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Effect of angle of abduction and illumination level on performance in a human-machine interaction environment

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Abstract: An experimental investigation was conducted to evaluate the human performance in the context of human-machine interaction environment. It was observed that both the illumination level and an angle of abduction have significant effect on human performance when workers work in human-machine interaction environment.

Key words: ergonomics, angle of abduction, illumination level, anthropometry

INTRODUCTION

In this era of automation both management and workers are concerned with the quality of work lives, ergonomics and occupational safety and health. Since the 1960's, the rapid growth of information systems has led to the wide development of research on human-machine interaction (HMI) that aims at the designing of human machine interfaces presenting ergonomics properties such as usability, transparency, compatibility etc. Stenzel and Sommer [1] measured output from 12 people working at a leather goods factory over a 4 year period in the middle of which illumination was varied. It was found that the performance improved with increased illumination. Benneti et al. [2] studied the effect of illumination levels on catching behavior in professional cricketers. It was noted that the illumination level should be optimized to get superior performance from the cricketers. Juslen and Tenner [3] suggested that changing the lighting increases the workers performance.

Body movements occur around moveable joints. Each type of joint allows certain type of movements. Abduction is a movement of a body segment towards the midline as when moving the arm from the outward horizontal position downwards to the vertical position. Cormick and Sanders [4] found truck drivers to be taller and heavier than general civilian population. Body measurements vary as a function of age, sex and for different ethnic population. Okunribido [5] conducted an anthropometric survey of female workers in Nigeria and it was observed that Nigerian female hand is wider and thicker but shorter than females from UK, Hongkong and America. Akmal [6] studied the effect of angle of abduction pertaining to the optimum design of human-machine interaction system and concluded that angle of abduction has no statistically significant effect on the data entry task. Khan and Asghar [7] performed a study of an angle of abduction in a computer numerically controlled electro discharge machine (CNC-EDM). It was found that the optimized angle of abduction was 45° for superior performance. The main purpose of ergonomists is to design workplaces which are comfortable to fit both the body and mind of the worker. Nowadays, there has been a rapid growth in the use of computers at variety of workplaces and a new field of study is emerged which is termed as human machine interaction environment. In the present research work, two studies have been carried out. Firstly, the effect of illumination level when the workers work on computer numeric control milling machine have been studied. Secondly, the effect of angle of abduction was evaluated experimentally.

BRIEF DESCRIPTION OF EXPERIMENTAL SET UP

For the experimental investigations an experimental set up was fabricated within the CNC room in the National small scale industries corporation limited (NSIC), Aligarh, and (India). The fluorescent tubes were arranged to obtain different illumination levels (100 lux to 900 lux).

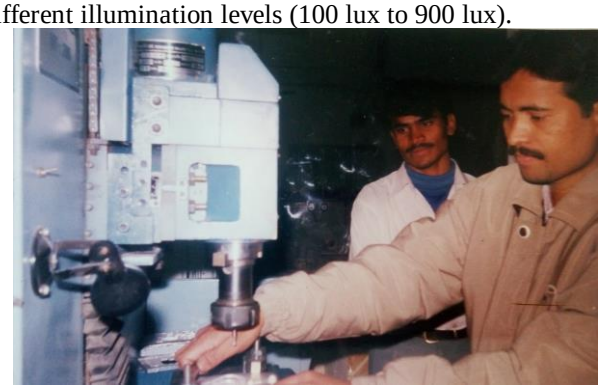

Fig 1: photograph showing a subject fixing a job

A digital lux meter was used to measure the illumination level. The arrangements have been depicted in Figs. 1, 2, 3 and 4.

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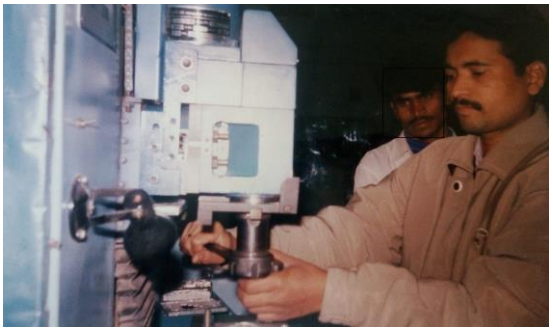

