Regret, Feedback and Risk Taking Behavior

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Abstract

Anticipated regret is primarily determined by the information (feedback) the decision-maker expects to receive about the outcomes of the options she did not choose. We examine how feedback influences a regret-averse decision-maker's well-being and risk-taking behavior. To achieve this, we use the concept of Blackwell sufficiency to categorize the different feedback structures based on their informational content. As regret aversion and feedback aversion are inextricably linked, we determine the conditions under which a regret-averse decision-maker is feedback-averse: the decision-maker is better off when feedback is less informative. Additionally, we demonstrate that in regret theory, risk-taking behavior is shaped by risk preferences, regret aversion, and feedback informativeness. In particular, when the DM is feedback-averse, the risk premium decreases as feedback becomes more informative. We offer a new theoretical perspective on the Allais paradox, suggesting that participants in Allais' experiment do not expect to receive information about the unchosen lottery outcomes. This particular informational context must be considered when analyzing the paradox with regret theory. Our approach also allows us to differentiate the roles of risk and regret aversion in the Allais paradox. We show that risk aversion and regret aversion are partially substitutable in the genesis of the choices that characterize the paradox.

Keywords: Regret theory, feedback, Risk-taking, Risk premium, Allais paradox.

JEL classification D80 . D81 . D91

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1 Introduction

Regret occurs when individuals compare the outcomes of a chosen alternative with those of the alternatives they did not select. This comparison relies heavily on the individual's knowledge about the payoffs of the options that were not chosen (feedback). Numerous empirical studies emphasize the influence of anticipated regret and the significant role that feedback plays in decision-making. However, regret theory (RT) has not thoroughly explored this topic, as much of it assumes perfect information, where the payoffs of the unchosen alternatives are fully observable. Among the few exceptions, Bell (1983) considers the possibility of the unchosen option being unresolved when a decision maker (DM) has the choice between two lotteries. More recently, Gabillon (2020) proposed a general model that makes it possible to consider any level of feedback on the foregone alternative payoffs. Gabillon (2020) shows that anticipated regret does depend on anticipated feedback. Bell (1983) was the first to understand that feedback is not neutral to a regret-averse DM. Considering an additive regret-utility function and a choice set containing two risky alternatives, the author obtains, under a series of assumptions, that a DM would prefer to have the foregone lottery unresolved rather than fully resolved. Curiously, this critical result has yet to be further developed and explored in the literature on RT. This paper presents a theoretical analysis of how feedback influences a regret-averse DM's well-being and risk-taking behavior.

On the empirical side, Van Dijk and Zeelenberg (2005) find that factors limiting the feedback regarding the foregone alternative outcome mitigate the experience of regret. Evidence also suggests that people tend to adopt options that shield them from potentially regret-inducing feedback about unchosen alternatives (Josephs *et al.*, 1992; Larrick and Boles, 1995; Zeelenberg *et al.*, 1996; Zeelenberg and Beattie, 1997; Shani and Zeelenberg, 2007). Although they seem different, feedback aversion and regret aversion are very closely related since feedback makes anticipated regret more salient. Feedback aversion has been documented in empirical studies. In what follows, we briefly review these empirical investigations, distinguishing between post-decisional and feedback pre-decisional aversion. We define feedback post-decisional aversion as when a DM observing the result of their choice prefers not to have feedback about the outcomes of their foregone options. In contrast, we define feedback pre-decisional aversion as a preference for not receiving future feedback. This preference is occurs when the DM is making their choice. Pre-decisional feedback aversion can significantly influence decision-making.

Post-decisional feedback aversion is highlighted in Reb and Connolly (2009)'s experimental study: in repeated decision-making tasks, after learning the outcome of their chosen option, people tend to reject feedback on foregone options to avoid short-term regret, at the cost of reduced learning and poor long term performance. Mechera-Ostrovsky *et al.* (2023) reports more ambiguous findings. In their experiment, the authors employed a standard method to assess risk preferences. Each participant made a series of choices between a fixed lottery and increasing amounts of guaranteed winnings. When a participant preferred a guaranteed win over the lottery, they were asked to rate their interest in learning the outcome of the gamble they chose not to take. The study found that as the value of the accepted guaranteed win increased, so did the desire for feedback regarding the outcome of the forgone gamble. This result suggests that feedback aversion declines or disappears with higher sure-win values, likely due to an increased potential for rejoicing. Another branch of the empirical literature (Shani and Zeelenberg, 2007; Shani *et al.*, 2008; Summerville, 2011) shows that experienced regret prompts post-decisional feedback seeking. Individuals who experience post-decisional regret—believing they could have made a better decision—are more likely to seek information about the unchosen alternative in the hope of alleviating their feeling of regret. Given the disparity in results, more empirical observations are required to have a clear overview of post-decisional feedback preferences. It seems to emerge from available studies, however, that post-decisional feedback preferences could depend on the chosen alternative's outcome. In this paper, we do not postulate feedback post-decisional aversion.

In contrast, feedback pre-decisional aversion, although less frequently studied in empirical research, benefits from more consistent empirical support. Zeelenberg *et al.* (1996) performed an experiment in which participants, when making their decision, try to avoid future feedback on the foregone options. The experiment set up two risky lotteries to which participants were indifferent. Indifference, as regards the two lotteries, is established when there is no feedback on the foregone lottery. People exclusively obtain feedback on the lottery of their choice. One of the two lotteries is relatively risky, the other relatively safe. Zeelenberg *et al.* (1996) modify the feedback context and observe the behavioral consequences. When people know that the result of the relatively safe lottery will be systematically revealed, they are no longer indifferent, tending to prefer the relatively safe lottery. People try to protect themselves against having information about the relatively safe lottery if they choose the risky lottery. Zeelenberg *et al.* (1996) show that regret aversion induces risk-avoiding behavior (when people expect feedback on the safe lottery) or risk-seeking behavior (when people anticipate feedback on the risky lottery). Inman and Zeelenberg (1998) find similar results in experiments involving consumer decisions rather than lottery choices. To our knowledge, there is no empirical evidence of pre-decisional feedback seeking. Naturally, future feedback about the outcomes of foregone options presents not only the risk of future regret—when the chosen option performs worse than the alternatives—but also the potential for future rejoicing—when it performs better (Bell, 1982; Loomes and Sugden, 1982). However, feedback pre-decisional aversion can be understood through another important finding: anticipated regret tends to have a stronger effect on decision-making than anticipated rejoicing. Numerous empirical studies consistently demonstrate that anticipated regret more significantly influences choice behavior than anticipated rejoicing (Zeelenberg and Beattie, 1997; Mellers *et al.*, 1999; Mellers, 2000). Besides, substantial evidence suggests that decision-makers are more motivated to avoid negative experiences than to pursue positive ones (Kahneman and Tversky, 1979; Taylor, 1991). Boles (1991, 1992) found evidence that the satisfaction of receiving an outcome that is better than an alternative's outcome is not as great as the dissatisfaction of receiving a worse outcome. Psychological research further supports this asymmetry, showing that counterfactual thinking tends to be more focused on how outcomes could have been improved rather than on how they could have been worse (Gilovich, 1983; Roese, 1997; Epstude and Roese, 2008).

Given the above, we find feedback pre-decisional aversion to be the most interesting assumption to explore. Building on Gabillon (2020)'s work, we explicitly model feedback as signals received after the choice about the outcomes of the options that were not chosen. Each alternative is associated with a signal about the other options' outcomes. In this paper, we use Blackwell sufficiency (Blackwell, 1951) to classify the different feedbacks according to their informational contents: feedback F_A is said to be more informative on the foregone option outcomes than F_B if signals under F_A are Blackwell sufficient for signals under F_B. We define feedback pre-decisional aversion, later referred to as feedback aversion: a decision-maker is feedback-averse if they prefer to avoid future feedback on the outcomes of the options they did not choose. More specifically, a feedback averse DM prefers F_B over F_A when F_A is more informative than F_B. We determine sufficient conditions under which a regret-averse DM is feedback-averse. For a feedback-averse DM, the non-informative feedback represents the best situation, and the perfectly informative feedback represents the worst situation.

This paper also studies the impact of regret aversion and feedback on risk-taking behavior. In uncertainty economics, disentangling the effects of risk and regret aversion on risk-taking behavior remains empirically and theoretically underexplored. This issue is addressed in empirical studies on sealed-bid first-price auctions (Filiz-Ozbay and Ozbay, 2007; Engelbrecht-Wiggans and Katok, 2009). In these experiments, people's tendency to bid higher than the risk-neutral Nash equilibrium is explained by the anticipation of loser regret (the regret of not having bid enough) rather than risk aversion. To our knowledge, Somasundaram and Diecidue (2017) is the only theoretical and experimental paper examining risk attitudes under regret aversion. The authors consider two opposite situations: perfect feedback and no feedback. They do not, however, model feedback. They use the preferences of Bell (1982) and Loomes and Sugden (1982), assuming that feedback increases regret aversion. Indeed, the authors conjecture that feedback makes anticipated regret more salient. Empirically, the authors obtain strong support for regret aversion, but no confirmation of the risk attitudes predicted by their model. In this paper, our approach is different. We explicitly model feedback and we do not assume that feedback modifies regret aversion. We consider that preferences are independent of feedback, and we look at how risk behavior changes when feedback is modified. We show that, when the feedback is non-informative, the risk premium under regret aversion is higher than the Arrow-Pratt risk premium. We refer to this result as a preference for certainty. When they do not expect to learn the result of the risky lottery, a regretful DM will likely choose the sure thing more than a von Neumann-Morgenstern DM (henceforth vNM DM). The sure thing fully protects the DM against anticipated regret: after choosing the sure thing, the DM cannot observe the lottery's payoff and compare it to the sure thing. Consequently, the DM does not experience regret. Independently of risk preferences, this protection against anticipated regret strengthens the attractiveness of the sure thing and increases the risk premium compared to the Arrow-Pratt risk premium. We go further by showing that, under feedback aversion, the risk premium decreases with the informativeness of the feedback. The risk premium is thus maximal when the feedback is non-informative and minimal when the feedback is perfectly informative. The informational context influences risk-taking behavior. Under a non-informative feedback, the choice of the sure thing fully protects the DM against anticipated regret. When, however, some information about the risky lottery is available after the choice, the sure thing no longer offers complete protection against regret and becomes less attractive. We even show that, under a perfectly informative feedback, the preference for certainty can give way to a reverse phenomenon: the risk premium can be lower than the Arrow-Pratt risk premium, which reveals a preference for uncertainty. Risk preferences, regret aversion and feedback are all factors that determine risk-taking behavior. Empirical studies illustrate this result. Zeelenberg (1999) show that people are more likely to choose the certain outcome over a risky lottery when they do not expect to learn the result of the lottery, compared to when they do. Similarly, Larrick and Boles (1995) investigate the impact of anticipated regret on risk-taking in negotiation decisions. The authors conducted an experiment where a buyer negotiates a price with a seller. Each negotiator was presented with a random external opportunity. The results showed that people tend to be more risk-averse in their negotiation choices—meaning they are more likely to accept unfavorable prices—when they do not expect to receive feedback on their external opportunity. Conversely, when feedback is expected, the potential for regret regarding the negotiation outcome increases, making the negotiation process tougher.

In our model, we also consider a feedback-averse DM indifferent between two risky options, Y_1 and Y_2. We show that providing additional information about the outcome of Y_2 if Y_1 is chosen causes the DM to be no longer indifferent, favoring now Y_2. Feedback aversion promotes risk-taking when Y_2 is the riskier option and encourages risk-avoidance when Y_2 is the safer choice. This finding is in complete agreement with the observations made by Zeelenberg *et al.* (1996) (see above in this introduction). The consistency of our findings with empirical observations lends support to the feedback aversion hypothesis.

