EFFECT OF TEMPERATURE AND MAZE LEARNING ON SIMPLE MUSCULAR ACTIVITY OF WHITE RATS

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The paper discusses the effects of temperature variation on the simple muscular activity of white rats. Two groups of white rats were selected. Members of one group were trained to run a Proteus maze prior to the experiment. Muscular activity of both the groups was compared when subjected to temperature variation. The results show a superiority of trained rats over the others in respect of their muscular activity.

The effects of temperature on human performance have been studied both in laboratory and factory situations. An exploratory investigation was conducted to evolve an objective criterion for measuring the fluctuations in physical activity due to varying temperature stress on white rats. The object in view was to make use of the data collected in studies related to heat acclimatisation. In this pilot study simple muscular activity was taken as a criterion for discriminating the performance at different temperatures.

A few interesting phenomena were observed at the early stages of the investigation. These observed facts are summarised as under

(*a*) The individual variations in the performance of simple muscular activity among the white rats were rather wide at a particular temperature. The ratio of the poorest to the best performance could be put approximately as 1 : 25.

(*b*) The pattern of output curves of simple muscular activity of white rats plotted against varying temperatures did not follow the gross pattern of output curves of human performance under similar conditions of temperature stress.

(*c*) The overall performance of the group of white rats which was earlier taught to run a maze box showed higher activity at each temperature than the untrained group. It was also observed that variation in performance due to temperature differences was wider among the group which was trained to run the maze than the untrained group. Both groups were taken from the same stock.

Based on the above observations an experimental design was made and study was taken up to correctly assess the following two aspects

(*a*) The significance of relative amount (in percentage) of gain or loss in activity performance caused by temperature variations.

(*b*) The relative performance of the new group of white rats with that of the previously trained group.

The hypothesis for the exprimental testing was that the exposure of white rats at the temperatures below or above their own body temperature must affect their muscular performance. It was anticipated that the performance of the trained group would show a superiority over that of the untrained group while subjected to varying temperature stress.

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EXPERIMENTAL DESIGN

The experiment was designed to expose the subjects at different temperatures for a set duration, say, 20 minutes at each trial, before recording their muscular activity at the required temperature so that the body temperature of the subjects attained the temperature at which the observations were to be recorded. During this period, they were prevented from jumping out of the water bath by covering it with a perforated metal sheet. For maintaining a constant temperature at a particular level, a water bath with a thermostatic arrangement was used.

Assuming that the rats would always attempt to escape by jumping out of the water as it is not a comfortable environment for them, the muscular activity to be observed in the experiment was in terms of their alertness and ability to jump out of the water bath. The depth of the water in the tank was kept at such a level that the rats were prevented from contacting the bottom by their legs and resting while keeping their mouths out of water. This depth by trial and error was found to be 20 cm. The level of the water below the upper edge of the water bath was again to be such as requiring a good effort for the rats to jump up to it and the suitable level was found to be 10 cm. below the upper edge. So the total height of the water bath was 30 cm. filled with water up to a depth of 20 cm. while the remaining upper height of 10 cm. was to be jumped by the rats within the fixed duration of 15 minutes. Successful jumps were taken to be the measure of performance at the temperature at which these were exposed.

Muscular activity was recorded in terms of the number of successful jumps made by each rat during 15 minutes of observation after getting exposed to temperatures of 33°C, 37°C and 41°C. Readings were taken at intermediary temperature as well. As a reward and motivation each rat was allowed to remain out of the uncomfortable environment of water for 5 seconds before it was again placed in the water bath.

The subjects used in the experiment were 12 white rats approximately of the same weight and age and randomly selected from the same population. These were again divided into two groups, each consisting of six members. One of these two groups of six rats was trained on 'maze learning' before the actual experiment commenced. The muscular performance of each rat of both the groups in terms of successful jumps was recorded at all the temperatures mentioned above.

