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Contracts with Wishful Thinkers

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In a setting with a wishful thinking agent and a realistic principal, the paper studies how incentive contracts should be designed to control for both moral hazard and self-deception. The properties of the contract that reconcile the agent with reality depend on the weight the agent attaches to anticipatory utility. When this is small, principal and agent agree on full recollection. For intermediate values the principal bears an extra cost to make the agent recall bad news. For large weights, the principal gives up on inducing signal recollection. We also extend the analysis to the case in which the parameter of anticipatory utility is private information.

1. Introduction

There is widespread psychological evidence that most individuals hold overly positive evaluations about the self and exaggerated perceptions of control or unrealistic optimism (Taylor and Brown, 1988).[1] Recent economic literature has tried to reconcile this with individual decision making, by constructing models with endogenously wishful thinkers. The present paper introduces moral hazard in such a model and studies an employment contract between an endogenously optimistic agent and a realistic principal. Optimism is modeled assuming that the agent enjoys anticipatory utility, that is, derives utility from the anticipation of his future payoff: the greater his future payoff, the greater his current utility. A greater anticipatory utility can be achieved by suppressing current bad information affecting future payoffs, thus expecting good outcomes more

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1. In the economic literature, such attitudes are especially documented for businessmen. For example, Cooper et al. (1988) argue that entrepreneurs see their own chances for success higher than that of their peers, whereas Malmendier and Tate (2005) and Malmendier and Tate (2008) find evidence that CEOs overestimate their firms' future performance.

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often than is warranted. But because distorted beliefs distort actions, optimism has an influence on decisions and exacerbates incentive problems. We study how the need to control for both optimism and moral hazard affects the design of incentive contracts.

To analyze this problem, we develop a model that unifies various themes from psychology and economics within a simple contract-theoretic framework. According to an influential literature in psychology (Taylor and Brown, 1988), normal mental functioning is skewed in a positive direction and processes of self deception—the active misrepresentation of reality to the conscious mind—are characteristic of mental health (Trivers, 2000). The resulting biases guide the processing of information, such that mildly negative or ambiguous information is distorted to be more positive than may actually be the case. In particular, individuals adjust to threatening events by constructing benign interpretations of the same events.[2] One of the many forces that may favor mechanisms of self-deception is that positive illusions may give intrinsic benefits (Taylor and Brown, 1988; Trivers, 2000). As Taylor (1989) describes it, "It is just as easy to construe future events in a manner that promises success and happiness rather than one that portends failure. Self-deception can be healthful and bolstering if it doesn't involve gambling one's resources beyond salvage." The beneficial effect of self-deception is modeled in the economic literature by assuming that prior to the resolution of uncertainty, individuals experience feelings of anticipation. Through imperfect memory, they select their beliefs so as to enjoy the greatest comfort or happiness, thus leading to cognitive dissonance.

However, there are limits to the extent of self-deception. "At one level, [the normal human mind] constructs beneficent interpretations of threatening events that raise self-esteem and promote motivation; yet at another level, it recognizes the threat or challenge that is posed by these events" (Taylor, 1989). To capture the "consciousness/awareness" that rejoins individuals with reality, most of the theoretical literature has assumed individuals to be Bayesian information processors (Piccione and Rubinstein, 1997; Bénabou and Tirole, 2002): they are aware of the flaws of memory and in making choices take into account the possibility of having suppressed unfavorable information.[3]

Our paper builds on this literature and by applying a game of belief management à la Bénabou and Tirole (2002) into a principal-agent framework with wishful thinking agents, inquires into how a principal should reward a forgetful agent in the awareness that well-designed payoffs can limit his tendency to self-deception. The agent's forgetfulness is modeled as in Bénabou (2008) and Bénabou (2013), which incorporates anticipatory utility into the model of Bénabou and Tirole (2002). The contracting framework we adopt represents a further mechanism through which the individual can be reconciled with reality and is the main contribution of this paper.

In our model, a risk-neutral principal hires a risk-neutral agent for a project. When the principal offers the contract, the parties are symmetrically informed. If the agent accepts, he chooses a level of effort that affects the project's probability of success. After signing but before choosing his unobservable effort, the agent receives a private signal about the profitability of the task. A good signal implies a high return in case of success and a bad signal only an intermediate return. Finally, in case of failure, the return is zero regardless of type of signal. If the signal is informative about the return from effort, the agent would benefit from having accurate news. However, because he derives utility

2. Freud (1940, 1957) argues that when events from the internal and external world are highly threatening, people may deny or repress their implications in order to avoid intolerable anxiety. Denial involves a distortion of negative experiences so complete that it can block out the memory of the experience altogether (cited in Taylor, 1989).

3. See Mullainathan (2002) for the case of naive decision makers.

from the anticipation of his final payoff, the suppression of a bad signal may induce a positive interim emotional effect. We assume that the principal cannot observe the agent's choice. Thus, to induce him to choose the right action, she makes compensation contingent on project revenues. More specifically, parties can write a complete contract specifying the rewards contingent on the various outcomes and the effort levels to be exerted contingent on the recalled signals.

Does the optimal contract always ensure recall? We show that if the agent's anticipatory utility is sufficiently low, there is no conflict of interest between principal and agent's desired recall because both parties prefer accurate signal recollection. There is a conflict for intermediate values of this parameter where the principal chooses to bear the extra cost necessary to have the agent recall the bad signal and exert the right level of effort. Finally, for a sufficiently high weight on anticipatory utility, the principal becomes indifferent between inducing signal recollection or not. In this latter case, the optimal contract is characterized by a pooling equilibrium reminiscent of adverse selection models.

Why does the optimal contract look like this? Informed agents face a trade-off between ensuring that the level of effort they choose reflects accurate news and savoring emotionally gratifying good news. However, the agent's preferred level of memory may differ from the principal's. As a result, the principal may want to affect this dimension of the agent's choice when writing the contract. If in the agent's utility the weight of emotions is sufficiently small, accurate news becomes a priority for the agent too and there is no conflict over information recollection. Here, a contract can attain the optimal recall at no extra cost.[4] For larger weights on anticipatory utility, the agent's trade-off tilts away from accurate news toward good news, so that enticing proper information recollection becomes costly. For intermediate values of the parameter, the principal chooses to move the agent's trade-off toward accuracy by making it costly to recall a good signal when the true signal is bad. This is done by increasing the cost to the agent when he exerts the effort expected for the good rather than the bad signal. But if the weight on emotions instead is sufficiently large, the optimal contract calls for a pooling equilibrium in which the agent exerts the same level of effort and receives the same payments regardless of signal type. Intuitively, when the weight on anticipatory utility is high, the agent will recall the signal accurately only if he does not anticipate a lower payment when the signal is bad.[5]

The analysis so far implicitly relies on the assumption that the principal knows the weight the agent attaches to anticipatory utility. We extend the analysis to the opposite extreme, assuming that this parameter is the agent's private information. In this case, the optimal contract will be designed so as to induce all agents with a parameter of anticipatory utility below a threshold level to recall the bad signal, and all those above to forget it. Relative to the perfect information benchmark, the set of agents who will be induced (by the contract) to recall the bad signal is now larger and also includes some agents who (due to the conflict of interests) impose an extra recollection cost on the principal.

The paper is organized as follows. After presenting a brief review of the relevant theoretical and experimental literature in the next subsection, Section 2 presents the

4. No extra cost with respect to the resources needed to solve the moral hazard problem.

5. There also exists an outcome-equivalent equilibrium where investors prefer not to elicit information recollection, the manager never recalls a bad signal, and the level of effort is the same as in the pooling equilibrium.

model. Section 3 sets out the results concerning the conflict between principal's and agent's optimal recall. Section 4 characterizes the optimal contract and underlines some implications of the theory for "job design." Section 5 extends the analysis to the case in which the parameter of anticipatory utility is the agent's private information. Section 6 concludes. Proofs are in Appendix A while Appendix B presents an alternative modeling strategy.

1.1 Related Literature

1.1.1 Theoretical Literature

The papers closest to ours are Bénabou (2008) and Bénabou (2013) who, using a selective awareness framework within a model of anticipatory utility, [6] provide theories of ideology and groupthink. In particular, Bénabou (2013) develops a model in which multiple agents are engaged in a joint project displaying complementarity in actions. Due to anticipatory utility, each agent faces a trade-off between recalling and forgetting a common signal about the project value. This trade-off depends on how others deal with bad news and may lead to situations of *collective denial* or *willful blindness* (Bénabou, 2013, p. 2). In our paper, because we have one single agent, payoffs depend only on the agent's own actions, but they are determined by the principal who affects effort choice and recollection.

The paper is also related to Bénabou and Tirole (2002) who provide a theory of personal motivation and discuss the idea that information can have negative value. In particular, they show that adverse signals may always be transmitted, or always forgotten.[7] Similarly in our paper, whether information is interpreted truthfully or ignored depends on the parameter of anticipatory utility. However, unlike Bénabou and Tirole (2002), the principal may affect the agent's recollection through the contract.

Still within the selective awareness framework, Gottlieb (2014) proposes a model in which the decision maker can exert effort both to remember and to forget signals. He shows that it is no longer true that when both are present, there is a benefit from being uninformed. It is unclear if the results of our paper in which the agent can only forget bad signals, generalize also to the case in which the agent can remember good signals.