Finally, we reexamine the risk-taking behavior observed in the common consequence effect (CCE) version of the Allais paradox, paying attention to the type of feedback that characterizes this experience. Regret theory has already tackled the problem of preference reversal within the CCE (Loomes and Sugden, 1982; Bleichrodt and Walker, 2015). These works are carried out under the implicit assumption of perfect feedback. However, it is not clear that participants in Allais' experiment expected to receive information about the outcomes of the lotteries they did not choose. Bell (1982) points out that the problem statement in Allais' experiment does not specify whether the unchosen gamble will be resolved. In this paper, we argue that when people are asked to select their preferred lottery without further details, they are unlikely to anticipate the resolution of the alternative they did not choose. The most natural (and even unconscious) attitude is not to expect the resolution of the unchosen lottery. Therefore, we propose a new analysis of the Allais paradox based on the assumption of non-informative feedback. Our explanation of the paradox differs from the perfect feedback approach of Loomes and Sugden (1982) and Bleichrodt and Walker (2015). We demonstrate how a non-informative feedback accounts for the risk-taking behavior observed in the Allais paradox. The typical choice pattern observed in the first step of Allais' experiment shows a preference for the safe option over the risky lottery. Even though the risky lottery nearly dominates the safe option in terms of first-order stochastic dominance, most individuals opt for the safe option. This preference suggests extreme levels of risk aversion under expected utility theory (EUT). We refer to the EUT's failure to adequately explain the preference for the safe option in the Allais' experiment as the 'certainty bias puzzle.' This terminology draws an analogy to the 'equity premium puzzle,' which highlights EUT's inability to rationalize the US financial equity premium without assuming unrealistically high levels of risk aversion (Mehra and Prescott, 1985). The certainty bias is distinct from the 'certainty effect' proposed by Kahneman and Tversky (1979) to account for preference reversal in the presence of a sure option. What we call the certainty bias puzzle is not related to the violation of the independence axiom; it stands independently of the second choice made in Allais' experiment. Both RT under perfect feedback and the certainty effect of Kahneman and Tversky aim to explain the preference reversal observed in the Allais experiment. However, neither of these approaches clarifies why individuals tend to prefer the safe option over the risky lottery in the initial step of the experiment. In our model, non-informative feedback, combined with regret aversion, proves to be the key factor in explaining the certainty bias puzzle. The preference for certainty, mentioned earlier in this introduction, explains the certainty bias puzzle. Under a non-informative feedback, the safe option offers complete protection against anticipated regret. We can predict the safe lottery's choice without assuming extreme levels of risk aversion, as in the EUT. Except for high-risk lovers, our model predicts the safe choice if people are sufficiently regret-averse. Besides, except for high risk-averse (who are expected to make choices consistent with the EUT) and high risk-lover DMs, our model can also predict the preference reversal which characterizes the Allais paradox. Furthermore, unlike previous explanations of the Allais paradox using RT, our model enables us to distinguish the effects of risk aversion and regret aversion on decision-making. We identify risk and regret aversion ranges that make preferences consistent with the CCE choice pattern. The paper is organized as follows: Section 2 discusses the concept of feedback and categorizes the different types of feedback according to their informativeness. Section 3 discusses preferences and introduces feedback aversion. Section 4 examines the risk-taking behavior of a regret-averse DM. Finally, Section 5 focuses on an analysis of the Allais paradox under a non-informative feedback.

2 Feedback

In this section, we use the concept of feedback introduced in Gabillon (2020) and we introduce the concept of sufficiency. Let $\Phi = \{Y_1, .., Y_{N+1}\}$ denote the set of $N+1$ risky alternatives. A risky alternative Y_n is a random variable taking its values on a set Ω, which contains a finite number of positive values. Without loss of generality, let X denote the chosen alternative and $Y_1, .., Y_N$ the foregone alternatives. In the rest of the paper, either $\{Y_1, .., Y_{N+1}\}$ or $\{X, Y_1, .., Y_N\}$ will refer to the choice set Φ depending on whether we need or not to distinguish the chosen alternative X from the other alternatives. To shorten our notations, let θ denote the realized payoffs $x, y_1, .., y_N$ and θ_{-X} the foregone realized payoffs $y_1, .., y_N$ when alternative X has been adopted. Let $p\left(\theta\right)$ denote the prior probability distribution of θ. We assume that, after the choice, a DM receives information about the alternative payoffs θ and revises their prior accordingly. When alternative X is adopted, the information obtained by the DM is a collection of probability spaces $\left\{\left(\mathcal{M}_X, \mathcal{F}_X, P_X^\theta\right)\right\}_{\theta \in \Omega^{N+1}}$, where $(\mathcal{M}_X, \mathcal{F}_X)$ is a measurable space representing the space of all possible signals endowed with a family of probability measures P_X^θ. A signal on state of nature θ is a random variable M_X taking its value m_X in $\mathcal{M}_X$. The probability distribution P_X^θ will, henceforth, be denoted by its generic term $p\left(m_X \left|\theta\right.\right)$. Probability $p\left(m_X \left|\theta\right.\right)$ represents the conditional probability of $M_X = m_X$ given the realized payoffs θ.

We also assume that a DM observes the payoff of the alternative they have selected: $\forall X \in \Phi$, signal M_X perfectly reveals the payoff x of the chosen option X. Definitions 1, 2 and 3 are from Gabillon (2020):

Definition 1. *M_X is said to be non-informative if the probability distribution of M_X is the same for all θ_{-X}: $\forall x \in \Omega, \forall\ \theta_{-X} \in \Omega^N$, $p\left(m_X \left|x, \theta_{-X}\right.\right) = p\left(m_X \right| x)$. One cannot learn about θ_{-X} by observing from M_X.*

M_X is said to be perfectly informative if for every pair $\left(\theta^i_{-X}, \theta^j_{-X}\right) \in \Omega^N \times \Omega^N$, the intersection of the support sets on which $p\left(m_X \left|\theta^i_{-X}, x\right.\right)$ and $p\left(m_X \left|\theta^j_{-X}, x\right.\right)$ are strictly positive is an empty set. After observing M_X, θ_{-X} can be identified with certainty.

M_X is said to be imperfectly informative in all other situations.

Hereafter, we give the definition of a feedback associated to a choice set Φ:

Definition 2. *The feedback F_Φ, associated to the choice set $\Phi = \{Y_1, .., Y_{N+1}\}$, consists of the signals associated with each alternative in the choice set:*

$F_\Phi = \left\{M_{Y_1}, ..., M_{Y_{N+1}}\right\}$

Definition 3. *F_Φ is said to be non-informative if $\forall Y_n \in \Phi, M_{Y_n}$ is non-informative (see Definition 1). A non-informative feedback will be denoted by F_Φ^{ni}.*

F_Φ is said to be perfectly informative if $\forall Y_n \in \Phi, M_{Y_n}$ is perfectly informative (see Definition 1). A perfectly informative feedback will be denoted by F_Φ^{pi}.

F_Φ is said to be imperfectly informative in all other situations.

Given that correlations between the alternatives are possible, a DM can infer information about the foregone options by observing the chosen alternative's payoff, regardless of the feedback. These correlations stem from the structure of the choice set and not from the feedback itself. In the following discussion, we will compare the informativeness of different feedbacks while maintaining a constant choice set and its associated correlations.

In this paper, we use the criteria of Blackwell sufficiency to compare the informational content of two different signals M_X^a and M_X^b. The concept of Blackwell sufficiency is used to compare information systems in the information economics literature (see for example Kihlstrom 1974).

Definition 4. *M_X^a is Blackwell sufficient[1] for M_X^b relative to θ_{-X} if there exits a stochastic transformation $\pi\left(m_X^b\left|m_X^a\right.\right)$ such that*

$$\forall\theta \in \Omega^{N+1}, \forall m_X^b \in \mathcal{M}_X,\ p\left(m_X^b\left|\theta\right.\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^b\left|m_X^a\right.\right) p\left(m_X^a\left|\theta\right.\right)$$

with $\sum_{m_X^b \in \mathcal{M}_X} \pi\left(m_X^b\left|m_X^a\right.\right) = 1, \forall m_X^a \in \mathcal{M}_X.$

M_X^a is sufficient for M_X^b means that M_X^a is at least as good as M_X^b for learning about θ. We move from signal M_X^a to signal M_X^b by adding noise.

With the concept of sufficiency, we define a partial ordering on the set of all feedbacks:

Definition 5. *F_Φ^a is sufficient for F_Φ^b if, $\forall Y_n \in \Phi$, $M_{Y_n}^a$ is Blackwell sufficient for $M_{Y_n}^b$.*

To go further, we introduce the following assumption:

A1. $\forall Y_n \in \Phi$, two signals $M_{Y_n}^a$ and $M_{Y_n}^b$ belonging to two alternative feedbacks, F_Φ^a and F_Φ^b, are conditionally independent given θ: $p\left(m_X^b\left|m_X^a, \theta\right.\right) = p\left(m_X^b\left|\theta\right.\right)$.

[1] It is also said that M_X^b is a Blackwell garbling of M_X^a.

Assumption $A1$ rules out uninteresting situations that have no connection with reality in which, given θ, a signal $M^a_{Y_n}$ provides information about another signal $M^b_{Y_n}$, which would have taken place under another feedback. $A1$ is verified when, for example, signals give information exclusively on θ.

We obtain the following Proposition:

Proposition 1. *F^{pi}_{Φ} is sufficient for any feedback. Under $A1$, any feedback is sufficient for F^{ni}_{Φ}.*

Proof. Proof See Appendix A. □

3 Preferences and feedback aversion

In this section, we will discuss the choice of Gabillon (2020)'s utility function used in this article and then present this utility function. Regret theory is known to exhibit intransitivity in pairwise choice situations. Specifically, a DM might prefer option Y_1 over Y_2, prefer Y_2 over Y_3, yet still prefer Y_3 over Y_1. At first glance, this intransitivity suggests that an individual with regret-based preferences could be vulnerable to a money pump, where a sequence of pairwise choices among three or more options gradually leads to repeated losses, potentially depleting their wealth to zero over time. For example, suppose the DM initially chooses Y_3 over Y_1. She is then willing to pay a positive amount of ε_1 to exchange Y_3 for Y_2; subsequently, they are willing to pay ε_2 to exchange Y_2 for Y_1, and finally, ε_3 to exchange Y_1 for Y_3, returning to their original position with reduced wealth. In this setup, a manipulator orchestrating these pairwise choices faces no risk and secures a guaranteed gain of $\varepsilon_1 + \varepsilon_2 + \varepsilon_3$. Repeating this cycle enough times could ultimately deplete the DM's wealth to zero. However, Loomes and Sugden (1987) have argued that individuals with regret-based preferences would, in such situations, take into account the complete set of options (Y_1,Y_2 and Y_3 in this example). As a result, they would be immune to exploitation via a money pump. Only purely myopic decision-making would leave individuals vulnerable.

In the case of a general choice set, Quiggin (1994) has shown that another form of manipulation remains possible, one that is immune to the argument of Loomes and Sugden. If introducing a state-dominated alternative into the choice set affects preferences, the DM remains vulnerable to a money pump. For instance, suppose that option A is preferred to B in a pairwise choice and that this preference can be reversed by adding an unattractive alternative, which is state-dominated by either A or B. Each time such a state-dominated alternative is introduced, the manipulator triggers a switch in preference between A and B and extracts a payment. This form of money pump evades the defense of Loomes and Sugden (1987) since the manipulator continuously alters the choice set. The general utility function axiomatized by Sugden (1993) is vulnerable to this type of manipulation when it assigns a positive weight to every available option:

$$u(X, \{Y_1, .., Y_{N+1}\}) \tag{1}$$

where X represents the random payoff of the chosen alternative X.