Fig 2: photograph showing a subject fitting a tool

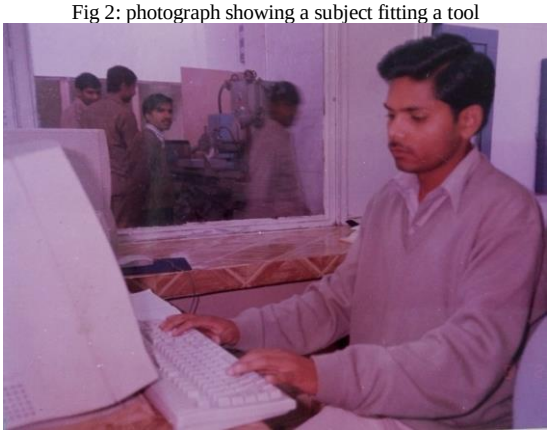

Fig 3: photograph showing operator entering the computer program for machining

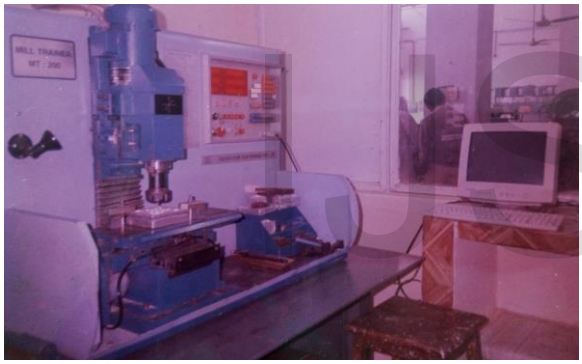

Fig 4: photograph showing CNC milling room

The set-up is comprised of following subsystems: CNC mill trainer *MT200*, a digital lux meter (*Model 101, Range 1 to 50,000 lux*), an electronic switchboard having arrangements of a fluorescent tube lights, an electronic timer (*LCO stopwatch quartz-016*), provision of fluorescent light sources, VDU with the keyboard and a program in machine control language for feeding the program in the computer of CNC milling machine.

SUBJECTS SELECTION

The subject's selection has been one of the most important factors which determine the reliability of results of any ergonomics experiment. When illumination level was varied eight subjects from same sex (males) were selected to participate in the study. When angle of abduction was varied twenty-one subjects were selected to participate in the study. All the subjects chosen were skilled and have knowledge of CNC milling m/c.

EXPERIMENTAL DESIGN

One of the primary purposes of experiments in which the same subject was observed under each of the treatment was to provide a control on differences between subjects. In this type of experiment, treatment effects for subjects 'i' was measured relative to the average response made by subjects on all treatments. So, each subject serves as his own control and responses of individual objects to the treatment was measured in terms of deviation about a point. The average responsiveness of the subjects was measured. The experiments in which the same elements were used all the 'k' treatments required observations on each element. Hence, the term repeated measure was used to describe this kind of design. The present work was based on single factor repeated measure type of statistically design. Here two dependent studies are undertaken as detailed below.

Study 1: The independent variable is level of illumination. The various illumination levels used were (100 lux, 200 lux, 530 lux, 860 lux). At these illumination levels the task structure was to enter the computer program for machining. Four levels of illumination were used to evaluate the effect of illumination on human performance. Based on the calculations the optimum illumination level was determined.

Study 2: The independent variable is angle of abduction. The two types of tasks were performed by the subjects, one was to fix the job and another one was to change the tool. Twenty one subjects performed this experiment. Seven subjects of height 5′4″, seven subjects of height 5′6″, seven subjects of height 5′9″were chosen for the experiment. The time taken to complete the task was noted as an index of performance.

METHODOLOGY USED DURING EXPERIMENT

In the NSIC in the machine room where CNC milling machine was kept the illumination level was kept (i) 100 lux (ii) 200 lux (iii) 530 lux (iv) 860 lux and then the 8 skilled subjects perform the experiment. The time to feed the program was noted. In the second study where the effects of angle of abduction was considered the 21 subjects were asked to perform the tasks. The time to fix the job and the time to fit the tool was noted down.

RESULTS

For the study on the effects of illumination level in a human machine interaction environment the data was collected and the results were obtained for the eight subjects belonging to male population. The time taken to feed the program was taken as an index of human performance. Over the data collected the analysis of variance pertaining to the single factor repeated measure type of statistical design was performed. The results of the analysis have been shown in Table I.

Table I: Summary of analysis of variance for the study pertaining to the effect of illumination (Study 1)

Sources of variation	S.S	Df	MS	F
Between people	3.75	7		
Within people	6.75	24		
illumination	1.99	3	0.6633	1.67
Residual	8.34	21	0.3971	

At $\alpha = 0.10$, F ratio was used in testing hypothesis about the effect of level of illumination on human performance while working on CNC milling machine. At 0.10 level of significance the null hypothesis (with the critical value of F ratio as $\{F_{0.90}(3, 21) = 2.36\}$ was contradicted by the experimental data.