PROCEDURE

Before the actual observation started both groups were given two days acquaintance training in jumping out of the water under similar conditions of temperature and duration. One of the groups was given advance training in running the Proteus Maze for about one month. This trained group, for the sake of discrimination from the other, was labelled as 'old' while the other was called 'new' group.

The experiments were not conducted consecutively to eliminate chances of heat or cold adaptation. The experiments lasted for a period of two weeks. The data collected are presented in Tables 1—8.

To compare the individual performance of all the rats at different temperatures, analysis of variance was carried out which yielded the results given in Table 3.

TABLE 1

NUMBER OF JUMPS AT DIFFERENT TEMPERATURES

(The actual number of jumps in 15 minutes for each animal at different temperatures is in columns 1 to 8. The numbers indicate the serial number of the animal.)

	No	Temperature °C.							
		33	36	37	38	39	40	41	42
		1	2	3	4	5	6	7	8
Old Group	2	7	7	9	9	10	10	7	6
	3	14	10	9	10	15	18	16	16
	5	36	12	12	17	29	35	31	30
	6	5	6	4	4	4	6	4	3
	7	18	8	9	10	14	12	11	12
	8	42	21	10	19	47	74	48	40
	Mean	20·3	10·7	8·8	11·5	19·8	24·2	19·5	12·8
New Group	9	13	20	22	23	28	29	25	21
	10	2	1	1	2	1	3	2	0
	11	30	9	1	8	17	32	14	8
	12	3	1	1	1	3	2	1	1
	13	15	18	19	20	20	23	19	14
	14	4	5	7	8	7	3	2	0
	Mean	11·2	9·0	8·5	11·0	12·7	15·3	10·5	7·3
	Grand Mean	15·8	9·8	8·6	11·3	16·3	19·5	15·0	10·1

TABLE 2

AVERAGE NORMAL BODY TEMPERATURES OF ALL SUBJECTS (12 WHITE RATS) BEFORE SUBJECTING THEM TO HEAT STRESS

Temperature at which exposed (°C)	33·0	36·0	37·0	38·0	39·0	40·0	41·0	42·0
Average normal body temperature (°C)	38·6	38·5	38·8	38·7	38·5	38·8	38·7	38·6

Mean of the daily average temperatures = 38·65°C.

As the range of individual differences is wide, the performance at 37°C has been considered as the base to have a clearer picture of actual performance. Relative increase/decrease in performance, in terms of percentage, is given in Table 5 after reducing the formance at 37°C to zero.

TABLE 3

INDIVIDUAL PERFORMANCE OF THE RATS AT DIFFERENT TEMPERATURES

Source		Sum of Squares	Degrees of freedom	Mean Square	F Value	Significance
Between rats	A	6144·167	5	1288·834	19·013	Significant at ·01 level
	B	3406·854	5	681·3708	27·029	—do—
Between temperatures	A	1444·917	7	206·417	3·063	Significant at ·05 level
	B	268·312	7	38·3303	1·5205	Not significant
Remainder	A	2358·833	35	67·3952		
	B	882·312	35	25·2089		
Total	A	9947·917	47			
	B	4557·479	47			

N.B.—A for Old Group; B for New Group.

TABLE 4

COMBINED ANALYSIS FOR BOTH OLD AND NEW GROUPS

Source	Sums of squares	Degrees of freedom	Mean square	F value	Significance
Between groups	918·8438	1	918 8438	15 948	Significant at ·01 level
Between temperatures	1308·6563	7	186 9509	3 253	Not significant
Remainder	13196·7395	87			
Experimental error	404·5728	7	57·6533		
Sampling error	12792·1667	80	159·9021		
Total	15424·2396	95			

