Fast & Slow Decisions Under Risk:

Intuition Rather than Deliberation Drives Advantageous Choices

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Abstract

Would you take a gamble with a 10% chance to gain $100 and a 90% chance to lose $10? Even though this gamble has a positive expected value, most people would avoid taking it given the high chance of losing money. Popular "fast-and-slow" dual process theories of risky decision making assume that to take expected value into account and avoid a loss aversion bias, people need to deliberate. In this paper we directly test whether reasoners can also consider expected value benefit intuitively, in the absence of deliberation. To do so, we presented participants with bets and lotteries in which they could choose between a risky expected-value-based choice and a safe loss averse option. We used a two-response paradigm where participants made two choices in every trial: an initial intuitive choice under time-pressure and cognitive load and a final choice without constraints where they could freely deliberate. Results showed that in most trials participants were loss averse, both in the intuitive and deliberate stages. However, when people opted for the expected-value-based choice after deliberating, they had predominantly already arrived at this choice intuitively. Additionally, loss averse participants often showed an intuitive sensitivity to expected value (as reflected in decreased confidence). Overall, these results suggest that deliberation is not the primary route for expected-value-based responding in risky decision making. Risky decisions may be better conceptualized as an interplay between different types of "fast" intuitions rather than between two different types of "fast" and "slow" thinking per se.

***Keywords*:** risky decision making, risk perception, intuition, dual-process theory, two-response paradigm

Introduction

Imagine that you are faced with a gamble that gives you a 10% chance to gain $100 and a 90% chance to lose $10. Would you take it or avoid it? The outcomes and their probabilities imply that if you were to play this gamble ten times you would win once ($100) and lose nine times (−$90). At the end, you would have gained $10. So, based on the expected value, it is in one's best financial interest to take the above gamble. However, when faced with such gambles most people would avoid taking them given the high chance of losing money (Kahneman & Tversky, 1984). In fact, people often make biased decisions when it comes to evaluating risk, as they overestimate the impact of losses compared to the prospect of comparable potential gains (Kahneman & Tversky, 1979). This bias–often referred to as ”loss aversion” (Kahneman & Tversky, 1979)–has been widely studied and applied in a range of real-world contexts (Camerer, 2005).

A popular explanation for the loss aversion bias has been put forward by dual process theories. These theories support that reasoning involves two types of processes; a fast, effortless, intuitive process (“System 1”) and a slower, effortful, deliberate one (“System 2”; e.g., Kahneman, 2003; Kahneman & Frederick, 2002; Slovic et al., 2005). When it comes to evaluating risk, researchers have termed these two ways in which risks are assessed as “risk-as-feelings” and “risk-as-analysis” respectively (Loewenstein et al., 2001; Slovic et al., 2005). Dual process theories of risky choice support that to take the probabilities and outcomes of a gamble into account, people need to engage in effortful, deliberate processing (Slovic et al., 2005). On the contrary, when people process a gamble intuitively they will not be responsive to its probabilities. Instead, they are susceptible to affect and, consequently, loss aversion. Thus, when intuitive processing contradicts a gamble’s probabilities and outcomes, it leads to biased decisions, which need to be overridden with effortful deliberation. However, people often act as cognitive misers and tend to minimize mental effort, so they are not likely to engage in deliberate processing once they have already made a choice intuitively (Evans & Stanovich, 2013; Kahneman, 2011; Sirota et al., 2023). This is why when faced with gambles like the above, the majority of people stick to their intuitively cued loss averse choices. Only the most highly skilled and motivated reasoners will manage to deliberate and override them.

Introspectively, the dual process account of risky decision making does not seem unreasonable. When faced with the above gamble, for example, many may instantly feel they want to avoid any possible loss. Making the choice that will maximize our payoffs may seem to require more time and effort. However, there is little direct empirical evidence showing that reasoners who take expected value maximizing risks manage to do so only after deliberating. Studies that tried to manipulate intuitive and deliberate risk taking point to inconclusive results (e.g., Drichoutis & Nayga, 2022). To clarify, the experimental rationale here is that deliberation is assumed to require time and cognitive resources (Kahneman, 2011; Sirota et al., 2021). When people are deprived of these resources by making choices under time-pressure and/or a cognitive load, one would expect to see an increase in loss aversion (i.e., the alleged intuitive response).

In line with the classic dual-process view, a number of studies that imposed cognitive load on participants while they made choices involving risks observed that people tend to be more loss averse and take fewer risks under load (e.g., Benjamin et al., 2013; Deck & Jahedi, 2015; Gerhardt et al., 2016). Critically, these studies also showed that this increase in loss aversion cannot be attributed to choices becoming more random under load (Deck & Jahedi, 2015; Gerhardt et al., 2016). Conversely, a separate study not involving gambles, showed that cognitive load did not impact economic rationality (Drichoutis & Nayga, 2020). This study employed a budget allocation task where participants had to distribute a fixed budget among various commodities, and found that risk preferences remained stable when participants were under load (Drichoutis & Nayga, 2020). Finally, a recent meta-analysis found no credible association between cognitive abilities and loss aversion (Mechera-Ostrovsky et al., 2022).

Studies using time constraints also present mixed findings. Ben Zur and Breznitz (1981) found that time pressure increases loss aversion for mixed prospects (i.e., gambles involving both gains and losses). Kocher et al. (2013) found that under time pressure, people become more loss averse when dealing with losses, while for mixed prospects loss aversion depends on problem framing. Finally, some studies found that time pressure leads to greater risk-taking for gains (Busemeyer, 1985; Young et al., 2012). Recent studies have also suggested that cognitive load or time pressure do not lead to systematic changes in risk preferences, but rather to changes in choice consistency (e.g., choices might simply become more random; Andersson et al., 2016; Olschewski & Rieskamp, 2021).

In sum, based on the current literature, it is difficult to infer whether cognitive resources are necessary for people to take advantageous risks, or whether such risks can also be taken intuitively. In theory, it is possible that in addition to the deliberate route to profit-maximizing risky choices, there also exists an intuitive route via which the expected value maximizing choice is cued. Put differently, in some cases people's intuitive choices might not be loss averse, but instead they might be based on an intuitive understanding of expected value.

Interestingly, recent evidence from the reasoning field lends some indirect credence to this "expected-value intuitor" account. These studies have shown that in a range of classic "bias" tasks from the heuristics-and-biases literature, such as base-rate neglect, bat-and-ball (e.g., Burič & Konrádová, 2021; Raoelison & De Neys, 2019), conjunction fallacy (Boissin et al., 2022), and belief-bias syllogism problems (Bago & De Neys, 2017; Raoelison et al., 2020), logico-probabilistic principles which were traditionally thought to be processed only after deliberation, can also be processed intuitively (Bago & De Neys, 2017; De Neys, 2023). To demonstrate this, the studies adopted a so-called two-response paradigm (Thompson et al., 2011) in which participants are instructed to provide the first response that comes to mind as quickly as possible, and to then take their time to reflect on the given problem before providing their final response. To be maximally sure that participants do not deliberate during the initial stage, they are forced to give their initial response under time-pressure while performing a concurrent load task which burdens their cognitive resources (Bago & De Neys, 2017). Since deliberation requires time and cognitive resources, by restricting both, possible deliberation is minimized during the initial stage and participants are maximally forced to rely on intuitive processing. Results from these two-response studies showed that when participants manage to give a correct response after deliberation, they have often already arrived at this response in the initial, intuitive stage (Bago & De Neys, 2019; Burič & Konrádová, 2021; Thompson & Johnson, 2014). Hence, sound reasoners are often good at accurate intuiting, and not necessarily at deliberately correcting their erroneous intuitions.

In the present study we introduce a two-response paradigm to directly investigate the nature of expected-value-based choices in risky decision making. In all studies participants played risky choice games (a game with mixed prospects and a game with pure gain prospects). On each trial, they had to first make an initial choice as fast as possible (under time pressure and concurrent cognitive load), and immediately after they could take time to deliberate before making their final choice. They also indicated their confidence in their initial and final choices. Our main question was whether in the cases where people make expected-value-based choices after deliberation, they can also make such choices intuitively in the initial response stage (i.e., when deliberation is prevented).

Our studies differ from previous research as they combine three validated procedures to eliminate deliberation: instructions, time pressure and cognitive load. This is crucial because when participants are only burdened with cognitive load, they might compensate by taking more time to make a choice (Drichoutis & Nayga, 2020). Conversely, relying solely on time pressure may not be adequately challenging, as it may fail to place a significant burden on cognitive resources. In addition, in our studies all time pressure deadlines were pretested, ensuring that they afford just enough time to participants to read the problem and click on their preferred choice. Finally, the two-response paradigm enables us to compare intuitive and deliberate responses within a single trial, thereby allowing us to observe the unique influence of intuition and deliberation on the nature of people's choices.

A second question that we explore in this paper is whether, in the cases where people make loss averse choices, they are sensitive to the fact that these choices violate expected value. Dual process theories generally assume that the reason people provide responses that contradict logico-probabilistic principles is because they do not consider these principles (Evans & Stanovich, 2013). However, the reasoning findings we alluded to above have shown that even biased responders often show intuitive sensitivity to the fact that that their response conflicts with competing logical principles (Bago & De Neys, 2017; Burič & Šrol, 2020; Stupple et al., 2011; Stupple & Ball, 2008). For example, when reasoners give a biased response in the initial response stage of the two-response paradigm, they typically show increased response doubt (as indexed, for example, by lowered response confidence compared to control problems, for a review see De Neys, 2017). So, as a second step in the present study, we examined whether in those cases where participants provide loss averse initial intuitive choices, they show conflict sensitivity (as measured by decreased confidence). To this end, we also included control trials in our games, in which the conflict between the loss averse and the expected value maximizing choice was removed or reduced (e.g., a gamble that gives you a 90% chance to gain $100 and only a 10% chance to lose $10). If people refrained from random guessing, we expected a strong preference for the expected value maximizing choice on these "no conflict" control problems. On the standard "conflict" problems, the conflict between the expected value maximizing and loss averse options is–in theory–more pronounced. Following the reasoning literature (e.g., De Neys, 2017), we expected that if people who make intuitive loss averse choices do not completely disregard expected value considerations, the conflict should decrease their response confidence.

To test the generality of the findings, in each of our studies participants played two different types of classic risky choice games: the betting game (Keysar et al., 2012) and the lottery game (Holt & Laury, 2002). The betting game consisted of two-outcome positive-expected-value bets (in addition to no-conflict control bets) that could result in either a gain or a loss, and participants chose whether they wanted to accept them or not. The lottery game consisted of lottery pairs which could lead to gains of different magnitudes, and participants had to select their preferred lottery (they were also presented with no-conflict lottery pairs, see Method for details).

We present three studies. In Study 1 we introduce the paradigm and in Study 2 and 3 we test the robustness of the findings.

Preregistration and data availability

The design and hypotheses were preregistered on the Open Science Framework (OSF) both for Study 1 (https://osf.io/5gqst) and for Study 3 (https://osf.io/rdj7h). No specific analyses were preregistered. The data and material for all three studies are also available on OSF (https://osf.io/hzjt8/files/osfstorage).

Study 1

Method

Participants

We recruited our participants online on Prolific Academic (www.prolific.ac). Only native English speakers from Canada, Australia, New Zealand, the United States of America, or the United Kingdom were allowed to take part in the study. Participants were paid £2.10 for their participation (£5 hourly rate). One hundred participants (80 female, mean age = 35.8 years, *SD* = 12.8 years) participated in the study. A total of 32% of participants reported high school as their highest completed educational level, while 66% reported having a postsecondary education degree.

Given that this was, to our knowledge, the first study to test risky decision making in a two-response format, we based our sample size on previous two-response studies in the logical and moral reasoning field (Bago & De Neys, 2017, 2019), in which also approximately 100 participants per condition were tested. To contextualize, overall, such a sample size would allow for the detection of small to medium (*d* = .36) differences between initial and final response accuracy with 95% power.

Materials

Betting Game. The betting game was based on Keysar et al.'s (2012) loss aversion task. Participants were presented with a total of 15 bets (5 conflict , 5 no-conflict and 5 filler) that could result in either a gain or a loss. Every bet stated the probability of winning a certain amount of money and the probability of losing a certain amount of money. Participants were asked whether they wanted to take the bet or not. They indicated their choices by clicking on one of two options, labelled as "yes" (take the bet) and "no" (do not take the bet).

Conflict bets. All standard, conflict bets had a positive expected value and a high probability of losing money. Therefore, a conflict was created between avoiding a potential loss (i.e., by not taking the bet) and taking a risk in order to acquire a bigger potential gain (i.e., by taking the bet). An example of a conflict bet is presented below:

If you take this bet you have:
5%** probability to **WIN €110
95%** probability to **LOSE €5
Do you take the bet?
o Yes
o No

Note that in the instructions it was stressed that the goal was to make as much profit as possible (see supplementary material A for the literal instructions). So, according to an objective outcome calculation and in the absence of a loss aversion bias, participants should always take the (positive-expected-value) bet. This is why, in all conflict items, taking the bet was labelled as the Expected Value (EV) maximizing choice, and not taking the bet was labelled as the loss averse choice.

Each conflict item had a different probability pair. This variation made the task engaging and ensured that our loss aversion results were not dependent on specific probabilities. At the same time, we made sure to keep the probabilities relatively similar between items, so as to avoid differential risk preference (i.e., participants being loss averse with the probabilities of one conflict item, but not with the next one). We varied the probability of winning (P_{win}) from 5% to 25%, and the probability of losing (P_{lose}) from 95% to 75%, in 5% intervals. Thus, the following pairs were created: P_{win} = 5% and P_{lose} = 95%; P_{win} = 10% and P_{lose} = 90%; P_{win} = 15% and P_{lose} = 85%; P_{win} = 20% and P_{lose} = 80%; P_{win} = 25% and P_{lose} = 75%. The values were chosen so that the expected value difference (P_{win} * $Value_{win}$ – P_{lose} * $Value_{lose}$) was kept as similar as possible between all conflict bets (see supplementary material B for all items), to make sure that the items were of equal complexity.

No-conflict bets. The control, no-conflict bets had a positive expected value and a low probability of losing money. These were constructed by reversing the P_{win} and P_{lose} of the conflict items, while keeping the values identical. For example, the no-conflict version of the above conflict item would be:

If you take this bet you have:
95% *probability to* ***WIN €110***
5% *probability to* ***LOSE €5***
Do you take the bet?
o Yes
o No

Hence, in the no-conflict items participants always had a very high probability of winning a large amount and only a very small probability of losing a small amount. Consequently, the items should not (or only minimally) cue loss aversion and should not (or only minimally) create conflict with expected value considerations. Consequently, if people refrained from random guessing, we expected a strong preference for the expected value maximizing choice in these items: everyone should take the bet and show high confidence. These control trials served as a baseline for our conflict sensitivity analysis. Critically, if loss averse individuals on conflict trials consider the conflicting expected value option, they should experience some minimal doubt and show decreased response confidence compared to control trials. However, if those individuals do not consider expected value, the conflict trials should be a no-brainer for them (i.e., not involve any processing conflict) and they should remain highly confident in not taking the bet.

Filler bets. The filler bets had a negative expected value. Therefore, the most advantageous choice for participants, both in terms of loss aversion and EV calculation, was to not take the bet. An example of a filler bet is presented below:

If you take this bet you have:
50% *probability to* ***WIN €10***
50% *probability to* ***LOSE €15***
Do you take the bet?
o Yes
o No

These bets allowed us to verify whether participants were using a “take the bet” heuristic. More specifically, some participants may have applied a heuristic strategy where they were always taking the bet during the study. In this case, their responses would align with the EV maximizing choice in every conflict and no-conflict bet, which would distort our findings. In the filler items however, these participants would have a very low accuracy, which allowed us to detect the strategy.

Each filler item had a different probability pair, but we kept the probabilities as comparable as possible between items. We varied the probability of winning (P_{win}) from 50% to 70%, and the probability of losing (P_{lose}) from 50% to 30%, in 5% intervals. Thus, the following pairs were created: P_{win} = 50% and P_{lose} = 50%; P_{win} = 55% and P_{lose} = 45%; P_{win} = 60% and P_{lose} = 40%; P_{win} = 65% and P_{lose} = 35%; P_{win} = 70% and P_{lose} = 30%. The exact values were chosen so that the expected value difference (P_{win} * $\text{Value}_{\text{win}}$ – P_{lose} * $\text{Value}_{\text{lose}}$) was kept as similar as possible between filler bets (see supplementary material B for all items).

Lottery Game. The lottery game was a variation of the Holt-Laury lottery choice task (Holt & Laury, 2002). We presented participants with a total of 15 lottery pairs (5 conflict , 5 no-conflict and 5 filler), and they had to choose one lottery from each pair (lottery A or lottery B). Both lotteries (A & B) consisted of a large probability to gain a large amount of money and a small(er) probability to gain a small(er) amount of money. In each lottery pair, lottery A and lottery B had the same large and small probabilities. Participants indicated their lottery choice by clicking on one of two options, labelled as "A" (for lottery A) and "B" (for lottery B).

