

EFFECTS OF HEAT STRESS AND PHYSICAL EXERTION
ON SIMPLE AND CHOICE REACTION TIME¹

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INTRODUCTION

The effects of heat stress on performance have been mainly studied in the industrial and military contexts (Hancock, 1986; Parsons, 1993; Yaglou & Minard, 1957). Few studies have specifically focused on the problems of heat stress in sports, especially in the cognitive domain. Nevertheless, climate could represent a major stressor in many sports events, especially for outdoor activities.

Sports situations are characterized by simultaneous high demands on the physiological and cognitive resources of the individual. Generally the effects of stressors on each system of resources have been studied separately. As physiological and cognitive processes appear to have important mutual influences (Tomporowski & Ellis, 1986), a more comprehensive approach seems necessary.

The effects of exercise on cognitive processes have been mainly approached, in recent years, through the study of reaction time tasks (Delignières, Brisswalter & Legros, 1994; Legros, Delignières, Durand & Brisswalter, 1992; Paas & Adam, 1991). These studies have shown that exercise led to a decrement of simple reaction time, but to an enhancement of choice reaction time, especially with collective and combat sports experts. These contrasting effects seemed related to a complex interaction between a specific influence of exercise on some cognitive processes (Arcellin, Delignières & Brisswalter, this volume), and a mental effort mobilization under exertion (Delignières, Brisswalter & Legros, 1994).

Several hypotheses have been proposed to explain the detrimental effects of heat stress on cognitive processes. According to Hancock (1986), the influence of a dynamic change of body core temperature is determinant, and could explain most of the experimental results. On the other hand, some authors have emphasized the influence of subjective thermal discomfort (Allnut & Allan, 1973; Epstein *et al.*, 1980).

¹ This experiment had been performed at the National Institute for Sport and Physical Education, Paris, where both authors were working. We thank the French Federation of American Football for its help in this experiment.

The specific effects of heat stress on physiological processes have been widely studied (for a review, see Karvonen, 1992). It has been shown that high ambient temperature increased the physiological reactions to exertion (Powers & Howley, 1985). In a preliminary study, we have observed that the realization of a pedalling task corresponding to 50% of the maximal aerobic power (MAP) at 20°C, led at 38°C to physiological reactions corresponding to 80% of the MAP.

The aim of the present experiment was to analyze the combined influences of heat stress and exertion on cognitive processes.

METHOD

8 male subjects (mean age: 18.2, SD: 1.5) were involved in this experiment. They were all members of the French Federation of American Football.

A climatic chamber was used, which allowed to control ambient temperature and relative humidity. The subjects were submitted to two conditions: (1) 20°C E.T.² (23°C dry temperature, 50% relative humidity) and (2) 38°C E.T. (42°C dry temperature, 70% relative humidity). Air velocity was negligible. In each condition the subjects were submitted to the climate during 30 minutes before the beginning of the experiment.

The pedalling task was performed on an *Ergomeca* cycloergometer. To provide subjects with feedback regarding pedalling rate, a screen displaying the number of revolutions per minute was positioned in front of them. The experimental device could be adapted to the morphology of each subject, in the aim of a maximal standardization of the test.

Reaction time tasks were performed on a computer, connected to two joysticks, mounted on the ergometer handlebar. The subject placed his forearms on special supports on the handlebar (Figure 1). Subjects had to respond to the highlighting of squares drawn on the screen. Two conditions were used (simple reaction time and four-choice reaction time). In the first condition subjects had to respond by tilting the right joystick to the left. For the choice reaction time, four squares were horizontally aligned on the screen. The subjects responded to the two left signals by tilting the left joystick to the left or to the right, and conversely for the two right signals with the right joystick. There was no preparation signal: each stimulus

² Effective temperature (E.T.) was proposed by Houghten et Yagloglou (1923) for assessing heat stress. It combined in a global index dry temperature, relative humidity and air velocity.

appeared 1100 ms after the preceding response. Response time and errors were recorded by the computer.