Finally, the paper is related to Smith (2009) who shows that imperfect memory leads to a preference for increasing payments as these allow the individual to make inference on forgotten signals.

Relative to this literature, an individual decision-making problem has the same qualitative features, signals may be forgotten, of a contracting problem in which payoffs are designed by the principal.

Our contribution with respect to this literature is to show that in a contracting framework features that are qualitatively true for an individual decision maker remain true when payoffs are designed by the principal.

Regarding underlying potential psychological effects of the contracting framework, the paper is also linked to Bénabou and Tirole (2003) and Fang and Moscarini

6. Other papers featuring belief distortion are those on cognitive dissonance; see Festinger (1957) for a psychological reference, or Akerlof and Dickens (1982), Rabin (1994), Carrillo and Mariotti (2000), Bénabou and Tirole (2002), among others, for economic references. On anticipatory utility, see (among others) Loewenstein (1987), Caplin and Leahy (2001), Bernheim and Thomadsen (2005), Brunnermeier and Parker (2005), and Koszegi (2006) .

7. Note that this depends on the individual's time-discounting profile. Also note that there may be equilibria with perfect recall, with no recall or with partial recall.

(2005).[8] The first authors work in a setting in which the agent has imperfect knowledge about his ability and undertakes a certain task only if he has sufficient confidence in his ability to succeed. They study how an informed principal should reward the agent knowing that rewards can undermine intrinsic motivation. Similarly, Fang and Moscarini (2005) study the design of wage contracts that provide incentives and affect work morale. In our paper, rewards serve to limit wishful thinking, whereas in these papers they manipulate motivation . This is to be ascribed to the different information structures of the two settings: in the above contributions the principal has *ex ante* information about the agent's characteristics, whereas in our paper parties are *ex ante* symmetrically informed.

Finally, the paper is related to a companion one (Immordino et al., 2011) in which we show that emotional aspects may render it impossible to implement the first-best output, thus providing a negative result. Specifically, although parties are symmetrically informed and contracts are complete, it may be impossible to achieve the first-best if the weight on emotions is too high. Instead, in the present paper, we start from a second best world and study the properties of the contract that reconciles the agent with reality. In this way, the two analyses are complementary.

1.1.2 Experimental Literature

The paper is also related to some recent experimental literature documenting people's tendency to process information in a biased manner. For example, individuals tend to view themselves as intelligent and will process information in a biased way to support that belief. Mobius et al. (2011) conduct an experiment with college students who perform an IQ test for which they receive noisy signals of their performance. They find that subjects systematically discount bad news about their own intelligence. Similarly, Eil and Rao (2011) find that subjects are asymmetric updaters: close to proper Bayesian updating for positive news about their intelligence and beauty, but underupdating for negative news.

A differential response to good and bad news is also documented in Mayraz (2011) who designs an experiment in which subjects observing a financial asset's historical price chart have to predict the price of the asset. They receive both an accuracy bonus for predicting the price at some future point in time and an unconditional award that is either increasing or decreasing in this price. It turns out that subjects gaining from high prices make significantly higher predictions than those gaining from low prices, with the magnitude of the bias independent of the amount paid for accurate predictions. Finally, recent experimental evidence shows that belief distortion responds to incentives. In particular, Mijovic-Prelec and Prelec (2010) propose an experimental study showing that self-deceptive judgements can be elicited with financial incentives, with the latter affecting even the degree of self-deception. In addition to the findings of both the empirical and the experimental literature showing that incentives may have mixed effects on performance according to the task to be accomplished—see the surveys of Prendergast (1999) and Camerer and Hogarth (1999)—this literature also provides some preliminary evidence of a further role for incentives in their ability to affect beliefs.

8. Other papers on motivation effects in incentive design are Ishida (2006), Swank and Visser (2007), and Crutzen et al. (2013).

2. The Model

2.1 Players and Environment

In our model, a risk-neutral principal hires a risk-neutral agent for a risky project. When the principal offers the contract C at time $t = 0$, the parties are symmetrically informed.

If the agent accepts, at $t = 1$ he receives a private signal $\sigma \in \{L, H\}$ about the profitability of the task. A good signal implies a high return in case of success, a bad signal only an intermediate return (in the case of success). The probability of a good signal H is q and that of a bad signal L is $(1 - q)$, with $q \in (0, 1)$. Finally, in the case of failure, the return is low regardless of the type of signal. We assume that the agent can costlessly forget bad news.[9]

At $t = 2$, the agent chooses unobservable effort $a \in [0, 1]$ that affects the project's probability of success. We assume that effort has disutility $c(a) = ca^2/2$ (but most of our results extend to more general cost functions). In our setting, good (bad) news means that the outcome is v_H (v_L) or v_0 with probability a and $1 - a$, respectively. [10] Thus, the project has three possible outcomes, $\widetilde{v} \in \{v_0, v_L, v_H\}$ with $0 \leq v_0 < v_L < v_H$, where each outcome occurs with probabilities $1 - a$, $(1 - q)a$ and qa, respectively.[11]

Before the effort decision is taken, a bad signal can be voluntarily repressed. This gives rise to a memory game between Agent 1 and Agent 2, that is, the agent's self at time 1 and the agent's self at time 2. In this game, Agent 1 chooses his memory strategy and Agent 2 forms his beliefs about the true signal realization. We denote the signal recollection by $\widehat{\sigma} \in \{L, H\}$ and the decision to recall ($j = R$) or to forget it ($j = F$) by $j \in \{R, F\}$.[12]

Because the signal gives information on the return from effort, in choosing its level the agent would benefit from accurate news. But if the agent derives utility from the anticipation of his final payoff, the suppression of a bad signal may induce a positive emotional effect. This is modeled assuming, as in Bénabou (2013), that total utility is a convex combination of the actual physical outcome and the anticipation of it, with weights $1 - s$ and s, respectively, where s is the realization of a random variable distributed over the compact support $S \equiv [0, 1]$ according to the twice continuously differentiable and atomless cumulative distribution function $F(s)$, with density $f(s)$. Following the literature—see for instance Bénabou (2008) and Bénabou (2013)—we assume, for the time being, that the parameter s is common knowledge.[13]

To ensure interior solutions, we assume that $v_H < c$. Moreover, we denote by $C \equiv \{w_0, w_L, w_H\}$ the contract that the principal offers the agent, where w_i is the reward corresponding to $v = v_i$, for any $i = 0, L, H$.

Finally, we assume that the agent has limited liability, so that $w_i \geq 0$ for any i, and we maintain the standard assumption of individuals as rational Bayesian information processors.

Figure 1 depicts the timing of the game.

9. Assuming costly recollection would not change our results qualitatively.

10. In other words, we assume for simplicity that the signal is perfectly correlated with the return $\tilde{v}$, implying that $\Pr(\tilde{v} = v_0|\sigma = L) = \Pr(\tilde{v} = v_0|\sigma = H) = 1 - a$, and $\Pr(\tilde{v} = v_L|\sigma = H) = \Pr(\tilde{v} = v_H|\sigma = L) = 0$.

11. This modeling choice that distinguishes between the project's characteristics and the agent's effort allows us to deal in the simplest possible way with two imperfections: moral hazard and imperfect recall. For an alternative modeling strategy see Appendix B (for which we thank an anonymous associate editor).

12. Notice that we restrict the analysis to the pure strategy equilibria of the memory game. This is without loss of generality because we assume that, when the agent is indifferent between recalling or forgetting, he

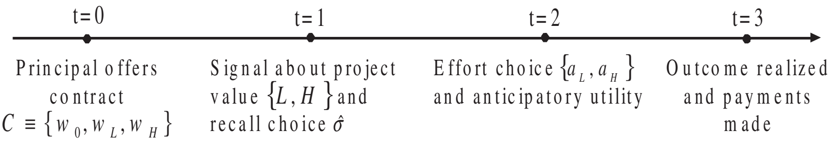

FIGURE 1. TIME-LINE

2.2 Equilibrium

The equilibrium concept is Perfect Bayesian Equilibrium. The game can be solved by first identifying the agent's optimal effort choice a, given his beliefs about σ and a contract C; then, finding the equilibrium of the memory game for any given contract; and finally, by computing the principal's contract offer using the agent's optimal effort choice rule and inference .

3. The Conflict over Optimal Recollection between Principal and Agent

In this section, we show that the principal always prefers perfect recollection. Then, we show that, if the weight on anticipatory utility is sufficiently high, the agent prefers to forget bad news when he is offered the second-best contract. This points to a potential conflict of interest between principal and agent over the memory strategy.

To establish the former result, we proceed in three steps. First, we solve the principal's maximization problem under the assumption that the agent recalls the signal in the memory game. Then we solve the principal's maximization problem under the assumption that he forgets bad news. Finally, we compare the principal's expected profits under the two different assumptions and find the best recollection strategy from her point of view.

Notice that here we do not focus on the analysis of the equilibrium of the memory game because it has been studied by Bénabou and Tirole (2002). [14] We simply define a recalling equilibrium (R) where Agent 1 chooses accurate signal recollection and a forgetting equilibrium (F) where Agent 1 chooses to forget a bad signal.[15] We now determine the effort that Agent 2 chooses under the assumption of a recalling equilibrium and under the assumption of a forgetting equilibrium in the memory game.