Quiggin (1994) has further demonstrated that non-manipulable preferences, which satisfy the irrelevance of statewise dominated alternative (ISDA property), require that regret depend solely on the best outcome in each state of the world. Quiggin's regret-utility function (r-utility function) is written as follows:

$$u(X, R) \tag{2}$$

with $R = Max\{Y_1, .., Y_{N+1}\}$.

The reference point R is defined as the payoff of the best-performing option. R reflects the impact of anticipated regret on the DM's utility. Regret is experienced when the event $R > X$ occurs. Although derived from non-manipulability principles rather than psychological insights, Quiggin also noticed that his reference point corresponds with the core intuition of regret. Regret, by its very nature, is an emotion anchored in counterfactual evaluation. It is elicited by the recognition that another course of action—specifically, the one that *ex-post* yields the best possible outcome—was available but not taken. As noted by Van Dijk and Zeelenberg (2005), "People experience regret when they realize that they would have been better off had they decided differently." This definition implicitly invokes an optimization criterion: the counterfactual benchmark for regret is the alternative that would have produced the highest utility for the decision maker—i.e., the option that, had it been selected, would have maximized their welfare. In this paper, we uphold this definition of regret by utilizing the utility function of Gabillon (2020), which extends Quiggin's reference point to account for imperfect feedback. Unlike Quiggin, however, we cannot derive this utility function from a non-manipulability criterion. Quiggin obtains his non-manipulability result under perfect feedback and the implicit assumption that feedback is not manipulable. When these two assumptions are not held (as in this paper), regardless of the utility function, a manipulator can always take advantage of feedback to create a money pump, provided that preferences are affected by feedback. For instance, consider that option A is favored over option B when there is feedback about the option that is not chosen but that option B is preferred over option A when there is no feedback. The manipulator can obtain a payment each time the feedback is altered. Does this imply that the RT cannot be applied to situations with different levels of feedback? We don't believe that to be the case. Manipulation relies on somewhat unrealistic assumptions: namely, that the manipulator possesses perfect knowledge of the decision maker's preferences, and that the DM lacks the foresight to decline participation in a game where they are vulnerable to manipulation. In this paper, we utilize Gabillon (2020)'s utility function, as it effectively captures the counterfactual optimization associated to regret[2].

In what follows, we briefly recall the approach of Gabillon (2020) (Definitions 6 and 7, assumptions $A2$ to $A5$). Gabillon generalizes the concept of choiceless utility (c-utility), which was first introduced by Loomes and Sugden (1982) and Bell (1982):

Definition 6. *The c-utility function, defined as $v(x) = u(x, x)$, measures the satisfaction generated by the consumption of payoff x.*

The c-utility function represents preferences in which sensitivity to regret has been removed ($r = x$) and corresponds to the DM's preferences if they were not regret-averse. After the choice, when the DM observes the chosen alternative's outcome and receives feedback on the foregone

[2] Other elements that we do not consider can influence feelings of regret. For instance, the number of alternatives that turn out to be better than the chosen option can impact the level of regret experienced. There is a lack of empirical investigations on this topic. However, we believe that the reference point, which focuses on the best-performing option, captures the essence of regret effectively.

alternatives, the $N+1$ alternatives are evaluated and compared with the c-utility function. Function $v(.)$ also represents a benchmark, which will allow us to compare the results obtained under regret aversion with those in the EUT.

Let $u_1(x,r)$ denote $\frac{\partial u(x,r)}{\partial x}$, $u_2(x,r)$ denote $\frac{\partial u(x,r)}{\partial r}$ and $v^{'}(x)$ denote $\frac{\partial v(x)}{\partial x}$. Gabillon (2020) makes the following assumptions about the r-utility function $u(x,r)$:

A2. The r-utility $u(x,r)$ is differentiable on $\mathbb{R}^{+2}$.

A3. $v'(x) = u_1(x,x) + u_2(x,x) > 0$.

A4. $u_1(x,r) > 0$.

A5. $u_2(x,r) < 0$.

Assumptions $A3$ and $A4$ state that the utility increases with payoff x. Assumption $A5$ characterizes regret aversion. Regret aversion means that the DM considers the experience of regret to be unpleasant. Given payoff x, anticipated regret increases with the reference point, which decreases utility.

After observing the signal M_X, the DM revises their prior probability $p(\theta)$ in a Bayesian way. After the information has been processed, beliefs are characterized by the posterior probability distribution $p(\theta|M_X)$. The DM evaluates the $N+1$ alternatives with the posterior probability distribution and the c-utility function. We can compute the posterior Arrow-Pratt certainty equivalent of a foregone alternative Y_n with the marginal posterior probability distribution $p(y_n|M_X)$:

$$v\left(CE_{Y_n}^{v,M_X}\right) = E\left[v(Y_n)|\, M_X\right], \tag{3}$$

where the operator $E[.|\, M_X]$ represents the conditional expectation, given the signal M_X. The notation $CE_{Y_n}^{v,M_X}$ indicates, in superscript, that the Arrow-Pratt certainty equivalent is computed with the c-utility function $v(.)$, given information M_X.

In this framework, $CE_{Y_n}^{v,M_X}$ represents the value of alternative Y_n given feedback M_X. The values of the foregone alternatives represent the DM's opinion about the performance of the nonchosen options. The feeling of regret arises from the comparison between the chosen alternative's payoff X and the values of the foregone options.

The following two definitions describe Gabillon (2020)'s utility function:

Definition 7. *The reference point R^{M_X} is the highest posterior Arrow-Pratt certainty equivalent:* $R^{M_X} = Max\left\{X, CE^{v,M_X}_{Max}\right\}$ *with* $CE^{v,M_X}_{Max} = Max\left\{CE^{v,M_X}_{Y_1}, ..., CE^{v,M_X}_{Y_N}\right\}$.

Under assumption $A3$, the reference point is the value of the alternative which maximizes the expected c-utility, given available information after the choice. The DM compares the chosen alternative's outcome X to the values of the foregone alternatives. In the event $R^{M_X} > X$, the DM regrets their choice since a foregone alternative proves to be more attractive than the chosen alternative. It is important to highlight that a non-informative feedback does not protect against feelings of regret. Consider a decision between playing Lottery X or Lottery Y. Lottery X has outcomes of 40 or 0, while Lottery Y offers outcomes of 20 or 10. If a DM chooses Lottery X and ends up with a payout of zero, they may regret not selecting Lottery Y, even if they never see the outcome of Lottery Y. Gabillon (2020) argues that the DM compares the result of Lottery X with the value of Lottery Y calculated based on the information available after making the choice (see Equation 3). This comparison can lead to feelings of regret even when the feedback M_X is not informative about Y. In our example, regardless of the informativeness of M_X, we have $CE^{v,M_X}_{Y} \in [10, 20]$. Regret is systematically felt when $X = 0$ since $0 < CE^{v,M_X}_{Y}$.

Definition 8. *The preferences of a regret-averse DM are given by* $E\left[u\left(X, R^{M_X}\right)\right] = E\left[u\left(X, Max\left\{X, CE^{v,M_X}_{Max}\right\}\right)\right]$.

The properties of these preferences are analyzed in Gabillon (2020). The reference point excludes the feeling of rejoicing an individual may experience when their chosen alternative outcome is better than the foregone alternatives. As empirical studies find that the fear of regret outweighs the appeal of rejoicing in decision-making (see Introduction), we focus on regret aversion.

In this paper, we introduce the definition of feedback aversion:

Definition 9. *If F_{Φ}^{a} is sufficient for F_{Φ}^{b} then a feedback-averse DM prefers F_{Φ}^{b} to F_{Φ}^{a}:* $\forall X \in \Phi, E\left[u\left(X, Max\left(X, R^{M_X^a}\right)\right)\right] \leq E\left[u\left(X, Max\left(X, R^{M_X^b}\right)\right)\right]$.

A feedback-averse DM prefers to minimize their exposure to future feedback about the foregone alternatives. Note that Definition 9 considers feedback pre-decisional aversion which occurs at the time of decision-making, before any uncertainty is resolved. When making a choice, a feedback-averse DM prefers to stay as uninformed as possible about the outcomes of the foregone option.

From Proposition 1 and Definition 9, we obtain the following corollary:

Corollary 1. *Among all feedbacks, F_{Φ}^{pi} represents the worst feedback for a feedback-averse DM. Under $A1$, among all feedbacks, F_{Φ}^{ni} is the preferred feedback.*

While Definition 9 considers the feedbacks that can be ordered with the sufficiency criteria, we stress the generality of Corollary 1. Among all feedbacks (without any restrictions), a feedback-averse DM prefers the non-informative feedback. Similarly, among all feedbacks, the perfectly informative feedback represents the least desirable one.

Let $u_{22}(x, r)$ denote $\frac{\partial^2 u(x,r)}{\partial r^2}$. We obtain the following proposition:

Proposition 2. *A DM who is reference-point-risk-averse $u_{22}(x, r) \leq 0$ (assumptions $A6$) and risk-averse $v''(x) \leq 0$ (assumption $A7$) is feedback-averse.*

Proof. Proof See Appendix B. Proposition 2 is obtained under assumptions $A2$ to $A7$. □

Assumptions $A6$ and $A7$ provide sufficient conditions for feedback pre-decisional aversion. Under these sufficient conditions, the DM is also classified as feedback post-decisional averse (see Equation B.24 in Appendix B).

It's important to note that feedback aversion can coexist with linearity when $u_{22}(x, r) = 0$ or/and $v''(x) = 0$. Under linearity, the DM is not feedback neutral. When the inequality in $A6$ is strictly satisfied, however, the DM demonstrates reference-point-risk aversion (RPRA). A DM exhibiting RPRA experiences an increasing marginal disutility of regret. As the reference point changes with feedback, RPRA leads to a higher level of feedback aversion compared to the linear case where $u_{22}(x,r) = 0$. Furthermore, when inequality $A7$ is strictly satisfied, it indicates risk aversion, which also contributes to feedback aversion.

To get the intuition of Proposition 2, let us consider the following property obtained under $A7$ (see Equation B.19 in Appendix B):

$$\begin{aligned} &\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X, \\ &R^{m_X^b} \leq \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b \right.\right) R^{m_X^a}. \end{aligned} \tag{4}$$

For each signal value m_X^b, the reference point under F_Φ^b is lower than the average value of reference points under F_Φ^a. Under $A5$ ($u_2(x,r) < 0$) and $A6$ ($u_{22}(x,r) \leq 0$), easy computations give that the expected r-utility is higher under F_Φ^b than under F_Φ^a.

4 Feedback and risk behavior

In Gabillon (2020), the regret certainty equivalent (RCE) is defined under the assumption of a non-informative feedback. In what follows, we define the RCE for any feedback and give the definition of the risk premium of a regret-averse DM.

Definition 10. *When a regret-averse DM chooses between a sure payoff Z and a risky alternative Y, the RCE of the risky alternative Y under F_Φ, denoted by RCE_Y^{u,F_Φ}, corresponds to the value of the sure payoff Z which makes the DM indifferent about choosing Z or Y under F_Φ.*

$\Pi_Y^{u,F_\Phi} = E(Y) - RCE_Y^{u,F_\Phi}$ *denotes the risk premium under F_Φ.*

RCE_Y^{u,F_Φ} is the Z-solution of the following equation [3]:

[3] Gabillon (2020) shows that the reference point in the left-hand side of Equation (5) does not correspond to anticipated regret. Instead, it represents the psychological opportunity cost the DM is willing to support to avoid anticipated regret.

$$E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right]$$
$$= E\left[u\left(Y, Max\left(Y, Z\right)\right)\right], \tag{5}$$

where M_Z is the signal on the risky alternative Y when the sure payoff Z is adopted, and $v\left(CE_Y^{v,M_Z}\right) = E\left[v\left(Y\right)\middle| M_Z\right]$ (see Equation 3).