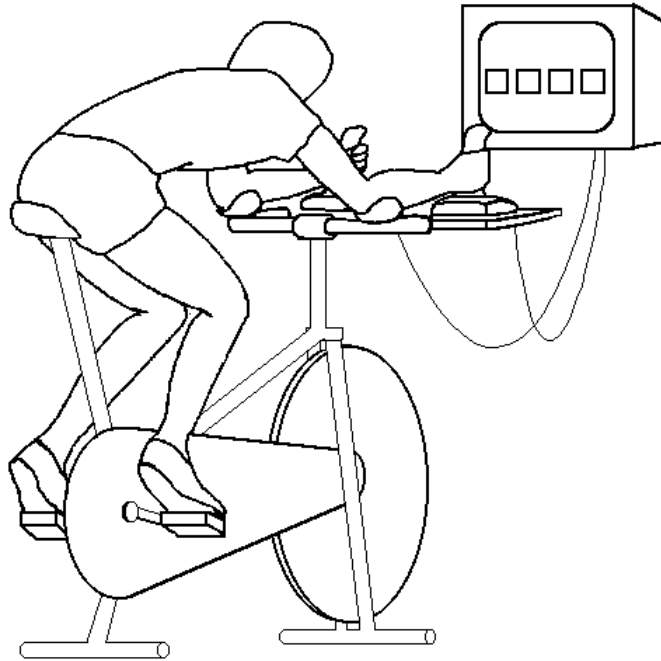


Fig. N°1: Experimental Device.

The protocol was divided into three sessions, distributed among different days. During the first session the individual maximal aerobic power (MAP) of each subject was assessed, according to a triangular protocol derived from those described by Patton, Vogel and Mello (1982). Pedalling frequency was held constant at 75 rev.min⁻¹. The load was progressively increased by 0.5 kg (37.5 watts) each minutes. The first step was performed at 37.5 watts. The highest load entirely performed for a minute allowed an estimation of the maximal aerobic power. During this first session the subjects performed for familiarisation 3 blocks of 20 trials on each RT tasks.

During session 2, with an effective temperature of 20°C, subjects performed RT tasks (1) at rest, (2) concurrently with the pedalling task at 50% of their individual MAP, and (3) concurrently with the pedalling task at 80% of their individual MAP. The pedalling frequency was fixed at 60 rev.min⁻¹. RT tasks were performed from the second minute of exertion, after the subject have reach a physiological steady state.

During session 3, with an effective temperature of 38°C, subjects performed RT task concurrently with the pedalling task at 50% of their individual MAP. The order of the sessions 2 and 3, and within each session, the order of the two RT tasks were systematically varied between subjects. The three sessions took place at the same time of the day, of each subject.

Heart rate was recorded continuously, and oral temperature was measured at the entry in the climate chamber, and at the beginning of each RT test. Finally, an assessment of subjective thermal comfort was requested at the end of session 3. Subjects had to rate their feeling of discomfort according to a 15-point category scale, labelled from "extremely comfortable" to "absolutely unbearable".

RESULTS

Oral temperatures are reported in table 1. Data were submitted to a one-way analysis of variance, with 6 level of repeated measurement. This analysis revealed a significant main effect of experimental conditions on oral temperature ($F_{5,35}=27.74$, $p<.001$). Post-hoc analysis indicated that oral temperature did not vary within the 20°C condition, and was equivalent at the entry in the climate chamber in the 38°C. After 30 minutes of exposure to heat stress, a significant raise in oral temperature was observed, but there was no difference between oral temperature at rest and under exertion.

TABLE 1: Mean Oral Temperatures.

20°C E.T.			38°C E.T.		
Rest	50% MAP	80% MAP	Entry	Rest	50% MAP
37.10	36.85	37.07	36.95	38.13	38.27
(0.31)	(0.43)	(0.48)	(0.65)	(0.50)	(0.67)

Note: Data were obtained at the beginning of each RT test, and at the entry in the climate chamber for the 38°C condition (standard deviation in brackets)

Heart rate data are reported in table 2. Data were submitted to a one-way analysis of variance, with 5 levels of repeated measurement. This analysis revealed a significant main effect of experimental conditions ($F_{4,28}=67.07$, $p<.001$). Post-hoc analyses showed that there

was no difference at rest in heart rate between the two climate conditions. At 20°C, there was a significant difference between rest and 50% MAP, and a significant difference between 50% MAP and 80% MAP. For an exertion of 50% MAP, heart rate was significantly higher at 38°C than an 20°C. But there was no difference in heart rate between 50% MAP at 20°C and 80% MAP at 38°C.