It is important to note that the loss aversion tested in the lottery game does not involve, strictly speaking, losses since all the lottery pairs have positive expected values. However, even in the absence of losses, people usually experience a risk aversion bias, in that they tend to prefer outcomes with low uncertainty compared to outcomes with high uncertainty but higher potential gains. For consistency with the betting game, we will refer to this risk aversion bias as loss aversion throughout the paper. Given that the lottery game did not involve losses, it allowed us to test the generalisability of our findings beyond the strict loss domain per se.

Conflict lottery pairs. In the standard conflict lottery pairs, one of the lotteries always had the highest expected value in the set, while the other lottery had a lower expected value but the highest guaranteed minimal gain. Therefore, a conflict was created between choosing a lottery with a potentially big but uncertain gain, and a lottery with a lower but more certain gain. An example of a conflict lottery pair is presented below:

Lottery A	***Lottery B***
70% *probability to* ***win €350***	***70%*** *probability to* ***win €230***
30% *probability to* ***win €10***	***30%*** *probability to* ***win €160***

Which lottery do you choose?

o A

o B

In the above example, Lottery A has a higher expected value, but only guarantees a gain of €10, while Lottery B has a lower expected value, but guarantees a gain of €160. As mentioned, participants were instructed to try to make as much profit as possible. So, according to an objective outcome calculation and in the absence of a loss aversion bias, participants should always choose the lottery with the highest expected value. That is why, choosing the lottery with the highest expected value was labelled as the EV maximizing choice, while choosing the lottery with the highest guaranteed minimal gain was labelled as the loss averse choice.

Each conflict item had a different probability pair, but we kept the probabilities as similar as possible between items (for an explanation see Conflict bets subsection). The probability of getting the large gain (P_{large}) varied from 60% to 80%, and the probability of getting the smaller gain (P_{small}) varied from 40% to 20%, in 5% intervals. Thus, the following pairs were created: P_{large} = 60% and P_{small} = 40%; P_{large} = 65% and P_{small} = 35%; P_{large} = 70% and P_{small} = 30%. P_{large} = 75% and P_{small} = 25%; P_{large} = 80% and P_{small} = 20%. The values were chosen so that the expected value difference [(P_{A_large} * V_{A_large}) + (P_{A_small} * V_{A_small}) – (P_{B_large} * V_{B_large}) + (P_{B_small} * V_{B_small}) was kept as similar as possible between the conflict lottery pairs (see supplementary material B for all items).

No-conflict lottery pairs. In the control, no-conflict lottery pairs, one of the lotteries always had both the highest expected value in the set and the highest guaranteed gain. Therefore, no conflict was created; participants were always expected to prefer one of the two lotteries, both in terms of certainty and potential gain. The no-conflict pairs were constructed by reversing the P_{large} and P_{small} in each lottery, while keeping the values identical. For example, the no-conflict equivalent of the above conflict item would be:

Lottery A	***Lottery B***
70% *probability to* ***win €10***	***70%*** *probability to* ***win €160***
30% *probability to* ***win €350***	***30%*** *probability to* ***win €230***

Which lottery do you choose?
o A
o B

In the above example we would expect participants to choose Lottery B. The no-conflict items also allowed us to verify whether participants were using a "pick the highest value" heuristic. More specifically, some participants may have applied a heuristic strategy where they would always pick the lottery that includes the highest value in the whole set. In this case, their responses would always align with the EV maximizing choice in the conflict and filler (see below) lottery pairs, which would distort our findings. In the no-conflict items however, these participants would have a very low accuracy, which would allow us to detect the strategy.

Filler lottery pairs. The filler lottery pairs were designed so that they did not cue a loss averse response. An example of a filler lottery pair is presented below:

Lottery A	***Lottery B***
90% *probability to* ***win €350***	***90%*** *probability to* ***win €260***
10% *probability to* ***win €310***	***10%*** *probability to* ***win €220***

Which lottery do you choose?
o A
o B

In the above example it is obvious that Lottery A is the most advantageous lottery. Some of the filler items had the same probability pairs, but the values always varied between items so that participants never saw the exact same filler item twice. When creating the items, the aim was to make the correct choice obvious for any adult with a basic understanding of the problems' probability rules. With this in mind, the following probability pairs were created: P_{large} = 100% and P_{small} = 0%; P_{large} = 50% and P_{small} = 50%; P_{large} = 90% and P_{small} = 10%. The filler items allowed us to test for a guessing confound. If people refrained from random guessing, we expected them to constantly choose the lottery with the highest EV.

Load task. In order to make maximally sure that the initial responses in the two-response paradigm were indeed intuitive, we used a load task to burden participants' cognitive resources during the initial stage. The reasoning behind this manipulation is simple. Dual process theories assume that deliberation requires more cognitive resources than intuition (Evans & Stanovich, 2013). By engaging participants' resources with a secondary load task it will be more likely that their responding to the main task will be intuitive. We used the dot memorization task because it has been previously shown to successfully prevent deliberation in logical reasoning and economic decision making tasks (De Neys et al., 2011; De Neys & Schaeken, 2007; De Neys & Verschueren, 2006; Franssens & De Neys, 2009). Before each bet or lottery pair, participants were presented with a 3x3 grid, in which four grid squares were filled with crosses. They were instructed to memorize the location of the crosses. It was also emphasized that participants first had to try to memorize the crosses and then respond to the bet or lottery pair. After participants responded to the bet or lottery, they were shown four different matrices and they had to choose the correct, to-be-memorized pattern. They then received feedback as to whether their choice was correct or not. The load was applied only during the initial response stage and not during the subsequent final response stage in which participants were allowed to deliberate (see Two-response games).

Procedure

One-response (deliberative-only) pretest. To obtain a baseline performance in both games, we ran a traditional one-response version of our study, without load or deadline. This pretest determined the initial response deadlines, which were set at 4.5 s for the betting game and 5.5 s for the lottery game (for details on how they were determined see supplementary material C).

Additionally, this pretest allowed us to assess whether participants experienced time pressure in the conflict trials, during the initial stage of the two-response study. Welch Two Sample t-tests showed that participants responded significantly faster in the initial two-response stage compared to the one-response pretest, both in the betting game, $t(51.94) = 6.52$, $p < .001$, $d = 1.81$, and in the lottery game, $t(51.80) = 8.40$, $p < .001$, $d = 2.33$, thereby confirming that they were under time pressure (see supplementary material C for the mean reaction times).[1]

The pre-test also examined a potential consistency confound for the conflict trials in the main two-response study (for details see supplementary material C). Welch Two Sample t-tests revealed no significant difference in the proportion of EV maximizing responses between the one-response pre-test and the final responses of the two-response study, both for the betting game $t(123.05) = 0.04$, $p = .96$, $d = 0.01$, and the lottery game, $t(96.32) = -0.17$, $p = .87$, $d = -0.03$. Thus, no consistency confound was present in the main two-response study.

Two-response games. The experiment was run online on the Qualtrics (www.qualtrics.com) software server. Participants were instructed at the beginning that the study consisted of two games, a betting game and a lottery game. After the general instructions, participants directly started playing one of the games. First, they were presented with game-specific instructions (see supplementary material A

[1] In this analysis as well as the respective analysis of Study 3 we excluded from the two-response study all trials with incorrect load memorization and/or a missed deadline (see further).

for full instructions). They were also told to imagine that they were playing for real money and that the aim was to make as much profit as possible. Afterwards, they were presented with an example bet or lottery pair, depending on the game they were playing. Participants were told that we were first interested in the initial answer that came to their mind and that they would have additional time afterwards to reflect on the problem and provide a final answer.

After the game instructions, participants started a practice session to familiarize themselves with the experimental procedure. First, they were presented with two practice bet/lottery pair trials in which they simply had to respond before the deadline. Next, they solved two practice dot matrix load problems (without concurrent bet/lottery pair). Finally, at the end of the practice, they had to solve the two earlier practice examples under cognitive load and deadline, just as in the main study. Then, they began the experimental trials.

Each trial started with the presentation of a fixation cross for 2 s followed by the load matrix that stayed on the screen for 2 s. Next, the bet or lottery pair appeared. From this point onward, participants had to enter their answer within the deadline; 1 s before the deadline, the background of the screen turned yellow to warn participants that the time limit was approaching. If they did not provide an answer before the deadline, they were asked to pay attention to provide an answer within the deadline on subsequent trials. If they responded within the deadline, they were asked to rate their confidence in the correctness of their initial response on a scale from 0 (absolutely not confident) to 100 (absolutely confident). After the confidence question, participants were presented with four matrix patterns and were asked to recall the correct, to-be memorized pattern. They were then given feedback on whether their recall was correct or not. Finally, participants saw the full problem again and were asked to provide their final answer. Next, they were asked to report their confidence in the correctness of their final response.

The colour of the answer options was green during the initial response and blue during the final response phase to visually remind participants which question they were answering. Under the question we also presented a reminder sentence: "Please indicate your very first, intuitive answer!" and "Please give your final answer," respectively, which was coloured like the answer options. At the end of the study, participants completed standard demographic questions and were shown a debriefing message.

The presentation order of the games was randomized. At the end of the first game participants were presented with a short transition message which informed them that they had finished the first game and that they could take a short break before continuing to the second game.

Counterbalancing. Participants were presented with a betting game and a lottery game. Each game was composed of five conflict, five no-conflict and five filler items. For the lottery game two sets of items were created (set A and set B) in which the conflict status of each item was counterbalanced. More specifically, all the conflict items of set A appeared in their no-conflict version in set B, and all the no-conflict items in set A appeared in their conflict version in set B. Half of the participants were presented with set A of problems while the other half was presented with set B. All participants were presented with the same filler items. In the betting game only one set of conflict and no-conflict items was created, since it was not possible to create a second set of items with the same values and, simultaneously, keep the EV difference similar. However, the no-conflict items had slightly different values (−/+ €5-€10) from the conflict ones so although all participants saw the same items, none of them saw the same value pair twice. In sum, in both games, the same content was never presented more than once to a participant and everyone was exposed to items with the same probabilities and EV differences. This minimized the possibility that mere item differences influence the results.

Exclusion criteria

The trials in which participants failed the load and/or the deadline were excluded from subsequent analyses, since in these trials we could not ensure that deliberation was minimized during the initial stage.

Betting game. Participants failed to answer before the deadline on 2.3% of trials and failed the load task on 12.1% of trials. Overall, by rejecting the missed deadline and missed load trials we kept 85.5% of all trials. On average, each participant contributed 12.8 trials (out of 15 trials, *SD* = 2.0).

To ensure that participants were not using an "always take the bet" heuristic in the betting game (see Filler bets subsection above), following our pre-registration, we ran a control analysis where we excluded participants who had an accuracy lower than 50% both in their initial and final filler trials (*n* = 12). In this control analysis all of our conclusions remained the same, suggesting that the heuristic did not bias our results. Therefore, in the results section below, we present the intended complete analysis without exclusions. The partial results excluding these participants are reported in supplementary material D.

Lottery game. Participants failed to answer before the deadline on 1.9% of trials and failed the load task on 15.2% of trials. Overall, by rejecting the missed deadline and missed load trials we kept 82.9% of all trials. On average, each participant contributed 12.4 trials (out of 15 trials, *SD* = 2.2).

To ensure that participants were not using a "pick the highest value" heuristic in the lottery game (see No-conflict bets subsection), following our pre-registration, we ran a control analysis where we excluded participants that had an accuracy lower than 50% both in their initial and final no-conflict trials (*n* = 4). In this control analysis all of our conclusions remained the same, suggesting that the heuristic did not bias our results. Therefore, in the results section below, we present the intended complete analysis without exclusions. The partial results excluding these participants are reported in supplementary material D.

Results and Discussion

Proportion of EV maximizing choices

Our main question in this study was whether people who manage to make an EV maximizing choice after deliberating on a risky problem can also make this choice intuitively. So, we calculated, for each participant, the average proportion of EV maximizing initial and final responses for the conflict items. Figure 1 provides a summary of the percentage of EV maximizing choices for the critical conflict trials, both for the initial, intuitive and the final, deliberate responses, separately for both games. Note that for the statistical tests that are mentioned below loss averse trials were recoded as 0 and EV maximizing trials as 1.

Betting game. As Figure 1 shows, in the critical conflict trials of the betting game, the majority of responses were loss averse, but people still managed to provide EV maximizing responses. The proportion of EV maximizing responses reached 20.5% (*SD* = 30.9%) in the initial stage and 13.8% (*SD*

= 27.9%) in the final stage. Interestingly, this percentage was higher in the initial, intuitive compared to the final stage where people were allowed to deliberate, and a paired-samples t-test showed that this difference was significant, $t(99) = 2.92$, $p = .004$, $d = 0.29$.[2] One possible explanation for this pattern could be that the loss aversion heuristic required some minimal deliberation to be activated (see Bago & De Neys, 2017). Critically, these results indicate that although the loss aversion bias is very prevalent people still manage to intuitively generate EV maximizing responses.

In the control, no-conflict trials, it was in participants' best interest to take the bet, both in terms of avoiding losses and acquiring gains. So, as expected, the proportion of trials in which participants took the bet reached 96.6% (*SD* = 9.4%) in the initial stage and 98.4% (*SD* = 7.6%) in the final stage. Given that the initial stage of the games was challenging–participants had to respond under a deadline and a cognitive load–one might argue that the intuitive responses in our study resulted from mere guessing. However, if the cognitive constraints had forced people to randomly click on one of the answer options, we would have found a much lower accuracy on the no-conflict problems. So, the ceiled initial performance argues against an overall guessing confound.

Finally, as expected, the filler items had a high accuracy both in the initial (*M* = 78.6%, *SD* = 33.8%) and final (*M* = 84.0%, *SD* = 30.2%) stage. This shows that, overall, participants did not rely on a "take the bet" heuristic when responding to the bets, which would have resulted in a floored performance on the filler trials (see also our control exclusion analysis in supplementary material D).

Lottery game. As Figure 1 shows, in the critical conflict trials of the lottery game, the majority of responses were loss averse[3], but participants still managed to provide EV maximizing responses. The proportion of EV maximizing responses reached 40.8% (*SD* = 37.0%) in the initial stage and 29.8% (*SD* = 32.9%) in the final stage. As in the betting game, this percentage was higher in the initial, intuitive stage compared to the final, deliberate stage, and a paired-samples t-test showed that this difference was significant, $t(99) = 4.14$, $p < .001$, $d = 0.42$.

In the control, no-conflict trials participants were expected to always prefer one of the two lotteries, both in terms of certainty and potential gain. So, as expected, the proportion of trials in which participants chose the expected "correct" lottery pair reached 83.8% (*SD* = 23.6%) in the initial stage and 88.0% (*SD* = 23.8%) in the final stage. This shows that, overall, participants did not rely on a "pick the highest value" heuristic when responding to the lottery pairs, which would have resulted in a floored performance on the no-conflict trials (see also our control exclusion analysis in supplementary material D).

In the filler items the correct answer was made obvious for any adult with a basic understanding of the problems' probability rules. So, as expected, the proportion of trials in which participants gave the correct response was high both in the initial (*M* = 79.8%, *SD* = 25.0%) and the final (*M* = 90.3%, *SD* = 19.5%) response stage. If the cognitive constraints of the initial stage had forced people to provide random responses in the lottery game, we would have found a much lower accuracy at the filler problems. Thus, the good filler accuracy argues against an overall guessing confound.

[2] As one reviewer suggested we also conducted ANOVAs both for the betting game and the lottery game of Studies 1 and 2, which point to similar conclusions (see supplementary material E for the results).

[3] We use the loss averse label for consistency here. As noted in the Method, the lottery game does not imply losses per se, but rather measures risk aversiveness.

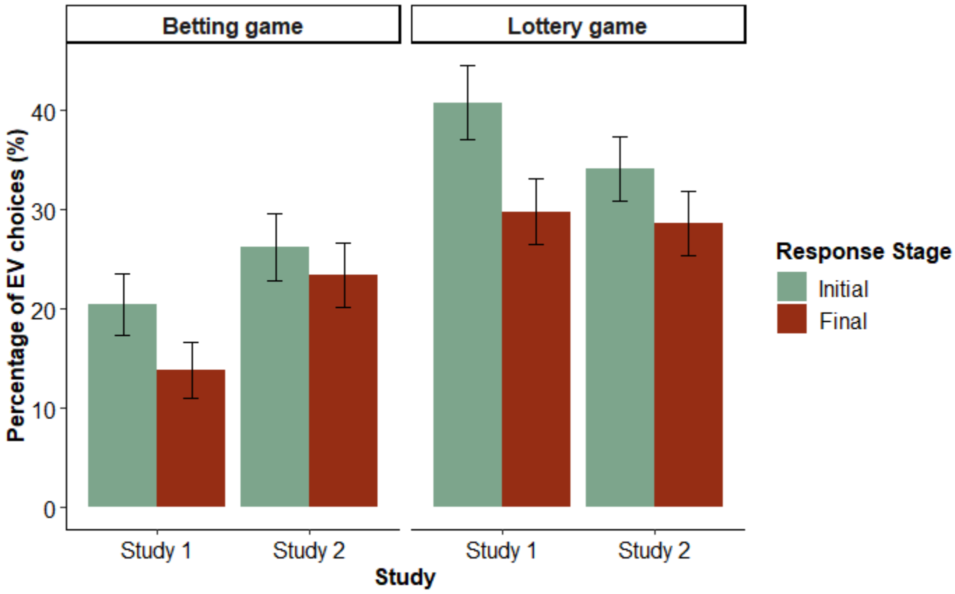

Figure 1. Percentage of Expected Value (EV) maximizing initial and final choices on conflict trials in the betting and lottery game, in Study 1 and Study 2. Error bars are standard errors of the mean.

