Risk Aversion and Effort in an Incentive Pay Scheme with Multiplicative Noise: Theory and Experimental Evidence

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Email address corresponding author	zubanov@ese.eur.nl
Address	Erasmus Research Institute of Management (ERIM) RSM Erasmus University / Erasmus School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: + 31 10 408 1182 Fax: + 31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

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ABSTRACT AND KEYWORDS	
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Risk aversion and effort in an incentive pay scheme with multiplicative noise: Theory and experimental evidence

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Abstract

This study applies the classical "linear" model of incentive pay to the case when the noise to output multiplies with effort, deriving two propositions: 1) given the strength of incentives, more risk-averse workers will put in less effort, and 2) a performance target will weaken the negative risk aversion–effort link. The data from a real-effort laboratory experiment involving $N = 85$ student participants support both propositions. Implications of the model and empirical findings to the literature on, and practice of, personnel management are discussed.

JEL: M52; J33; C91
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1 Introduction

Worker risk aversion is known to be an important factor affecting the design of incentive pay schemes and their effectiveness. For one thing, greater dislike of risk requires higher compensation for a given exposure to it (Prendergast, 2000), implying that more risk-averse workers are less

*Erasmus University Rotterdam, The Netherlands. Email: zubanov@ese.eur.nl.
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likely to be found in incentive pay jobs, as has been confirmed empirically in Bellemare and Shearer (2010) and Grund and Sliwka (2010). Second, higher risk aversion by the worker implies lower optimal strength of incentives offered to him by the firm (Lazear and Gibbs, 2009, p. 289), resulting in lower effort. However, since sorting of people into jobs is never perfect, workers with varying risk preferences are often observed in jobs giving the same exposure to financial risk through a standard incentive pay scheme applying to all in a given firm. As workers want to strike a balance between their expected earnings and exposure to risk as befits their risk preferences, will there be any systematic differences in their performance linked to their risk aversion? This study presents a simple model (Section 2) predicting this link in one often occurring case, and tests it by running a laboratory experiment.

At first sight, this link may seem superfluous. In the classical "linear" incentive pay model (Holmstrom and Milgrom, 1987) with a fixed incentive strength and the noise to outcome of the worker's effort additive and independent of the worker's actions, the dislike of this noise should not affect the optimal effort choice. Indeed, experimental results in Sloof and van Praag (2008) suggest that, holding incentive strength fixed, effort is independent of the additive noise variance. However, the variance of the noise to outcome is often *not* independent on the agent's actions, implying that risk preferences will be among factor affecting the optimal effort. In particular, when the noise is multiplicative in effort, optimal effort will decrease with agent's risk aversion. An example of such "multiplicative noise" case is the work of a sales agent who contacts potential customers for a deal, earning a commission for each deal, and succeeds with a certain probability at each contact. Intuitively, the more contacts he makes, the higher his expected earnings are, but so is their variance, implying that agents with a greater dislike for earnings variance will optimally choose to make fewer contacts.

To my knowledge, the only empirical evidence to support this intuition is available in Cadsby, Song and Tapon (2009). Running a laboratory experiment involving 115 economics undergraduate students paid for solving word anagrams, they find that more risk-averse participants report lower improvement in performance once the payment scheme is switched from a fixed fee to pay per anagram solved. In fact, a quarter of their participants did worse after the payment scheme switch. This study features an experiment that is similar in spirit to Cadsby et al.'s (2009) but differs from it as explained in Section 3. The findings from this experiment, too, show that more risk-averse participants put in lower effort under an incentive pay scheme with multiplicative noise, and that this negative risk aversion–effort link is powerful enough to bring performance gains from incentive pay to naught.

What can be done to restore the promised efficiency gains from incentive pay in the multiplicative noise case? A solution proposed in this study is to weaken the risk aversion–effort link by introducing the *minimum output requirement* (MOR), whereby commissions are paid only if the actual output is at or above a specified target. The intuition behind the effect of MOR is that, compared to the case of no MOR, it increases the marginal utility of effort when effort is relatively low, compelling more risk-averse agents to work harder. The experimental results (Section 4) support this intuition: the negative relationship between risk aversion and effort becomes significantly weaker as MOR is introduced, as more risk-averse experiment participants start to put in relatively higher effort.

The rest of the paper is organized as follows. The next section introduces a model of incentive pay with multiplicative noise to effort, deriving the relationships between risk aversion and optimal effort without and with MOR and illustrating them numerically. Section 3 contains the details of the real-effort experiment set to test this model, and reports some descriptive statistics for the treatment and control groups. Section 4 presents the empirical model designed to fit the experimental data, and reports the estimation results from it. Section 5 concludes with a discussion of the results and relates them to the existing literature and practice of personnel management.

2 A model of incentive pay with multiplicative noise

Consider a worker doing a standard repetitive task, such as the work of a sales agent given as an example in the introduction, each attempt having a certain probability of success $\bar{\gamma}$. The worker earns a fixed wage B plus a commission depending on the actual number of successes, $S = \gamma x$ (the monetary value of a commission per unit of value is normalized to 1), where x is the number of attempts and $\gamma \in [0, 1]$ is the empirical success frequency. The dispersion of γ around its expectation $\bar{\gamma}$ introduces noise to output which is multiplicative to worker's effort, hence the name of the model. Indeed, the variance of earnings is $x\bar{\gamma}(1 - \bar{\gamma})$, which is increasing with effort. The worker can choose any x starting from a certain minimum x_0. The firm can only observe and enforce this x_0, but not any effort above it; therefore, the firm contracts on the output S rather than effort.

I assume that the worker's utility function is increasing and concave in total earnings, $B + \gamma x$, with a constant absolute risk aversion

(CARA)[1], and that his cost of effort, $c(x)$, is a monotonically increasing and convex function of x. Approximating the discrete distribution of the success frequency γ with a continuous one for large x, the worker's expected utility net of effort costs is specified as follows:

$$\mathrm{U}(x) = \int_0^1 \frac{1 - e^{-\delta(B+\gamma x)}}{\delta} dF(\gamma) - c(x), \quad c'(x) > 0, c''(x) > 0 \qquad (1)$$

Here δ is the Arrow-Pratt measure of risk aversion (higher δ means greater risk aversion, negative δ means risk loving) and $F(\gamma)$ is the cumulative distribution function of γ, which converges to normal with mean $\bar{\gamma}$ and standard deviation $\sqrt{\frac{\bar{\gamma}(1-\bar{\gamma})}{x}}$ as x becomes large. I further assume that the cost of effort function $c(x)$ is steep enough for an optimal level of effort $x^* < \infty$, maximizing (1), to exist.

