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TIME PRESSURE EFFECTS ON DECISION MAKING IN A DYNAMIC TASK ENVIRONMENT

08

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SUMMARY

The present experiment investigates time pressure effects on both the quality of task performance and the underlying cognitive processes. The task that was used is dynamic in nature, such that the environment changes over time both autonomically and as a result of actions taken by the decision maker. Twenty subjects were required to monitor the fitness level of an athlete, that continually changed over time, and to recover the athlete whenever fitness decline had a physiological cause. Their major decision problem was to trade-off the costs of requesting information and applying treatments on the one hand, and increasing chances on a serious consequence on the other. The results showed that time pressure drastically declined task performance under severe time pressure, which was majorly caused by reacting too late to declines in fitness level. Subjects requested the smallest number of information under moderate time pressure. Time pressure had no significant effect on the speed of information processing.

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Het effect van tijdsdruk op beslissingsgedrag in een dynamische taaksituatie

J.H. Kerstholt

SAMENVATTING

In een experiment werd het effect van tijdsdruk onderzocht op zowel de kwaliteit van de taakprestaties als de onderliggende cognitieve processen. Een dynamische taak werd gebruikt, hetgeen betekent dat over de tijd de omgeving zowel autonoom als door acties van de beslisser verandert. Twintig proefpersonen zagen op een beeldscherm het steeds veranderende conditieniveau van een atleet en moesten het conditieniveau herstellen indien een teruggang een fysiologische oorzaak had. Hun belangrijkste beslissingsprobleem was de afweging tussen enerzijds de kosten van het opvragen van informatie en het behandelen van de atleet en anderzijds de toenemende kans op een negatieve consequentie. Uit de resultaten blijkt dat onder een lichte vorm van tijdsdruk de taakprestaties niet verminderen. Hoge tijdsdruk daarentegen had een negatief effect op de taakprestaties. Dit wordt met name veroorzaakt doordat men te laat reageerde op een teruggang in het conditieniveau. De kleinste hoeveelheid informatie werd opgevraagd onder een lichte vorm van tijdsdruk. De snelheid van informatieverwerking werd niet door tijdsdruk beïnvloed.

1 INTRODUCTION

Time pressure effects on decision making are a common experience. Traffic lights are for example ignored in order to catch a plane or the intended quality of a plan is reduced on approaching a deadline. It is generally assumed that time pressure has a detrimental effect on performance levels. However, despite the acknowledgement of its potential consequences, time pressure effects have received rather limited attention in empirical research.

1.1 Empirical findings on time pressure

To date, research has focused on two mechanisms that people use to adapt to time-pressured situations: acceleration and filtration. Acceleration refers to increases in speed of information processing. Under low amounts of time pressure people may remain doing the same thing but at a faster rate (Ben Zur & Breznitz, 1981; Maule & Mackie, 1990; Payne, Bettman & Johnson, 1988). Filtration, on the other hand, refers to the selective processing of only a subpart of the available information. It has for example been suggested that under time pressure people focus on information that helps them to avoid extremely negative consequences (Ben Zur & Breznitz, 1981; Svenson, Edland & Slovic, 1990; Wright, 1974). Furthermore, people may employ completely different decision strategies under time pressure. Several studies have observed that deadlines caused subjects to switch from compensatory strategies to noncompensatory strategies (Svenson, Edland & Slovic, 1990; Zakay, 1985). Compensatory rules are characterized by a consideration of trade-offs: low values on one attribute may be compensated by a high value on another attribute. This means that in order to employ this rule all relevant information is needed for each alternative. Noncompensatory rules on the other hand, are characterized by an interactive use of information. Whether options are retained or eliminated depends on the correspondence between an attribute value and some criterion.

