Chapter V

Results and Discussion.

Two experiments in all were conducted to study the effect of mental workload and physical workload stress on CFF and performance level. The results of the two experiments have been discussed in this chapter to see whether the hypotheses formulated earlier are supported.

Experiment I was conducted to study the effect of mental workload stress on CFF threshold and hand steadiness task performance. In this experiment, two groups before-after design was used. In low stress group, Ss worked on a single cognitive task for 40 min. The Ss in the high stress group worked for 120 min. on three cognitive tasks. Before and after measures of CFF and performance were taken.

In order to test the significance of differences, t-test was employed between no stress and after stress scores of blood pressure, CFF threshold, and errors in hand steadiness test.

It has been well established that the high stress increases the blood pressure. Higher the stress, more the increment in blood pressure (Buhler, 1961; Melville, 1981). In this investigation blood pressure (BP) was
used as an index to measure the degree of stress. BP measurements in before and after conditions were taken. The difference in before and after BP was insignificant in low mental stress group whereas in the high mental stress group, there was a highly significant increment in blood pressure (Table I). This confirms to the fact that degree of stress was high in mental stress group.

Table 1. Showing the mean blood pressure before and after the low and high mental stress treatment and the significance of difference between these means.

<table>
<thead>
<tr>
<th>Blood pressure (BP)</th>
<th>Treatment</th>
<th>Mean blood pressure</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before stress</td>
<td>After stress</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>Low mental stress</td>
<td>90.3</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>High mental stress</td>
<td>89.6</td>
<td>103.3</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>Low mental stress</td>
<td>112.8</td>
<td>113.4</td>
</tr>
<tr>
<td></td>
<td>High mental stress</td>
<td>115.3</td>
<td>133.5</td>
</tr>
</tbody>
</table>

* p < .005
Besides this, the degree of increase in the BP scores in low and high mental stress group were also calculated in terms of differences in the before-after score of each group. The t-value between the mean increase in low and high level of mental stress was computed. The increase of BP after high mental stress was found to be significantly higher than low mental stress group confirming that there was a significant difference in the two levels of stress induced in two groups.

Table 2. Showing the mean increase (difference in before-after scores) of blood pressure in low and high mental stress and significance of difference between these increases.

<table>
<thead>
<tr>
<th>Blood pressure (BP)</th>
<th>Mean increase in blood pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low mental stress group</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>.8</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>1.1</td>
</tr>
</tbody>
</table>

\* p ≤ .01
\** p ≤ .005
Fig. 5 Showing the CFF measures of individual subjects in low mental stress group.

Fig. 6 Showing the CFF measures of individual subjects in high mental stress group.

Fig. 7 Showing the mean CFF threshold of low and high mental stress group in before and after condition.
As already mentioned, now the investigator wanted to find out, if these different levels of stress affected the performance in a different way. The first hypothesis predicted that low level of mental stress would increase CFF threshold. In low mental stress condition, the mean CFF threshold in before condition was 32.075 and in the after condition, it was 33.825 (Table 3, Fig. 7). This increase in CFF was significant (P < .01, Table 3).

Table 3. Showing the mean CFF threshold before and after the low and high mental stress treatments and significance of differences between these means.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean CFF threshold</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before stress</td>
<td>After stress</td>
</tr>
<tr>
<td>Low mental stress</td>
<td>32.075</td>
<td>33.825</td>
</tr>
<tr>
<td>High mental stress</td>
<td>32.444</td>
<td>28.76</td>
</tr>
</tbody>
</table>

* p < .01  
**p < .005
The second hypothesis related to the effect of mental stress, predicted that FFT would decrease as a result of high mental stress. Table 3 clearly indicates that the mean CFF threshold before giving the stress treatment was 32.44 which reduced to 28.76 after the stress treatment (Fig. 7). This decrement was significant at .005 level. Thus both the hypotheses predicting the effect of mental stress have been proved.

