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Is Pay for Performance Detrimental to Innovation?

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Previous research in economics shows that compensation based on the pay-for-performance principle is effective in inducing higher levels of effort and productivity. On the other hand, research in psychology argues that performance-based financial incentives inhibit creativity and innovation. How should managerial compensation be structured if the goal is to induce managers to pursue more innovative business strategies? In a controlled laboratory setting, we provide evidence that the combination of tolerance for early failure and reward for long-term success is effective in motivating innovation. Subjects under such an incentive scheme explore more and are more likely to discover a novel business strategy than subjects under fixed-wage and standard pay-for-performance incentive schemes. We also find evidence that the threat of termination can undermine incentives for innovation, whereas golden parachutes can alleviate these innovation-reducing effects.

Key words: organizational studies; motivation incentives; personnel; research and development; innovation
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1. Introduction

Previous research on the effectiveness of incentive pay argues that paying an agent based on his performance induces the agent to exert more effort thereby improving productivity. There is ample evidence supporting this thesis in different types of studies, ranging from quasi experiments in empirical data to economic field experiments and laboratory studies. For example, Lazear (2000) shows that the productivity of windshield installers in Safelite Glass Corporation increased when management changed their compensation from fixed wages to piece-rate pay. Shearer (2004) finds similar evidence in a randomized field experiment with Canadian tree planters. Dickinson (1999) shows that subjects in a laboratory experiment type more letters when their compensation is more sensitive to performance. As in the above examples, most of the existing evidence of the effect of financial incentives on performance comes from studying simple routine tasks, in which effort is the main determinant of productivity.[1]

In contrast, a substantial body of experimental and field research in psychology provides evidence that, in tasks that require exploration and creativity, pay for performance can actually undermine performance. McGraw (1978), McCullers (1978), Kohn (1993), and Amabile (1996) summarize the findings of this line of research by stating that pay for performance encourages the repetition of what has worked in the past, but not the exploration of new untested approaches. These studies conclude that in tasks that involve creativity and innovation, monetary incentives should not be used at all to motivate agents. Taken together, the available evidence seems to suggest that *standard* performance pay works well for certain types of tasks (physical effort) but not for others (creativity). In this paper we present evidence that is fully in line with this view, but, more importantly, we also show that *correctly structured* performance-based financial incentives can motivate innovation in creative tasks and can lead to superior results than those achieved in the absence of financial incentives. Our findings provide support for the idea that for any task, "the effects of incentives depend on how they are designed," as Gneezy et al. (2011, p. 206) suggest in the conclusions of their comprehensive review article on incentive effects.

In a controlled experimental setting in which subjects perform a task that involves a trade-off between exploration and exploitation, we provide evidence that incentive plans that tolerate early failure and reward long-term success lead to more innovation and better performance than fixed wages or standard pay-for-performance incentive schemes. We also

[1] Detrimental incentive effects on effort have also been studied in economics with more nuanced conclusions as to when monetary rewards lead to better performance (Gneezy and Rustichini 2000a, b; Frey and Jegen 2001; Ariely et al. 2009).

find evidence that the threat of termination can undermine incentives for innovation, whereas golden parachutes can alleviate these innovation-reducing effects. Finally, we show that risk aversion is an important factor in explaining these results.

Our results have implications for various situations in which enabling entrepreneurship is an important concern. In fact, "stimulating innovation, creativity, and enabling entrepreneurship" is a top priority for management and widely regarded as the "greatest human resource challenge" facing organizations according to CEO surveys (Rudis 2004, pp. 3, 7).[2] These situations range from the design of compensation packages of top executives and middle managers in large corporations to structuring compensation for entrepreneurs in start-up companies. For example, some of the most innovation- and creativity-driven firms including pharmaceutical and advertising companies have adopted reward systems that tolerate or even reward the failure of employees.[3] In the context of executive compensation, tolerance for early failure can be achieved through commonly used practices such as managerial entrenchment, golden parachutes, or option repricing. These practices are often criticized because they protect or even reward the manager after poor performance and, therefore, can induce the manager to shirk or divert funds from the corporation. There have been several proposals to restrict the use of some of these practices.[4] Our results suggest that when combined with appropriate long-term incentives, these practices can be effective in motivating innovation. Regulations that restrict their use could thus have an adverse effect on innovation.

Innovation is often defined as the production of knowledge through experimentation (Arrow 1969, Weitzman 1979). As pointed out by March (1991), the central concern that arises when learning through experimentation is the tension between the exploration of new untested approaches and the exploitation of well-known approaches. A substantial management literature following March (1991) has investigated the organizational factors that favor either of the two forms of innovation and how to optimally balance the tension between them in ambidextrous organizations.[5] This literature has abstracted away from how different incentive systems might affect the trade-off, an issue that we specifically address in the present paper. We conduct a series of large-scale economic laboratory experiments with 379 subjects in which subjects face the tension between exploration and exploitation. Subjects control the operations of a computerized lemonade stand and must choose between fine-tuning the product choice decisions given to them by the previous manager or choosing a different location and radically altering the product mix to discover a better strategy.

To study the impact of different incentive schemes on productivity and innovation in the above tasks, we first consider three different baseline treatment groups. The only difference between these treatment groups is the compensation offered to subjects. Subjects in the first group (fixed wage) receive a fixed wage in each period of the experiment. Subjects in the second treatment group (pay for performance) are given a standard pay-for-performance (or profit sharing) contract, receiving a fixed percentage of the profits produced during the experiment. Subjects in the third treatment group (exploration) are allocated a contract that is tailored to motivate exploration. Their compensation is a fixed percentage of the profits produced during the second half of each of the two experiments.[6]

Our main hypothesis is that subjects under the exploration contract explore more and are more likely to find a superior strategy than subjects under the fixed-wage or standard pay-for-performance contracts. Two features of the exploration contract encourage subjects to explore. First, tolerance for early failure permits subjects to fail at no cost in the first half of the experiment while they explore new strategies. Second, the prospect of pay for performance later on encourages subjects to learn better ways of performing the task. Therefore, even though the exploration contract combines elements of the fixed-wage and pay-for-performance contracts, it is plausible that performance under the exploration contract is superior to performance under both the fixed-wage and the pay-for-performance contracts.

Our results strongly support the main hypothesis stated above. We find that subjects given the exploration contract end the experiment in the best location 80% of the time, whereas subjects given the fixed-wage and the pay-for-performance contracts

[2] Rudis (2004) reports that the highest response (31%) among surveyed CEOs is that stimulating innovation is of the greatest concern to their company.

[3] For a discussion of this issue in the popular press, see Shellenbarger (2011).

[4] See, for example, Bebchuk and Fried (2004) and UK Department of Trade and Industry (2003).

[5] A comprehensive overview of this literature can be found in the special issue on organizational learning in *Management Science* (Argote et al. 2003).

[6] This exploration contract is based on the work of Manso (2011), who showed that the combination of tolerance for early failure and reward for long-term success is optimal to motivate innovation. The exploration contract can be implemented in practice through stock grants that increase with the tenure of the manager in the firm independently of the manager's performance. Alternatively, it can be implemented via stock option grants with long vesting periods, and option repricing in case the manager performs poorly early on.

end the experiment in the best location only 60% and 40% of the time, respectively. To explain these differences, we examine the reasons behind the relatively poor performance of subjects under the fixed-wage and pay-for-performance contracts. Although subjects given the fixed-wage contract explore a lot, they are not as systematic in their exploration as subjects who are given an exploration contract. For example, when we analyze the notes subjects take in a table we provide to them at the beginning of the experiment, we find that only 55% of the subjects under the fixed-wage contract carefully keep track of their choices and profits; when facing the exploration contract, 82% of the subjects keep track of their choices and profits using the table. Subjects under the pay-for-performance contract, on the other hand, tend to direct their effort toward fine-tuning the previous manager's product mix instead of searching for better locations. During the first 10 periods of the experiment, subjects under the exploration contract choose a location other than the initial default location 80% of the time, whereas subjects under the pay-for-performance contract do so only 50% of the time. Different attitudes toward risk can also affect the outcome under the different contracts. We find that risk aversion plays an important role in explaining differences in the exploration behavior and performance of the subjects under the pay-for-performance contract. Under the pay-for-performance contract, more risk-averse subjects are less likely to find the optimal strategy and they obtain lower average profits than less risk-averse subjects.

To study the effects of termination on innovation and performance, we introduce two new treatment groups in the lemonade stand experiment: a termination treatment group and a termination with golden parachute treatment group. Subjects in both groups receive the exploration contract and are also told that the experiment will end early if their profits in the first 10 periods are lower than a certain threshold. Subjects in the termination with golden parachute treatment group are told that they will receive a reparation payment if the experiment ends after 10 periods. Our hypothesis is that subjects in the termination treatment are less likely to find the optimal location than subjects in the exploration treatment. We further hypothesize that subjects in the termination with golden parachute treatment group are more likely to find the optimal location than subjects in the pure termination treatment group. This hypothesis is supported by the data: only 45% of the subjects in the termination treatment group find the optimal location, whereas 65% of the subjects in the termination with golden parachute treatment group find the optimal location.

