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.[1] Selective attention was measured using one of the tests of cognitive function described by Broadbent.[2] Reaction time (RT) was assessed using a task selected from the AGARD STRES Battery.[3] 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.[4] 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_{re} and mean temperature of the torso skin sites (T_{torso}) were associated with RT in the selective attention task. T_{torso} was an explanator 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.[5] 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.[6] Although T_{re} was related to RT in the attention task, T_{torso} accounted for more of the variance in RT in this task and also acted as an explanator of RT in the memory search task.

REFERENCES

1. Nuechterlain K., Parasuraman R. and Jiang Q. 1983, Visual sustained attention: Image degradation produces rapid sensitivity decrement over time, *Science* 220, 327-329.

2. Broadbent D.E., Broadbent M.H.P. and Jones J.L. 1986, Performance correlates of self-reported cognitive failure and of obsessionality, *Brit. J. Clin. Psychol.* 25(4), 285-299.

3. AGARD Aerospace Medical Panel Working Group 12. 1989, Human performance assessment methods, AGARDograph No. 308.

4. Warr P. 1989, The measurement of well-being and other aspects of mental health, SAPU Memo No. 1035 (MRC/ESRC Social and Applied Psychology Unit, UK).

5. Grether W.F. 1973, Human performance at elevated environmental temperatures, *Aerospace Med.* 44(7), 747-755.

6. Allnutt M.F. and Allan, J.R. 1973, The effects of core temperature elevation and thermal sensation on performance. *Ergonomics* 16(2), 189-196.