It is convenient to "standardize" success frequency γ, using

$$z = \sqrt{x}\frac{\gamma - \bar{\gamma}}{\sqrt{\bar{\gamma}(1-\bar{\gamma})}} \sim \mathrm{N}(0,1),$$

instead of γ in the utility function (1). Then $F(\gamma) = \Phi(z)$, where $\Phi(\cdot)$ is the cumulative standard normal distribution function. The utility function (1) redefined in terms of z becomes

$$\mathrm{U}(x) = \int_{-\infty}^{\infty} \frac{1 - e^{-\delta(B+z\sqrt{x\bar{\gamma}(1-\bar{\gamma})}+\bar{\gamma}x)}}{\delta} d\Phi(z) - c(x) \qquad (2)$$

The optimal effort level x^* maximizing (2) is determined from the following first-order condition:

$$\mathrm{U}'(x) = \int_{-\infty}^{\infty} e^{-\delta(B+z\sqrt{x^*\bar{\gamma}(1-\bar{\gamma})}+\bar{\gamma}x^*)} \left(\frac{z\sqrt{\bar{\gamma}(1-\bar{\gamma})}}{2\sqrt{x^*}} + \bar{\gamma} \right) d\Phi(z)$$

$$-c'(x^*) = 0 \qquad (3)$$

[1]The theoretical results for the constant *relative* risk aversion (CRRA) utility function, available from the author, are weaker but still hold for reasonable values of the decision parameters.

Differentiating x^* in (3) with respect to δ gives:

$$\frac{dx^*}{d\delta} = -\frac{\int_{-\infty}^{\infty} e^{-\delta(B+z\sqrt{x^*\bar{\gamma}(1-\bar{\gamma})}+\bar{\gamma}x^*)} \left(\frac{z\sqrt{\bar{\gamma}(1-\bar{\gamma})}}{2\sqrt{x^*}} + \bar{\gamma}\right) \left(B + z\sqrt{x^*\bar{\gamma}(1-\bar{\gamma})} + \bar{\gamma}x^*\right) d\Phi(z)}{\int_{-\infty}^{\infty} e^{-\delta(B+z\sqrt{x^*\bar{\gamma}(1-\bar{\gamma})}+\bar{\gamma}x^*)} \left[\delta\left(\frac{z\sqrt{\bar{\gamma}(1-\bar{\gamma})}}{2\sqrt{x^*}} + \bar{\gamma}\right)^2 + \frac{z\sqrt{\bar{\gamma}(1-\bar{\gamma})}}{4x^*\sqrt{x^*}}\right] d\Phi(z) + c''(x^*)} \tag{4}$$

The sign of $\dfrac{dx^*}{d\delta}$ in (4) is always negative. Hence, the first hypothesis of this study:

Hypothesis 1: For a given incentive pay contract with multiplicative noise, optimal effort x^* decreases with risk aversion.

Intuitively, in an incentive pay model where the noise to output is multiplicative in effort, the optimal effort level should decrease with risk aversion because higher effort creates extra uncertainty which is the more costly to bear the more risk-averse a worker is. In contrast, when the noise is additive to, and statistically independent of, effort, the uncertainty it creates is independent of the worker's actions. In fact, any additive and independent noise component to the utility function (2) can be separated from effort by factoring it out of the integral, and thus will not affect the first-order conditions determining x^*. Sloof and van Praag (2008, pp. 796-798) provide analytical results supporting this statement. I therefore abstract from additive noise in the model as well as in the experiment designed to test it.

2.1 Minimum output requirement

With minimum output requirement (MOR), the worker receives fixed wage plus commissions, $B+\gamma x$, if the number of successes is at or above a certain minimum output level $y_0 > 0$:

$$\gamma x = z\sqrt{x\bar{\gamma}(1-\bar{\gamma})} + \bar{\gamma}x \geq y_0$$

Failing this, he receives only fixed wage B. His expected utility function then becomes

$$\begin{aligned} \mathrm{U}^{MOR}(x) &= \int_{-\infty}^{\bar{z}(x)} \frac{1-e^{-\delta B}}{\delta} d\Phi(z) + \int_{\bar{z}(x)}^{\infty} \frac{1-e^{-\delta(B+z\sqrt{x\bar{\gamma}(1-\bar{\gamma})}+\bar{\gamma}x)}}{\delta} d\Phi(z) - c(x) \\ &= \mathrm{U}(x) - \mathrm{A}(x), \end{aligned} \tag{5}$$

where $\bar{z}(x) = (y_0 - \bar{\gamma}x) / \sqrt{x\bar{\gamma}(1-\bar{\gamma})}$ is the minimum of the standardized success frequency at which MOR is met given the level of effort x, and the term

$$\mathrm{A}(x) = \int_{-\infty}^{\bar{z}(x)} \frac{e^{-\delta B} - e^{-\delta(B + z\sqrt{x\bar{\gamma}(1-\bar{\gamma})} + \bar{\gamma}x)}}{\delta} d\Phi(z) \tag{6}$$

can be interpreted the expected utility loss from failing to meet MOR despite trying.

Three facts are true about $\mathrm{A}(x)$:

1. $\mathrm{A}(x) > 0$ for all $x_0 \leq x < \infty$, since for these values of x the expression under the integral sign in (6) is negative.

2. $\lim_{x\to\infty} \mathrm{A}(x) = 0$, since $\lim_{x\to\infty} \bar{z}(x) = -\infty$.

3. $\mathrm{A}(x)$ is monotonic in x as long as the probability of meeting MOR increases with x at a faster rate than does the disutility of effort. This happens whenever the curvature of the cumulative distribution function $\Phi(z)$ at $z = \bar{z}(x)$ is steeper than that of $\left(e^{-\delta B} - e^{-\delta(B+y_0)}\right) / \delta$ (the value of the expression under integral in (6) at $z = \bar{z}(x)$), and in particular when y_0 is close to the expected number of successes given the effort without MOR, $x^*\bar{\gamma}$.

