a zero expectation (which was unattractive), it would enhance the expectation from the local context in unattractive risky-safe trials and lead to a difference between the two information conditions. Although sample choice proportions in Experiment 2 did support such a difference, inferential statistics suggested the opposite. For attractive risky-safe trials in Experiment 2, a zero (and thus unattractive) expectation from the global context contradicted that from the local context. Therefore, it was unlikely that information condition would lead to a difference, but the observed data provided strong evidence for such a difference. To reconcile a zero expectation from the global context with the current data, one needs to assume some complicated interaction between the expectations from the local and global contexts. For example, an outcome

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expectation produced by the global (and possibly minor) context might serve as a reference point for that from the local (and possibly major) context. Consequently, a zero expectation from the global context might highlight and thus enhance rather than nullify an attractive expectation from the local context. In any case, future research should study the impacts of both local and global contexts and their interaction for a more systematic understanding of the role of context-dependent outcome expectation in experience-based risky choice and its contribution to the description-experience gap in risky choice.

Recently, Aydogan (2021) showed that a model combining belief updating with probability weighting provided a better account of the data sets analyzed in Glöckner et al. (2016) than the traditional model which assumed no belief updating. According to the belief-updating model, when making a risky choice under experience, people rely on prior beliefs about the distribution of possible outcomes and gradually update such beliefs with their experience in a Bayesian way. Specifically, Carnap's (1952) rule of updating was adopted as a working hypothesis and was shown to produce a better model of risky choices under experience. This rule suggests that the more samples a decision maker takes from a safe option, the more confidence he/she will gain about its status of certainty. Consequently, context-dependent outcome expectation should have less and less impact on the evaluation of a safe option as sample size increases. This means that, when no hint information is provided, a larger sample size of the safe option in an unattractive risky-safe trial implies a lower probability of choosing the risky option. Similarly, a larger sample of the safe option will produce a higher probability of choosing the risky option for an attractive risky-safe trial. Data from the current research, however, did not fully support this hypothesis. Specifically, results of Bayesian logistic regression on choice response (with the difference in experienced average outcome, the baseline risk preference, and the sample size of safe option as predictors) showed that a larger sample size was always associated with a lower choice probability of the risky option in Experiment 2, no matter whether the rare outcome of the risky option was unattractive (95% CI of the slope of sample size = [–0.209, –0.102], $LOOIC_{null}$ = 527.36, $LOOIC_{alt}$ = 487.13) or attractive (95% CI of the slope of sample size = [–0.211, –0.095], $LOOIC_{null}$ = 553.30, $LOOIC_{alt}$ = 522.15). In Experiment 1, a larger sample size was associated with a lower choice probability of the risky option when its rare outcome was unattractive (95% CI of the slope of sample size = [–0.143, –0.051], $LOOIC_{null}$ = 265.03, $LOOIC_{alt}$ = 247.99), but was not associated with choice probability of the risky option when its rare outcome was attractive (95% CI of the slope of sample size = [–0.047, 0.044], $LOOIC_{null}$ = 290.13, $LOOIC_{alt}$ = 293.16). The results regarding unattractive rare outcomes were consistent with the hypothesis based on belief updating, but those regarding attractive rare outcomes were either neutral or opposite to the hypothesized impact. Interestingly, the same patterns of association between the sample size of the safe option and the choice probability of the risky option were found when analyzing the data under the hint condition in the same way. This common association implied a contribution of the difference in the sample size of the safe option to the difference in choice proportion between the two information conditions, which was not fully controlled for in the relevant regression analysis. It seems that the association between the sample size of a safe option and its evaluation in a risky choice under experience is more complicated than what Carnap's updating rule suggests, and other mechanisms beyond outcome expectation might play a role. In summary, larger samples were not necessarily associated with a lower impact of context-dependent outcome expectation on risk choices under experience. Future research could investigate the common determinants of sample size and choice response to shed new light on the relationship between these two variables.

Yet another issue to be considered is how the evaluation of risky options contributes to the gap and the effect of the structure of decision problem on the gap. In the current research we focused on the role of the evaluation of safe options and treated risky options as the context to induce outcome expectation. An influence in the opposite direction might also exist in that experiencing an apparently safe option decreases the perceived probability of the rare outcome of the risky option, leading to underweighting of such an outcome relative to a description-based choice or an experience-based choice between two risky options. Attention might also play a role in the evaluation of risky options, given that attention allocation in a risky-safe trial may differ between description and experience conditions, and attention allocation may differ between risky-safe and risky-risky trials under experience. Future research could also investigate this issue for a better understanding of the gap and relevant factors.

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Appendix: Incentivization procedure for the evaluation trials in Experiments 1 and 2

Participants were told that, if they were lucky to get extra payoff according to their response in a randomly picked evaluation trial, a random number between the two possible outcomes of the evaluated gamble would be drawn by the computer program. If the drawn number was greater than the reported certainty equivalent, then participants would receive the drawn number as the extra payoff. If the drawn number was less than the reported certainty equivalent, the gamble would be played according to its objective outcome distribution and participants would get the resultant random outcome. If the drawn number was equal to the certainty equivalent, participants would either receive the drawn number as the extra payoff or play the gamble with equal probabilities. Participants were also informed that, given this procedure, it was always to their best interest to report their true evaluation of each gamble.

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