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The Effect of Machine Pacing of Simulated Inspection Tasks on Physiological and Psychological Stress Reactions

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THE EFFECT OF MACHINE PACING OF SIMULATED INSPECTION TASKS ON PHYSIOLOGICAL AND PSYCHOLOGICAL STRESS REACTIONS

BY

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PREFACE

The purpose of this study was to obtain data on the impact of machine-paced industrial inspection tasks upon workers. Psychological and physiological stress reaction measures were gathered from subjects under simulated work conditions. Typical stress indicators such as heart rate, electromyograph readings, temperature, and psychological stress scales comprised the raw data. After being subjected to statistical analysis, results and conclusions will be discussed in order to gain knowledge and insight as to the stress reactions of the machine-paced inspection worker, and to provide implications for further research.

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INTRODUCTION

The term stress has been borrowed from the field of engineering. According to Hooke's Law of Elasticity (Cox, 1978), each entity or substance has an "elastic limit". If the amount of stress placed on the entity falls within this limit, when the stress is removed the substance will return to its normal state. Should the amount of stress exceed this point, however, permanent damage will result. Every bridge has a stress-point, the weakest link, which will give way first. Furthermore, the bridge will fall even when there is no apparent change in the external application of pressure. This is due to the continual and cumulative nature of stress over time (McGrath, 1970). This analogy suggests that each person has their own "elastic limit" and can therefore withstand or tolerate a certain amount of stress. But like all physical substances, once the elastic limit has been surpassed the body will give way at its weakest point and permanent damage will result.

Throughout the literature, three basic approaches have been utilized to investigate the complex area of stress. The first approach is known as the response-based theory (Cox, 1978), and began with Selye (1946).

This theory treated stress as the dependent variable or as some type of response (usually physiological) on the part of the individual to certain noxious environmental conditions. The environmental conditions include both physical and psychosocial situations. The emphasis here was not on the type of stressor per se, but the degree of physiological reactions the person experienced. As a result of Selye's research, came the now famous definition of stress as "the non-specific response of the body to any demand made upon it"(Selye, 1907, p. 27).

A different approach treated stress as the independent variable. It described stress as certain stimulus characteristics of an unpleasant environment. This theory suggests that the physiological response is not determined solely by the stressor but by its psychological interpretation via the individual. An example of this type of stimulus-based theory is represented in Lazarus' (1966) concept of cognitive appraisal and psychological stress. According to his hypothesis, the imbalance exists between the individual's <u>perceived</u> demand and the <u>perceived</u> capability. There is no threat to the person as long as the demands are perceived to be within the limitations of that individual's resources.

The third approach to defining stress concerns the "fit" between the person and their environment.

It is an eclectic theory which investigates the interactions or relationships between the stimulus conditions and the physiological consequences (Cox, 1978). In McGrath's four-stage paradigm of the "stress problem" (Dunnette, 1976), the area of interest lies in the stress arising from person-to-person interactions, called social-psychological stress. He focuses on the psychological and sociological factors as distinct from the physiological (heart rate) or physical (dust, heart) levels of stress. McGrath's organizational definition of stress (cited in Dunnette, 1976) proposes that:

> There is a potential for stress when an environmental situation is perceived as presenting a demand which threatens to exceed the person's capabilities and resources for meeting it, under conditions where he expects a substantial differential in the rewards and costs from meeting the demand versus not meeting it. (p. 1352)

Although the aforementioned theories lend considerable insight into the psychological factors involving stress, some problems arise. One problem is the individual differences in perception and reaction to stress. What is considered stressful to one individual may not be to another. The psychological, social and cultural resources employed as buffers, relative to the stressful event, must also be considered (Antonovsky, & Kats, 1967; Chiriboga, 1977; Lazarus, 1971). Lazarus

(1963) tried to differentiate between the psychological and physiological reactions to stress. Lazarus showed a need to identify the psychological processes that determine whether or not the physiological changes occur. The answer to the cause of stress, according to Lazarus, is determined by showing the "link" between psychological perception and physical reaction.

Physiological Reactions

Modern industrialized society has witnessed a change from the infectious diseases of the past to the chronic diseases of today as the major killers. In recent years, the subject of stress and its pathogenic role in chronic disease has become more apparent. More specifically, stress has been related to coronary heart disease, (Carruthers, 1980; House, Wells, Landerman, McMichael, & Kaplan, 1979; Rosenman, Friedman, Strauss, Wurm, Kositchek, Hahn, Werthessin, 1964; Rosenman, Friedman, Strauss, Jenkins, Zyzanski, and Wurm, 1970; Sales, 1969), schizophrenia (Brown & Birley, 1968), depression (Caplan & Jones, 1975) and psychiatric impairment (Myers, Lindenthal, & Pepper, 1971).

More research (Dubos, 1965) has linked stress to the susceptibility of microbial infectious diseases. Susceptibility to infection is thought to be a function of surrounding conditions which culminate in physiological stress reactions in the individual, rather than simply being exposed to the external source of infection. House et al. (1979) provided further evidence that psychosocial job stressors make workers less able to combat the effects of noxious physical, chemical or biological agents in their (the workers') milieu.

The dogma from scientific investigation that stress causes physiological changes emerged from Cannon's work in 1929. Cannon's theory is called the "fight or flight" response to stress. Particularly strong emotions such as anger and rage cause the body to prepare for fighting and subsequent injury. The sympathetic nervous system prepares the body for emergency by the following physiological changes: the contraction and relaxation of the arteries which divert blood from the digestive system to somatic muscles to fuel their exertions; increase in heart rate and blood pressure; the dilation of the bronchial tubes leading to the lungs; an increase in perspiration; the contraction of the sphincters to stop digestion; increase in respiration rate and the release of adrenaline into the bloodstream (Leukel, 1976). If elimination by a natural response does not follow this preparation, or the response is blocked by external factors, the changes persist and cause damage to the system.

An additional view of the importance of physiological reactions is represented by Selye's General Adaptation Syndrome (1907). This theory suggests that stress is divided into three stages: the alarm reaction (initial response to stress); a period of adjustment (tolerence to stress); a stage of exhaustion (period of disorientation and physical disorders). If the stress cannot be overcome by the organism the end result is death (Leukel, 1976).