These three facts taken together imply that $\mathrm{A}'(x) < 0$ and $\mathrm{A}''(x) > 0$. Given (5), $\mathrm{A}'(x) < 0$ further implies that for the optimal effort level without MOR, x^*, derived from (3), $\mathrm{U}'(x^*) - \mathrm{A}'(x^*) = -\mathrm{A}'(x^*) > 0$. Therefore, the optimal level of effort with MOR, x^*_m, will exceed x^*. Finally, given that $\mathrm{A}'(x^*_m) = -\left(\mathrm{U}'(x^*_m) - \mathrm{U}'(x^*)\right)$, the convexity and monotonicity of $\mathrm{A}(x)$ implies that the difference between x^*_m and x^* decreases with x^*, that is

$$\frac{d(x^*_m - x^*)}{dx^*} = \frac{\frac{dx^*_m}{d\delta} - \frac{dx^*}{d\delta}}{\frac{dx^*}{d\delta}} < 0 \tag{7}$$

Recalling from (4) that $dx^*/d\delta < 0$, inequality (7) implies:

$$\frac{dx^*_m}{d\delta} - \frac{dx^*}{d\delta} > 0$$

Hence the second hypothesis:

Hypothesis 2: For a given incentive pay contract without MOR, the introduction of MOR will weaken the negative relationship between effort and risk aversion.

For the intuition behind Hypothesis 2, consider how the introduction of MOR changes the levels of effort previously chosen by two workers: W^H_L with low risk aversion (high effort), and W^L_H with high risk aversion (low effort). For the hard-working W_L^H, there is almost no change, since his effort practically guaranties a fulfillment of MOR. On the other hand, the relatively low effort that W_H^L used to put in exposes him to a higher expected utility loss $\mathrm{A}(x)$ from not meeting MOR, compelling him to increase effort to reduce the probability of incurring this loss.

Hypothesis 2 will apply only to the workers who still choose to participate in the contract when MOR is introduced. In the case of the optimal, profit-maximizing incentive pay contract without MOR, the participation constraint will be binding for the least productive worker who will make the minimum acceptable effort x_0. As MOR is introduced, this worker and those near him in effort (the cut-off effort level depends on y_0) will pull out of the contract, since for these workers the utility from participation will fall below their reservation utility by $-\mathrm{A}(x) < 0$. Thus, similar to the incentive pay model with additive noise as tested in Lazear (2000), the introduction of MOR is expected to result in i) the departure of the least productive workers, and ii) an increase in the effort by the workers for whom it is still profitable to remain in the firm. However, in what follows I will abstract from MOR's effect on participation (the experimental sample size is not enough to test it anyway) and concentrate on the risk aversion–effort link in the case when participation is continued. The experimental setting in which I test the hypotheses derived from the model will help ensure participation.

2.2 Numerical solutions for optimal effort

This section reports numerical solutions for the worker's optimal effort levels x^* (no MOR) and x_m^* (MOR) as functions of risk aversion, to help visualize the effects of risk aversion that the model predicts under these two regimes.[2] The parameters of the utility functions (2) and (5), underlying the solutions, are listed in Table 1. The values of the probability of success ($\bar{\gamma}$), fixed wage (B) and minimum acceptable effort and output requirement (x_0 and y_0) are the same as in the experiment (next Section 3). The range of the risk aversion parameter δ is restricted to be above 0, to guarantee the existence of an optimal solution given the parameters of the cost function. These parameters have been chosen so that the optimal solution without MOR, x^*, corresponding to the average risk aversion level in the experiment's treatment group is close to its empirical counterpart.

Figure 1 plots logarithms of optimal effort levels without and with MOR as functions of risk aversion calculated from their respective first-order conditions given the parameters in Table 1. More risk-averse workers optimally put in lower effort under both regimes. However, with

[2]The Matlab code for the numerical solutions is available on request.

Table 1: Parameters underlying numerical solutions for optimal effort levels without and with MOR

Parameter	Value
The probability of success, $\bar{\gamma}$	0.25
Cost function: $c(x) = ae^{bx}$	
a	10^{-6}
b	0.35
Fixed wage, B	0
Minimum output requirement, y_0	8
Minimum acceptable effort, x_0	0
Risk aversion parameter, δ	$[0; 1]$

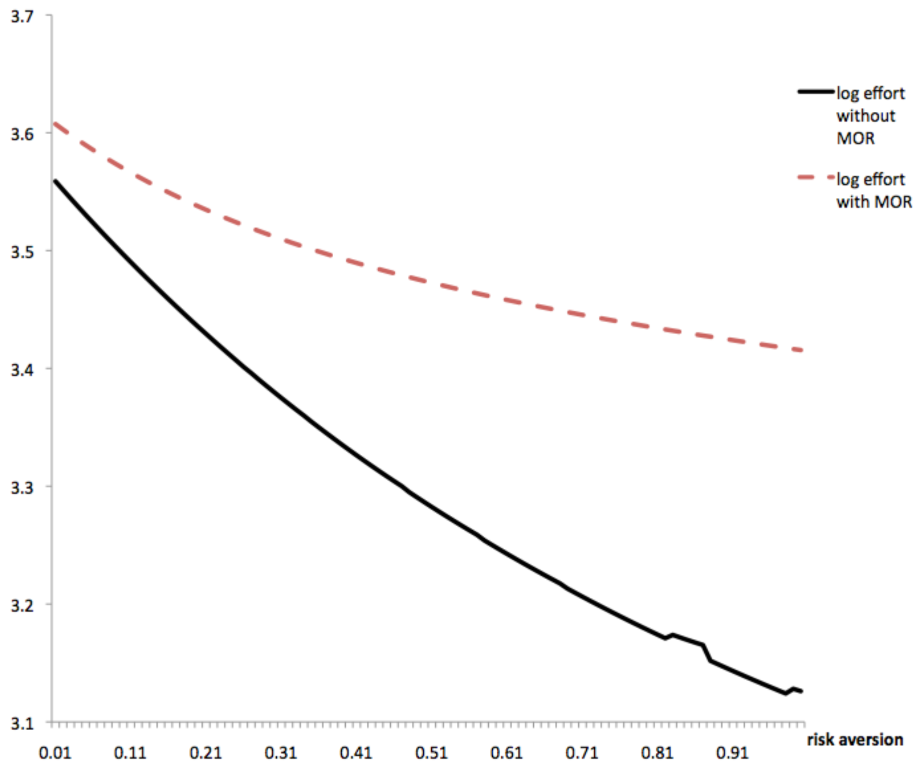
MOR the effort is higher for all levels of risk aversion, and increasingly so for more risk-averse workers, resulting in a weakening of the risk aversion-effort link observed in the absence of MOR. Conveniently, the log effort-risk aversion link is linear to a good degree of approximation, permitting empirical estimation of this link with a simple linear regression.