Finally, we demonstrate that our results are robust to modifications in the experimental design. We first address potential signaling effects of incentive contracts in the lemonade stand experiment. In addition, we show that in a second experiment, the gold prospecting experiment, which uses the chosen effort approach and allows full control of the beliefs of subjects in a parameterized setting, incentive contracts that tolerate early failure encourage exploration and are superior to both standard pay for performance and fixed wages.

Several recent papers investigate the effects of institutional features on innovation such as debtor-friendly bankruptcy laws (Acharya and Subramanian 2009), stringent labor laws (Acharya et al. 2009), takeover pressure (Sapra et al. 2008, Atanassov 2008, Chemmanur and Tian 2011), leverage (Liu and Wong 2011), as well as the failure-tolerant attitude of institutional investors (Aghion et al. 2008) and of venture capitalists (Chemmanur et al. 2011, Tian and Wang 2013). Another burgeoning literature investigates the interplay between noncompete agreements and innovation, in particular in relation to California and Silicon Valley (Almeida and Kogut 1999, Gilson 1999, Sorenson and Stuart 2003), but causal evidence remains thin (Fallick et al. 2006, Marx et al. 2009).

Our work is most closely related to contributions that investigate the relation between explicit incentive structures and innovation.[7] Long-term incentives for the heads of research and development departments (Lerner and Wulf 2007), golden parachutes for CEOs (Francis et al. 2010), and longer stock option vesting period lengths (Yanadori and Marler 2006) are associated with more (heavily cited) patents. Finally, Azoulay et al. (2011) address whether funding policies with tolerance for early failure and long horizons to evaluate results motivate creativity in scientific research.

All these papers provide some support for the thesis that tolerance for early failure coupled with reward for long-term success motivates innovation. Because they use naturally occurring data, however, they either restrict themselves to merely showing correlation patterns, or they are subject to the criticism that the variation in the incentive schemes may not be completely exogenous. In our paper, we are able to study the effects of incentives on innovation by exogenously varying compensation schemes in a controlled laboratory environment.

A common approach to the study of incentives using laboratory experiments is to give subjects a cost function and require them to choose an effort level (Bull et al. 1987, Fehr et al. 1997, Nalbantian and Schotter 1997). Meyer and Shi (1995) and Banks et al. (1997) investigate the tension between exploitation

[7] Related theoretical contributions that also focus on the interplay of incentives and innovation include those by Aghion and Tirole (1994), Hellmann (2007), and Hellmann and Thiele (2011).

and exploration in an experimental setting using monetary efforts and report results in broad accordance with the theoretical bandit model. Neither of these papers considers the effect of different incentive schemes on subject behavior.[8] Experimental researchers have also conducted incentive studies in both the lab and the field in which subjects have to exert real effort to complete routine tasks such as typing letters (Dickinson 1999), decoding a number from a grid of letters (Sillamaa 1999), cracking walnuts (Fahr and Irlenbusch 2000), stuffing letters into envelopes (Falk and Ichino 2006), or picking fruit (Bandiera et al. 2005). These tasks, however, are inadequate to study incentives for innovation. In this paper, we therefore introduce a new task to investigate the causal impact of incentives on exploration.

2. Experimental Design

We establish an environment in which we can measure the effects of different incentive schemes on innovation and performance. For this purpose we conduct experiments in which participants have to solve a real effort task in which the trade-off between exploration and exploitation takes center stage.

2.1. Procedures and Subject Pool

The experiments were programmed and conducted with the software *z*-Tree (Fischbacher 2007) at the Harvard Business School Computer Laboratory for Economic Research (HBS CLER). Participants were recruited from the HBS CLER subject pool using an online recruitment system. A total of 379 subjects participated in our experiments.

After subjects completed the experiment we elicited their degree of risk aversion and ambiguity aversion. We describe the exact procedures for risk and ambiguity aversion elicitation in the online appendix (available at http://www.anderson.ucla.edu/faculty/florian.ederer/em_onlineappendix.pdf).[9] Subjects were then privately paid. A session lasted, on average, 60 minutes.

Experimental currency units called francs were used. The exchange rate was set at 100 francs = $1, and the show-up fee was $10. Subjects, on average, earned $24.

2.2. Task Description

Subjects take the role of an individual operating a lemonade stand. The experiment lasts 20 periods. In each period, subjects make decisions on how to run the lemonade stand. These decisions involve the location of the stand, the sugar and the lemon content, the lemonade color, and the price. As is natural for this type of task, some of the variables are discrete choices (location, color), whereas others are more continuous (sugar, lemon content, price), thus yielding 6,181,806 possible combinations. The exact parameters of the game are provided in the online appendix.

At the end of each period, subjects learn the profits they obtained during that period. They also learn customer reactions that contain information about their choices. Customer feedback is implemented by having the computer randomly select one of the continuous choice variables to provide a binary feedback to the subject. This feedback is only informative for the location in which the subject chose to sell in the current period.[10]

Subjects do not know the profits associated with each of the available choices. Attached to the instructions is a letter from the previous manager, which is reproduced in the online appendix. The letter gives hints to the subjects about a strategy that has worked well for this manager and offers an accurate description of a good business strategy for one particular lemonade stand location. The strategy suggested by the previous manager involves setting the stand in the business district, choosing a high lemon content, a low sugar content, a high price, and green lemonade. The manager's letter also states that the manager has tried several combinations of variables in the business district location, but that he has never experimented with setting up the stand in a different location. It further suggests that different locations may require a very different strategy.

The participants in the experiment thus face the choice between fine-tuning the product choice decisions given to them by the previous manager (exploitation) or choosing a different location and radically altering the product mix to discover a more profitable strategy (exploration). The strategy of the previous manager is not the most profitable strategy. The most profitable strategy is to set the lemonade stand in the school district and to choose a low lemon content, a high sugar content, a low price, and pink lemonade. The payoffs in the game were chosen in such a way that without changing the default location the additional profits earned from improving the strategy in the business district are relatively small.

[8] Other related experimental papers using search problems akin to our lemonade stand experiment and dealing with innovation modeled as a computationally complex problem include those by Gabaix et al. (2006) and Meloso et al. (2009).

[9] For our statistical analysis we split subjects into a less and a more risk/ambiguity-averse group based on the median observation for each measure in the sample.

[10] For example, if the subject chose a sugar content that is above the optimal level for the particular sales location, the feedback takes the form, "Many of your customers at this location told you that the lemonade is too sweet." We chose to give only limited feedback because, in practice, it is expensive for a firm to collect information from customers, and feedback is only likely to be forthcoming for combinations that have been tried by the firm.

On the other hand, changing the location to the school required large changes in at least two other variables to attain an equally high profit as suggested by the default strategy.

In addition to the previous manager's letter, the instructions contain a table in which subjects can input their choices, profits, and feedback in each period. Subjects are told that they can use this table to keep track of their choices and outcomes. We use the information subjects record in this table as one measure of their effort during the experiment.

2.3. Treatment Groups and Testable Hypotheses

We initially implement three treatment conditions to examine how different incentive schemes affect innovation success, exploration behavior, time allocation, and effort choices. The only difference between the groups is the way subjects are compensated. The three incentive schemes are as follows:

Incentive Scheme 1 (*fixed wage*). "You will be paid a fixed wage of 50 francs per period."

Incentive Scheme 2 (*pay for performance*). "You will be paid 50% of the profits you make during the 20 periods of the experiment."

Incentive Scheme 3 (*exploration*). "You will be paid 50% of the profits you make during the last 10 periods of the experiment."

There were 51, 46, and 47 subjects in each of these three treatments, respectively. Our main hypothesis concerns the extent to which the different payment schemes considered in our treatment groups affect the exploration activity of subjects. In particular, building on the theoretical predictions of Manso (2011), we hypothesize that subjects under the exploration contract condition should find the optimal business strategy more often than subjects in the other treatments.

Main Hypothesis. *Subjects under the exploration contract choose a business strategy that is closer to the optimal business strategy than subjects under the fixed-wage and pay-for-performance contracts*.

The above hypothesis constitutes the central part of the present paper and may appear surprising at first glance, because the exploration treatment is a hybrid of fixed-wage and pay-for-performance treatments. Thus, a plausible null hypothesis would be that the choices and performance of subjects in the exploration treatment lie in between those of the fixed-wage and the pay-for-performance treatments. Similarly, a null hypothesis based on models of repeated effort (Rogerson 1985, Holmstrom and Milgrom 1987, Sannikov 2008) would predict that the exploration contract induces shirking during the first 10 periods and high effort and good performance in the latter 10 periods of the experiment. Thus, incentive schemes that tolerate early failure are inadequate because they lead to lower effort and productivity than standard pay-for-performance incentive schemes. However, as Manso (2011) formally shows in a theoretical model that features the same trade-off between exploitation and exploration in addition to a costly effort choice as in our experiment, contracts such as the exploration contract used here are effective in motivating exploration (and consequently innovation).[11] There are two important reasons for the difference in performance between subjects in the exploration treatment and subjects in the other two treatments. First, because the compensation of subjects under the pay-for-performance contract depends on their performance from the very first period, they are less willing to explore than subjects under the exploration contract. This is because a subject who is given the pay-for-performance contract and uses his first few periods to explore different strategies is likely to obtain lower profits and would only lower his compensation during those periods compared with the compensation he would receive from the default strategy. In an environment where exploration is desirable, pay-for-performance compensation therefore leads to insufficient exploration. In contrast, the exploration treatment with its tolerance for early failure encourages subjects to explore early on. Thus, relative to the pay-for-performance contract, the exploration contract tilts the scales toward exploration for the subjects' exploitation–exploration trade-off.