The obtained results are similar to the results of many other investigations (Piern, 1952; Busch and Wachholder, 1953; Payne, 1982). Payne (1982) reported an increased flicker sensitivity after low levels of stress. Piern (1952) on the other hand demonstrated in experiments conducted with small groups of Ss that CFF threshold is lowered due to mental fatigue.

Busch and Wachholder (1953) have reported an increase in FFT as a result of low mental stress i.e. mental work of 70 to 90 min. However, high mental stress had a different effect. A decrease in CFF was reported in the same study as a result of high mental stress i.e. working for the whole day.

The third and fourth hypotheses of the study were related to the effect of mental workload stress on performance. In the third hypothesis, it was predicted that low mental stress would improve performance on hand
Fig. 8 Showing the errors committed by individual subjects on hand steadiness task in low mental stress group.

Fig. 9 Showing the errors committed by individual subjects on hand steadiness task in high mental stress group.

Fig. 10 Showing the mean number of errors on hand steadiness task in low and high mental stress group in before and after conditions.
steadiness task. The results show that the mean errors on hand steadiness in no stress condition were 21.8 which decreased to 16.7 after low stress treatment (fig. 10). This decrement in errors after low level of mental stress is an indication of improvement in the performance on hand steadiness task. The obtained difference was found to be significant at .005 level upon t-test (Table 4).

Table 4. Showing the mean number of errors on hand steadiness test before and after low stress treatment and significance of difference between these means.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean number of errors</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before stress</td>
<td></td>
</tr>
<tr>
<td>Low mental stress</td>
<td>21.8</td>
<td>8.43*</td>
</tr>
<tr>
<td>High mental stress</td>
<td>21.1</td>
<td>4.91*</td>
</tr>
</tbody>
</table>

The last hypothesis related to the effect of mental stress had predicted that compared to no stress, high mental stress would lead to performance decrement on hand steadiness task. It is evident from Table 4 and fig. 10 that mean number of errors in no stress condition was 21.1 and after the high stress treatment, it was 28.5. The significance of this difference was tested
by employing t-test, and the observed difference was found to be significant (P < .005). This increment in errors clearly indicates an impairment of the task performance capability. Thus the hypotheses predicting the effect of mental stress have been proved. It is evident from the above discussion that low mental stress improved the performance and high mental stress decreased the performance as predicted by third and fourth hypothesis respectively. These results are consistent to the results reported by Thorndike and Wood Yard (1934), Zander (1944), Verville (1946), McClelland and Apicella (1947), Clark and McClelland (1951), and Sant'Anna (1951). Clark and McClelland (1951) reported an improvement in performance as a result of low degree of stress. Zander (1944) on the other hand, observed a decrement in digit span when the level of stress was increased by increasing the difficulty level of stress. Similarly Sant'Anna (1951) also demonstrated a decrement in number of correct answers in a mental counting task as a result of high level of stress produced by fatigue. Thus the results of the present study are congruent with the above studies, in which the opposite kind of changes in CFF and performance output as a result of low and high level of mental stress have been reported.

The impairment in performance as a result of high mental workload can be explained on the basis of
an opinion given by Luczak (1971, 1975) and Bainbridge (1974). They felt that stress increased with the proportion of capacity used in information processing i.e. mental workload. This implies that performance eventually decline as a result of mental workload.