Psychological Reactions

Studies on the measurement of stress in industrial and laboratory settings have concentrated mainly on psychological aspects such as; individual satisfaction and involvement (Hall & Lawler, 1971) and perceived difficulty of the task, physical and mental loads, the subjective aspects of mental performance, perceived effort and exertion and fatigue (Borg, 1978). Most information is derived subjectively through questionnaires concerning job-related pressures such as role ambiquity, role conflict, and role over-under-load (Borg, 1978; Gupta & Beehr, 1979; Hurst, & McKendry, 1971; Mattone, 1980; and Sales, 1970). Stress has also been shown to be inversely related to job satisfaction (Burke, 1976). Objective measurements of the psychological factors are obtained through quantifiable recordings of job performance in relation to stress (Hall & Lawler, 1971; Hurst & McKendry, 1971; Sales, 1969), and withdrawal behavior exemplified by absenteeism and turnover (Gupta & Beehr, 1979) also thought to be related to stress.

Physiological/Psychological Relationships

As mentioned earlier, there are a number of physiological changes occurring in the body as a result of stress. The traditional measurements of the physiological responses of stress include; heart rate, peripheral skin temperature, levels of serum cholesterol, and adrenaline excretion (Aunola, Nykyri, & Rusko, 1978; Caplan, & Jones, 1975; Friedman, Rosenman, & Carroll, 1958; Hennigan & Wortham, 1975; Johansson, Aronsson, & Lindstrom, 1978; Sales, 1970; Sapira, & Shapiro, 1966). All of the above studies have shown positive correlations between situations identified as being stressful and increases in physiological responses. For example, Sales (1970) has investigated the effects of role overload and role underload, a psychological variable, on performance in an experimentally designed setting among 73 undergraduates. Each individual was asked to decode varying numbers of anagrams presented in the overload and underload condition. The overload condition was characterized by requiring the individual to decode 35 percent more anagrams than he could normally decode in a five minute period. The underload condition was designed to keep the student waiting 30% of the time. Sales then determined from each subject his feelings of tension and anger through the use of a single item measure. The results indicated that the subjects in the overload condition reported a significant increase in tension and anger.

Sales also found that the more anxious subjects, as defined by self report, reacted to overload with slight increases in heart rate and to underload with strong decreases in heart rate. The less anxious subjects responded to both conditions with moderate decreases in heart rate. Sales concluded that changes in heart rate between the two conditions (overload and underload) lead one to surmise that overload causes changes in the physiological reactions of anxious persons and could affect their health.

Similarly, Hennigan and Wortham (1975) have studied the relationship between potentially stressful situations (as identified by the subjects) and increases in heart rate. Electrocardiograms were taken of 24 male engineers during their normal work day in two different companies to determine the effect of their work conditions on heart rate. An analysis of variance revealed within-company differences in heart rate under different work conditions, but no between-company differences. For example, Hennigan and Wortham also found that non-physical work activities identified by participants as stressful were related to higher heart rates than non-stressful, non-physical work activities.

Machine-Paced Stress Studies

Two main studies in the 1950's on workers' perception of and attitudes toward repetitive work lead to several generalizations. Cox, Dyce, Sharp and Irvine (cited in Cox, 1978) interviewed 160 women in a variety of industries in Britain. Three main concerns regarding their jobs were expressed: freedom of action; security; and opportunity for creativity. Changes regarding materials to be worked on, methodology of work, and type of job were regarded positively because when change occurred it broke the monotony and seemed to make time pass quickly. Jobs that were machine-paced or controlled by another person were not as well liked as jobs that were self-paced.

Walker and Guest (1952) interviewed 180 car assembly plant workers in their homes regarding their work on the "Assembly Line". They found that the two most negative aspects of their jobs were the machine-pacing and the repetitiveness. Most workers reported a desire to move from the highly paced jobs to ones "off the line". However, some regarded the fast pace as a challenge.

More recently, Caplan et al. (1975) assessed levels of job stress for machine-paced assembly-line workers. Job stress was subjectively measured in terms of feelings about job security, future value of their skills, social support of co-workers, discrepancies between the amount of job complexity and responsibility held and the amount desired, and under utilization of skills and activities. Comparisons were made between workers on machined-paced assembly lines and those on "improved" lines where work-groups set the pace (Caplan et al. 1975). "Improved" line workers were generally happier.

Johansson, Aronsson, and Lindstrom (cited in Carruthers, 1980) investigated various psychological reactions of two groups of workers to highly mechanized work in a Swedish sawmill. One group (high risk) consisted of sawyers, edgermen and graders. Their jobs required continuous attention and alertness, were subject to short-work cycles and were paced. It was also arranged that this group's production created a "bottleneck" in the flow of materials and output. The control group was made up of repairmen, maintenance workers and workers in similar job conditions. Both groups worked inside and were paid on a piece-rate basis.

The high risk group reported the following subjective complaints:

1. Their jobs were too monotonous and boring.

2. Their ideas and knowledge were underutilized.

3. They were tied to the job.

4. They were isolated from their work mates because of (a) the noise, (b) the physical constraints of work, and (c) the "pace" of work.

5. They felt distressed/uneasy on going to work. (cited in Carruthers, 1980, p. 25)

In a different study of Johansson, Aronsson, and Lindstrom (1978), social, psychological and neurendocrine stress reactions were measured in highly mechanized work situations. Two groups of workers were compared. A high risk group whose job was characterized by repetitiveness, physical constraints, machine-regulation of work pace and high demands of continuous attention was compared to a control group who performed under more flexible conditions. Measurements were taken during work and off time for adrenaline excretion, and self-rating of moods and alertness were obtained. There was a significant difference of higher adrenaline excretion in the high risk group as compared to the control group. This study found that the high risk group showed a greater occurrence of psychosomatic illness and

Based on the literature thus far reviewed, there clearly exists a need to measure psychological and physiological stress reactions of machine-paced industrial workers. The intent of the subsequent study is to investigate the interaction of experimentally induced stress and psychological and physiological reactions of subjects under simulated working conditions. The questions being investigated are; are there differences between resting baseline physiological measures and physiological measures observed during simulated work conditions; do various speeds of performing the task have a significant effect on physiological changes; and what are the relationships between physiological measures and psychological indications of stressful situations.