Direction of change

To better understand how people changed (or did not change) their responses after deliberation we performed a direction of change analysis where we looked into how the accuracy changed from the initial to the final response stage (Bago & De Neys, 2017). In the conflict trials of both games participants could choose between two options: an EV maximizing choice and a loss averse choice. For simplicity, we coded the loss averse choice as "0", and the EV maximizing choice as "1". Consequently, four possible response patterns were possible on every trial: initial loss averse response and final loss averse response ("00"), initial loss averse response and final EV maximizing response ("01"), initial EV maximizing response and final loss averse response ("10"), and initial and final EV maximizing response ("11"). Figure 2 shows the mean proportions of each direction of change category in the conflict trials, separately for each game.

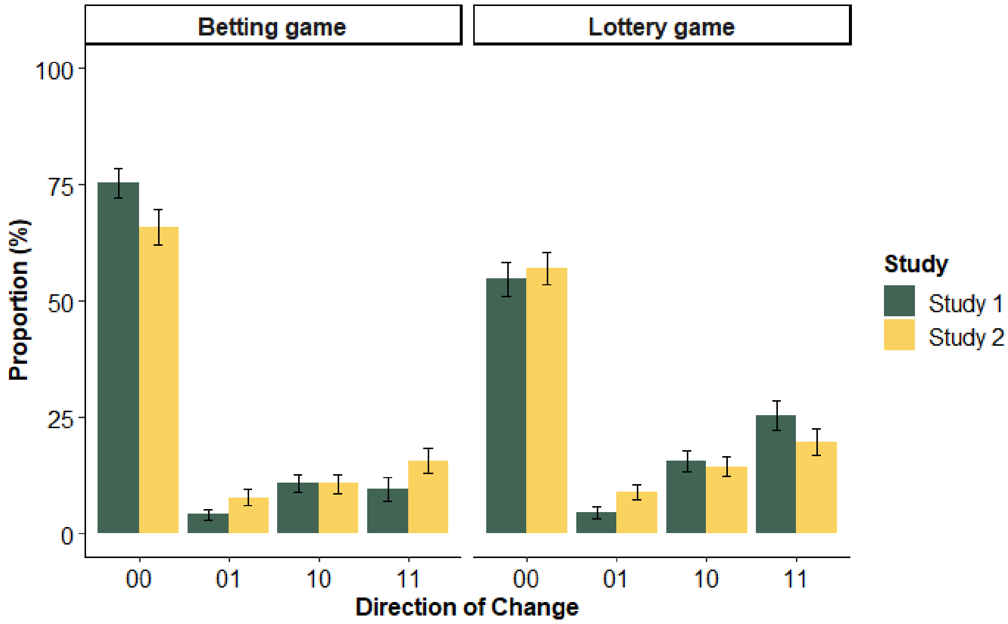

Figure 2. Proportion of each direction of change category in the conflict trials, separately for the betting game and the lottery game and for Study 1 and Study 2; "00" = initial and final loss averse response; "01" = initial loss averse response and final Expected Value (EV) maximizing response; "10" = initial EV maximizing response and final loss averse response; "11" = initial and final EV maximizing response. Error bars are standard errors of the mean.

The majority of conflict trials had a "00" pattern (75.4% in betting game; 54.7% in lottery game) which demonstrates that when taking risky decisions most participants remained loss averse even after they were given time to deliberate. Critically, "11" responses (9.7% in betting game; 25.3% in lottery game) were more frequent than "01" responses (4.1% in betting game; 4.5% in lottery game). This shows that in the cases where participants managed to generate an EV maximizing response after deliberation (i.e.,"01" and "11" cases), most of the time they had already arrived at this choice intuitively (i.e., "11" cases). In other words, deliberate correction exists, but it is relatively rare and not always necessary for EV-based responding. This is further highlighted by the percentage of "10" responses (10.8% in betting game; 15.5% in lottery game). These are the cases in which people intuitively provided EV maximizing answers and only after deliberating they changed them to loss averse ones. As in Bago and De Neys (2017) we also calculated the so-called non-correction rate (i.e., proportion 11/11+01). The non-correction rate indicates the proportion of final EV-maximizing choices which were already EV-maximizing in the initial response stage. In other words, it shows the proportion of trials for which participants did not need to deliberate to make an EV-maximizing choice. The mean non-correction rate for the conflict items reached 70.3% in the betting game and 84.9% in the lottery game. So, when participants managed to make an EV-maximizing choice at the final stage of the conflict items, they had typically already made that choice at the initial stage most of the time.

Throughout this paper, we excluded trials in which participants failed to respond before the deadline or failed to correctly recall the load. In theory, this exclusion could have artificially inflated the rate of EV-maximizing responses and, consequently, the critical non-correction rate. However, even after accounting for these excluded trials, the proportion of "11" responses and the non-correction rate remained high in all three studies (see supplementary material F for the full results).

Stability index

We also calculated a stability index on the standard, conflict trials. More specifically, for each participant we calculated on how many out of the five conflict trials they showed the same dominant direction of change pattern (i.e., "00", "01", "10", or "11").

To calculate the stability index we first counted the occurrences of each direction of change type ("00", "10", "01", "11") for every subject (e.g., Subject 1 had three occurrences of "00" and two of "10"). Next, we determined the relative frequency that each direction of change type represented for each subject (e.g., Subject 1 had 60% "00" and 40% "10"). Then, we identified the dominant frequency for each subject (e.g., Subject 1's dominant frequency would be 60%). Finally, we computed the stability index by averaging these dominant frequencies across all participants.

The average stability index for the betting game of Study 1 was 85.6% (SD = 19.0%), which was higher than 40% chance[4], $t(99) = 24.00$, $p < .001$, $d = 2.40$. For the lottery game, it was 75.4% (SD = 21.0%), which was also higher than 40% chance, $t(99) = 16.90$, $p < .001$, $d = 1.69$.[5]

Note that for completeness, we also tested against 50% chance and results were identical, $t(99) = 18.74$, $p < .001$, $d = 1.87$ for the betting game and $t(99) = 12.12$, $p < .001$, $d = 1.21$ for the lottery game. Similar results were observed in Studies 2 and 3.

Confidence ratings

Following our preregistration and previous two-response studies on logical reasoning, we examined whether people who intuitively provide loss averse responses to conflict trials show some sensitivity to the fact that their answer goes against the items' EV. This would indicate that loss averse responders do not disregard EV altogether; instead they might be sensitive to EV principles, but they cannot overcome their loss aversion bias when making a choice. Note that in the no-conflict items loss aversion and EV calculations point to the same response. So, to see whether people are sensitive to the EV of the conflict problems, we can contrast their confidence at the correctly solved no-conflict items (i.e., their baseline confidence) with their confidence at the conflict items where they gave loss averse responses.

If loss averse people completely ignore the EV, they should process these conflict and no-conflict trials the same way. If, however, they detect that their loss averse responses are opposing the item's EV, they should show increased doubt in conflict trials. In other words, an increased doubt (or inversely a lowered confidence) in the conflict trials would be an indication that–despite their loss averse answer–people show some minimal sensitivity to EV.

[4] Participants have a 50% chance of providing an EV-maximizing response ("1") or a loss averse response ("0") in both the initial and final stage of conflict trials. Thus, in theory, each direction of change pattern ("00", "10", "01", "11") has a 25% probability of occurring in each trial. Given that there are five conflict trials, if someone were guessing they could guess one of the four patterns in each of the first four trials, but the fifth trial would necessarily repeat one of the previous patterns. Therefore 2 out of 5 trials, or 40%, represents the lowest possible stability index under random guessing.

[5] In all our studies, we used a one-sample, one-sided t-test for the stability analysis.

Figure 3 shows the general mean initial confidence ratings for conflict and no-conflict trials as a function of response type (EV maximizing; Loss averse; Other).[6] In the betting game, a Wilcoxon signed-rank test (n = 92)[7] revealed significantly lower confidence ratings in conflict loss averse responses (M = 72.4%, Mdn = 80.0%), compared to no-conflict correct responses (M = 78.5%, Mdn = 82.3%), W = 1080, Z = −3.14, p = .002. Similar results were observed in the lottery game (n = 83), with confidence in conflict loss averse responses (M = 67.8%, Mdn = 70%) being lower than in no-conflict correct responses (M = 70.3%, Mdn = 72.5%), W = 835, Z = −2.06, p =.04. Thus, participants showed increased response doubt when making a loss averse choice on conflict trials, which suggests they were detecting to some extent that their answer conflicted with EV maximizing considerations. In other words, they considered the EV maximizing option, even though they eventually decided on the loss averse choice. Importantly, this doubt concerned people's initial responses for which deliberation was minimized[8]—suggesting that the conflict sensitivity was intuitive in nature. However, given that observed trends were small (e.g., 2.5%-6.1% mean difference) this result remains to be interpreted with caution.

For completeness, we also observed a mean confidence decrease in the cases where people provided EV maximizing responses in the conflict items (see Figure 3 for the general means). In the betting game, a Wilcoxon signed-rank test (n = 43) showed significantly lower confidence ratings in conflict loss averse responses (M = 44.2%, Mdn = 41.0%), compared to no-conflict correct responses (M = 78.9%, Mdn = 82.0%), W = 4.0, Z = −5.31, p < .001. Similarly, in the lottery game (n = 64), confidence in conflict loss averse responses (M = 60.5%, Mdn = 61.3%) was lower than in no-conflict correct responses (M = 67.1%, Mdn = 70.0%), W = 407.0, Z = −2.56, p = .01. Hence, when choosing the EV maximising option, people also considered the alternative (loss averse) option, and detected that their answer was conflicting with the high chance of losing money.

For exploratory purposes we also looked into the mean confidence levels for each of the direction of change categories separately in supplementary material G. As in the logical reasoning field (e.g., Thompson et al., 2011), our results showed that initial confidence is lower on trials in which the initial response is changed after deliberation (i.e., "01" and "10" vs. "11" and "00" categories).

[6] In the no-conflict trials of the betting game participants could either choose to take the bet, which in Figure 3 is the "EV maximizing" choice, or to not take the bet, which is "Other" since it was neither loss averse nor EV maximizing. In the no-conflict items of the lottery game both expected value considerations and loss aversion led to the same choice. For consistency with the betting game, in Figure 3 this choice is named "EV maximizing". Note, however, that it could also be driven by loss aversion. When participants did not choose this option their choice was named "Other" since it was neither loss averse nor EV maximizing.

[7] Participants without matched pairs were excluded from this analysis. The sample size (n) reported here reflects the number of participants included in the Wilcoxon signed-rank test.

[8] As a reminder, note that the initial confidence rating was also given under load.

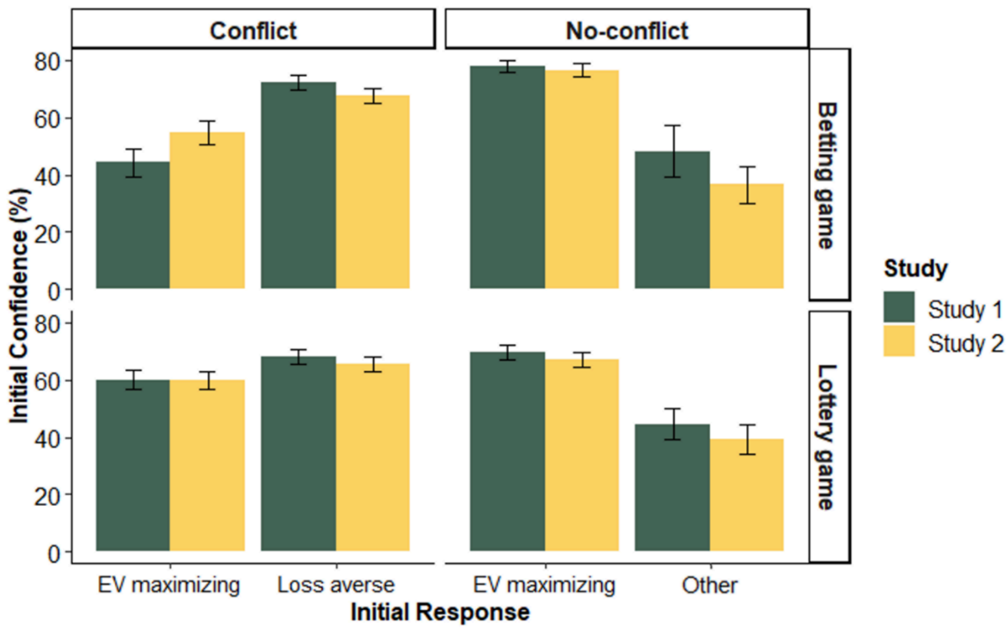

Figure 3. Initial response confidence ratings as a function of response type (Expected Value maximizing; Loss averse; Other) and conflict status (conflict; no-conflict) separately for the two games and for Study 1 and Study 2. Error bars are standard errors of the mean.

Study 2

The results of our first study demonstrate that people who manage to make an EV maximizing choice when deliberating on a risky decision, have typically already made this choice intuitively. Deliberate correction is, thus, not the prevalent route for EV-based responding. In addition, Study 1 also revealed that even when people make loss averse choices, they have an intuitive sensitivity to the fact that their decisions conflict with EV considerations (just like EV responders showed sensitivity to the presence of a conflicting loss averse option). This further indicates that taking EV considerations into account does not necessarily require deliberation.

In Study 2, we introduced methodological refinements to test the robustness of our findings. First, Study 1's sample consisted of 80% female participants, and previous studies have shown that loss aversion is susceptible to gender differences (see Croson & Gneezy, 2009 for a review; but see also Filippin & Crosetto, 2016). So, in Study 2 we recruited a gender-balanced sample. Second, participants in Study 1 played the games for hypothetical pay-offs, but in Study 2 we incentivized our participants (see Hertwig & Ortmann, 2001 for a discussion on the importance of monetary incentives).

It should be noted that Study 2 was designed as the present Study 3 (which includes 5 "easy" conflict items on top of the items of Study 1, see further). However, due to a coding error, in Study 2 participants were presented with the items of Study 1 but saw each conflict item twice. To ensure that our results were not influenced by repeated exposure effects, in Study 2 we only kept the item from each conflict pair that was presented first. This way, the present study served as a refined robustness test of Study 1.

The results of this study were completely in line with those of Study 1 (see Figure 1-3 for descriptive key results). For the sake of brevity, all the methods and analyses are moved to supplementary material H.

Study 3

Results from Study 1 and Study 2 showed that in most cases that people arrive at an EV maximizing response after deliberation, they have already generated this response intuitively. So, although deliberate correction exists in risky decision making, it is not the primary route for EV-based responding. However, one cannot ignore that, across our two studies, the majority of responses were loss averse, even in the final, deliberate stage (*M* = 81.4% in the betting game; *M* = 72.6% in the lottery game). This implies that participants found it particularly difficult to opt for the expected value option in these items. In turn, this raises the concern that perhaps only the participants with very high cognitive capacities were able to provide EV maximizing responses. This could explain why, in our studies, EV maximizing responses are mostly generated intuitively (i.e., because highly gifted reasoners are particularly good at logical intuitive responding, e.g., Raoelison et al., 2020; Thompson et al., 2018). Hence, our results may only be representative for harder EV items. With easier items (where a wider range of participants arrives at the EV maximizing choice), the EV calculation might still require deliberation—as predicted by the standard dual process model. To test this, and to ensure that our findings are generalizable to different item types, in Study 3 we included "easy" conflict items (i.e., items that have a higher expected value difference than those of Studies 1 and 2). These "easy" items should show a higher selection of EV choices and allow us to test whether deliberate correction is more common than among the "hard" conflict items from Study 1 and 2. Similarly to Study 2, Study 3 was also incentivized and had a gender balanced sample.

Method

Participants

The recruitment platform and criteria were the same as in Study 1. Participants were paid £2.50 for their participation (£6 hourly rate). They also received a possible monetary bonus payment of up to £1, depending on the game's outcome. One hundred participants (49 female, mean age = 38.5 years, SD = 12.2 years) participated in the study. A total of 29% of participants reported high school as the highest completed educational level, while 71% reported having a postsecondary education degree.

Materials

Betting Game. The hard-conflict, no-conflict and filler bets were the same as in Study 2. All easy-conflict bets had the same probability of losing money as their respective hard-conflict bets, but a larger expected value. Therefore, the conflict between avoiding a potential loss (i.e., by not taking the bet) and taking a risk in order to acquire a(n) (even bigger) potential gain (i.e., by taking the bet) was reduced. Below we present an example of an original hard-conflict bet (left) and its equivalent easy-conflict bet (right):

Hard-conflict bet:	Easy-conflict bet:
If you take this bet you have:	*If you take this bet you have:*
5%** probability to **WIN €110	***5%** probability to **WIN €290***
95%** probability to **LOSE €5	***95%** probability to **LOSE €1***
Do you take the bet?	*Do you take the bet?*
o Yes	*o Yes*
o No	*o No*

The easy-conflict items were constructed based on the hard-conflict items by keeping all probabilities the same and decreasing the losing value (V_{lose}) by €4-€5 while increasing the winning value (V_{win}) by €120-€180. In all cases, an easy-conflict bet had more than double the winning value (V_{win}) of their equivalent hard-conflict bet. The exact values of the easy-conflict items were chosen so that the expected value difference (P_{win} * V_{win} – P_{lose} * V_{lose}) was kept as similar as possible between them (see supplementary material B for all items), to make sure that the items were of equal complexity.

