Effective Cognitive Task Analysis for Improvement of Performance- Application of SWAT

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ABSTRACT

Process Control monitoring has an added dimension in view of the complexity of the job , mental workload of the operator under stress, human error due to lack of experience in receiving stimuli and lag in choice reaction time and response time. This paper analyzed the different condition of human being under mental workload in cognitive environment and the error which may be generated due to fatigue in operating consistently within the manufacturing system. The nature of task and workplace variables with respect to an intensity of perceived workload measured in a suitable scale to compare their impact on different types of factors involved in it . Attempt has been made to measure the subjective mental workload through Subjective Workload Assessment Technique (SWAT). This is compared to the reaction and response time of an operator in receiving the signal visually and combining it with an auditory system as required in simulated condition to project skill and knowledge of an operator to run the computer controlled machine as well to interpret the machine language and program. The result of the performance in different working condition and with the knowledge and capability to interpret signals will help in system's improvement increasing its cognitive ability.

Key words : SWAT, Cognitive, Mental work load, Stimuli

INTRODUCTION

Operators engaged in any technical cognitive system are often required to adopt to dynamically changing task and environmental demands. This may be achieved by modifying systems management strategies in order to maintain high priority task goals , ensuring system ability as well as correcting and repairing system fault (Meshkati , 2003). In complex system when the system runs into an unknown state ,training in a simulator is one possible consequence ,better is permanent on line control. According to Bainbridge, high skilled operator tends to lose the potential to be aware of the whole process. They need a special attribute to be open minded. To increase the signal rate of the system comprising of machine and human operator artificially is not an appropriate design strategy for the network including subroutine of the system.

Primarily mental workload can be considered as the theoretical constructs in improving cognitive performance(Moray 1979,Wickens 2008) and analyzing such task complexity it has been opined by many ergonomist that human operator face increasing cognitive demands associated with increased task complexity in operations where cognitive skills are more important than physical ones(Cacaibue, 2004, Boksem and Tops 2008).Even if task complexity related to task characteristic is one of the most essential factors affecting performance, most frequently mental workload (MW) a cognitive workload is the term used to describe the mental task of accomplishing task demands (Wickens 1984, 2002, 2008). In analyzing cognitive task it has been noted to introduce automation and to reduce the risk of task and increasing workload benefit(Sheridan and Parsuraman, 2005, Parsuraman and Wickens 2008) the question remain regarding automation design of functional allocation about what degree of automation is acceptable in maximizing performance of human-machine system(Ingaki, 2003). But level of automation should follow a mean level based on the demand of particular industry otherwise over automation poses problem in continuously changing product or a product of complex nature in comparison to range and accuracy in automation system. Intermediate levels of automation results in better performance(Lorentz et ,al , 2002, Manzey et al 2008b)and reduced operator workload supported by involvement of minimum cost and hazards (Miller and Parsuraman,2007). Static or fixed automation cannot serve the varying product requirement or inter alia machine requirement and less flexibility in automatic always causing problem in performance improvement (Ingaki 2003, M Endsley 2006, Jergress Sauer and others 2012).

1.1 The multiple resource model developed by Wickens (1984,2008) is a theoretical framework for workload assessment related to human information processing. The model provides an explanation for mental activity changes that follow after changes of the operational difficulty (e,g. task difficulty and time pressure etc,). Wickens model studied and the following features noted: (a) input /output modalities of information processing (b) effect of response based on stimulus perception depending on short term memory and long term memory(c) response execution. However high similarity in the resource demands imposed by task components leads to severe competition for similar resources which results in high level of workload. This could be the case probably due to high demands of perceptual analysis or working memory processing. The development technique for measuring mental workload has been a fundamental research topic in psychology and applied ergonomics for considerable period. In order to estimate alternative solutions to a system design, it is not only necessary to focus on the output supplied by the system but also on the workload experienced by the operator .Consequently , the ability to continually measure mental workload correctly, is closely related to measuring performance in Safety Critical context (Gould ,2009) and designing and appropriate and adequate strategies for automation(Jou Y-T, et,al 2009; Cacaibue and Carston 2010). Eventually mental workload is required to be measured indirectly by measuring variables considered to be related to it.