TABLE 5

RELATIVE INCREASE/DECREASE IN PERFORMANCE REDUCING THE PERFORMANCE AT 37°C TO ZERO

	Nos	33°C	36°C	37°C	38°C	39°C	40°C	41°C	42°C
		1	2	3	4	5	6	7	8
Old Group	2	—22	—22	0	0	+11	+11	—22	—31
	3	+56	+11	0	+11	+50	+100	+78	+78
	5	+200	±0	0	+42	+150	+192	+158	+150
	6	+25	+50	0	±0	±0	+50	±0	—25
	7	+100	—11	0	+11	+56	+33	+22	+33
	8	+320	+110	0	+90	+370	+640	+380	+300
	Mean	113·2	23·0	0	25·6	106·2	171·0	102·6	84·2
New Group	9	—41	—9	0	+45	+27	+32	+14	—5
	10	+100	±0	0	+100	0	+200	+100	±0
	11	+2900	+800	0	+700	+1600	+3100	+1300	+700
	12	+200	±0	0	+0	+200	+100	0	0
	13	—21	—5	0	+53	+5·3	+21	—5	—26
	14	—43	—29	0	+14	±0	—57	—71	0
	Mean	+515·8	126·2	0	+137·3	305·3	566·0	223·0	111·5
	Grand Mean	314·5	74·6	0	81·4	205·8	368·5	162·8	97·8

TABLE 6

PERCENTAGE OF PERFORMANCE

Between temperatures	^{6}p1	p2	C.R.	
	A*	B*	A	B
33°C—37°C	28·6	116·5	3·9†	4·42†
36°C—37°C	18·6	28·0	1·384‡	4·5†
37°C—38°C	19·3	26·7	1·3‡	4·9†
37°C—39°C	28·8	51·6	3·7†	5·9†
37°C—40°C	20·3	131·3	8·4†	3·9†

*A represents Old Group. B represents New Group.
†For df = 10, CR is significant at 0·01 level (3·17).
‡Not significant (even at 0·10 level for df = 10 (1·81)).

TABLE 7

RELIABILITY BETWEEN THE PERCENTAGES OF THE MEAN PERFORMANCES OF BOTH THE GROUPS

Between temperatures	^{6}p1 — p2	C.R.
36°C — 37°C	19·74	3·78*
37°C — 38°C	20·14	4·04*

*With 22 degrees of freedom—significant at ·02 level (2·51) and at ·01 level (2·82).

TABLE 8

RELIABILITY BETWEEN THE PERCENTAGES OF PERFORMANCES AT DIFFERENT TEMPERATURES

Between temperatures	^{6}p1 — p2		C.R.	
	A	B	A	B
33°C — 36°C	26·7	169·20	3·37**	15·56**
33°C — 37°C	28·6	116·5	3·9**	4·42**
37°C — 39°C	28·8	51·6	3·68**	5·91**
39°C — 40°C	46·0	220·8	8·47**	1·17†
40°C — 41°C	40·9	196·8	1·67†	1·74†
40°C — 42°C	34·4	44·07	2·49‡	8·1**

**For df = 10, CR is significant at 0·01 level (3·17).
‡For df = 10, CR is significant at 0·1 level (1·81).
†Not significant (even at 0·10 level for df=10).

The reliability between the percentages of performances at 37°C and other temperatures has been presented in Table 6. The C.R. has been computed as suggested by Garrett.[3]

Coefficient of correlation between the means of actual number of jumps (from Table 1) at different temperatures

$$\rho = 0{\cdot}78^{*}$$

Hence, it is not statistically significant at 0·01 level. It has to be 0·834 to be significant at 0·01 level for df = 6.

* The rank-difference correlation has been computed as suggested by Garrett[3].

DISCUSSION

The analysis of variance shows that the muscular performances at different temperatures of different rats belonging to each group vary significantly among themselves. A similar significant difference is observed when the performance of the old group is compared with that of the new one. The leading cause of marked individual differences within the same group could be the different levels of capacity of rats concerned in relation to the physical difficulty of the task to which they were set. This argument is supported by the fact that even advance training imparted to the subjects of the old group in running a maze—which is another similar muscualr activity—failed to eliminate the significant range of their individual differences. Mackworth[9] too, as a result of his famous experiments on human performances, noticed wide individual differences in human sensitivity to environmental stress on account of individual's ability to cope with the situation. His results on Wireless Telegraphy Test and Clock Test supported an identical general finding. The pronounced group differences may partly be the effect of prior training given to the former group and partly be the consequence of individual differences found among the rats included in both the groups.