Let CE_Y^v denote the Arrow-Pratt certainty equivalent of a risky alternative Y:

$$v\left(CE_Y^v\right) = E\left[v\left(Y\right)\right]. \tag{6}$$

Gabillon (2020) shows that, under a non-informative feedback (M_Z conveys no information on Y), the RCE exists, is unique, and that $RCE_Y^{u,F_\Phi^{ni}} < CE_Y^v$. Let $\Pi_Y^v = E\left(Y\right) - CE_Y^v$ denote the Arrow-Pratt risk premium. Based on Gabillon (2020), we can state the following corollary:

Corollary 2. *When the feedback is non-informative, a regret-averse DM exhibits a preference for certainty regardless of their risk preferences:* $\Pi_Y^{u,F_\Phi^{ni}} > \Pi_Y^v$.

The risk premium is higher when anticipated regret is considered in decision-making than when it is not. We will call this property 'the preference for certainty'. Under a non-informative feedback, the sure payoff offers protection against anticipated regret. A regret-averse DM is less likely to take risks than a vNM DM. Regret aversion under a non-informative feedback increases the proportion of seemingly risk-averse people. Risk-neutral DMs exhibit a positive risk premium, and so do some risk lovers. It is worth noting that the preference for certainty does not resort to the assumptions of feedback aversion but only to regret aversion (assumption $A5$). Corollary 2 has implications for empirical experiments aimed at eliciting risk preferences. In these experiments, it is important to consider the type of feedback provided, as non-informative feedback can lead to an overestimation of risk aversion. Specifically, when participants make choices between lotteries (Holt and Laury, 2002; Dave *et al.*, 2010) or between a guaranteed payoff and a lottery (Dohmen *et al.*, 2010), unless specified in the experiment, people do not anticipate to observe the outcomes of the unselected lottery or lotteries. People's risk aversion may be overstated if anticipated regret influences decision-making.

The property of preference for certainty is obtained under a non-informative feedback. In what follows, we demonstrate the existence of the RCE under any feedback:

Proposition 3. *$\forall\ F_{\Phi}$, $RCE_Y^{u,F_{\Phi}}$ exists, is unique, and belongs to $\left]\underline{y},\overline{y}\right[$, where $\underline{y}$ and $\overline{y}$ respectively denote the minimum value and the maximum value that Y takes on its support Ω.*

Proof. Proof See Appendix C. Proposition 3 is obtained under assumptions $A1$ to $A5$. □

The following results are obtained under the assumption of feedback aversion (see Definition 9).

Proposition 4. *Under feedback aversion, if F_{Φ}^{a} is sufficient for F_{Φ}^{b}, we have $RCE_Y^{u,F_{\Phi}^{b}} \leq RCE_Y^{u,F_{\Phi}^{a}}$, or else $\Pi_Y^{u,F_{\Phi}^{a}} \leq \Pi_Y^{u,F_{\Phi}^{b}}$.*

Proof. Proof See Appendix C. Proposition 4 is obtained under assumptions $A2$ to $A7$. □

As the feedback becomes informative, choosing the sure payoff offers less protection against feedback and anticipated regret. The sure payoff that a regretful DM would accept instead of the risky alternative Y increases with the informativeness of the feedback, and the risk premium decreases.

From propositions 1 and 4, we obtain:

Corollary 3. *Under feedback aversion, $\forall F_{\Phi}$, $\Pi_Y^{u,F_{\Phi}^{pi}} \leq \Pi_Y^{u,F_{\Phi}}$ and, under A1, $\Pi_Y^{u,F_{\Phi}} \leq \Pi_Y^{u,F_{\Phi}^{ni}}$.*

Proposition 4 states that, under feedback aversion, the risk premium decreases with the feedback's informativeness. It is under a perfectly informative feedback that a feedback-averse DM is the most risk-taker and it is under a non-informative feedback that they are the less.

In what follows, we introduce the risk premium's decomposition of Bell (1983):

$$\begin{aligned}\Pi_Y^{u,F_{\Phi}} &= E\left(Y\right) - CE_Y^{v} + CE_Y^{v} - RCE_Y^{u,F_{\Phi}^{ni}} \\ &\quad - \left[RCE_Y^{u,F_{\Phi}} - RCE_Y^{u,F_{\Phi}^{ni}}\right]. \end{aligned} \tag{7}$$

e

The first term is the Arrow-Pratt risk premium. The second term is the regret premium, and the last term is a generalization to any feedback of the resolution premium introduced by Bell (1983). The regret premium is the difference between the Arrow-Pratt certainty equivalent and the regret certainty equivalent when the feedback is non-informative. Compared to a vNM DM, the regret premium represents the extra amount a regret-averse DM will pay to avoid regret. At the utility level, Gabillon (2020) provides a psychological interpretation of the regret premium as the maximum psychological opportunity cost a DM will support to avoid anticipated regret. The resolution premium is the difference between the RCE under F_{Φ} and the RCE under the non-informative feedback. Bell (1983), who compare a situation of perfect feedback ($F_{\Phi} = F_{\Phi}^{pi}$) with a situation of no feedback, shows that the resolution premium is positive when the regret fonction is concave. The author considers an additive regret/rejoicing utility function. In this framework, the concavity of the regret function is a special case of our definition of feedback aversion. In this paper, we obtain that, whatever the feedback, the resolution premium is positive when the DM is feedback-averse (see Proposition 4). For Somasundaram and Diecidue (2017), who also compare perfect feedback with no feedback, the resolution premium can be negative or positive depending on the prospect. The author's interpretation of the resolution premium stems from their hypothesis that feedback increases regret aversion (see Introduction).

Since the Arrow-Pratt risk premium and the regret premium are constant, the resolution premium is the portion of the risk premium that increases with the feedback's informativeness (see Proposition 4). The following Proposition states that, under perfect feedback, the resolution premium can be so significant that the risk premium under regret aversion is lower than the Arrow-Pratt risk premium. Paradoxically, this happens for a risk-averse DM, who displays a preference for *un*certainty under perfect feedback.

In the following proposition, we consider the linear r-utility function $u(x, r) = x^{\alpha} - k(r - x)$ which satisfies $A2$ to $A7$. According to Proposition 2, a DM whose preferences are represented by $u(x, r)$ is feedback-averse.

Proposition 5. *When preferences are represented by the r-utility* $u(x, r) = x^{\alpha} - k(r - x)$ *and when the feedback is perfectly informative, the risk premium* $\Pi_Y^{u,F_\Phi^{pi}}$ *satisfies* $0 \leq \Pi_Y^{u,F_\Phi^{pi}} \leq \Pi_Y^v$ *when the DM is risk-averse (*$\alpha < 1$*),* $\Pi_Y^{u,F_\Phi^{pi}} = \Pi_Y^v = 0$ *when the DM is risk neutral (*$\alpha = 1$*) and* $\Pi_Y^v \leq \Pi_Y^{u,F_\Phi^{pi}} \leq 0$ *when the DM is risk-lover (*$\alpha > 1$*).*

Proof. Proof See Appendix D. □

In Proposition 5 and the rest of the paper, risk preferences are defined with the c-utility function, representing the DM's preferences if they were not regret-averse. This approach allows us to disentangle the effect of risk aversion and regret aversion. We can see how anticipated regret affects risk behavior. All our model is based on the implicit comparison between the preferences of a regret-averse DM, represented by the r-utility function $u(x, r)$, and the corresponding vNM preferences, represented by the c-utility function $v(x) = u(x, x)$.

When $u(x, r) = x^{\alpha} - k(r - x)$, under perfect feedback, the risk premium of a risk-and-regret-averse DM is positive but lower than the Arrow-Pratt risk premium. The risk premium of a risk-neutral and regret-averse DM is equal to zero, and the risk premium of a risk-lover and regret-averse DM is negative but higher than the Arrow-Pratt risk premium. Risk behaviors are less differentiated when regret aversion is involved in decision-making than when it is not: a risk-averse DM is more risk-taker, and a risk-lover DM is less risk-taker. This result contrasts with what we obtain when the feedback is non-informative. Under a non-informative feedback, preference for certainty prevails regardless of risk preferences, systematically resulting in a risk premium above the Arrow-Pratt risk premium (see Corollary 2). Under perfect feedback, however, when $u(x, r) = x^{\alpha} - k(r - x)$, only risk-lover DMs exhibit a preference for certainty. For risk-averse DMs, Proposition 5 highlights a reverse phenomenon, which characterizes a preference for uncertainty (still compared to the EUT). Risk-taking behavior and feedback on the foregone options cannot be considered separately.

Let's consider now a choice set containing two risky alternatives $\Phi = \{Y_1, Y_2\}$ and a DM who is indifferent between Y_1 and Y_2 :

$$E\left[u\left(Y_1, Max\left(Y_1, CE_{Y_2}^{v,M_{Y_1}}\right)\right)\right]$$
$$= E\left[u\left(Y_2, Max\left(Y_2, CE_{Y_1}^{v,M_{Y_2}}\right)\right)\right], \tag{8}$$

with M_{Y_1} the signal about Y_2 when Y_1 is selected and M_{Y_2} the signal about Y_1 when Y_2 is selected.

From Definition 9, we also obtain the following proposition:

Proposition 6. *We consider a choice set* $\Phi = \{Y_1, Y_2\}$ *containing two risky alternatives to which a feedback-averse DM is indifferent. If the informativeness of signal* M_{Y_1} *increases (the new signal about* Y_2 *is sufficient for the previous signal), the DM is no longer indifferent and prefers alternative* Y_2*.*

When a DM is feedback-averse, if information about the forgone alternatives increases, the expected r-utility of the chosen alternative decreases. In our case, improving information about Y_2 when Y_1 is selected decreases the expected r-utility of Y_1, leading to a shift in preference, with the DM now favoring option Y_2. Feedback aversion favors risk-taking behavior when Y_2 is the riskier of the two alternatives and risk-avoiding behavior when Y_2 is the safest alternative. This result perfectly aligns with the observations of Zeelenberg *et al.* (1996) (see Introduction).

5 Preference for certainty and the Allais paradox

In this section, we offer a new explanation for the Allais paradox by proposing that non-informative feedback may help account for the observed risk-taking behavior. While previous studies have examined the paradox under the assumption of perfect feedback ((Loomes and Sugden, 1982; Bleichrodt and Walker, 2015)), we argue that this does not align with participants' actual expectations. In most cases, individuals do not expect to learn the outcomes of unchosen options—unless the experimental setting explicitly informs them that such feedback will be provided. The original Allais experiment includes no such specification. This leads us to re-examine the paradox under the assumption of non-informative feedback. Our explanation differs from that derived under perfect feedback and highlights the critical role of feedback structure in shaping decision behavior.

In Allais' experiment, people are asked the following two questions[4]:

Do you prefer situation A or situation B?

$$A \rightarrow \quad 1 \quad [1] \text{ and } B \begin{array}{lll} \nearrow & 5 & [0,1] \\ \rightarrow & 1 & [0,89] \\ \searrow & 0 & [0,01] \end{array}$$

Do you prefer situation C or situation D?

$$C \begin{array}{lll} \nearrow & 1 & [0,11] \\ \searrow & 0 & [0,89] \end{array} \text{ and } D \begin{array}{lll} \nearrow & 5 & [0,1] \\ \searrow & 0 & [0,9] \end{array}$$

The CCE is a behavioral regularity characterized by the A and D choice, which violates the EUT. An appeal to certainty (Kahneman and Tversky 1979, Wakker 2010, Schneider and Schonger 2019, Cerreia-Vioglio *et al.* 2015) or an aversion to zero (Incekara-Hafalir *et al.* 2021) have been proposed as possible explanations of why people choose A over B but prefers D over C. The first explanation considers that the CCE is an evidence of the certainty effect. The certainty effect can be defined as a tendency of people to favor a risk-free option in violation of Expected Utility. When choosing A while they prefer D to C, people overvalue certainty.