1.2 Accuracy versus efficiency

Kienan, Friedland and Ben-Porath (1987) note that the effects of time limits may often be ascribed to the fact that it is physically impossible to invest sufficient time. In this regard, it seems appropriate to differentiate between decision *accuracy* and decision *efficiency*. Accuracy, the relationship between actual performance and some optimal standard, is generally found to decrease under time pressure (Zakay & Wooler, 1984). However, in order to attain optimal performance one mostly had to judge all relevant information which may not have been possible given the time constraints. Efficiency can be described as the quality of task performance given the time available to the decision maker.
Payne, Bettman and Johnson (1988) simulated the employment of several strategies under time limits and registered the accuracy of the outcome and the

invested effort. These simulations indicated that simplifying, noncompensatory decision rules are often superior to compensatory decision rules under time constraints (Payne, Bettman & Johnson, 1988). Since noncompensatory rules process at least some information for all alternatives early in the decision making process they are "further ahead" when time runs out. Payne et al. (1988) also compared subjects' performance under time constraints with the outcome of the simulation studies. These results showed that the subjects selected to a large extent the decision strategies that were prescribed as most efficient by the simulation. They adaptively reacted to a time-pressured environment by efficiently incorporating choice accuracy and required effort in the decision making process (Christensen-Szalanski, 1980; Smith, Mitchell & Beach, 1982; Payne et al., 1988). Therefore, even though accuracy decreases under time pressure, the available resources may be employed optimally, resulting in efficient task performance. An important implication for the understanding of time pressure effects is that deteriorated decision quality cannot directly be ascribed to a stress reaction. In order to differentiate between an adaptive reaction to a physical constraint and an unadaptive stress reaction, one should define the most efficient task performance within the constraints of time. Another possibility, which is applied in the present experiment, is to construct a task environment that allows subjects to attain the task requirements by an adaptive reaction to time pressure.

1.3 Static versus dynamic task environments

Existing experimental studies on time pressure all investigated decision making in a static task environment. Subjects are typically required to make a choice between several alternatives that have different values on a number of attributes. A dynamic task on the other hand, is characterized by an environment that changes both autonomously and as a result of actions taken by the decision maker. These dynamic tasks are therefore representative of a different class of decision problems in the real world, such as process control or patient treatment. Cognitive mechanisms may differ in functionality in static versus dynamic environments and the findings that were observed within the static task paradigms need not generalize to dynamic situations (Hogarth, 1981).
An important characteristic of a dynamic environment is the opportunity to observe the influence of executed actions, which elaborates the set of decision strategies. A decision maker may execute a certain action, observe its effect on the environment, and alter or adjust actions until the desired state is realised. Compared with the typical "first diagnose than act" strategy, this strategy may indeed result in superior performance (Kleinmuntz & Thomas, 1987).

1.4 Externally and internally defined time pressure

The distinction between static and dynamic environments may also assign a different meaning to the concept of time pressure itself. In a static environment time pressure is always defined externally. Subjects see some kind of time indication and are required to make a choice within a predefined time span. In a dynamic environment on the other hand, time pressure may be internally defined by the evolving situation, meaning that (the prospects of) negative consequences build up with time passing. Delaying a response to a fire alarm for example, will also increase the possibility of being caught by the fire. On the other hand, it is often sensible to make a correct diagnosis of the actual situation first, in order to avoid the detrimental effects of an action. After a fire alarm, people usually do not immediately jump out of a building, but instead try to find the best action given the risks and seriousness of the actual situation. Therefore, in a dynamic task environment there may be considerable strain between avoidance of progressive negative consequences and need for information to make a good judgement of the risks involved in the actual situation.

1.5 Moment of interference

In contrast with static environments dynamic situations offer the possibility to interfere with the environment at different moments in time. On the assumption that a false alarm was given one may refrain from action until further information on potential threats arrives. In a critical situation on the other hand, one may unceasingly update knowledge on the state of the system in order to be in time for action. Such decisions are evidently only meaningful in changing environments.

