Time is money –

Time pressure, incentives, and the quality of decision-making*

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Abstract: Many decisions in economics and finance have to be made under severe time pressure. Furthermore, payoffs frequently depend on the speed of decision-making, like, for instance, when buying and selling stocks. In this paper, we examine the influence of time pressure and time-dependent incentive schemes on the quality of decision-making in an experimental beauty-contest game. We find that convergence to equilibrium is faster and payoffs are higher under low time pressure than under high time pressure. Interestingly, time-dependent payoffs under high time pressure lead to significantly quicker decision-making *without* reducing the quality of decisions.

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Even though many decisions in economics and finance have to be made under severe time pressure, the effects of time pressure are largely unexplored territory in these fields. This is obviously not the case for psychology, where the study of fast decision-making in combination with the application of heuristics and rules of thumb is an important research agenda (see, for instance, Gigerenzer et al., 1999). However, psychological theories and experiments concerning time pressure generally lack an interactive or strategic environment, which is central to economic models or thinking. They can therefore only partly be applied in economics and finance. Only recently, Sutter et al. (2003) have begun to study the influence of time pressure in an interactive setting. In their paper, they examine the effects of time pressure on bargaining, showing that time pressure has high efficiency costs by leading to significantly higher rejection rates of offers. In this paper, we address an equally important issue namely whether time pressure and time-dependent incentive schemes have an influence on the quality of decision-making in economics and finance.

Investment decisions – like trading stocks – are the prime example for the relevance of time pressure and time-dependent incentive schemes. Watching the floors of the New York Stock Exchange, for instance, convinces even the layman that trading is, typically, prone to severe time pressure, yielding the conclusion that there is not much time to decide in order to make money in some instances. But, more than that, time *is* money, because profits from trading (both for the principal investor and the agent trader) may depend crucially on the speed of the trader's reaction to relevant new information.

Time pressure and time-dependent incentives are also important on labor markets. First, think of piece rate wages where both, time pressure and time-dependent payoffs, influence compensation of non-managerial workers. Second, many companies offer a contractual bonus to CEOs or top-level managers if they reach certain (profit) targets in a pre-specified time period. Third, applicants for job vacancies may have to take part in assessment centers where they have to compete against other applicants, sometimes under heavy time pressure (like when being asked to elaborate on a sales strategy for a given product in less than one hour) in order to test candidates' abilities to cope with situations of stress.

Finally, consumers – the main decision-making agents in economics – often have to make decisions under time pressure. Think, for instance, of shopping a few minutes before shops close or participating in an auction. Some companies seem to be willing to exploit the existence of time pressure as part of their sales strategy by offering special discount prices for a typically rather narrow time period. Shopping TV-channels, like *Home Shopping Europe (HSE)*, provide another example for deliberately inducing time pressure. When selling products with a limited number of available items (or at least, when the impression of scarcity of items is intended), the number of sold or still available items is updated and shown on the TV-screen after each purchase, thereby pushing consumers to make a quick decision if they are interested in the product.

Our examples demonstrate that time pressure is a common phenomenon which may appear in different forms and circumstances. The decisive aspect of time pressure is that there is a (more or less) tight time limit for making a decision which involves monetary consequences. It is of minor importance here whether this time limit is really tight or only subjectively perceived to be tight.

The aim of this paper is to analyze the effects of time pressure on the quality of economically relevant decision-making. In particular, we will address two research questions: (i) Is there a tradeoff between the quality of decision-making and time pressure? (ii) How do time-dependent incentive schemes affect the (possible) trade-off between the quality of decision-making and time pressure?

In principal, the best way to address these questions would be to gather data from the field. However, even if data existed, they would have to meet a series of demands. (i) They would have to provide exact measurement of the degree of time pressure and the time-dependency of the incentive scheme. (ii) There would be a need for an objective evaluation criterion for the quality of subjects' decisions taken under time pressure. (iii) One would have to set up a control group without time pressure (and/or time-dependent incentive scheme) in order to be able to compare the quality of decision-making under time pressure and without.

These demands can be approximately satisfied with field data on the effects of piece rate wages compared to fixed hourly wages for non-managerial workers. Most studies in this domain actually show that piece rates raise productivity and output (see Prendergast, 1999, for an overview, or the case studies of Lazear, 2000, or Nagin et al., 2002).

However, with respect to the other examples addressed above no adequate field data exist. With regard to consumer decisions, measurement of time pressure as well as of a decision's quality and in particular the set-up of a control group are demands next to impossible to meet. Data on trading decisions on financial markets may be much easier to obtain. However, besides problems in the accurate measurement of time pressure, their largest drawback is the lack of a *ceteris paribus* control group without time pressure and with identical market conditions.

Given the limitations of field data for the questions at hand, we use an economic laboratory experiment to examine the role of time pressure and of time-dependent incentive schemes on the quality of decision-making. Experimental economics is a suitable method because it enables us to (i) control exactly for the degree of time pressure, (ii) design a decision-making experiment in which the quality of decision-making and the profits associated with a given decision can be evaluated unequivocally, and (iii) set-up a control group with the identical task, but without time pressure.