METHOD

Subjects

Sixteen undergraduate students from the University of Central Florida served as volunteer subjects. Each student was required to read and sign an informed consent form (See Appendix A) before beginning participation in the experiment.

Apparatus

A Kodak carousel slide projector was employed to show slides of integrated circuits. The complexity of the slides varied. The speed of presenting the images was the manipulated variable. The three speeds were fast, moderate and self-paced. The subjects were provided with instructions and guidelines for judging errors prior to the task session. They were asked to inspect each image for errors and mark on a score sheet provided the number and type of errors each slide contained.

An Autogen 1700 EMG Monitor (Autogenic Systems, Inc.) was used to monitor Electromyograph (EMG) levels. The Bandpass Selector was set at 100-200 Hz. An Autogen 2000b temperature machine was used to measure the absolute peripheral skin temperature. Both the Autogen

1700 and 2000b were connected to Autogen 5100 Display Integrators for quantifying both analog and digital information in a form easily recorded for future analysis. The main function of the digital integrators is to compute the cumulative average value of a constantly changing physiological parameter for a preselected period of time. To measure heart rate, a pulse rate monitor (Gulf and Western Applied Science Laboratories, Cardio-Tack, model 4600) was employed. This equipment provided a digital display reading of a 4-beat average.

Procedure

A preliminary task analysis was performed in order to assess the nature of the task and determine the parameters for the simulation. This involved on-site observations of several different inspection processes. Specific areas of interest were: the speed or pace at which the average inspection worker actually performs, the complexity of the item inspected, and the environmental working conditions to which the worker is subjected (noise, dust heat, etc.).

As a result of this preliminary task analysis, Harris Corporation donated the replication and use of the slides they use in their training program for inspection workers. Therefore, the image to be inspected most closely resembled that of an integrated circuit.

The first session resulted in baseline data on heart rate, EMG, and skin temperature. One set of electrodes (two active and one ground) were attached to the frontalis muscle and a second set attached to the forearm extensor muscle. The photoelectric sensor for heart rate measure was attached to the left (or non-dominant) middle fingertip, and the temperature thermistor was attached to the non-dominant index finger.

As in typical clinical experimental studies of physiological measurements, the subjects were instructed to sit quietly for 20 minutes while readings were recorded at 2 minute intervals in an adjacent room.

Task Session

One to three weeks following the baseline session the simulated task session was conducted. The electrode and sensor attachment procedure was the same as in the baseline session. Upon entering the room, each subject was instructed to be seated in a straight back chair beside a table holding the Kodak carousel slide projector. The subjects were informed of the nature of the task to be performed. They were shown examples of the four types of errors that they would be searching for. The subjects were handed a typewritten set of guidelines to read and study before the slide presentation began. These guidelines explained the types of errors and the percentages of acceptable errors. Their task was to either accept the image as correct or reject the image, based on the percentages of marginal errors. Each subject recorded their decision on paper provided.

After each 18-minute time segment the pace of the inspection task was changed. The three speeds of presentation were: fast (one slide every 15 seconds), moderate (one slide every 30 seconds), and a self-paced rate. Each subject performed the task at each of the four rates, which changed every 18 minutes for a total of 1 hour and 12 minutes.

The first three conditions were competitive in that monetary rewards were provided based on the combined performance scores of those conditions; $25 for best performance, $15 for second best performance, and $10 for third best performance. The last condition (self paced two) was non-competitive and subjects were encouraged to relax.

It is recognized that the purpose of the present study was to take measures of experimentally induced stress reactions. A second purpose was to investigate the differences between subjects baseline (resting) physiological readings and their task session (stress induced) physiological readings in general. The stress factor was the result of the various speeds of the stimulus presentation. High speed was used to increase failure and cause anxiety. However, for additional information purposes, a self-paced situation was also recorded for comparison. The speed of presentation; fast, moderate and self-paced, was randomized across subjects to control for carryover effects in the final analysis. For example, the order for $\underline{S}_1$ was fast, moderate, self-paced; for $\underline{S}_2$ it was self-paced, fast, moderate, and so on.

True EMG readings were possible since one arm was not in use. EMG readings of muscle tension from the frontalis were accurate also, since no head movement was involved in performing the task.

After each 18-minute session each subject was asked to complete a brief self-report scale (See Appendix B) to measure psychological reactions to the inspection task. In the final analysis this score was treated as a dependent variable. Questions concerned the perceived difficulty of the task, the physical and mental workload, boredom, repetitiveness, fear of failure, anxiety and other subjective aspects of mental performance.

Experimental Design

To analyze the effect of the independent variable (three levels of speed) on four dependent measures, a one-way analysis of variance with repeated measures was utilized. This analysis of variance was performed for each of the dependent measures; heart rate, EMG readings, skin temperature and performance. For heart rate, EMG and skin temperature the difference between each subject's baseline measure and measures on the respective dependent variables were utlized. Post hoc multiple comparisons were made using the Scheffe' Method.

RESULTS

Table 1 shows the order of speed presentation of conditions for each of the sixteen subjects. All subjects performed an eighteen minute self-paced session last.

Table 2 shows the absolute average means and standard deviations of the four dependent variables across the baseline, three randomly ordered speed presentations, and the self-paced condition. Since the order in which the first three speeds were presented was randomly assigned to the subjects, Tables 3-6 show summaries of the analyses of variance performed to assess potential effects of the order of presentation of the independent variable, speed. The speed presentation order had no significant effect on temperature (See Table 3). Table 4 shows a significant main effect for the independent variable subjects for EMG levels, $F(3, 45) = 4.35$, $p < .05$. However, there was no significant main effect for order of speed presentation, $F(3, 45) = .71$, $p > .05$. Table 5 shows that there was also a significant main effect for the independent variable subjects for heart rate, ($F(3, 45) = 16.72$, $p < .05$) but no significant main effect was found for the order of speed presentation $F(3, 45) = 1.93$, $p > .05$. Table 6 indicates that order of presentation