With this result it was concluded that statistically, the level of illumination considered in this study showed a significant effect on human performance.

The analysis of variance based on the single factor repeated measures type of design revealed that the variable, illumination has been a significant factor in human machine interaction environment. To establish which one out of the four considered illumination levels could be more compatible the data was further analyzed by method of comparison of means proposed by Winer [8]. This indicated that illumination level 860 lux offered an optimum performance. The analysis of variance is employed where the F- ratio ($F= MS_{illumination\ level}/ MS_{residual}= 1.67$) is used in testing hypothesis about time in minutes to enter the program as a function of the effects of the illumination level.

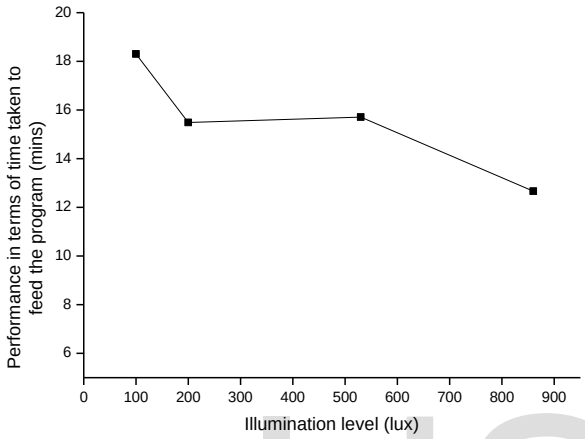

Fig. 5: Graphical representation of the performance in terms of time taken to enter the program in minutes when illumination level is varied

For a 0.10 level test on the hypothesis that $T_1=T_2=T_3=T_4$, the critical values from ANOVA table for the F-ratio is $F_{0.90}=2.36$. The experimental data contradicts this hypothesis. The data indicates that illumination at 860 lux is different in its effects on the performance of an operator, from the effects of the other three illumination level.

To test the hypothesis $T_1=T_2=T_4$ the sum of squares for these three illumination level is given by

$$SS_{illumination\ 1,2,4} = [T_1^2 + T_2^2 + T_4^2] / n - [T_1 + T_2 + T_4] /3n \quad (1)$$
$$= 0.61375$$

Observed F statistic

$$F = MS_{illumination\ 1,2,4} / MS_{res} = 0.7866 \quad (2)$$

And by the comparison of means for a 0.10 level test the critical value of this statistics is

$$F_{0.90}\ (2, 21) = 2.57 \quad (3)$$

Since the observed F statistic does not exceed the critical value , the data do not contradict the hypothesis that $T_1= T_2 =T_4$ which shows that the performance at 860 lux is optimum illumination level as far as human performance in human machine interaction environment is concerned.

Table II: mean value of time taken to enter the program in minutes at respective level of illumination

Level of illumination (lux) i	Mean value of time taken to enter the program in minutes (P)
100	18.3
200	15.49
530	15.71
860	12.66

An attempt was made to develop a mathematical model for representing human performance measured in terms of (time taken by skilled operator to enter the computer program) under varying levels of illumination (See Fig. 5). A curvilinear model was filled in the data. It had the following form

$$P = A + Bi + C\ i^2 \quad (4)$$

Where P is the performance of skilled operator (expressed in terms of time in minutes taken to enter the program)

i is the illumination (lux) and A, B and C are the coefficient's of 2nd order quadratic. This data was used to develop the model as shown in following Table II.

Using the data of Table II, the mathematical model which was developed is as follows:

$$P = 14.25 + 4(10)^{-5}\ i + 1.59(10)^{-11}\ i^2 \quad (5)$$

The error sum of squares of this model has been noted to be 15.93.

Table III: Observation table showing effect of illumination level

Subjects	Time (min) required to enter the program at different levels of illumination			
	100 lux	200 lux	530 lux	860 lux
1	3.40	1.51	1.29	1.43
2	2.03	2.16	2.02	1.36
3	1.46	1.14	1.15	1.16
4	2.08	2.25	2.32	1.51
5	2.29	1.58	2.12	1.28
6	2.12	1.36	2.00	2.13
7	2.39	3.09	2.39	1.26
8	2.53	2.40	2.42	2.53

