42

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OF AMBIENT TEMPERATURE
SWINGS ON COMFORT,
PERFORMANCE AND BEHAVIOUR

by

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I. INTRODUCTION

It has recently been shown (Fanger, 1973; Fanger *et al.*, 1973] that each individual has a well-defined preferred ambient temperature which does not change significantly during a normal working day or from day to day (provided clothing, activity, air velocity and humidity are constant). One might however raise the question whether a constant ambient temperature also is optimal for the performance of mental work. It has sometimes been claimed that a constant thermal environment creates « climate monotony », resulting in decreased arousal and increased fatigue when man is working mentally. If this is correct it might be beneficial in practice to create temperature swings about man's preferred ambient temperature. On the other hand, temperature swings might have a negative influence on comfort.

The purpose of the present paper is to study the possible positive and negative effects on comfort and performance of ambient temperature swings of varying amplitudes and periods.

EARLIER STUDIES

While man's comfort and performance during steady-state conditions have been extensively investigated, there have been only few studies of his response to ambient temperature swings. GAGGE, STOLWIJK and HARDY (1967) studied the physiological and subjective response of naked subjects to large and abrupt temperature changes, and found that thermal sensation and thermal comfort followed ambient temperature much more closely than did skin temperature. SPRAGUE and McNALL (1970) exposed groups of subjects in a climate chamber to sinusoidal temperature swings, obtaining their thermal comfort response at intervals of 7 1/2 minutes by means of a written questionnaire. Their results did not show conclusively the form of the dependence of the comfort sensation on the amplitude and period of the temperature swings, nor was it possible to derive any definite limit to either the amplitude or period of temperature swings for comfort.

WYON *et al.* (1971) investigated some of the factors affecting subjective tolerance of ambient temperature swings by exposing individuals to a continuously changing temperature whose direction of change could be reversed by pressing one of two buttons. The amplitude of the temperature swings was thus under the subjects' control. It was found that subjects tolerated greater amplitudes when the temperature changed rapidly, as skin temperature lagged and effectively reduced the experienced temperature swings. It was also found that subjects tolerated greater amplitudes when performing mental work than when resting, not only of air temperature, but also of skin temperature. This implies that attention is an important factor. Although in this experiment subjects did perform mental work for two hours of each four-hour exposure, each subject had in effect exposed himself to a different pattern of temperature swings. In order to ensure that they did work in the work periods and rest in the rest periods, they were paid per item correctly completed and thus motivated to work quite hard. The present experiment was designed to investigate the effects of pre-determined temperature swings on comfort and performance under more normal working conditions.

II. METHOD

A. Experimental design

16 subjects were exposed in pairs to a total of 8 different temperature swing conditions in a small climate chamber. They were university students aged 21-28 years, 8 male and 8 female. Each pair was exposed to all 8 conditions consecutively in an 8 $\times$ 8 Randomized Latin Square design. The temperature swings took place about the average preferred ambient temperature for each pair, individual preferred temperatures having been determined in a preliminary exposure and pairs made up with closely similar preferred temperatures on the basis of theses results. The subjects were thus on average in thermal neutrality, and were not told that temperature swings were under investigation. They wore standard cotton uniforms with a thermal resistance of 0.6 clo (KSU-uniform, first used in comfort studies by Nevins, 1966). Measures of skin temperature, thermal comfort and performance were obtained throughout. Subjects assessed their level of arousal, degree of fatigue and the freshness of the air at the end of their exposure to each condition. Their rest-taking behaviour was passively registered. The following combinations of peak-to-peak amplitude and period were investigated: 0 °C (constant temperature); 2 and 4 °C with a period of 8 min; 2, 6 and 8 °C with a period of 16 min; 4 and 8 °C with a period of 32 minutes. Each condition was maintained for three whole periods, *i. e.* the shortest exposure was for 24 min, which was also the length of the exposure to constant temperature. Subjects encountered the conditions in random order with no break between conditions, except that on practical grounds, the total exposure was carried out as two sessions of roughly equal length on successive days, each of which commenced with 30 min at the preferred temperature. The total exposure was thus for 7 hours 48 min. The experiment was carried out in April 1971 on Danish subjects at the Technical University of Denmark.