However, the investigator was interested not only in studying mental workload, but also in investigating the effect of physical workload on both i.e. CFF and performance. Experiment II was conducted to study the effect of physical workload stress. Just like experiment I two groups design was employed in the experiment and before after measurements were taken on CFF and performance levels. However, in experiment I the effect of mental stress was studied only on physical natured task or perceptual motor task. Since the media to induce stress was also the mental performance on cognitive tasks, the investigator had decided not to study its effect on a similar natured task. The similarity of the task could lead to the effect of practice. Therefore, the effect of mental stress was studied on hand steadiness task only. But in the second experiment, since the nature of the task to be given in the form of physical workload (i.e. bicycle ergogram) was different from hand steadiness, So the effect of this workload was studied on both the tasks i.e. mental task and hand steadiness task.
First of all, the differences in blood pressure in before and after conditions were analysed to see whether the required levels of stress in two groups were induced or not. It was observed that the increment in both diastolic and systolic BP as a result of low physical stress was insignificant (p > .05), whereas in the high stress group there was a highly significant increment in blood pressure (Table 5). This confirms to the fact that degree of stress was high in high physical stress group.

Table 5. Showing the mean blood pressure before and after the low and high physical stress treatment and significance of differences between these means.

<table>
<thead>
<tr>
<th>Blood Pressure</th>
<th>Treatment</th>
<th>Mean blood pressure</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before stress</td>
<td>After stress</td>
<td></td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>Low physical 90.9 stress</td>
<td>91.5</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>High Physical stress 90.2</td>
<td>111.2</td>
<td>15.95 *</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>Low physical 114.7 stress</td>
<td>115.2</td>
<td>.63</td>
</tr>
<tr>
<td></td>
<td>High Physical stress 115.7</td>
<td>138.5</td>
<td>12.94 *</td>
</tr>
</tbody>
</table>

*P < .005
Like experiment I, the significance of difference between the mean increase in low and high physical stress group was tested upon t-test. The increase of blood pressure after high physical stress was found to be significantly higher than low group confirming that there was a significant difference in the degree of stress induced in the two groups.

Table 6. Showing the mean increase (difference in before-after scores) of blood pressure in low and high physical stress conditions and significance of difference between these increases.

<table>
<thead>
<tr>
<th>Blood Pressure (BP)</th>
<th>Mean Increase in blood Pressure</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diastolic BP</td>
<td>Low physical stress group .6</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>High Physical stress group</td>
<td></td>
</tr>
<tr>
<td>Systolic BP</td>
<td>Low physical stress group .5</td>
<td>22.8</td>
</tr>
</tbody>
</table>

Now the effect of these different levels of stress was studied on CFF threshold and performance. It was respectively stated by the fifth and sixth hypotheses of the study that low physical stress would increase the CFF threshold and high physical stress would result in lowering of CFF threshold. In low physical stress condition, the mean CFF threshold in before condition was 32.3 and in the after condition, it
Fig. 11 Showing the CFF measures of individual subjects in low physical stress group.

Fig. 12 Showing the CFF measures of individual subjects in high physical stress group.

Fig. 13 Showing the mean CFF thresholds of low and high physical stress group in before and after conditions.
was 35.67 (Table 7, Fig. 13) on the other hand as a result of high physical stress condition, mean CFF thresholds decreased from 32.94 to 28.59 (Table 7, Fig. 13). Both of these differences were found to be significant upon t-test ($p < .005$). These results indicate an increase in the CFF threshold after low physical stress and a decrease after the high physical stress as predicted by fifth and sixth hypotheses, respectively.

Table 7. Showing the mean CFF thresholds before and after the low and high physical stress treatment and significance of differences between these means.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean CFF threshold</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low physical stress</td>
<td>32.3</td>
<td>35.67</td>
</tr>
<tr>
<td>High physical stress</td>
<td>32.94</td>
<td>28.59</td>
</tr>
</tbody>
</table>

*P < .005

In a study conducted on job for key punch operators and calculators, a reduced level of stress by giving rest for sometime was shown to increase FFT, whereas an increased stress resulted in lowering of CFF thresholds (Wang, 1965). A decrease in CFF thresholds had been reported in many other incidences (Piern, 1952; Kotter et al, 1964). In these studies a lowering of
CFF threshold after physical exercise has been demonstrated. Grandjean (1971) also reported a decreased flicker sensitivity in air traffic controllers as a result of physical workload.