1.6 The present task environment

In order to investigate time pressure effects on decision making behaviour in a dynamic environment the following task was designed. Subjects are required to control the changing condition of an athlete, which is graphically presented to them on a computer screen. Some declines in the athlete's condition have a physiological cause and some declines are random fluctuations from which the athlete will spontaneously recover. Subjects can request information on all physiological parameters and restore the athlete's condition level by applying a treatment whenever the decline has a physiological reason. Each time information is requested or a treatment is applied the athlete is out of the race. Thus, subjects have to make trade-offs between the costs of information and treatments (time) versus increasing likelihood of a negative consequence (athlete collapses at a condition level of zero). Time pressure is defined internally by the rate at which the athlete's condition declines.
Of major interest in the present experiment were the effects of time pressure on speed of information processing (acceleration), amount of requested information (filtration) and moment of interference (either for requesting information or for applying a treatment).

2 METHOD

2.1 Subjects

20 students of the University of Utrecht participated in the experiment. Their mean age was 21 years (σ = 1.4). They were paid Dfl.40,- for their participation.

2.2 Stimulus material

A computer program graphically depicts the fitness of an imaginary athlete who is running a race. The fitness value can vary between 100 (optimal fitness) and 0 (the athlete collapses and the trial ends). Figure 1 gives an example of a computer screen depicting the athlete's condition in one of its windows.

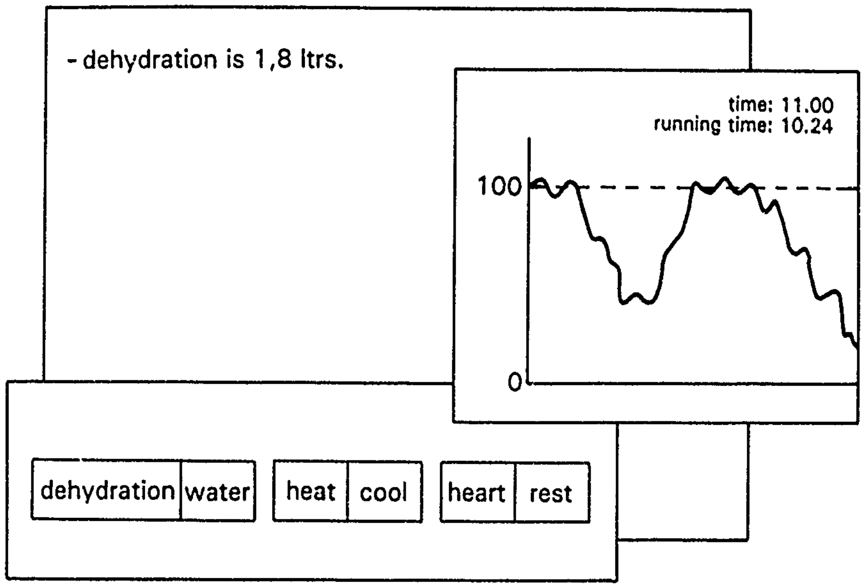

Fig. 1 Example of a computer screen showing the graphical representation of the athlete's condition, choice options for information and treatments and requested information.

Four reasons may cause the athlete's fitness to deteriorate: three "physiological" causes, which are dehydration, overheating and cardiac overload, and one unknown "natural" cause from which the athlete will recover spontaneously. The decline of each parameter at a certain point in time is defined by a linear function of the form: $Y=aX+b$. Therefore, without intervention of the subject the athlete will collapse as a result of the on-set of some physiological disturbance. In each trial the slope, indicating the deterioration of the fitness level per second, remains constant. However, over trials the slope may differ, which defines the time pressure condition (see Fig. 2 for an illustration).