3 The experiment and the data

To test Hypotheses 1 and 2 empirically, an experiment was run at Tilburg University in The Netherlands. The experiment consisted of an instructions session (5 minutes), an unpaid training round (3 minutes) and two paid-for rounds (5 minutes each) with a five-minute break in between and afterwards, followed by a questionnaire on risk aversion which took a few minutes to fill in. Altogether, the experiment lasted about 45 minutes, including the time it took to allocate the participants to their seats in the computer lab and to disburse the earnings. 85 participants (54 women and 31 men, average age 23 years), all humanities and social science students, were recruited locally through advertisements put up in public areas. The participants were randomly assigned to the control group, receiving a fixed pay for participation in each round of the experiment, and the treatment group, receiving payment depending on their performance at the experimental task. The full details of the experiment, including the instructions and the forms, are available in the Appendix.

The experimental task was to find the word on a specified page, line and position in a piece of printed text, and to enter it into an electronic form created for each round. Once the word was entered, the computer program behind the experiment would determine whether the

Figure 1: The theoretical link between log optimal effort and risk aversion with and without MOR.



entry was correct and assign a payment to each participant in each round. Participants in the control group received a fixed pay of €1.50 per round, irrespective of the number of words they entered. Those in the treatment group were paid per word, earning €0.20 with probability 0.25, and zero with probability 0.75. This method of payment, implemented using a built-in random numbers generator, mimics the incentive pay scheme with multiplicative noise in which pay uncertainty increases with effort. To avoid satisficing, the participants were not informed how many words they entered correctly or, for the treatment group, how many of them were "winning" (i.e., carrying the €0.20 reward) until the very end of the experiment.

The payment rules for the treatment group participants differed by round. During the first paid-for round (round 1), they were paid for every winning word, as workers would be paid in the model without MOR. During round 2, they got paid only if the number of winning words was equal or exceeded 8, as in the MOR case studied in Section 2.1.

Two differences between the experimental designs in this study and

Cadsby et al.'s (2009) are worth mentioning. The first difference is in the experimental task. Word inputting, to my knowledge, has not been used in experimental work before. Yet, it suits the purpose of the experiment well, since performance on this task, while requiring effort, does not depend on ability as much as anagram solving does, allowing more easily to abstract from this potentially confounding factor. The second difference lies in the payment rule, which was implemented in Cadsby et al. (2009) as a payment per anagram solved. The basic feature of an incentive pay scheme under which a negative risk aversion–effort link may exist is multiplicative noise. The uncertainty in the time it takes to solve an anagram does result in the earnings uncertainty increasing with effort (see the concluding section 5 for an example). However, paying per unit of task with a given probability, as is done in my experiment, is a more "clean" way of modeling the risk aversion–effort link, since it guarantees that earnings uncertainty will depend on effort, not ability.

Risk aversion, the key explanatory variable in this study, was measured using the menu of lottery choices developed in Holt and Laury (2002) at the end of round 2. Participants were asked to choose between a safe (low variance) and a risky (high variance) options in ten lottery decisions in which the difference in expected values of the risky and the safe options increased progressively. The expected values of lottery payments were of a similar magnitude to the earnings in the experimental rounds. I use the number of chosen safe options as the measure of the degree of risk aversion in the statistical analysis to follow.[3] To incentivize participants to give honest answers, one of the ten lottery decisions was picked at random and the option chosen by a participant in that decision was played to him or her. Together with the winnings from this lottery and a show-up fee of €1.50, the average earnings in the control and treatment groups were €6.3 and €7, respectively.

Table 2 reports summary statistics for the main variables of the experiment by group. The participants, mostly women in their mid twenties, exhibit an average attitude to risk close to neutrality. The average number of safe choices, about 4, is somewhat lower than a mildly risk-averse 5.17 reported by Holt and Laury's (2002) experiment participants when confronted with lottery payments of a comparable monetary value.[4] There is considerable variation in the reported number of safe

[3]One could also recover intervals of the direct measure of risk aversion, δ, consistent with the stated lottery preferences and use the midpoint in each interval as an alternative measure of risk aversion. The results with this measure (available on request) are qualitatively the same.

[4]The average number of safe choices in the Holt and Laury experiment was cal-

choices spanning from 0 to 7 in the control group, and from 0 to 9 in the treatment group.

Table 2: Descriptive statistics by group

Control group, $N = 43$							
Variable	Mean	Std. Dev.	Pairwise correlations				
			1.	2.	3.	4.	5.
1. Total words round 1	35.39	7.410	1				
2. Total words round 2	36.186	5.799	0.789	1			
3. Risk aversion	3.884	1.096	-0.012	-0.203	1		
4. Age in years	22.714	2.690	0.056	-0.096	0.160	1	
5. Gender (1 = female)	0.558	0.502	-0.112	-0.159	0.207	0.334	1
Treatment group, $N = 42$							
Variable	Mean	Std. Dev.	Pairwise correlations				
			1.	2.	3.	4.	5.
1. Total words round 1	34.690	7.779	1				
2. Total words round 2	37.119	6.078	0.821	1			
3. Risk aversion	4.452	2.086	-0.603	-0.274	1		
4. Age in years	24.071	2.168	-0.172	-0.400	-0.002	1	
5. Gender (1 = female)	0.714	0.457	-0.108	-0.295	0.062	0.243	1

The measure of effort I use is the total number of words entered (there were few incorrect entries). It averages at about 35 words for both groups in round 1 and then increases a little, to 36 in the control group and to 37 in the treatment group. It shows correlations with risk aversion mostly consistent with my theory: negative (-0.6) in the treatment group in the no-MOR round 1, negative but weaker in the same group in the MOR round 2 (-0.27), and insignificant in the control group in round 1. A small but hard to ignore negative correlation between effort and risk aversion in the control group in round 2 (-0.2) suggests that more risk averse people tend to get tired more quickly. The relationship between risk aversion and fatigue is outside my model but it may affect the estimation results as I explain below.

The similarity between average effort levels across groups and treatments is surprising, since it is only the treatment group whose performance was incentivized. The nature of the experimental task, which might have been regarded by some participants as mildly entertaining, may be one explanation; however, other factors closer to the interest of this study are likely to be at work as well. Thus, even though the

culated based on the results reported Table 3 in their 2002 article.

allocation of participants into groups was random, the treatment group happens to be, on average, more risk-averse than control: 4.45 vs. 3.88, though this difference is statistically insignificant. There is also a large negative correlation between risk aversion and effort in the treatment group, consistent with the model. Further analysis will show that these two factors together have lowered the treatment group's average effort, bringing it close to that of the un-incentivized control group.