However, this paper considers the choice of situation A to be puzzling, regardless of the preference between C and D. To clarify this point, let us compare the following two situations:

$$A \rightarrow \quad 1 \quad [1] \text{ and } B' \begin{array}{lll} \nearrow & 5 & [0,1] \\ \searrow & 1 & [0,9] \end{array}$$

Situation B' first-order stochastically dominates situation A. Under the EUT, any DM with an increasing utility function prefers B'. One could expect that, by continuity, moving from B' to B will not significantly modify preferences between the two situations. Contrary to observation, one would expect that most people prefer situation B to situation A. In the EUT, the preference for situation A, observed in the Allais paradox, can only be explained by an extreme level of local risk

[4] In Allais' experiment, payoffs are expressed in millions of francs.

aversion. If we consider the utility function $v(x) = x^{\alpha}$, situation A is preferred to situation B in the EUT when $\alpha < \frac{\ln(1{,}1)}{\ln(5)} \simeq 0,05921954 = 0,059^{+}$, which approximately corresponds to the 6% most risk-averse people in the experimental study of Holt and Laury 2002. We call the certainty bias puzzle the choice of the safe option in Allais' experiment.

Bleichrodt and Walker (2015) who confront the model of Loomes and Sugden (1982) with various paradoxes, analyze the CCE. A DM who has previously chosen A chooses situation D when they fear enough the state of nature in which C gives 0, and D gives 5. When the difference between 5 and 0 results in an intense regret (under a convexity assumption), Bleichrodt and Walker (2015) obtain the CCE. In Allais' experiment, however, people are not explicitly told that the result of the foregone situation will be disclosed. Since people are just told to choose the situation they prefer, it is reasonable to consider that they do not anticipate the resolution of the foregone situation. In our terminology, Allais' experiment is led under a non-informative feedback. The "strong regret" arising from comparing the perceived payoff 0 and the lost payoff 5 has no reason to be anticipated. In our approach, a DM who chooses C anticipates comparing the result of C to their opinion about D, which corresponds, under a non-informative feedback, to the Arrow-Pratt certainty equivalent of D, which will be denoted by CE_D^v in the following.

In what follows, we use the Arrow-Pratt certainty equivalent of situation B, CE_B^v, as a measure of risk preferences:

$$v\left(CE_B^v\right) = 0,1v\left(5\right) + 0,89v\left(1\right) + 0,01v\left(0\right). \tag{9}$$

Situation A is preferred to situation B in the EUT when $CE_B^v < 1$. Under risk aversion, CE_B^v is lower than the expected payoff of situation B, equal to $1,39$. In the following table, we summarize the different categories of risk preferences to which we will refer. The last line of the table gives the values of α when the c-utility function is $v(x) = x^{\alpha}$.

Table 1

$CE_B^v < 1$	$1 \leq CE_B^v < 1,39$	$CE_B^v = 1,39$	$CE_B^v > 1,39$
Highly risk-averse	Risk-averse	Risk-neutral	Risk-lover
$\alpha < 0,059^+$	$0,059^+ \leq \alpha < 1$	$\alpha = 1$	$\alpha > 1$

Let us first analyze the certainty bias puzzle. Under a non-informative feedback, a DM chooses situation A if[5]:

$$u\left(1, Max\left(1, CE_B^v\right)\right) > 0,1v\left(5\right) + 0,89v\left(1\right) + 0,01u\left(0,1\right). \tag{10}$$

To go further, let us introduce the additive r-utility function $u\left(x,r\right) = v\left(x\right) - kg\left(r-x\right)$ with $k > 0$, $v'\left(.\right) > 0$, $v\left(0\right) = 0$, $g'\left(.\right) > 0$ and $g\left(0\right) = 0$. Parameter k could be integrated into function $g\left(.\right)$, but we prefer to keep it outside as a measure of regret aversion. We summarize our findings in the following proposition:

Proposition 7. *Property 1: When $CE_B^v < 1$, a DM prefers situation A, whether or not they are regret-averse.*

Property 2: When $CE_B^v \geq 1$, a DM can prefer situation A only if they are regret-averse.

Property 3: When $CE_B^v \geq 1$ and $u\left(x,r\right) = v\left(x\right) - kg\left(r-x\right)$, a DM prefers situation A when $CE_B^v < 1+\delta < 2$ and when regret aversion k is sufficiently high: $k > k_{\min} = \frac{0,1v(5)-0,11v(1)}{0,01g(1)-g\left(CE_B^v-1\right)}$. If $g(.)$ is linear then $1+\delta = 1,01$. If $g(.)$ is strictly convex then $1+\delta > 1,01$. If $g\left(x\right) = x^{\beta}$ then $1+\delta = 1+0,01^{\frac{1}{\beta}}$.

Proof. Proof See Appendix E. □

A highly risk-averse DM ($CE_B^v < 1$) prefers situation A, whether or not they are regret-averse (property 1). Property 2 of Proposition 6 states that regret aversion is necessary to explain the certainty bias puzzle: the choice of situation A with a reasonable level of risk aversion ($CE_B^v \geq 1$) can only occur under regret aversion. Under a non-informative feedback, situation A offers a protection against anticipated regret, creating a preference for certainty.

As the risk of feeling regret in situation B is very low (the probability is $0,01$), property 3 of Proposition 6 states that the protection against anticipated regret offered by situation A is not

[5] In the right-hand side of Equation (10), when $x = 0$ and $r = 1$, the reference point represents anticipated regret. On the left-hand side of Equation (10), the reference point does not represent anticipated regret, but a psychological opportunity cost (see Gabillon 2020). The DM supports a psychological cost because choosing situation A implies missing out situation B, which represents a "better" option (when $CE_B^v > 1$) that the DM would have adopted if she had not been regret-averse.

sufficiently attractive when risk aversion is too weak ($CE_B^v > 1+\delta$). When, on the contrary, risk aversion and regret aversion are sufficiently high ($CE_B^v < 1+\delta$ and $k > k_{\min}$), situation A is adopted. This choice happens all the more easily when the regret function is convex, corresponding to our assumption $A6$ of RPRA. Under a non-informative feedback, the RPRA property should not be interpreted as feedback aversion but rather as a hypothesis of increasing marginal disutility of regret. When $g(x) = x^{\beta}$, we have $1+\delta \longrightarrow 2$ when $\beta \rightarrow +\infty$. The value of δ increases with the convexity of the regret function $g(.)$ but tends to a boundary. Proposition 6 states that RT with an additive r-utility function is unable to predict the preference for situation A when people are highly risk lovers ($CE_B^v \geq 2$). For all the other cases, however, any DM can prefer situation A if they are sufficiently regret-averse (k sufficiently high) and reference point-risk-averse (β sufficiently high).

Contrary to the EUT, our model explains the preference for situation A without assuming extreme levels of risk aversion. When $1 < CE_B^v < 1+\delta$, situation A is not the best option in the EUT (because $CE_B^v > 1$), whereas it is the right choice under regret aversion when $k > k_{\min}$. When the sensitivity to anticipated regret is sufficiently high ($k > k_{\min}$), we have $RCE_B^u < 1 < CE_B^v$: the regret-averse DM chooses situation A, whereas the vNM DM chooses situation B. The underlying property, which explains this result, is the preference for certainty under a non-informative feedback ($RCE_B^u < CE_B^v$) presented in section 4. The informational context of Allais' experiment is the key to understanding people's extreme prudence when choosing situation A. When $u(x,r) = x^{\alpha} - k(r-x)^{\beta}$, the choice between situation A and situation B depends on three parameters: the risk aversion parameter α, the regret aversion parameter k, and the RPRA parameter β. Table 2 illustrates, for different values of α, the conditions that the regret parameters k and β must meet for the DM to prefer situation A to situation B:

Table 2

α	β	$k_{\min}$
$\alpha = 0,059^{+}$ $(CE_B^v = 1)$	$\beta_{\min} = 0^{+}$	$k_{\min} = 0^{+}$
$\alpha = 0,3$ $(CE_B^v \simeq 1,18)$	$\beta_{\min} \simeq 2,7234$	$k_{\min} \simeq +\infty$
	$\beta = 3$	$k_{\min} \simeq 13,94$
	$\beta = 5$	$k_{\min} \simeq 5,32$
	$\beta = 10$	$k_{\min} \simeq 5,21$
$\alpha = 0,5$ $(CE_B^v \simeq 1,24)$	$\beta_{\min} \simeq 3,23$	$k_{\min} \simeq +\infty$
	$\beta = 5$	$k_{\min} \simeq 12,35$
	$\beta = 10$	$k_{\min} \simeq 11,362$
$\alpha = 1$ $(CE_B^v = 1,39)$	$\beta_{\min} \simeq 4,891$	$k_{\min} \simeq +\infty$
	$\beta = 6$	$k_{\min} \simeq 60,174$
	$\beta = 10$	$k_{\min} \simeq 39,321$
$\alpha = 1,5$ $(CE_B^v \simeq 1,59)$	$\beta_{\min} \simeq 8,775$	$k_{\min} \simeq +\infty$
	$\beta = 10$	$k_{\min} \simeq 212,48$
	$\beta = 15$	$k_{\min} \simeq 104,80$

Table 2 reads: when $CE_B^v = 1$, situation A is strictly preferred as soon as k and β are strictly positive. When $CE_B^v = 1,18$, situation A is selected if β exceeds $2,7234$. But for $\beta = 2,7234$, k must be extremely high ($+\infty$). For $\beta = 3$, however, k must be greater than $13,94$. The rest of Table 2 reads the same way. Appendix E shows that $\beta_{\min}$ and $k_{\min}$ both increase with α: when risk aversion decreases, the attractiveness of situation B increases (CE_B^v increases with α). Regret parameters must increase in return to preserve the preference for situation A. This result shows that risk aversion and regret aversion can be substitutable when it comes to avoiding or taking risks. If we reduce risk aversion, we need to increase regret aversion in order to continue preferring situation A. Appendix E also shows that $k_{\min}$ decreases when β increases.

Let us now analyze the preference reversal paradox. All we have to do is to find the conditions under which situation D is preferred to situation C and confront these conditions with those under which A is preferred to B. Under a non-informative feedback, a DM chooses situation D if:

$$\begin{aligned}&0,1u\left(5, Max(5, CE_C^v)\right)\\&+0,9u\left(0, Max\left(0, CE_C^v\right)\right)\\&>\\&0,11u\left(1, Max(1, CE_D^v)\right)\\&+0,89u\left(0, Max\left(0, CE_D^v\right)\right).\end{aligned} \tag{11}$$

We analyze Equation (11) in Appendix E. We summarize our results in the following table. Some results are general, and others are obtained with the r-utility function $u(x,r) = x^{\alpha} - k\left(r-x\right)^{\beta}$. Table 3 gives choices predicted by the EUT and RT for different levels of risk aversion. The main insights are given just after the table. We recall that the CCE is characterized by choices A and D.

