PACING, DEFECT RATE AND TASK PERCEPTION IN SIMULATED INSPECTION

by

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INTRODUCTION

Today with rapid advancement in technology sophisticated machines have replaced many people in industry. But evidence exists that people still affect product quality and reliability. According to Rook (1965) an analysis of 23,000 defects found in testing components for nuclear weapon systems indicated that 82 percent or 19,200 of these defects, were directly attributable to human error. An examination of a product's life-cycle reveals how human performance affects quality of the product. People conceive and design a product. People select the materials, processes and equipment required for the new product. People assemble, inspect, and test. Finally, people pack, deliver, and service these products. Here we confine ourselves to human performance in the inspection task only.

Basic Elements in Inspection Tasks

An inspection job can be considered to consist of a basic set of four activity elements as discussed by Harris and Chaney (1969). These activity elements are interpretation, comparison, decision making, and action.

Interpretation. An inspection job requires the interpretation of some type of established standard. The standard may be written or unwritten; it may take the form of a general understanding or it may be a precisely written, quantitative specification of tolerances with respect to product characteristics.

Comparison. Quality characteristics are compared with specified standards by the inspector to determine whether or not all specified quality standards are met. Some inspection may involve the inspector making a mental comparison while other inspections may involve much more straightforward comparisons such as measuring dimensions of a part.

Decision making. There is a significant element of judgment in most inspection decisions. The inspector might accept or reject the same item to be used under different circumstances.

Action. Actions taken by the inspector on the basis of his decisions are of two basic types. The inspector may scrap the item, reinspect it, or give it to someone else for review. The second concerns recording the information obtained. The inspector transmits his findings in a way that can be utilized later.

Types of Inspection Task

Harris and Chaney (1969) discuss three basic categories into which most inspection tasks can be classified. These categories are scanning tasks, measurement tasks, and monitoring tasks.

Scanning task. This is probably the most common category of an inspection task. Here the inspector examines an item visually, although other senses may be employed; for example, a scanning task may consist of examining a machined part for it's surface roughness by rubbing the finger over some surfaces.

Measurement task. The measurement task category includes inspections in which the inspector checks whether dimensions of a part are within specified tolerance limits or not. A simple go, no-go guage might be used for this purpose or the inspector may even resort to a complicated instrument for inspecting items that are to be machined to precise tolerances.

Monitoring task. Monitoring tasks are associated with the control of some type of automatic or semiautomatic equipment. The task of the inspector is to observe displays for indications of out-of-tolerance conditions. The basic difference between monitoring task and scanning and measurement tasks is that the inspector does not deal with the item directly; for example, the inspector observes dials and printed readouts during the test of an electronic equipment but does not observe the equipment directly. His indication of an unsatisfactory item is an abnormal reading by one of the indicators.

Factors in Inspection Accuracy

According to Harris and Chaney (1969), there are three factors affecting inspection accuracy: those associated with individual abilities of the inspectors, those associated with the physical nature of the inspection task and the surroundings in which the inspection is conducted, and those relating to the organization and methods that define the inspection job.

Individual abilities. There are large variations in the ability of individuals to perform inspection tasks. Some of the findings are shown in Figure 1 for each of several general types of electronic item. The average performance for some items is better than the average performance for other types of items; also in each case the performance of some inspectors is several times better than the performance of other inspectors.