B. Climate chamber

In order to achieve reproducible temperature swings, a special climate chamber was constructed in which an approximation to unidirectional horizontal air flow could be established. In this way it was hoped to reduce mixing of the inlet air and the consequent damping of air temperature swings that would have occurred. The chamber was built with a light wooden frame on which a double layer of transparent plastic foil (PVC) was stretched, with an air space between layers. The chamber was 2 m wide, 1.90 m high and 1.80 m long. The inlet air was admitted through a fine nylon mesh stretched over the whole of the front wall, and left the chamber through openings in the rear wall.

The inlet air velocity was between 0.06 and 0.10 m/s. Control of the inlet air temperature was achieved by taking air at about 14 °C from the cooling system of the building, and passing it over a 6 kW electrical heating battery, without re-circulation. The heating effect was controlled by means of a commercially available proportional controller (Philips PID) linked to a thermocouple sensor at the inlet to the chamber and to a mechanical device providing sinusoidal variation of the setpoint. This device consisted of a rotating arm whose length and speed of rotation could be varied to adjust the amplitude and period of the temperature swings, respectively. A string attached to the end of the arm ran over the shaft of the multi-turn set-point potentiometer, with several turns round it, and down to a counterweight to maintain tension. By altering the length of the arm only when it was horizontal, abrupt changes in amplitude could be produced with no change in phase. The period could be changed at the same time simply by altering the frequency of the pulse-train to the stepmotor driving the rotating arm. By these means it was possible to make a smooth transition from one temperature swing condition to another. Inside the provisional climate chamber, a narrow table was placed against the front wall, extending across the full width of the wall. Two subjects could sit at the table, facing the incoming air, which moved horizontally towards them at low velocity from the whole of the front wall, above and below the table surface.

C. **Thermal voting**

At each work position on the table a dial voting apparatus was provided with which each subject could at any time register the magnitude of his thermal discomfort sensation by setting a pointer on a circular scale with a clearly marked comfort zone. This method of spontaneous magnitude estimation of thermal discomfort has been described by WYON *et al.* (1972). In the present experiment, a rather different version of the method was used. The comfort zone was narrower, occupying only about 30° of a 330° scale whose end points were marked ‚much too hot' and ‚much too cold'. The setting of the pointer was automatically registered as before, but the pointer was automatically returned to the zero point after a few seconds. In addition to spontaneous votes, a lamp signal requested subjects to vote at irregular intervals at approximately ten minutes.

D. **Performance testing**

Subjects worked at an addition test consisting of units of five two-digit numbers. Subjects were paid a small amount for each unit correctly completed when working, and at a flat rate that was slightly less than their average earning rate, when resting. They were free to take rest periods at any time.

E. Registration of rest periods

The above payment scheme was employed to provide motivation for subjects to co-operate in registering their rest periods by replacing their pen in a holder when not working. A micro-switch on the holder made automatic registration of rest and work periods possible. It was pointed out to subjects that if they took a rest period without replacing their pen in the holder, it would continue to be regarded as a work period, and they would effectively be earning nothing during that time.

F. Subjective scaling

After experiencing three complete periods of a temperature swing condition, subjects were asked to assess their level of arousal, degree of fatigue and the freshness of the air by marking three semantic differential scales. Each scale consisted of a line about 20 cm long with the mid-point clearly marked, and opposite ends labelled by words of opposing meaning. The three word pairs, which were of course in Danish, may be roughly translated as alert/sleepy, fresh/fatigued, and fresh/stuffy. The distance of each mark from the end of the scale was measured in millimetres for analysis.