In particular, we use a beauty-contest game, which we consider an ideal choice to assess the impact of time pressure and time-dependent incentive schemes on reasoning and decision-making. The beauty-contest game has the considerable advantage over several other interactive games that it has a clear ex-post evaluation criterion upon which one can evaluate performance and the quality of decision-making and that behavior in the beauty-contest game is not affected by other motives of decision-making, like risk aversion, fairness considerations or related distributional concerns. The latter aspect prevents confounding the possible effects of time pressure and time-dependent incentive schemes with the influence of social preference motives, for instance. Note, finally, that the beauty-contest game (sometimes also called guessing game) was already likened to professional investment activity by Keynes (1936), and it is therefore related to real economic and financial environments in which time pressure prevails. Our experimental design with continuous pay-off functions, which is expounded below in greater detail, closely resembles decision-making in financial markets.

The rest of the paper is organized as follows. Section 1 introduces our experimental design. Section 2 presents the experimental results, and section 3 concludes.

1 The beauty-contest game

A. Experimental design

The standard version of the game is straightforward: n decision-makers simultaneously choose a real number from the closed interval [0,100]. The mean of all choices for round r is denoted $\bar{x}_r$. The (only) winner in round r is the decision-maker whose number is closest to a target number x_r^*, defined as $p \cdot \bar{x}_r$, where $p \in (0,1)$ and p is pre-announced at the beginning of each round.

Our design differs from the standard version in two respects: First, we let subjects experience several different parameters of the game by varying p and by adding a variable constant C to the average guess to create interior equilibria.[1] By using different parameters we can easily change the game theoretic equilibrium and, thus, test for the adaptability of players to a changing environment under time constraints without altering the general nature of the game.

Second, contrary to the usual winner-takes-all payoff scheme, we use a beauty-contest game where payoffs for each participant are continuously decreasing with the distance between the chosen number and the target number within a group (similar to Güth et al., 2002). We consider a continuous payoff function especially suitable for an experiment with time pressure, because it provides each participant with incentives to think hard and to invest a considerable effort. Contrary to that the usual winner-takes-all scheme might potentially lead single players to mentally retire or play around with odd numbers, given the relatively high demand on the concentration of the participants during the game. Note also that the continuous payoff scheme and the existence of interior equilibria resemble financial decision-making much more than the basic winner-takes-all scheme with a boundary equilibrium.

Our two modifications are captured in the general calculation of round r's target value x_r^* in equation [1] and subject i's payoff $\pi_{i,r}$ (given guess $x_{i,r}$) in equation [2].

$$x_r^* = p \cdot \left(\sum_{i=1}^{n} x_{i,r} / n + C \right) \qquad [1]$$

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[1] Guessing games with interior equilibria or with changing p, however without time pressure, have already been reported by Nagel (1995) or Güth et al. (2002).

$$\pi_{i,r} = 1.00 - 0.04 \cdot \left| x_{i,r} - x_r^* \right| \qquad [2]$$

Payoffs in equation [2] are in euro. That means that subjects can earn 1 euro if their guess is identical to the target number of period *r*. Every (absolute) unit difference between subject *i*'s guess $x_{i,r}$ and the target number x_r^* decreases the payoff by 4 euro-Cent. If the difference is larger than 25, a subject makes a loss in the respective period.[2]

Group size *n* is fixed at *n* = 4 in our experiment. There are 3 phases à 8 rounds in the experiment. In the first phase (rounds 1-8) subjects face $p = 2/3$ and $C = 0$, yielding a Nash equilibrium of zero.[3] In the second phase (rounds 9-16) we set $p = 0.4$ and $C = 90$, implying a Nash equilibrium at 60. In the final phase (rounds 17-24) we let $p = 0.2$ and $C = 100$, where the Nash equilibrium is to choose 25.

B. Treatments

To examine the effects of (i) time pressure and (ii) time-dependent incentive schemes on the quality of decision-making, we have set up three treatments which differ in the combination of (i) the time limit for decision-making and (ii) the multiplication of the payoffs – given in equation [2] – with a time-dependent factor. Table 1 summarizes the main characteristics of the treatments.

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[2] Losses in single rounds could, of course, be balanced with gains in other rounds. Adding up all rounds, there was not a single participant who ended up with an overall loss.

[3] Rational players will exclude the interval [100*p*,100] because any number in this interval is dominated by 100*p*. If a rational player believes all others to be rational as well (by also excluding the interval [100*p*,100]), she will exclude [100p^2,100], and so on. After infinitely many eliminations of dominated strategies, choosing zero remains the only non-excluded strategy, given common knowledge

Table 1: Treatment conditions and parameters

treatment conditions	*'120 sec'*	*'15 sec'*	*'15 sec incentives'*
time for decision-making	120 seconds	15 seconds	15 seconds
payoffs time-dependent within time limit	no	no	yes
group size (n)	4	4	4
number of participants	48	48	48
number of independent observations (= groups)	12	12	12
parameter conditions in each treatment	p	C	*Nash equilibrium*
phase 1 (rounds 1-8)	2/3	0	0
phase 2 (rounds 9-16)	2/5	90	60
phase 3 (rounds 17-24)	1/5	100	25

The first treatment is denoted '120 sec', because subjects have 120 seconds time for making a decision. Our previous experience with beauty-contest experiments (see Güth et al. 2002 as well as Kocher and Sutter, 2004) has, in fact, shown that the average decision-making time drops from about 60 seconds in the first round to about 20 seconds in the 8th round. The time limit in '120 sec' is therefore well beyond the time even slow decision-makers typically need, meaning that this is the treatment without time pressure. Payoffs in '120 sec' are as defined in equation [2] above.

The second treatment is denoted '15 sec'. It differs from the '120 sec' treatment only with respect to a time limit of 15 seconds for making a decision. Given our previous experience, we think that this time limit is sufficient to create quite severe time pressure. Since subjects learned the parameters p and C of each phase only in the first

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of rationality. The iterated elimination of dominated strategies can also be applied in case of interior equilibria (see Güth et al., 2002).

round of a given phase, we added 5 seconds of additional decision-making time in rounds 1, 9, and 17, where parameters *p* and *C* changed.