The improvement in the treatment group's average effort in round 2 relative to round 1, though consistent with the theory, is modest. While there were no cases of a steep decline in effort that would suggest a refusal to participate, fatigue might have negatively affected effort in round 2. If fatigue is unrelated to risk aversion, its average effect will be part of the constant term without causing a bias to the regression estimates. However, looking at the correlations between risk aversion and effort in the control group, it seems that more risk-averse participants are more prone to fatigue. If this is the case, there will be a downward bias in the estimated effect of risk aversion on effort in round 2, making Hypothesis 2 harder to test.

4 Econometric specification and regression results

In principle, one could treat the first-order conditions for the optimal effort levels with and without MOR, x_m^* and x^*, as implicit functions of risk aversion, and estimate their parameters from the data using nonlinear least squares. However, making statistical inferences from the results of this procedure will be difficult, since there is no structurally comparable model for the control group. As a simpler and more direct way of testing the predictions of my model, I approximate the relationship between the logarithm of effort and risk aversion as a linear regression, allowing its parameters to vary between the treatment and control groups. The numerical solutions presented in Section 2.2 show that log-linear is indeed a good approximation for the effort-risk aversion link implied by the theory.

To test my hypotheses, I regress the logarithm of effort in rounds 1 and 2 on the risk aversion measure (the number of safe options in the Holt and Laury lottery), the treatment group dummy, the cross product between the two, and age and gender added as controls:

$$\begin{aligned}\ln(\textit{total words}_i^{\text{round 1}}) = {} & \beta_0^{\text{round 1}} + \beta_1^{\text{round 1}}\textit{treatment}_i + \beta_2^{\text{round 1}}(\textit{risk aversion}_i) \\ & + \beta_3^{\text{round 1}}\textit{treatment}_i \times (\textit{risk aversion}_i) \\ & + \beta_4^{\text{round 1}}\textit{age}_i + \beta_5^{\text{round 1}}\textit{gender}_i + u_i^{\text{round 1}}, \qquad (8)\end{aligned}$$

$$\ln(\textit{total words}_i^{\text{round 2}}) = \beta_0^{\text{round 2}} + \beta_1^{\text{round 2}}\textit{treatment}_i + \beta_2^{\text{round 2}}(\textit{risk aversion}_i) + \beta_3^{\text{round 2}}\textit{treatment}_i \times (\textit{risk aversion}_i) + \beta_4^{\text{round 2}}\textit{age}_i + \beta_5^{\text{round 2}}\textit{gender}_i + u_i^{\text{round 2}}, \quad (9)$$

where $u_i^{\text{round 1}}$, $u_i^{\text{round 2}}$ are the error terms. Coefficient $\beta_3^{\text{round 1}}$ is the text statistic for Hypothesis 1; it measures the difference between the effect of risk aversion on effort in the treatment group, where it is supposed to matter, and the control group, where such link is not expected. Though not part of my theory, a correlation between risk aversion and effort may exist in the control group as well, for instance, due to cognitive ability affecting both effort and risk aversion (Dohmen et al., 2010). Coefficients $\beta_2^{\text{round 1}}, \beta_2^{\text{round 2}}$ measure this correlation in the respective rounds. Lastly, expression $\beta_1^{\text{round 1}} + \beta_3^{\text{round 1}} \times \textit{risk aversion}_i$ and its corresponding expression in round 2 measure the effects of incentive pay on effort. Clearly, if $\beta_3 \neq 0$, these effects differ with risk aversion.

The test statistic for Hypothesis 2 (MOR weakens the negative relationship between risk aversion and effort) is $\beta_3^{\text{round 2}} - \beta_3^{\text{round 1}}$, which is the difference between the effects of risk aversion on effort in round 2 (MOR) and round 1 (no MOR) estimated from equations (9) and (8) respectively. Note that, given the adopted, linear, regression specification, $\beta_3^{\text{round 2}} - \beta_3^{\text{round 1}}$ also measures the effect of risk aversion on the effort increase caused by MOR.[5] To calculate the standard error of this statistic, the variance-covariance matrix of coefficients $\beta_3^{\text{round 2}}$ and $\beta_3^{\text{round 1}}$ is needed. I obtain this matrix by estimating equations (8) and (9) simultaneously, using Zellner's (1962) method of seemingly unrelated regressions. Since the regressors in both equations are identical, this method produces exactly the same results as ordinary least squares (OLS) applied to each equation separately (Greene, 2003, pp. 343-344).

Table 3 reports results for equations (8) and (9) estimated jointly in specifications with and without controls. All controls are individually insignificant and their inclusion makes little difference to the estimates of main interest. As expected, there is no significant link between risk aversion and effort in the control group (coefficients $\beta_2^{\text{round 1}}$ and $\beta_2^{\text{round 2}}$). In the treatment group, however, the link is negative. The test statistic

[5] The equation linking effort increase to risk aversion,

$$\ln\left(\frac{\text{total words round 2}}{\text{total words round 1}}\right)_i = \tilde{\beta}_0 + \tilde{\beta}_1\textit{treatment}_i + \tilde{\beta}_2(\textit{risk aversion}_i) + \tilde{\beta}_3\textit{treatment}_i \times (\textit{risk aversion}_i) + \tilde{\beta}_4\textit{age}_i + \tilde{\beta}_5\textit{gender}_i + \tilde{u}_i,$$

where $\tilde{x} = x^{\text{round 2}} - x^{\text{round 1}}$, is derived by subtracting equation (8) from (9) part by part. The treatment effect is $\tilde{\beta}_3 \equiv \beta_3^{\text{round 2}} - \beta_3^{\text{round 1}}$.

for Hypothesis 1, $\beta_3^{\text{round 1}}$, is estimated at about -0.08, and is significant, supporting the prediction that effort under a linear incentive pay scheme with multiplicative noise decreases with risk aversion. The test statistics for Hypothesis 2, $\beta_3^{\text{round 2}} - \beta_3^{\text{round 1}}$ is also about 0.08 in magnitude and is strongly significant. Hence, the existence of the MOR reduces, in fact neutralises, the negative risk aversion-effort link observed without it. This link weakens because more risk-averse participants increase their effort by a greater margin (8% with a unit increase in risk aversion, or about 0.6 of its standard deviation) than do less risk-averse ones. Recalling that more risk-averse participants may have reduced their effort because of experiencing greater fatigue, this estimate is likely to be a conservative one.