Next hypothesis of the study predicated that as a result of low physical stress, there would be an increment in performance on multiplication task as well as on hand steadiness. The results show that in low stress condition, the mean number of multiplications was 82.5 in before condition which increased to 91.7 after the low physical stress treatment. This increase was significant at .005 level (Table 8). The mean errors on hand steadiness were 21.0 in before condition, compared to 16.8 in the after condition. The obtained decrease in errors in performance, was significant at .005 level (Table 8). This significant decrease in errors is a clear indication of improvement in performance. Thus the results are consistent with the hypothesis and improvement in performance on both the tasks i.e. multiplication and hand steadiness as a result of low level of physical stress was observed.
Fig. 14 showing the output of individual subjects on multiplication task in low physical stress group.

Fig. 15 showing the output of individual subjects on multiplication task in high physical stress group.

Fig. 16 showing the mean output on multiplication task of low and high physical stress group in before and after conditions.
Fig. 17 Showing the errors committed by individual subjects on hand steadiness task in low physical stress group.

Fig. 18 Showing the errors committed by individual subjects on hand steadiness task in high physical stress group.

Fig. 19 Showing the mean no. of errors on hand steadiness task in low and high physical stress group in before and after condition.
Table 8. Showing the mean score of performance before and after the low and high physical stress treatment and significance of differences between these means.

<table>
<thead>
<tr>
<th>Task</th>
<th>Mean score on Performance</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment</td>
<td>Before stress</td>
</tr>
<tr>
<td>Multiplication task</td>
<td>Low physical stress</td>
<td>82.5</td>
</tr>
<tr>
<td>(number of multiplications</td>
<td>High physical stress</td>
<td>86.2</td>
</tr>
<tr>
<td>done by S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand steadiness (number of</td>
<td>Low physical stress</td>
<td>21.0</td>
</tr>
<tr>
<td>errors)</td>
<td>High physical stress</td>
<td>20.9</td>
</tr>
</tbody>
</table>

*P < .005

The last hypothesis of the study had predicted that high physical stress would decrease the performance on both multiplication task and hand steadiness test. The mean number of multiplications done by Ss decreased to 58.6 in after condition compared to 86.2 in before condition (Fig. 16). This observed decrement was significant (p < .005). Mean number of errors on hand steadiness in before and after condition were 20.9 and 29.9 respectively (Fig. 18). The increment in errors was significant at .005 level (Table 8) indicating that the
decrement in performance on hand steadiness task as a result of high physical stress was significant. So, the hypothesis which predicted that there would be a decrement in performance on multiplication task and hand steadiness, is also proved.

Thus, the effect of the physical stress was similar to the effect of mental stress on CFF and level of performance.

Summarising the results of the two experiments, low degree of stress, whether mental or physical was observed to improve the level of performance and CFF threshold, whereas a high degree of stress was observed to cause a decrease in flicker fusion sensitivity and an impairment in performance.

The obtained variation in the effect of low and high levels of stress on both i.e. CFF and performance may be interpreted on the basis of arousal hypothesis (Yerkes and Dodson, 1908; McBain, 1961). In fact these are the two different physiological systems which determine the level of performance i.e. activating and inhibitory system. These are highly influenced by the arousal. The arousal hypothesis states that the relationship between the level of arousal and level of performance takes the from of an inverted U. And according to this hypothesis at very low levels of arousal due to the lack of activation the performance
level may be low. But at relatively low and moderate level of arousal, the activating system starts ruling over the inhibitory system and improved performance may result. However, after an optimum level of arousal any further increase would lead to an impairment of performance potentialities, due to distingregation of physiological systems. Grandjean (1979) have given a similar explanation for changes in CFF threshold as a result of stress. According to him, during inactivity or performance of very monotonous tasks, CFF decreases due to central inhibition.