Lottery Game. The hard-conflict , no-conflict and filler lottery pairs were the same as in Study 2. All easy-conflict lottery pairs had the same probabilities (P_{A_large}, P_{A_small}, P_{Blarge}, P_{B_small}) and the same smaller values (V_{A_small} & V_{B_small}) as their respective hard-conflict lottery pairs. However, they had a higher V_{large} in the most profitable but uncertain lottery and a lower V_{large} in the lottery with the highest guaranteed minimal gain and lower overall profit. Therefore, less conflict was created (when compared to the hard-conflict items). Below is an example of an original hard-conflict lottery pair (left) and its equivalent easy-conflict pair (right):

Hard-conflict lottery pair:		Easy-conflict lottery pair:	
Lottery A	***Lottery B***	***Lottery A***	***Lottery B***
70%** probability to **win €350	***70%** probability to **win €230***	***70%** probability to **win €440***	***70%** probability to **win €180***
30%** probability to **win €10	***30%** probability to **win €160***	***30%** probability to **win €10***	***30%** probability to **win €160***
Which lottery do you choose?		*Which lottery do you choose?*	
o A		*o A*	
o B		*o B*	

The easy-conflict lottery pairs were constructed on the basis of the hard-conflict items, by keeping all "smaller" values (V_{A_small} & V_{B_small}) the same and decreasing the "large" value (V_{B_large}) of the certain but less profitable lottery pair by €20-€50, while increasing the "large" value (V_{B_large}) of the uncertain but more profitable lottery pair by €90-€150. The values were chosen so that the expected value difference [(P_{A_large} * V_{A_large}) + (P_{A_small} * V_{A_small}) – (P_{B_large} * V_{B_large}) + (P_{B_small} * V_{B_small})] was kept as similar as possible between all easy-conflict lottery pairs (see supplementary material B for all items).

Procedure

One-response (deliberative-only) pretest. Since participants were presented with 5 extra items in this study, we decided to recalibrate the deadline. As before, we ran a traditional one-response version of our study (without load or deadline) to obtain a baseline performance. This pretest determined the initial response deadlines, which were set at 4 s for the betting game and 4.5 s for the lottery game (for details see supplementary material C).

Welch Two Sample t-tests showed that participants responded significantly faster in the initial two-response stage compared to the one-response pretest, both in the betting game, $t(86.68) = 9.42$, $p < .001$, $d = 2.02$, and the lottery game, $t(103.11) = 10.73$, $p < .001$, $d = 2.11$, confirming that they were under time pressure.

Regarding the consistency confound (for details see supplementary material C), Welch Two Sample t-tests revealed no significant difference in the proportion of EV maximizing responses between the one-response pre-test and the final responses of the two-response study in the lottery game, $t(223.03) = 0.39$, $p = .70$, $d = 0.05$. In the betting game the difference was significant, $t(220.67) = -2.00$, $p = .05$, $d = -0.27$, but with the final trials of the two-response study having a higher accuracy than those of the one-response pretest. These results directly show that a consistency confound cannot account for the lack of deliberate EV correction.

Two-response games. The experiment was run online on the Qualtrics (www.qualtrics.com) software server. Apart from the differences in the items, the instructions and the procedure were the same as those in Study 2.

Counterbalancing. Each game (betting and lottery) was composed of five easy-conflict, five hard-conflict, five no-conflict and five filler items. For each game separately, two sets of items (set A and set B) were created in which the conflict status of the no-conflict and the hard-conflict items was counterbalanced. More specifically, all the hard-conflict items of set A appeared in their no-conflict version in set B, and all the no-conflict items in set A appeared in their hard-conflict version in set B. We also created two variations of the easy-conflict and filler items for set A and set B respectively. The items of set B were created by increasing the items' values by €5 to €10. The exact values were determined so that the EV difference remained the same for the respective items of both sets. Half of the participants were presented with set A while the other half were presented with set B. So, in both games, the same content was never presented more than once to a participant and everyone was exposed to the same items, which minimized the possibility that mere item differences influence the results.

Exclusion Criteria

As before, the trials in which participants failed the load and/or the deadline were excluded from subsequent analyses.

Betting game. Participants failed to answer before the deadline on 3.8% trials and they failed the load task on 9.8% of trials. Overall, by rejecting the missed deadline and missed load trials we kept 86.4% of all trials. On average, each participant contributed 17.3 trials (out of 20 trials, $SD = 2.2$).

We also ran a control analysis where we excluded participants that had an accuracy lower than 50% both in their initial and final filler trials ($n = 10$). In this control analysis all of our conclusions remained the same (see supplementary material D). Therefore, in the results section below, we present the intended complete analysis without exclusions.

Lottery game. Participants failed to answer before the deadline on 2.9% of trials and failed the load task on 12.6% of trials. Overall, by rejecting the missed deadline and missed load trials we kept 84.6% of trials. On average, each participant contributed 16.9 trials (out of 20 trials, $SD = 2.5$).

We also ran a control analysis where we excluded participants that had an accuracy lower than 50% both in their initial and final no-conflict trials ($n = 2$). In this control analysis all of our conclusions remained the same (see supplementary material D). Below we present the intended complete analysis without exclusions.

Results and Discussion

Proportion of EV maximizing choices

Betting game. As Figure 4 shows, for the hard-conflict items, the proportion of EV maximizing responses reached 30.6% (*SD* = 33.3%) in the initial stage and 27.1% (*SD* = 34.7%) in the final stage, while for the easy-conflict items, it reached 45.1% (*SD* = 34.0%) in the initial stage and 53.3% (*SD* = 36.4%) in the final stage. Overall, these results show that for the hard-conflict items people manage to provide EV maximizing responses intuitively around 30% of the time, while for the easy-conflict items they manage to do so around 45% of the time. Thus, as expected, the proportion of EV maximizing responses was higher in the easy items, which implies that our manipulation of the items' difficulty was successful and that participants were indeed more likely to take bets with higher EV. A repeated-measures ANOVA was conducted to test the effect of response stage (initial; final) and difficulty (easy; hard) on the proportion of EV maximizing responses. There was not a main effect of response stage, $F(1, 99) = 1.46$, $p = .231$, $\eta^2 g = .001$, but there was a main effect of difficulty, $F(1, 99) = 75.37$, $p < .001$, η^2g = .081, and an interaction effect, $F(1, 99) = 12.63$, $p = .001$, $\eta^2 g = .007$. Pairwise comparisons with Bonferroni correction revealed that final responses to easy-conflict problems had a higher proportion of EV-maximizing responses compared to both initial ($p < .001$) and final ($p < .001$) responses to hard conflict problems. Furthermore, initial responses to easy conflict problems had a significantly higher proportion of EV responses compared to final responses to hard-conflict problems ($p = .002$). All other comparisons yielded non-significant results.

In the control, no-conflict items, participants' accuracy remained at ceiling. For these items, the proportion of trials where participants took the bet reached 92.3% (*SD* = 16.0%) in the initial stage and 92.9% (*SD* = 16.8%) in the final stage. Finally, the filler items had a high accuracy both in the initial (*M* = 77.0%, *SD* = 31.7%) and the final (*M* = 83.7%, *SD* = 28.6%) stage.

Lottery game. For the hard-conflict items, the proportion of EV maximizing responses reached 40.7% (*SD* = 36.2%) in the initial response stage and 31.8% (*SD* = 35.7%) in the final stage, while for the easy-conflict items, it reached 53.6% (*SD* = 33.9%) in the initial stage and 51.3% (*SD* = 37.8%) in the final stage. Overall, for the hard-conflict items people managed to provide EV maximizing responses intuitively around 40% of the time, and for the easy-conflict items around 54% of the time. A repeated-measures ANOVA was conducted to test the effect of response stage (initial; final) and difficulty (easy; hard) on the proportion of EV maximizing responses. There was a main effect of response stage, $F(1, 99) = 5.45$, $p = .022$, $\eta^2 g = .006$, a main effect of difficulty level, $F(1, 99) = 37.233$, $p < .001$, $\eta^2 g = .049$, but there was no interaction effect, $F(1, 99) = 3.66$, $p = .06$, $\eta^2 g = .002$.

In the control, no-conflict problems the proportion of trials in which participants chose the expected, "correct" lottery pair reached 88.4% (*SD* = 19.2%) in the initial stage and 93.7% (*SD* = 14.8%) in the final stage. Finally, as expected, in the filler items the proportion of trials in which participants gave the correct response was high both in the initial (*M* = 79.8%, *SD* = 23.3%) and the final response stage (*M* = 92.7%, *SD* = 18.67%).

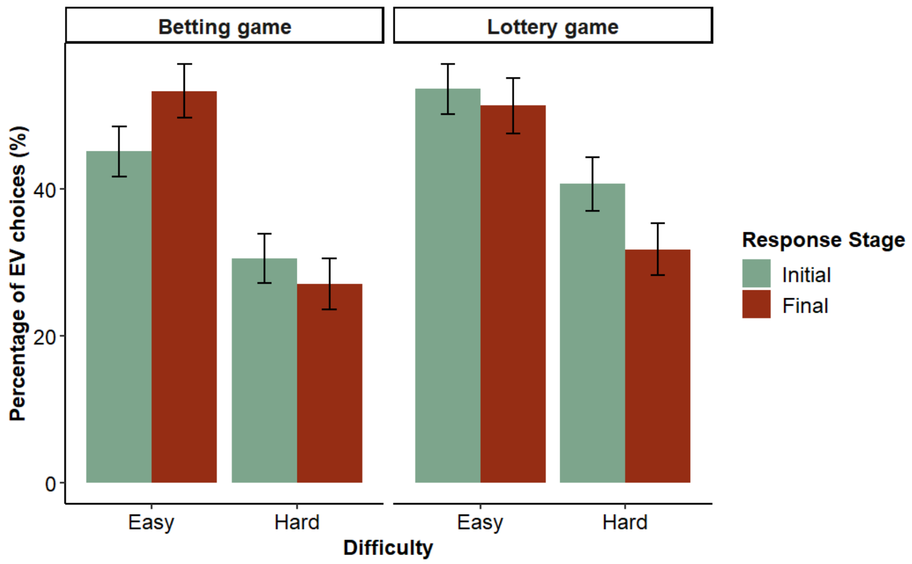

Figure 4. Percentage of Expected Value (EV) maximizing initial and final choices on the conflict trials of Study 3, separately for the betting and lottery game and for easy and hard conflict items. Error bars are standard errors of the mean.

Direction of change

As it can be seen in Figure 5, for the hard-conflict items, the majority of conflict trials had a "00" pattern (64.0% in betting game; 52.4% in lottery game) which indicates that, even after deliberating, most people remained loss averse. Critically, the "11" responses (21.6% in betting game; 24.8% in lottery game) were more frequent than the "01" responses (5.4% in betting game; 7.0% in lottery game), and the non-correction rate reached 80.0% in the betting game and 78.0% in the lottery game.

For the easy-conflict items, most conflict trials had either a "00" pattern (39.9% in betting game; 34.8% in lottery game) or a "11" pattern (38.3% in betting game; 39.7% in lottery game). There were fewer cases of "01" (15.0% in betting game; 11.6% in lottery game) patterns. Hence, although people were less loss averse when responding to the easy-conflict (compared to the hard-conflict) items, intuitive and deliberate loss averse responses were still prevalent. Critically, the "11" responses were again more frequent than the "01" responses, and the non-correction rate reached 71.9% in the betting game and 77.4% in the lottery game. So, even with the easier items, people predominantly made EV choices without deliberating.

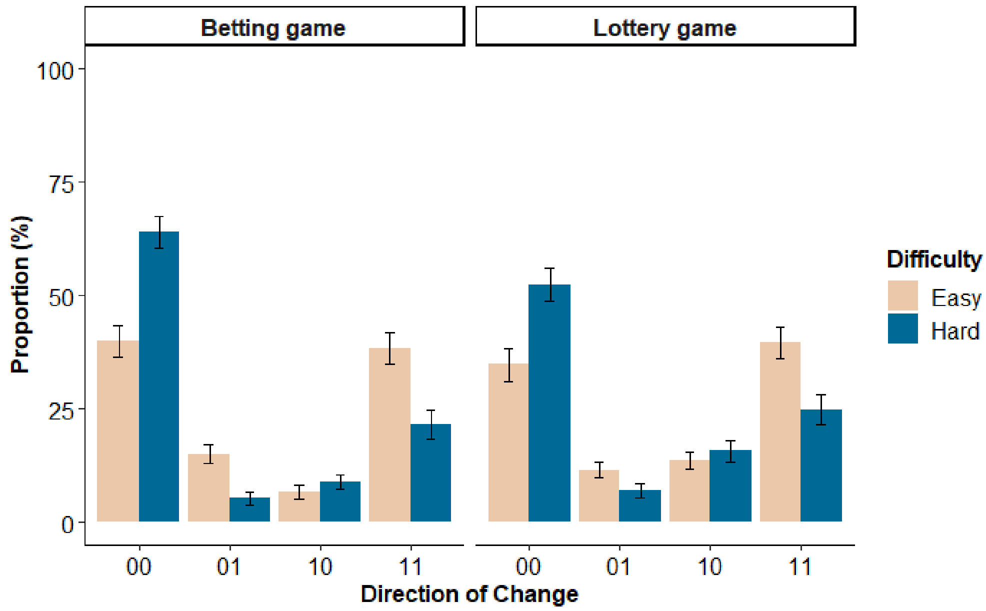

Figure 5. Proportion of each direction of change category in the conflict trials of Study 3, separately for the betting game and the lottery game and for easy-conflict and hard-conflict items; "00" = initial and final loss averse response; "01" = initial loss averse response and final Expected Value (EV) maximizing response; "10" = initial EV maximizing response and final loss averse response; "11" = initial and final EV maximizing response. Error bars are standard errors of the mean.

Stability index

Regarding the hard-conflict items, the average stability index was 80.0% (*SD* = 20.4%) in the betting game, which was higher than 40% chance, $t(99) = 26.90$, $p < .001$, $d = 2.69$, and 75.3% (*SD* = 21.5%) in the lottery game, which was also higher than 40% chance, $t(99) = 16.45$, $p < .001$, $d = 1.64$. For the easy-conflict items the index reached 71.2% (*SD* = 20.9%) in the betting game, which was higher than 40% chance, $t(99) = 14.94$, $p < .001$, $d = 1.49$, and 69.8% (*SD* = 22.4%) in the lottery game, which was also higher than 40% chance, $t(99) = 13.34$, $p < .001$, $d = 1.33$. This response consistency further indicates that participants were not systematically responding randomly.

Confidence Ratings

Figure 6 shows the general mean initial confidence ratings for hard-conflict, easy-conflict and no-conflict trials as a function of response type (EV maximizing; Loss averse; Other).

Starting with the hard-conflict items, in the betting game a Wilcoxon signed-rank test ($n = 91$) revealed lower confidence ratings in conflict loss averse responses (*M* = 70.0%, *Mdn* = 73.3%), compared to no-conflict correct responses (*M* = 79.5%, *Mdn* = 81.0%), $W = 695.5$, $Z = -4.65$, $p < .001$. Similarly, in the lottery game ($n = 86$), confidence in conflict loss averse responses (*M* = 68.1%, *Mdn* = 70.8%) was lower than in no-conflict correct responses (*M* = 69.9%, *Mdn* = 72.0%), but this difference was not significant, $W = 1053.5$, $Z = -1.28$, $p = .20$. Thus, in the hard-conflict items of the betting game, participants showed an increased response doubt when they were choosing the loss averse option, suggesting that they were detecting that their answer conflicted with EV maximizing considerations.

Concerning the easy-conflict items, in the betting game, a Wilcoxon signed-rank test (n = 83) revealed lower confidence ratings in conflict loss averse responses (M = 65.7%, Mdn = 70.0%), compared to no-conflict correct responses (M = 78.5%, Mdn = 80.0%), W = 396.0, Z = −5.52, p < .001. Similarly, in the lottery game (n = 82), confidence in conflict loss averse responses (M = 64.7%, Mdn = 67.5%) was lower than in no-conflict correct responses (M = 69.1%, Mdn = 71.8%), W = 859, Z = −2.70, p = .007.

As in our previous studies, we also observed a confidence decrease when people provided EV maximizing responses in the conflict problems. In the hard-conflict items of the betting game, a Wilcoxon signed-rank test (n = 61) revealed significantly lower confidence ratings in conflict loss averse responses (M = 52.4%, Mdn = 55.0%), compared to no-conflict correct responses (M = 80.0%, Mdn = 83.0%), W = 27.5, Z = −6.28, p < .001. Similarly, in the hard-conflict items of the lottery game (n = 69), confidence in conflict loss averse responses (M = 64.1%, Mdn = 65.0%) was lower than in no-conflict correct responses (M = 66.9%, Mdn = 69.5%), but this difference was not significant, W = 645.5, Z = −1.43, p = .15.