G. Information to the subjects

No mention of temperature swings was made to the subjects. Instead, they were told that their preferred temperature had been determined in the preliminary exposure, but that there were other factors that might influence their feelings of well-being. They were asked to work in the chamber as they might at home or in an office, and told that they would ‚from time to time' be asked to assess their feelings of arousal and fatigue, and the freshness of the air. It should by remembered that this assessment took place at intervals of 24, 48 and 96 min, in random order, so that subjects had no idea when the next assessment was to be made. They were instructed in the use of the dial voting equipment and the penholder. It is likely that many of them will initially have assumed that relative humidity was under investigation.

H. Measurement of skin temperature

The skin temperature of the forehead, shoulder blade, upper arm, back of hand, abdomen, back of thigh, and instep were measured at intervals of 3 min for one member of each pair, using thermistors taped to the skin and connected to remote-reading equipment outside the chamber.

III. RESULTS

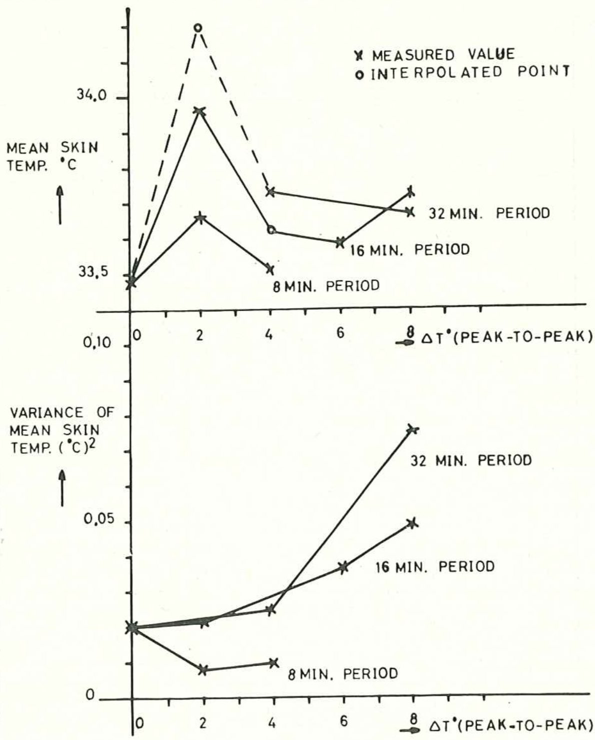
A. Preliminary exposure

Preferred temperatures for each individual were obtained by the standardised method employed in several earlier studies OLESEN & FANGER, 1971; OLESEN *et al.*, 1972], *i. e.* by adjusting the air temperature up or down by decreasing amounts every ten minutes during a 2 1/2 hour exposure, until the subject cannot say whether he would like it warmer or cooler. Preferred temperatures ranging from 23.3 to 26.7 °C were obtained, with a mean of 25.6 ± 0.8 °C. Pairs were formed on the basis of these results so that the members of each pair had closely similar preferred temperatures. The midpoint of the temperature swings to which each pair was subsequently exposed was taken as the mean of their preferred temperatures less 0.8 °C, this correction being introduced on the basis of earlier work to compensate for the difference between resting in the preliminary exposure and performing mental work during the temperature swings.

B. Air temperature swings

The inlet air temperature followed accurately the intended sinusoidal temperature swings, but in spite of the approximately horizontal unidirectional flow of the inlet air and the short distance — approximately 70 cm — between inlet and subject, it was found that considerable mixing had apparently taken place. This resulted in damping of the amplitude of the temperature swings as measured beside the subject, and particularly below head height. At head height the reduction was found to be 23 percent on average, but at table height and below the table the measured air temperature swings beside the subject had amplitudes that were on average only 25 percent of the intended values. For this reason the experiment is probably best regarded as an investigation of air temperature swings at head height. However, it is worth noting that skin temperatures measured at all sites on the body responded systematically to changes in the amplitude and period of the inlet air temperature swings. The vapour pressure, which was not controlled, was constant throughout each exposure in the range 6-8 mm Hg. Mean radiant temperature was intended to follow air temperature but the amplitudes were actually lower than half of the intended air temperature amplitudes.

FIG. 1 Mean and variance of skin temperature during swings.