TABLE 1

Order of Speed Presentation
For The 16 Subjects

Subject	1st	2nd	3rd	4th
S_1	Fast	Moderate	SP_1	SP_2
S_2	SP_1	Moderate	Fast	SP_2
S_3	Fast	SP_1	Moderate	SP_2
S_4	SP_1	Moderate	Fast	SP_2
S_5	Moderate	Fast	SP_1	SP_2
S_6	Moderate	Fast	SP_1	SP_2
S_7	SP_1	Moderate	Fast	SP_2
S_8	SP_1	Moderate	Fast	SP_2
S_9	Fast	SP_1	Moderate	SP_2
S_{10}	Moderate	SP_1	Fast	SP_2
S_{11}	SP_1	Moderate	Fast	SP_2
S_{12}	Moderate	Fast	SP_1	SP_2
S_{13}	Fast	Moderate	SP_1	SP_2
S_{14}	Fast	SP_1	Moderate	SP_2
S_{15}	Moderate	Fast	SP_1	SP_2
S_{16}	SP_1	Moderate	Fast	SP_2

TABLE 2

Average Absolute Means and Standard Deviations of the Four Dependent Variables Across the Baseline; Three Randomly Oradered Speed Presentations; and a Self-Paced Session

	Base	1st	2nd	3rd	4th
TEMPERATURE: (Degrees Fahrenheit)					
$\overline{X}$	87.6	90.9	92.1	93.3	93.3.
SD	1.22	1.33	.95	.86	.77
EMG: (Microvolts)					
$\overline{X}$	2.92	5.71	5.60	4.52	5.03
SD	.78	1.47	2.0	1.28	1.29
HEART RATE: (Beats per minute)					
$\overline{X}$	68.7	81.8	78.8	78.4	77.9
SD	4.32	4.76	3.87	3.99	4.90
PERFORMANCE: (Number of correct responses)					
$\overline{X}$		13.9	10.8	13.3	22.3
SD		7.23	6.92	10.25	18.5

TABLE 3

Summary of Analysis of Variance With Repeated Measures for the Effect of the Order of Treatment Conditions on Absolute Mean Scores in Temperature

Source of Variation	Sum of Squares	df	Mean Squares	F
Order	61.05	3	20.42	.25
Subjects	436.32	15	29.13	.36
Interaction	3619.2	45	80.4	

* $p < .05$.

TABLE 4

Summary of Analysis of Variance With Repeated Measures for the Effect of the Order of Treatment Conditions on Mean Scores of EMG Levels

Source of Variation	Sum of Squares	*df*	Mean Squares	*F*
Order	13.7	3	4.56	.71
Subjects	418.5	15	27.90	4.35*
Interaction	288.22	45	6.40	

* $p < .05$.

TABLE 5

Summary of Analysis of Variance With Repeated Measures for the Effect of Order of Treatment Conditions on Mean Scores in Heart Rate

Source of Variation	Sum of Squares	*df*	Mean Squares	*F*
Order	155.77	3	51.92	1.93
Subjects	6738.4	15	449.23	16.72*
Interaction	12.09	45	26.87	

* $p < .01$.

TABLE 6

Summary of Analysis of Variance With Repeated Measures for the Effect of Order of Treatment Conditions on Mean Scores of Performance

Source of Variation	Sum of Squares	*df*	Mean Squares	*F*
Order	1650.3	3	550.13	3.93*
Subjects	2146.4	15	143.1	1.02
Interaction	6302.7	45	140.06	

* $p < .05$.

had a significant effect ($F(3, 45) = 3.93$, $p < .05$) on performance. Post hoc comparisons utilizing the Scheffe' method ($\alpha = .05$) revealed that the mean for performance under the fourth (or self-paced) condition was significantly higher than those of the other three conditions. No other means differed significantly from each other.

In regard to the question of significant changes between baseline and treatment condition levels of the physiological dependent variables, planned comparisons were utilized between all four treatment (speed) conditions and the resting baseline for temperature, muscle tension, and heart rate. Significant increases in all three dependent variables were revealed; $t(60) = 6.35$, for temperature, $t(60) = 3.16$, for muscle tension, and $t(60) = 5.93$, for heart rate. Although the significant increases in muscle tension and heart rate are supportive of traditional physiological stress reactions, the significant increase in temperature was not expected.

Table 7 shows the absolute average means and standard deviations of the four dependent variables across the baseline, the three speed presentations and the self-paced condition. The three paces of speed were fast, moderate and self-paced.

Tables 8-11 show summaries of the analysis of variance performed to determine if there were any

TABLE 7

Average Absolute Means and Standard Deviations of the Four Dependent Variables Across the Baseline and the Four Speed Presentations

	Base	SP_1	SP_2	MOD.	FAST
	TEMPERATURE (Degrees Fahrenheit)				
$\overline{X}$	87.6	92.1	93.3	91.8	92.4
SD	1.22	1.22	.77	1.06	.93
	EMG: (Microvolts)				
$\overline{X}$	2.92	6.10	5.03	5.26	4.48
SD	.78	1.48	1.29	1.81	1.45
	HEART RATE: (Beats per minute)				
$\overline{X}$	68.7	80.5	77.9	78.5	80.0
SD	4.32	4.40	4.90	4.23	4.10
	PERFORMANCE: (Number of correct responses)				
$\overline{X}$		16.4	22.5	8.13	13.8
SD		10.5	18.5	5.93	6.64
%		22	22	16	19

TABLE 8

Summary of Analysis of Variance With
Repeated Measures for Mean Difference Scores
Of Speed Conditions in Temperature

Source of Variation	Sum Of Squares	*df*	Mean Squares	*F*
Speed	16.3	3	5.45	.95
Subjects	1282.7	15	85.51	14.95*
Interaction	257.6	45	8.73	

* $p < .05$.

TABLE 9

Summary of Analysis of Variance With Repeated Measures for Mean Difference Scores Of Speed Conditions on EMG Levels

Source of Variance	Sum of Squares	df	Mean Squares	F
Speed	32.36	3	10.79	1.52
Subjects	399.32	15	26. 62	3.74*
Interaction	319.5	45	7.12	

* $p < .05$.