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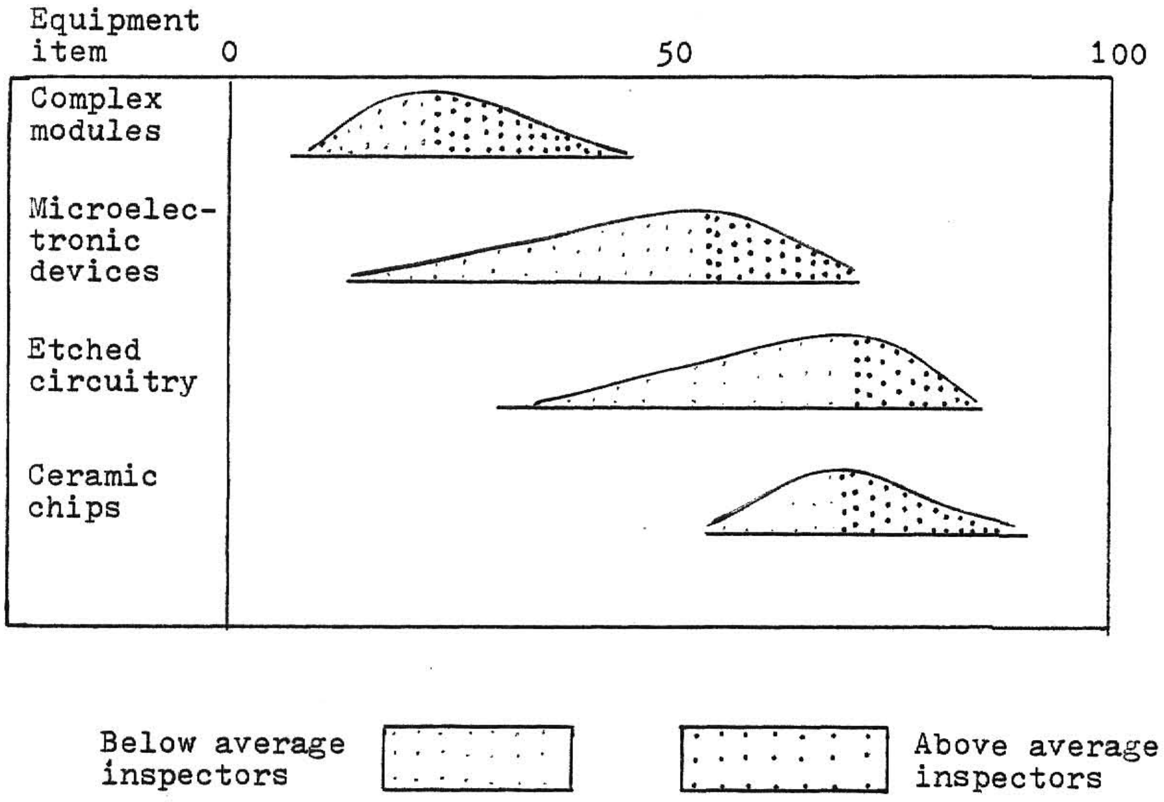


Figure 1. Distributions of inspection ability for different items (cited from Harris and Chaney 1969).

Large differences are also observed in measurement tasks. In a study the best inspector observed as many as four times the defects detected by the poorest inspector. The distribution of the percentages of defects identified by a sample of 26 experienced machined parts inspectors is shown in Figure 2.

Harris and Chaney (1969) state on selection of personnel for scanning inspection tasks:

> " Many inspection jobs require a person simply to look at quality characteristics to determine whether or not they meet quality standards. Jobs of this general type are usually referred to as scanning inspection jobs. Although certain minimum levels of visual acuity and mental alertness are probably required for inspection jobs of this type, little success has resulted from attempting to predict inspection performance from measures of visual acuity or mental alertness. There appears to be a relatively specialized aptitude or combination of aptitudes required for scanning inspection work. "

Environmental factors

Temperature. According to Murrell (1965) temperature of the work room influences the efficiency and/or safety of the workpeople. Studies on effect of temperature have been carried out by Applied Psychology Research Unit at Cambridge (Mackworth, 1950) on effects of both heat and cold and in heat by the R.N. Tropical Research Unit in Singapore (Pepler,1958) indicate the performance decreases if the temperature is over the region 27 to 30 degree Centigrade (81 to 86 degree Farenheight). Experimental work related to performance in cold is said by McFarland et al (1954) to fall sharply at below 10 degree Centi-