It could thus conveniently be concluded that even though all the rats were randomly drawn from the same population trying to keep them approximately alike in both the groups, the individual and group differences continued to exist.

Again the analysis of variance shows a significant change in the muscular performance of the old group as a result of variations in temperature. But even though one notices a parallel pattern of performance curves for both the groups in Fig. 1, the statistical significance of variations in the case of new group is not established. Combined analysis of variance for both the groups fails to establish any significantly direct casual relationship between the change in temperatures and variations in muscular output. This apparent discrepancy about the effects of temperature on the performance of each group can be attributed to two main reasons. Firstly the old group had acquired certain initial level of muscular activity as a result of training and maximum mobilization of their stores of energy before the experimental trials under reference. Their later performances thus could hardly be distorted by any other factor and the changes observed in them were due to environmental stress alone. But the new group could every time resort to a greater effort under the increase of temperature stress by drawing more and more on their energy reserves. This increase in effort modified to some extent the variations which would have occurred due to change of temperature alone. Mackworh[9] established on human subjects also by using Pull Test and having an output criterion that men who are already working hard at some test of physical effort experienced more difficulty in carrying the extra burden of an abnormally high temperature and thus showed a more marked change in their output,

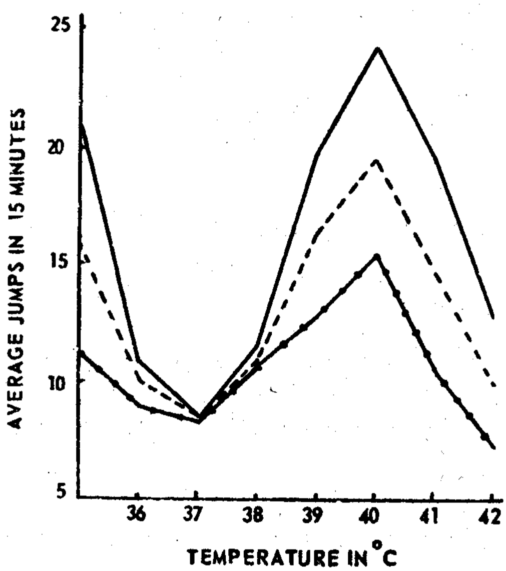

FIG. 1—Pattern of performance curves. [——— Old group ; ●——●——● New group — — — — — Average of both the groups]

Secondly the new group being untrained and unskilled in muscular performance was comparatively gaining more as a result of practice and this gain in turn may partially be counteracting the level of change in performance on account of temperature variation alone. The maximum mean relative gain shown at 40°C is about 171% in the old group and 386·5% in the new group. This marked excess in percentage of gain in the case of new group over that of the old at various temperatures indicates the benefit of practice.

It seems quite relevant to mention here that the relative amplitudes of variations in mean performances of both the groups at various temperatures being appreciably different uphold the above argument. The differences between the lowest and highest mean performances of the old and new groups are observed to be 15·4 and 6·8 units respectively which roughly indicate that the fluctuation is more in the case of the old group than the new one.

The coefficient of correlation between the means of actual number of jumps of both the groups at different temperatures reveals that a significant degree of correlation between them is not present. A bare comparison of the mean performances of both groups from Table 1 and Fig. 1 establishes the superiority of performance of the old group over that of the new at each temperature level.