Faced with the contract $C \equiv \{w_0, w_L, w_H\}$ and the recalled signal $\widehat{\sigma}$, at $t = 2$ Agent 2 chooses the level of effort that maximizes his expected utility. When $\widehat{\sigma} = L$, Agent 2 is sure that $\sigma = L$ and his expected utility simplifies to $[a w_L + (1 - a)w_0] - ca^2/2$, where the term in square brackets is the sum of the agent's expected material payoff, $(a w_L + (1 - a)w_0)$, weighted by $(1 - s)$, and the anticipatory utility experienced by savoring

chooses the action preferred by the principal. Then, the equilibrium of the game has pure strategies and perfect recall. This result is proved in Proposition 1 of the working paper version (Immordino et al., 2012).

13. This assumption is relaxed in Section 5.

14. To derive the equilibrium of the memory game, (i) for any realized σ, Agent 1 chooses his message $\widehat{\sigma}$ to maximize his expected utility, correctly anticipating the inferences that Agent 2 will draw from $\widehat{\sigma}$, and the action that he will choose; (ii) Agent 2 forms his beliefs using Bayes' rule to infer the meaning of Agent 1's message, knowing his strategy.

15. Notice that by an abuse of notation, $j \in \{R, F\}$ denotes both the action and the equilibrium.

the future material payoff, $(aw_L + (1-a)w_0)$, weighted by s.[16] The effort level that maximizes the agent's utility is the a_L that satisfies the following first-order condition:

$$w_L - w_0 = ca_L. \tag{1}$$

When $\widehat{\sigma} = H$, if Agent 2 believes that Agent 1's signal recollection was accurate ($j = R$), his expected utility is $aw_H + (1-a)w_0 - ca^2/2$. The effort level that maximizes his expected utility is a_H^R such that

$$w_H - w_0 = ca_H^R. \tag{2}$$

If instead Agent 2 believes that Agent 1 forgets bad news ($j = F$), he is unsure whether he actually received a good signal or instead received a bad signal and forgot it. In this case, the probability that he attaches to the good signal is the prior q, and his expected utility is $a(qw_H + (1-q)w_L) + (1-a)w_0 - ca^2/2$. The effort level that maximizes his expected utility is the a_H^F that solves

$$qw_H + (1-q)w_L - w_0 = ca_H^F. \tag{3}$$

Denote the vectors of effort levels solving equations (1), (2), and (3) by $a(j, C) \equiv \{a_L, a_H^j\}$, with $j \in \{R, F\}$.

The agent's payments must always be nonnegative by limited liability, that is,

$$w_i \geq 0, \ \forall i \in \{0, L, H\}. \tag{4}$$

Because the agent can choose to exert no effort at all, the incentive compatibility and the limited liability constraints ensure that the participation constraint is always satisfied. Hence, in the following analysis we will neglect it.

The principal's expected profit in period 0 in the case of a recalling equilibrium is

$$qa_H(v_H - w_H) + (1-q)a_L(v_L - w_L) + (1 - qa_H - (1-q)a_L)(v_0 - w_0), \tag{5}$$

and, in the case of a forgetting equilibrium,

$$qa_H(v_H - w_H) + (1-q)a_H(v_L - w_L) + (1 - a_H)(v_0 - w_0), \tag{6}$$

where a_L, a_H are the effort levels contingent on $\hat{\sigma} = L$ and $\hat{\sigma} = H$, respectively. If the agent recalls bad news, the principal's problem reduces to the choice of effort levels a_L, a_H, and payments w_0, w_L, w_H that maximize her expected profit (5) subject to the incentive constraints (1) and (2), and to the limited liability constraints (4). Assuming that the agent always forgets bad news, the principal's problem is instead to choose the effort level a_H and payments w_0, w_L, w_H that maximize her expected profit (6) subject to the incentive constraint (3), and to the limited liability constraints (4). Notice that the limited liability constraint on w_0 is binding. Thus, from now on, we set $w_0 = 0$. Moreover, without loss of generality, we normalize $v_0 = 0$.[17] By comparing the solutions of the above programs, we show that:

Proposition 1: *In the memory game, the principal's maximum expected profit is greater at a recalling equilibrium than at a forgetting equilibrium.*

The intuition behind this result is the following. An accurate signal recollection has both a positive and a negative effect on the principal's expected profit. Indeed for any

16. Notice that the anticipatory and expected material payoffs of Agent 2 are equal.
17. By rearranging equations (5) and (6), it can be shown that for any value of v_0, v_H and v_L can be redefined so as to leave the solutions unchanged.

contract C, the probability of success in the high state of the world ($\sigma = H$) is higher in the recalling equilibrium than in the forgetting equilibrium, that is, $a_H^R > a_H^F$. In contrast, the probability of success in the low state of the world ($\sigma = L$) is lower in the first equilibrium, that is, $a_L < a_H^F$.[18] Because the positive effect outweighs the negative, the principal prefers the recalling equilibrium.

We now compare the expected utility of Agent 1 in the recalling equilibrium (recalling utility), with the expected utility of Agent 1 when he deviates from the announced recollection strategy (deviation utility). The recalling utility is $[q w_H^2 + (1-q) w_L^2]/2c$,[19] whereas the deviation utility is $\{[q + (1-q)s] w_H^2/2 + (1-q)(1-s)(w_L - w_H/2) w_H\}/c$.[20] By computing the difference between the recalling and the deviation utility, we obtain the following nonforgetfulness constraint

$$\frac{c}{2}\left(\left(\frac{w_H}{c}\right)^2 - \left(\frac{w_L}{c}\right)^2\right) \geq s\frac{w_H}{c}(w_H - w_L) + \left(\frac{w_H}{c} - \frac{w_L}{c}\right) w_L, \tag{7}$$

where w_H/c is the effort chosen by Agent 2 when a good signal is correctly recollected, whereas w_L/c is the effort chosen by Agent 2 when a bad signal is recollected.

From the above constraint we conclude that Agent 1 has an incentive to recall when the extra cost he incurs to exert high rather than low effort $(c/2((w_H/c)^2 - (w_L/c)^2))$ exceeds the sum of the emotional gain from forgetting $(s(w_H/c)(w_H - w_L))$ and the gain due to obtaining w_L rather than w_0 with an increased probability $(w_H/c - w_L/c)$. It is clear that the incentive to recollect the bad signal is greater the lower the parameter capturing anticipatory utility s.

Let us denote by $C^{SB} \equiv \{0, v_L/2, v_H/2\}$ the second-best contract offered by the principal to the agent in the recalling equilibrium. The next proposition shows that for s low enough, the second-best contract satisfies the nonforgetfulness constraint (7) and implements the second-best efforts. By substituting out C^{SB} in the incentive constraints (1) and (2), these turn out to be $a_L^{SB} = v_L/2c$ and $a_H^{SB} = v_H/2c$.

Proposition 2: *There exists a threshold s^{SB} such that for all $s \leq s^{SB}$, the second-best contract C^{SB} satisfies the nonforgetfulness constraint* (7) *and implements the second-best efforts, where*

$$s^{SB} \equiv \frac{(v_H - v_L)}{2v_H}. \tag{8}$$

The threshold s^{SB} is the greatest weight placed on anticipatory utility that makes the agent indifferent between recalling and forgetting bad news. Notice that, because s^{SB} is lower than 1/2, condition (7) is violated if $s > 1 - s$. That is, whenever the weight

18. From the incentive constraints (1), (2), and (3), it is immediate that $a_H^F \in (a_L, a_H^R)$.

19. This is obtained by replacing the levels of effort a_L and a_H^R implicitly defined by the incentive constraints (1) and (2), in the expected utility of Agent 1 when he recalls:

$$q\left(a_H^R w_H - \frac{c}{2}(a_H^R)^2\right) + (1-q)\left(a_L w_L - \frac{c}{2}a_L^2\right).$$

20. This is obtained by substituting the level of effort a_H^R in the expected utility of Agent 1 when he deviates:

$$q\left(a_H^R w_H - \frac{c}{2}(a_H^R)^2\right) + (1-q)\left[s\left(a_H^R w_H - \frac{c}{2}\left(a_H^R\right)^2\right) + (1-s)\left(a_H^R w_L - \frac{c}{2}\left(a_H^R\right)^2\right)\right].$$

Notice that when Agent 1 deviates, Agent 2 always observes a good signal and chooses the level of effort a_H^R. Moreover, because the information sets of Agent 1 and Agent 2 are different, the anticipatory utility savored by Agent 2 $(a_H^R w_H - \frac{c}{2}(a_H^R)^2)$ differs from the actual utility $(a_H^R w_L - \frac{c}{2}(a_H^R)^2)$

attached to anticipatory utility is greater than the weight attached to the physical outcome. Taken together, Propositions (1) and (2) highlight a potential conflict in a setting where memory is endogenous: the principal always prefers perfect signal recollection, but the agent could prefer to forget bad news if the weight placed on anticipatory utility is great enough, that is, $s > s^{SB}$ (unless the contract is appropriately modified).[21] Interestingly, the importance of the signal is inversely related to the distance between the intermediate return v_L and the good return v_H. Indeed, the signal is worthless if $v_L = v_H$, whereas it is crucial when $v_L = 0$. As a consequence, the significance of the conflict of interest between principal and agent over the memory strategy also depends on the distance between the return for an extremely good project v_H, and for a business-as-usual result, v_L. In the following, we will interpret this distance as a measure of the riskiness of the project. Generally, as the distance between v_H and v_L decreases, the agent's incentive to forget bad news increases.