Having confirmed both hypotheses, let us examine what the risk aversion–effort link means to the effect of incentive pay on effort. Although the treatment dummy itself has a large positive and significant coefficient in round 1 ($\beta_1^{\text{round 1}}$), the treatment effect is greatly reduced by the negative risk aversion–effort link specific to the treatment group. In fact, the treatment effect for the average participant in round 1 ($\beta_1^{\text{round 1}} + \beta_3^{\text{round 1}} \times$ *average risk aversion* in Table 3) is almost zero, suggesting that the negative risk aversion–effort link is powerful enough to bring performance gains from incentive pay to naught. The situation improves, albeit slightly, in round 2, where the MOR is introduced. In that round, the treatment effect for the average participant is 0.042-0.059 and is on the brink of statistical significance. It is, again, a conservative estimate, since the treatment group, more risk-averse on average, may have experienced greater fatigue than the control group. Thus, there are signs that the MOR could restore the efficiency of incentive pay schemes.

5 Discussion and conclusion

Let us take stock of the findings and relate them to the wider literature and the practice of personnel management. The model presented in this study predicts that risk aversion will affect individual choice of effort in the multiplicative noise case, when the noise to output and effort are not independent (Hypothesis 1). Only limited scholarship exists on this case. Yet, it is important practically, applying whenever each individual instance of effort succeeds with a certain probability, such as in the sales agent example in the introduction. Another example, more relevant to the case of MOR to which we return below, is that of a tenure tracker who receives a tenure if the amount of his published research exceeds a certain minimum.

In fact, situations where noise to output is not independent of effort abound and include cases when reward is certain and given per each

Table 3: Regression results for Hypotheses 1 and 2

Dependent variable: log total words round 1		
	(1)	(2)
Treatment ($\beta_1^{\text{round 1}}$)	0.326**	0.350**
	(0.135)	(0.138)
Risk aversion ($\beta_2^{\text{round 1}}$)	0.002	0.006
	(0.028)	(0.028)
Treatment×Risk aversion ($\beta_3^{\text{round 1}}$)	-0.079**	-0.084***
	(0.032)	(0.032)
Controls	no	yes
Dependent variable: log total words round 2		
Treatment ($\beta_1^{\text{round 2}}$)	0.017	0.072
	(0.108)	(0.106)
Risk aversion ($\beta_2^{\text{round 2}}$)	-0.033	-0.024
	(0.022)	(0.022)
Treatment×Risk aversion ($\beta_3^{\text{round 2}}$)	0.006	-0.003
	(0.025)	(0.025)
Controls	no	yes
$\beta_1^{\text{round 1}} + \beta_3^{\text{round 1}} \times$ *average risk aversion*	-0.005	0.001
	(0.044)	(0.046)
$\beta_1^{\text{round 2}} + \beta_3^{\text{round 2}} \times$ *average risk aversion*	0.042	0.059*
	(0.035)	(0.035)
$\beta_3^{\text{round 2}} - \beta_3^{\text{round 1}}$	0.085***	0.081***
	(0.018)	(0.018)

** - significant at 5%, *** - significant at 1%.
Standard errors for linear combinations of regression coefficients are calculated using the coefficient variance-covariance matrices estimated with seemingly unrelated regressions.

attempt (as in Cadsby et al.'s (2009) experiment) but the length of time per attempt varies randomly. For instance, going back to the sales agent example, if the length of time it takes to talk to a customer is exponentially distributed, the number of customers that can be contacted in a working day follows Poisson distribution, with variance equal to the mean equal to the expected number of customer contacts per day. That is, even when paid per contact rather than per deal, agents who will make more contacts will face higher earnings uncertainty.

The data from the real-effort laboratory experiment featured in this study support Hypothesis 1, although further experiments, carried out on a larger scale, are necessary to strengthen its empirical foundations. The finding that effort tends to decrease with risk aversion will inform personnel managers that efficiency gains from incentive pay schemes in their firms may be limited by workers' dislike of risk, which is in what what is found from calculating the treatment effects for the average participant. This finding speaks to the literature on the determinants of incentive pay's adoption by firms, especially with respect to non-managerial employees (Lazear, 1986; Brown, 1990; Parent, 2002; Barth et al., 2008), suggesting that workers' risk aversion could be one of such determinants, at least in the short run when sorting of people of different risk preferences into jobs with different exposure to risk cannot complete.

The second hypothesis following from my model was that minimum output requirement (MOR) should weaken the link between risk aversion and effort, at least for the workers who will still participate. This hypothesis, which also implies that MOR will cause workers to put in the more additional effort, the more risk-averse they are, thus restoring part of the incentive pay effect on performance, has been strongly supported by the experimental results. This finding relates to the literature on incentive pay based on performance targets (Murphy, 2000; Anderson et al., 2010), helping to explain the existence of this rather popular practice. The lesson for management is that performance targets can be an effective tool for motivating workers, especially those economizing on effort because of being risk-averse.

Is MOR economically efficient as well as effective? The utility loss caused by the MOR requires compensation to keep the workers employed at the firm, the more the higher their risk aversion. In my simple model, a risk-neutral firm could weaken the negative risk aversion–effort link more cheaply by replacing a random commission γ with its expectation, $\bar{\gamma}$, so as to remove the multiplicative noise component from incentive pay. Doing so, however, may invite dysfunctional behavioral response in a more complicated setting, whereby workers would maximize throughput compromising on quality. Exploring behavioral responses and efficiency implications of different compensation options within the context of incentive pay model with multiplicative noise awaits further research.

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Appendix: Experimental procedures

Section A1. Summary

A real-effort experiment involving 85 humanities and social science students was run at Tilburg University, The Netherlands, in two sessions: one in June, the other in September 2011. Both sessions took place on the same day of the week (Wednesday) at 11.00. A total of 85 participants (54 women, 31 men, average age 23 years) were recruited locally through adverts placed in public areas and allocated randomly into the control (43 participants) and treatment (42 participants) groups. Each session had one control and one treatment group, seated in two separate computer rooms with at least one member of the experimental team in presence. The language of communication was English.

The experiment consisted of an instructions session (5 minutes), an unpaid training round (3 minutes) and two paid-for rounds (5 minutes each) with a five-minute break in between and afterwards, followed by a questionnaire on risk aversion which took at most 5 minutes. The duration of the rounds and the breaks was controlled automatically. The total duration of the experiment was about 45 minutes, including the arrival and reception and disbursement of earnings. The detailed schedule of the stages of the experiment is presented in Section A.2 of this document. The participants were seated at a distance from one another and were asked to remain silent during the rounds and the breaks.

