MULTI-TASK PERFORMANCE IN THE HEAT: UNCHANGED WITH MODERATE HEAT STRAIN

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INTRODUCTION

Studies of cognitive performance in the heat suggest that performance on vigilance tasks, and on complex and dual tasks, considered representative of industrial or military work, starts to be impaired in the 30 to 33°C WBGT (Wet Bulb Globe Temperature) range, as the level of heat stress increases (1). The present study investigated the effects of hot environments on the performance of tasks analogous to some in-flight activities.

METHODS

On separate occasions, 6 subjects (3 men, 3 women) dressed in summer clothing (excluding helmet and gloves) worn in an RAF fast jet (Tornado) were exposed for 2 h to each of 3 environmental conditions:

* T_{db} (dry bulb temperature) = T_g (globe temperature) = 24°C; RH (relative humidity) = 40%; air speed, 0.3-0.5 m·s^{-1}, (18.2°C WBGT), which served as the "thermoneutral," control condition
* $T_{db} = T_g$ = 40°C; RH = 60%; air speed, 0.3-0.5 m·s^{-1}, (35.1°C WBGT)
* $T_{db} = T_g$ = 42°C; RH = 57%; air speed, 0.3-0.5 m·s^{-1}, (36.2°C WBGT)

During the exposures, the subjects performed a Multi-Attribute Task (MAT) battery (2), which included 4 tasks: tracking (maintaining a randomly moving circle onto a fixed target by means of a hand-held joystick), monitoring (observing and responding appropriately to red and green lights, and to moving scale indicators), auditory communications (identifying own "call-sign" and responding to instructions) and resource management (maintaining target levels of "fuel" within 2 tanks by activating fuel "pumps"). At any one time, simultaneous performance on 2, 3 or 4 tasks was required. Before exposures, subjects had trained intensively on the MAT battery tasks.

After the MAT battery, subjects also carried out a digit symbol substitution (DSS) task (3) and completed subjective assessments of performance (mental, physical and temporal demand, own performance, effort, frustration) (4) and thermal comfort. Each set of objective and subjective measures took 35 min to perform and was repeated 3 times with a rest of 5 min at the start of exposure to each environment, and between each of the 3 performance sessions. Subjects drank water freely during the rest periods. Throughout exposures, physical activ-

ity was minimal with subjects seated in front of amonitor, carrying out the paper and pencil task, manipulating a joystick or keying-in responses on a keyboard during performance on the MAT battery.

Deep-body (rectal) temperature was recorded every 1 min. Skin temperatures at 4 sites (biceps, chest, thigh, calf) were recorded every 1 min and the area-weighted mean skin temperature (5) was calculated. Heart rate was monitored continuously and recorded every 5 min. Body water loss was calculated from the weight of clothing, from the nude and clothed weights of the subjects, both before and after exposure in the environmental chamber and corrected for fluids consumed and urine excreted. Repeated measures analyses of variance, with environment as the within-subjects factor, were used for statistical analysis of all performance and physiological data. Any significant differences observed were further analyzed using Newman Keuls' range test.

RESULTS

No effects of heat on objective measures of performance were observed (Table 1). Subjects perceived that greater effort was needed in the 42°C, compared with the 24°C, environment ($P < 0.05$), and they felt less thermally

Table 1. Performance measures during exposures to ambient temperatures of 24, 40 or 42°C (means for 3 performance sessions and 6 subjects)

		Ambient (dry-bulb) temperature (°C)		
Task	Measures	24°C	40°C	42°C
Monitoring	Green light % errors	0.00	0.00	0.00
	Green reaction time (sec)	1.11	1.11	1.10
	Red light % errors	0.00	0.00	0.00
	Red reaction time (sec)	1.23	1.22	1.26
	Scales % errors	0.63	0.46	0.78
	Scales reaction time (sec)	3.14	3.21	3.34
Communications	Percentage errors	2.31	2.49	2.84
	Reaction time (sec)	11.15	11.25	11.33
Resource Management	Mean deviations	125.7	124.8	129.4
	No. of responses/minute	5.32	5.07	5.52
Tracking	Root mean error score	83.41	85.48	89.15
DSS	Number of substitutions	204.3	206.4	204.8

comfortable in both the 40 and 42°C environments, compared with the 24°C environment ($P < 0.001$).

Heart rate, rectal and mean skin temperatures, and sweat loss were increased in the 40 and 42°C, compared to the 24°C, environments ($P < 0.001$). Rectal temperature rose by approximately 0.5 and 0.7°C in the 40 and 42°C environments, respectively (Figure 1). The increase in heart rate and in rectal temperature was greater in the 42°C than in the 40°C environment ($P < 0.001$ & $P < 0.05$, respectively).

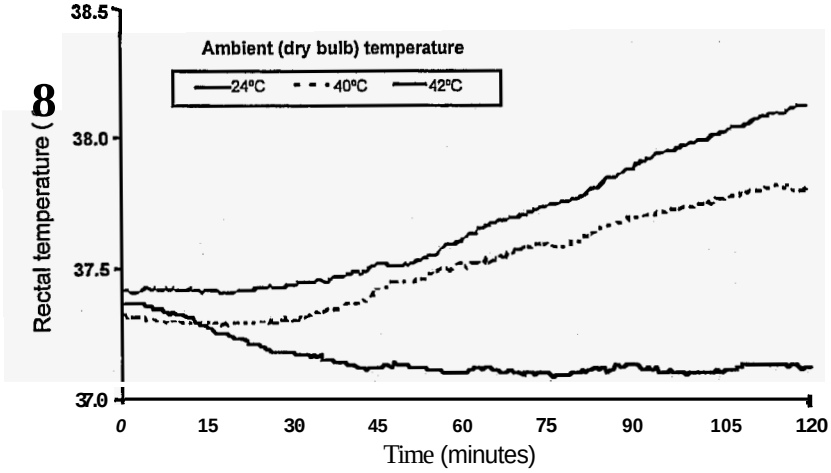

Figure 1. Rectal temperature during a 2-hour exposure to ambient temperatures of 24, 40 or 42°C (means for **6** subjects)

DISCUSSION

In a previous study (6), no effect of moderate heat (ambient temperature 34 or 37°C) on performance of the MAT battery was found. This was considered to be related to the lack of thermal strain observed, particularly as it had previously been suggested that performance on vigilance tasks, and on complex and dual tasks, was degraded as thermal strain (deep-body temperature) increased (1). However, the present study has also shown that performance on the MAT battery was not impaired during exposure to higher ambient temperatures (40 and 42°C), even though moderate thermal strain and subjective feelings of increased effort and hstration were evident.

With complex tasks, such as the MAT battery, which require **a** long period of training to attain performance at a consistent level of competence, it is possible that, under conditions of heat stress, performance on such a well-learned task is difficult to disrupt. Subjects may also be able to recruit extra effort to maintain adequate performance, particularly as, in the present study, they were aware of the duration of exposure. Some support for *this* contention was evident as subjects perceived that greater effort was needed in the heat, particularly in the 42°C environment. Whether a less well-learned task or a task requiring low activity monitoring would also remain unchanged under the environmental conditions used in the present study, would need to be established.

It would appear, therefore, that short duration exposure to ambient *(dry* bulb) temperatures up to 42°C is without effect on multi-task performance. However, in the context of flying, where aircrew have to carry out physical activities and/or wear additional protective clothing that restrict body heat loss through evaporation of sweat, body temperature may rise above that expected

from environmental conditions alone. The effect of this increased heat strain on flying performance is uncertain.

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