4. The Optimal Contract

In this section, we explore the implications of violating condition (7). Earlier we showed that if the agent attaches a large weight to anticipatory utility (i.e., if $s > s^{SB}$) the second-best outcome cannot be achieved because contract C^{SB} fails to induce the agent to recollect his private information correctly. This gives rise to a third-best scenario, in which effort is unverifiable and the agent elects to forget bad news. In such circumstances, the principal's problem which we denote by $\mathcal{P}^{TB}$, is to choose a vector of effort levels and a contract that maximize the expected profit (5), under the incentive constraints (1) and (2), the limited liability constraints (4), and the nonforgetfulness constraint (7) where the agent is indifferent between forgetting and remembering bad news, which can be rewritten as

$$(w_H - w_L)\,[(1-2s)\,w_H - w_L] = 0. \tag{9}$$

Satisfaction of the previous equality produces two possible equilibria: a *separating* equilibrium, denoted by the superscript S, where $w_L = \phi(s)w_H$ with $\phi(s) \equiv (1-2s)$, which is possible only if $s \le 1/2$; and a *pooling* equilibrium, denoted by the superscript P, where $w_H = w_L$.[22] Proposition 3 solves the principal's problem in these two equilibria.

Proposition 3: *In the separating equilibrium, the optimal levels of effort are*

$$a_H^S = a_H^{SB} + \gamma\,(1-2s)\,(1-q)\,,\ a_L^S = a_L^{SB} - \gamma q,$$

and are implemented by the following state-contingent rewards

$$w_0^S = 0,\ w_H^S = w_H^{SB} + c\gamma\,(1-2s)\,(1-q)\,,\ w_L^S = w_L^{SB} - c\gamma q,$$

where $\gamma \equiv \frac{v_H(s-s^{SB})}{c(q+(1-q)(1-2s)^2)}$ *is positive for any* $s \ge s^{SB}$.

In the pooling equilibrium, the optimal level of effort is given by

$$a_H = a_L = a^P = q a_H^{SB} + (1-q)\,a_L^{SB},$$

and is implemented by the following state-contingent rewards

$$w_0^P = 0, w_H = w_L = w^P = q w_H^{SB} + (1-q)\,w_L^{SB}.$$

21. This result generalizes to any convex cost function with positive third derivative. The proofs are available upon request.

22. If $s > 1/2$, the binding nonforgetfulness constraint (9) would imply $a_L < 0$.

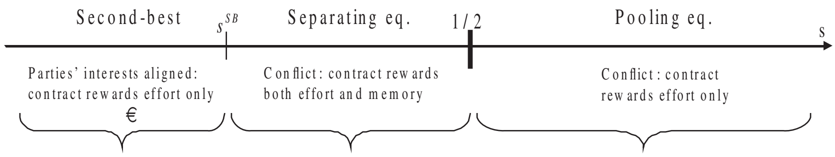

FIGURE 2. OPTIMAL CONTRACT AS A FUNCTION OF S

The above proposition makes it clear that there are two opposite ways to elicit accurate recollection. In the separating equilibrium, the principal increases the cost of forgetting (i.e., the left-hand side of condition (7)) by offering a reward higher than second-best when the agent recalls good news and lower when he recalls bad news.[23] In the pooling equilibrium, the principal eliminates any incentive to suppress bad news by offering a flat contract paying a constant amount w^P regardless of result $\{v_H, v_L\}$ and asking for the same level of effort a^P following both signals. As neither effort levels nor rewards depend on signal recollection, the agent is indifferent between recalling and forgetting bad news.[24]

Proposition 4 states the conditions for the parameter s to generate either the separating or the pooling equilibrium and describes the pattern of the principal's utility as s varies.[25]

PROPOSITION 4: *The separating equilibrium arises for all $s \in (s^{SB}, 1/2]$, the pooling equilibrium for all $s > 1/2$. Moreover, the principal's expected utility is highest in the second best equilibrium, it decreases in s for all $s \in (s^{SB}, 1/2]$ and is lowest in the pooling equilibrium.*

A possible way of interpreting this result is by seeing s as a measure of the importance of effort with respect to anticipatory utility. Thus, depending on the weight placed on anticipatory utility, we get the three possible scenarios depicted in Figure 2. When s is sufficiently small ($s \leq s^{SB}$), the agent recollects the signals correctly and the principal designs a contract that rewards effort but not memory. Due to moral hazard, the principal achieves the second-best. For $s^{SB} < s \leq 1/2$, the emotional impact of bad news may induce the agent to suppress it. To induce accurate memory recollection, the principal has to design a separating contract that punishes forgetfulness and rewards memory. This is achieved by setting payments and effort levels further apart, as made clear by Proposition 3. However, when $s > 1/2$, a separating contract is not feasible because w_L becomes negative, violating limited liability. The weight attached to emotions is so great that it is impossible for the principal to elicit effort and memory through an incentive contract. As a consequence, she offers a flat-rate contract paying w^P for

23. It is immediate to see from Proposition 3 that because a separating contract is offered only if $s^{SB} \leq s \leq 1/2$, $a_H^S \geq a_H^{SB}$ and $w_H^S \geq w_H^{SB}$, while $a_L^S < a_L^{SB}$ and $w_H^S < w_H^{SB}$.

24. It is interesting to observe that in the pooling equilibrium, a^P is the average between a_H^{SB} and a_L^{SB}, and w^P is the average between w_H^{SB} and w_L^{SB}.

25. This result generalizes to any convex cost function such that the ratio between average and marginal costs is monotone for all $a \in [0, 1]$. This assumption being satisfied (for instance, by any power function) guarantees a regularity condition on the nonforgetfulness constraint and states that average costs always grow at a higher or lower rate than marginal costs. The proofs are available upon request.

effort a^P irrespective of the level of output $\{v_H, v_L\}$, thereby removing any incentive to suppress bad news.[26,27]

The above results have implications not only on the design of the compensation contract for emotional agents, but also on the selection process, that is, on the type of agent preferred by the principal. According to the weight of s, three scenarios can arise: for $s \in [0, s^{SB}]$, the optimal contract and the effort chosen by the agent are independent of s. Indeed, if the parties' preferences on memory strategy are perfectly aligned, the weight the agent attaches to emotions relative to physical utility does not affect his effort decision, so the principal's second-best expected utility $E_0\Pi^{SB}$ does not depend on s. But for $s \in (s^{SB}, 1/2]$, principal and agent disagree, both rewards and effort depend on s and the principal's third-best expected profit in the separating equilibrium $E_0\Pi^S$ decreases with s. When $s > 1/2$, the principal stops distorting rewards to induce recollection, and neither effort nor payments are affected by the weight the agent attaches to emotions. Consequently, in the pooling equilibrium the principal's third-best expected utility is independent of s.

The previous discussion implies that, having the possibility of selecting agents on the basis of the characteristics captured by the parameter s, the principal will choose any agent with $s \leq s^{SB}$. Moreover, the preference over these features should be more pronounced for less risky firms/industries/occupations. Although seemingly counter-intuitive, this can be rationalized considering that in our setup, incentive contracts play the dual role of inducing effort and eliciting memory. To see this, recall the comparative statics on s^{SB}. When the distance between v_H and v_L increases, s^{SB} shifts rightward (toward 1/2) and leftward when it decreases. Thus, when v_H and v_L are distant (high-risk firms), in order to induce effort the principal must offer high-powered incentive contracts that also alleviate the agent's memory problem. Thus, by means of a standard second-best contract, the principal manages to resolve the memory problem of more emotional agents. When v_H and v_L are close to each other (low-risk firms), a low-powered incentive contract suffices to induce effort. But because s^{SB} is smaller, this may conflict with the memory problems of more emotional agents, calling for a high-powered incentive contract, which results in a separating contract. Thus, despite the attenuated moral hazard, lower risk firms may be faced with the problem of overoptimism.

Thus, principals with riskier projects can "afford" to employ more emotional agents because they can also control their tendency to self-deception at no extra cost by offering high-powered incentives to induce effort. Those with less risky projects, instead, have less difficulty in inducing effort, but are confronted with the problem of controlling the agent's optimism. Because this is costly, they prefer to resort to less emotional agents.

4.1 Job Design

Would the principal prefer to set more modest goals for agents who are more prone to memory problems? Or in other words, how is the task assigned to an agent and

26. The three scenarios described above can emerge only if $v_H > v_L > 0$. As v_L varies, the separating contract interval expands or shrinks (s^{SB} shifts leftward or rightward). In particular, if $v_L = 0$ then $s^{SB} = 1/2$ and the separating equilibrium never arises. Although if $v_L = v_H$ then $s^{SB} = 0$, but here there is no incentive to forget a bad signal and hence no memory problem.