Second, subjects who are given a fixed-wage contract should also be willing to explore because they do not face any costs from failing while they explore different strategies. Thus, one might reasonably expect that exploration activity is equally high among subjects in the fixed-wage treatment. However, under a fixed-wage contract subjects do not have any explicit incentives for good performance, and they should minimize the costly contemplation effort necessary to find the best business strategy. Thus, the failure of the fixed-wage contract is due to the lack of incentives to exert costly effort that it provides to the subjects.

In the two following subhypotheses we investigate in detail the problems of the fixed-wage and pay-for-performance contracts in exploration settings.

Exploration Subhypothesis. *Subjects under the exploration contract are more likely to explore than subjects under the pay-for-performance contract*, *who are more likely to focus on exploitation activities*.

Because the pay-for-performance contract fails to encourage exploration, we hypothesize that subjects

[11] For a full discussion of the particular model and formal results, we refer the interested reader to (Manso 2011, Section IV.B). Here, we focus on the intuition of the main findings that are relevant for the present paper.

will explore less than subjects under the exploration contract. Although the above exploration hypothesis explains the differential effects of exploration and pay-for-performance contracts, it does not predict how subjects under the fixed-wage contract will behave. Subjects under the fixed-wage contract do not have explicit incentives for good performance. We therefore hypothesize that they will minimize their effort.

Shirking Subhypothesis. *Subjects under the fixed-wage contract exert less effort than subjects under the exploration contract.*

Although we predict that subjects under the exploration contract are more likely to explore than subjects under the pay-for-performance contract and less likely to shirk than subjects in the fixed-wage contract, it need not be the case that they also produce better average performance than subjects under these two other contracts.

In Manso (2011), agents are assumed to be risk-neutral. In contrast, in our experiment some of the subjects are risk averse, and there is considerable heterogeneity in attitudes toward risk. Although risk (or loss) aversion does not qualitatively change (but actually strengthens) the main results regarding tolerance of early failure, it introduces interesting heterogeneous treatment effects between more and less risk-averse subjects. Compensation is potentially quite variable in the pay-for-performance treatment, in particular when subjects choose to explore by diverging from the default strategy. Thus, in the pay-for-performance treatment we expect more risk-averse subjects to explore less than less risk-averse subjects. On the other hand, we predict that there is no significant difference in exploration behavior between more and less risk-averse subjects in the fixed-wage treatment where compensation is constant by design.

We then turn to investigating how the threat of early termination influences exploration behavior and performance.[12] Early termination can undermine the exploration behavior induced by the exploration contract by eliminating the tolerance for early failure. We further show that this effect can be mitigated by the use of "golden parachutes" or reparation payments that subjects receive in case of early termination because these payments reintroduce the tolerance for early failure that is required to encourage exploration. We introduce two additional treatment groups that enable us to investigate the effects of termination and golden parachutes.

Incentive Scheme 4 (*termination*). "You will be paid 50% of the profits you make during the last 10 periods of the experiment. However, if the profits you make during the first 10 periods of the experiment are below 800 francs, the experiment will end after 10 periods."

Incentive Scheme 5 (*termination with golden parachute*). "You will be paid 50% of the profits you make during the last 10 periods of the experiment. If the profits you make during the first 10 periods of the experiment are below 800 francs, the experiment will end early and you will receive a payment of 250 francs."

There were totals of 71 and 78 subjects who participated in the termination and the golden parachute treatments, respectively. Pure termination inhibits exploration activities because it does not offer sufficient tolerance for early failure.[13] Although the threat of termination produces strong incentives for good performance, it also forces individuals to focus on producing good performance from the very beginning and thus reduces the incentives for exploration. In contrast, in the golden parachute treatment we expect subjects to explore a little more intensively than in the termination treatment at the beginning of the experiment despite the pending threat of termination, because the golden parachute payment provides them with some insurance in case of failure.

Termination Hypothesis. *Subjects under the termination contract are less likely to find the optimal business strategy than subjects under the exploration treatment. Furthermore, subjects under the golden parachute treatment are more likely to find the optimal business strategy than subjects in the termination treatment.*

3. Results

We present the results obtained in our experiments comparing the outcome across the five different incentive scheme treatments. Subjects were randomly assigned to the different treatments, and there are no significant ex post differences in age, gender, risk aversion, and self-reported income.

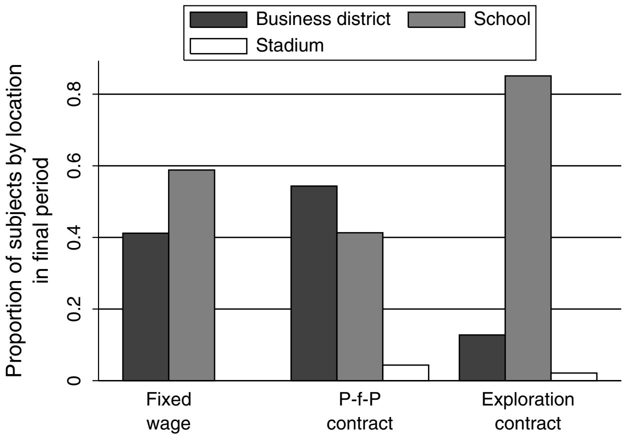
3.1. Innovation, Exploration Behavior, and Effort Choice

We first focus on the exploration behavior of subjects across the first three different treatments. Subjects do not make any decisions that influence any other subjects, and we have a total of 20 period decisions for each of the 379 individual subjects. However, because decisions are correlated over time for each subject, each individual subject participating in the experiment constitutes only one independent observation. Unless noted otherwise, nonparametric tests are therefore based on averages of the relevant variables of the individual subject, and throughout our

[12] See also Manso (2011, Section VI).

[13] The prediction that termination has an adverse effect on exploration depends crucially on our choice of the termination threshold, which is chosen such that it can be achieved without exploring.

Figure 1 Proportion of Subjects by Location in the Final Period of the Experiment for the Fixed-Wage, Pay-for-Performance, and Exploration Contracts



analysis we cluster standard errors at the level of the individual subject. Our first result shows that the prediction that the exploration contract leads to more innovation than the other two contracts is confirmed by the data.

Result 1 (Innovation). *Subjects under the fixed-wage and pay-for-performance contracts are significantly less likely to choose to sell at the school (highest profit location) in the final period of the experiment than subjects under the exploration contract. Subjects under the exploration contract come closest (in terms of maximum and last-period profit) to finding the optimal business strategy.*

Initial supporting evidence for Result 1 comes from Figure 1, which shows the proportion of subjects under the fixed-wage, pay-for-performance, and exploration contract conditions choosing to sell lemonade in a particular location in the final period. Consistent with our exploration hypothesis, subjects under the exploration contract setting are more likely to sell at the school, which is the location with the highest profits in the final period of the experiment, than subjects under the fixed-wage and pay-for-performance conditions. Whereas in the exploration contract condition more than 80% of subjects choose to sell lemonade at the school, only 40% of subjects choose to do so in the pay-for-performance condition, and 60% choose to do so under the fixed-wage contract. Mann–Whitney–Wilcoxon rank sum tests of the individual subject averages show that these differences are highly significant between the exploration contract and the fixed-wage contract (p-value, 0.0042) and the exploration and the pay-for-performance contract (p-value, 0.0001). The difference is less marked between the fixed-wage and pay-for-performance contracts (p-value, 0.0865).[14] Finally, the difference in performance between the fixed-wage and the pay-for-performance treatments is in line with the negative effects of performance pay found in the psychology literature.

We also examine how close subjects come to finding the optimal strategy over the course of the experiment in terms of the profits they achieve. In particular, we use the maximum per-period profit achieved by a subject. Per-period profit is a more comprehensive measure than location choice. It captures the multidimensional aspect of the task, which involves the choice of several variables. On average, subjects under the exploration contract achieve the highest maximum per-period profits (145 francs), whereas subjects under the fixed-wage (128 francs) and pay-for-performance (117 francs) contracts perform worse on this dimension. The same pattern holds for final-period profit, where the respective values are 140 (exploration), 120 (fixed wage), and 111 francs (pay-for-performance). As before, the differences in maximum per-period profit as well as final-period profit between the exploration contract and the other two contracts are highly significant (Mann–Whitney–Wilcoxon test: p-values of 0.013 and 0.0001 for maximum profit, p-values of 0.009 and 0.0001 for final-period profit), whereas the difference between the fixed-wage and pay-for-performance contracts is not statistically significant (p-value of 0.1144 for maximum profit, p-value of 0.28 for final-period profit).