TABLE 2: Mean Heart Rate (Standard Deviation in Brackets).

20°C E.T.			38°C E.T.	
Rest	50% MAP	80% MAP	Rest	50% MAP
87.19	163.94	172.75	86.50	172.13
(23.14)	(17.25)	(21.36)	(12.43)	(21.50)

Note: Data were collected at the beginning of each RT session.

Mean RT data are reported in table 3. RT data were processed at equivalent physiological solicitation (80% MAP at 20°C ET vs 50% at 38°C ET). Data were submitted to a three-way analysis of variance (task: simple RT vs choice RT, heat stress: 20°C vs 38°C, and exertion: rest vs pedalling). Results indicated a significant main effect of task ($F_{1,7}=152.86$, $p<.001$), and an interaction exertion X task ($F_{1,7}=117.23$, $p<.001$): simple RT deteriorated under exertion, but choice RT was significantly improved. No other effect or interaction was significant.

TABLE 3: Mean Performance (msec) for Simple Reaction Time Task (SRT) and Choice Reaction Time Task (CRT), according to Climate and Exertion (Standard Deviation in Brackets).

	20°C E.T.			38°C E.T.	
	Rest	50% MAP	80% MAP	Rest	50% MAP
SRT	220.34	235.14	236.30	226.10	245.86
	(11.61)	(18.07)	(21.13)	(11.23)	(11.45)
CRT	353.46	340.83	331.56	361.46	343.93
	(22.24)	(23.40)	(23.14)	(30.50)	(31.04)

Error data were submitted to a similar analysis, which revealed no main effect and no interaction between factors.

With the aim to assess the influence of physical fitness on the effects of heat stress, partial correlations were computed between VO₂max and each performance measurement at 38°C, controlling for the influence of their 20°C counterpart. None of the correlations did reach significance (SRT, rest: $r=.025$; SRT, exertion: $r=-.038$; CRT, rest: $r=.569$; CRT, exertion, $r=.056$).

The same procedure was used to assess the influence of subjective thermal comfort. Significant partial correlation were obtained for simple reaction time (SRT, rest: $r=.844$, $p<.01$; SRT, exertion: $r=.901$, $p<.01$), but not for choice reaction time (CRT, rest: $r=.213$; CRT, exertion: $r=-.377$). This result indicated that for simple reaction time, the decrement in performance was related to the thermal discomfort.

DISCUSSION

The increase of oral temperature observed after an exposure of 30 minutes to the 38°C E.T. climate is a classical result in heat stress studies. It is more surprising to not obtain neither a main effect of exertion, nor an interaction between effort and climate. We hypothesize that the increase in ventilation during exertion could induce a reduction of the observed oral temperature.

As suggested by our pre-experimental observations, heat stress seemed to widely enhance the physiological reactions of the organism to exertion. This result in accordance with specific literature shows that even with fit young people, hot climates have a strongly detrimental effect on physiological performances.

The effects of exertion on simple and choice reaction time are consistent with those previously described with similar protocols (Brisswalter, Legros & Delignières, 1994; Delignières, Brisswalter & Legros, 1994). No main effect was obtained for heat stress, nor interaction between heat stress and exertion. Generally the exposure to such climate lead to significant decrements in performance (see for example Delignières, this volume). As in this experiment subjects were young football experts, we could suppose that physical condition play a major role in the moderation of the effects of heat stress (Parsons, 1993). Nevertheless our results showed that within the group, differences in physical condition are not related to the magnitude of performance decrement.

Finally, this experiment showed a relation between performance alteration and subjective discomfort, but uniquely for simple reaction time. This result is still difficult to explain, but it is clear through reaction time data that simple and choice reaction time are differently affected by stressors. We have shown recently that the enhancement of choice reaction time under exertion could be explained by the investment of extra resources (Delignières, Brisswalter & Legros, 1994). But this increase in mental effort, revealed by ratings of perceived difficulty, did not lead to similar effects in simple reaction time tasks. We suppose, in accordance with Sanders (1983)'s model, that simple and choice reaction time are controlled by different energetical reservoirs. Within this frame of reference, our results suggest that subjective thermal comfort has a specific rather than general effect on cognitive processes.

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