Table 3: Is the CCE possible? Yes or No

	$CE_B^v < 1$	$1 \leq CE_B^v < 1^+$	$1^+ \leq CE_B^v < 2$	$CE_B^v \geq 2$
		Highly risk-averse	Risk-averse, risk-neutral and risk-lover	Highly risk-lover
EUT	AC	BD	BD	BD
RT	AC	choice A possible choice C	choice A possible choice D possible	choice B choice D possible
CCE possible?	No.	No.	Yes under RT.	No.

When risk aversion is very high ($CE_B^v < 1$), RT is unable to explain the choice of situation D in the Allais paradox. For a highly risk-averse DM, situation C is more attractive for two reasons:

a. Given their risk aversion, the DM values more C than D: when $CE_B^v < 1$, we have $CE_C^v > CE_D^v$.

b. Anticipated regret in situation D is more significant than in situation C. In situation D, the probability of experiencing regret is higher $(0,9 > 0,89)$, and anticipated regret is stronger: in situation D, the DM feels regret when they compare 0 to CE_C^v whereas, in situation C, they feel regret when they compare 0 to $CE_D^v < CE_C^v$. In our model, anticipated regret depends on both regret aversion and risk aversion (which determines CE_C^v and CE_D^v).

When $1 \leq CE_B^v < 1^+$, this is a small intermediate case. Despite that CE_D^v is now greater than CE_C^v, situation C remains the optimal choice because the probability of experiencing regret in situation D is higher $(0,9 > 0,89)$.

When $1^+ \leq CE_B^v < 2$, RT under a non-informative feedback can explain both the preference for situation A (contrary to the EUT) and the choice of situation D. In situation D, although the probability of experiencing regret is higher $(0,9 > 0,89)$, anticipated regret is weaker: the DM feels regret when they compare 0 to CE_C^v whereas, in situation C, they feel regret when they compare 0 to $CE_D^v > CE_C^v$.

When $CE_B^v \geq 2$ ($\alpha \geq 2,295$), the DM is such a risk lover that our model cannot predict the choice of the safe situation (situation A). Given that risk lovers with $\alpha > 1,95$ represent only 3% of participants in Holt and Laury (2002)'s experiment, we guess that probably almost nobody in the population displays $\alpha \geq 2,295$.

Our model is consistent with the Allais paradox since we predict that the A and D choice will be the most frequently observed if people are sufficiently regret-averse. According to our model, only high-risk-averse or high-risk-lover people will systematically exhibit a different pattern of choice.

6 Conclusion

One result of this paper shows that the risk-taking behavior of a regret-averse DM depends not only on risk aversion but also on regret aversion and feedback on foregone options. In particular, we show that while a regretful DM systematically exhibits a preference for certainty under a non-informative feedback, they can display, on the contrary, a preference for uncertainty under a perfectly informative feedback. Gabillon (2020) also shows that statewise stochastic dominance, a natural property of preferences, is satisfied under perfect feedback but cannot be generalized to any other feedback. Given the particularity of its implications, the assumption of perfect feedback should be used with caution when drawing general conclusions about decision-making under regret aversion since risk-taking behavior and preference properties vary with the degree of resolution of the foregone options.

Appendix A

Let M_{Y_n} denote the signal associated to an alternative Y_n under any F_Φ.

Signal M_{Y_n} is conditionally independent of θ given $M_{Y_n}^{pi}$: $p\left(m_{Y_n} \middle| m_{Y_n}^{pi}, \theta\right) = p\left(m_{Y_n} \middle| m_{Y_n}^{pi}\right)$ since $m_{Y_n}^{pi}$ reveals θ. We thus have:

$$p\left(m_{Y_n}\left|\theta\right.\right)=\sum_{m_{Y_n}\in\mathcal{M}_{Y_n}}p\left(m_{Y_n}\left|m_{Y_n}^{pi}\right.\right)p\left(m_{Y_n}^{pi}\left|\theta\right.\right).\tag{A.1}$$

$M_{Y_n}^{pi}$ is sufficient for M_{Y_n}.

Let us now consider signals M_{Y_n} and $M_{Y_n}^{ni}$. We have:

$$\begin{aligned}p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right)&=\sum_{\theta\in\Omega^{N+1}}p\left(m_{Y_n}^{ni},\theta\left|m_{Y_n}\right.\right)\\&=\sum_{\theta\in\Omega^{N+1}}p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)p\left(\theta\left|m_{Y_n}\right.\right).\end{aligned}\tag{A.2}$$

Under $A1$, Equation (A.2) gives

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right)=\sum_{\theta\in\Omega^{N+1}}p\left(m_{Y_n}^{ni}\left|\theta\right.\right)p\left(\theta\left|m_{Y_n}\right.\right).\tag{A.3}$$

Given that $M_{Y_n}^{ni}$ is independent of θ, we obtain:

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right)=p\left(m_{Y_n}^{ni}\right)\sum_{\theta\in\Omega^{N+1}}p\left(\theta\left|m_{Y_n}\right.\right)=p\left(m_{Y_n}^{ni}\right).\tag{A.4}$$

In addition, we have:

$$\begin{aligned}p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)&=\frac{P\left(m_{Y_n}^{ni},m_{Y_n},\theta\right)}{p\left(m_{Y_n},\theta\right)}\\&=\frac{p\left(m_{Y_n}\left|m_{Y_n}^{ni},\theta\right.\right)p\left(m_{Y_n}^{ni}\left|\theta\right.\right)p\left(\theta\right)}{p\left(m_{Y_n}\left|\theta\right.\right)p\left(\theta\right)}.\end{aligned}\tag{A.5}$$

Under $A1$, Equation (A.5) give:

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)=\frac{p\left(m_{Y_n}\left|\theta\right.\right)p\left(m_{Y_n}^{ni}\right)}{p\left(m_{Y_n}\left|\theta\right.\right)}=p\left(m_{Y_n}^{ni}\right).\tag{A.6}$$

Equations (A.4) and (A.6) imply

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)=p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right).\tag{A.7}$$

We also have:

$$p\left(m_{Y_n}^{ni}\left|\theta\right.\right) = \sum_{m_{Y_n}\in\mathcal{M}_{Y_n}} p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right) p\left(m_{Y_n}\left|\theta\right.\right). \tag{A.8}$$

Equations (A.7) and (A.8) give

$$p\left(m_{Y_n}^{ni}\left|\theta\right.\right) = \sum_{m_{Y_n}\in\mathcal{M}_{Y_n}} p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right) p\left(m_{Y_n}\left|\theta\right.\right). \tag{A.9}$$

M_{Y_n} is sufficient for $M_{Y_n}^{ni}$.

Appendix B

We use the sufficiency property to obtain Equation $B.12$, and then we consider the properties of preferences to obtain Equation $B.25$.

F_Φ^a is sufficient for F_Φ^b (see definitions 4 and 5) implies that $\forall X \in \Phi, \forall\theta \in \Omega^{N+1}, \forall m_X^b \in \mathcal{M}_X$,

$$p\left(m_X^b\left|\theta\right.\right) p\left(\theta\right) = \sum_{m_X^a\in\mathcal{M}_X} \pi\left(m_X^b\left|m_X^a\right.\right) p\left(m_X^a\left|\theta\right.\right) p\left(\theta\right), \tag{B.1}$$

with $\sum_{m_X^b\in\mathcal{M}_X} \pi_X\left(m_X^b\left|m_X^a\right.\right) = 1$.

Equation (B.1) can be rewritten as follows:

$$p\left(m_X^b,\theta\right) = \sum_{m_X^a\in\mathcal{M}_X} \pi\left(m_X^b\left|m_X^a\right.\right) p\left(m_X^a,\theta\right). \tag{B.2}$$

By summing over θ, we obtain:

$$p\left(m_X^b\right) = \sum_{m_X^a\in\mathcal{M}_X} \pi\left(m_X^b\left|m_X^a\right.\right) p\left(m_X^a\right). \tag{B.3}$$

Besides, Equation (B.2) can also be written as follows:

$$p\left(\theta\left|m_X^b\right.\right)p\left(m_X^b\right)=\sum_{m_X^a\in\mathcal{M}_X}\pi\left(m_X^b\left|m_X^a\right.\right)p\left(\theta\left|m_X^a\right.\right)p\left(m_X^a\right). \tag{B.4}$$

Equation (B.4) becomes:

$$p\left(\theta\left|m_X^b\right.\right)=\sum_{m_X^a\in\mathcal{M}_X}\frac{\pi\left(m_X^b\left|m_X^a\right.\right)p\left(m_X^a\right)}{p\left(m_X^b\right)}p\left(\theta\left|m_X^a\right.\right). \tag{B.5}$$

Since $\frac{\pi\left(m_X^b\left|m_X^a\right.\right)p\left(m_X^a\right)}{p\left(m_X^b\right)}=\pi\left(m_X^a\left|m_X^b\right.\right)$, we have

$$p\left(\theta\left|m_X^b\right.\right)=\sum_{m_X^a\in\mathcal{M}_X}\pi\left(m_X^a\left|m_X^b\right.\right)p\left(\theta\left|m_X^a\right.\right). \tag{B.6}$$

Lastly, given that $\theta=\{x,y_1,...,y_N\}$, we obtain from Equation (B.6) that $\forall X\in\Phi,\forall Y_n\in\Phi/\{X\},\forall y_n\in\Omega,\forall m_X^b\in\mathcal{M}_X$,

$$p\left(y_n\left|m_X^b\right.\right)=\sum_{m_X^a\in\mathcal{M}_X}\pi\left(m_X^a\left|m_X^b\right.\right)p\left(y_n\left|m_X^a\right.\right). \tag{B.7}$$

$\forall X\in\Phi,\forall Y_n\in\Phi/\{X\}$, we also have (see Equation 3)

$$v\left(CE_{Y_n}^{v,M_X^b}\right)=E\left[v\left(y_n\right)\right|M_X^b\left.\right]. \tag{B.8}$$

Or, equivalently:

$$v\left(CE_{Y_n}^{v,m_X^b}\right)=\sum_{y_n\in\Omega_{Y_n}}p\left(y_n\left|m_X^b\right.\right)v\left(y_n\right). \tag{B.9}$$

From Equation (B.7) and Equation (B.9), we obtain that

$$v\left(CE_{Y_n}^{v,m_X^b}\right)=\sum_{y_n\in\Omega}v\left(y_n\right)\sum_{m_X^a\in\mathcal{M}_X}\pi\left(m_X^a\left|m_X^b\right.\right)p\left(y_n\left|m_X^a\right.\right). \tag{B.10}$$

Or, equivalently,

$$v\left(CE_{Y_n}^{v,m_X^b}\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) \sum_{y_n \in \Omega_{Y_n}} v\left(y_n\right) p\left(y_n \left| m_X^a \right.\right). \tag{B.11}$$

We obtain the following relationship between $CE_{Y_n}^{v,m_X^a}$ and $CE_{Y_n}^{v,m_X^b}$ which states that $\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall m_X^b \in \mathcal{M}_X$,

$$v\left(CE_{Y_n}^{v,m_X^b}\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) v\left(CE_{Y_n}^{v,m_X^a}\right). \tag{B.12}$$

Equation (B.12) is exclusively obtained from the property of sufficiency: when F_Φ^a is sufficient for F_Φ^b, the c-utility of a foregone alternative Y_n given signal m_X^b is equal to the average c-utility of alternative Y_n under F_Φ^a.

Given that the c-utility function is an increasing function (assumption $A3$), Equation (B.12) implies that

$$v\left(CE_{Y_n}^{v,m_X^b}\right) \leq \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) v\left(CE_{Max}^{v,m_X^a}\right), \tag{B.13}$$

with $CE_{Max}^{v,m_X^a} = Max\left\{CE_{Y_1}^{v,m_X^a}, ..., CE_{Y_N}^{v,m_X^a}\right\}$.