27. There also exists an equilibrium in which the principal chooses not to elicit accurate signal recollection and opts for an *accommodating* strategy by neglecting constraint (7), so that the agent never recollects the bad signal. As a result, he always exerts high effort a_H^A, where a_L is off the equilibrium path. It turns out that $a_H^A = a^P$ and $w_H^A = w^P$, so that this is welfare-equivalent to the pooling equilibrium.

the corresponding wage affected by the agent's anticipatory utility? To answer these questions, in this section we assume that the principal can choose one characteristic of the job (or equivalently can choose among different jobs) to assign to a specific agent. The model we consider differs from the benchmark model only by the following definition: $v_H = v$ and $v_L = vk$ with $0 < k < 1$. In this setting the common term v determines the importance of the task and the relevance of effort. Conversely, because the difference between the two outcomes in case of good and bad news $v_H - v_L$ is equal to $v(1-k)$, the parameter k is a measure of the memory problem: the smaller k, the larger s^{SB}, that is, the less severe the memory problem. We assume that the principal can choose which v to assign to a given agent.

Substituting $v_H = v$ and $v_L = vk$ in (8) we deduce that the agent chooses to recall only if

$$s \leq s^{SB} \equiv \frac{1-k}{2} < \frac{1}{2}. \tag{10}$$

As in the general case, the threshold s^{SB} is the greatest weight placed on anticipatory utility that makes the agent indifferent between recalling and forgetting bad news. Notice that the relevance of the task measured by v does not play any role in the determination of the threshold, which is completely determined by the memory problem measured by k.

For $s \in (s^{SB}, 1/2]$, the emotional impact of bad news may induce the agent to suppress it. The principal then has to design a separating contract that punishes forgetfulness and rewards memory in order to induce accurate memory recollection. We now study how the principal's profits are affected by the possibility of assigning different agents to different tasks. Substituting $v_H = v$ and $v_L = vk$ in the principal's value function (17 in Appendix A) and differentiating with respect to s and v we get:

$$\frac{\partial^2 E_0 \Pi^S}{\partial s \partial v} = \frac{2v(1-q)(q+(1-q)\phi(s)k)}{c(q+(1-q)\phi(s)^2)} \left[\phi(s)(q+(1-q)\phi(s)k) - k\right],$$

which is negative for all agents' types in the relevant range. This result leads to the following prediction:

Prediction 1 *More ambitious tasks (higher v) are assigned to agents less prone to memory problems.*

Let us now turn our attention to analyze how the incentive power of the agent's wage is affected by both the job which has been assigned to him and his anticipatory utility. First, notice that the agent's *ex ante* payment is equal to

$$q a_H^S w_H^S + (1-q) a_L^S w_L^S, \tag{11}$$

which, using Proposition 3 can be rewritten as

$$\frac{v^2 (q + (1-q)\,\phi(s)k)^2}{4c\left(q + (1-q)\,\phi(s)^2\right)}. \tag{12}$$

Notice that the agent's *ex ante* payment is (not surprisingly) increasing in the relevance of the task v. More interestingly, it is decreasing in the agent's memory problem s and the cross-partial derivative with respect to v and s is negative in the relevant range. Linking these results about payment with that about job assignment in Prediction 1, we get the following second prediction:

Prediction 2 *Agents who are assigned to more ambitious projects (those less prone to memory problems) get higher expected wages than those who are assigned to less ambitious ones (those more prone to memory problems).*

5. The Agent Has Private Information

Following the literature, the analysis conducted so far has assumed that the parameter of anticipatory utility is public information. However, perfect knowledge of s on the part of the principal could be unrealistic. Thus, we extend the analysis to the case in which the weight s is the agent's private information and we look at the effects of this modification on the optimal contract.

If only the agent knows s, the principal can offer no contract (second-best, separating, or pooling) contingent on s. For any contract $C = \{w_0, w_L, w_H\}$, both the preferred recollection strategy and the level of effort chosen will depend on the agent's type s.

Let us denote by $\widehat{S}$ a subset of the agents' types such that all those with $s \in \widehat{S}$ prefer to recall their private information when offered the contract C. Then the principal's decision problem is to choose the set $\widehat{S}$, the level of effort and the contract C that maximize her expected profits, subject to the incentive constraints for both accurate recollection and forgetfulness (1), (2), and (3), the nonforgetfulness constraint (7) for all agents with $s \in \widehat{S}$, and the limited liability constraints (4). Finally, as in the complete information case, because the agent can choose to exert no effort at all, the incentive compatibility and the limited liability constraints ensure that the participation constraint is always satisfied. Hence, in the following analysis we will neglect it.

Given the recalled signal $\widehat{\sigma}$ and the memory strategy "recall bad news" if $s \in \widehat{S}$ and "forget bad news" if $s \notin \widehat{S}$, a type s agent faced with the contract C chooses the level of effort that maximizes his expected utility: $a_L = w_L/c$ for an agent in $\widehat{S}$ observing bad news, and $a_H^R = w_H/c$ for $s \notin \widehat{S}$ observing good news. On the other hand, the level of effort of an agent who chooses to forget bad news turns out to be $a_H^F = q\,w_H/c + (1-q)w_L/c$ regardless of the observed signal. Notice that a_L, a_H^R, and a_H^F follow from (1), (2), and (3), respectively, and that a_H^F is the average of a_H^R and a_L. Thus, the effort of a forgetful agent is higher than the effort of an agent with accurate memory if the private signal is bad, and it is lower if the private signal is good. Because effort affects the probability of success, when the project value in case of success is low, the most successful projects are those run by forgetful agents.

To simplify the analysis of the principal's decision problem, we assume that the weight s is distributed uniformly over [0, 1] and denote by $\widehat{s}$ the supremum of $\widehat{S}$. Proposition 5 states our first result.

Proposition 5: *When s is the agent's private information, the optimal contract $C^{AI} \equiv \{w_0, w_L^{AI}, w_H^{AI}\}$ is such that all agents with $s \leq \widehat{s}$ will recall a bad signal, whereas those with $s > \widehat{s}$ will forget it, with $\widehat{s} \in (s^{SB}, 1/2]$.*

To grasp the intuition behind $\widehat{s} \in (s^{SB}, 1/2]$, consider that the principal's profits are the average profits produced by agents who choose to recall the bad signal and those produced by agents who choose to forget it. For the latter group, the principal prefers not to elicit information recollection, opting instead for an *accommodating* strategy that accepts the agent's forgetfulness by neglecting constraint (7). In this setting, suppose there is a contract such that $\widehat{s} < s^{SB}$. The principal could do better by offering the second-best contract C^{SB}: this induces recollection from all agents up to s^{SB}, and maximizes the profits generated by those agents who choose to forget.[28] Thus $\widehat{s}$ cannot be lower than s^{SB}. In fact there is another contract C^{AI} that does better than C^{SB} as it induces recollection from a set of agents strictly larger than s^{SB}. Indeed, from the previous section, we know that for all $s \in (s^{SB}, 1/2]$, the emotional impact of bad news may induce the agent to suppress it and recall good news instead. To induce accurate recollection, the principal has to design a costly separating contract that punishes forgetfulness and rewards memory. Thus, it may seem surprising that the optimal contract with imperfect information is such that the principal decides to induce recollection also from agents with $s > s^{SB}$. However, for those whose weight is slightly greater than s^{SB}, the extra cost of inducing recollection is small and the increase in profits obtained by switching from accommodating to separating is large. In other words, the direct effect of an increase in the threshold $\widehat{s}$ is first-order whereas the indirect effect via the nonforgetful constraint is second order.

The next corollary generalizes the comparative statics obtained for the case of complete information (see comment to Proposition 2), showing that, as the distance between v_H and v_L increases, the agent incentive to forget bad news increases.

Corollary 1: *The threshold $\widehat{s}$ is equal to $1/2$ if the distance between v_L and v_H is large enough and tends to s^{SB} as v_L approaches v_H.*

To complete the analysis, in the next proposition we compare equilibrium rewards in the asymmetric information setting with second-best payments.

Proposition 6: *If s is the agent's private information, the distance between equilibrium rewards when the good and the bad signals are observed grows relative to the second best.*

These results, along with those in the previous section, have interesting implications. In particular for a given riskiness, if the principal knows the type of the agent, she should take on agents who give low weight to anticipatory utility (those with $s \leq s^{SB}$, as from Proposition 4), offering them low-powered incentive schemes. Conversely, when s is private information the principal (being unable to screen agents) will offer the same contract to all types, thus hiring some forgetful agents (those with $s > \widehat{s}$, as from Proposition 5). However, to reduce the set of forgetful agents the principal designs more high-powered incentive schemes relative to the perfect information case (Proposition 6) This in turn suggests that high-powered contracts may be driven by behavioral factors rather than by the need to control incentive problems, in line with some recent experimental literature showing that incentives affect beliefs (Mijovic-Prelec and Prelec, 2010).

6. Conclusion

We have modeled an employment contract between an optimistic agent and a realistic principal. After showing the existence of a potential conflict over memory strategy, we have shown that the agent's optimism may be affected by monetary incentives. More specifically, we have found that for sufficiently low levels of anticipatory emotions, principal and agent's preferences over optimal recollection are perfectly aligned so that the second-best contract C^{SB} that solves the moral hazard problem also satisfies a nonforgetfulness constraint. However, if the agent places a large weight on anticipatory

28. Neglecting the memory problem, the second-best contract solves the moral hazard problem under limited liability.

utility the second-best outcome cannot be achieved because contract C^{SB} fails to induce the agent to recall his private information correctly. This gives rise to a third-best world in which the principal must distort effort levels and payments to make the agent indifferent between forgetting and remembering bad news.