In the easy-conflict items the same pattern was observed. In the betting game, a Wilcoxon signed-rank test (n = 80) revealed significantly lower confidence ratings in conflict loss averse responses (M = 63.6%, Mdn = 68.8%), compared to no-conflict correct responses (M = 79.7%, Mdn = 82.5%), W = 460, Z = −4.99, p < .001. Similarly, in the lottery game (n = 83), confidence in conflict loss averse responses (M = 64.1%, Mdn = 67.0%) was lower than in no-conflict correct responses (M = 66.4%, Mdn = 70.0%), but this difference was not significant, W = 1072, Z = −1.70, p = .09. Hence, in the betting game EV responders showed sensitivity to the alternative loss averse option.

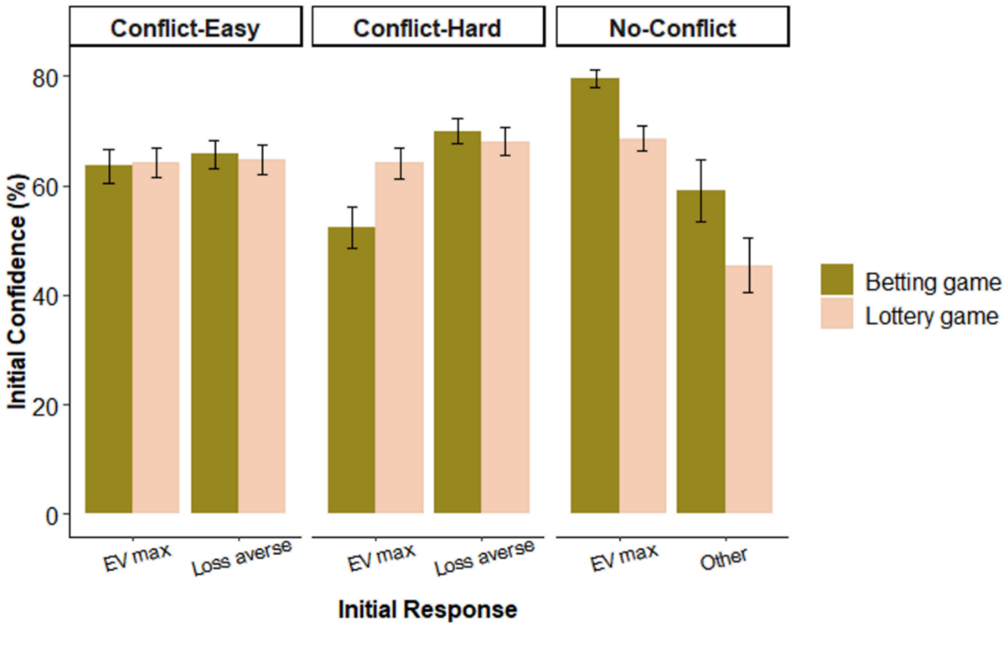

Figure 6. Initial response confidence ratings in Study 3 as a function of response type (Ex maximizing; Loss averse; Other) and conflict status (conflict-easy; conflict-hard; no-conflict) separately for the two games. Error bars are standard errors of the mean.

General Discussion

Our main goal in this paper was to test the corrective dual process assumption of risky decision making. According to this popular view, when people take risky decisions, deliberation is necessary for them to take the expected value of their decision into account and avoid the loss aversion bias (Slovic et al., 2005). In this paper we directly tested whether expected value maximizing decisions can also be intuitively generated, in the absence of deliberate processing. Across our three studies we found that, when playing two-outcome risky choice games, participants usually opted for the loss averse choice (instead of the expected value maximizing one), both after mere intuitive processing and after deliberating. However, in the cases where people chose the expected value maximizing choice after deliberation, they had predominantly already arrived at this choice intuitively. In Study 3 we replicated this finding with items that had a larger expected value. With these items more participants managed to provide expected value choices after deliberation and, here too, they had predominantly already made the expected-value maximizing choice in the intuitive stage. In sum, across our three studies we found that deliberation is not the primary route for expected-value-based responding.

As a second step in our paper, we examined whether people were sensitive to expected value principles even when they intuitively chose the loss averse option. We found that in the conflict trials of the betting game, people consistently displayed decreased intuitive confidence levels (compared to baseline confidence) when they made a loss averse choice. Interestingly, they also showed decreased confidence in the conflict trials where they chose the expected value maximizing option. This suggests that, no matter what option people end up selecting, they intuitively process the alternative option as well. However, in the lottery game the observed effects were small(er) and less consistent, as participants reported a decreased confidence in some conflict trials (i.e., in Study 1 and in the easy-conflict items of Study 3), but not in others. In sum, these results cautiously indicate that when people opt for the loss averse choice, the expected-value maximizing choice is also often activated (and vice-versa).

The relatively low baseline (i.e., no-conflict) initial confidence in our items (on average around 70%) could potentially account for the small magnitude of the conflict effect observed in our studies. This might suggest that the no-conflict items we constructed were not entirely devoid of conflict and may have, at times, induced conflicts between different intuitions. For instance, in the no-conflict items of the lottery game, participants could adopt the strategy of consistently selecting the lottery with the highest value within the set. Such a strategy would lead them towards a choice that contradicted the correct option. While we did control for this on a general level (see supplementary material D) we cannot completely rule out its potential impact on confidence levels, or the potential effect of other strategies in generating conflicts. Moving forward, it is crucial that for a precise measurement of conflict detection, the no-conflict items genuinely avoid inducing any conflict. Admittedly, ensuring this in risky choice tasks might be more challenging than in other domains.

As mentioned in the Introduction, two-response studies in the reasoning field have also shown that logico-probabilistic principles traditionally thought to be processed only after deliberation, can be processed intuitively (e.g., Bago & De Neys, 2017; but see also Ghasemi et al., 2023; Meyer-Grant et al., 2023). To account for these findings, scholars have introduced an updated dual process model, sometimes referred to as Dual Process Theory 2.0 (De Neys, 2018). This model proposes that when a reasoner intuitively processes a "bias" problem, they will generate multiple types of intuitions which will compete with each other (De Neys, 2023). Two primary intuitions come into play: one that cues a heuristic response (also referred to as "heuristic intuition") and one that cues a logical response (also referred to as "logical intuition"). "Heuristic intuitions" are often based on stored semantic associations and may contradict logical rules, while "logical intuitions" stem from an automatized knowledge of mathematical and probabilistic principles (De Neys, 2012, 2023; Evans, 2019; Stanovich, 2018).

The model assumes that the stronger, most activated intuition will eventually become the selected intuitive response. In addition, when the activation levels of competing intuitions are similar in strength, the reasoner will feel more uncertain or conflicted about their response. This uncertainty might prompt further deliberation which will in turn either confirm or change the intuitive choice (De Neys, 2023; Pennycook et al., 2015). If, however, one intuition clearly dominates over another in strength, the reasoner will feel certain about their intuitive choice and the dominant intuition will lead to a response without further deliberation (De Neys, 2023).

The present findings align with this framework, as they suggest that when faced with a risky decision, people generate both a loss averse intuition and an expected-value maximizing intuition. The extension of the revised dual-process assumptions to the risky choice field holds significant importance. While the fundamental ideas of "fast-and-slow" dual process models have been applied in various domains (Melnikoff & Bargh, 2018), the primary evidence supporting this novel characterization of intuitive reasoning is derived from a few heuristics-and-biases tasks. To establish the new, revised core assumptions as a potential general theory of cognition (Reber & Allen, 2022), it is evidently crucial to test the generalizability of the central findings across diverse fields (e.g., see the commentaries on De Neys, 2023). Risky decision-making, in particular, holds theoretical importance as it forms the foundation of prospect theory (Kahneman & Tversky, 1979), a cornerstone of Kahneman and Tversky's work on heuristics and biases. Therefore, our results inform this new model and risky decision making research by showing that when people manage to take the expected value of their decisions into account, they often do so intuitively.

Investigating the nature of expected-value-based choices is also essential for practical and methodological reasons. In his influential work on the Cognitive Reflection Test (CRT), Frederick (2005) suggests that higher cognitive reflection is associated with more expected-value-based choices. If, however, these choices are often generated intuitively, future studies should be wary of using expected value maximizing choices as an index of one's deliberate reflection capacity per se. Rather, it might more likely reflect the accuracy of one's intuitive processing.

Finally, risk is ubiquitous in investment and managerial business decisions and such decisions are frequently made under time pressure and cognitive load (e.g., traders having to make split-second decisions under stress, Lo & Repin, 2002). If intuition is often sufficient for the generation of profit-maximizing choices, then the idea that lack of deliberation and time-pressure is necessarily detrimental for financial and administrative business decisions might be reconsidered (Kahneman, 2011; McAfee, 2012; World Bank Group, 2015). This also may be linked to evidence suggesting that people higher in cognitive capacity have more accurate intuitions (Reyna & Brainerd, 2011; Thompson et al., 2018) and that top traders have superior intuitive processing skills (Kandasamy et al., 2016). Likewise, Reyna and colleagues (e.g., Reyna, 2012) have long stressed the importance of intuitive processing for optimal decision making and cognitive functioning. Their fuzzy-trace theory suggests that cognitive processing can switch from verbatim to more intuitive, gist-based representations (see Reyna et al., 2018 for a review). Although our findings do not inform us on the underlying representations, they agree with the central claim of the fuzzy-trace theory, which is the importance of sound intuitive reasoning in human cognition and more specifically risky decisions (Reyna, 2004).

It is worth noting that across our studies there was a non-negligible amount of conflict trials where participants selected the expected value maximizing choice in the initial, intuitive stage and after deliberating opted for the loss averse choice instead. These "10" cases ($M_{proportion}$ = 9.3% in the betting game; $M_{proportion}$ = 14.6% in the lottery game) are the main reason why the proportion of expected value maximizing choices is higher in the initial, intuitive than in the final, deliberate stage. This pattern seems contradictory since deliberation is thought, if anything, to make people more likely to consider logico-probabilistic principles like expected value (Slovic et al., 2005). Indeed, most two-response studies in the reasoning field that used classic "bias" tasks, found that "10" trials were negligible (see Boissin et al., 2021 for bat-and-ball problems; see Bago & De Neys, 2017 for base-rate neglect problems and syllogisms). However, in line with our findings, some studies researching the conjunction fallacy found that people also tended to provide more logical responses intuitively than after deliberation (Boissin et al., 2022; Dujmović et al., 2021; Voudouri et al., 2022). The authors suggested that the processing of the biased response might require some minimal deliberation (Boissin et al., 2022). In other words, at the constrained intuitive stage, the biased response might not yet be fully activated and might need some time and resources to reach its peak strength (Bago & De Neys, 2017; Pennycook et al., 2015). In line with the theoretical model mentioned above, we can assume that in the initial stage both the loss averse and the expected value maximizing intuitions get activated at various speeds. If the latter is stronger it will be selected as the initial response. However, in the deliberate stage, the loss averse intuition might peak in strength and prevail as the final response (De Neys, 2023; Pennycook et al., 2015). Indeed, both in the present studies (see supplementary material G) and in previous research (Bago & De Neys, 2017, 2019; Thompson et al., 2011), it has been observed that for "10" responses participants experience the most doubt. This aligns with the idea that change is most likely when competing intuitions are similar in strength, and uncertainty is the highest.

Similarly, one might question why people continue to make loss averse choices even when they detect conflict in their responses. To reiterate, our findings show that merely being sensitive to expected value principles does not guarantee that a reasoner will provide expected-value-maximizing responses. In line with the model mentioned above, this could be attributed to the idea that the conflict experienced by the reasoner might not be strong enough to reverse the strength of the competing intuitions, and make the expected-value maximizing intuition prevail (De Neys, 2023).

One potential critique of the study is that we cannot guarantee that responses in the final response stage are truly deliberate. Although participants are encouraged to take their time and actively reflect on the problem, they are not explicitly trained to deliberate. It is worth noting that we observed consistent accuracy between the one-response pretest and the final two-response study (even though participants were not randomly allocated to these studies), suggesting that people tend to provide the same responses in the final response stage as they would in a free-response format. Nevertheless, we believe that explicit prompting or training could promote deeper reflection and lead to more expected-value-maximizing responses (see also Bago & De Neys, 2019 for a similar discussion). Indeed, studies have found that one-shot interventions which draw attention to biases or explain why a response is considered incorrect, often make reasoners provide more logical responses (Hoover & Healy, 2017; Morewedge et al., 2015; Trouche et al., 2014). Interestingly, this effect is not only observed for deliberate responses, but also for intuitive ones (Boissin et al., 2021, 2022). Based on these findings, we believe that a short explanation on expected value, could boost both intuitive and deliberate expected-value-maximizing responses.

A potential limitation in the current paper pertains to how participants interpret the provided instructions and how this interpretation influences the way they play the games. Participants are told that they will play two games, each comprising 15 gambles. However, the manner in which they approach these gambles, whether as independent, standalone events or as integral components of a larger game, may significantly affect their decision-making. In addition, the fact that we randomly select a single trial to determine their bonus payment may have prompted participants to consider each gamble in isolation, which could, in turn, amplify loss aversion. It may be beneficial for future risky choice studies to explicitly instruct participants to either view the game as a whole or as consisting of independent gambles, and assess whether this affects the nature of their choices. An alternative way to address this issue could be to use sampling methods, where participants actively engage with the gambles and learn from their choices in real-time.

To conclude, the present paper shows that expected value maximizing choices in risky decision making are most of the time the result of mere intuitive processing and not that of effortful deliberation. Consistent with recent advances in dual process theorizing this suggest that risky decision making may be better conceptualized as an interplay between different types of “fast” intuitions rather than two different types of “fast” and “slow” thinking per se.

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Supplementary Material

A. Literal Instructions

Study 1

Please read these instructions carefully!

This experiment is divided into two parts: a betting game and a lottery game.

In the **betting game** you will be asked to choose either **to take** or **to not take bets**.

In the **lottery game** you will be asked to **choose one out of two lotteries**.

In each game you will have to answer 15 multiple-choice questions and a couple of practice questions. The questions will be presented to you one after the other and **you should not pause between them.**

After you finish the first game, you can take **a short break.**

It is important that you complete the experiment in one sitting and without distractions.

Click on **Next** to continue.

Participants were then either first presented with the instructions for the betting game or with the instructions of the lottery game. For the betting game the instructions were the following:

Welcome to the betting game!

In this game you will be presented with **a different bet on every trial**.

You will be given **both probabilities of winning and losing a certain amount of money**.

Based on these probabilities, you can decide **whether you want to take the bet or not**.

Imagine you are playing for real money and want to make **as much profit as possible.**

Imagine that any money you win, you get to keep and any money you lose you need to pay for.

We are interested in whether or not you would want to take the bet if you were to play for real.

See the example below:

If you take this bet you have:

70% *probability to* ***WIN €100***
30% *probability to* ***LOSE €15***

Do you take the bet?

- ***YES***
- ***NO***

In the actual game, you can choose whether you want to take the bet or not **by clicking on one of the**

answer options.

Critically, in this game we want to know what your **initial, intuitive response** to the bets is and **how you respond after you have thought about these bets for some more time.**

First, we want you to respond with the **very first answer that comes to mind**. You don't need to think about it. Just give the first answer that intuitively comes to mind as quickly as possible.

To make sure that you answer as fast as possible, **a time limit was set for the first response**, which is going to be **4.5 seconds**. When there is 1 second left, the background colour will turn to yellow to let you know that the deadline is approaching. Please make sure to **answer before the deadline passes**.

Next, **the bet will be presented again** and you can take all the time you want to actively reflect on it. Once you have made up your mind you give your **final response**.

After you made your choice and clicked on it, you will be automatically taken to the next page.

After you have entered your first and final answer we will also ask you to indicate how confident you are that you made the right decision.

We are going to clarify all of this with a couple of practice questions.

We are going to start with **two practice questions** to familiarise you with the game.

For each question, a fixation cross will appear first. Then, the bet will be presented. You then enter your first hunch as fast as possible before the deadline.
Next, the bet will be presented again and you can take all the time to reflect on it and enter your final response.
After you have entered your initial and your final answer we will also ask you to indicate how confident you are that you made the right decision.

We will let you practice now.

Click on **Next** when you are ready to start the practice session.

Participants were then given two practice trials, without the concurrent load task. They were then introduced to the load task.

You will also need to **memorize a pattern** while you respond to the bets.

You will see a grid with crosses and you will have to memorize their location.

You will first practice with 2 patterns without a bet.

The pattern will be displayed for **2 seconds** and then you will have to select it among **4 different patterns**.

Click on **Next** to begin.

Participants were then given two practice trials for the cognitive load task, without the bets. They were then presented with the following instructions:

In the actual study you will need to memorize the pattern while you respond to the bet. The pattern is briefly presented before each bet.

The difficulty of the pattern might vary. Always try to memorize as many crosses as possible. Each cross counts!

We know that it is not always easy to memorize the pattern while you are also thinking about the bet. The most important thing is to correctly memorize the pattern.

First, **try to concentrate on the memorization task**, and then try to respond to the bet.

As a next step, you can practice this with two questions.

Click on **Next** to proceed.