C. Skin temperature swings

Skin temperature at 7 sites was measured at 3 min intervals throughout the exposure for one member of each pair. The average, unweighted skin temperature was derived for each subject for each such set of measurements. Within each temperature swing condition, the mean and variance of this value were derived for each subject, based on 8, 16 or 32 values according to the period of the temperature swings. The average was then taken over all 8 subjects within each condition. Fig. 1 shows the results so obtained. It is evident that there were systematic variations of both mean and variance of skin temperature with both amplitude and period of the air temperature swings. In order to avoid assumptions about the distribution of skin temperature values, non-parametric analysis was used in testing the reality of these effects. Table 1 shows the mean skin temperatures for each subject and amplitude with a 16 min period. FRIEDMAN two-way analysis of variance, described by SIEGEL (1956), is shown for the effect of amplitude on mean skin temperature.

TABLE I

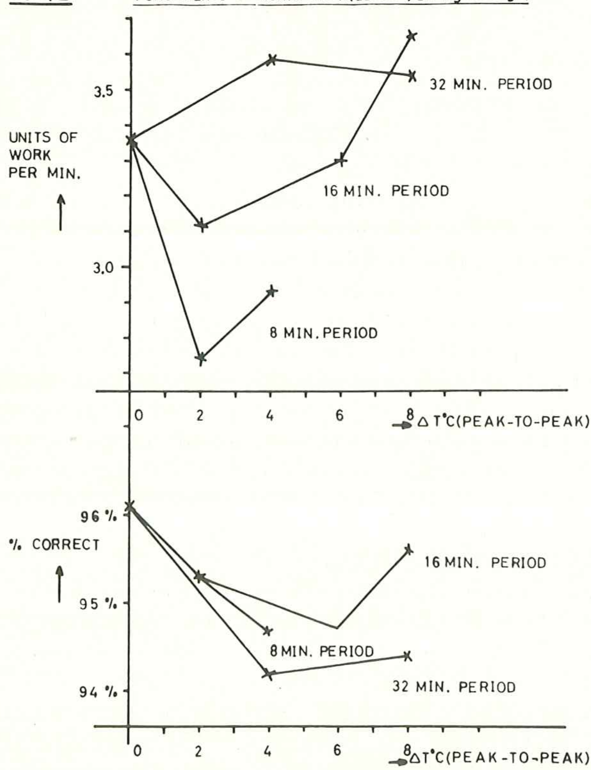
Mean skin temperature during swings with 16 min. period

Subject No.	Peak — to peak Amplitude :								Wilcoxon analysis	
	0°		2°		6°		8°			
	T_0	Rank	T_2	Rank	T_6	Rank	T_8	Rank	(T_2-T_0)	Rank
1.	33,346	1	33,755	4	33,563	2	33,746	3	0,408	5
2.	32,316	2	32,581	3	32,638	4	32,118	1	0,265	4
3.	33,155	2	33,067	1	33,436	3	33,527	4	— 0,088	2
4.	33,829	3	33,910	4	33,496	2	33,411	1	0,081	1
5.	33,654	1	33,855	4	33,674	2	(33,729)	3	0,201	3
6.	33,968	1	34,752	3	34,164	2	34,796	4	0,784	7
7.	32,968	1	34,610	4	34,335	3	33,397	2	1,642	8
8.	34,609	2	35,247	4	33,351	1	35,106	3	0,638	6
		13		27		19		21		T = — 2
	Friedman Analysis : Chi-square (3 d.f.) = 7,5 ($P \simeq 0,06$)								($P < 0,02$)	

This yields a value of chi-square of 7.5 on 3 degrees of freedom, for which ($P \simeq 0.06$). Inspection of fig. 1 indicates that the main variation contributing to this apparently significant effect is the increase in mean skin temperature from constant air temperature to an amplitude of 2° peak-to-peak. This effect is examined in Table I by means of Wilcoxon's Matched-Pairs Signed-Ranks test, described by SIEGEL (1956). Again, no assumptions about the distribution of skin temperature values are necessary. The critical value of the T-statistic for a 2-tail test at the 0.02 level for 8 pairs is 2. The mean skin temperature was thus significantly raised by temperature swings of 2° peak-to-peak amplitude in comparison with constant temperature. Similar analyses were performed for conditions with periods of 8 and 32 min, but no significant effects could be shown. It should be noted that temperature swings of amplitude 2° and period 32 min were not investigated, and that the broken line in fig. 1 is therefore an interpolation.