TABLE 10

Summary of Analysis of Variance With Repeated Measures for Mean Difference Scores of Speed Conditions in Heart Rate

Source of Variation	Sum of Squares	*df*	Mean Squares	*F*
Speed	73.09	3	24.33	.59
Subjects	4171.7	15	278.11	6.75*
Interaction	1855.2	45	41.23	

* $p < .05$.

TABLE 11

Summary of Analysis of Variance With Repeated Measures For The Effect of Speed Conditions On Performance

Source of Variance	Sum of Squares	*df*	Mean Squares	*F*
Speed	2759.6	3	919.86	16.59*
Subjects	4362.9	15	290.86	5.25*
Interaction	2493.9	45	55.42	

*$p < .05$.

significant increases or decreases in the dependent variables as a result of the manipulated variable, speed. These calculations were performed on the difference scores between each subject's baseline average and the average of each speed condition for each dependent variable (except performance). The expectation that temperature and performance would decrease as a result of speed incrementation and that heart rate and EMG levels would increase were not supported. There was, however, a significant main effect of speed on performance, $\underline{F}(3, 45) = 16.29$, $\underline{p} < .05$. Multiple comparisons employing the Scheffe' method revealed significant differences in performance between all conditions except self-paced-one and fast. Surprisingly, the moderate condition had the lowest mean average of 8.13, and the self-paced-two (last) condition had the highest at 22.5. Also shown in Table 7 are the percentage scores of the number of correct responses for each condition.

For easier interpretation, Figures 1-4 show the absolute values of each dependent variable under each condition. These figures depict the minute differences in heart rate, temperature and EMG levels among each of the conditions, as well as the larger differences between the baseline and each condition.

According to Lazarus (1963), the cause of stress

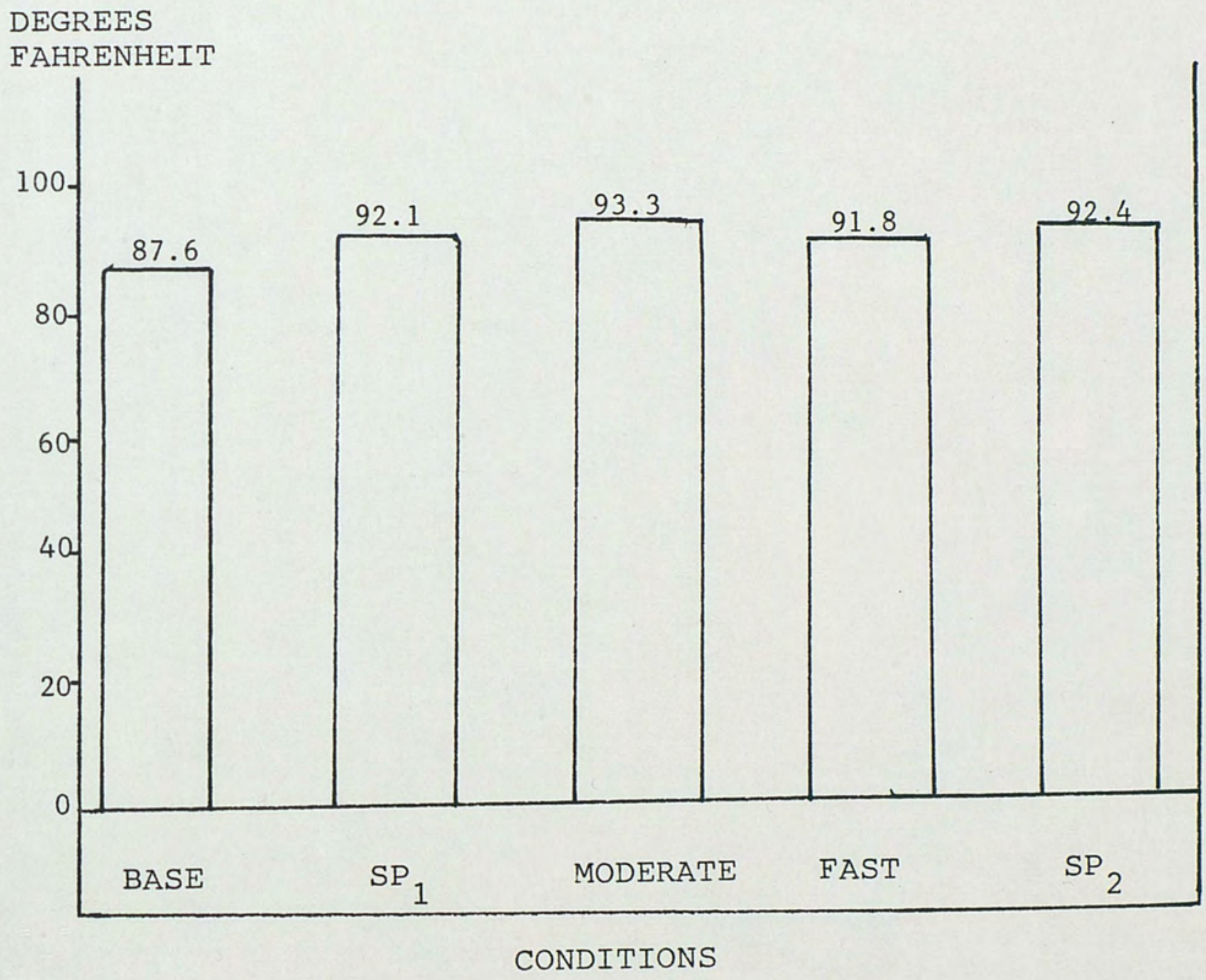

Figure 1. Absolute Values of Temperature Under Baseline and Each Condition.