And thus, we also have:

$$v\left(CE_{Max}^{v,m_X^b}\right) \leq \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) v\left(CE_{Max}^{v,m_X^a}\right), \tag{B.14}$$

with $CE_{Max}^{v,m_X^b} = Max\left\{CE_{Y_1}^{v,m_X^b}, ..., CE_{Y_N}^{v,m_X^b}\right\}$.

Under assumption $A7$, Equation (B.14) implies:

$$v\left(CE_{Max}^{v,m_X^b}\right) \leq v\left(\sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) CE_{Max}^{v,m_X^a}\right). \tag{B.15}$$

Which implies under $A3$:

$$CE_{Max}^{v,m_X^b} \leq \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) CE_{Max}^{v,m_X^a}. \tag{B.16}$$

Which implies

$$Max\left(x, CE_{Max}^{v,m_X^b}\right) \leq Max\left(x, \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b \right.\right) CE_{Max}^{v,m_X^a}\right). \tag{B.17}$$

Moreover, since the Max function is convex, we have:

$$Max\left(x, CE_{Max}^{v,m_X^b}\right) \leq \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b \right.\right) Max\left(x, CE_{Max}^{v,m_X^a}\right). \tag{B.18}$$

Given Definition 7, Equation (B.18), we obtain a key intermediate result:

$\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X,$

$$R^{m_X^b} \leq \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b \right.\right) R^{m_X^a}. \tag{B.19}$$

For each signal value m_X^b, the reference point $R^{m_X^b}$ is lower than the average value of the reference point $R^{m_X^a}$.

Under $A5$, Equation (B.19) implies that

$$u\left(x, \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b \right.\right) R^{m_X^a}\right) \leq u\left(x, R^{m_X^b}\right). \tag{B.20}$$

Which implies, under $A6$, that

$$\sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) u\left(x, R^{m_X^a}\right) \leq u\left(x, R^{m_X^b}\right). \tag{B.21}$$

Since $\pi\left(m_X^a \left| m_X^b \right.\right) = \frac{\pi\left(m_X^b \left| m_X^a \right.\right) p\left(m_X^a\right)}{p\left(m_X^b\right)}$, we obtain:

$$\sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^b \left| m_X^a\right.\right) p\left(m_X^a\right) u\left(x, R^{m_a}\right)$$
$$\leq p\left(m_X^b\right) u\left(x, R^{m_X^b}\right). \tag{B.22}$$

Which implies that

$$\sum_{m_X^b \in M_X} \sum_{m_X^a \in M_X} \pi\left(m_X^b \left| m_X^a\right.\right) p\left(m_X^a\right) u\left(x, R^{m_X^a}\right)$$
$$\leq \sum_{m_X^b \in \mathcal{M}_X} p\left(m_X^b\right) u\left(x, R^{m_X^b}\right). \tag{B.23}$$

Or, equivalently, that $\forall X \in \Phi, \forall x \in \Omega$,

$$\sum_{m_X^a \in M_X} p\left(m_X^a\right) u\left(x, R^{m_X^a}\right) \leq \sum_{m_X^b \in M_X} p\left(m_X^b\right) u\left(x, R^{m_X^b}\right). \tag{B.24}$$

Taking the expectation with respect to x, we obtain that $\forall X \in \Phi$,

$$E\left[u\left(X, Max\left(X, R^{M_X^a}\right)\right)\right] \leq E\left[u\left(X, Max\left(X, R^{M_X^b}\right)\right)\right]. \tag{B.25}$$

Equation (B.25) means that the DM demonstrates feedback pre-decisional aversion. Regardless of the chosen alternative X, their expected utility is greater under F_Φ^b than F_Φ^a. Note that Equation (B.24) is the property of feedback post-decisional aversion or neutrality. Given the observation of the chosen option's outcome x, the DM is better under F_Φ^b than F_Φ^a.

Appendix C

Proof of Proposition 3 :

First, let us show that, for any feedback, the solution of Equation (5) exists and is unique.

If $Z = \underline{y}$ then the left-hand side (LHS) of Equation (5) is

$$E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right] = E\left[u\left(\underline{y}, CE_Y^{v,M_Z}\right)\right]. \tag{C.1}$$

The right-hand side (RHS) is

$$E\left[u\left(Y, Max\left(Y, Z\right)\right)\right] = E\left[u\left(Y, Y\right)\right] = E\left[v\left(y\right)\right]. \tag{C.2}$$

Equation (5) is not satisfied since, under $A4$ and $A5$, we have:

$$E\left[u\left(\underline{y}, CE_Y^{v,M_Z}\right)\right] \leq u\left(\underline{y}, \underline{y}\right) = v\left(\underline{y}\right) < E\left[v\left(y\right)\right]. \tag{C.3}$$

The RHS of Equation (5) is greater than the LHS.

If $Z = \overline{y}$ then the LHS of Equation (5) is

$$E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right] = u\left(\overline{y}, \overline{y}\right). \tag{C.4}$$

The RHS is

$$E\left[u\left(Y, Max\left(Y, Z\right)\right)\right] = E\left[u\left(Y, \overline{y}\right)\right]. \tag{C.5}$$

Equation (5) is not satisfied since, under $A4$, $u\left(\overline{y}, \overline{y}\right) > E\left[u\left(Y, \overline{y}\right)\right]$. The LHS of Equation (5) is now greater than the RHS.

Moreover, under $A3$ and $A4$, function $E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right]$ increases with Z and under $A4$, function $E\left[u\left(Y, Max\left(Y, Z\right)\right)\right]$ decreases with Z. Under $A2$, the solution of Equation (5) exists, is unique, and belongs to $\left]\underline{y}, \overline{y}\right[$.

Proof of Proposition 4 :

The choice set is $\Omega = \{Z, Y\}$.

If Z_a and Z_b respectively denote the Z-solution of Equation (5) under F^a and F^b, let us show that $Z_b \leq Z_a$.

If F_Φ^a is sufficient for F_Φ^b, feedback aversion implies that (see Definition 9):

$$\begin{aligned} & E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z^a}\right)\right)\right] \\ & \leq E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z^b}\right)\right)\right]. \end{aligned} \tag{C.6}$$

The LHS of Equation (5) is greater under F_Φ^b than under F_Φ^a. The RHS of Equation (5), $E\left[u\left(Y, Max\left(Y, Z\right)\right)\right]$, is independent of the feedback and decreases with Z under $A5$. We thus have $Z_b \leq Z_a$.

Appendix D

Under the assumptions of Proposition 5, RCE_Y^{u,F_Φ^i} is the Z-solution of the following equation (see Equation 5):

$$\begin{aligned} & Z^\alpha - kE\left[Max\left(Y, Z\right) - Z\right] \\ & = E\left(Y^\alpha\right) - kE\left[Max\left(Y, Z\right) - Y\right]. \end{aligned} \tag{D.1}$$

Equation (D.1) can be rewritten as follows:

$$Z^\alpha + kZ = E\left(Y^\alpha + kY\right). \tag{D.2}$$

The Z-solution of Equation (D.2) is the Arrow-Pratt certainty equivalent of Y computed with the vNM utility function $\widehat{v}\left(Y\right) = Y^\alpha + kY$.

When $\alpha < 1$, the utility function $\widehat{v}\left(Y\right)$ displays less risk aversion than the c-utility function $v\left(Y\right) = Y^\alpha$ and $CE_Y^v < RCE_Y^{u,F_\Phi^{pi}} < E\left(Y\right)$.

When $\alpha = 1$, the utility function $\widehat{v}\left(Y\right)$ displays risk neutrality as the c-utility function $v\left(Y\right) = Y^\alpha$ and $RCE_Y^{u,F_\Phi^{pi}} = CE_Y^v = E\left(Y\right)$.

When $\alpha > 1$, the utility function $\widehat{v}(Y)$ displays less risk loving than the c-utility function $v(Y) = Y^{\alpha}$ and $CE_Y^v > RCE_Y^{u,F_\Phi^{pi}} > E(Y)$.

Appendix E

Proof of Proposition 6:

Under a non-informative feedback, we have $RCE_B^u < CE_B^v$ (see Corollary 2). When $CE_B^v < 1$ (risk aversion is high), we thus have $RCE_B^u < CE_B^v < 1$, which allows us to conclude that Equation (10) is satisfied.

In what follows, we pursue our analysis with $CE_B^v \geq 1$ (B is preferred to A in the EUT). Equation (10) is satisfied if

$$u(1, CE_B^v) > 0,1v(5) + 0,89v(1) + 0,01u(0,1). \tag{E.1}$$

Since $u(1, CE_B^v) \leq v(1) \leq v(CE_B^v)$, Inequality (E.1) can only be satisfied if $u(0,1) < v(0)$ (see Equation 9). When $CE_B^v \geq 1$, the DM must be sensitive to anticipated regret to exhibit a preference for situation A. Inequality (E.1) is satisfied when $RCE_B^u < 1 < CE_B^v$ which means that situation B is preferred in the EUT, while situation A is preferred under regret aversion. This result is possible due to the property of preference for certainty ($RCE_B^u < CE_B^v$) stated in Corollary 2.

When $u(x,r) = v(x) - kg(r-x)$ with $v(0) = 0$, RCE_B^u is the Z-solution of the following equation:

$$v(Z) - kg(CE_B^v - Z) = 0,1v(5) + 0,89v(1) - 0,01kg(Z). \tag{E.2}$$

Equation (E.2) is obtained with Equation (5) and $RCE_B^u < CE_B^v$.

Using Equation (9), we write Equation (E.2) as follows:

$$v(Z) + k[0,01g(Z) - g(CE_B^v - Z)] = v(CE_B^v). \tag{E.3}$$

Given that inequality (E.1) is satisfied when $RCE_B^u < 1$, Equation (E.3) implies:

$$v(1) + k[0,01g(1) - g(CE_B^v - 1)] > v(CE_B^v). \quad \text{(E.4)}$$

Equation (E.4) and $CE_B^v \geq 1$ imply:

$$0,01g(1) - g(CE_B^v - 1) > 0. \quad \text{(E.5)}$$

Given that $g'(.) > 0$, Equation (E.5) cannot be verified when $CE_B^v \geq 2$. When $CE_B^v \geq 2$, the DM is such a risk-lover that RT cannot explain the preference for situation A observed in the Allais paradox.

Let us introduce $\delta < 1$, which verifies:

$$g(\delta) = 0,01g(1). \quad \text{(E.6)}$$

The preference for situation A can only be explained when $CE_B^v < 1 + \delta$. When the regret function $g(.)$ is linear ($g(tx) = tg(x)$), we obtain $\delta = 0,01$. When the regret function is strictly convex ($g(tx) < tg(x)$ when $t < 1$), we have $\delta > 0,01$. When $g(x) = x^\beta$, we obtain $\delta = 0,01^{\frac{1}{\beta}}$. When $\beta \to +\infty$, we have $\delta \longrightarrow 1$ and situation A is preferred when $CE_B^v < 2$.

Secondly, Equation (E.4) is satisfied when k is high enough:

$$k > k_{\min} = \frac{v(CE_B^v) - v(1)}{0,01g(1) - g(CE_B^v - 1)}. \quad \text{(E.7)}$$

Or else:

$$k > k_{\min} = \frac{0,1v(5) - 0,11v(1)}{0,01g(1) - g(CE_B^v - 1)}. \quad \text{(E.8)}$$

Computations for Table 2:

When $u(x,r) = x^\alpha - k(r-x)^\beta$, Equation (E.5) can be written as follows:

$$0,01-\left(CE_B^v-1\right)^{\beta}>0. \tag{E.9}$$

Which gives:

$$\beta>\beta_{\min}=\frac{0,01}{\ln\left(CE_B^v-1\right)} \text{ when } CE_B^v<2. \tag{E.10}$$

We also have:

$CE_B^v=\left(0,1\times 5^{\alpha}+0,89\right)^{\frac{1}{\alpha}}$ increases with α.