The variance with time of mean skin temperature, derived as set out above, was similarly examined for the effect of changes in the amplitude of temperature swings of constant period, using the nonparametric FRIEDMAN analysis

FIG. 2 Performance of mental work (addition) during swings.



The following values of chi-square were obtained for periods of 8, 16 and 32 min respectively : 0.750 on 2 d.f. (NS); 7.65 on 3 d.f. ($P \simeq 0.06$); 13.00 on 2 d.f. ($P < 0.01$). These calculations are not shown. It is evident that the variance of mean skin temperature increased significantly with increasing amplitude of temperature swings for periods of 16 and 32 min, but not for periods of 8 min.

On grounds of space, the results of similar analyses carried out on the skin temperature measured at each site separately are not given. However, similar and significant increases in variance with the amplitude of the temperature swings could be shown for all measurement sites. The form of the response was closely similar to that of fig. 1, with the possible exception of skin temperature measured on the instep, for which the variance with 16 min period appeared to be increased from the value at constant temperature to the same extent by small amplitudes as by large, i.e. it appeared to increase almost at once to a maximum value as the amplitude of temperature swings of this period was increased. However, in view of the uncertainty introduced by turbulent mixing of the inlet air below the table, this may have been due to systematic errors in the air temperature to which the feet were exposed. No significant differences between conditions could be shown for the mean skin temperature at any site considered separately.

D. **Performance**

The performance of the addition task was analysed in terms of rate of working and accuracy of working. Since rest periods could be taken at will, the total working time could vary between subjects, and was examined for systematic variation between conditions. No significant differences could be shown. Because of the relatively short exposures to each condition, and the rather few rest periods taken, this is a rather insensitive index. The registration of rest periods made it possible to examine rate of working in work periods, as opposed to total rate of working, in order to test the possibility that subjects taking more frequent rest periods compensated by working faster in work periods. This was found not to be the case. Non-parametric SPEARMAN correlation analysis indicated that under conditions in which less total work was performed, the rate of working in work periods was lower ($R_s = 0.953$ for 8 pairs, $P < 0.01$) and vice versa. In view of this, total rate of working was taken as the measure of performance in further analysis, for this is reduced both by working slowly and by taking more frequent rests. Table II shows the raw data for this criterion, expressed as items completed in 10 min, to avoid decimals. Values in brackets are missing values that have been interpolated. This data was found to be normally distributed, and analysis of variances was performed. The repeated-measures model used is set out on p. 112 of WINER (1962). Table III shows the results obtained. COCHRAN'S C test indicated homogeneity of variance. The differences between temperature swing conditions were found to be significant at the 0.01 level. The NEWMAN-KEULS procedure was used to investigate empirically the differences between conditions, and is also shown in Table III. Performance was found to be significantly better under conditions F, G and H than under condition B. These trends can be seen in fig. 2. The larger,

TABLE II

Units of work performed in 10 minutes

Period :	–	8 minutes		16 minutes			32 minutes	
Amplitude :	0	2	4	2	6	8	4	8
Condition :	A	B	C	D	E	F	G	H
Subject No.								
1.	35	33	35	46	26	(40)	50	32
2.	45	35	38	29	52	57	36	68
3.	40	16	34	32	37	38	33	33
4.	21	29	23	26	36	50	26	40
5.	28	24	26	29	25	26	31	29
6.	27	34	21	28	26	29	42	25
7.	60	47	48	46	41	60	59	48
8.	21	0	10	13	34	52	32	36
9.	43	31	32	29	36	23	35	39
10.	48	35	41	32	35	48	42	34
11.	32	35	38	54	37	(44)	53	36
12.	40	30	26	36	42	28	36	45
13.	30	24	24	26	28	24	29	29
14.	11	9	14	10	9	12	10	20
15.	30	30	23	30	33	36	38	34
16.	27	27	35	31	31	17	23	17
TOTAL. . .	538	439	468	497	528	584	575	565