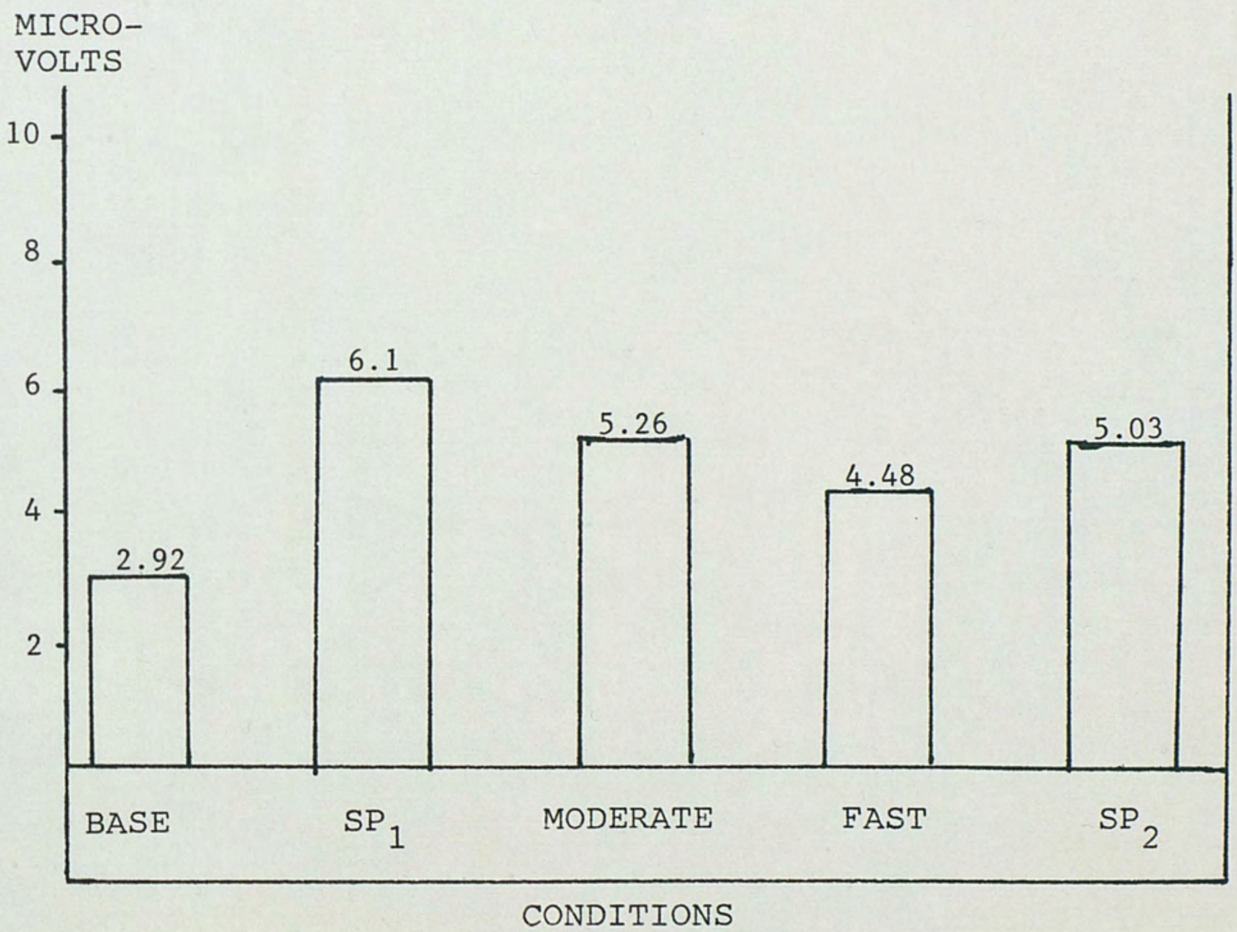

Figure 2. Absolute Values of EMG Levels Under Baseline and Each Condition.