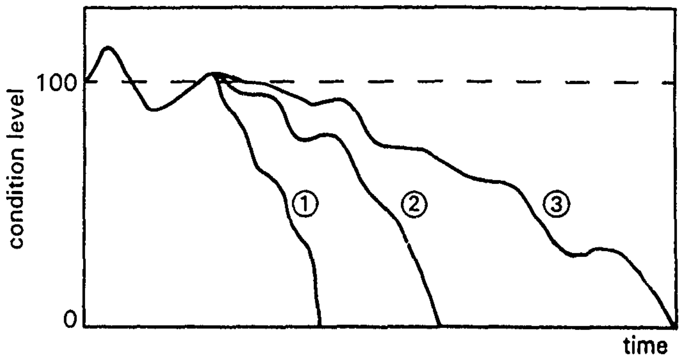

Fig. 2 Illustration of condition decline in three time pressure conditions: 1: slope=-2, 2: slope=-1, 3: slope=-0.5.

The subject sees only one function depicting the condition level of the athlete over time. The condition function is constructed from the four separate functions that specify the condition declines for each parameter, with the addition of some random noise.
If a decline is of a physiological nature, the subject can recover the athlete by giving the appropriate treatment, i.e. water for dehydration, rest for cardiac overload and cooling for overheating. If the athlete is not recovered to the maximum level the constant parameter b is lowered. The effects are therefore additive, but the on-sets of each event are separated far enough in time to allow the subjects to fully recover the athlete.
Unless the athlete collapses, she will run for a fixed amount of time, which is approximately half an hour.

2.3 Procedure

The subject is instructed to monitor the fitness of an athlete who is running a race and to avoid the athlete to collapse (i.e. to reach a fitness level of zero). To attain this goal the subject can request information and apply treatments.
Information can be requested on the state of the athlete's dehydration, her temperature or her heart rate. After the nature of the information is selected the subjects are asked whether they want subjective information, objective-general information or exact information. Subjective information is a response of the athlete indicating whether she is thirsty, warm or has an accelerated heart rate. The athlete will give this response when fitness level declines below 60 (on a scale of 0 to 100). In order to get the objective-general information type we added a noise-factor to the exact value (normally distributed with a standard deviation of 10%). The exact information type gives the exact value of the physiological parameter. In selecting one of these information types subjects have to make trade-offs between the reliability of information and the time to

get the information (2, 3 and 4 seconds respectively). The athlete is out of the race during retrieval of this information.
In addition, subjects can apply the following treatments: give water, rest or cool. Only one treatment is suitable for each possible physiological state; water for dehydration, rest for cardiac overload and cooling for overheating. After a treatment is selected the subjects are prompted to specify the time period the athlete should rest or cool or the amount of water that has to be given to the athlete. During the time a treatment is applied the athlete is out of the race.
In order to motivate the subjects to stop the athlete for the shortest possible time we informed them that a bonus (Dfl.50,-) would be given to the subject with the most efficient task performance (least time spent on information and treatments). They were told to take care that the athlete did not collapse, since that would end the trial block and consequently reduce the chance to win the bonus.
Subjects start with a training session that allows them to get acquainted with the physical task environment and to develop strategies to cope with time pressure. Both the training session and the experimental session lasted approximately two hours.

2.4 **Design**

There are three time pressure conditions expressed by the slopes of the functions $Y=aX+b$: low time pressure ($a=-0.5$), moderate time pressure ($a=-1$), and high time pressure ($a=-2$). Each subject supervised one athlete in each time pressure condition. A run of one athlete (one trial block) consists of 4 trials (a decline caused by a physiological parameter) and 8 dummy trials in each time pressure condition. Dummy trials were "natural" declines from which the athlete would recover spontaneously.

3 RESULTS

We will first indicate the effect of time pressure on the quality of decision making and then explore its influence on the selection of information, acceleration and moment of intervention.
The subjects were required to monitor an athlete running a race and to avoid the athlete's collapse (fitness level 0). This means that they had to apply a treatment in time, before the condition level reaches 0, and to select the correct treatment. The top part of Table I shows the number of trials that were accurately dealt with in each time pressure condition, meaning that a correct treatment was applied before the bottom-line was reached. Note that each trial block consisted of a maximum of 4 trials, but that a trial block would end as soon as a fitness level of 0 was reached. The bottom part of Table I shows the proportion correct treatments.