$k_{\min}=\frac{0,1v(5)-0,11v(1)}{0,01g(1)-g\left(CE_B^v-1\right)}=\frac{0,1\times 5^{\alpha}-0,11}{\left[0,01-\left(CE_B^v-1\right)^{\beta}\right]}$ increases with α, and decreases with β when $CE_B^v<2$.

Choice between C and D:

Given that $0<CE_C^v<1$ and $CE_D^v>0$, Equation (11) can be written as follows:

$$\begin{aligned}&0,1v\left(5\right)+0,9u\left(0,CE_C^v\right)\\&>0,11u\left(1,Max(1,CE_D^v)\right)+0,89u\left(0,CE_D^v\right).\end{aligned} \tag{E.11}$$

We must consider two cases: the first case is $CE_D^v\leq 1$ which encompasses all the risk-averse DMs ($CE_D^v\leq 0,5$) and some risk lovers ($0,5<CE_D^v\leq 1$). The second case is $CE_D^v>1$.

1. When $CE_D^v\leq 1$, Equation (E.11) becomes:

$$0,1v\left(5\right)+0,9u\left(0,CE_C^v\right)>0,11v\left(1\right)+0,89u\left(0,CE_D^v\right). \tag{E.12}$$

Which gives:

$$\begin{aligned}&\underbrace{\left[0,1v\left(5\right)-0,11v\left(1\right)\right]}_{(I)}\\&+\underbrace{\left[0,9u\left(0,CE_C^v\right)-0,89u\left(0,CE_D^v\right)\right]}_{(II)}>0.\end{aligned} \tag{E.13}$$

In what follows, we posit $v(0) = 0$ for the sake of simplicity. Expression (I) represents the difference between the expected utility of D and the expected utility of C in the EUT. Expression (II) represents the difference between anticipated regret in D and C. We consider three subcases:

(a) When $CE_B^v < 1$ ($\alpha < 0,059^+$), we have $0,11v(1) > 0,1v(5)$ (see Equation 9), and thus $CE_C^v > CE_D^v$. Expression (I) and Expression (II) in Equation (E.13) are both negative, and Equation (E.13) cannot be satisfied. When $CE_B^v < 1$, the EUT ($(I) < 0$) and RT ($(I) + (II) < 0$) predict that situation C will be chosen instead of situation D.

(b) When $CE_B^v = 1$ ($\alpha = 0,059^+$), we have $0,11v(1) = 0,1v(5)$ (see Equation 9), and thus $CE_C^v = CE_D^v$. Expression (I) is equal to 0, and Expression (II) is negative. When $CE_B^v = 1$, the EUT predicts indifference between C and D. Regret theory predicts the choice of situation C because the probability of experiencing regret is lower in C than in D.

(c) When $CE_B^v > 1$ ($\alpha > 0,059^+$), we have $0,11v(1) < 0,1v(5)$ (see Equation 9), and thus $CE_C^v < CE_D^v$. Expression (I) in Equation (E.13) is positive. The EUT predicts choice D. By continuity with the previous case, the sign of Expression $(I) + (II)$ is negative when CE_B^v is just greater than 1.

If we consider, however, the r-utility function $u(x,r) = x^\alpha - k(r-x)^\beta$, Expression (I) and Expression (II) are both positive when $\alpha \geq 0,059633542 = 0,59^{++}$ ($\Leftrightarrow CE_B^v \geq 1,001230184 = 1^+$) and $\beta \geq 1$ (the regret function is linear or convex). See online appendix.

2. When $CE_D^v > 1$, Equation (E.11) can be written as follows:

$$\begin{aligned} &0,1v(5) + 0,9u(0, CE_C^v) \\ &> 0,11u(1, CE_D^v) + 0,89u(0, CE_D^v). \end{aligned} \tag{E.14}$$

Or else:

$$\underbrace{[0,1v\,(5)-0,11u\,(1,CE_D^v)]}_{(I)}$$

$$+\underbrace{[0,9u\,(0,CE_C^v)-0,89u\,(0,CE_D^v)]}_{(II)}>0. \tag{E.15}$$

When $CE_D^v > 1$, we also have $CE_B^v > 1$. When $\alpha \geq 0,59^{++}$ and $\beta \geq 1$, we know that Equation (E.13) is satisfied (see subcase c), which implies that Equation (E.15) is also satisfied.

References

Allais M (1953) Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'Ã©cole americaine. *Econometrica* 21(4):503–546.

Bell D.E (1982) Regret in decision making under uncertainty. *Operations Research* 30(5):961–981.

Bell D.E (1983) Risk premiums for decision regret. *Management Science* 29(10), 1156–1166.

Blackwell D (1951) Comparison of experiments. *Proceedings of the second Berkeley symposium on mathematical statistics and probability. Berkeley* (University of California Press).

Bleichrodt H, Walker P.P (2015) Regret theory: a bold alternative to the alternatives. *The Economic Journal* 125, 493–532.

Boles T.L (1992) Evaluation of outcomes under reference point conflict (Doctoral dissertation, University of California, Santa Barbara , 1991). Dissertation Abstract International, 52, 5577.

Boles T.L, Messick D.M (1995) A Reverse Outcome Bias: The Influence of Multiple Reference Points on the Evaluation of Outcomes and Decisions. *Organizational Behavior and Human Decision Processes* 61, 262-275.

Cerreia-Vioglio S, Dillenberger D, Ortoleva P (2015) Cautious expected utility and the certainty effect. *Econometrica* 83(2):693–728.

Dave C, Eckel C.C, Johnson C.A, Rojas C (2010) Eliciting Risk Preferences: When is Simple Better? *J Risk Uncertain* 41, 219–243.

Diecidue E, Somasundaram J (2017) Regret theory: A new foundation. *Journal of Economic Theory* 172, 88–119.

Dohmen T, Falk A, Huffman D, Sunde U (2010) Are Risk Aversion and Impatience Related to Cognitive Ability? *The American Economic Review* 100(3), 1238-1260.

Engelbrecht-Wiggans R, Katok E (2009) A Direct Test of Risk Aversion and Regret in First Price Sealed-Bid Auctions. *Decision Analysis*, 6(2), 756–86.

Epstude, K., Roese, N. J., 2008. The functional theory of counterfactual thinking. *Personality and Social Psychology Review* 12(2), 168-192.

Filiz-Ozbay E, Ozbay E.Y (2007) Auctions with Anticipated Regret: Theory and Experiment. *American Economic Review*, 97(4), 1407–1418.

Fishburn P.C (1989) Non-transitive measurable utility for decision under uncertainty. *Journal of Mathematical Economics* 18(2), 187–207.

Gabillon E (2020) When choosing is painful: Anticipated regret and psychological opportunity cost. *Journal of Economic Behavior & Organization* 178, 644–659.

Gilovich, T., 1983. Biased evaluation and persistence in gambling. *Journal of Personality and Social Psychology* 44(6), 1110-1126.

Holt C.A, Laury S.K (2002) Risk aversion and incentive effects. *The American Economic Review* 92(5), 1644–1655.

Incekara-Hafalir E, Kim E, Stecher J.D (2021) Is the Allais paradox due to appeal of certainty or aversion to zero? *Experimental Economics* 24, 751–771.

Inman J. J, Zeelenberg M (1998) What might be: The role of potential regret in consumer choice, In Abendroth, L. J. (Chair), Regret Me Not: An examination of regret in pre- and post-purchase evaluations, *Symposium conducted at the SCP-Winter Conference*, Austin, Texas.

Josephs R.A, Larrick R.P, Steele C.M, Nisbett R.E (1992) Protecting the self from the negative consequences of risky decisions. *Journal of Personality and Social Psychology* 62(1), 26-37.

Kahneman D, Tversky A (1979) Prospect theory: an analysis of decision under risk. *Econometrica* 47(2), 263–292.

Kihlstrom R (1974) A general theory of demand for information about product quality. *Journal of Economic Theory* 8(4), 413–439.

Larrick R. P, Boles T. L (1995) Avoiding regret in decisions with feedback: A negotiation example. *Organizational Behavior and Human Decision Processes 63(1), 87–97.*

Loomes G, Sugden R (1982) Regret theory: an alternative theory of rational choices under uncertainty. *Economic Journal* 63(368), 805–824.

Loomes G, Sugden R (1987) Some implications of a more general form of regret. *Journal of Economic Theory* 41(2), 270–287.

Luce R.D, Raiffa H (1956) Games and decisions: introduction and critical survey. (New York: John Wiley & Co).

Mellers, B. A., 2000. Choice and the relative pleasure of consequences. *Psychological Bulletin* 126(6), 910-924.

Mechera-Ostrovsky T, Liew S.X, Newell B.R (2023) The role of risk, regret, and rejoice in non-instrumental information seeking. *Journal of Behavioral Decision Making* 36(1), e2294.

Mehra, R., Prescott E (1985) The Equity Premium: A Puzzle, *Journal of Monetary Economics* 15, 145-161.

Mellers B.A, Schwartz A, Ritov I (1999) Emotion-based choice. *Journal of Experimental Psychology: General* 128(3), 332-345.

Quiggin J (1994) Regret theory with general choice sets. *Journal of Risk and Uncertainty* 8(2), 153–165.

Reb J, Connolly T (2009) Myopic regret avoidance: Feedback avoidance and learning in repeated decision making *Organizational Behavior and Human Decision Processes* 109(2), 182–189.

Roese N.J., 1997. Counterfactual thinking. *Psychological Bulletin* 121(1), 133-148.

Savage L.J (1951) The theory of statistical decision. *Journal of the American Statistical Association* 46, 55–67.

Schneider F.H, Schonger M (2019) An experimental test of the anscombe-aumann monotonicity axiom. *Management Science* 65(4), 1667–1677.

Shani Y, Tykocinski O. E, Zeelenberg M (2008) When ignorance is not bliss: How feelings of discomfort promote the search for negative information. J*ournal of Economic Psychology* 29, 643-653.

Shani Y, Zeelenberg M (2007) When and Why Do We Want to Know? How Experienced Regret Promotes Post-Decision Information Search. *Journal of Behavioral Decision Making* 20, 207–222.

Somasundaram J, Diecidue E (2017) Regret theory and risk attitudes. *Journal of Risk and Uncertainty* 55(2-3), 147–175.

Sugden R (1993) An axiomatic foundation for regret theory. *Journal of Economic Theory* 60(1), 159–180.

Summerville A (2011) Counterfactual Seeking: The Scenic Overlook of the Road Not Taken. *Personality and Social Psychology Bulletin* 37(11), 1522-1533.

Taylor S. E (1991) Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin* 110(1), 67–85.

Van Dijk E, Zeelenberg M (2005) On the psychology of 'if only': Regret and the comparison between factual and counterfactual outcomes, *Organizational Behavior and Human Decision Processes* 97, 152–160.

Wakker P.P (2010) Prospect theory for risk and ambiguity. (New York: Cambridge University Press).

Zeelenberg M (1999) Anticipated regret, expected feedback, and behavioral decision making. *Journal of Behavioral Decision Making* 12, 93–106.

Zeelenberg M, Beattie J (1997) Consequences of Regret Aversion 2: Additional Evidence for Effects of Feedback on Decision Making. *Organizational Behavior and Human Decision Processes*, 72(1), 63-78.

Zeelenberg M, Beattie J, van der Plight J, de Vries N.K (1996) Consequences of regret risk aversion: Effects of expected feedback on risky decision making. *Organizational, Behavior and Human Decision Processes* 65(2), 148–158.