The instructions to participants were communicated in the form of messages appearing on their computer screens. These instructions are given in Section A.3. The questionnaire on risk aversion is given in Section A.4.

The experimental task was to find the word on a specified page, line and position in a piece of printed text, and to enter it into an Excel form created for each round. A fragment from the piece of text used in rounds 1 and 2 (the dry round had a separate piece of text), as it appeared to the participants, is given in Section A.5. Section A.6 contains a screenshot of a typical Excel form wherein the words had to be entered during the paid rounds 1 and 2. The form used during the dry round is similar, except that the participants could see immediately whether they had entered the correct word.

The payment rule differed by the group and the round. The control group participants received 1.50 Euro in each round. The treatment group participants in round 1 were paid per word: 0.20 Euro with probability 0.25, zero with probability 0.75. The random number generator was used to determine the ``winning'' words each of which attracted the 0.20 Euro payment. In round 2, the treatment group participants received their payment only if the total number of winning words in that round was equal to or exceeded 8. These payment rules were announced at the start of each round as part of the instructions.

In addition to the payments per round, each participant received a 1.50 Euro show-up fee plus his or her win in one of the ten lotteries they chose in the Holt and Laury risk aversion questionnaire. They were asked to indicate their lottery choices in a simple Excel form, which was then used to pick up a lottery at random and play it. The total payments, communicated at the end of the experiment, averaged at 6.30 Euro in the control group and 7.00 Euro in the treatment group.

Section A.2. The detailed schedule of the experiment

Stage	**Duration**
Arrival and reception	Approx. 2 minutes
Instructions	Exactly 5 minutes
Unpaid training round	Exactly 3 minutes
Break	Exactly 5 minutes
Round 1	Exactly 5 minutes
Break	Exactly 5 minutes
Round 2	Exactly 5 minutes
Break	Exactly 5 minutes
Risk aversion questionnaire	Max. 5 minutes
Disbursement of earnings and departure	Approx. 5 minutes
Total duration	Approx. 45 minutes

Note: the instructions for rounds 1, 2 and the risk aversion questionnaire appeared 30 seconds before the start of the stage in question.

Section A.3. Instructions to participants

Instructions to the treatment group during the instructions session:

Dear Participant,

First of all, thank you for showing up and agreeing to participate in our experiment. The purpose of this experiment is to compare the behavioural consequences of two different ways of paying salary. The first one is paying fixed wages, and the second is paying per unit of output produced. You will get paid for taking part.

The experimental task is to find the word in the piece of text to be found on your desk, located in a given place as specified in the Excel form that will appear at the start of each round. In general, a single task looks like this: "Find the word on page A, line B, position C". For example, the word on page 1, line 1, position 2 in this piece of text is "participant". Please note that every word counts, including articles, such as "a" or "the", and prepositions, such as "of". The words linked with a dash, count individually; that is, "merry-go-round" consists of three words. Having found the word, you will have to type it in the field corresponding to the given task number in the Excel form. Please type the word starting with a small letter (not CAPITAL!) and make sure that you spell it exactly as it is spelled in the text, as incorrectly spelled words will not count.

The experiment will start with a dry round for training. Then there will be two rounds, five minutes each, with five-minute breaks between the rounds, followed by a short questionnaire about your risk preferences. The payment rules vary by round; you will be notified of them in due time. It is not possible to say for certain how much you will earn. As an indication, we have tried doing the task ourselves, and our total earnings for the two rounds were between 3 and 4 Euros. Your payment will be ready at the end of the experiment.

Thanks again for participating, and we wish you good luck!

The Experiment team

Instructions to the control group during the instructions session:

Dear Participant,

First of all, thank you for showing up and agreeing to participate in our experiment. The purpose of this experiment is to compare the behavioural consequences of two different ways of paying salary. The first one is paying fixed wages, and the second is paying per unit of output produced. You will get paid for taking part.

The experimental task is to find the word in the piece of text to be found on your desk, located in a given place as specified in the Excel form that will appear at the start of each round. In general, a single task looks like this: "Find the word on page A, line B, position C". For example, the word on page 1, line 1, position 2 in this piece of text is "participant". Please note that every word counts, including articles, such as "a" or "the", and prepositions, such as "of". The words linked with a dash, count individually; that is, "merry-go-round" consists of three words. Having found the word, you will have to type it in the field corresponding to the given task number in the Excel form. Please type the word starting with a small letter (not CAPITAL!) and make sure that you spell it exactly as it is spelled in the text, as incorrectly spelled words will not count.

The experiment will start with a dry round for training. Then there will be two rounds, five minutes each, with five-minute breaks between the rounds, followed by a short questionnaire about your risk preferences. You will get paid 1.50 Euro for each of the two rounds of the experiment.

Thanks again for participating, and we wish you good luck!

The Experiment team

Instructions to the control group at the start or round 1:

Your task in this round is to find words corresponding to the page, line and order number as specified in the task table you are about to see. The layout of the task table is the same as in the dry round. You will receive a fixed payment of €1.50 for this round.

Instructions to the control group at the start of round 2:

This round is the same as the previous one. Just keep finding words, and you will receive the same fixed payment of €1.50 for this round as well.

Instructions to the treatment group at the start of round 1:

Your task in this round is to find words corresponding to the page, line and order number as specified in the task table you are about to see. The layout of the task table is the same as in the dry round.

For every correctly found word there is one chance out of four to receive €0.20 and three out of four to receive €0.00. The one chance out of four does not necessarily mean that every fourth word will win, or that one in every four words will win. For a given number of words, there may be more or less than a quarter of wins. Your pay for this round is the number of winning words times €0.20.

Instructions to the treatment group at the start of round 2:

The task for this round is exactly the same as in the previous round, except that now you have to score at least 8 (EIGHT) winning words to receive your payment. If you score fewer, your payment for this round will be €0.00.

Instructions for filling in the risk aversion questionnaire:

Imagine you have a choice between two lotteries: A and B. Each lottery has two prizes that can be won with specified probabilities. The table below lists the prizes and the corresponding probabilities for different configurations of the lotteries. Please read this table and indicate for each configuration which lottery you would choose: A or B. Please indicate your choice by entering 1 in the Decision A or Decision B cell in the Excel form on your screen. Remember: one of the ten choices you will make will be picked at random and the lottery you have chosen will be played to you.