The third treatment is denoted ’15 sec incentives’. It differs from the second treatment by applying a time-dependent factor to the payoff equation [2]. Faster decisions implied higher payoffs than slower decisions (keeping the distance to the target value constant). The factor, depending upon the time consumed for entering a decision, is shown in Table 2. It has been set at 1.00 if the decision is entered in the 10th second (respectively in the 15th second in the first round of each phase), because the average decision-making time in the second treatment ’15 sec’ had been rather stable at about 10 seconds.[4]

Table 2: Time-dependent factor for the payoffs in treatment ’15 sec incentives’

	Decision entered in second…										
Round 1, 9, 17	1 – 10	11	12	13	14	15	16	17	18	19	20
Rounds 2-8, 10-16, 18-24	1 – 5	6	7	8	9	10	11	12	13	14	15
Time-dependent factor	1.80	1.64	1.48	1.32	1.16	1.00	0.84	0.68	0.52	0.36	0.20

C. Experimental protocol

We conducted two sessions with 24 participants for each treatment. In total, 144 undergraduate students of the University of Innsbruck, who had never before taken part in a beauty-contest experiment, participated in the experimental sessions. The experiment was fully computerized with the help of z-tree (Fischbacher, 1999). When

[4] We ran sessions with treatment ’15 sec’ before those with ’15 sec incentives’ in order to be able to set the time-dependent multiplication factor of 1.00 at the average decision-making time in ’15 sec’.

registering for the experiment, all participants were randomly assigned to treatment conditions and, within sessions, to groups of four subjects, where group composition remained constant in all 24 rounds.

When preparing and designing the experiment, we put particular emphasis on the following issues. First, it was one of our major concerns to keep experimental sessions short to avoid signs of exhaustion towards the end of the experiment. Sessions with 15 seconds for decision making lasted about 25 to 30 minutes, with the 24 rounds being finished in exactly 6 minutes. Sessions with 120 seconds for decision-making lasted about 35 to 40 minutes. Second, in order to study the effects of time pressure under very salient conditions, payoffs were exceptionally high, with average payoffs of 20.4 € per person. Third, we checked hard- and software for proper functioning, in particular whether all mice in our lab worked smoothly, since they were essential to enter a decision. Fourth, needless to say that we put great emphasis on drafting the instructions in a way that allowed to comprehensively understand the following task.

In the instructions (see Appendix), we presented the general formula (and a verbal description of how) to calculate the target number, given above in equation [1], and the payoff scheme, given in equation [2]. Participants were informed that there would be three phases, each consisting of 8 rounds, with changing parameters, but that the two parameters remain constant within each period. We also presented sample screens in the instructions, where we showed participants how to enter their decisions, where they could see the remaining time etc. From the material presented in the instructions participants had, however, no clue concerning the range of the parameters we were about to apply in the experiment.[5] The actual parameters *p* and *C* were displayed on the

[5] We also abstained from running practice rounds, because we wanted to examine the learning and convergence effects under time pressure and we wanted to avoid to give subjects a clue of the type of parameters we were about to apply in the experiment.

screen in the first round of each of the phases, where participants in the treatments with time pressure had 20 seconds to decide instead of 15 to account for the necessary time to read the parameters.

When the time limit of a given round was reached, a new screen appeared which contained all important feedback information (own guess, group average, target number and own payoff in the previous round) in the upper half, and in the lower half subjects had to enter the decision for the next round. Note that in the treatments with time pressure, subjects had 15 seconds to digest both the feedback information from the previous round *as well as* to enter the decision for the next round. After the time limit had been reached, a subject could no longer enter a decision and therefore earned nothing in this round.

Having presented the basic structure of the game and the course of action on the screens, we asked each participant separately whether he/she had some open questions and whether he/she had understood everything. At the end of the experiment, participants were paid privately in cash.

D. Hypotheses

Psychology offers several explanations for a negative influence of time pressure on the quality of decision-making. Time pressure induces subjects to rely more heavily on heuristics or so-called rules of thumb for decision-making in complex environments.[6] It has long been established that such heuristics – even in the absence of time pressure – frequently result in systematic decision-making errors (Tversky and Kahneman, 1974; Wickens and Holland, 2000). Time pressure adds to the pitfalls of heuristics, because it prevents a thorough (and time-consuming) check of the internal logic of decisions and its consistency with the expected behavior of other subjects and because it induces subjects to focus on the most salient cues when making a decision, even if these cues are of no importance for the decision to be made (Wallsten and Barton, 1982).[7] Besides affecting actual decisions, time pressure has also an influence on the willingness to gather information and process it before even making a decision. This phenomenon is known as 'closing of the mind' (Kruglanski and Freund, 1983), meaning that people seek cognitive closure and stop considering multiple alternatives.[8] These effects of time pressure let us put forward our first hypothesis:

Hypothesis 1: Time pressure reduces the quality of decisions. In our beauty-contest game we expect subjects' guesses to be further away from the equilibrium and their earnings to be lower under time pressure than without time pressure.

