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CENTRAL AND PERIPHERAL VISUAL CHOICE-REACTION TIME UNDER CONDITIONS OF INDUCED CORTICAL HYPERTHERMIA[1]

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Summary.—Six right-handed male subjects performed a central and peripheral visual choice-reaction time (RT) task. After two initial practice periods, subjects performed counterbalanced manipulations of control, placebo, and heat conditions. In the heat condition, a helmet selectively raised cortical temperature, measured in the external auditory meatus, by 7°F while the placebo condition utilized the helmet with no external heat applied. Analysis indicated that the elevation of cortical temperature caused an increase in RT and decreased rate of errors. This conservatism in subjects' response under induced cortical hyperthermia is contrasted with previous accounts of visual RT performance under manipulations of whole-body heat stress.

The study of thermal stress and its effects on man has its origins in antiquity (Hippocrates, 1939; Sanctorius, 1614); observations within temperature-controlled environments were reported in the late eighteenth century (Blagden, 1775a, 1775b). However, the naturally occurring fluctuation of human performance with body temperature was first noted in the present century. Kleitman and his colleagues (Kleitman, 1933; Kleitman, Titelbaum, & Feiveson, 1938) noted that circadian variation in visual choice-reaction time (RT) was inversely related to body temperature. These effects on RT became more pronounced as the complexity of the response task increased. Kleitman proposed that chemical action in the cortex was facilitated by increased temperature where either mental processes represented chemical actions or metabolic activity in cortical cells was enhanced by increasing body temperature.

Since this seminal work, studies of visual RT under heat stress have been sporadic. Most reports have included RT only as a constituent in a battery of tasks (Fraser & Jackson, 1955; Reilly & Parker, 1967). In addition, although accounts of simple RT (Benor & Shvartz, 1971; Lovingood, Blyth, Peacock, & Lindsay, 1967; Ramsey, Dayal, & Ghahramani, 1975) and serial RT (Pepler, 1959; Wilkinson, Fox, Goldsmith, Hampton, & Lewis, 1964) of subjects exposed to high ambient temperature have appeared, relatively little work has addressed the problem of choice reaction under heat stress.

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In 1971 Grether and co-workers examined the effect of a rise of 18°F in the effective temperature of the environment (Houghten & Yagloglou, 1923) and found decrement in RT to a green light being extinguished but no change in RT to a red light being illuminated. This choice RT was performed concurrently with a central tracking task and the effect of heat on RT alone was not recorded. Similarly, Leibowitz, Abernethy, Buskirk, Bar-Or, and Hennessy (1972) investigated the effect of elevated ambient temperature on a central and peripheral simple RT but with concomitant physical exercise. Even under conditions of severe heat stress and dehydration no decline in performance was found.

The specific effects of selective cortical heating on visual reaction alone were reported by Holt and Brainard (1976). They found facilitation for both a choice-RT and a Neisser (1964) search task when a mild rise in cortical temperature of 1.11°C was induced. The present study was designed to extend the latter research on selective cortical heating and its effects on reaction to visual stimuli. Specifically, the current experiment examined central and peripheral visual choice RT under varying conditions of induced cortical hyperthermia. Further, attentional narrowing under whole-body heat stress has been implicated by the work of Bursill (1958). However, this has occurred in a dual-task performance paradigm, with concomitant reaction to simple visual stimuli in the periphery. The current peripheral manipulation yielded data on such possible narrowing in a peripheral choice-RT task.

METHOD

Experimental Test Facility

The experiment was conducted in two adjoining sound and light isolated rooms. The subject responded to light stimuli presented in the darkened room, while experimental control apparatus and two experimenters, who recorded physiological and reaction time data, occupied the adjoining room. These rooms were maintained at 75°F, 40% relative humidity and air velocity of less than 0.1 ms^{-1} throughout all experimental sessions. Such thermal conditions do not independently affect humans' core temperature (Lind, 1963).

Experimental Task

The subject was seated and viewed three black panels each 25 cm wide and 50 cm high on a 60-cm radial arc. The central panel, subtending an angle of 0° from the subject contained four white lights (Muralite L28/40) in a vertical array, each set 2.5 cm apart. Situated between the two central lights was a low luminance, red fixation light (Muralite 28/40). Two similar panels were set at an angle of 70° to the left and 70° to the right of the subject's meridian in the peripheral visual field. These panels contained four vertically arranged white lights but no fixation light. An adjustable chair and head rest positioned the subject at eye level with the central fixation light. The subject responded to the imperative stimulus with the right hand on a 30-cm × 30-cm board containing four key-press buttons (Microswitch AML 20 series, double-pole/throw push button). From left to right the buttons were pressed in correspondence to any one, two, three, or four lights being illuminated on any panel during a single trial. The instructions to the subject emphasized both speed and accuracy of response.