What happens in our setting if effort is verifiable but the signal is private information? If payments are contingent on the outcome so that a better outcome is associated with a higher payment, the agent will always have an incentive to forget bad news. To prevent this, the principal can offer a flat contract and obtain the first-best utility. In other words, it is the presence of both an emotional agent and of a second imperfection that makes our analysis interesting.

Appendix A

In the analysis to follow, the limited liability constraint on w_0 is always binding. Thus, throughout all the proofs we set $w_0 = 0$.

Proof of Proposition 1: To show that the principal always prefers accurate signal recollection we proceed in three steps. First we solve the principal's maximization problem under the assumption that the equilibrium of the memory game is the recalling one. Then we solve the principal's maximization problem under the assumption that the equilibrium of the memory game is the forgetting one. Finally, we compare the expected profits of the principal under the two different assumptions and find the best recollection strategy from the principal's point of view.

In the case where the equilibrium of the memory game is the recalling one, we solve the incentive constraints (1) and (2) for a_L and a_H^R, and we substitute $a_L(w_L)$ and $a_H^R(w_H)$ in the objective function (5). Rearranging terms, the principal's objective function becomes $(q w_H(v_H - w_H) + (1-q)w_L(v_L - w_L))/c$. Maximizing with respect to w_L and w_H, gives $w_L = v_L/2$ and $w_H = v_H/2$. Substituting in objective function, we obtain that the maximum expected profits of the principal in the recalling equilibrium are:

$$q\,\frac{v_H^2}{4c} + (1-q)\,\frac{v_L^2}{4c}. \tag{A1}$$

In the case where the the equilibrium of the memory game is the forgetting one, we solve the incentive constraint (3) for a_H^F, and we substitute $a_H^F(w_L, w_H)$ in the objective function (6). Rearranging terms, the principal's objective function becomes $(q w_H + (1-q)w_L)(q(v_H - w_H) + (1-q)(v_L - w_L))/c$. Maximizing with respect to w_L and w_H, gives $(q w_H + (1-q)w_L) = (q v_H + (1-q)v_L)/2$. Substituting into the objective function, we obtain that the maximum expected profits of the principal under the assumption of forgetfulness are:

$$\frac{(q v_H + (1-q)v_L)^2}{4c} \tag{A2}$$

Simple algebraic calculus shows that (A1) is always larger than (A2). □

Proof of Proposition 2: Substituting the second-best payments $w_0 = 0$, $w_L = v_L/2$, and $w_H = v_H/2$ in constraint (7) and solving for s, we find that the agent would choose accurate signal recollection if and only if $s \leq \frac{(v_H - v_L)}{2v_H}$. □

Proof of Proposition 3: In order to induce the agent to recall the signal, the principal offers a contract that satisfies the nonforgetfulness constraint (9) with equality. Satisfaction of this equality for $w_H \neq w_L$ gives rise to $w_L(w_H) = \phi w_H$, where $\phi \equiv 1 - 2s$ to simplify notation. To solve the principal's problem in the separating scenario, we substitute $w_L(w_H)$ in the incentive constraint (1) to obtain $a_L(w_H)$. Then, by substituting $a_L(w_H)$, $a_H^R(w_H)$ and $w_L(w_H)$ in (5), the objective function becomes $[q w_H(v_H - w_H) + (1-q)\phi w_H(v_L - \phi w_H)]/c$. Differentiating with respect to w_H gives the necessary and sufficient condition $q(v_H - 2w_H) + (1-q)\phi(v_L - 2\phi w_H) = 0$. Solving with respect to w_H gives:

$$w_H^S = \frac{q v_H + (1-q)\phi v_L}{2(q + (1-q)\phi^2)}. \tag{A3}$$

Substituting (A3) in $a_L(w_H)$, $a_H^R(w_H)$, and $w_L(w_H)$ and rearranging terms we obtain the effort levels and payments in the proposition.

To solve the principal's problem in the pooling scenario, we set $w_L = w_H$ (from the non-forgetfulness constraint (9)). Substituting $w_L = w_H = w$ in (3), gives $a_H^F(w) = w/c$. Substituting $w_L = w$, $w_H = w$, and $a_H^F(w)$ in (6) and rearranging terms, the objective function becomes $w(q v_H + (1-q)v_L - w)/c$. Differentiating with respect to w gives the necessary and sufficient condition $q v_H + (1-q)v_L - 2w = 0$. Solving for w and considering that $w_L^P = w_H^P = w$, we obtain

$$w_L^P = w_H^P = \frac{q v_H + (1-q)v_L}{2}. \tag{A4}$$

Substituting (A4) in $a_H^F(w)$ and rearranging terms we obtain the effort level and payments in the proposition.

Proof of Proposition 4.: To demonstrate that a separating equilibrium arises for all $s \leq 1/2$, we work out the expected profits and show that for all $s \leq 1/2$ $E_0\Pi^S > E_0\Pi^P$. Substituting a_H^S, a_L^S, w_H^S, and w_L^S into (5), and a^P and w^P into (6) we obtain the principal's expected profits in the separating and pooling equilibrium respectively, that is,

$$E_0\Pi^S = \frac{q v_H + (1-q)\phi v_L}{2c(q + (1-q)\phi^2)} \cdot \\ \cdot \left\{ q \left[v_H - \frac{q v_H + (1-q)\phi v_L}{2(q + (1-q)\phi^2)} \right] + (1-q)\phi \left[v_L - \phi \frac{q v_H + (1-q)\phi v_L}{2(q + (1-q)\phi^2)} \right] \right\} \tag{A5}$$

and

$$E_0\Pi^P = E_0\Pi^{SB} - \frac{q\,(1-q)\,(v_H - v_L)^2}{4c}, \tag{A6}$$

where

$$E_0\Pi^{SB} = q\,\frac{v_H^2}{4c} + (1-q)\,\frac{v_L^2}{4c} \tag{A7}$$

is the principal's second-best expected profit. By comparing (A5) and (A6), after some tedious algebra we obtain that $E_0\Pi^S > E_0\Pi^P$ for all $s \leq \bar{s}$, with $\bar{s} \equiv 1 - (v_H v_L)/(q(v_H - v_L)^2 + v_L(2v_H - v_L))$. Recalling that a separating equilibrium can arise only for $s \leq 1/2$ (otherwise w_L^S would be negative) and noticing that $\bar{s} > 1/2$, we conclude that the separating equilibrium arises for all $s \in (s^{SB}, 1/2]$, whilst the pooling equilibrium arises for all $s > 1/2$.

To show that the principal's expected profits are weakly decreasing in s, observe that:

1. from (A7), $\partial E_0[\Pi^{SB}]/\partial s = 0$ for all $s \in [0, s^{SB}]$;
2. from (A5), $\partial E_0[\Pi^S]/\partial s = -2(1-q)w_H^S[v_L - 2w_H^S\phi]/c \leq 0$ for all $s \in (s^{SB}, 1/2]$, because

   $$v_L - 2w_H^S\phi \geq 0 \iff v_L \geq -2w_L^S \iff v_L \geq v_L - 2\gamma cq,$$

   that is true for all $s > s^{SB}$;
3. from (A6), $\partial E_0[\Pi^P]/\partial s = 0$ for all $s > 1/2$.

The proof is completed noticing that $E_0[\Pi^{SB}] = E_0[\Pi^S(s^{SB})]$ and $E_0[\Pi^S(s^S)] > E_0[\Pi^P]$. □

Proof of Proposition 5: The equilibrium contract has to be such that all agents with $s \in \widehat{S}$ prefer to recall the signal, which is ensured if we impose the non-forgetfulness constraint (7) for all $s \in \widehat{S}$. But this is equivalent to $w_L \leq \phi(s)w_H$ for all $s \in \widehat{S}$, where $\phi(s) \equiv (1-2s)$. Then, noticing that $\phi(s)$ is decreasing in s, this condition is clearly satisfied for all $s \in \widehat{S}$ if and only if

$$w_L \leq \phi(\widehat{s})w_H. \tag{A8}$$

Now, we demonstrate that $\widehat{S}$ is an interval. Suppose, by contradiction, that there exists an agent with $s = s' < \widehat{s}$ which prefers to forget bad news. Because the contract offered by the principal is the same for all agents, from the incentive constraints we know that the effort chosen by each agent does not depend on his type. Then, an agent with $s = s'$ prefers to forget bad news if $w_L \geq \phi(s')w_H$, which is possible only if $s' \geq \widehat{s}$ because $w_L \leq \phi(\widehat{s})w_H$ and $\phi(\widehat{s})$ is decreasing. This contradicts our assumption and implies that $\widehat{S} = [0, \widehat{s}]$.