To explain why subjects under the exploration contract are more likely to find the optimal location and business strategy than subjects under the other two contracts, we analyze different measures of exploration and effort.

Result 2 (Exploration Behavior). *Subjects under the pay-for-performance contract explore less than subjects under the fixed-wage contract and the exploration contract with the latter exploring the most.*

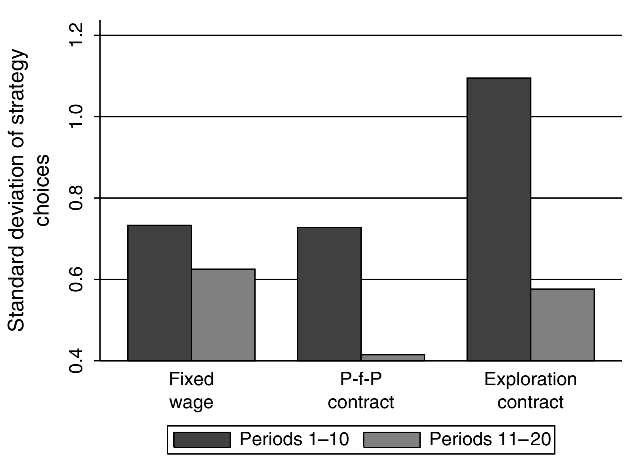
Using the different choice variables available to the agents, we can construct several measures of exploration activity. Subjects in the pay-for-performance condition explore locations other than the default location (business district) less often than subjects under the other two contracts, with subjects under

[14] In addition, we estimated a subject fixed-effects logit model where the dependent binary variable takes the value 1 if the final location choice is the school, which is the optimal location choice in the experiment, and 0 otherwise. The independent variables are binary variables for the three different contracts. As before, the coefficient estimates show that subjects under the pay-for-performance (p-value, 0.0001) and fixed-wage contracts (p-value, 0.0054) are significantly less likely to choose to sell in the school in the final period of the experiment than subjects in the exploration contract. The negative effect on finding the optimal location in which to sell is particularly pronounced for the pay-for-performance contract, whereas the difference between fixed-wage and pay-for-performance contracts is not as significant (p-value, 0.0865).

the exploration contract choosing to explore the most often. Whereas subjects under the exploration contract choose a location other than the default location in 82% and 85% of cases in the first and the last 10 periods, subjects under the fixed-wage contract choose to do so only in 60% and 63% of cases, and the proportions are as low as 51% and 48% for subjects in the pay-for-performance contract. The tolerance for early failure of the exploration contract relative to the fixed-wage and pay-for-performance contracts encouraged individuals to attempt new untried approaches in the first 10 periods. Mann–Whitney–Wilcoxon rank sum tests of the individual subject averages reveal that this difference in location choice behavior between the different contracts is statistically significant. In the first 10 periods, subjects under the exploration contract choose to explore a different location more often than subjects under the fixed-wage contract (p-value, 0.0053) and the pay-for-performance contract (p-value, 0.0001). The difference in exploration behavior as measured by location choice in the first 10 periods is not statistically significant between subjects under the fixed-wage and the pay-for-performance contracts (p-value, 0.1482), but subjects under the fixed-wage contract choose to explore significantly more often than subjects under the pay-for-performance contract in the last 10 periods of the experiment (p-value, 0.0985).

This particular form of exploration activity is also reflected in Figure 2, which shows the average subject-specific standard deviation in strategy choices for the three continuous choice variables (sugar content, lemon content, and price) during the first and last 10 periods of the experiment. This standard deviation measure captures variation in all the variables of this multidimensional choice problem.

Figure 2 **Average Subject-Specific Standard Deviation of Strategy Choices for the Three Continuous Variables (Sugar Content, Lemon Content, Price) in Periods 1–10 and 11–20 of the Experiment for the Fixed-Wage, Pay-for-Performance, and Exploration Contracts**



First, the variability of action choices significantly declines over the course of the experiment in the pay-for-performance (p-value, 0.0005) and exploration contracts (p-value, 0.0001). This occurs because in Periods 11–20 the beneficial learning effects of exploration relative to exploitation are no longer as large as at the beginning of the experiment because the time horizon is shorter. In contrast, the variability of action choices only decreases slightly in the fixed-wage contract and this decline is not statistically significant (p-value, 0.2194). Because agents are not penalized for low profits, exploration behavior in the fixed-wage contract is exclusively driven by intrinsic motives, and subjects may therefore continue to explore even though the additional benefits of exploration are small.

Second, the variability of action choices in the first 10 periods is significantly higher in the exploration contract than in the pay-for-performance (p-value, 0.0012) and the fixed-wage contracts (p-value, 0.0027). This shows that subjects under the exploration contract experiment and consciously take very different actions in a directed attempt to find more promising strategies. In contrast, in the pay-for-performance contract the standard deviation of action choices is much lower as subjects opt to fine-tune the default values. This is also true for subjects under the fixed-wage contract who explore less than subjects under the exploration contract during the first 10 periods. However, because subjects in the other two treatments explore much less in the later periods of the experiment when their compensation is directly linked to their performance, the variability of action choices of subjects under the fixed-wage contract is higher (though not always significantly so) than in the pay-for-performance (p-value, 0.0246) and the exploration contracts (p-value, 0.6567). The relatively high exploration behavior of subjects under the fixed-wage contract in the last 10 periods of the experiment also explains why they are more likely to find the highest-profit location than subjects under the pay-for-performance contract who explore the least over the entire course of the experiment among the three contract treatment groups.

We also expect the variability of profits to mirror the variability of action choices. First, the variability of profits significantly declines over time, with the decline in variability being particularly marked for the exploration contract and the pay-for-performance contracts. Second, the variability of profits in the first 10 periods is significantly higher for subjects under the exploration contract than subjects under the other two contracts, whereas there is no significant difference in profit variability across subjects under the three contracts in the last 10 periods.

We use Cox hazard rate models to analyze the dynamics that govern the strategy choices of

Table 1 Estimates from a Cox Hazard Rate Model Reporting the Hazard Rates for Exiting an Exploration Phase with the Exploration Contract as the Baseline

	Cox hazard rate models			
	Period 1–20	Period 1–10	Period 1–20	Period 1–10
Relative hazard				
Fixed wage	0.217	0.564***		
	(0.136)	(0.204)		
Pay for performance	0.334***	0.632***		
	(0.126)	(0.201)		
Termination			0.487***	0.861***
			(0.110)	(0.185)
Parachute			0.297**	0.580***
			(0.123)	(0.199)
t				
Profits	−0.001***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Pseudo-R^2	0.011	0.013	0.014	0.015
N	2,418	1,068	2,995	1,458

Notes. Separate estimations are shown for the entire 20 periods of the experiment and the first 10 periods. Robust standard errors are reported in parentheses.

**Statistically significant at the 5% level; ***significant at the 1% level (clustered at the individual subject level).

individuals in the experiment. This allows us to test whether the different treatment conditions also influence whether, once they have decided to explore, subjects continue to explore and what other factors contribute to making them persist in their exploration activities. We classify subjects as having entered an explorative phase as soon as they choose a location other than the default location (business district) suggested by the previous manager. An explorative phase ends when subjects make only small changes to strategy choices relative to the previous period or switch back to the default location.[15] As can be seen from column 1 of Table 1, the hazard rate of ending an explorative phase is significantly higher under the pay-for-performance contract than under the exploration contract. The hazard rate is also higher in the fixed-wage contract, although this effect is not statistically significant. Moreover, higher profits significantly decrease the hazard rate as subjects are encouraged to persist in their exploration effort. Column 2 of Table 1 shows that the estimates for the first 10 periods are qualitatively similar.

Finally, answers in the open-ended postexperiment questionnaire in which all subjects were asked to describe their strategies and the effect the compensation scheme had on their choices also reflected the described exploration pattern. Subjects under the exploration contract spontaneously argued that the tolerance for early failure of the compensation scheme as well as the strong rewards for success in later periods influenced their strategic choices, causing them to experiment with untested locations and action choices early on and then to choose and fine-tune the best available strategy beginning in Period 11.

So far, our results have largely focused on exploration behavior. However, we also predicted that subjects under the fixed-wage contract should exert less effort than subjects under the other two contracts because their compensation does not depend on their performance in the experiment.

Result 3 (Time Allocation and Effort Choice). *Subjects under the fixed-wage contract spend less time making and evaluating decisions and exert less effort recording their previous choices and outcomes in the experiment than subjects under the pay-for-performance and exploration contracts*.