Personnel economics has provided both theoretical explanations as well as empirical evidence for the typically positive effects of incentive schemes on workers' productivity in organizations. Whether a time-dependent incentive scheme has any effects on the quality of decision-making, however, has not been addressed yet. However, if one accepts the introduction of piece rate wages as a reasonable analogue, one might expect faster decisions, but no significant change in the quality of decisions – equivalent to more output per unit of time with piece rates, but with the same quality of output, on average (Prendergast, 1999). This leads us to our second hypothesis:

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[6] Gigerenzer et al. (1999) call them 'fast and frugal' heuristics.

[7] Nevill et al. (2002) or Sutter and Kocher (2004), for instance, have shown that soccer referees are heavily influenced by the crowd noise in the stadium when making decisions on fouls, penalties or extra time.

[8] De Dreu (2003) provides a good overview of the psychological literature on time pressure and information processing.

Hypothesis 2: Time-dependent incentive schemes reduce decision-making time without lowering quality in terms of deviation from the equilibrium and in terms of payoffs in the beauty-contest game.

2. Experimental results

A. Aggregate results across phases

An overview of our results is provided in Table 3 which reports the average absolute difference to equilibrium in each of the three phases, the average decision-making time and the average profit according to equation [2]. Average data tell us that in each phase guesses are on average closest to the equilibrium in the treatment ‘120 sec’, where there is practically no time pressure. Average guesses in treatments with 15 seconds time limit are farther away from the relevant equilibria. Applying a (two-sided) U-test with average guesses within groups and over all 8 rounds of a phase as the units of observation, we find that guesses in ‘120 sec’ are significantly closer to the equilibrium than in ’15 sec’ ($p < 0.01$ in any phase; $N = 24$) or in ’15 sec incentives’ ($p < 0.01$ in any phase; $N = 24$). On the level of phase averages we can therefore confirm our Hypothesis 1: Time pressure reduces the quality of decisions.

Comparing behavior in the two treatments with time pressure, we find that average guesses are closer to the equilibrium in each phase in the treatment ’15 sec incentives’. However, the differences in the average absolute distance to the equilibrium are not significantly different between ’15 sec’ and ’15 sec incentives’ ($p = 0.11$ in phase 1; $p = 0.08$ in phase 2; $p = 0.20$ in phase 3; two-sided U-test; $N = 24$).

Average decision-making time is clearly higher in the ‘120 sec’ treatment (decreasing from 42 seconds in phase 1 to 25 seconds in phase 3) than in the time pressure treatments ($p < 0.001$ in any phase and any pairwise comparison between ‘120 sec’ and either ’15 sec’ or ’15 sec incentives’; two-sided U-test; $N = 24$).

The introduction of a time-dependent incentive scheme in ’15 sec incentives’ leads to significantly lower decision-making times than in ’15 sec’ ($p < 0.001$ in any phase; two-sided U-test; $N = 24$). Furthermore, whereas the average decision-making time is decreasing (significantly) by about 15% from phase 1 to phase 3 in the ’15 sec’ treatment (from 10.8 to 9.3 seconds), it is decreasing by almost 40% (from 7.2 to 4.5 seconds) in treatment ’15 sec incentives’. Shorter decision-making times, paired with no decline in decision-making quality, lead us to the conclusion that the introduction of a time-dependent incentive scheme has positive effects for decision-making under time pressure, which was our expectation from Hypothesis 2.

Since guesses and payoffs are very closely related, payoffs according to equation [2] are highest in the treatment without time pressure, followed by the time-dependent treatment ’15 sec incentives’, and lowest in the ordinary time pressure-treatment ’15 sec’. The difference between treatments ‘120 sec’ and ’15 sec’ (’15 sec incentives’) is significant at $p < 0.001$ ($p < 0.01$) for each phase (two-sided U-test; $N = 24$). Payoffs according to equation [2] – disregarding the time-dependent factor in treatment ’15 sec incentives’ – are marginally higher in ’15 sec incentives’ than in ’15 sec’ ($p = 0.061$ in phase 1; $p = 0.057$ in phase 2; $p = 0.063$ in phase 3; two-sided U-test; $N = 24$). Within treatments, average profits get higher in each successive phase ($p < 0.025$ for any transition and treatment; Wilcoxon signed ranks test).

Table 3: Overview of results

	Treatment		
	120 sec	**15 sec**	**15 sec incentives**
Average (absolute) distance to equilibrium			
Phase 1 (EQ[a]=0)	15.81	27.52	24.90
Phase 2 (EQ=60)	5.45	13.38	9.91
Phase 3 (EQ=25)	2.30	6.69	4.31
Average time for decisions (in seconds)			
Phase 1 (EQ=0)	42.48	10.80	7.19
Phase 2 (EQ=60)	38.50	9.68	5.53
Phase 3 (EQ=25)	25.72	9.33	4.49
Average profits according to equation [2]			
Phase 1 (EQ=0)	0.71	0.47	0.56 (0.82)[b]
Phase 2 (EQ=60)	0.82	0.59	0.70 (1.14)[b]
Phase 3 (EQ=25)	0.92	0.74	0.85 (1.45)[b]
Average total profits in €	19.60	14.29	16.88 (27.24)[b]
Standard deviation of total profits	2.12	6.26	2.16 (6.48)[b]
Average number of guesses (max=24)	23.88	22.85	23.71
Relative frequency of subjects with EQ-guesses			
Phase 1 (EQ=0)	0.06	0.02	0.01
Phase 2 (EQ=60)	0.22	0.08	0.14
Phase 3 (EQ=25)	0.48	0.13	0.38

[a] EQ: Nash equilibrium.

[b] Real profits (by applying the time-dependent factor to equation [2]) are given in parentheses.