slower temperature swings seem to have produced better performance than the smaller, faster temperature swings. Non-parametric FRIEDMAN analysis of performance during temperature swings with period 8 min confirmed that the decrease in performance at amplitudes of 2 and 4° peak-to-peak, as opposed to constant temperature, was significant. The value of chi-square on 2 degrees of freedom was 8.094, which is significant at the 0.02 level. However, similar analysis of performance during temperature swings with periods of 16 and 32 min indicated that the apparent increase in performance above the level at constant temperature was not significant.

TABLE III

Analysis of variance of rate of working

Source of variation	S.S.	d.f.	M.S.	F	P
Between people.....	10 054,97	15	–	–	–
Within people......	7 404,0	112	–	–	–
Conditions..........	1 198,97	7	171,28	2,90	0,01
Residual............	6 205,03	105	59,10	–	–
Total.........	17 458,97	127	–	–	–

Cochran's C = 0.194 NS

Newman - Keuls procedure

Totals	B 439	C 468	D 497	E 528	A 538	H 565	G 575	F 584
439............	–	29	58	89	99	126	136	145
468............	–	–	29	60	70	97	107	116
497............	–	–	–	31	41	68	78	87
528............	–	–	–	–	10	37	47	56
538............	–	–	–	–	–	27	37	46
565............	–	–	–	–	–	–	10	19
575............	–	–	–	–	–	–	–	9
584............	–	–	–	–	–	–	–	–

Critical difference at 0.05 level : 134, 131, 126 for 8, 7. 6 steps respectively.

Conclusion : Performance differed significantly between conditions at the 0.01 level. Performance at F, G, H was significantly better than at B.

Accuracy of performance was examined separately. The raw data is shown in Table IV, and the results are shown in fig. 2, lower half. The data was found not to be normally distributed, and non-parametric FRIEDMAN analysis was used to examine the influence of increasing amplitude of temperature swings on accuracy of performance, for each value of the period separately. The values of chi-square obtained for the periods 8, 16 and 32 min respectively were as follows : 3.031 on 2 d.f. (NS) ; 9.376 on 3 d.f. ($P < 0.05$); 9.375 on 2 d.f. ($P < 0.01$). Constant temperature is included as a reference condition in each of these analyses. When period is neglected, and the average percentage correct during conditions with temperature swings of 0, 2, 4, 6 and 8° C peak-to-peak amplitude are examined, Friedman analysis gives a value of chi-square of 10.538 on 4 d.f., which is significant at the 0.05 level. The

TABLE IV

Accuracy in performance test-promille correct

Period :	–	8 minutes		16 minutes			32 minutes	
Amplitude :	0	2	4	2	6	8	2	8
Condition :	A	B	C	D	E	F	G	H
1.	940	925	941	945	968	947	965	945
2.	990	988	989	985	976	985	977	985
3.	980	940	950	943	960	978	974	942
4.	100	985	1 000	993	994	996	975	990
5.	850	828	794	822	854	853	817	845
6.	100	950	980	970	960	958	953	984
7.	995	985	965	950	950	957	975	960
8.	980	(970)	1 000	1 000	970	1 000	976	977
9.	902	960	910	956	896	930	933	910
10.	886	917	825	875	886	886	886	865
11.	960	1 000	945	939	948	(956)	946	958
12.	978	985	951	972	977	985	983	963
13.	960	895	950	944	890	940	920	938
14.	1 000	955	1 000	1 000	1 000	984	860	890
15.	972	985	982	952	944	955	972	970
16.	985	985	976	995	980	986	960	980
MEAN....	961	953	947	953	947	956	942	944