A principal deciding whether to pay agents a fixed wage might worry that, absent any intrinsic motivation and implicit incentives, the agent will choose to minimize costly effort. Similarly, in our experiment—where subjects have to mentally focus and record past choices to try to maximize their performance—subjects whose compensation does not depend on their performance may choose to minimize costly and time-consuming contemplation and deliberation effort. Indeed, many subjects under the fixed-wage contract claimed in the postexperiment questionnaire that they attempted to minimize the time and effort necessary to complete the experiment because their

[15] In particular, an explorative phase is defined as ending when a subject switches back to the default location or when a subject does not change location and lemonade color, and also does not change lemon content, sugar content, and price by more than 0.25 units. As a robustness check we also used other definitions thresholds for the end of an exploration phase. The resulting magnitudes and significance levels are very similar.

performance did not affect their compensation. This pattern is also borne out in our data.

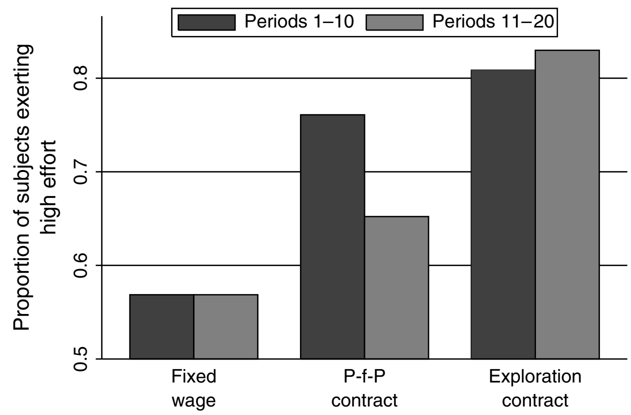
Whereas subjects under the fixed-wage contract spend only an average of 24 seconds on the decision screen (where subjects enter their strategy choices), subjects under the exploration and the pay-for-performance contracts spend 31 and 30 seconds, respectively. That is, over the entire duration of the experiment, subjects under the exploration and pay-for-performance contract conditions spend almost 30% more time on the decision screen than subjects under the fixed-wage condition. These differences are statistically significant (p-values of 0.0014 and 0.0175) over the course of the entire experiment as well as in subperiods. Moreover, subjects in the exploration contract treatment spend significantly more time on the decision screen than subjects in the fixed-wage treatment (p-value, 0.022) even during the first 10 periods of the experiment, when they receive no compensation. This difference in time spent between the exploration and pay-for-performance contracts is not significant- (p-value, 0.8477).

This evidence stands in contrast to dynamic principal–agent models of repeated effort (Rogerson 1985, Holmstrom and Milgrom 1987, Sannikov 2008), which predict that the exploration contract should induce more shirking during the first 10 periods of the experiment than the pay-for-performance contract. These models fail to incorporate the learning produced by the exploration of new strategies, which potentially enhances performance in later periods, and may thus provide incentives for the agent to exert effort in early periods, even when his compensation does not depend on productivity in those early periods. The results above suggest that experimentation and learning can indeed be important components in incentive problems and should be taken into account when designing compensation schemes for innovative tasks.

Furthermore, in addition to spending less time making decisions, subjects under the fixed-wage contract also exert less effort by entering less information into the sheet given to them than subjects under the pay-for-performance and exploration contracts. Figure 3 shows that across the three contracts there is a considerably smaller proportion of subjects under the fixed-wage contract who fill out half or more of the fields in the decision table than in the other two contract treatments. This difference in effort choice is statistically significant between the exploration contract and fixed-wage contracts (p-value, 0.0053) as well as between the pay-for-performance and fixed-wage contracts (p-value, 0.0804).

In the first 10 periods of the experiment, subjects under the exploration contract are significantly more likely to record information than subjects in the fixed-wage contract (p-value, 0.0111), thereby refuting once more the shirking prediction of the standard repeated moral hazard model. The difference in effort exerted during the first 10 periods between subjects under the exploration contract and the pay-for-performance contract is not significant (p-value, 0.5782).

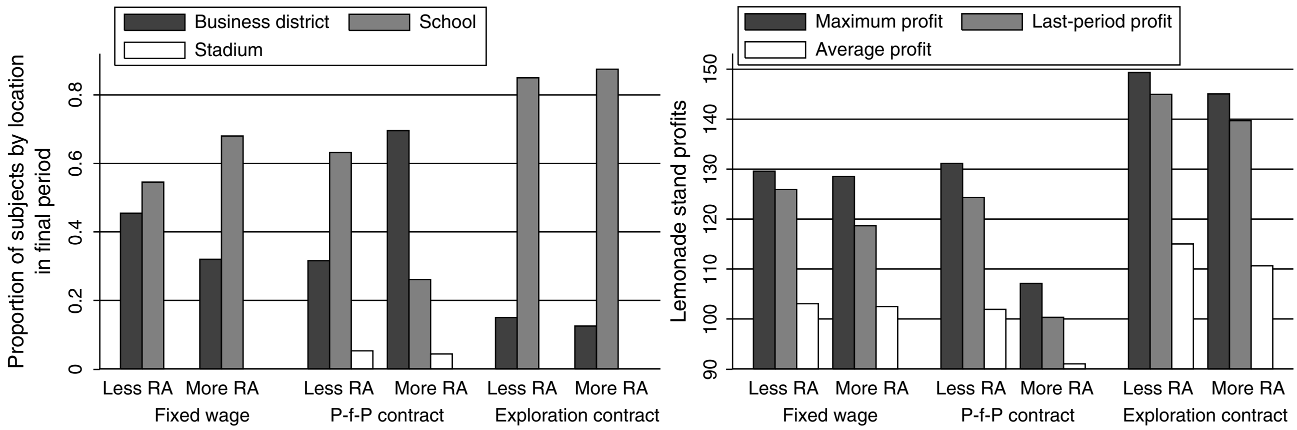
Figure 3 **Proportion of Subjects Who Complete More Than Half of the Fields in the Decision Record Table for the Fixed-Wage, Pay-for-Performance, and Exploration Contracts**



The difference in effort choice between the exploration contract and the pay-for-performance contract is positive but not statistically significant (p-value, 0.29). On the one hand, subjects under the pay-for-performance contract are given more powerful incentives overall because their compensation depends on performance both in the first and the last 10 periods of the experiment. On the other hand, because subjects under the exploration contract choose to experiment with very different strategies in the first 10 periods, as we showed in Result 3, they need to exert more effort when evaluating their decisions than subjects under the pay-for-performance contract. This is also visible in Figure 3, which shows that effort declines in the pay-for-performance contract. This occurs because subjects in the pay-for-performance contract essentially stop exploring and experimenting with different choices very early in the experiment, and therefore they barely change their choices in the last 10 periods. Because there is little change, they do not have to record their choices as carefully as subjects in the exploration contract treatment.

We also note that time allocation and effort choice in the fixed-wage is strictly greater than zero because some of the subjects are sufficiently motivated by intrinsic rewards to exert effort. An inspection of effort choices by subjects in the fixed-wage treatment reveals a bimodal distribution. Subjects either fully record or do not record any of their past choices. Moreover, subjects in the fixed-wage treatment who exert more effort are more likely to successfully innovate: 65% of them end up selling at the school in

Figure 4 **Proportion of Subjects by Location in the Final Period of the Experiment (Left) and Maximum Profit, Last-Period Profit, and Average Per-Period Profit of Subjects (Right) for the Fixed-Wage, Pay-for-Performance, and Exploration Contracts, Adjusting for Differences in Risk Aversion**



Note. RA, risk averse.

the final period compared to 47% of the subjects who exert less effort, but this difference is not statistically significant (p-value, 0.2047). However, maximum profits are significantly higher for subjects in the fixed-wage treatment who exert more effort (p-value, 0.0298).[16]

3.1.1. Average Performance. We now turn our attention to subjects' overall performance in the experiment as measured by average profit.

Result 4 (Performance). *Subjects under the exploration contract produce higher average profits than subjects under the pay-for-performance and fixed-wage contracts.*

Preliminary evidence for Result 4 comes from inspecting the average profit for the three contracts. This performance measure is highest in the exploration contract (111 francs), and the difference in performance between the exploration contract and the pay-for-performance (96 francs) and fixed-wage contracts (102 francs) is statistically significant (Mann–Whitney–Wilcoxon test: p-values of 0.0009 and 0.0253). This difference in performance exists despite the fact than the average wage received by subjects under the exploration contract is lower than that in the other two contracts.[17]

To explain the differences in performance documented in Result 4, we now focus on differential attitudes toward risk.