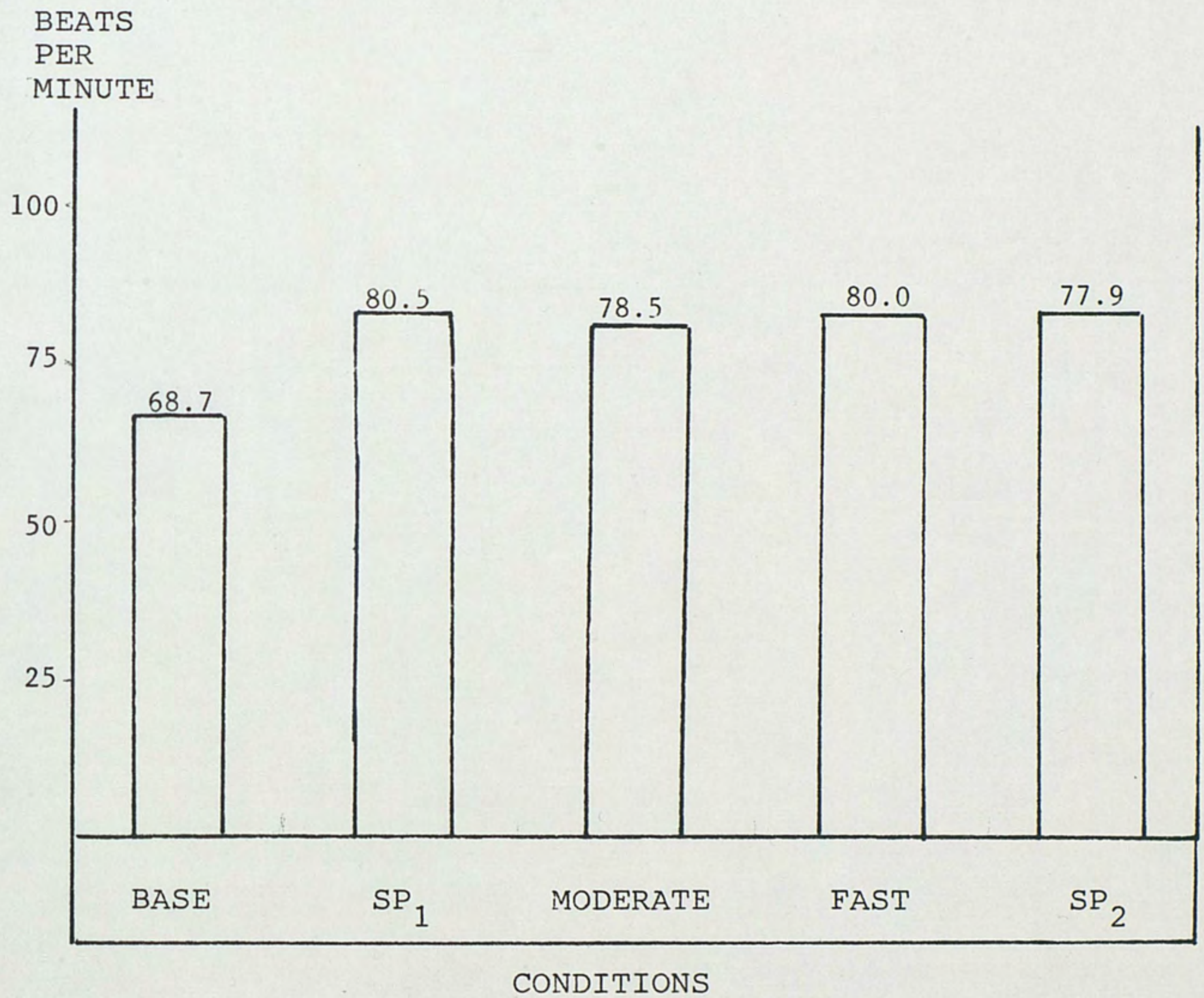

Figure 1. Absolute Values of Heart Rate Under Baseline and Each Condition.

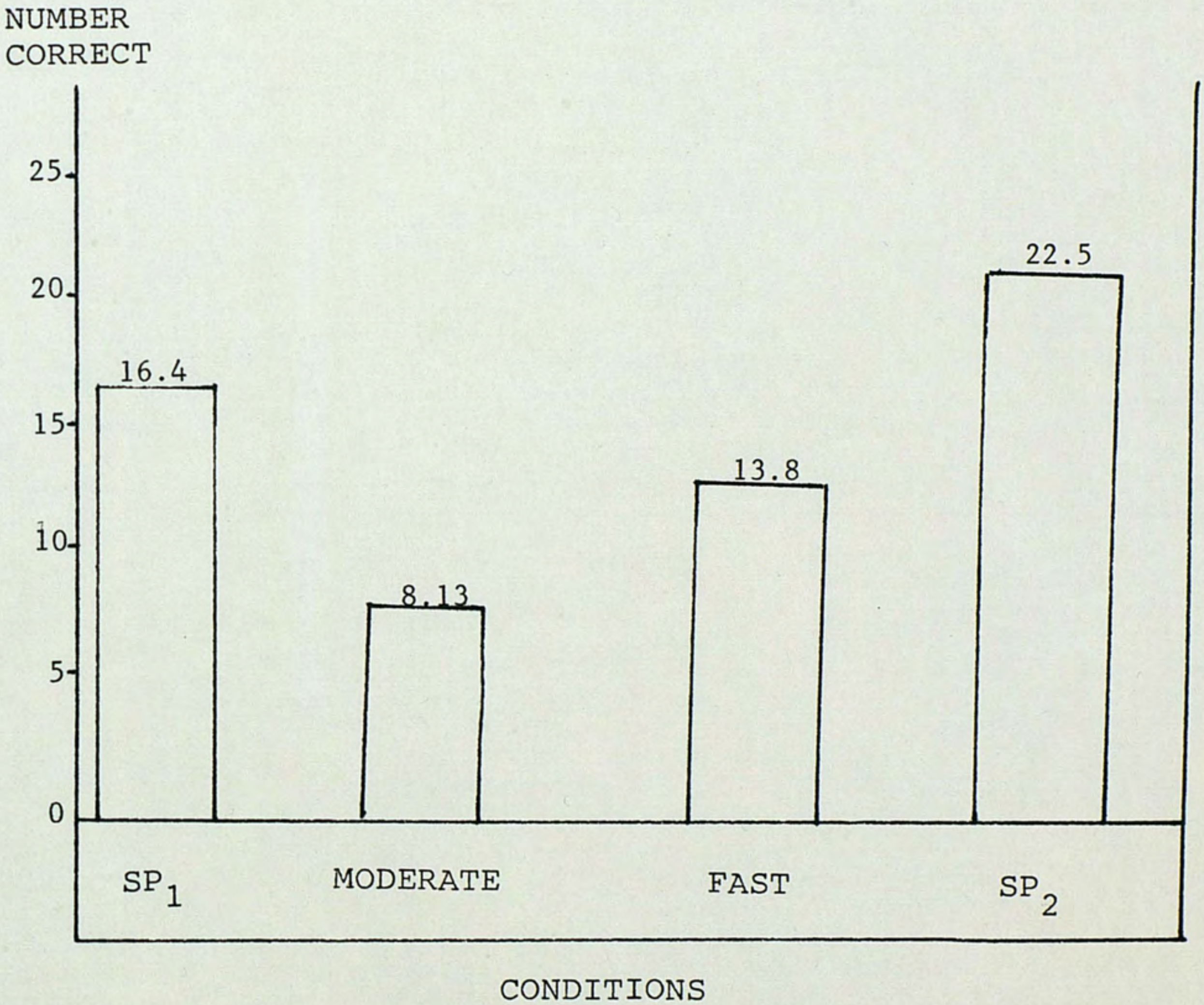

Figure 4. Absolute Values of Performance Under Each Condition.

physiological reactions. Tables 12-15 are correlational matrices. These correlations represent the degree of linear relationship between the amount of physiological stress reaction and the amount of psychological stress reaction under each speed. For each subject, the difference between his/her baseline and the treatment physiological measure was correlated with his/her response to each question. Fourteen of the seventy-two correlations were significant ($p < .05$). Of these, seven were in the predicted direction, five more were subject to interpretation, and two were not in accord with predictions. Thus, no consistent pattern of relationship emerged.

For example, when subjects indicated a greater understanding of the nature of the task, muscle tension decreased significantly in the self-paced one and the fast conditions ($r(14) = -.70$; $r(14) = -.87$ respectively; $p < .05$). Also, in the fast paced session when subjects indicated their fear of failure in performing the task, their heart rate increased significantly ($r(14) = .74$; $p < .05$). These findings were all in accordance with expectations. However, in the self-paced two session, muscle tension increased significantly as a result of high indications of boredom. This finding is subject to interpretation. In the moderate condition a decrease in heart rate was associated with a high score on fear of

TABLE 12

Correlations Between Physiological Difference Scores (Treatment Minus Baseline) and Psychological Questionnaire Responses For the Self Paced One Condition

Item		Temperature	EMG	Heart Rate	Performance
Q_1	Difficulty Level	-.36	-.21	-.45	-.10
Q_2	Understood Task	.30	-.70*	.37	.00
Q_3	Repetitiveness	.67*	-.43	.57	.14
Q_4	Anxiety	-.31	-.08	-.16	.30
Q_5	Fear of Failure	.14	.12	-.38	.41
Q_6	Boredom	.47	.26	.37	.06

* $p < .05$.