1.2 For the safe and efficient operations of complex systems require material workload impounded on users does not exceed their capacity (Eggemeiver , Wilson, Kramer & Dames, 1991, Jex 1988, Tsang and Vidulich 2006) .Even if capacity is not exceeded , a system design that imposes a high mental workload leaves less capacity for the task as such and is more taxing to use them a system design that imposes low mental workload .This may have important consequences because users change their behavior when they experiences high mental workload by e.g. responding more quickly to catch up towering their performance criteria , post poning minor tasks to preserve resources for major tasks , or experiencing distress (Eggemeir & Wilson 1991).For these reasons reliable , valid ,and easy to administer methods for measuring mental workload are important to the evaluation and iterative design of systems (Tsang and Vidulich , 2006; Xie and Salvendry,2000).Perceived time has been proposed as one such method (e.g., Block, Hancock & Zakay, 2010; Hart, 1975; Liu & Wickens, 1994; Zkay and Strub ,1998). Incidentally Subjective Workload Assessment Technique(SWAT) has been developed as a generalized procedure for scaling pilot mental workload in a variety of systems ,and for a number of tasks (Reid and Nygren, 1988, Meskati 1995)

1.3 Again in the industrial climate cognitive ability demands mental alertness which is varying with the nature of job. Psychologists and ergonomists have particularly shown their interest in speed of reaction to give response against the stimulus received by the operator. because a study of reaction time give them an insight into mental problems, and ergonomists because reaction time can often be used as a way of assessing the ability to perform mental tasks. Reaction time means the interval between the receipt of a signal and the required response compose of some essential parts discussed afterwards occupying the substantial part in processing of the signal in brain (Wargo , M, J,1967). A simple reaction time is one that involve a simple signal, and one that is expected ,which is answered by simple motor reaction. The average time for such a reaction is 0.15-0.20 secs. (Swink J.R,1966).Choice reaction time is higher as the time required to process in the brain is higher (Demon A Stouldt et, al 1966).

1.4 People who scores highly on intelligence tests also tend to have faster and less variable reaction time. Efficient size estimates for the reaction time-intelligence test associations are longer in sampling for better representation of samples. For better results we can test the reaction in two different methods or two different machines and can compare them for effective job size for the larger span of operation time and giving better results (Jack Nissan,David Li Wald and I,J Deavy,2o13 Sept Oct).

MATERIAL AND METHODS

An experiment conducted at production engineering department on SWAT and NASA- TLX system with 20 candidates for drilling holes in sized M.S. plates of dimension 50x50x5 mm at four corners each of which will be 5mm dia and 5mm depth with a center hole of approximately 10 mm dia. The task involved the following steps : 1) Making the M.S strips of appropriate dimension from M.S. sheets by electrically powered jaw. 2) Marking at the appropriate positions for drilling holes. 3) Fixing the 5 mm diameter drill bits in magnetic chuck. 4) Lowering the bit on the marking aligning the tool and job. 5) Turn on the power to rotate the drill. 6) Press the radial wheel for lowering the bits for drilling up to 5 mm. 7) Stop the operation and fix the drill for the next corner just like first and 8) complete all the four corner holes 9) Change the drill bits for 10 mm dia. 10) Repeat the operation for 10 mm 11) Finish the job after polishing with the grinder. The workload for the subjective task is a bit complex as the job to be completed maximum of 5 nos. and within one hour and depends on skill, mental work load on timing and . 2.1 As work demands more complex, the need for measures to determine mental workload increases. Several techniques have been proposed to quantify ability to focus on multiple complex phenomena at the same time. Mental workload techniques can be grouped into three broad measures: Psychophysical, Performance and Subjective (Owen 1992, Veltman, 2002). Each measure has specific applications an limitations in determining the mental workload associated with work demands and environment. Following table 1 provides an overview of the three workload measures briefly:

Table 1: An overview of the three workload measures briefly

Measures	Underlying Assumptions	Measurement Indicates	Measurement Limitations	References
Psycho-Physiologic	Physical functioning changes when cognitive demands change	HeartRate, Variability, Respiratory changes, B.P. Fluctuations, eye blinks, Control Limbs And Oxygen Assumptions	Internal Validity is inspected by complexity of effects, dependent and independent variables Control and pressure confounding and extreme variables	Haga, et al 2002;Robinson 1921 and Veltman 2002
Performance	Attention Load Change cause performance or behavior changes that can be measured and predicted	Change in Reaction time and accuracy of the task or performance measure	Participant must perform a second task in order to assess the processing demands of a primary task.	Gregg , 1993 , Haga et al 2002 ,Kerr 1973 Owen 1992a,1992b
Subjective	Participants are aware of their mental workload or attention capacity and can estimate variations in mental workload.	Self reported responses to questions about the amount of mental processing required to complete their work.	Validity relies on the human's ability to provide information about the effort and support required to complete the work.	Hart and Steveland 1988,Tomporwski 2003; Veltman 2002

The principle that guided the development of SWAT was the following:

1 To develop as precise measures as possible while minimizing the intrusiveness of data collection procedure in the operational situation. 2 To place minimal measurement constraint on the complexity of judgement task that is required of the operations making workload evaluations. 3 To provide a mechanism for testing validity of the formal measurement model that is assumed by the underlying additive model of SWAT (Reid and Nygen, 1988).