Result 5 (Risk Aversion). *Under the pay-for-performance contract, more risk-averse subjects are significantly less likely to explore and to choose to sell in the optimal location in the final period of the experiment. They also produce significantly lower profits. Attitudes to risk have a similar (though statistically insignificant) effect in the exploration contract, whereas no systematic effects of risk are found for the fixed-wage contract.*

Using the data from the separate risk aversion experiment, we classify subjects into more and less risk-averse groups. The left panel of Figure 4 provides a first indication for the sign and magnitude of the effect of risk aversion on the likelihood of finding the best strategy. In this figure we use the risk aversion measures to further analyze the final-period location choice as we did in Figure 1. We separately present final location choices for more and less risk-averse subjects for each of the three contracts. In the pay-for-performance contract, more risk-averse subjects are less likely to find the optimal location because they are less likely to explore than the less risk-averse subjects. This innovation-reducing effect of risk is statistically significant in the pay-for-performance contract treatment (p-value, 0.0170), but it is not statistically significant in the other two treatments.[18] This lower rate of innovation success caused by risk aversion is driven by the lower levels of exploration under the pay-for-performance contract because in this treatment the proportion of location choices other than the default location (p-value, 0.0075) as well as the variability of action choices (p-value, 0.0181) are significantly lower for subjects with higher risk aversion. However, in the exploration contract where subjects'

[16] For a study of the effect of intrinsic motivation on innovation productivity, see Sauermann and Cohen (2010).

[17] During the first 10 periods of the experiment, the three contracts are quite similar in terms of average profits. After Period 10, the average profits under the different contracts begin to diverge as subjects under the exploration contract revert to and subsequently fine-tune the best strategy they found during the first 10 periods of the experiment.

[18] However, even among less risk-averse subjects there exists a statistically significant innovation-reducing effect of standard pay for performance relative to the exploration contract (p-value, 0.0367).

failure is tolerated in early periods of the experiment and compensation has a much smaller risky component, the effect is smaller in magnitude and not statistically significant. The same is true in the fixed-wage contract, where compensation entails no risk.[19] It is important to note at this point that, as with all subgroup analysis, the heterogeneous treatment effects with respect to risk aversion need to be treated with caution. It is possible that these may merely be driven by correlated omitted variables (e.g., cognitive reflection ability; Frederick 2005) as we can only exogenously vary the incentive schemes administered to the experimental subjects.

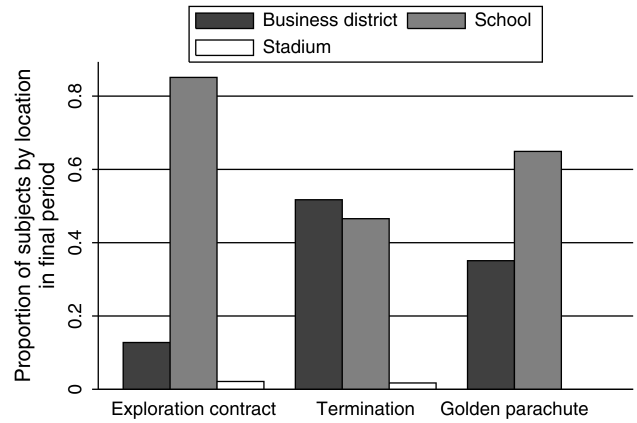
Because more risk-averse subjects under the pay-for-performance contract are less likely to explore and therefore less likely to sell lemonade in the optimal location in the final period, they also produce lower profits, as can be seen in the right panel of Figure 4. This profit-reducing effect of risk aversion in the pay-for-performance contract is large in magnitude and statistically significant for maximum profit (p-value, 0.0563) and final-period profit (p-value, 0.0382), but it is not statistically significant for average profit (p-value, 0.1846). Furthermore, as in the case of the final-period location choice, risk aversion also has a small negative but statistically insignificant effect on profit measures in the exploration and fixed-wage contract treatments.[20]

There could be reasons in addition to risk aversion for the difference in average profits across the three treatment groups. For example, in our experiment subjects are not given precise information about the profits associated with each of the available choices.[21] The differences in average profits across the three treatment groups could thus be due to subjects being pessimistic about the returns to exploration. The explanation mirrors that given in the above two paragraphs with pessimism in place of risk aversion.

3.2. Termination

We now show that the threat of termination reduces the probability that subjects successfully innovate because the threat of early termination reduces exploration activities. However, the adverse effects of termination are less pronounced in the golden parachute treatment, especially for risk-averse subjects.

Figure 5 **Proportion of Subjects by Location in the Final Period of the Experiment for the Exploration Contract, Termination, and Golden Parachute Treatments**



Result 6 (Termination). *The threat of termination has adverse effects on innovation success and exploration activities, but golden parachutes alleviate these negative effects. Risk aversion further reduces innovation success, exploration activities, and performance in the termination treatment.*

Figure 5 shows final-period location choices in the exploration contract, termination, and golden parachute treatments where in the case of the latter two treatments we eliminated subjects that are terminated after the first 10 periods. The threat of termination in the pure termination and golden parachute treatments significantly reduces the probability that subjects end up choosing to sell at the best location in the final period of the experiment relative to the exploration contract treatment (p-values, 0.0001 and 0.0200), whereas the use of golden parachutes raises the innovation success probability (p-value, 0.0485) relative to the termination treatment.[22]

Focusing on subjects that are not subject to termination, we find that termination has an innovation-reducing effect because average maximum profit in the exploration contract treatment (145 francs) is significantly higher than in the termination (126 francs; p-value, 0.0037) and the golden parachute treatments (134 francs; p-value, 0.0772). Golden parachutes

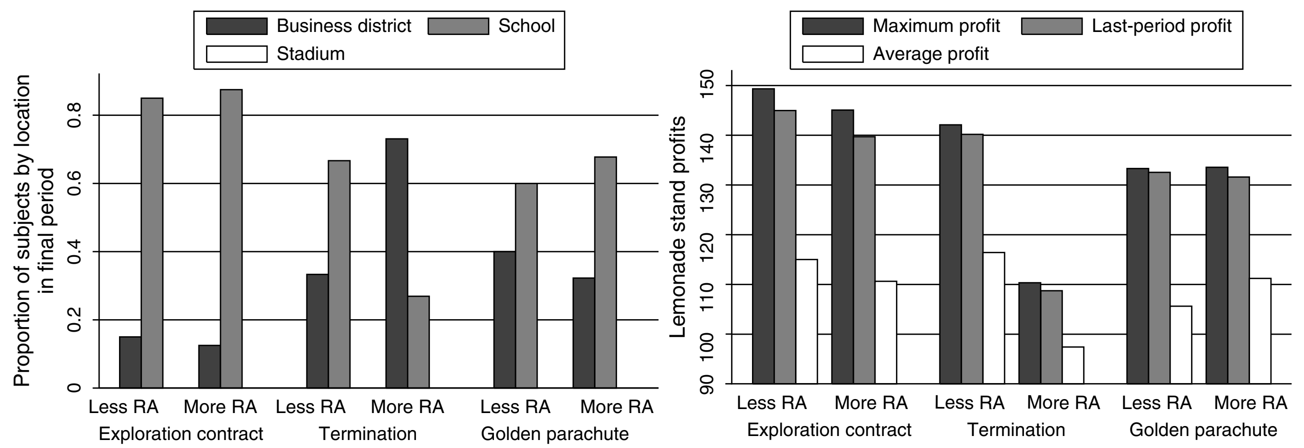
[19] Qualitatively similar results hold for the ambiguity aversion measure. The effects are of the same sign as the effects of risk aversion, but they are generally smaller in magnitude and in some cases not statically significant.

[20] We also speculate that loss aversion, similar to risk aversion, may further exacerbate the exploration-reducing effects of pay-for-performance compensation. Under the pay-for-performance contract, any loss-averse agent may set the payoff of the default strategy as a reference point and will not deviate from this strategy to avoid any losses relative to the reference point.

[21] This is also the case in some of the aforementioned psychology experiments that find that subjects under a fixed-wage contract perform better than subjects under a pay-for-performance contract.

[22] The same results hold when focusing exclusively on the final location choice after the first 10 periods using all the subjects in the termination and golden parachute treatments. The threat of termination reduces the probability of finding the best location relative to the exploration treatment (p-values, 0.0063 and 0.0562), and the use of reparation payments increases (though not statistically significantly) the innovation success probability in the golden parachute treatment relative to the termination treatment (p-value, 0.3176).

Figure 6 **Proportion of Subjects by Location in the Final Period of the Experiment (Left) and Maximum Profit, Last-Period Profit, and Average Per-Period Profit of Subjects (Right) for the Exploration Contract, Termination and Golden Parachute Treatments, Adjusting for Differences in Risk Aversion**



Note. RA, risk averse.

slightly mitigate these adverse effects, though the effect is not significant (p-value, 0.1784). The unfavorable effect of termination is more pronounced if we consider the full sample of subjects and only focus on the first 10 periods. The average maximum profit in the termination and the golden parachute treatments is significantly lower than in the exploration contract treatment (p-values, 0.0032 and 0.0037). However, the difference between the termination and the golden parachute treatments is not statistically significant (p-value, 0.7989).

