

## THE EFFECTS OF ELEVATED AMBIENT TEMPERATURE ON COGNITIVE FUNCTION

Elinor M O'Connor  
Department of Psychological Sciences  
Centre for Human Sciences, Defence Research Agency,  
Farnborough, Hampshire, UK

### INTRODUCTION

Despite considerable research interest, the relationship between heat and psychological performance remains poorly understood. The development of a coherent account of performance under thermal stress has been impeded by several factors, including concentration on a restricted range of performance variables, and excessive reliance on arousal theory to account for findings, often post hoc and in the absence of collateral evidence of arousal change.

Previous research on performance in the heat has tended to focus on gross performance parameters, which has hindered identification of the mechanisms underlying performance change. This experiment sought to investigate the effects of heat on specific components of cognitive performance in an attempt to identify the locus of stressor effects within the information processing system.

Theoretical accounts of the relationship between heat and performance typically assume that performance change is mediated by changes in arousal. However, this approach is unsatisfactory in several respects. It is typically used *post hoc* to describe rather than to predict patterns of performance and so the relationship between arousal and performance under thermal stress remains largely untested. Furthermore, the implicit assumption that arousal is a unitary entity is simplistic. This experiment sought to explore the role of arousal in performance in the heat by assessing the relationship between performance under thermal stress and state correlates of arousal.

### METHOD

Twelve male subjects completed two 2 hour test sessions, one in thermally stressful conditions ( $T_{db}$  40° C, 70% RH) and one in control conditions ( $T_{db}$  24° C, 25% RH).

The physiological variables measured were rectal temperature ( $T_{re}$ ), skin temperature at eight sites (chest, abdomen, upper and lower back, biceps, inner forearm, thigh and calf) and heart rate.

Performance in several domains was measured. Visual vigilance was assessed using a 'degraded digits' task based on that developed by Nuechterlain.<sup>1</sup> Selective attention was measured using one of the tests of cognitive function described by Broadbent.<sup>1</sup> Reaction time (RT) was assessed using a task selected from the AGARD STRESS Battery.<sup>2</sup> This task consists of a number of blocks, which load onto separate stages of the reaction process, including perceptual encoding, response choice, motor programming, and motor activation. Short term memory search was measured using a fixed set memory search task.

Mood was measured using a mood rating questionnaire which yields three mood factors: anxiety, depression and fatigue. Subjective thermal comfort was assessed using a nine point scale.

### RESULTS

Data were analyzed using repeated measures analysis of variance.  $T_{re}$ , skin temperatures and heart rate were significantly higher in the thermally stressful condition ( $p < 0.001$  for all variables).

Analysis of the performance data indicated a significant reduction in response latency for the RT task under thermal stress ( $p < 0.01$ ). Response latency varied significantly with block type but this effect did not interact with condition and therefore it was not possible to identify which components of the response process were affected by heat. RT in the memory search task was significantly lower in the hot condition ( $p < 0.05$ ) but there was no evidence of change under thermal stress in the accuracy of performance or in the search strategies employed by subjects. The only task to demonstrate change in performance accuracy under thermal stress was the selective attention task, with error rate increasing in the heat ( $p < 0.05$ ). Vigilance was unaffected by heat.

Analysis of the performance data with the body temperature **data as** covariates indicated that  $T_{\text{torso}}$  and mean temperature of the torso **skin sites** ( $T_{\text{torso}}$ ) were associated with **RT** in the selective attention **task**.  $T_{\text{torso}}$  was an explainer of **RT** in the memory search **task**. Body temperature was inversely related to **RT**.

Anxiety, fatigue and depression, and subjective **discomfort** were all significantly higher in the hot condition. However, there **was no** evidence that performance **was** influenced by mood **or** thermal comfort.

## CONCLUSIONS

Shortening of response latency was a consistent feature of subjects' performance under thermal stress. Reduction of **RT** in the heat is widely reported in the literature; it has **been** suggested that neural conduction velocity increases **as** body temperature rises and that **this** phenomenon may contribute to **the** lowering of **RT** associated with exposure to **heat**.<sup>5</sup> The **RT** test used in this experiment is designed **to** explore differential effects of **stressors** on components of the response process, however it **was** not possible to identify specifically the locus of the effect of heat **on RT**, which suggests that thermal **stress** may have a general effect **on** response latency.

Accuracy of performance was largely unaffected by heat with the exception of **an** increase in error rate in **the** selective attention **task**. Overall error **rates** were low (**3-4.4%** across **tasks**), which suggests that the **tasks** were relatively undemanding. Cognitive function may be relatively resistant to heat **stress**, although the apparently easy nature of the **tasks** used in **this** study renders **this** conclusion uncertain. Further research with more demanding **tasks** is **required to** explore the effects of thermal **stress on** higher cognitive function.

**The** results of **this** experiment highlight the **limitations** of existing theoretical accounts of the relationship between heat stress and performance, in particular the arousal theory of heat stress effects. Although both mood and performance were affected **by** heat **stress**, it was not possible to demonstrate that the effects of heat on performance were mediated by affective state. Nonetheless, the possible links between arousal and **performance** under **stress** merit further exploration.

The results of this study **also** cast doubt **on** an **earlier** suggestion that core **and skin** temperature determine speed and accuracy of performance **respectively**.<sup>6</sup> Although  $T_{\text{torso}}$  was related to **RT** in the attention task,  $T_{\text{torso}}$  accounted for more of the variance in **RT** in **this** task and also acted **as** an explainer of **RT** in **the** memory search task.

## REFERENCES

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