Because $\widehat{S}$ is an interval, the principal's expected profits can be written as $\int_0^{\widehat{s}}[q\, a_H^R (v_H - w_H) + (1-q)\, a_L(v_L - w_L)]ds + \int_{\widehat{s}}^1 a_H^F [q\ (v_H - w_H) + (1-q)(v_L - w_L)]ds$. Substituting incentive constraints into expected profits and rearranging terms we get

$$\begin{aligned}\Pi(w_H, w_L, \widehat{s}) &= \tfrac{\widehat{s}}{c} \cdot [w_H q(v_H - w_H) + w_L(1-q)(v_L - w_L)] + \\ &+ \tfrac{1-\widehat{s}}{c} \cdot [w_H q + w_L(1-q))[q(v_H - w_H) + (1-q)(v_L - w_L)].\end{aligned} \tag{A9}$$

Thus, the principal's problem simplifies to choosing w_H, w_L and $\widehat{s}$ that maximize (A9), subject to (A8).

Next, we show that constraint (A8) is binding in equilibrium. Suppose by contradiction, that this is not true. If (A8) is not binding, the principal's expected profits (A9) are linear in $\widehat{s}$ with slope $q(1-q)(w_H - w_L)[(v_H - w_H) - (v_L - w_L)]/c$. The optimal $\widehat{s}$ would be 1 if this expression is positive and 0 otherwise. However, $\widehat{s} = 1$ is not possible because w_L cannot be negative and constraint (A8) would require $w_L \leq \phi(1)w_H < 0$. Suppose that the optimal contract entails $\widehat{s} = 0$. In this case, the first-order conditions on w_H and w_L would imply $(q w_H + (1-q)w_L) = (q v_H + (1-q)v_L)/2$. It is easy to verify that such a contract would entail a negative slope. Thus $\widehat{s} \in (0, 1/2]$ and constraint (A8) is binding in equilibrium.

In the following, we show that $\widehat{s} > s^{SB}$. Substituting (A8) into (A9) and rearranging terms gives the following expression for expected profits:

$$\begin{aligned}&\tfrac{\widehat{s}}{c} \cdot w_H[q(v_H - w_H) + (1-q)\phi(\widehat{s})(v_L - \phi(\widehat{s})w_H)] + \\ &+ \tfrac{1-\widehat{s}}{c} \cdot w_H[q + (1-q)\phi(\widehat{s}))[q(v_H - w_H) + (1-q)(v_L - \phi(\widehat{s})w_H)].\end{aligned} \tag{A10}$$

The principal's problem simplifies to the choice of w_H and $\widehat{s}$ that maximize (A10). Differentiating (A10) with respect to w_H gives the following necessary and sufficient condition for an interior solution:

$$-2\left[4(1-q)\widehat{s}\left(q\widehat{s}^2+(1-q)\widehat{s}-1\right)+1\right]w_H$$
$$+2\widehat{s}(1-q)\left[\widehat{s}q(v_H-v_L)-(qv_H+(1-q)v_L)\right]+qv_H+(1-q)v_L=0.$$

Solving for w_H, we obtain:

$$w_H(\widehat{s})=\frac{2\widehat{s}^2q(1-q)(v_H-v_L)+(qv_H+(1-q)v_L)(1-2\widehat{s}(1-q))}{2\left[4(1-q)q\widehat{s}^3+(1-2(1-q)\widehat{s})^2\right]}. \tag{A11}$$

Differentiating (A10) with respect to $\widehat{s}$, substituting (A11) into it and rearranging terms gives the following necessary and sufficient condition for an interior solution:

$$\varphi(\widehat{s})\equiv 2((q(1-q)\widehat{s}^3+1))(v_H-v_L)-((1-q)(v_H-v_L)+v_H)(3-2(1-q)\widehat{s})\widehat{s}=0.$$

Observe that $\varphi'(\widehat{s})=6q(1-q)(v_H-v_L)\widehat{s}^2+(4(1-q)\widehat{s}-3)((2-q)v_H-(1-q)v_L)\leq 0$ for all $\widehat{s}\in[0,1/2]$. Indeed, $\varphi''(\widehat{s})=4(1-q)(3q(v_H-v_L)\widehat{s}+((2-q)v_H-(1-q)v_L))>0$ for all $\widehat{s}>0$, so that $\varphi'(\widehat{s})$ is increasing for positive $\widehat{s}$, and $\varphi'(\widehat{s}=1/2)=1/2((v_H-v_L)q-3v_H-v_L)q-2v_H+v_L<0$. Hence, the function $\varphi(\widehat{s})$ is decreasing for all $\widehat{s}\in[s^{SB},1/2]$. Moreover, when $\widehat{s}=s^{SB}$

$$\varphi(\widehat{s}=s^{SB})=\frac{(v_H-v_L)}{4v_H}\left(\frac{q(1-q)(v_H-v_L)^3}{v_H{}^3}+2\left(\frac{(1-q)(v_H-v_L)}{v_H}-1\right)^2\right),$$

which is positive for all $v_L\leq v_H$ and when $\widehat{s}=1/2$

$$\varphi(\widehat{s}=1/2)=((q+1)q\,v_H-(q^2+4+3q)v_L)/4v_H,$$

which is positive if and only if

$$v_L\leq\frac{(q+1)q\,v_H}{q^2+4+3q}. \tag{A12}$$

Because the derivative of $\Pi(w_H(\widehat{s}),\widehat{s})$ with respect to $\widehat{s}$ is positive when $\widehat{s}=s^{SB}$, then the optimal $\widehat{s}$ is larger than s^{SB}, and it is equal to 1/2 if $\varphi(\widehat{s}=1/2)>0$ and lower than 1/2 otherwise. □

Proof of Corollary 1: The corollary follows immediately by noticing that $\widehat{s}=1/2$ iff condition (A12) is satisfied. □

Proof of Proposition 6: Let us define the distance between equilibrium rewards when the good and the bad signals are observed by the agent as $\Delta w(\widehat{s})\equiv w_H(\widehat{s})(1-\phi(\widehat{s}))$ and the distance between second best rewards as $\Delta w^{SB}\equiv\frac{v_H}{2}(1-\frac{v_H}{v_L})$. In order to show that $\Delta w(\widehat{s})$ is always larger than Δw^{SB} we will prove the following claims:

Claim 1: $\inf_{\widehat{s}\in(s^{SB},1/2]}w_H(\widehat{s})\geq\frac{v_H}{2}$ for all $\frac{v_L}{v_H}\in[0,1]$.

The claim is immediately proved by noticing that $\partial w_H(\widehat{s})/\partial\widehat{s}\geq 0$ for all $\widehat{s}\in(s^{SB},1/2]$ and, then, $\inf_{\widehat{s}\in(s^{SB},1/2]}w_H(\widehat{s})=w_H(s^{SB})=\frac{v_H}{2}$.

Claim 2: $\inf_{\widehat{s}\in(s^{SB},1/2]}(1-\phi(\widehat{s}))\geq(1-\frac{v_L}{v_H})$ for all $\frac{v_L}{v_H}\in[0,1]$.

Observe that: $\inf_{\widehat{s}\in(s^{SB},1/2]}(1-\phi(\widehat{s}))\geq(1-\frac{v_L}{v_H})$ iff $\sup_{\widehat{s}\in(s^{SB},1/2]}\phi(\widehat{s})\leq\frac{v_L}{v_H}$. Because $\partial\phi(\widehat{s})/\partial\widehat{s}\leq 0$ for all $\widehat{s}\in(s^{SB},1/2]$, then $\sup_{\widehat{s}\in(s^{SB},1/2]}\phi(\widehat{s})=\phi(s^{SB})=\frac{v_L}{v_H}$. □

Appendix B: A Model with Two Outcomes

In this appendix, we check whether our results hold in a model in which the project returns can take two values rather than three (only success and failure) where a "good" signal means a high probability of success whereas a "bad" signal means a low probability of success. In the following, we will show that under two different assumptions about the functional form of the probabilities of success, there is a conflict of interest between principal and agent over the recollection strategy. Indeed, as in the baseline model the principal always prefers perfect signal recollection, whereas if s is sufficiently high the agent prefers to forget bad news when he is offered the second-best contract. However, unlike the baseline model, in such a setting the principal cannot design a contract that separates good from bad directly, but he may be still able to do so indirectly through the different incentives given by the different probabilities of success. It turns out that whether this is possible or not depends on the functional form of the probabilities of success. For instance, when both probabilities are linear in effort (Setting 1), then the incentive to forget bad news does not depend on payments and the principal cannot induce a forgetful agent to recall. But in Setting 2, we show by way of a numerical example with concave probabilities of success, that memory can be induced through the contract even in a two-states setting.

The model we consider differs from the benchmark model because we assume that the return of the risky project can be either low or high and that the private signal that the agent observes is correlated with the probability of success (a good signal implies high effort productivity and a bad signal low effort productivity). More precisely, we assume that (1) the return of the project is $\tilde{v} = 0$ in case of failure and $\tilde{v} = v \in (0, c)$ in case of success, and that (2) $\Pr(\tilde{v} = v|\sigma = H) = p_H(a)$ and $\Pr(\tilde{v} = v|\sigma = L) = p_L(a)$, with $p_H(a) \geq p_L(a)$ for all $a \in [0, 1]$, and $p_i'(a) > 0$ and $p_i''(a) \leq 0$ for all $a \in [0, 1]$ and $i \in \{H, L\}$.