In the present study Subjective workload ratings measured vide commonly utilized scale as described subsequently by Nasa Task Load Index (NASA- TLX-Hart and Steveland,1988) and the model scale method as mentioned in Reid and Nygen ,1988. Secondary Task Method applied in our study to measure the residual mental load after measuring the Primary Task of Drilling from task at Sl no 3 to Sl no 11 and the secondary task of sizing and marking for holes drilling in the activity 1 and 2.In the assessment of mental workload different approaches subgrouped in the pattern as 1 Measures as Primary Purpose (activity 3 to 11) 2 Secondary task of sizing and marking as a change of job 3 Application of Subjective Rating ale 4 Reaction and response study of the operator.

Further personal opinion of the operator obtained through a questionnaire devised exclusively related to their task. The age groups of the operators are around from 21 to 24 and in the group three ladies were also present for carrying out their task. The questionnaire includes the main thrust areas in 8 fields with total 20 subgroups to make the idea clear to the operator. These questions are in the field 1Mental Demand (4) 2Physical Demand (3).Temporal Demand (2) 4 Performance (2) 5 Effort mental and sensory (3) 6 Fatigue (2) 7 Activity (2) 8 Frustration (2).Example of such questions are in the field of Mental Demand are A How much mental and perceptual activity was required(e.g; thinking, deciding, calculating, remembering, looking or searching) B Was the task easy or demanding C Was the task simple or complex D Was the task exacting or forging ?. Similarly the Temporal Demand can be elaborated through A How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?(heavy, moderate or negligible) and B How satisfied are you on accomplishing the job ? (80-100%, 60-80% and 40-60%).The participant have to answer by ticking the alternative against each.

Presently the scale applied is Thurston Scale for performance rating in all the fields of study in Nasa Telex Load Index. In this scale two extreme points of favorable and unfavorable points rated as 0 and 1.and the ratings are subdivided equally in ten points with the difference between any two consecutive sub group is 0.2.For measurement purpose the rating for High is 0.8-1, Average 0.6-0.8 and Low as 0- 4-0.6 and for precision in between reading indicated specifically. The primary and secondary task was explained to the candidates for three days and the study of Reaction time noted in a computer with the help of computer operated system for marking the holes after receiving the signal. Each operator is required to complete the marking the hole within the same specified limit.

This exercise will help in identifying the mental alertness, accuracy and capability to complete the operation within the scheduled time .The starting and finishing of the job will be kept by the computer and the accepting the grid holes will be decided by computer depending on the hitting position of the cursor of the total grid. Performance recorded for reaction time in time in millisecond(Kosinki , Robert J.2005, Marieb Elaine N) While the total time required to complete the job has been recorded as response time. The achievement is recorded in Thurston scale identifying the three level of operation as A indicate 80-100%, B 60-80% and C as 40-60%.However the entire range of reading has been subdivided from 0 to 30 in 10 equal grading and 0% at 0 to 100% at 30. Choice reaction time test which tests how fast the candidate can respond after appearance of dots and at random selection of grid holes for total selection within 30 seconds. This exercise compared with SWAT measure of time load, mental effort and stress load. The result of reaction and response time is applied for assessment of spare time and confusion level.

Result thus obtained in NASA-TLX method can be compared with the computerized system for performance test in Reaction and Response time and the same can be analyzed for further improvement considering the actual problem in occupation. Result obtained separately for both the experiment and thereafter compared for analysis .de Computer used for this purpose is LENOVO DESKTOP 57-130225, Core 13, 2GB, 500 GB, and DVD RW.DOS

RESULTS

Table 2: NASA–TLX rating scales application for evaluating the Subjective Work Load (Thurston Scale)