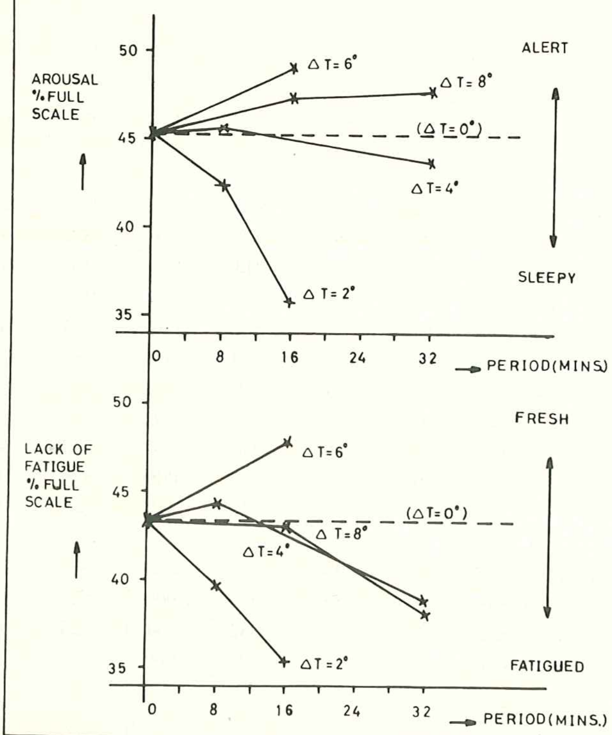
greatest accuracy was obtained at constant temperature, but there appears to have been a minimum at an amplitude of 4 °C. 12 of the 16 subjects worked with greater average accuracy when exposed to temperature swings of 8 °C amplitude than when exposed to swings of 4° amplitude.

E. Subjective scaling

The subjective scaling of arousal, degree of fatigue and the freshness of the air was examined using the distance in millimetres from the end of each scale as a working measure. As for skin temperature non-parametric FRIEDMAN analysis was used to examine the differences between conditions, thus avoiding assumptions about scaling. No significant differences could be shown. The results are shown in fig. 3 and 4, expressed as mean values of percent full-scale, *i.e.* 50 percent represents the middle of the scale. Increasing period seems to have had an effect only for 2° amplitude, for which an increase from 8 to 16 minutes tended to reduce arousal, increase fatigue and reduce the perceived

FIG. 3

Subjective scaling of sensation during swings.

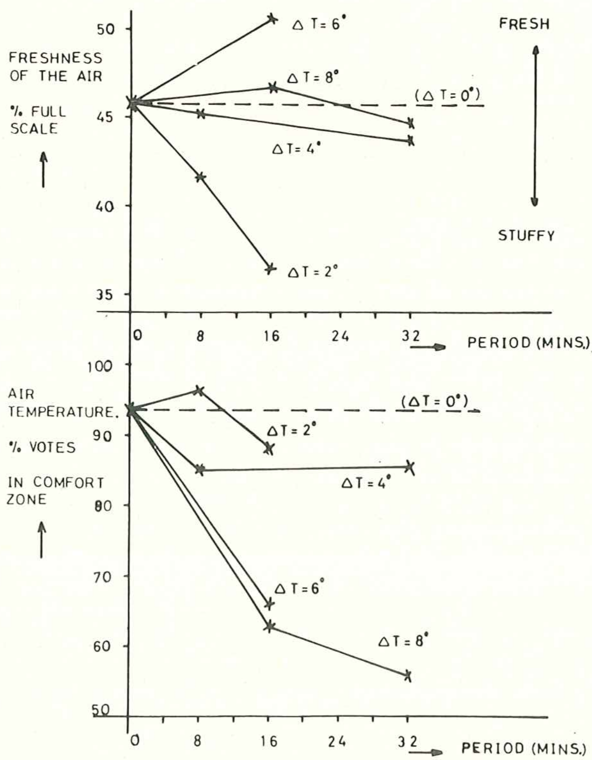


freshness of the air. It is noteworthy that the condition with 16 min period and 2° peak-to-peak amplitude, which was judged most negatively on all three scales, was also the condition shown above to have resulted in significantly increased skin temperature (see fig. 1). This is the most striking tendency, but the effect of increasing amplitude from 2 to 4 to 8 °C resulted in a monotonic increase in both arousal and the freshness of the air, and to an apparent decrease of fatigue as well.