Since decision-making is very quick and on average clearly below 10 seconds in treatment ’15 sec incentives’, actual profits – which are based on equation [2] and adjusted by the time-dependent factor from Table 2 – are highest in this treatment. They are even higher than in ‘120 sec’, because the gain from quicker decision-making overcompensates the loss from decisions of lower quality.

Table 3 also reports the average number of guesses participants make in the experiment. The maximum number is 24, i.e. the number of rounds. All treatments are rather close to the maximum, with the lowest average number of guesses in the ordinary time pressure treatment ’15 sec’.

Finally, Table 3 reports the relative frequency of subjects guessing the Nash equilibrium of a certain phase. In line with previous studies (see Nagel, 1995; Duffy and Nagel, 1997; Ho, Camerer and Weigelt, 1998), this relative frequency is very low in phase 1, where subjects have no experience and face a boundary equilibrium. With experience and with interior equilibria, the number of subjects guessing the Nash equilibrium rises steadily, most so in the treatment without time pressure, least so in the simple time pressure treatment ’15 sec’.

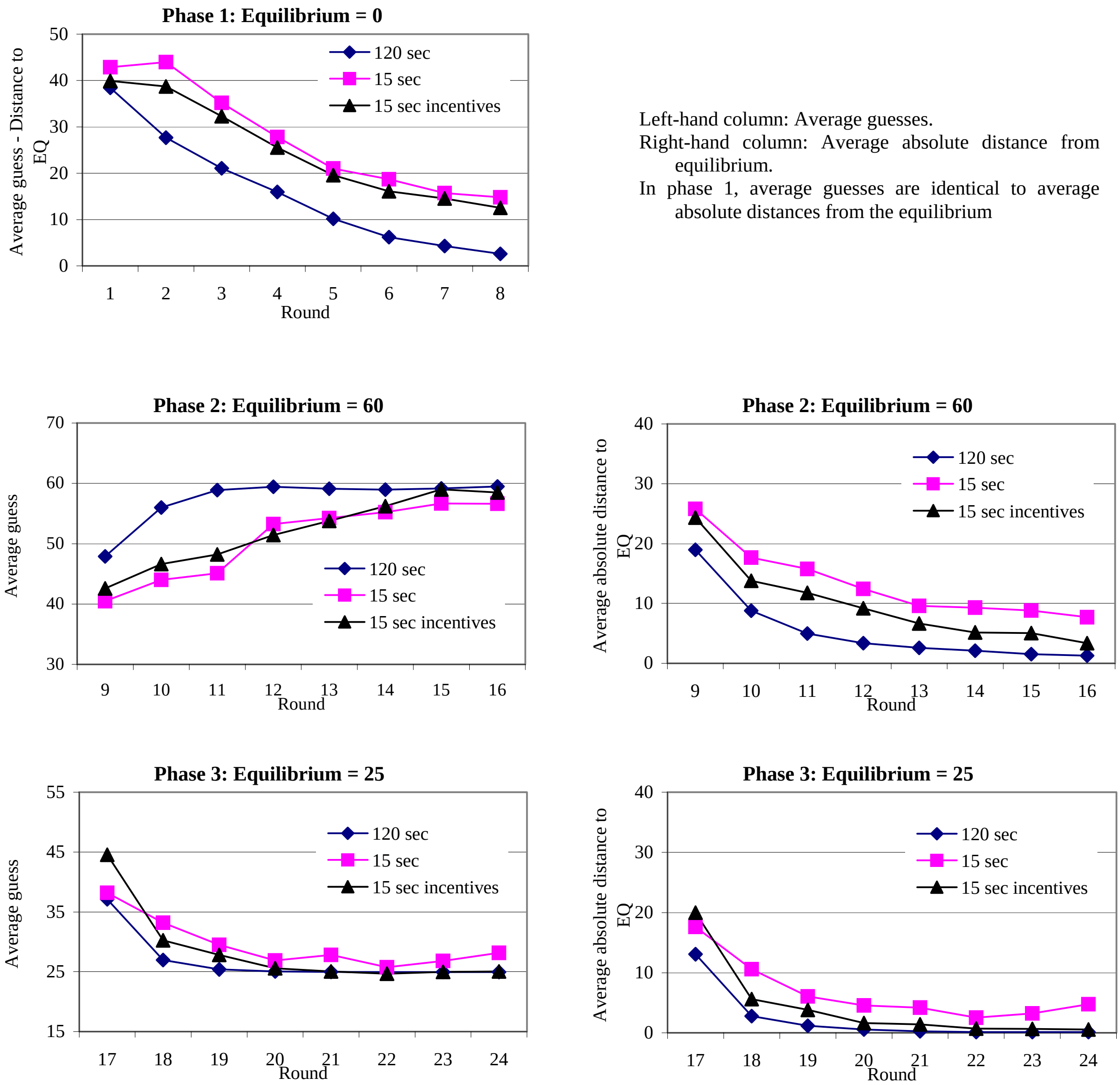
In the following subsections, we will have a closer look at round-by-round behavior in order to test our hypotheses at a more disaggregated level.

B. Results in single rounds

B.1. Quality of decision-making in game-theoretic terms

We start by analyzing results with respect to the convergence to the game-theoretic equilibrium. On the left-hand side of Figure 1 we present average guesses per round, whereas on the right-hand side the average absolute distance from the equilibrium is displayed. Note that in phase 1 the Nash equilibrium is zero and average guesses are identical to the average absolute distance from the equilibrium. However, in phases 2 and 3 with interior equilibria, the average absolute distance from the equilibrium may be different from the distance of average guesses from the equilibrium, because guesses can be too high or too low with respect to the equilibrium.