We can trace the differences in innovation success back to differences in exploration behavior. To guard against potential selection effects arising from attrition, we focus exclusively on choices in the first 10 periods. As expected, exploration is lower in the termination treatment, where subjects shy away from exploring other locations in the first 10 periods. Whereas the average proportion of location choices other than the default location is 82% in the exploration contract, it is only 47% in the termination treatment and 59% in the golden parachute treatment. This exploration-reducing effect of the threat of termination is statistically significant (p-values, 0.0001 and 0.0009). Moreover, golden parachutes increase exploration relative to the pure termination treatment (p-value, 0.0495).[23]

The subject-specific standard deviation of action choices in the first 10 periods for the full sample of subjects is highest in the exploration contract (standard deviation, 1.09). This measure is significantly lower in the termination treatment (standard deviation, 0.74; p-value, 0.0014) and in the golden parachute treatment (standard deviation, 0.79; p-value, 0.0071). The use of golden parachutes slightly increases exploration activity relative to the termination treatment, but this effect is not statistically significant (p-value, 0.2821).[24]

We use the same hazard rate model as in our analysis of the baseline treatments but concentrate exclusively on the first 10 periods. Column 3 of Table 1 shows that both in the termination treatment and in the golden parachute treatment subjects are significantly more likely to stop exploring than in the exploration contract. Moreover, subjects in the termination treatment are also significantly more likely to stop exploring than subjects under the golden parachute treatment (p-value, 0.0663). Column 4 of Table 1 reports estimates for the first 10 periods showing statistically significant differences in the hazard rate between the exploration contract and the termination as well as the golden parachute treatments. The difference between termination and golden parachute is also statistically significant (p-value, 0.0604).

Figure 6 shows that more risk-averse subjects in the termination treatment are less likely to sell in the school in the final period of the experiment, and they achieve lower maximum, final-period, and average profits. Throughout, there is a statistically significant negative effect of risk aversion in the termination treatment on the correct final-period location choice (Mann–Whitney–Wilcoxon test: p-value, 0.0041) as well as on maximum profits

[23] In the postexperiment questionnaire subjects argued that the threat of termination forced them to concentrate on selling in the business district and left no leeway for exploration.

[24] The different proportions of subjects who are terminated in the termination and the golden parachute treatments are also in line with subjects exploring more in the latter case. Whereas in the termination treatment 13 of 71 subjects (18%) do not meet or exceed the termination threshold, 21 of 78 subjects (27%) are terminated in the golden parachute treatment, but the difference is not statistically significant (p-value, 0.2124).

(p-value, 0.0023), final-period profits (p-value, 0.0041), and average profits (p-value, 0.0037).[25]

Finally, in the termination treatment the number of times subjects choose to deviate from the proposed strategy and to explore a location other than the business district in the first 10 periods is significantly lower for subjects who are more risk-averse (p-value, 0.0114). Similarly, in the termination treatment the variability of action choices in the first 10 periods is also significantly lower for more risk-averse subjects (p-value, 0.0040). There are also small negative effects of risk aversion on exploration activity in the golden parachute treatment, but these effects are never statistically significant.

4. Robustness

In this subsection, we show that our results are robust to modifications in the experimental design.

4.1. Signaling Effects of Incentive Contracts

In the analysis we conducted previously, each subject only ever saw one particular incentive contract. The subjects were not made aware that a variety of different incentive schemes were administered to different subjects. This means that subjects might make different inferences from the different contracts they are given about what the best strategy to play is. For example, whereas subjects under the pay-for-performance contract might infer that the best strategy is not to explore, subjects under the exploration contract might infer that the best strategy is to explore.

To account for these potential signaling effects, we administered another treatment in which subjects were able to see that both pay-for-performance and exploration contracts were available. In this treatment, after having observed the set of possible contracts (pay for performance or exploration), the incentive scheme that would be applied to each subject was determined by having the subject roll a die. After having observed the outcome of the die roll the experimenter circled the relevant compensation scheme and crossed out the irrelevant compensation scheme. A total of 70 subjects participated in this treatment, of which 32 subjects rolled the die and received a pay-for-performance contract and 38 subjects rolled and received an exploration contract.

Our results again underline the importance of correctly structured incentives for motivating innovation. Sixty-nine percent of subjects who roll the die and receive an exploration contract choose to sell in the best location in the final period of the experiment, whereas only 39% of subjects who receive a pay-for-performance contract do so after their die roll (Mann–Whitney–Wilcoxon test: p-value, 0.0152). Subjects with an exploration contract also achieve significantly higher maximum profits (138 francs) and higher final-period profits (134 francs) than subjects under a pay-for-performance contract (120 francs and 118 francs, respectively). The respective p-values for the comparisons are 0.0372 and 0.0654.

This difference in innovation success is driven by the differences in exploration behavior that incentive schemes induce. The proportion of location choices other than the default location is significantly higher for subjects who obtain an exploration contract following their die roll (p-value, 0.0045), and the variability of strategy choices is also higher, although this difference is not significant (p-value, 0.1343) due to the smaller sample size.

Mirroring our previous results, subjects under the pay-for-performance contract also have low average profits, although this effect is not statistically significant (p-value, 0.1591). Furthermore, risk aversion again has an innovation- and profit-reducing effect in the pay-for-performance treatment. In the pay-for-performance treatment there is a statistically significant negative effect of risk aversion on the correct final-period location choice (p-value, 0.0583), but there is no significant effect in the exploration contract treatment. The negative effect of risk aversion when subjects obtain a pay-for-performance contract is also apparent in the lower profits for more risk-averse subjects, but this effect is not statistically significant due to the small sample size.

4.2. Gold Prospecting Experiment

In the lemonade stand experiment, subjects exerted real effort and had to form beliefs about the outcomes associated with each of the available actions. As another robustness check, we conducted a second experiment using neutral language, the chosen effort approach, clearly specified success and failure probabilities, and a within-subjects design. This robustness check allows us to alleviate any concerns about the subjects' (mis)interpretation of our experimental instructions, to uniformly control the costs and beliefs associated with the subjects' choices and associated outcomes, and to make clean statistical comparisons across incentive contracts holding each individual subject fixed. The experimental parametrization mirrors that of Manso (2011), which provides exact predictions for optimal subject behavior. Finally, we can measure the potential profit implications for a principal who chooses among the different incentive plans.

4.2.1. Procedures and Subject Pool. The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007) at the California Social

[25] This finding is in line with our previous analysis where we found similarly strong effects of risk aversion for the pay-for-performance contract. Like for our finding for the exploration contract treatment, there is no statistically significant effect of risk aversion in the golden parachute treatment.

Science Experimental Laboratory (CASSEL) at the University of California, Los Angeles. Participants were recruited from the CASSEL subject pool using an online recruitment system. A total of 30 subjects participated in these experiments. We employed a within-subjects design so that all subjects experienced all three treatment conditions. The experimental session lasted 50 minutes.

During the experiment, experimental currency units called "gold nuggets" were used to keep track of monetary earnings. The exchange rate was set at 3 gold nuggets (gn) = \$1, and the show-up fee was \$10. On average, subjects earned \$33.

4.2.2. The Task. Subjects play several separate instances of a gold prospecting game that exactly mirrors the theoretical model in Manso (2011). Each gold prospecting game consists of two periods. In each period, each subject chooses to prospect gold in one of two mountains or to stay at home. Each of these options has an associated revenue and cost. The option "Stay at home" always yields 0 gn, and it costs the subject 0 gn to choose this option. In contrast, the option "Mountain 1" yields 100 gn with a probability of 50% and 0 gn with a probability of 50%, and it costs 0.25 gn to choose this option. Each payoff realization of Mountain 1 is an independent draw. Finally, the option "Mountain 2" allows for learning. With probability p, Mountain 2 is a gold-rich mountain, in which case it yields 100 gn in both Periods 1 and 2 whenever this option is chosen. With a probability of $1-p$, Mountain 2 is a gold-poor mountain, in which case it always yields 0 gn whenever this option is chosen. The cost of choosing Mountain 2 is 0.75 gn. Each instance of the gold prospecting game is an independent draw. Thus, each subject can only learn about the quality of Mountain 2 for that particular instance of the gold prospecting game.

The participants in the experiment thus face the choice between an outside option of 0 gn (Stay at home), an option with a known and constant payoff distribution (Mountain 1) and an option with an unknown payoff distribution (Mountain 2) that allows for learning.

We elicit subject choices using the strategy method: subjects are asked to provide a full contingent plan of action for all possible outcomes. Thus, on the input screen for each gold prospecting game, subjects enter (a) their choice for Period 1, (b) their choice for Period 2 conditional on a payoff of 0 gn in Period 1, and (c) their choice for Period 2 conditional on a payoff of 100 gn in Period 1.

At the end of each gold prospecting game, subjects learn how much revenue they obtained and are reminded of the cost they incurred. In addition, at the end of each gold prospecting game subjects are informed about their cumulative payoff balance.