Subjects

Six healthy male subjects volunteered to participate in the experiments. Their physical characteristics were: age 22.5 ± 3.5 yr.; weight 86.9 ± 15.45 kg; height 189.4 ± 7.1 cm (mean ± range). All were righthanded and had no form of visual impairment at the time of testing. Subjects were aware of the general nature of the investigation, for consent purposes, but were naive of individual thermal manipulations during each experimental session.

Experimental Design

Each subject performed two initial practice periods to become familiar with the experimental procedure and reaction time apparatus. After practice the three experimental conditions, i.e., control, placebo and heat, were administered to the six subjects in a counterbalanced order. Individual subjects were tested at different times during the day but each subject commenced experimentation within the same 30-min. period for each of the five experimental sessions. This manipulation was intended to mitigate the effects of diurnal fluctuation in deep-body temperature on performance.

Thermal Conditions

Head-skin and auditory canal temperatures were monitored during all experimental sessions. A Yellow Springs Instrument Company (YSI) skin thermistor was affixed 5 cm horizontally from the right eye on the supraorbital ridge and taped to prevent interference in peripheral vision. Auditory canal temperature was measured by a YSI tympanic sensor contained in an ear-plug attachment which was inserted and secured in the right external auditory meatus. In the placebo condition an insulating rubber cap and heat helmet (Holt & Brainard, 1976) were worn but the latter was not activated. This procedure produced a heat-trapping effect which mildly elevated cortical temperature. In the heat condition the same apparatus was worn but temperature of the helmet was increased to cause a 7°F elevation in the subject's cortical temperature, over the monitored resting level.

Procedure

The subject had recording thermistors attached in the response room. Trials began after cortical temperature had been elevated 7°F above normal resting value in the heat conditions, which took approximately 7 to 10 min. An equivalent waiting period was imposed in both control and placebo conditions. The experiment was controlled by an electro-mechanical eight-track stepping tape recorder. The red fixation warning light was illuminated for 2 sec. prior to stimulus presentation. Either 1 or 2 sec. after the fixation light was extinguished the white stimulus lights were presented. The subject was required to respond to either 1, 2, 3, or 4 lights illuminated on any single panel within a particular trial. After each response the subject was given knowledge of RT results by a digital clock timer, a correspondent of which was also used to record RT and response errors in the experimental control room. At the completion of Trials 60 and 120 the subject was given a 1-min. rest. Total time for the 180 responses was approximately 30 min. per session.

RESULTS

Temperature Recordings

Head-skin temperature was elevated by a mean of 4.7°F in the heat condition, while the insulation of the helmet caused a mean 1.1°F rise during the placebo manipulation. Similarly, head-core temperature, as measured in the external auditory meatus, produced a mean overshoot of 2.3°F after the initial artificial elevation. In the placebo condition helmet application alone caused head-core temperature to rise by 2.1°F.

From a previous experiment (Hancock & Dirkin, 1981) no concomitant change in heart rate was noted during a similar use of the helmet. In absence of change in this arousal metric for the placebo condition the graded effect for RT and error in the current results are considered due mainly to cortical temperature manipulation.

Reaction Time

The model employed for the analysis of data was a 6 (subjects) × 3 (heat condition) × 3 (panels) × 4 (lights) × 15 (observations per light), with repeated measures over the first four factors and the error term derived from observations per light. This design yielded 180 observations per subject per condition in which stimulus presentation was randomized across both panel and lights within panel.

The main effect for heat condition was significant ($F_{2,28} = 70.24$, $p < .001$). Scheffé's *post hoc* test demonstrated that RT under cortical heat stress was slower than both the placebo and the control condition and that the placebo condition was also reliably slower than the control condition ($p < .01$). Mean RTs for heat × panel conditions are summarized in Table 1.

A significant interaction of heat condition × panel was present in the RTs ($F_{4,56} = 3.02$, $p < .025$). *Post hoc* tests indicated that the peripheral panels exhibited significantly slower RTs for the thermal manipulations in comparison to control performance ($p < .05$). These significant differences are mitigated by increasing rate of errors.

