THE MEDIATING EFFECT OF PERSONALITY TYPE UPON THE RELATIONSHIP BETWEEN MANUFACTURING SYSTEM DESIGN AND MENTAL WORKLOAD

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Abstract: In the last decades, the conveyor belt system has partly switched to a cellular manufacturing system in Japanese manufacturing industry. It has brought both economic and environmental successes to the leading companies. Although the cell system stimulates the motivational aspects of workers according to the concept of the Herzeberg's two-Factor Theory increasing job complexity is expected to place higher mental demands on workers with Type A personalities. This study was designed to test an empirical hypothesis: job complexity might be positively related to subjective mental workload and sympathetic arousal among participants rated high on the type A behavior pattern. The results from the NASA Task Load Index and spectral analysis of heart rate variability presented evidence for the mediating role of the type A behavior pattern in the relationship between manufacturing system design and mental workload placed on workers.

1. INTRODUCTION

The Job Characteristics Model proposed by Hackman and Oldham (1976) is a widely studied model of motivational job design, which describes the relationship between job characteristics and psychological states to work. The model includes five core job characteristics related to the motivating potential of a job: “skill variety” (i.e., the perceived variety and complexity of skills and talents required to perform the job), “task identity” (i.e., the extent the job is seen as involving a whole, identifiable task); “task significance” (i.e., the extent that the job affects the well being of others); “autonomy” (i.e., the extent the job is seen as allowing for personal initiative in performing the work); and “feedback from the job” (i.e., the extent that the job, itself, provides information about job performance). This core set of job characteristics impacts the level of job satisfaction and then leads to high intrinsic motivation, high job performance, high job satisfaction and low absenteeism/turnover among workers.

A production system using conveyor belts invented as early as 1785 has been considered a very efficient production method in terms of mass productivity and installed in Japanese manufacturing industry. In the last decades, however, the conventional system has been partly replaced by a new cellular manufacturing system wherein the workstations are arranged in an efficient sequence to produce products from start to finish in a single process flow. Since the system asks each worker to have complete responsibility for producing a family of parts or a product in the system, it will tend to have the core job characteristics in contrast with the conveyor system. As a result, the system will improve the motivational states and raise the level of job satisfaction and accomplishment among workers (Shikdar and Das, 2003). On the other hand, each worker is asked to have mastered a full range of operating skills required by the cell unit. In addition, systematic job rotation and much training necessary for effective cell operations could increase job complexity and place much complex mental requirements on workers pushing into stressful situations. If the new manufacturing system adversely influences worker’s health, the characteristics of mental and physical health consequences stemming from the system need to be seriously considered.

Type A personality is a personality trait that includes being impatient, excessively time-conscious, insecure about one's status, highly competitive, hostile and aggressive, and incapable of relaxation and was described as a potential risk factor in coronary heart disease by Friedman & Rosenman (1959). These
characteristics tend to be invoked when a type A individual is confronting stress and challenge. Since complex jobs potentially represent the stressful situation, a person with type A behavior pattern could respond with adverse cardiovascular reactions such as high blood pressure to the jobs (Oishi et al., 1999, Sudhakaran and Mirka, 2005). Therefore, it seems plausible that job complexity may place greater mental demands on a certain personality trait of workers who are engaged in the new “cell” system. This study was designed to compare mental workload between two different types of manufacturing system; a conventional “conveyor” system and a new “cell” system. In addition, the mediating role of the type A personality in the relationship between manufacturing system design and mental workload was investigated.

2. METHODS

2.1 Participants

Fourteen male university students were recruited as paid participants. The mean age of the participants was 22 years (range 20-25). All participants reported themselves to be in good health and had no history of hypertension, renal disease, diabetes mellitus, or other disease that could affect autonomic nervous function. The nature and purpose of the study were explained in a document personally inviting each participant. All participants agreed to cooperate with the experiment and gave their informed consent.

2.2 Type A Behavior Pattern

Participants were screened using the Japanese version of type A behavior pattern questionnaire for the adults (the KG’s Daily Life Questionnaire, Yamazaki, Tanaka, and Miyata, 1992) to establish a measure of their personality type. The KG Questionnaire consists of 55 items (44 relevant and 11 irrelevant items). Respondents were asked to choose one of the three answers (yes, ?, or no) for each item. The scores of personality type ranged from null to eighty eight. The Type B group consisted of participants who scored less than the median value (39) of the participant group (average 33.3). The Type A group consisted of participants who scored higher than 39 (average 50.3). Finally the fourteen participants were studied in two personality groups of seven Type A participants and seven Type B participants for the experiment.

2.3 Experimental Task

Experimental task was an assembly task of an electric circuit. Participants were instructed to make an electric circuit with twenty-one components with reference to a diagram and a prototype. The 21 component parts were comprised of ten lead wires, two kinds (56 k ohms and 680 ohms) of four resistors, two condensers, two transistors, two light-emitting diodes, and a switch. These components were assorted in different racks to provide an easy discrimination for the participants. The circuit assembled properly had alternately lighting LEDs by distributed power.

2.4 Experimental Conditions

Two experimental conditions were set to evaluate the relation between mental workload and manufacturing system design; a conveyor condition and a cell condition. In the cell condition, the task performance simulated a cellular manufacturing system and was designed to have “skill variety”, “task identity”, “autonomy”, and “feedback” as the core job characteristics. On the other hand, the conveyor condition simulated a production system using conveyor belts was designed not to have the core job characteristics.