Figure 1: Average guesses and average absolute distance from equilibrium



Left-hand column: Average guesses.
Right-hand column: Average absolute distance from equilibrium.
In phase 1, average guesses are identical to average absolute distances from the equilibrium

From Figure 1 we can judge that, in general, the convergence to the equilibrium is rather smooth in all treatments. However, absolute distances to the equilibrium are always smallest in the ‘120 sec’ treatment, when compared to the treatments with a time limit of 15 seconds. The differences between the no time-pressure treatment and those with time pressure are significant for any single round at the 5%-level (two-sided U-test; $N = 24$ in pairwise comparisons). Exceptions to that results are rounds 1, 9, and 17, the first rounds in each phase, where guesses in ‘120 sec’ are not closer to the equilibrium than guesses in ’15 sec’. Comparing ‘120 sec’ and ’15 sec incentives’, the only exception is round 1. Comparing guesses in both time-pressure treatments, we find that in most rounds there are no significant differences between ’15 sec’ and ’15 sec incentives’. Only in rounds 18 to 22, guesses are closer to the equilibrium in ’15 sec incentives’ ($p < 0.05$; two-sided U-test; $N = 24$).

These results provide further evidence on the disaggregated round-level in favor of our hypotheses. Without time pressure, convergence to the equilibrium is significantly faster. Given time pressure, the introduction of a time-dependent incentive scheme has no significant effect on the quality of decision-making.

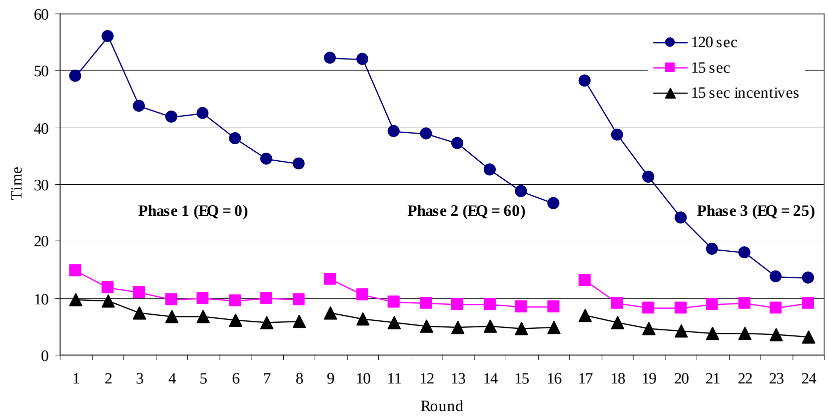
It is, finally, noteworthy that in the very first round of the experiment we can find no differences (neither in means nor in distribution) between any of our three treatments. Average guesses range from 38.4 (in ‘120 sec’) to 42.9 (in ’15 sec’). It has already been documented by Camerer (1997), Bosch-Domenech et al. (2002) or Kocher and Sutter (2004) that first-round behavior in the beauty-contest game is characterized by very similar patterns across very different subject pools and group sizes. Our results add another piece of evidence to that relatively robust finding.

B.2. Decision-making time

In Figure 2 we present average decision-making time in each round. It is significantly longer without time pressure (in ‘120 sec’) than with time pressure ($p < 0.05$ in any single round; two-sided U-test; $N = 96$). Only in the two very last rounds of the experiment (rounds 23 and 24), decision-making time in ‘120 sec’ is not significantly longer than in ’15 sec’ ($p > 0.1$). Note that only in these two final rounds average decision-making time in ‘120 sec’ is below 15 seconds, which is the time limit in our time-pressure treatments.

The introduction of a time-dependent incentive scheme in ’15 sec incentives’ leads in any single round to significantly shorter decision-making time than in the simple time-pressure treatment ’15 sec’ ($p < 0.05$ in any single round; two-sided U-test; $N = 96$). Hence, taking into account the evidence on decision-making quality, time pressure with profits contingent on decision time leads to faster decision-making without triggering worse decisions.[9]

Figure 2: Decision-making time



[9] It is rather noteworthy that the average decision-making time of female subjects is in all treatments shorter than the one of male subjects, however the difference is significant only in a few cases.

Looking at the development of decision-making time within phases, one can discern from Figure 2 that average decision-making times become almost always shorter. There is one striking exception. In round 2 of treatment ‘120 sec’, subjects take significantly more time to make their decision than in the first round ($p < 0.05$; Wilcoxon signed ranks test; $N = 48$). Corresponding to taking more time for deliberation is a steep decline in chosen numbers, as can be seen in the upper left panel of Figure 1. Hence, people seem to improve the quality of their decisions, based on the very important information feedback from the first round.[10]

B.3. Performance in terms of payoff

As a first approach to compare payoffs across treatments we disregard the time-dependent component of payoffs in the ’15 sec incentives’ treatment. Hence, we compare only payoffs according to equation [2] above. As can be expected from our results on the quality of decision-making, payoffs are in (almost) all rounds significantly higher without time pressure (in ‘120 sec’) than with time pressure ($p < 0.05$ in any round for pairwise comparisons; two-sided U-test; $N = 96$). The only exceptions are round 1, where payoffs in all treatments are insignificantly different from each other, and rounds 2, 9 and 10, where we find no difference between payoffs in ‘120 sec’ and ’15 sec incentives’.