Sl No	SWAT FACTORS	Range L(0.4-0.6) M(0.6-0.8) H(0.8-1.0)	Description	Reading	Total/Mean	Remarks
1	Mental Demand	L,M,H	1Level of Mental & Perceptual Activity 2 Was the task easy or demanding 3Simple or Complex 4Easy or Demanding	10 - - L 7- - M 3-- H	5.64(0.56) 4.41(0.63) 2.45(0.85)	σ=1.78 S.E=1.02
2	Physical Demand	L,M,H	1 How much physical activity needed in aligning , tools setting& operation 2Was the task easy or demanding etc 3 Leisurely and rapid	9- - L 6--- M 5-- H	4.86(0.54) 3.90(0.65) 4.10(0.82)	σ=0.13 S.E=0.075
3	Temporal Demand	L,M,H	1Time pressure required for task 2 Personal Satisfaction	8—L 7—M 5-- H	4.184(0.523) 4.34(0.620) 4.06(0.812)	σ=0.05 S.E=0.029
4	Performance	Excellent 80—100 Good 60—80 Fair Rest	1Successfulin minimum time 2 Job satisfaction 3 % achievement of target	Exc— 5 Good—7 Fair-- 8	265(53) 501.34(71.62) 448(56)	Exc – Excellent σ=67.43 S.E=38.93
5	Effort	L,M,H	1 Mentally how much effort required 2 How hard physically you have to work	L— 6 M- 8 H-- 6	3.252(0.542) 5.152(0.644) 4.95(0.825)	σ=0.74 S.E=0.427
	Fatigue	L,M,H	Tired, worry & worn out versus energetic, fresh & vigorous	L— 8 M-- 8 H-- 4	4.416(0.552) 5.08(0.635) 3.256(0.814)	σ=0.21 S.E=0.121
7	Activity Type	As per description	1Skill2Ruleor 3Knowledge based	5-skill,7-Rule,9-Kn	04APT,0.3RULE 0.3 Knowledge	
8	Frustration Level	L,M,H	Fulfilled or Exasperated	Nil Exas.		

Table 3 : Measurement of Choice Reaction time and total Response Time Performing Dot Test Duration 30 Sec

Sl No	Candidate Identity/Age	Total of 5 reaction time for Starting in millisecs Starting , hitting1st dot	Average reaction Time in millisec Starting hit	Response Time Score in 30 Secs Maximum Score 40	Response Performance InThurston Scale
1	M1(22)	1435 2963	287 580	27	0.675
2	M2(23)	1566 , 3067	315 611	23	0.575
3	M3(22)	1548 2886	309.6 577.2	26	0.65
4	M4 (23)	1428 2912	285.6 582.4	27	0.675
5	M5(24)	1623 3114	324.6 622.8	28	0.70
6	M 6(22)	1670 3026	334.0 605.2	26	0.65
7	M 7(23)	1522 2995	304.4 599	25	0.625
8	M 8(22)	1467 3216	293.4 643.2	30	0.75
9	F1(22)	1586 3365	317.2 673	21	75.5
10	F 2(21)	1621 3298	324.2 659.6	23	0.575
11	F3 (22)	1586 3139	317.2 627.8	24	0.60
12	M9 (21)	1576 3266	315.2 653.2	26	
13	M10 (22)	1494 3196	298.8 639.2	28	0.65
14	M 11(21)	1598 3218	319.6 643.6	25	0.70
15	M 12(23)	1466 2945	293.2 589	24	0.625
16	M13(22)	1594 3078	317.2 615.6	19	0.60
17	M14(21)	1534 3176	306.8 635.2	23	0.475
18	M15(22)	1599 3323	319.8 664.6	22	0.575
19	M16(21)	1622 3400	324.4 680	23	0.55
20	M17(22)	1523 2965	304.6 593	21	0.575
					0.525
	Mean Value		**310.59 559.03**	**24.55**	**0.625**

Subjective Workload Asessment Technique (Wickens and Holland,2000) as rated with the performance analysis of Table 2 and Table 3 on 1Time load 2 Mental Effort Load and 3Stress Load are as follows:

1Time Load: a Spare time available within experiment 10% b Spare time frequently available 30% and C No spare time available: 60 %

2 Mental Effort Load: a Automatic 40% b Very little Effort: 30% c Extensive mental effort is necessary: 30%

DISCUSSION

After considering both sets of task as noted from NASA-TLX or SWAT(Holland and Wickens) it is apparent the there is a relationship between the two sets of reading and observe the time factor is an essential element in the mental Workload (MLW). Mental Effort is related with knowledge base where the skill is related with the automatic operation of the machine .This is inferred from the reading of the choice reaction time where the standard deviation is comparatively less among the candidates while effort required with skill draws excessive demand both mentally and physically in drilling and sizing. In actual cognitive task particularly in production this difference can be eliminated by training or induction in the areas where the temporal demand, effort and skill or knowledge level is not harmonized. This obviously leads to seeking support and premature fatigue about the job. Therefore regarding performance the minimum time can be improved by practicing the jo and increasing the machine knowledge. The interest in performing the hit and dot test is much more than the actual drilling exercise .Environmental factors and task or load of the job are important factor for this type of difference. The benefit of subjective technique is apparent. The do not affect primary task performance and they are relatively easy to apply and interpret in actual work situation.