Table I Mean number of trials accurately dealt with in each time pressure condition (maximum=4), and the proportions correct treatments.

time pressure	low	moderate	high
mean number of trials	3.75	3.40	1.70
proportion correct treatments	0.91	0.96	0.91

Statistically, the number of trials that were correctly dealt with significantly differed between time pressure conditions ($\chi^2(4)=24.69$; $p<0.0001$). As can be seen from the means in Table I performance clearly declines between the moderate time pressure condition (MOD TP) and the high time pressure condition (HIGH TP). The difference between low time pressure (LOW TP) and MOD TP is only marginal.
Even though the proportions correct treatments were overall quite high, they significantly differed between time pressure conditions ($\chi^2(4)=10.4$; $p<0.05$). Contrary to what we expected the best performance was observed under MOD TP. Under both LOW and HIGH TP the subjects applied relatively more incorrect treatments.

We will next turn to the effects of time pressure on the selection of information, acceleration and moment of intervention.
Table II presents the number of times the subject requested information in each time pressure condition. Whenever the athlete's condition declined for a physiological reason, subjects would end information search as soon as the underlying cause was known. We therefore only present the mean number of information requests for the dummy trials (a "random" decline from which the athlete would recover spontaneously).

Table II Mean number of information requests (total number of information requests divided by the total number of dummy trials) in each time pressure condition.

time pressure	low	moderate	high
mean number of requests	3.09	2.07	2.30

Subjects kept the athlete in the race for varying amounts of time, and consequently faced a different number of dummy trials. For this reason we calculated the mean number of information requests, i.e. the total number of information requests over dummy trials divided by the number of dummy trials.
The mean number of requests significantly varied between time pressure conditions (Friedman test statistic=6.28; $p<0.05$). Subjects requested the greatest number of information in the LOW TP condition and the smallest number of information in the MOD TP condition.
In addition to a selective request of information subjects could have used qualitatively different information in the various time pressure conditions. After they had indicated on which physiological parameter they wanted to be informed, they were prompted to specify which type of information was required: subjective, objective-general and exact information. These information types varied on reliability and retrieval time. Subjects mostly preferred objective-general information (Table III). However, the proportions of this type of information did not vary across time pressure levels ($\chi^2(2)<1$).

Table III Proportion of requested information that was of an "subjective", "objective-general", and "exact" nature for each time pressure condition.

time pressure	low	moderate	high
subjective	0.22	0.20	0.24
objective-general	0.73	0.77	0.72
exact	0.05	0.03	0.04

The second mechanism that subjects might use to adapt to a time pressured situation is to increase speed of information processing. An indication of processing speed would be the difference between the moment the subjects received information and the moment they applied a treatment. In this time span subjects made a conclusion on the underlying cause of the decline in fitness level, selected a treatment and calculated its dose. The mean times are given in Table IV for each time pressure condition.

Table IV Mean times (in seconds) that subjects needed to apply a treatment after the relevant information had appeared on the screen for each time pressure condition.

time pressure	low	moderate	high
mean treatment decision time	9.72	8.33	8.72

No significant effect was found over time pressure conditions [$F(2,26)=1.48$; $p>0.1$]. Thus, the results do not support the idea that information processing speeds up with increases in time pressure.

The last mechanism that people can use to adapt to time pressure is to intervene sooner. Requesting information at higher fitness levels implies that more time is available for diagnosis and treatment. Figure 3 shows the mean fitness level of the athlete at which the subject decided to request information and the fitness level at which a treatment was applied in the different time pressure conditions.