TABLE 13

Correlations Between Physiological Difference Scores
(Treatment Minus Baseline) and
Psychological Questionnaire Responses
For the Self Paced Two Condition

Item		Temperature	EMG	Heart Rate	Performance
Q_1	Difficulty Level	-.37	.13	-.23	.45
Q_2	Understood Task	.15	.17	-.13	-.18
Q_3	Repetitiveness	.72*	.04	.06	-.25
Q_4	Anxiety	-.70*	.00	-.20	.27
Q_5	Fear of Failure	-.46	.11	.09	-.10
Q_6	Boredom	-.06	.88*	-.23	.16

* $p < .05$.

TABLE 14

Correlations Between Physiological Difference Scores (Treatment Minus Baseline) and Psychological Questionnaire Responses For the Moderate Paced Condition

Item		Temperature	EMG	Heart Rate	Performance
Q_1	Difficulty Level	-.11	.36	-.49	.06
Q_2	Understood Task	-.09	-.36	.03	-.11
Q_3	Repetitiveness	-.07	-.48	-.48	.01
Q_4	Anxiety	-.16	.50*	-.34	.51*
Q_5	Fear of Failure	.04	.31	-.70*	.34
Q_6	Boredom	-.49	-.14	.17	.37

* $p < .05$.

TABLE 15

Correlations Between Physiological Difference Scores (Treatment Minus Baseline) and Psychological Questionnaire Responses For the Fast Paced Condition

Item		Temperature	EMG	Heart Rate	Performance
Q_1	Difficulty Level	.00	-.85*	.14	.09
Q_2	Understood Task	-.04	-.87*	-.03	-.08
Q_3	Repetitiveness	.05	-.88*	-.37	-.07
Q_4	Anxiety	.02	-.41	-.23	-.08
Q_5	Fear of Failure	.31	.09	.74*	-.12
Q_6	Boredom	-.46	-.73*	-.50*	-.04

* $p < .05$.

failure in performance. No significant increases in either muscle tension or heart rate were found in the fast paced session as a result of high anxiety scores. These findings were not in accordance with expecations.

CONCLUSIONS

The results of the analyses of variance indicated that the order of speed presentation had no significant effect on the three dependent physiological variables. However, performance was significantly higher in the last (SP_2) condition. This suggests that a learning effect occurred as opposed to the idea that subjects performed better under a more relaxed, non-competitive situation. As previously mentioned in the method section the fourth self-paced non-competitive session was performed in order to compare the dependent physiological measures with the dependent measures of the first three competitive sessions. No significant physiological changes occurred between the competitive sessions and the last on temperature, muscle tension or heart rate.

The significant differences between the resting physiological measures and combined speed condition measures on each variable imply that physiological changes do occur during simulated inspection work. If undergraduates show physiological changes under simulated work conditions, it may be assumed that paid inspection workers may undergo these same physiological changes. The questions are to what degree do workers experience physiological changes and what types of coping techniques do they employ to contend with these changes. Analogous to the findings of Sales (1970) these simulated work conditions may have represented an "overload" condition and similar situations in real work conditions could effect the workers' health (Sales, 1970).

Even though there were no significant differences caused by levels of the independent variable speed, this may be related to insufficient speed incrementation. Or it could have been that the mental workload (complexity) of the task was not great enough. Subjects were asked to inspect each circuit for four errors, with percentage guidelines for rejection visible at all times. The preliminary task analysis revealed that real inspection workers are trained for two weeks before beginning and actually look for up to forty memorized errors.

Regarding the relationship between physiological measures and psychological responses the low number of significant correlations may have been caused by the questionable validity of self-reports (Austin & Hemsley, 1978; Holzbach, 1978). Another speculation is that people may not be aware of their own physiological reactions.

Future investigations of on the job stressors and their effects on behavior may clarify the interaction between the task, stressor, individual and situation. These studies in turn, may lead to the development of coping mechanisms and/or training programs to reduce the impact of stress reactions in the industrialized workforce.

APPENDIX A

CONSENT FORM

PSYCHOLOGICAL RESEARCH

The purpose of this study is to gather data on physiological and psychological activity that occurs when people perform inspection work under simulated conditions.

Sensors will be placed on the surface of the skin of the forehead and forearm, and both the middle and index fingers, to monitor temperature, heart rate and muscle tension.

Subjects are encouraged to discontinue participation in the study at any time, if they feel uncomfortable about their participation.

Your signature below acknowledges that you have read and understand the above and are willing to participate in the study.

SIGNATURE:____________________________________

Address:________________________________

____

Phone Number:___________________

Age:________ Sex:_____

APPENDIX B

PSYCHOLOGICAL INDEX

Please circle the number which most closely represents your feelings regarding this task.

I. I felt that the difficulty of this task was:

1	2	3	4	5	6	7
Δ			Δ			Δ
Not At All Difficult			Moderately Difficult			Extremely Difficult

II. I understood the nature of the task:

1	2	3	4	5	6	7
Δ			Δ			Δ
Not At All			Moderately Understood			Very Clearly Understood

III. I felt this task was repetitious:

1	2	3	4	5	6	7
Δ			Δ			Δ
Not At All			Moderately Repetitious			Extremely Repetitious

IV. I felt anxious during the performance of this task:

1	2	3	4	5	6	7
Δ			Δ			Δ
Not At All			Felt Moderately Anxious			Felt Extremely Anxious

PSYCHOLOGICAL INDEX
(con't)

V. I was afraid I would fail at performing this task:

1	2	3	4	5	6	7
Δ			Δ			Δ
Not At All			Moderately Afraid			Extremely Afraid

VI. I felt this task was boring:

1	2	3	4	5	6	7
Δ			Δ			Δ
Not At All			Moderately Boring			Extremely Boring

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