RELEVANCE

Worker engaged himself in the operation of controlling electrical and electronics based systems related with current, voltage or amplification simultaneously with related mechanical control of speed, feed, drives, temperature, pressure or supplied volume of fluid be needs to be assessed for the mental alertness, MWL or aptitude for which both type of test important for analyzing the performance and difficulties. Operation with multiple machines also requires careful handling and sensory part should be effectively applied with MLW and temporal demand of the operator. The nature of change of task in different machine makes the prediction sometimes insensitive due to task variation. Graphical presentations of some factors are shown below:

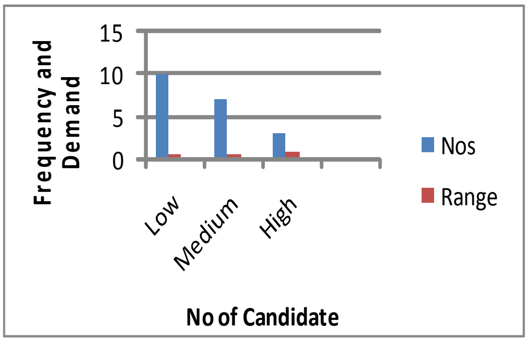

Fig 1: Mental Demand vs no of Candidate

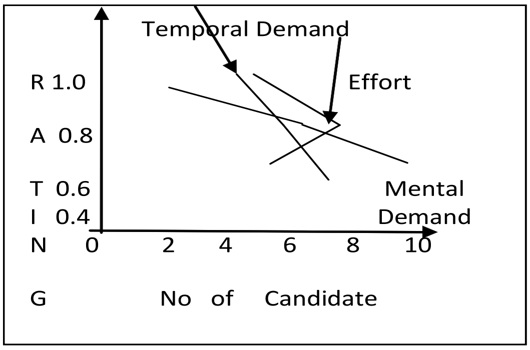

Fig 2: Relation of Mental Demand with Effort

From the graphical presentation of the mental demand it has been observed that mental demand increases with the effort of the candidate. The high rating associated with lower clustering of manpower profile .The rating of the effort on the part of the candidate is being interfered with the other factor like fatigue, performance and physical demand of the job so long it is in the lower and middle order range but the higher reading of the effort drag the results upwards overcoming the barrier improving the performance.

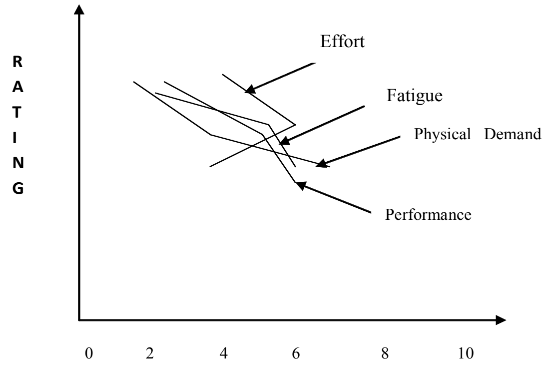

Fig 3: Clustering of candidate vs Factors SWAT

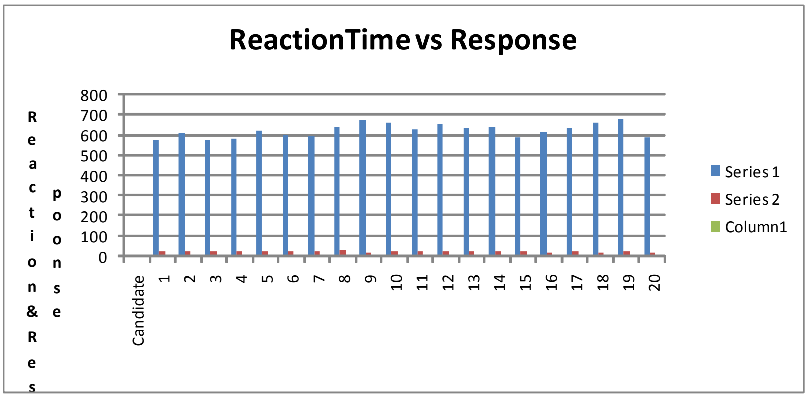

Fig 4: Showing reaction of candidate

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