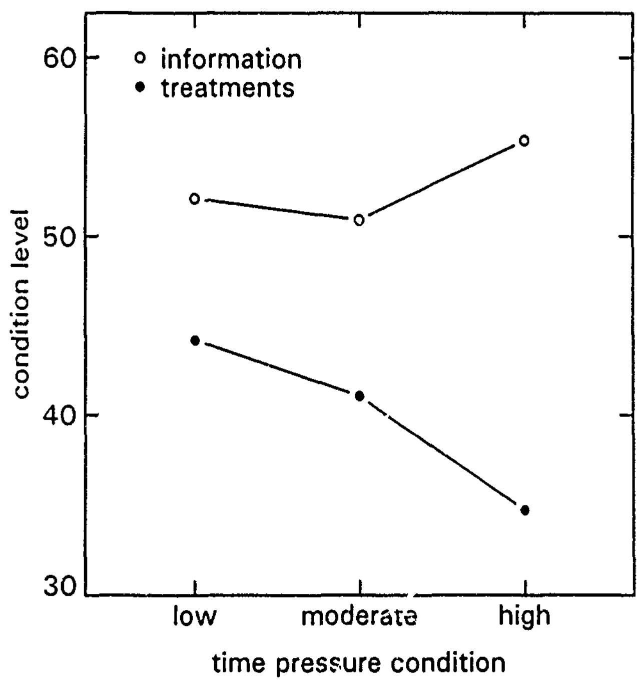

Fig. 3 Mean fitness level of the athlete at which the subjects requested information and applied a treatment for each time pressure condition.

The differences in fitness levels for the request of information were only marginally significant over time pressure conditions [$F(2,38)=2.85$; $p=0.07$]. As can be seen from the figure subjects decided to request information at a higher fitness level under HIGH TP as compared to MOD TP. The fitness level at which a treatment was applied varied over time pressure conditions [$F(2,26)=3.28$; $p=0.05$]. When time pressure increases subjects gradually apply a treatment at lower fitness levels.

A specific feature of this dynamic situation is the dependence between various treatments. If a physiological event happened, say dehydration, and the subject did not recover the athlete to 100%, a lowered base-line fitness level remained. In Table V we indicate the amount of treatment that was applied in each time pressure condition. As a reference, a score of 1 means that the exact treatment dose was given to recover the athlete to a fitness level of 100%. A score less than 1 means that the fitness level stabilizes below the maximum level and a score higher than 1 indicates that more treatment is given than necessary.

Table V Relative amount of treatment given to the athlete for each time pressure condition.

time pressure	low	moderate	high
level of restore	0.95	0.89	0.73

Even though the means suggest a lowered treatment dose over time pressure conditions, analysis of variance showed that this effect is only marginally significant [$F(2,26)=2.26$; $p=0.1$].

4 DISCUSSION

The present experiment clearly shows the detrimental effects of time pressure on the quality of decision performance. The task required subjects to monitor an athlete for a fixed amount of time and to apply a treatment as soon as her fitness level declined for some physiological reason. However, obviously not all subjects were able to adapt effectively to the requirements of the task, which resulted in inferior performance under severe time pressure.

A popular framework describes human decision making behaviour as an optimization process between costs and benefits (Christensen-Szalanski, 1980; Smith, Mitchell & Beach, 1982; Russo & Dosher, 1983). Explicit empirical support for this framework comes from Payne, Bettman and Johnson (1988), who demonstrated that subjects rather effectively integrated the effort that is required to utilise a decision rule and the accuracy of the resulting choice. Under high time pressure subjects increased their speed of information processing and

employed different strategies, such that a relatively accurate performance could be maintained.
In the present task the subjects had to make a trade-off between the costs of requesting information and the benefits of making a diagnosis at an early point in time. A straightforward reaction to time pressure would be to request information at an early point in time, i.e. after only small declines in condition level. This would allow more time to diagnose correctly within the time limit (benefits) but at the expense of requesting more information (costs). Information costs would increase because subjects are less able to discriminate between the "spontaneous" and the "physiologically driven" declines and consequently request more information not contributing to a diagnosis.