After those two last practice trials, participants were presented with the following instructions:

This is the end of all practice!

Remember:

In this game you have to answer to 15 questions.

The questions will be presented to you one after the other and **you should not pause between them.**

Click on **Next** when you are ready to start with the actual game.

After the first game participants were presented with the instructions for the second game (either the lottery or the betting game). The instructions for the lottery game were the following:

Welcome to the lottery game!

In this game you will be presented with **two different lotteries** on every trial: Lottery A and Lottery B.

No matter which lottery you choose, **you can always win some money**.

For each lottery you will be given **the probabilities of winning**.

Based on these probabilities, you can decide which lottery to choose.

Imagine you are playing for real money and want to make **as much profit as possible.**

Imagine that any money you win, you get to keep.

Which lottery would you choose if you were to play for real?

See the example below:

Lottery A	***Lottery B***
80% *probability to* ***win €55***	***80%*** *probability to* ***win €180***
20% *probability to* ***win €380***	***20%*** *probability to* ***win €300***

Which lottery do you choose?

- ***A***
- ***B***

In the above example, the probabilities that are under Lottery A, correspond to Lottery A.
The probabilities that are under Lottery B, correspond to Lottery B.

In the actual game, you can choose the lottery you want to take **by clicking on one of the answer options**.

Then participants saw the same instructions, considering the practice trials as in the first game. The instructions were identical with the first game, apart from the deadline which was adjusted accordingly.

Study 2-3

In the general instructions of Studies 2-3 the renumeration information was added. The instructions were the following:

Please read these instructions carefully!

This experiment is divided into two parts: a betting game and a lottery game.

In the **betting game** you will be asked to choose either **to take** or **to not take bets**.

In the **lottery game** you will be asked to **choose one out of two lotteries**.

In each game you will have to answer 20 multiple-choice questions and a couple of practice questions.
After you finish the experiment we will **randomly** select **one bet** from the betting game and **one lottery** from the lottery game.
Then we will play both this bet and this lottery in our software according to the responses you gave.

Any money you make or lose in this bet and this lottery will be added together. Then, your payment will be multiplied by a factor of 0.0013.
This means that you can make from 1 pound to 0 pounds extra (depending on your choices) in addition to your standard payment.

Your goal in both games is to make **as much profit as possible.**
The questions will be presented to you one after the other and **you should not pause between them.**

After you finish the first game, you can take **a short break.**

It is important that you complete the experiment in one sitting and without distractions.
Click on **Next** to continue.

The rest of the instructions were identical to Study 1. However, participants were simply told "**Remember:** your goal is to make as much profit as possible." Instead of being told "Imagine you are playing for real money and want to make **as much profit as possible.** Imagine that any money you win, you get to keep."

B. Items

Betting game

All betting game items had the following structure:

If you take this bet you have:
% probability to WIN €
% probability to LOSE €
Do you take the bet?
o Yes
o No

Table S1 below shows the win and lose sentences of each of the items. Note that Study 1 did not include counterbalancing (all participants viewed the same conflict, no-conflict and filler items). In Studies 2-3 we introduced counterbalancing. To make counterbalancing work in these studies, we added a set B of conflict and filler items and a new set A and B of no-conflict items. In Study 3 we also added the easy-conflict items.

Table S1. The betting game items according to the study (1, 2, 3) they were used in, the type (Conflict, No-Conflict, Filler), the Difficulty level of the conflict items (Hard; Easy), the Items' Number, and the counterbalancing set (A; B).

Study	Type	Difficulty	Number	Set	Win sentence	Lose sentence
1, 2, 3	C	Hard	1	A	5% probability to WIN 110€	95% probability to LOSE 5€
1, 2, 3	C	Hard	2	A	10% probability to WIN 100€	90% probability to LOSE 10€
1, 2, 3	C	Hard	3	A	15% probability to WIN 95€	85% probability to LOSE 15€
1, 2, 3	C	Hard	4	A	20% probability to WIN 90€	80% probability to LOSE 20€
1, 2, 3	C	Hard	5	A	25% probability to WIN 85€	75% probability to LOSE 25€
1	NC		1		95% probability to WIN 105€	5% probability to LOSE 25€
1	NC		2		90% probability to WIN 100€	10% probability to LOSE 20€
1	NC		3		85% probability to WIN 105€	15% probability to LOSE 15€
1	NC		4		80% probability to WIN 110€	20% probability to LOSE 10€
1	NC		5		75% probability to WIN 115€	25% probability to LOSE 5€
1, 2, 3	F		1	A	70% probability to WIN 5€	30% probability to LOSE 20€
1, 2, 3	F		2	A	65% probability to WIN 5€	35% probability to LOSE 15€
1, 2, 3	F		3	A	60% probability to WIN 10€	40% probability to LOSE 20€
1, 2, 3	F		4	A	55% probability to WIN 10€	45% probability to LOSE 20€
1, 2, 3	F		5	A	50% probability to WIN 10€	50% probability to LOSE 15€
2, 3	C	Hard	1	B	5% probability to WIN 120€	95% probability to LOSE 5€
2, 3	C	Hard	2	B	10% probability to WIN 115€	90% probability to LOSE 10€
2, 3	C	Hard	3	B	15% probability to WIN 100€	85% probability to LOSE 15€
2, 3	C	Hard	4	B	20% probability to WIN 85€	80% probability to LOSE 20€
2, 3	C	Hard	5	B	25% probability to WIN 80€	75% probability to LOSE 25€
2, 3	NC		1	A	95% probability to WIN 120€	5% probability to LOSE 5€
2, 3	NC		2	A	90% probability to WIN 115€	10% probability to LOSE 10€
2, 3	NC		3	A	85% probability to WIN 100€	15% probability to LOSE 15€

2, 3	NC		4	A	80% probability to WIN 105€	20% probability to LOSE 20€
2, 3	NC		5	A	75% probability to WIN 110€	25% probability to LOSE 25€
2, 3	NC		1	B	95% probability to WIN 110€	5% probability to LOSE 5€
2, 3	NC		2	B	90% probability to WIN 100€	10% probability to LOSE 10€
2, 3	NC		3	B	85% probability to WIN 95€	15% probability to LOSE 15€
2, 3	NC		4	B	80% probability to WIN 115€	20% probability to LOSE 20€
2, 3	NC		5	B	75% probability to WIN 120€	25% probability to LOSE 25€
2, 3	F		1	B	70% probability to WIN 10€	30% probability to LOSE 30€
2, 3	F		2	B	65% probability to WIN 10€	35% probability to LOSE 25€
2, 3	F		3	B	60% probability to WIN 5€	40% probability to LOSE 15€
2, 3	F		4	B	55% probability to WIN 5€	45% probability to LOSE 15€
2, 3	F		5	B	50% probability to WIN 20€	50% probability to LOSE 25€
3	C	Easy	1	A	5% probability to WIN 290€	95% probability to LOSE 1€
3	C	Easy	2	A	10% probability to WIN 285€	90% probability to LOSE 5€
3	C	Easy	3	A	15% probability to WIN 260€	85% probability to LOSE 10€
3	C	Easy	4	A	20% probability to WIN 220€	80% probability to LOSE 15€
3	C	Easy	5	A	25% probability to WIN 205€	75% probability to LOSE 25€
3	C	Easy	1	B	5% probability to WIN 295€	95% probability to LOSE 1€
3	C	Easy	2	B	10% probability to WIN 290€	90% probability to LOSE 5€
3	C	Easy	3	B	15% probability to WIN 265€	85% probability to LOSE 10€
3	C	Easy	4	B	20% probability to WIN 225€	80% probability to LOSE 15€
3	C	Easy	5	B	25% probability to WIN 210€	75% probability to LOSE 25€

Lottery game

For the Lottery game the hard-conflict and no-conflict items were the same across studies 1-2-3. Regarding the filler items, while Study 1 and 2 did not include counterbalancing (all participants viewed the same items) in Study 3 we added a set B of filler items in order to counterbalance. Study 3 also included easy-conflict items.

Table S2. The lottery game items according to the study (1, 2, 3) they were used in, the type (Conflict, No-Conflict, Filler), the Difficulty level of the conflict items (Hard; Easy), the Items' Number, and the counterbalancing set (A; B).

Study	Type	Difficulty	Number	Set	Lottery A	Lottery B
1, 2, 3	C	Hard	1	A	60% probability to win 180€, 40% probability to win 130€	60% probability to win 330 €, 40% probability to win 1€
1, 2, 3	C	Hard	2	A	65% probability to win 200€, 35% probability to win 155€	65% probability to win 340€, 35% probability to win 5€
1, 2, 3	C	Hard	3	A	70% probability to win 350€, 30% probability to win 10€	70% probability to win 230€, 30% probability to win 160€
1, 2, 3	C	Hard	4	A	75% probability to win 360€, 25% probability to win 20€	75% probability to win 260€, 25% probability to win 165€
1, 2, 3	C	Hard	5	A	80% probability to win 370€, 20% probability to win 45€	80% probability to win 290€, 20% probability to win 170€

1, 2, 3	NC		1	B	60% probability to win 1€, 40% probability to win 330€	60% probability to win 130€, 40% probability to win 180€
1, 2, 3	NC		2	B	65% probability to win 5€, 35% probability to win 340€	65% probability to win 155€, 35% probability to win 200€
1, 2, 3	NC		3	B	70% probability to win 10€, 30% probability to win 350€	70% probability to win 160€, 30% probability to win 230€
1, 2, 3	NC		4	B	75% probability to win 165€, 25% probability to win 260€	75% probability to win 20€, 25% probability to win 360€
1, 2, 3	NC		5	B	80% probability to win 170€, 20% probability to win 290€	80% probability to win 45€, 20% probability to win 370€
1, 2, 3	C	Hard	1	B	60% probability to win 185€, 40% probability to win 135€	60% probability to win 335€, 40% probability to win 5€
1, 2, 3	C	Hard	2	B	65% probability to win 205€, 35% probability to win 160€	65% probability to win 345€, 35% probability to win 10€
1, 2, 3	C	Hard	3	B	70% probability to win 235€, 30% probability to win 165€	70% probability to win 355€, 30% probability to win 15€
1, 2, 3	C	Hard	4	B	75% probability to win 365€, 25% probability to win 25€	75% probability to win 265€, 25% probability to win 170€
1, 2, 3	C	Hard	5	B	80% probability to win 375€, 20% probability to win 50€	80% probability to win 295€, 20% probability to win 175€
1, 2, 3	NC		1	A	60% probability to win 5€, 40% probability to win 335€	60% probability to win 135€, 40% probability to win 185€
1, 2, 3	NC		2	A	65% probability to win 10€, 35% probability to win 345€	65% probability to win 160€, 35% probability to win 205€
1, 2, 3	NC		3	A	70% probability to win 165€, 30% probability to win 235€	70% probability to win 15€, 30% probability to win 355€
1, 2, 3	NC		4	A	75% probability to win 170€, 25% probability to win 265€	75% probability to win 25€, 25% probability to win 365€
1, 2, 3	NC		5	A	80% probability to win 175€, 20% probability to win 295€	80% probability to win 50€, 20% probability to win 375€
1, 2, 3	F		1	A	100% probability to win 200€, 0% probability to win 250€	100% probability to win 350€, 0% probability to win 300€
1, 2, 3	F		2	A	100% probability to win 350€, 0% probability to win 400€	100% probability to win 410€, 0% probability to win 460€
1, 2, 3	F		3	A	50% probability to win 200€, 50% probability to win 50€	50% probability to win 275€, 50% probability to win 125€
1, 2, 3	F		4	A	90% probability to win 350€, 10% probability to win 310€	90% probability to win 260€, 10% probability to win 220€
1, 2, 3	F		5	A	90% probability to win 340€, 10% probability to win 305€	90% probability to win 250€, 10% probability to win 215€
2, 3	F		1	B	100% probability to win 210€, 0% probability to win 250€	100% probability to win 360€, 0% probability to win 310€
2, 3	F		2	B	100% probability to win 355€, 0% probability to win 410€	100% probability to win 415€, 0% probability to win 470€

2, 3	F		3	B	50% probability to win 225€, 50% probability to win 75€	50% probability to win 300€, 50% probability to win 150€
2, 3	F		4	B	90% probability to win 330€, 10% probability to win 290€	90% probability to win 240€, 10% probability to win 200€
2, 3	F		5	B	90% probability to win 350€, 10% probability to win 310€	90% probability to win 260€, 10% probability to win 220€
3	C	Easy	1	A	60% probability to win 160€, 40% probability to win 130€	60% probability to win 480€, 40% probability to win 1€
3	C	Easy	2	A	65% probability to win 170€, 35% probability to win 155€	65% probability to win 470€, 35% probability to win 5€
3	C	Easy	3	A	70% probability to win 180€, 30% probability to win 160€	70% probability to win 440€, 30% probability to win 10€
3	C	Easy	4	A	75% probability to win 450€, 25% probability to win 20€	75% probability to win 210€, 25% probability to win 165€
3	C	Easy	5	A	80% probability to win 460€, 20% probability to win 45€	80% probability to win 250€, 20% probability to win 170€
3	C	Easy	1	B	60% probability to win 165€, 40% probability to win 135€	60% probability to win 485€, 40% probability to win 5€
3	C	Easy	2	B	65% probability to win 175€, 35% probability to win 160€	65% probability to win 475€, 35% probability to win 10€
3	C	Easy	3	B	70% probability to win 185€, 30% probability to win 165€	70% probability to win 445€, 30% probability to win 15€
3	C	Easy	4	B	75% probability to win 455€, 25% probability to win 25€	75% probability to win 215€, 25% probability to win 170€
3	C	Easy	5	B	80% probability to win 465€, 20% probability to win 50€	80% probability to win 255€, 20% probability to win 175€

C. One response pretest details

For the one-response pretests, the recruitment platform and criteria were the same as in Study 1.

For the pretest of Study 1, we recruited an independent sample of 50 participants (72% female; mean age = 38.52 years, *SD* = 14.8). Participants were paid £0.85 for their participation (£5 hourly rate). A total of 38% of the participants reported high school as their highest completed educational level, while 60% reported having a postsecondary education degree.

For the pretest of Study 3, we also recruited an independent sample of 50 participants (48% female; mean age = 39.1 years, *SD* = 15.0). Participants were paid £1.2 for their participation (£6 hourly rate). A total of 44% of the participants reported high school as highest completed educational level, while 54% reported having a postsecondary education degree.

Deadline Study 1. Following previous studies, we wanted to base the deadline in the initial stage of our main, two-response study on the average response time in the pretest (Bago & De Neys, 2017, 2020). For this reason, the pretest included the same number of trials and same stimuli as the main study, but here participants had to provide only one answer to each bet and lottery pair without time restrictions. In the betting game the EV maximizing responses to the conflict bets took more time (7.8 s, *SD* = 7.9 s) than the loss averse responses (5.1 s, *SD* = 1.9 s). Thus, we decided to base the initial response deadline on the reaction time of the EV maximizing trials only. The first quartile of these trials was 4.45 s, so we rounded to the nearest decimal and set the deadline for the betting game to 4.5 s. In the lottery game the reaction times were overall longer, which was to be expected as the items were lengthier. In this game, the EV maximizing responses to the conflict lottery pairs took less time (7.8 s, *SD* = 5.4 s) than the loss averse responses (8.2 s, *SD* = 4.2 s). Thus, we based the initial response deadline on the overall reaction time across conflict trials. The first quartile of these trials was 5.6 s, so we rounded to the nearest decimal and set the deadline for the lottery game to 5.5 s.

Deadline Study 3. In the betting game, EV maximizing responses to the conflict bets took more time (5.3 s, *SD* = 2.7 s) than loss averse responses (4.8 s, *SD* = 2.5 s)[9]. So, following the same rationale as in Study 1, we based our deadline on the reaction time of the EV maximizing trials only. The first quartile of these trials was 3.3 s. However the mean reaction time for the correct no-conflict items was 3.9 s. To avoid excess missed trials and to be consistent with Study 1 (where the deadline was higher than the no-conflict baseline), we rounded the reaction time to the nearest integer and set the deadline for the betting game to 4 s (i.e., 0.5 s less than in Study 1). In the lottery game, the EV maximizing responses to the conflict lottery pairs (7.0 s, *SD* = 4.6 s) also took more time than the loss averse responses (6.1 s, *SD* = 3.4 s). So, following the same rationale as with the betting game we based our deadline on the reaction time of the EV maximizing trials only. The first quartile of these trials was 4.45 s, so we rounded to the nearest decimal and set the deadline for the lottery game to 4.5 s (i.e., 1 s less than in Study 1).

Time pressure. To make sure that participants were indeed under time pressure during the initial stage, we compared the response times on the conflict trials between the one-response pretest and the initial stage of the main two-response study. To do so, we first excluded from the two-response study all trials with incorrect load memorization or a missed deadline. Table S3 shows

[9] The reaction times presented in this section are the average reaction time across the hard-conflict and easy-conflict items.

the mean response times in the initial response stage of the two-response study and the one-response pretest.

Table S3. Mean response times for the conflict trials in the initial stage of the main two-response study and in the one-response pretest.