Comparing payoffs according to equation [2] in our time-pressure treatments, we have evidence that payoffs are on average higher with the time-dependent incentive

[10] Recently, Weber (2003) has shown that even in the absence of feedback, subjects are able to learn in the beauty-contest game, although convergence to the equilibrium is of course much slower than with feedback information.

scheme, but the difference is significant only in a few rounds ($p < 0.05$ in rounds 4, 12, 16, and 19-23; two-sided U-test; $N = 96$).

If we take into account the time-dependent incentive scheme in ’15 sec incentives’, we find that final payoffs are highest in this treatment (with $p < 0.05$ in all rounds but rounds 1-4, 9 and 17 for pairwise comparisons; two-sided U-test; $N = 96$).

Two minor results concerning performance are, finally, noteworthy. First, without time pressure, 44 out of 48 subjects submit a decision in every round. This fraction of subjects is significantly larger than in the other two treatments with 35 out of 48 in ’15 sec incentives’ ($\chi^2 = 5.8$; $p < 0.05$; $df = 1$), and with only 25 out of 48 in the ’15 sec’-treatment ($\chi^2 = 18.6$; $p < 0.01$; $df = 1$). In total, only one subject submitted less than 20 out of 24 possible guesses and the vast majority of subjects (90.3%) submitted either 23 or 24 guesses.

Table 4: Frequency of making a loss

	Round								
Phase 1	1	2	3	4	5	6	7	8	*Sum*
‘120 sec’	15	6	2	-	-	-	-	-	*23*
’15 sec’	9	9	10	3	2	3	1	3	*40*
’15 sec incentives’	14	11	5	4	2	2	2	1	*41*
Phase 2									
‘120 sec’	12	3	1	-	-	-	-	-	*16*
’15 sec’	16	7	6	6	3	3	4	3	*48*
’15 sec incentives’	21	6	3	2	1	1	2	1	*37*
Phase 3									
‘120 sec’	6	-	-	-	-	-	-	-	*6*
’15 sec’	9	5	1	1	3	-	1	2	*22*
’15 sec incentives’	10	1	1	-	-	-	-	-	*12*

Second, our continuous payoff function of equation [2] yields losses for bad guesses which are more than 25 units away from a group's target number. Table 4 presents the frequency of losses in single rounds and single treatments. Not surprisingly, the frequency of losses is highest in the first round of any phase (when parameters are new). It can also clearly be seen that the frequency of losses is smallest in '120 sec' (45 out of 1152 guesses, i.e. 3.9%), and highest in '15 sec' (9.5%).

3. Conclusion

Time pressure is important in many economically relevant situations like trading on financial markets, investing work effort when compensation is determined by piece rate wages, bidding in an auction, or shopping when the number of items of a given product is limited or is perceived to be limited. Surprisingly, the effects of time pressure on economic decision-making have not been addressed properly in the economics literature so far, even though most economists would subscribe to the popular slogan 'time is money', implying that quicker decisions may imply higher profits. However, quicker decisions may also cost money by possibly reducing the quality of decisions. Evidence from psychological research on *individual* decision-making tasks suggests that a tight time constraint for decisions may impair the capacity for information processing or the consistency of decision-making, thus reducing decision-making quality (Förster et al., 2003).

It has been the purpose of this paper to investigate (i) whether time pressure has a negative effect on the quality of decision-making in an interactive context and, given an affirmative answer to the first question, (ii) whether time-dependent incentive schemes have an effect on decision-making under time pressure.

Both questions have been addressed in a laboratory experiment, in which we were able to control for the degree of time pressure and for the quality of decision-making easily. We have chosen a simple beauty-contest game as our vehicle of research, since it resembles very closely decision-making on financial markets where time pressure is a prevailing phenomenon.

Our results suggest that convergence to the game-theoretic equilibrium is faster and payoffs are higher with a very weak time constraint (practically no time pressure), compared to a situation where subjects face a rather tight time constraint of only 15 seconds to decide. Hence, time pressure has a negative effect on the quality of decisions and on subjects' performance.

Our time-dependent incentive scheme in case of time pressure induces significantly quicker decision-making and, on average, even improves the quality of decision-making instead of reducing it, even though the latter effect is not statistically significant. We suspect that the time-dependent incentive scheme induces a shift in the effort levels exerted by subjects that offsets the negative effect of the decrease in decision-making time on the decision's quality. The opportunity to gain considerably higher payoffs seems to trigger higher concentration or effort levels. Hence, our results suggest that if decisions have to be taken under severe time pressure, the use of time-dependent monetary incentives should be considered as an appropriate means to speed up decision-making significantly without generally deteriorating decision-making quality.

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APPENDIX: Instructions for treatment '15 sec incentives' (originally in German)[‡]

Welcome to the experiment und thank you for your participation.

Please do not talk to other participants from now on.

Instructions for the experiment

You are about to participate in an experimental study on decision-making. You can earn 'real' money, which will be paid to you privately and confidentially in cash right after the end of the experiment. After reading through the instructions you will have enough time to ask private questions. Make sure that you understand everything before we start the experiment.

3 phases with 8 rounds each

The experiment consists of three phases with 8 rounds in each phase. Therefore, we have 24 rounds in total. Within a phase your task remains unchanged. Between phases two parameters that will be explained in the following will change.

Your decision

You are member of a group of 4 people, and you remain anonymous within your group throughout and after the experiment. At the beginning of each round, each group member has to choose a number $\mathbf{x_i}$ from the interval zero (0) to one-hundred (100). Zero and one-hundred can also be chosen. Your number does not have to be an integer number, but it cannot have more than two digits after the comma.