2.5 Measurements

Mental workload during the assembly work was multilaterally assessed using three measurements; task performance, subjective ratings, and cardiovascular autonomic recordings. The performance measure was the mean of the assembly time taken to make each circuit. The perceived workload was rated using the NASA-task load index and evaluated for the six dimensions of Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort and Frustration. The autonomic nervous activities during the
task were evaluated by means of spectral analysis of heart rate variability (HRV). Type A personalities have been known to cope with stressful situations accompanying adverse cardiovascular reactions. Both high frequency power (0.15-0.40 Hz) representing the parasympathetic activities and the ratio of low/high frequency power (L/HF ratio) representing the sympathetic activities were calculated to clarify whether the high arousal patterns of type A participants are elicited by the job complexity characterizing the cellular manufacturing system.

2.6 Procedure

The experiment was individually conducted on different days in the order corresponding to the cell condition as a first step and the conveyor condition as a second step. Each participant was provided plenty of practice time on the first day until he demonstrated the task performance without assistance. The cycle time performed in the conveyor condition was individually set according to the median value of the assembly time taken in the cell condition. The task was continuously performed at his own pace in the cell condition or at machine pace (corresponding to the cycle time) in the conveyor condition for 90 minutes. The KG type A questionnaire was administered before the task. The NASA-TLX was completed after the 90-minute task. The assembly time and ECG were measured throughout the task performance. ECG was also recorded for the 5-minute rest taken before and after the task.

3. RESULTS AND DISCUSSION

3.1 Task Performance

Mean assembly time taken to place a component is shown as a function of personality type and experimental condition in Figure 1. In the self-paced cell condition, assembly time for Type B group was significantly greater than that for Type A group (14.08 sec and 12.48 sec, respectively). The type A participants tended to build a circuit faster than those rated low on the type A questionnaire. In the machine-paced conveyor condition, there was no difference of the assembly time between Type A group and Type B group (11.59 sec and 12.24 sec, respectively). The significant difference of the assembly time between two experimental conditions was observed for Type B group, but not for Type A group. These results indicated that participants rated high on the type A personality had a tendency to assemble the electric circuits making his best effort even in the self-paced cell condition. It is presumable that the personality traits of type A participants such as competitiveness, time urgency, and high performance standards, had roused their struggle to accomplish more tasks in less time.

3.2 Subjective Ratings

Mean workload ratings by NASA-TLX were shown as a function of experimental condition for each personality type in Figure 2 or Figure 3. The weighted workload scores (WWL) of Type A group were 63.8 in the cell condition and 60.5 in the conveyor condition, respectively. The WWLs of Type B group were 33.5 in the cell condition and 44.1 in the conveyor condition. The differences of the WWLs between two groups were significant in either experimental condition. Type A participants had a tendency to perceive higher mental workload imposed on them than Type Bs, irrespective of experimental condition.

As shown in Figure 2, Type A group showed a greater WWL in the cell condition, but it was not significant. Workload ratings on the six subscales differed in experimental condition, indicating Mental Demand, Temporal Demand, and Effort rated higher in the cell condition as contrasted to Physical Demand, Performance, Frustration rated higher in the conveyor condition. On the other hand, Type B group showed a significantly greater WWL in the conveyor condition. The ratings of the subscales were higher in the conveyor condition than the cell condition except Frustration. Mental Demand, Temporal Demand, and Effort were rated higher in the conveyor condition by Type B group unlike Type A group. These results implied that the type A behavior pattern as a personality trait had an influence on the perceived mental workload in different manufacturing systems. If the core job characteristics are advocated on the grounds that they will elicit high intrinsic motivation, high job performance, or high job satisfaction, then higher mental demands placed on type A workers need to be seriously considered.
3.3 Cardiovascular Reactions

Time-shift LF/HF ratios as a mental workload index are shown as a function of experimental condition for each personality group in Figure 4 or Figure 5. LF/HF ratios calculated by the spectral analysis were transformed into the z score to compare the relative standings of the readings from distributions of two
experimental conditions with different means and/or different standard deviations. As shown in Figure 4, Type A group showed relatively high LF/HF ratios during task performance (15-75 minutes) as compared to the rest (RST) or the recovery (RCV) irrespective of the condition. In addition, LF/HF ratios during task were greater in the cell condition than in the conveyor condition, indicating the statistically insignificant difference. Figure 5 shows LF/HF ratios of Type B group, indicating the difference between the cell condition and the conveyor condition. LF/HF ratios of the conveyor condition were greater during task than the rest or the recovery. On the contrary, there was no significant change in the cell condition throughout the experiment. A comparison of LF/HF ratios during task indicated that LF/HF ratios were significantly increased in the conveyor condition than in the cell condition.

The ratio of LF/HF has been used as an index of the activity of the sympathetic nervous system in the previous studies concerning autonomic nervous function. The results of LF/HF ratios indicated that the type A behavior pattern as a personality trait might have mediated cardiovascular reactions to the task complexity. Although the participants rated low on the type A personality exhibited lower sympathetic arousal in the self-paced cell condition, the inhibited sympathetic activity in the same condition was not observed for the type A participants. The result of this study falls into line with the previous study which suggested the adverse effects of job complexity on cardiovascular health among those high on type A behavior pattern (Schaubroeck, Ganster and Kemmerer, 1994).
4. CONCLUSION

Although the core job characteristics are useful to design motivating jobs, the core job characteristics such as task complexity might elicit time-urgency and competitiveness that are characteristic of the type A behavior pattern and thereby lead to adverse cardiovascular reactions in the cellular manufacturing system among type A workers. We would recommend that the personality trait among workers be taken into account in installing the cellular manufacturing system on the grounds of job enrichment to promote the quality of working life or labor productivity.

REFERENCES