		$M_{two\text{-}response}$	$M_{one\text{-}response}$
Study 1	Betting game	2.7 s	5.3 s
	Lottery game	2.9 s	7.9 s
Study 3	Betting game	2.6 s	4.8 s
	Lottery game	2.7 s	6.4 s

Consistency confound. The one-response pre-test also allowed us to rule out a potential consistency confound in our main two-response study. More specifically, when participants are asked to give two consecutive responses, they might stick to their initial response in the final stage because they want to appear consistent (Thompson et al., 2011). Thereby, the paradigm may underestimate the rate of response change from the initial to the final stage. To check for this consistency confound in our study, we contrasted the proportion of EV maximizing responses in the conflict trials of the one-response pretest and that of the final stage of the main two-response study (see Table S4). If a consistency confound was present, we would find a significantly lower number of EV maximizing responses in the two response study. However, we found that the percentage of EV maximizing responses was very similar in the one-response pretest and in the final responses of the two-response study, hence ruling out this confound. To avoid confusion, note that this does not imply that people are not consistent between their intuitive and deliberate choices; they clearly are, as shown by the low prevalence of explicit answer change. Instead, the consistency confound refers to the tendency to stick to initial responses in two-response tasks solely for the sake of appearing consistent, which is not observed here.

Table S4. The percentage of EV maximizing responses in the conflict trials during the final response stage of the two-response study and the one-response pretest.

		$M_{two\text{-}response}$	$M_{one\text{-}response}$
Study 1	Betting game	13.8%	14.0%
	Lottery game	29.8%	28.8%
Study 3	Betting game	40.2%	31.6%
	Lottery game	41.6%	43.2%

D. Partial results excluding heuristics

When designing the items, we identified two possible heuristics, one for the betting game and one for the lottery game respectively which, when used, would result in a ceiled conflict accuracy. In the betting game this heuristic was “always taking the bet”, while in the lottery game it was “always picking the lottery with the highest value in the set”. However, the first heuristic would result in a low filler accuracy in the betting game, while the second would lead to a low no-conflict accuracy in the lottery game. To control for these heuristics and follow our preregistration, we excluded from the betting game participants with an accuracy lower than 50% both in their initial and final filler trials (n_{Study1}= 12; n_{Study2} = 8, n_{Study3} = 10), and from the lottery game participants with an accuracy lower than 50% both in their initial and final no-conflict trials (n_{Study1}= 4; n_{Study2} = 3, n_{Study3} = 2). Here, we report the partial accuracy (Figure S1, Table S5) and direction of change (Figure S2) results after excluding these participants.

As Figures S1 and S2 and Table S5 indicate, all trends regarding the proportion of EV maximizing choices and the direction of change respectively remained the same after the exclusion. Therefore, we conclude that these heuristics are not driving our results.

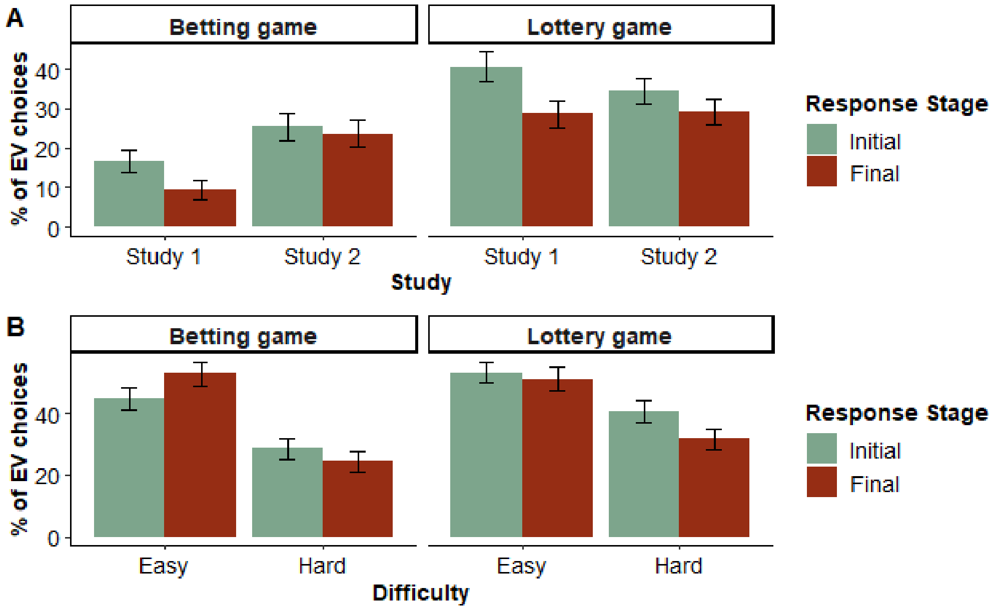

Figure S1. Percentage of Expected Value (EV) maximizing initial and final choices on conflict trials in the betting and lottery game. Panel A shows the means of Study 1 and 2, while Panel B shows those of Study 3, separately for the hard- and easy-conflict items. Error bars are standard errors of the mean.

Table S5. Paired-samples t-tests comparing the proportion of EV maximizing choices between the initial and the final stage, separately for each game, each study and for the hard- and easy-conflict items of Study 3. The mean difference is $M_{initial} - M_{final}$.

			mean difference	*t*	df
Betting game	Study 1		7%	3.07*	87
	Study 2		2%	0.65	91
	Study 3	Hard	4%	1.59	89
		Easy	−8%	−2.74*	89
Lottery game	Study 1		12%	4.46**	95
	Study 2		5%	1.86	96
	Study 3	Hard	9%	2.86*	97
		Easy	2%	0.74	97

*$p < .01$
**$p < .001$

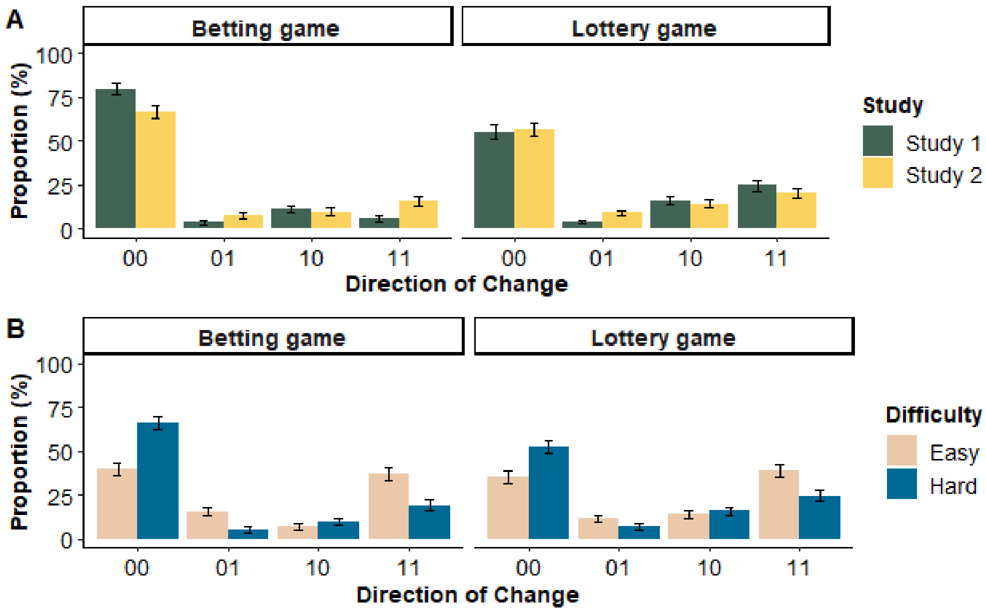

Figure S2. Proportion of each direction of change category in the betting game and the lottery game. Panel A shows the proportions of Study 1 and 2, while Panel B those of Study 3, separately for the hard- and easy-conflict items; "00" = initial and final loss averse response; "01" = initial loss averse response and final Expected Value (EV) maximizing response; "10" = initial EV maximizing response and final loss averse response; "11" = initial and final EV maximizing response. Error bars are standard errors of the mean.

E. ANOVA results for Studies 1 and 2

For both Study 1 and Study 2, we conducted a repeated-measures ANOVA to see whether there was an effect of response stage (initial; final) and conflict status (conflict; no-conflict) on the nature of responses. In these two studies, whenever an interaction was significant, pairwise comparisons with Bonferroni correction indicated that conflict problems had a lower proportion of EV-maximizing responses than no-conflict problems, both in the initial stage ($p < .001$) and the final stage ($p < .001$). The proportion of EV-maximizing responses was not significantly different between the initial and final stages, neither for conflict nor for no-conflict problems.

Study 1

In the betting game, there was a main effect of response stage, $F(1, 99) = 4.43$, $p = .04$, $\eta^2 g = .003$, a main effect of conflict status, $F(1, 99) = 837.40$, $p < .001$, $\eta^2 g = 0.776$, and a significant interaction, $F(1, 99) = 10.44$, $p = .002$, $\eta^2 g = 0.010$.

In the lottery game, there was no main effect of response stage, $F(1, 98) = 3.22$, $p = 0.076$, $\eta^2 g = .003$, but there was a main effect of conflict status, $F(1, 98) = 135.30$, $p < .001$, $\eta^2 g = .423$, and an interaction effect, $F(1, 98) = 20.18$, $p < .001$, $\eta^2 g = .014$.

Study 2

In the betting game, there was no main effect of response stage, $F(1, 99) = 0.11$, $p = .74$, $\eta^2 g < .001$, there was a main effect of conflict status, $F(1, 99) = 502.31$, $p < .001$, $\eta^2 g = .683$, and there was no interaction effect, $F(1, 99) = 2.37$, $p = .13$, $\eta^2 g = .002$.

In the lottery game, there was no main effect of response stage, $F(1, 99) = 0.05$, $p = .82$, $\eta^2 g < .001$, but there was a main effect of conflict status, $F(1, 99) = 250.48$, $p < .001$, $\eta^2 g = .532$, and an interaction effect, $F(1, 99) = 12.44$, $p = .001$, $\eta^2 g = .011$.

F. Inclusion of all trials

To make maximally sure that participants did not deliberate during the initial response stage, we excluded all trials in which they failed to answer before the deadline or failed to correctly recall the load. In theory this could have artificially boosted the rate of EV-maximizing responses and, thus, the critical non-correction rate. That is, if these excluded trials would be specifically of the "01" type, the true non-correction rate would obviously be lower suggesting that EV-maximizing intuitive response generation would be much rarer than reported here. To examine this possibility, we re-ran the direction of change analysis while including missed deadline and incorrect load recall trials. Since in the missed deadline trials the initial response was not recorded, we opted for the strongest possible test and coded all these as "0" (i.e., loss averse response). In the missed load trials both initial and final responses were recorded. Overall, this analysis showed that even after taking into account the excluded trials, the proportion of "11" responses and the non-correction rate remained high (See Table S6 and Figure S3).

Table S6. The proportion (%) of "01" and "11" direction of change categories and the non-correction rate (NCR) for conflict trials including missed deadline and incorrect load recall trials. Missed deadline trials were coded as "0" (i.e., loss averse response).

			"01"		"11"		NCR (11/01+11)	
			Before	After	Before	After	Before	After
Betting game	Study 1		5.8%	4.1%	9.4%	9.7%	61.8%	70.3%
	Study 2		9.2%	7.8%	14.0%	15.6%	60.4%	66.7%
	Study 3	Hard	6.2%	5.4%	19.6%	21.6%	76.0%	80.0%
		Easy	16.2%	15.0%	35.8%	38.3%	68.9%	71.9%
Lottery game	Study 1		5.6%	4.5%	24.8%	25.3%	81.6%	84.9%
	Study 2		10.2%	9.0%	19.0%	19.6%	65.1%	68.5%
	Study 3	Hard	7.2%	7.0%	25.4%	24.8%	77.9%	78.0%
		Easy	11.2%	11.6%	39.6%	39.7%	78.0%	77.4%

Note. "01" = initial loss averse response and final Expected Value (EV) maximizing response; "11" = initial and final EV maximizing response; NCR = Non-correction rate.

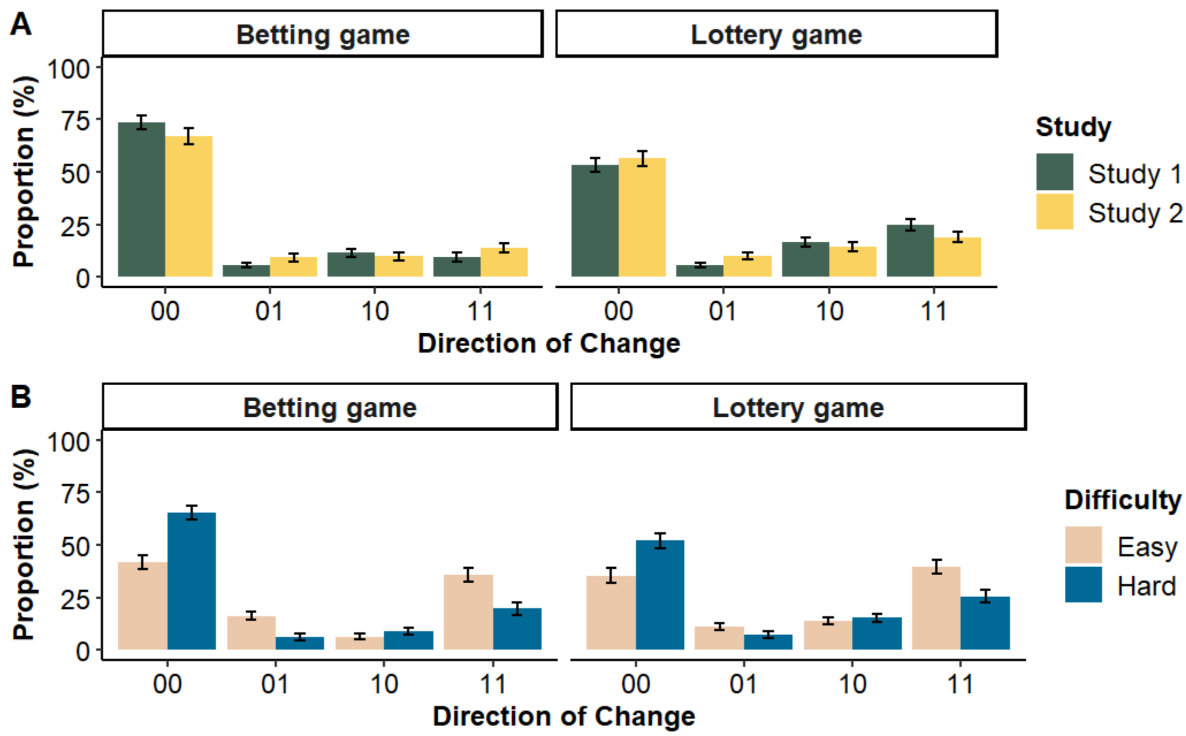

Figure S3. Proportion of each direction of change category in the betting game and the lottery game after including the trials with a missed deadline and/or an incorrect load recall. Panel A shows the proportions of Study 1 and 2, while Panel B those of Study 3, separately for the hard- and easy-conflict items; "00" = initial and final loss averse response; "01" = initial loss averse response and final Expected Value (EV) maximizing response; "10" = initial EV maximizing response and final loss averse response; "11" = initial and final EV maximizing response. Error bars are standard errors of the mean.

G. Confidence as a function of direction of change

For exploratory purposes, we also analysed the confidence ratings as a function of direction of change. In the logical reasoning field, it has been repeatedly shown that trials where participants change their initial response after deliberation (i.e., "01" or "10" trials) tend to show lower initial response confidence than trials where participants stick to their initial answer (i.e., "11" or "00" trials, Bago & De Neys, 2017; Thompson et al., 2011). This low confidence (or "Feeling of Rightness") is considered a key determinant of answer change (Bago & De Neys, 2017; Thompson & Johnson, 2014). Figure S4 shows the general mean, initial confidence ratings for each direction of change category for conflict items across our studies. Table S7 shows the Wilcoxon signed-rank tests comparing the initial response confidence between change (i.e., "01" or "10") and no change (i.e., "11" or "00") trials. We replicate the reasoning findings as we find lower initial confidence for change compared to no change trials across our studies.

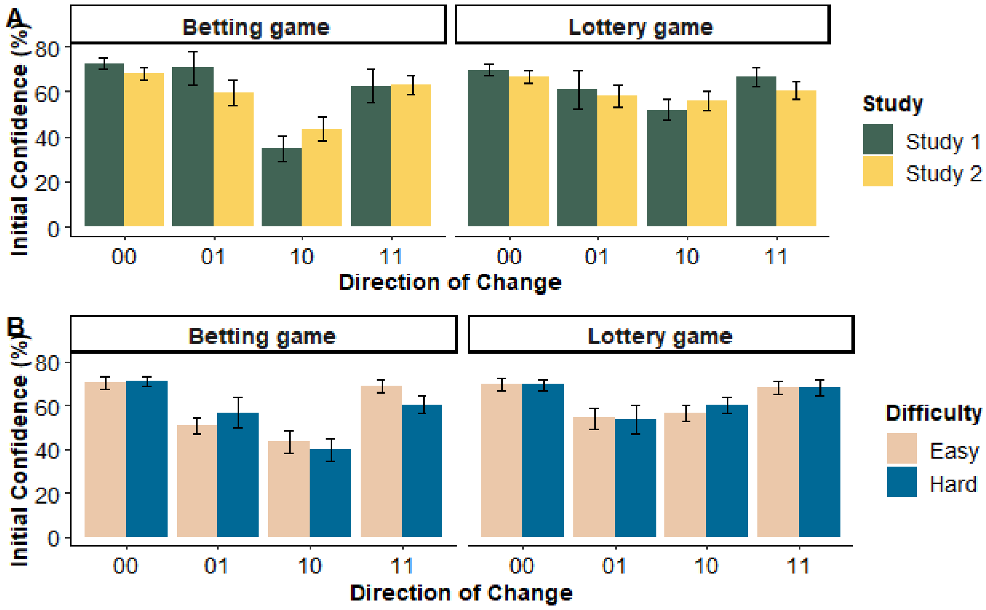

Figure S4. Initial general confidence ratings at conflict trials as a function of each direction of change category separately for the betting and the lottery game. Panel A shows the confidence ratings in Study 1 and Study 2, while panel B show the ratings in Study 3, separately for easy- and hard-conflict trials; "00" = initial and final loss averse response; "01" = initial loss averse response and final Expected Value (EV) maximizing response; "10" = initial EV maximizing response and final loss averse response; "11" = initial and final EV maximizing response. Error bars are standard errors of the mean.