In the present investigation also the low level of stress was not very low as the subject worked for 40 min in mental stress condition and for 3 min on bicycle ergogram in physical stress condition. Both of these workload levels were sufficient to induce stress as indicated by increase in blood pressure. This may be the cause of an increase in CFF and performance. Similarly the BP increase indicates that in high stress condition the stress was quite high, at least much more than the moderate level. Thus, the changes in CFF and performance as a result of high stress can also be interpreted on the basis of arousal hypothesis.

Welford (1973) have also emphasized that man is constituted in such a way that he functions best under conditions where a moderate demand is made upon him.
His performance is less than maximum not only if the demand upon him is too high, but also if it is too low. So, it is necessary to think in terms of both positive and negative departure from optimum as source of stress.

Korchin (1964) and Easter Brook (1959) concluded that deterioration of performance occurs due to restriction of perception.

Landis (1951) has described that any condition which decreases the available blood sugar and/or blood supply to the retina and/or brain decrease the CFF. whereas conditions increasing the efficiency of vascular supply increase the CFF. Since, two level of stress acts to facilitate the efficiency of retina and/or brain and as a result, there is an increment in CFF threshold. In high degree of stress, the efficiency of brain and/or retina is decreased due to over arousal and CFF threshold is decreased.

Pullen and Stagner (1953) have discussed two complex response systems as determinants of an individual's perception. System 'R' is related to reality oriented responses and system 'W' is responsible for withdrawal activities. Decrement in performance and CFF is observed because of the activation of 'W' system.
Generally, in high stress condition the S has a tendency to escape. As a result of high mental or physical workload, the psychological system 'W' might have been activated compared to activation of system 'R' in low stress condition, and thus resulting in lowering of CFF.

This investigation was mainly designed to see if the mental or physical workload could have an effect similar to the effect of stress. To sum up this investigation the low level of mental and physical workload increased the CFF thresholds and improved the task performance as observed in many previously cited studies in which other forms of stress were taken. Similarly, just like any other form of high stress, high workload (both mental and physical) was observed to lower the CFF thresholds and impair the performance. Thus, on the basis of the obtained results it could be inferred that the 'workload' either mental or physical does act as a stresser and the effect of mental and physical workload is similar to the effect of stress on CFF and performance.

Implications of this study:

From 1940s, psychologists have been interested in knowing about the numerous effects exerted by various forms of stress. Kakimoto (1964) reported that workload
acts as a stressor. In every day life we all perform various kinds of mental as well as physical activities which may act as stress, thus affecting the levels of performance, due to activation or inhibition of perceptual motor capabilities. In Industry and office routine work both mental and physical workload is an impinging force working on the employees. Similarly in military training also various kinds of work load is involved.

The present study was designed to investigate the effect of physical and mental workload on performance and CFF. The findings of this study are of immense practical utility in industry, military as well as our daily life. It clearly indicates that the workload should not exceed certain limits. The workload has been found to act as stressor and this stress, if increased beyond an optimum level was found to impair the motor and perceptual abilities. It has been inferred on the basis of obtained results that any work should not demand either too low or too high from an individual in order to maintain high efficiency levels and to avoid the disintegration of physical and psychological systems of an individual.

Suggestions for further work:

1. In the present study, only two levels of mental and physical workload were taken. To establish rather more clear relationship, more levels of physical and mental stress should be taken to study their effect on CFF
and performance.

2. The effect of mental and physical workload was studied on CFF and task performance in the laboratory and it was therefore a laboratory study. The concept of workload should be extended to industrial use to have a better idea of the effect of such workload in industry and military. Similar kind of studies should be conducted in actual industrial situations or simulatory set up and in the military itself.

3. It has been concluded in this investigation that workload acts as a stressor, on the basis of changes in performance level and CFF, which are more or less psychological in nature. Same should be confirmed by studying the biochemical and physiological changes brought by different levels of physical and mental workload, before actually concluding it in a definite manner that 'workload' is a stressor.