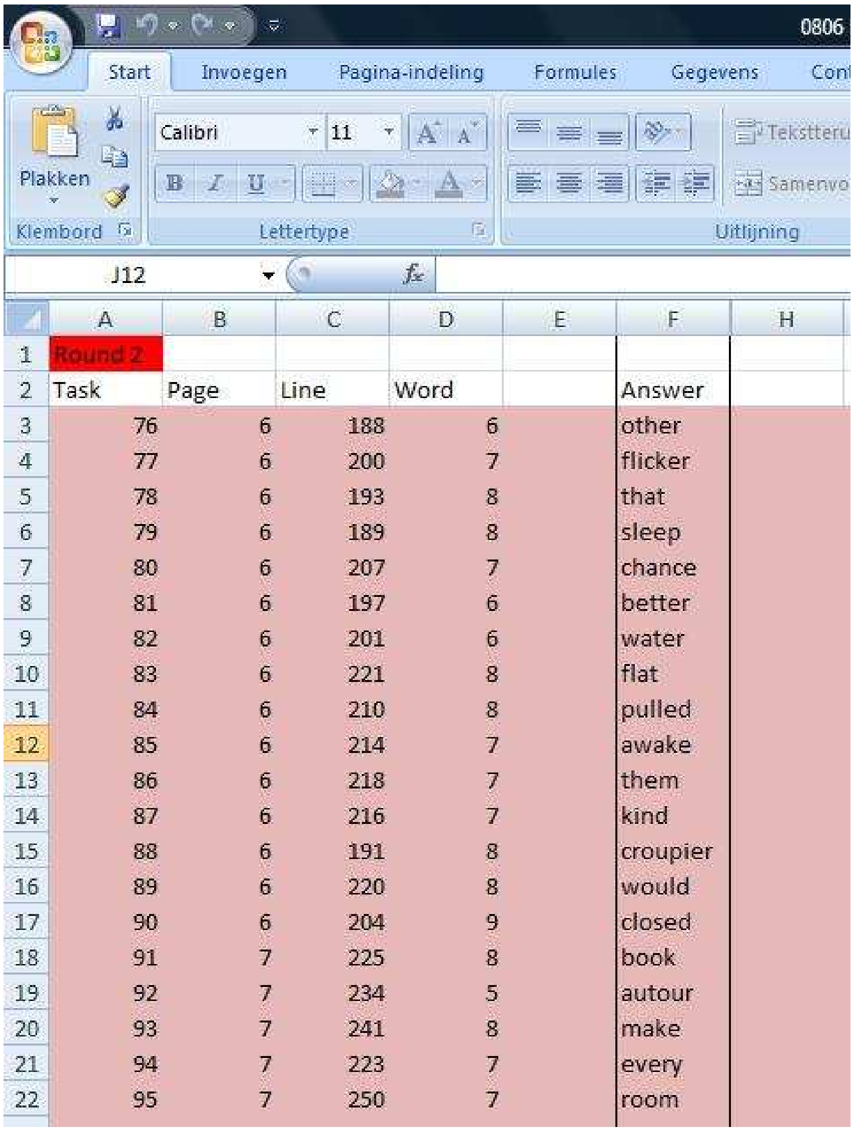
Section A.4. Risk aversion questionnaire:

Option A	Option B	Decision A	Decision B
1/10 of € 2 and 9/10 of € 1,60	1/10 of € 3,85 and 9/10 of € 0,10		
2/10 of € 2 and 8/10 of € 1,60	2/10 of € 3,85 and 8/10 of € 0,10		
3/10 of € 2 and 7/10 of € 1,60	3/10 of € 3,85 and 7/10 of € 0,10		
4/10 of € 2 and 6/10 of € 1,60	4/10 of € 3,85 and 6/10 of € 0,10		
5/10 of € 2 and 5/10 of € 1,60	5/10 of € 3,85 and 5/10 of € 0,10		
6/10 of € 2 and 4/10 of € 1,60	6/10 of € 3,85 and 4/10 of € 0,10		
7/10 of € 2 and 3/10 of € 1,60	7/10 of € 3,85 and 3/10 of € 0,10		
8/10 of € 2 and 2/10 of € 1,60	8/10 of € 3,85 and 2/10 of € 0,10		
9/10 of € 2 and 1/10 of € 1,60	9/10 of € 3,85 and 1/10 of € 0,10		
10/10 of € and 0/10 of € 1,60	10/10 of € 3,85 and 0/10 of € 0,10		

Section A.5. A fragment from the piece of text used in rounds 1 and 2 as it appeared to the participants:

20. When we got upstairs, and had left our hats and sticks with the doorkeeper,
21. we were admitted into the chief gambling-room. We did not find many people
22. assembled there. But, few as the men were who looked up at us on our entrance,
23. they were all types--lamentably true types--of their respective classes.
24. We had come to see blackguards; but these men were something worse. There is
25. a comic side, more or less appreciable, in all blackguardism--here there was
26. nothing but tragedy--mute, weird tragedy. The quiet in the room was horrible.
27. The thin, haggard, long-haired young man, whose sunken eyes fiercely watched the
28. turning up of the cards, never spoke; the flabby, fat-faced, pimply player, who
29. pricked his piece of pasteboard perseveringly, to register how often black won,
30. and how often red--never spoke; the dirty, wrinkled old man, with the vulture
31. eyes and the darned great-coat, who had lost his last soul, and still looked on

Section A.6. A screenshot of a typical Excel form wherein the words had to be entered during rounds 1 and 2:



	A	B	C	D	E	F	H
1	Round 2						
2	Task	Page	Line	Word		Answer	
3	76	6	188	6		other	
4	77	6	200	7		flicker	
5	78	6	193	8		that	
6	79	6	189	8		sleep	
7	80	6	207	7		chance	
8	81	6	197	6		better	
9	82	6	201	6		water	
10	83	6	221	8		flat	
11	84	6	210	8		pulled	
12	85	6	214	7		awake	
13	86	6	218	7		them	
14	87	6	216	7		kind	
15	88	6	191	8		croupier	
16	89	6	220	8		would	
17	90	6	204	9		closed	
18	91	7	225	8		book	
19	92	7	234	5		autour	
20	93	7	241	8		make	
21	94	7	223	7		every	
22	95	7	250	7		room	

Note: The word entries for each round were made on a separate sheet. These sheets were password-protected to prevent the participants from seeing them before they received the password from the experimental team. All cells in the sheets, apart from column F where words had to be entered, were also blocked.

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