F. Thermal comfort

Thermal comfort as registered on the dial-voting device was processed in the following way. For each subject within each condition separately, the mean and variance of all registered values, whether spontaneous or elicited, were derived. The working units were proportional to the deviation in degrees from the initial pointersetting at the centre of the scale. These values were

FIG. 4 Subjective scaling of freshness and thermal comfort.



then averaged over all subjects within each condition to give estimates of the parameters of the general comfort vote distribution within that condition. On the assumption that this was normal, the percentage of votes expected to fall within the comfort zone marked on the scale can be derived for each temperature swing condition by entering a table of the cumulative normal distribution with these parameters. The results are shown in fig. 4, lower half. The significance of the differences between conditions can be tested by using tables of the variance-ratio statistic F to compare the estimated variances. No significant increase in the width of the comfort vote distribution could be shown at any period for temperature swings of 2 and 4° peak-to-peak amplitude, compared with the comfort vote distribution at constant temperature. There was a tendency towards more discomfort votes during these swings than during constant temperature, but the percentage of votes in the comfort zone did not fall below 85 percent under any of these conditions. For temperature swings of amplitude 6 and 8° and period 16 min. and for temperature swings of amplitude 8° and period 32 min, the width of the comfort vote distribution was significantly greater than that obtained at constant temperature ($P < 0.05$). Only 66, 63 and 56 percent of comfort votes, respectively, were then in the comfort zone.

IV. DISCUSSION

In the amplitude-period region covered by this experiment, there appear to have been two kinds of effects of temperature swings on subjects who were working at their own speed. Small, rapid swings about the ideal temperature seem to have in the first place increased skin temperature without increasing the variance of skin temperature with time. This may be due to a difference in the time constant of skin temperature response to heat and cold. Much more closely controlled exposures to sinusoidal temperature swings would be necessary to reveal whether this is so, and these do not appear to have been carried out. Larger, slower temperature swings about the ideal temperature increased the variance with time of skin temperature, without altering the average skin temperature. The exact values of the ambient temperature amplitudes producing these effects cannot be stated with certainty. It should be remembered that the tabulated values are those of inlet air temperature, and that although the amplitude of the temperature swings experienced by the subjects at head height were only slightly less, they were considerably less for the rest of the body due to mixing of the inlet air.

The above skin temperature variations induced by the ambient temperature swings seem to have in turn affected the subjects in the following ways. Small, rapid swings of ambient temperature were associated with decreased rate of working and decreased accuracy, and subjects judged that they were more sleepy, more fatigued, and that the air was less fresh than at constant ambient temperature. They did not consider that they were less thermally comfortable. Larger, slower temperature swings were associated with faster, though not significantly faster, rates of working, and a tendency to return to the accuracy achieved at exactly constant temperature. Subjects tended to feel more alert and that the air was more fresh than during the smaller temperature swings. However, they were more often too hot and too cold during the larger temperature swings.

These results, obtained under laboratory conditions, in which subjects experienced some conditions for as little as 24 min, should not be taken to apply to conditions in the field without further investigation. Longer term studies, in which subjects work for days or weeks during temperature swings, will be necessary to investigate their performance and to determine the practical acceptability of temperature swings. Meanwhile, the present results provide some evidence that small temperature swings may lead to undesirable effects on performance by decreasing arousal, increasing fatigue and decreasing the subjective impression of freshness.

Large temperature swings may have a positive effect on man's performance, but such swings cause increased discomfort. A constant temperature, providing optimal comfort, seems preferable.

V. CONCLUSION

Large ambient temperature swings appear to have a stimulating effect that is to be preferred to the apparently opposite effect of small temperature swings, but a constant, optimally comfortable temperature, where this can be achieved, would still seem to be preferable to either.

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