Rate of Errors

There was a significant effect for heat conditions on rate of errors ($F_{2,28} = 3.38, p < .05$). *Post hoc* analysis indicated that rates of errors were lower for the heat condition than the control condition. Over-all rates of error are presented in Table 1. Current results suggest that performance variation is related to a speed-accuracy trade-off where subjects became more conservative by slowing response and reducing errors as cortical temperature was elevated.

TABLE 1

MEAN AND STANDARD DEVIATION FOR RT (MSEC.) AND MEAN PERCENTAGE ERROR RATE FOR THREE PANELS IN HEAT, PLACEBO, AND CONTROL CONDITIONS

Condition/ Panel	Panel 1 (70° left)			Panel 2 (center)		
	M_{RT}	SD_{RT}	Error	M_{RT}	SD_{RT}	Error
Heat	735	167	14.4	568	96	4.4
Placebo	707	154	13.8	549	94	5.2
Control	693	176	18.3	544	102	6.1
	Panel 3 (70° right)			Accumulative M		
Heat	725	170	10.8	676	144	9.9
Placebo	706	165	15.8	654	137	11.6
Control	673	161	15.5	637	146	13.3

DISCUSSION

The observation that RT increased while errors decreased is in direct contrast to the statement of Allnutt and Allan (1973) that under thermal stress, level of performance decreased while speed of performance was facilitated. There are three major factors which may account for the apparent disparity. First, evidence for the latter interpretation was partly provided by studies concerning memory and tracking performance in elevated ambient temperature conditions. Second, studies of RT under thermal stress have mostly examined simple RT responses rather than central and peripheral choice reactions as evinced in this study (Benor & Shvartz, 1971; Reilly & Parker, 1967). Third, almost all previous manipulations have concerned whole-body heat stress rather than a selective cortical heating. Given these considerations the current pattern of results, which are consistent across each panel and light condition, are not incompatible with previous findings which accrue from different thermal manipulations.

At first glance, the interaction reported between heat condition and panel appears to represent a most interesting finding. However, as with all RT results, the mean RT *per se* is a insufficient criterion from which to assess performance. When taken in conjunction with concomitant error rate, it may be seen that the significant interaction is mitigated by ascending error rate for the peripheral panels, see Table 1. This suggests no attentional narrowing under induced cortical hyperthermia and supports the contention of Provins and Bell (1970) who concluded that such narrowing was dependent on demands of the central task which in both their study and the present work was perhaps insufficient to induce the effect noted by Bursill (1958).

A study which selectively varied cortical temperature is that of Holt and Brainard (1976). They reported facilitation in a choice-RT task for a relatively mild 1.11°C rise in tympanic temperature. The results from their central choice-RT task, which was performed alone, were examined independently of errors, which were reported as uniformly low at 5%. Also, subjects responded in a lighted room and completed the experimental procedure in one 4-hr. session. The differing task demands and testing procedure make it difficult to synthesize results from this and the present study. However, it is interesting that both the present study and that of Holt and Brainard, which have selectively manipulated cortical temperature, have reported patterns of results which are radically different from those adduced from performance under whole-body thermal manipulation. At the current time it is uncertain as to why response criteria become more conservative with increasing heat. Comparison with the results of Holt and Brainard (1976), who employed only a central choice-RT task, suggests subjects are influenced in their responses by the necessity to monitor concurrent peripheral panels.

One problem common to the study of Holt and Brainard and the present work is the use of tympanic thermometry. Holt and Brainard indicated the efficacy of tympanic membrane temperature as a direct and precise measure of thermal changes within the cortical cavity. Benzinger (1969) noted, through comparison with other cranial sites, that the tympanic temperature can be shown to represent the internal cranial temperature, although some argument surrounds the inclusion of a skin-temperature component in this measure (Nadel & Horvath, 1970). In the current study, temperature was monitored at a more remote site, away from the membrane in the auditory meatus. Cooper, Cranston, and Snell (1964) suggested that such a temperature provides a valid indication of change in thermal state of the central receptors. However, the considerable thermal gradient down the wall of the meatus somewhat devalues levels of absolute temperature. The artificially induced rise of 7°F in the present work probably represents an elevation of a lesser value in actual cortical temperature, although this manipulation was consistent across all subjects. Despite the consistent pattern of results reported over all panel and light presentations, current experimentation is in progress to establish further the validity and reliability of the effect reported.

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