Your pay-off in the experiment is dependent on the distance between your number and the target number in each round. The closer your number is to the target number, the higher is your pay-off.

Calculation of target number

In order to arrive at the target number the average of the 4 numbers $\mathbf{x_i}$ within your group will be calculated. Then, a constant **C** is added to the average.

The sum of the average and the constant is, then, multiplied by a factor **p**. The resulting number is the target number.

The target number can be expressed mathematically:

[‡] The instructions for the two other treatments are available upon request from the authors.

$$\text{Target number} = p \cdot \left(\frac{\sum_{i=1}^{4} x_i}{4} + C \right)$$

Changes between phases

In each phase the parameters **p** and **C** change. At the beginning of each phase you will be informed on the values of the parameters **p** and **C** (see screen for round 1). These values remain constant over all 8 rounds of a phase!

Pay-off

Your pay-off in each round is dependent on the absolute distance between the number you chose and the target number in your group. If you hit the target number exactly, you earn 1.00 €. Each absolute unit of distance results in a deduction of 4 Euro-Cent. If the distance from the target number is 25 or more, you make a loss in this round. The loss can, of course, be balanced with earnings in other rounds.

Formally, your pay-off is

$$\text{Pay off per round (in €)} = 1.00 - 0.04 \cdot \left| x_i - p \cdot \left(\frac{\sum_{j=1}^{4} x_j}{4} + C \right) \right|$$

Time-dependency of your pay-off

Additional to the dependency of your pay-off on the distance to the target number, your pay-off is time-dependent because there is a limit of time for making your decision and because faster decisions will lead to higher pay-offs (keeping constant the distance from the target number).

The time limit for making a decision is as follows:

1st round: In the first round of each phase you have 20 seconds to decide.

2nd – 8th round: For the decisions in these rounds you have 15 seconds each to decide.

Your pay-off in each round (see the formula) will then be multiplied by a factor which is time-dependent (see Table 1).

Table 1

	decision entered in second…										
round 1	1 – 10s	11s	12s	13s	14s	15s	16s	17s	18s	19s	20s
rounds 2 - 8	1 – 5s	6s	7s	8s	9s	10s	11s	12s	13s	14s	15s
factor	*1,8*	*1,64*	*1,48*	*1,32*	*1,16*	*1*	*0,84*	*0,68*	*0,52*	*0,36*	*0,2*

Exceeding the time limit

If you exceed the time limit of a single round, you are not able to enter a number. In this round, you will earn nothing (0 €). The average within your group will then be calculated from the remaining decisions within the group. Of course, you can then participate in the next round without any restrictions.

Summary

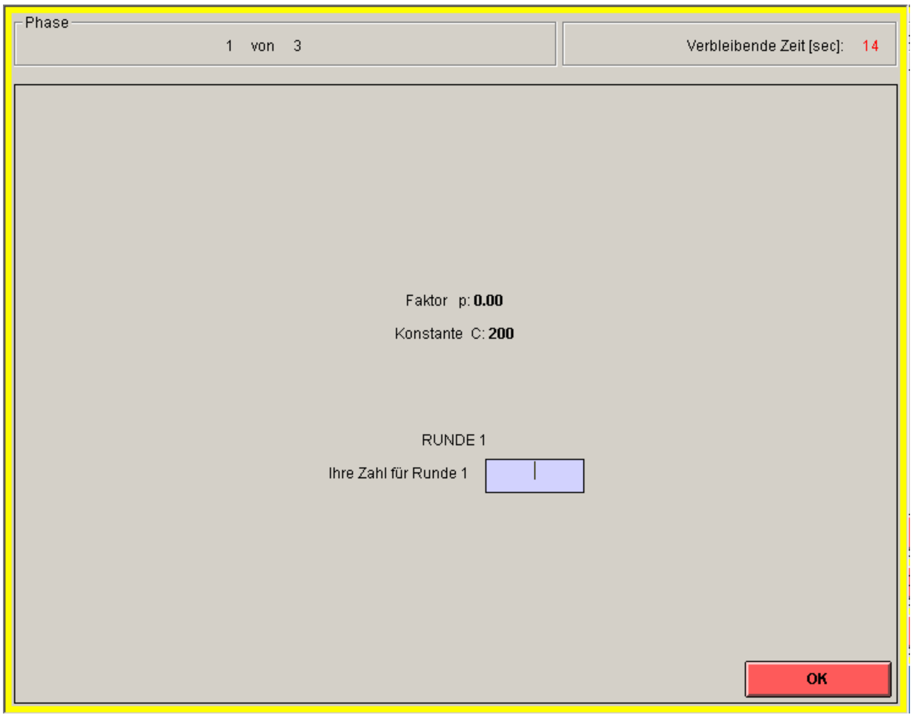
You have to choose a number which is as near as possible to the target number. The faster you decide and the closer you are to the target number, the higher is your pay-off. We ask you not to talk and to remain concentrated during the experiment.

Means of help

At your place you find a pen and a calculator. Please do not take them with you after the experiment.

Computer screens

In the first round of each phase you get the necessary information on **p** and **C** on the screen. Then you have to enter your decision. The cursor is already in the field, in which you have to type in your number. Then, you have to confirm your decision with a mouse click on the OK-field. On the upper right-hand part of the screen you can see the remaining time (counting down to zero).



From the second round on you see the values for **p** and **C** in the upper part of your screen in order to remind you on the valid parameters. Below you find the results for the previous round: your chosen number, the average of all number in your group, the target number and your pay-off from the previous round. Directly below that you have to type in your decision for the current round. Do not forget to confirm with OK.