Table S7. Wilcoxon signed rank tests comparing the initial response confidence between change (i.e., "01" or "10") and no change (i.e., "11" or "00") trials, separately for each game, each study and for the hard- and easy-conflict items of Study 3.

			$Median_{change}$	$Median_{nochange}$	*n*	*W*	*Z*
Betting game	Study 1		50.0	70.0	37	154.5*	−2.44
	Study 2		60.0	60.0	41	141.0*	−2.85
	Study 3	Hard	50.0	63.3	43	169.0**	−3.38
		Easy	50.0	67.5	54	240.5***	−4.08
Lottery game	Study 1		54.2	70.0	50	182.0**	−3.36
	Study 2		60.0	70.0	61	355.5*	−2.72
	Study 3	Hard	60.0	66.5	54	261.5**	−2.89
		Easy	58.8	66.3	60	236.5***	−4.00

*$p < .05$
**$p < .01$
***$p < .001$

H. Study 2 Methods and Results

Method

Participants

The recruitment platform and criteria were the same as in Study 1. Participants were paid £2.50 for their participation (£6 hourly rate). They also received a possible monetary bonus payment of up to £1, depending on the game's outcome. However, due to the coding error, participants were only presented with hard-conflict items, which had a lower expected value compared to the easy-conflict items. Consequently, their actual bonuses were lower than originally communicated, and they could not receive the full £1 bonus payment under any circumstances.

To address this, we rescaled the bonuses. We first computed a scaling factor, by calculating the ratio between the intended maximum bonus (£1) and the highest bonus observed during the experiment (£120 + £470 * 0.0013 = £0.77). Subsequently, we adjusted each participant's bonus by multiplying it by the calculated scaling factor (i.e., £1/£0.77 = 1.30). Participants were then remunerated with the rescaled bonuses.

One hundred participants (48 female, mean age = 35.7 years, SD = 12.0 years) participated in the study. A total of 40% of participants reported high school as the highest completed educational level, while 60% reported having a postsecondary education degree.

Procedure

One-response (deliberative-only) pretest. The initial response deadline of Study 2 was calculated based on the one-response pretest of Study 3 (see One-response pretest section in Study 3). For the betting game it was set to 4 s and for the lottery game it was set to 4.5 s. Note that this was a stricter deadline than in Study 1.

Two-response games. The experiment was run online on the Qualtrics (www.qualtrics.com) software server. The general instructions were the same as those in Study 1. However, here participants were told that, at the end of the study, one of their initial or final choices would be selected at random from each game, and would be played to determine the earnings for the option that they selected. It was specified that any money they made from the randomly selected bet and lottery pair would be added together and multiplied by a factor of 0.0013, meaning that they could earn from £0 to £1 extra in addition to their standard payment (i.e., a potential 40% increase in their total earnings).

With the exception of the initial response deadline, the practice and experimental trials were the same as in Study 1. As in Study 1, 1 s before the deadline the background of the screen turned yellow to warn participants that the time limit is approaching.

Finally, in both games the items were randomly presented, apart from the final item, which was always the same conflict item and was followed by a justification question. After they responded to this item, participants saw a screen that read "We are interested in the reasoning behind your response to the final bet/lottery". They were shown the item again and were asked to justify, in an open-response format, why they felt their previously entered response to the item was the most advantageous choice for them to make. We added this exploratory question to get an insight into the rationale participants used to arrive at their answers (see supplementary material I for an analysis of the justifications).

Counterbalancing. Each game (betting and lottery) was composed of ten[10] conflict, five no-conflict and five filler items. For each game separately, two sets of items (set A and set B) were created in which the conflict status of the conflict and no-conflict items was counterbalanced. More specifically, all the conflict items of set A appeared in their no-conflict version in set B, and all the no-conflict items in set A appeared in their conflict version in set B. It should be noted that in the betting game of this study, the values of the bets were slightly different compared to those of Study 1. This change allowed us to create a set B of items for counterbalancing, which was not possible with the bets of Study 1 (all items can be found in supplementary material B). In addition, we created two variations of the filler items for set A and set B respectively. The items of set B were created by increasing the items' values by €5-10, so that the EV difference remained the same in the respective items of both sets. Half of the participants were presented with set A while the other half was presented with set B. So, in both games, the same content was never presented more than once to a participant and everyone was exposed to the same items.

Exclusion Criteria

As in Study 1, the trials in which participants failed the load and/or the deadline were excluded from subsequent analyses.

Betting game. Participants failed to answer before the deadline on 3.5% of trials and failed the load task on 7.5% of trials. Overall, by rejecting the missed deadline and missed load trials we kept 89% of all trials. On average, each participant contributed 13.4 trials (out of 15 trials, *SD* = 1.8).

As in Study 1, to ensure that participants were not using an "always take the bet" heuristic in the betting game (see Filler bets subsection above), following our pre-registration, we ran a control analysis where we excluded participants that had an accuracy lower than 50% both in their initial and final filler trials (*n* = 8). In this control analysis all of our conclusions remained the same, suggesting that the heuristic did not bias our results. Therefore, in the results section below, we present the intended complete analysis without exclusions. The partial results excluding these participants are reported in supplementary material D.

Lottery game. Participants failed to answer before the deadline on 2.8% of trials and failed the load task on 8.5% of trials. Overall, by rejecting the missed deadline and missed load trials we kept 88.7% of trials. On average, each participant contributed 13.3 trials (out of 15 trials, *SD* = 1.9).

As in Study 1, to ensure that participants were not using a "pick the highest value" heuristic in the lottery game, following our pre-registration, we ran a control analysis where we excluded participants that had an accuracy lower than 50% both in their initial and final no-conflict trials (*n* = 3). In this control analysis all of our conclusions remained the same, so in the results section below we present the intended complete analysis without exclusions. The partial results excluding these participants are reported in supplementary material D.

[10] As noted, each conflict item was presented twice due to a coding error. However, we only analyzed the first presentation of each conflict item and discarded the repeated items.

Results and Discussion

Proportion of EV maximizing choices

As Figure 1 shows the accuracy results were very similar across Study 1 and Study 2, for both games.

Betting game. In the critical conflict trials of the betting game, the majority of responses were loss averse, but people still managed to provide EV maximizing responses. The proportion of EV maximizing responses reached 26.2% (*SD* = 34.4%) in the initial stage and 23.4% (*SD* = 32.3%) in the final stage, but a paired-samples t-test showed that this difference was not significant, $t(99) = 1.02$, $p = .31$, $d = 0.10$. Critically, these results again show that people managed to generate EV maximizing responses intuitively.

In the control, no-conflict trials, participants' accuracy remained at ceiling. The proportion of trials in which participants took the bet reached 95.8% (*SD* = 12.0%) in the initial stage and 97.7% (*SD* = 7.3%) in the final stage. Finally, as expected, the filler items had a high accuracy both in the initial (*M* = 77.1%, *SD* = 30.8%) and the final (*M* = 83.0%, *SD* = 26.8%) stage.

Lottery game. Similar to our previous results, most responses in the critical conflict trials of the lottery game were loss averse, but participants managed to provide EV maximizing responses. The proportion of EV maximizing responses reached 34.1% (*SD* = 32.2%) in the initial stage and 28.6% (*SD* = 32.4%) in the final stage, but a paired-samples t-test showed that this difference was not significant, $t(99) = 1.95$, $p = .05$, $d = 0.20$.

Concerning the control, no-conflict lottery pairs the proportion of trials in which participants chose the expected, "correct" lottery pair reached 86.8% (*SD* = 26.1%) in the initial stage and 93.1% (*SD* = 16.7%) in the final stage. In the filler items, as expected, the proportion of trials in which participants gave the correct response was high both in the initial (*M* = 82.5%, *SD* = 21.8%) and the final (*M* = 92.0%, *SD* = 15.2%) response stage.

Direction of change

In Study 2, the same direction of change analysis as in Study 1 was performed. As it can be seen in Figure 2, the direction of change analysis results were very similar across the two studies, for both games. The majority of conflict trials had a "00" pattern (66.0% in betting game; 56.9% in lottery game) which shows that, even after deliberation, most people remained loss averse. Critically, the "11" responses (15.6% in betting game; 19.6% in lottery game) were again more frequent than the "01" (7.8% in betting game; 9.0% in lottery game). The non-correction rate reached 66.7% for the betting game and 68.5% for the lottery game. It is worth noting that in Study 2 the proportion of "11" response slightly decreased and that of "01" slightly increased when compared to Study 1. However, the main response pattern remained the same in the sense that when people managed to provide an EV maximizing response after deliberation, they had often already arrived to this choice intuitively.

Stability index

The average stability index in Study 2 was 81.5% (*SD* = 21.1%) in the betting game, which was higher than 40% chance, $t(99) = 19.64$, $p < .001$, $d = 1.96$, and 73.1% (*SD* = 21.3%) in the lottery game, which was also higher than 40% chance, $t(99) = 15.51$, $p < .001$, $d = 1.55$. This response consistency further indicates that participants were not systematically responding randomly.

Confidence Ratings

As in Study 1, we looked at participants' initial confidence ratings to see whether people are intuitively sensitive to the EV of the conflict problems when making loss averse choices. Figure 3 shows the general mean initial confidence ratings for conflict and no-conflict trials as a function of response type (EV maximizing; Loss averse; Other). In the betting game, a Wilcoxon signed-rank test ($n = 91$) revealed lower confidence ratings in conflict loss averse responses ($M = 67.4\%$, $Mdn = 72.5\%$), compared to no-conflict correct responses ($M = 77.2\%$, $Mdn = 85.0\%$), $W = 791.0$, $Z = -4.65$, $p < .001$. Similarly, in the lottery game ($n = 86$), confidence in conflict loss averse responses ($M = 64.9\%$, $Mdn = 65.5\%$) was lower than in no-conflict correct responses ($M = 67.0\%$, $Mdn = 70.0\%$), but this difference was not significant, $W = 1261.0$, $Z = -1.56$, $p = .12$. Thus, in the betting game, participants showed an increased response doubt when making a loss averse choice, which suggests they were detecting that their answer conflicted with EV maximizing considerations. Importantly, this happened in the initial response stage where deliberation was minimized.

As in Study 1, we also observed a confidence decrease for conflict EV maximizing responses. In the betting game, a Wilcoxon signed-rank test ($n = 47$) revealed lower confidence ratings in conflict loss averse responses ($M = 54.9\%$, $Mdn = 60.0\%$), compared to no-conflict correct responses ($M = 78.8\%$, $Mdn = 87.5\%$), $W = 33.5$, $Z = -5.30$, $p < .001$. Similarly, in the lottery game ($n = 68$), confidence in conflict loss averse responses ($M = 59.3\%$, $Mdn = 60.0\%$) was lower than in no-conflict correct responses ($M = 65.0\%$, $Mdn = 67.5\%$), $W = 577$, $Z = -2.80$, $p = .01$. Hence, EV responders also showed sensitivity to the alternative loss averse option.

I. Justifications

In Studies 2 and 3 the last presented item in the betting game and the lottery game was always the same (hard-) conflict item. After responding to this item participants were asked to provide a rationale for their final, deliberate response in an open-response format. This appeared on the screen (the instructions were adapted accordingly for the lottery game):

> We are interested in the reasoning behind your response to the final bet:
>
> If you take this bet you have:
> **25%** probability to **WIN €85**
> **75%** probability to **LOSE €25**
> Do you take the bet?
> - o Yes
> - o No
>
> Could you please justify, why do you think that your previously entered response is the most advantageous choice for you?

Based on the justifications, the authors defined post-hoc categories. If the justification was given to an EV maximizing response, it was categorized as "Expected Value" or "Gambler" in the betting game and as "Expected Value" or "Partial information" in the lottery game. An "Expected Value" justification referred to the amounts, the probabilities and their relationship (e.g., "The amount you can win is more than the amount you'd statistically lose at the given probabilities. So, say, in 4 bets, you would lose 75 but gain 80, netting 5."). In the betting game, a "Gambler" justification did not refer to the amounts and probabilities, but simply to a preference for gambling (e.g., "I only just preferred to take the risk, it was practically 50/50."). In the lottery game, a "Partial information" justification focused only on the first line of the lotteries (i.e., on the amounts corresponding to the large probabilities, e.g., "80% is a good chance at winning so I think that A will be better for me to maximize my potential winnings.").

If the justification was given to a loss averse response, it was categorized as "Loss aversion" or "Probabilities & Values". A "Loss aversion" justification referred either to the amount or the probabilities, but not to both (e.g., "The loss is too great to justify taking the risk. To lose 25 is too much to gamble away."). A "Probabilities & Values" justification referred both to the amounts and the probabilities (e.g., "It's quite a low chance to win a small amount with a high chance of losing a sizeable amount.").

After the categories were defined, two coders classified the justifications. In the cases when an agreement was not reached, a third coder provided a classification and the most common category amongst the three coders was chosen. If none of the three coders agreed on a category or if they could not classify the justification to one of the categories, the justification was coded as "Other".

As it can be seen in Table S8, in the betting game, the majority of (the few) participants that chose the EV maximizing option could also explicitly justify it using expected value principles. In the lottery game however, most participants that opted for the EV maximizing choice failed to do this, and only focused on the largest probability when explicitly justifying their choice. In both games, when participants gave the loss averse option, about half the time they could justify it focusing both on the amounts and their probabilities. This indicates that in their explicit justifications about half of the loss averse participants considered all the necessary information (i.e., amounts and probabilities), while the other half only focused on either the amounts or the probabilities. For completeness, the average confidence levels for each justification category are reported in Table S9.

Table S8. Frequency (and count) of each justification category as a function of the type of response (EV maximizing; Loss averse), game (Betting game; Lottery game), and study (Study 2; Study 3). The justifications for EV maximizing responses are separated into the "Expected value", "Gambler/Partial information" and "Other" categories, while those for the loss averse responses are separated into the "Loss aversion", "Probabilities & Values" and "Other" categories.

Response	Justification category	Betting game		Lottery game	
		Study 2	Study 3	Study 2	Study 3
EV maximizing	Expected value	53.9% (7 out of 13)	42.9% (6 out of 14)	23.7% (9 out of 38)	32.1% (9 out of 28)
	Gambler	7.7% (1 out of 13)	28.6% (4 out of 14)		
	Partial information			57.9% (23 out of 38)	46.4% (13 out of 28)
	Other	38.5% (5 out of 13)	28.6% (4 out of 14)	18.4% (7 out of 38)	21.4% (6 out of 28)
Loss averse	Loss aversion	48.5% (32 out of 66)	50.8% (34 out of 67)	50.0% (28 out of 56)	36.8% (24 out of 57)
	Probabilities & Values	43.9% (29 out of 66)	46.3% (31 out of 67)	28.6% (16 out of 56)	42.1% (21 out of 57)
	Other	7.6% (5 out of 66)	3.0% (2 out of 67)	21.4% (12 out of 56)	21.1% (12 out of 57)

Table S9. Means (and standard deviations) of the average confidence of each justification category as a function of the type of response (EV maximizing; Loss averse), the game (Betting game; Lottery game), and the study (Study 2; Study 3). The justifications for EV maximizing responses are separated into the "Expected value", "Gambler/Partial information" and "Other" categories, while those for the loss averse responses are separated into the "Loss aversion", "Probabilities & Values" and "Other" categories.

Response	Justification category	Betting game		Lottery game	
		Study 2	Study 3	Study 2	Study 3
EV maximizing	Expected value	91.9 (13.9)	85.8 (15.0)	83.9 (14.5)	86.1 (10.5)
	Gambler	51.0 (*NA*)	28.3 (10.1)		
	Partial information			75.5 (24.2)	79.6 (16.9)
	Other	48.0 (39.6)	28.3 (10.1)	64.3 (24.4)	58.0 (37.0)
Loss averse	Loss aversion	80.0 (17.7)	79.1 (23.4)	84.5 (17.6)	83.7 (14.1)
	Probabilities & Values	79.0 (23.5)	83.0 (16.7)	84.8 (19.4)	84.5 (14.4)
	Other	56.0 (35.3)	3.0 (4.2)	82.1 (23.0)	78.3 (18.5)