A review of Fig. 1 justifies that the performance at 37°C could be taken as the base for computing the relative gain or loss in performance at other temperatures. It is clear that there is absolute agreement in performance at 37°C for both the groups. This tendency is

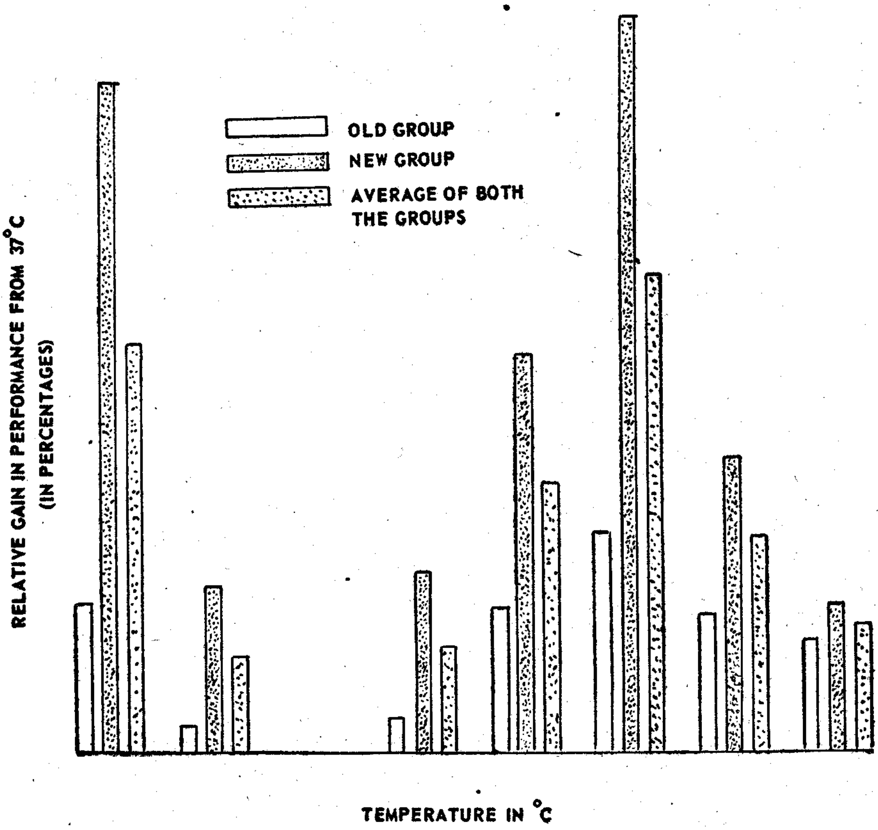

FIG. 2—Relative gain in performance at 37 °C

discernible at 36°C and persists till 38°C. The deviations in performances tend to be more or less equally wide at 33°C and 39°C. This converging and diverging tendencies at 36°C and 39°C respectively could possibly be due to the fact that the normal body temperature of the rats is within this zone. A close observation of the aforesaid graph shows that only a small range above or below the body temperatures of subjects could be held responsible for the immediate deterioration or improvement in their muscular activity. The mean of the daily average temperature is 38·65°C which approximately is midway between the temperatures 37°C and 40°C which are found to be the most detrimental and helpful temperatures respectively. One notices a marked similarity between the two curves the slight differences being probably due to random variation in the scores arising from chance factors in the experiments.

An inspection of the actual and relative percentage of gain in performances shows that the subjects indulged in maximum muscular activity at 40°C and thereafter showed a downward tendency with increase in temperature (Fig. 2). The upper limit of the temperature which shows optimum performance and above which further change in situation leads to a definite deterioration in performance is 40°C. The finding, therefore, suggests that when the temperature under which the living beings are to work is gradually increased in magnitude the output will show a positive decline beyond a critical limit of temperature which in present experiment for the rats is found to be 40°C.

The relative percentage of gain in mean performances with reference to that at 37°C is found to be significant at most of the other temperatures. The differences are not found to be stable in one group or the other for some temperatures. But the results of both the groups when combined show these marked differences at almost all the temperatures.

CONCLUSION

The muscular performance of the trained group is observed to be superior to that of the new group at all the temperatures.

The significant differences in the muscular output of the trained group are found as a result of temperature variation. But the same is not found to be true in the case of the new group.

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