To show that the principal always prefers accurate signal recollection, we proceed in three steps. First, we solve the principal's maximization problem under the assumption that the equilibrium of the memory game is the recalling one. Then we solve the principal's maximization problem under the assumption that the equilibrium of the memory game is the forgetting one. Finally, we compare the expected profits of the principal under the two different assumptions and find the best recollection strategy from the principal's point of view.

We denote by $C \equiv \{w_0, w_v\}$ the contract that the principal offers the agent, where w_0 is the reward corresponding to $\tilde{v} = 0$ and w_v is the reward corresponding to $\tilde{v} = v$. As in the benchmark framework, the agent's limited liability implies that $w_0 = 0$. Then, the offered contract can be written as $C \equiv \{0, w\}$, where $w_v = w$ to simplify notation.

Notice that when $\widehat{\sigma} = L$ the agent is always sure that $\sigma = L$, and the expected utility simplifies to $p_L(a)w - ca^2/2$. The incentive-feasible effort is $a_L(w)$ such that

$$p_L'(a_L(w))w = ca_L(w). \tag{B1}$$

When $\widehat{\sigma} = H$ under the recalling equilibrium, the agent's expected payoff is $p_H(a)w - ca^2/2$. The incentive-feasible effort is $a_H^R(w)$ such that

$$p_H'(a_H^R(w))w = ca_H^R(w). \tag{B2}$$

But under the forgetting equilibrium, when $\widehat{\sigma} = H$ the agent is unsure whether he actually received a good signal or instead received a bad signal and repressed it. The expected payoff is $(qp_H(a) + (1-q)p_L(a))w - ca^2/2$. The incentive-feasible effort $a_H^F(w)$ satisfies

$$(qp'_H(a_H^F(w)) + (1-q)p'_L(a_H^F(w)))w = ca_H^F(w). \tag{B3}$$

Denote the vector of incentive feasible effort levels for $\widehat{\sigma} \in \{L, H\}$, under the hypothesis of the recalling (R) and the forgetting (F) equilibrium, by $a(j, C) \equiv \{a_L, a_H^j\}$, $j \in \{R, F\}$.

In the case of the recalling equilibrium, by substituting (B1), (B2), and $w_0 = 0$ into the principal's expected profits, the principal's problem reduces to the choice of the payment w that maximizes

$$q \cdot p_H(a_H^R(w)) + (1-q) \cdot p_L(a_L(w)))\,(v-w)\,. \tag{B4}$$

In the case of the forgetting equilibrium, by substituting (B3) and $w_0 = 0$ into the principal's expected profits, the principal's problem reduces to the choice of payment w that maximizes

$$(qp_H(a_H^F(w)) + (1-q)p_L(a_H^F(w))\,(v-w)\,. \tag{B5}$$

Because $a_H^F(w) \in (a_L(w), a_H^R(w))$ for any level of wealth, then forgetting bad news affects the probability of success negatively in the case of a good signal and positively in the case of a bad signal.

In the following, we analyze this model under two different functional forms of the probabilities of success.

Setting 1: Linear Probabilities

Assume that $p_H(a) = a$ and $p_L(a) = ba$, with $b \in (0, 1)$ and for any $a \in [0, 1]$. By substituting $p'_L(a) = b$ and $p'_H(a) = 1$ in (B1), (B2), and (B3), respectively, we obtain the incentive-feasible efforts $a_L(w) = bw/c$, $a_H^R(w) = w/c$, and $a_H^F(w) = (q + (1-q)b)w/c$. Substituting $a_L(w)$ and $a_H^R(w)$ into (B4) gives $(q + (1-q)b)(v-w)w/c$. Substituting $a_H^F(w)$ into (B5) gives $(q + (1-q)b)^2(v-w)w/c$. By comparing those expressions, it is easy to see that the principal's expected profits under the recalling equilibrium (the first expression) are larger than the principal's expected profits under the forgetting equilibrium (the second expression) for any w. Thus, the accuracy of the agent's information is always valuable to the principal.

We next proceed to show the existence of a conflict of interest between principal and agent over the recollection strategy. For any contract $C = \{0, w\}$, the maximum expected utility of a non-forgetful agent who observes the bad signal is $(bw)^2/2c$, whereas the expected utility from deviation is $w^2(s + (1-s)(2b-1))/2c$. Thus, the agent has no incentive to deviate from the recalling strategy when $s < (b-1)/2$. Indeed, when the agent deviates from the recalling strategy, he enjoys a higher anticipatory utility and a lower actual utility with respect to the accurate memory case. Thus, if the weight on anticipatory utility is high, then the agent prefers to recall the bad signal when receiving the second-best contract. We also conclude that in the binary world, there is a potential conflict about the optimal memory strategy between the principal and the agent. The principal always prefers the recalling equilibrium, but the agent could prefer to forget bad news for sufficiently high s. However, by comparing the above utilities it is easy to notice that the incentive to forget bad news does not depend on payments. In contrast to the benchmark case, this implies that in a binary setting with linear probabilities the principal is unable to induce the agent with high s to recall a bad signal.

Setting 2: Concave Probabilities of Success

We now modify our setting by assuming $\Pr(\tilde{v} = v|\sigma = H) = \sqrt{a}$ and $\Pr(\tilde{v} = v|\sigma = L) = a$, for any $a \in [0, 1]$. By substituting $p'_L(a) = 1$ and $p'_H(a) = 1/(2\sqrt{a})$ into (B1) and (B2), respectively, we obtain the incentive feasible efforts $a_L(w) = w/c$ and $a^R_H(w) = \sqrt[3]{(w/2c)^2}$. For any feasible contract $C = \{0, w\}$, the maximum expected utility of a nonforgetful agent observing the bad signal is $w^2/2c$, whereas the expected utility from deviating is $[3s + (1 - s)((4\sqrt[3]{w/2c} - 1))](w/4)\sqrt[3]{w/2c}$. Because the difference between the first and the second expression is linear in s, positive for $s = 0$, and negative for $s = 1$, we deduce that for sufficiently high s the agent prefers to forget a bad signal when receiving the second best contract. [29]

Now we investigate the principal's preferred memory strategy. Under the recalling equilibrium, and by substituting $a_L(w)$ and $a^R_H(w)$ into (B4), the principal's problem reduces to the choice of the payment w that maximizes $(q\sqrt[3]{w/2c} + (1 - q)w/c)(v - w)$. Under the forgetting equilibrium, the principal's problem is to choose the payment w that maximizes $(q\sqrt{a^F_H(w)} + (1 - q)a^F_H(w)(v - w)$, where $a^F_H(w)$ is the incentive feasible effort satisfying the first order condition $qw + 2(1 - q)w\sqrt{a^F_H(w)} = 2c\sqrt{(a^F_H(w))^3}$. To simplify the algebra, we will henceforth assume $q = 0.5$, $c = 0.8$, and $v = 0.3$. Given these parameter values, the maximum profits of the principal are higher in the recalling equilibrium ($\simeq 0.075$) than in the forgetting equilibrium ($\simeq 0.0064$). So, the principal prefers accurate signal recollection.

From the previous analysis, we know that there exists an s^{SB} such that, when receiving the second-best payment the agent chooses to forget the bad signal for all $s > s^{SB}$. In the following, we will show that there is an $s^S > s^{SB}$ such that the principal prefers to induce accurate signal recollection for all $s \leq s^S$. For the parameter values set above, the payment that maximizes the principal's profits in the case of recalling equilibrium is $w^{SB} \simeq 0.108$. The nonforgetfulness constraint is now

$$1.25w - 0.8079s\sqrt[3]{w} - (1 - s)(1.1604\sqrt[3]{w^2} - 0.2693\sqrt[3]{w}) \geq 0.$$

By substituting $w = w^{SB}$ and solving for s, this gives $s^{SB} \simeq 0.00036$. Thus, in our numerical example all agents with $s > 0.00036$ choose to forget bad news when receiving the second-best contract. From the nonforgetfulness constraint it is evident that in this setting the incentives to forget depend on the payment in the case of success. This implies that the principal can induce accurate signal recollection by offering a payment that makes the agent indifferent between recalling and forgetting. This payment (denoted by $w(s)$) can be easily found by solving the nonforgetfulness constraint for w. By substituting $w(s)$ in the recalling expected profits, we obtain the expected profits enjoyed by a principal who decides to induce an agent with $s > s^{SB}$ to recall. Those profits are higher than the profits under forgetfulness ($\simeq 0.0064$) for any $s < s^S \simeq 0.2187$.

We then conclude that in this setting, there is again a potential conflict about the optimal memory strategy between the principal and the agent, but, unlike the case with linear probabilities, the principal is now able to induce recollection. Nevertheless, although it seems possible to separate types indirectly through the different incentives

29. When $s = 0$ the difference is $\sqrt[3]{(\frac{w}{2c})^4}[\sqrt[3]{(\frac{w}{2c})^2} - 2\sqrt[3]{(\frac{w}{2c})} + \frac{1}{2}] < 0$, whereas when $s = 1$ it is given by $\sqrt[3]{(\frac{w}{2c})^4}[\sqrt[3]{(\frac{w}{2c})^2} - \frac{3}{2}]$ for all feasible contracts, that is, for all $w \in [0, v]$, because $v<c$ by assumption.

given by the different probabilities of success, these probabilities are hardly under the principal's control.

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