The results show that even though the fitness level at which the subjects requested information was marginally significant over time pressure conditions, it only increased from 50.9 under moderate to 55.4 under severe time pressure. Yet, at a fitness level of 50 in the severe time pressure condition, only 25 seconds remain until the bottom line is reached, which is half as much as in the medium time pressure condition. This suggests that the major cause for the decline in performance under severe time pressure was due to the rather fixed moment of interference. Subjects traded-off the costs and benefits inefficiently which can be viewed as a failure to adapt to the time-pressured situation. In the following we will discuss three possible explanations for this result: more risks are taken, the available time is underestimated and the condition level is lowered over trials.

The first possible explanation is that subjects are willing to take more risks in order to keep costs of information low. They may wait as long as possible in order to avoid requesting information in dummy trials, at the expense of increased chances on athlete collapse.
A second explanation is that under severe time pressure subjects underestimate the time till the moment of collapse. The underestimation of the available time could be due to over-valuing the compensatory effects of increasing their speed of information processing, which was shown in previous research to be a response to time-pressure (Ben Zur & Breznitz, 1981; Maule & Mackie, 1990; Payne, Bettman & Johnson, 1988). However, even though the results suggested an increase in information processing speed under moderate time pressure this effect was not statistically significant. On the other hand, even though processing speed remained constant, the decision quality deteriorated under severe time pressure, such that less correct treatments were applied and the treatment doses were less precisely calculated. This suggests that under severe time pressure subjects maintained a constant speed at the expense of more errors.
A third explanation for requesting information at the same fitness level in each time pressure condition relates to the finding that recovery levels were below 100% under severe time pressure. If the athlete is not fully recovered the condition level would stabilize at a lower condition level, depending on the treatment dose, and each succeeding decline in condition level would

consequently start from a lowered condition level. Therefore, even if subjects had requested information soon after the onset of the decline, the mean condition level would have been low because of the reduced base-line level.

In line with previous findings subjects requested less information when time pressure increased (Svenson, Edland and Slovic, 1990; Zakay, 1985). However, even though the smallest number of information requests were made under moderate time pressure, task performance remained rather accurate as compared with the low time pressure condition. Almost all trials were accurately dealt with and the proportion correct treatments was even higher, which suggests that subjects performed more efficiently under moderate time pressure than under low time pressure. Under high time pressure subjects requested more information than under moderate time pressure, but at the same time performance drastically declined. This shows that the number of information requests cannot account for the performance decline under high time pressure.
In contrast with previous studies on time pressure effects the present task was dynamic in nature. Furthermore, our subjects needed one specific information unit to make a correct diagnosis, whereas in the other tasks information could be evaluated as more or less important or as redundant, or subjects could lower the goal they wished to attain (satisficing). More research is needed to investigate the differential effects of dynamic tasks and the nature of the available information on the request of information.

To conclude, the present task provides good opportunities to explore time pressure effects on decision making behaviour. The dynamic task environment that was used is representative of a different class of decision problems in the real world than the static tasks that were used in most previous research, such as for example process control. A distinctive feature of a dynamic environment is the possibility to observe the changing state of a system constantly and to interfere with the system at various state levels. The results of the present experiment suggest that in such a dynamic task the quality of decision performance mostly declines as a result of an inefficient trade-off between the costs of information and the benefit of increasing time to make a correct diagnosis.

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The present experiment investigates time pressure effects on both the quality of task performance and the underlying cognitive processes. The task that was used is dynamic in nature, such that the environment changes over time both autonomically and as a result of actions taken by the decision maker. Twenty subjects were required to monitor the fitness level of an athlete, that continually changed over time, and to recover the athlete whenever fitness decline had a physiological cause. Their major decision problem was to trade-off the costs of requesting information and applying treatments on the one hand, and increasing chances on a serious consequence on the other. The results showed that time pressure drastically declined task performance under severe time pressure, which was majorly caused by reacting too late to declines in fitness level. Subjects requested the smallest number of information under moderate time pressure. Time pressure had no significant effect on the speed of information processing. 25 * Cognition,

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