Table 2 Optimal Strategies for a Risk-Neutral Agent in Each Treatment Condition

	Optimal strategies			
	$p = 0.05$	$p = 0.35$	$p = 0.45$	p unknown
Fixed wage				
Period 1	Stay at home	Stay at home	Stay at home	n/a
Period 2 after 100 gn	Stay at home	Stay at home	Stay at home	n/a
Period 2 after 0 gn	Stay at home	Stay at home	Stay at home	n/a
Pay for performance				
Period 1	Mountain 1	Mountain 1	Mountain 2	n/a
Period 2 after 100 gn	Mountain 1	Mountain 1	Mountain 2	n/a
Period 2 after 0 gn	Mountain 1	Mountain 1	Mountain 1	n/a
Exploration				
Period 1	Stay at home	Mountain 2	Mountain 2	n/a
Period 2 after 100 gn	Mountain 1	Mountain 2	Mountain 2	n/a
Period 2 after 0 gn	Mountain 1	Mountain 1	Mountain 1	n/a

4.2.3. Treatment Groups and Predictions. We conduct four sets of treatments that differ in terms of the probability p that Mountain 2 is a gold-rich mountain. The probability p takes the value 5%, 35%, or 45%, or it is unknown to the subjects. When p is unknown, we choose it such that p is equal to 50%.

In each of the four treatment sets, each subject plays the gold prospecting game under three different compensation schemes.[26] Thus, there are a total of 12 separate gold prospecting games that each subject plays.

In particular, the three compensation schemes are as follows:

Incentive Scheme 1 (*fixed wage*). "You will be paid a fixed wage of 1 gn per period."

Incentive Scheme 2 (*pay for performance*). "You will be paid 10% of the gold revenue during the first and the second periods of the experiment."

Incentive Scheme 3 (*exploration*). "You will be paid 10% of the gold revenue in the second period of the experiment."

These incentive systems exactly mirror the payment schemes in the lemonade stand experiment and generate the same qualitative predictions. Table 2 shows the optimal choices for a risk-neutral agent in each treatment condition. Along the columns there are different values of p, whereas the different incentive schemes are shown in the different rows.

[26] To account for potential order effects, for each subject any of the four p conditions was equally likely and independently chosen as the first, second, third, or fourth treatment. Furthermore, within each p treatment, for each subject each compensation scheme was equally likely and independently chosen as the first, second, or third compensation scheme.

As is apparent from Table 2, as p increases, the choice of Mountain 2 becomes more attractive. This makes it the optimal choice of action in the first period for high values of p in the pay-for-performance and exploration contract treatments. Our main hypothesis, however, concerns the extent to which the different payment schemes encourage the choice of Mountain 2 in Period 1 of the gold prospecting game for a given level of p. In general, due to the tolerance for early failure and reward for long-term success, subjects under the exploration contract should be more likely to choose Mountain 2 in Period 1 than subjects under the fixed wage and the pay-for-performance contracts. The comparison is most clearly visible when $p = 0.35$: in Period 1 subjects should choose Stay at home under the fixed-wage contract, Mountain 1 under the pay-for-performance contract, and Mountain 2 under the exploration contract.

4.2.4. Results. We first compare strategy choices across the three incentive treatments for the four different levels of the success probability p. Each of the 30 subjects made choices under all the 12 different treatments.

Table 3 shows the first-period choices made by subjects in the different conditions as well as the associated theoretical predictions. Consistent with the prediction that the exploration contract encourages exploration, more subjects choose Mountain 2 under this incentive scheme than under the other two contracts. Moreover, subjects under the fixed-wage contract overwhelmingly choose the shirking option Stay at home, whereas subjects under the pay-for-performance contract choose to exploit Mountain 1.[27]

In Tables 2 and 3 we show that for $p = 0.35$, the predicted choice of action for a risk-neutral agent in the first period is different between the pay-for-performance and the exploration contracts, whereas for $p = 0.45$ the optimal choices for a risk-neutral agent under the two incentive systems coincide. Finally, for $p = 0.05$, a risk-neutral agent under the exploration contract is expected to choose Stay at home because the payoff from the exploration option Mountain 2 is too low, and subjects do not earn enough in the first period to justify the costs of choosing Mountain 2.

When $p = 0.35$, only 9 subjects chose Mountain 2 in Period 1 under the pay-for-performance contract, but 24 subjects chose to do so under the exploration contract. Using the within-subjects design of the experiment, a McNemar matched samples test shows that the difference in the choice of Mountain 2 for $p = 0.35$ under the pay-for-performance and the exploration contracts is highly statistically significant (p-value, 0.0007). The statistical significance of this difference is also confirmed by a subject fixed-effects logit regression where we compare the first-period choices for $p = 0.35$ under the pay-for-performance and the exploration contracts. The binary dependent variable takes the value 1 if a subject chose Mountain 2 in Period 1 and value 0 otherwise, and the dependent variable takes the value 1 if the treatment was the exploration contract and 0 if it was the pay-for-performance contract. The associated p-value of the coefficient of the dependent variable is 0.004, indicating again that the difference is highly statistically significant. As is obvious from the raw data shown in Table 3, the difference in behavior between the exploration and fixed-wage contracts is also statistically significant. Under the fixed-wage contract, subjects overwhelmingly choose the shirking option Stay at home. The relevant p-values for the McNemar test and the coefficient of the subject fixed-effects logit regression are 0.00001 and 0.001, respectively.

Although we are not able to provide precise predictions for subject behavior in the treatment conditions where p is unknown, this set of treatment conditions is of particular interest because it shares the feature of the unknown success probability with the more realistic lemonade experiment. Table 3 shows that subject behavior in the first period for unknown p is similar to when $p = 0.35$, and formal statistical tests confirm this impression. Subjects are significantly more likely to choose Mountain 2 in the

Table 3 Choices in Period 1 for Each Treatment Condition

	Choices in Period 1			
	$p = 0.05$	$p = 0.35$	$p = 0.45$	p unknown
Fixed wage				
Stay at home	23	25	24	26
Mountain 1	7	2	3	3
Mountain 2	0	3	3	1
Theoretical prediction	Stay at home	Stay at home	Stay at home	n/a
Pay for performance				
Stay at home	0	1	1	1
Mountain 1	26	20	11	18
Mountain 2	4	9	18	11
Theoretical prediction	Mountain 1	Mountain 1	Mountain 2	n/a
Exploration				
Stay at home	17	1	2	4
Mountain 1	11	5	5	6
Mountain 2	2	24	23	20
Theoretical prediction	Stay at home	Mountain 2	Mountain 2	n/a

[27] As a result of this increased exploration activity, the expected probability of finding 100 gn in Period 2 given the subjects' strategies is 60% under the exploration contract, yet only 52.9% and 8.2% under the pay-for-performance and fixed-wage contracts, respectively.

first period under the exploration contract than under the pay-for-performance incentive scheme (p-value, 0.032; fixed-effects logit). Thus, even when the success probability p is unknown, the early failure tolerance of the exploration contract relative to the pay-for-performance contract motivates subjects to choose the exploration option Mountain 2.

Given the observed behavior of the subjects the experiment also allows us to calculate how large the expected profit would be of a principal who implements different incentive plans. For $p = 0.05$ the profits of the principal are highest when he offers a pay-for-performance contract (75.53) rather than an exploration contract (59.47). For higher expected success probabilities of the exploratory option, i.e., $p = 0.35$, $p = 0.45$, or p unknown to the subjects, the principal always reaps a higher profit when offering an exploration (91.23, 103.13, 103.33) rather than a pay-for-performance contract (87.23, 94.2, 96). If $p = 0.35$ and the principal wanted to induce exploration, he would need to offer subjects 27% of the total gold revenue instead of just 10% to induce risk-neutral subjects to explore under a standard pay-for-performance contract.

5. Conclusion

In this paper, we argued that appropriately designed managerial compensation is effective in enabling entrepreneurship and motivating innovation. In a real-effort task that involves innovation through experimentation, we find that subjects under a payment scheme that tolerates early failure and rewards long-term success explore more and are thus more likely to discover superior strategies than subjects under fixed-wage or standard pay-for-performance incentive schemes. We also find that the threat of termination can undermine innovation, and that this effect is mitigated by the presence of a contract that mimics a golden parachute.

By using a controlled laboratory experiment in which individuals are randomly assigned to different contracts, we are able to establish a causal relationship between particular incentive schemes and innovation performance. Our results complement other contributions to the literature on entrepreneurship and innovation, which use naturally occurring data to show that tolerance for failure is associated with innovation activity.

The most direct out-of-sample implication of our results is that in situations in which enabling entrepreneurship and motivating innovation are important concerns, such as the design of compensation plans of top executives and middle managers in large corporations as well as of entrepreneurs in start-up companies, tolerance for early failure coupled with rewards for long-term success are effective in motivating innovation. In the context of executive compensation, for example, implementing tolerance for failure involves the use of practices that are often criticized, such as option repricing, managerial entrenchment, and golden parachutes. Our results suggest that restricting these practices can have adverse effects on innovation.

The framework and methods proposed in this paper can also be useful in studying other important problems in the entrepreneurship literature. For example, how does the choice of financing affect the entrepreneur's attitude toward innovation? How can we design compensation packages to attract creative entrepreneurs while keeping shirkers and conventional entrepreneurs away? We leave these questions for future research.

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