Table IV: Observation table showing effect of angle of abduction

Subjects	Time (mins) to perform the tool task (fixing of work piece and fitting of the tool) at different angle of abduction		
	34˚	36˚	43˚
1	1.38	0.59	0.93
2	0.97	0.67	1.53
3	0.84	0.60	0.81
4	0.89	0.83	0.74
5	1.42	0.78	0.61
6	0.94	0.70	0.44
7	0.92	0.69	0.65

Study 2: For the study of effect of angle of abduction the data was collected and the results were obtained from 21 subjects (male population)(See Table IV). The subjects were asked to perform the tasks. While doing the experiment the illumination level was maintained at 860 lux. Table III shows effect of angle of abduction. The analysis of variance pertaining to the single factor repeated measure type of statistical design was carried out. Table V shows the summary of variance analysis for the study of the effect of angle of abduction.

Table V: Summary of variance analysis for the study of the effect of angle of abduction.

Sources of variation	S.S	Df	MS	F
Between people	0.31	6		
Within people	1.19	14		
illumination	0.49	2	0.23	2.66
Residual	1.04	12	0.08	
Total	1.50			

Fratio was used in testing hypothesis about the effects of angle of abduction. At 0.10 level of sifnificance the null hypothesis (with the critical value of F ratio ie. $F_{0.90}(2,12) = 2.81$ was contradicted by the experimental data. With this result it was concluded that statistically, angle of abduction considered in the study has a significant effect on human performance. To establish which one out of three angle of abduction could be more compatible, the data was further analyzed by method of comparison by means. This indicated that 36° angle of abduction offered an optimum performance. Suppose it has been anticipated that angle of abduction 36° has different effect than others

$$F_{statistic} = SS_c / MS_{res} = 0.344 \quad (6)$$

By the comparison of means, the critical value for 0.10 level test of this hypothesis is

$$F_{0.90}(1,12) = 3.81 \quad (7)$$

The observed data does not contradict the hypothesis that $T_1 = T_3$, which shows the performance is optimum at 36° angle of abduction.

An attempt was made to develop a mathematical model for representing the human performance measured in terms of time taken to complete the task under varying angle of abduction. It had the following form:

$$P' = D + Ex + F x^2 \quad (8)$$

P′ = performance of CNC milling machine operator
x = level of angle of abduction
and D, E and F are coefficients of 2nd order quadratic.

Table VI: Mean values of time taken to complete the tasks under different angle of abduction

X	P′
34°	7.36
36°	4.86
43°	5.71

The data used for developing the model has been shown in Table VI. Using the given data the mathematical model obtained has been given as

$$P' = 5.95 + 0.54 x + (-0.014) x^2 \quad (9)$$

CONCLUSIONS

The experiments which have been conducted succeeded in highlighting the relative importance of selected system (CNC milling machine) and display variables (illumination level and angle of abduction, and provided some indication of the sensitivity of those variables. On the basis of study following conclusions were made

1. The illumination level has a significant effect on the performance of CNC milling machine operators as far as program entry task is considered. The results of the study indicated an optimum performance when the illumination level was 860 lux.
2. The angle of abduction has also a significant effect on human performance

REFERENCES

[1] A.E Stenzel, J. Sommer, 'The effects of illumination on tasks which are largely independent of vision, Licltechnik, Vol. 121, pp 143-6.
[2] K. Scott, D. Kingsbury, S. Benneti, "Effects of cricket ball colour and illuminance levels on catching behavior in professional cricketers," *Ergonomics*, vol. 43, pp 1681-1688, 2000.
[3] H. Juslena, A. Tenner, "Mechanisms involved in enhancing human performance by changing the lighting in the industrial workplace", International Journal of Industrial Ergonomics Vol. 35, pp. 843–855, 2005.
[4] Sanders, M. Cormick, " Human factors in engineering and design", Tata Mc Graw Hill publishing company limited, New Delhi, 2009.
[5] O.O. Okunribido, " Technical note: A survey of hand anthropometry of female rural farm workers in Ibadan, Western Nigeria", Ergonomics, vol 43, pp. 282-292.
[6] M.H. Akmal, "Studies on the effect of angle of abduction and keyboard inclination pertaining to the optimum design of a human computer interaction (HCI) system, MSc (Engg.) thesis, Z.H.C.O.E.T, AMU, Aligarh, UP (India).
[7] I. A. Khan, M. Asghar, " Ergonomic evaluation of the angle of abduction in a computer numerically controlled electro discharge machine environment" Cogn Tech Work Vol. 12, pp 263–269, 2010.
[8] B.J. Winer "Statistical principles in experimental design," 2nd Edition. New York Mc Graw Hill book, 2008.