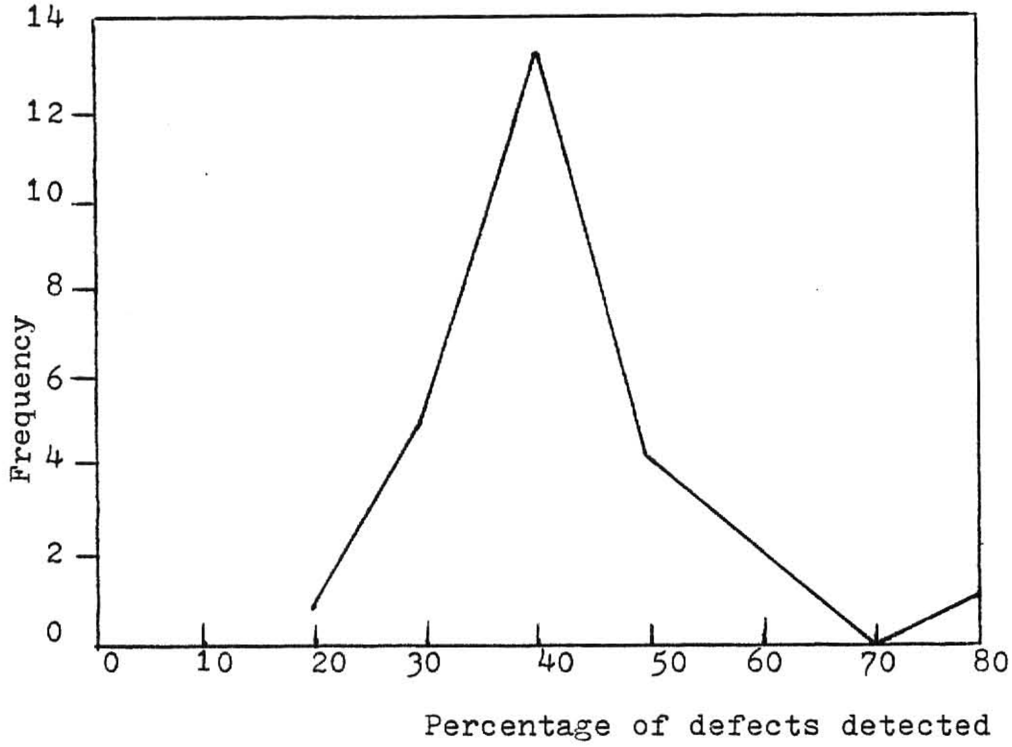


Figure 2. Distribution of percentages of defects detected by 26 machined parts inspectors (cited from Harris and Chaney 1969)

grade (50 degree Farenheight). Vernon and Bedford (1927) showed that in an industrial setting efficiency in a coal mining activity reduced when temperatures were above 24 degree Centigrade (75 degree Farenheight). On the industrial effects of cold, Bedford (1940) gives details of an industrial experiment on bicycle chain assembly in which reduction of temperature from 17.5 to 10 degree Centigrade (62 to 52 degree Farenheight) caused the time to complete a task to increase by 12%.

Noise. Sound frequencies audible to the human ear range from about 20 to 19,000 Hz. Broad-band noise is when sound is made up of frequencies covering a major part of the sound spectrum. According to Murrell (1965), in industry broad-band noise may cause deafness, may reduce working efficiency or interfere with communications. Another type of unwanted sound is the meaningful noise which is related to the information content of the noise rather than to it's sound pressure level. Noise can be steady or continuous (example constant hum of a motor) or intermittent (example successive blows of a pneumatic hammer). Damage-risk levels have been established for continuous sounds. The American Academy of Opthalmology and Otolaryngology (1957) proposed a damage-risk level of 85dB between 300 and 1200 Hz. American Standards Association (1954), Littler (1958) lowered the level further to 70 dB for frequencies between 1,200 and 9,600 Hz.

Illumination. Murrell (1965) states that at normal levels of illumination, the ability to see increases as the logarithm of illumination. This effect was shown by Weston (1949) with a test object of one minute of arc an increase in illumination from 5 to 10 lm/ft^2 produced an increase of 10% in visual performance, a further increase of 10 to 20 lm/ft^2 produced an additional increase of 10%, but an increase from 20 to 50 lm/ft^2 was required to produce a further increase of 12%. Kuntz and Sleight (1949) found that individuals with normal visual acuity had no significant increase in visual performance above 31.6 fL although the experiment was conducted upto 1000 fL. The actual increase in performance resulting from the increase in luminance from 31.6 to 1000 fL was about 7%.

According to Harris and Chaney (1969), it is difficult to determine the exact amount of illumination level required for each inspection task except by performing under each task. Extensive experimental studies have been carried out for visual inspection tasks and illumination levels required have been categorized according to the type of inspection task and illumination levels recommended have been shown in Table 1.

The main consideration in which illumination is provided is the trade-off between the illumination level required for the task and any glare that may be produced. Glare is brightness that discomforts the viewer. The possibility of glare is greatest when the illumination level is high. The problem is to maximize illumination level while minimizing glare. There are two types of glare. Direct glare refers to the effect of a light source within the visual field; specular glare refers to the effect of surfaces which reflect light coming from outside the visual field. Research has indica-

TABLE 1

Recommended Illumination Levels for Inspection Tasks

(cited from Harris and Chaney 1969)

Type of Work	Foot-candles
Unmagnified visual, functional, and dimansional product inspection	100
Large area magnification for inspection of small details frequently requiring low power magnification	200
Microscopic examination of materials, surfaces, and finishes usually requiring spot illumination.	500
Highly magnified examination of materials and small details always requiring high intensity special lighting.	1000

ted that direct glare may be reduced by (a) avoiding bright light sources within 60 degrees of the center of the visual field, (b) using shields, hoods, and visors to keep direct light out of the viewer's eyes, (c) using many low intensity lights instead of one high intensity light. Specular glare may be reduced by (a) using work surfaces and tools that diffuse reflected light, (b) using a diffused light source, and (c) positioning light sources and work so that light is not reflected toward the eye.

When two objects of different reflectivity are adjacent to each other there is said to be brightness difference or contrast between them and this depends on the relative amount of incident light reflected by the two objects. A measure of this brightness difference is the difference between the two reflectivities expressed as a percentage of the reflectivity of the bright surface. Blackwell (1959) found that in order to maintain a high level of performance, contrast should be high for low levels of illuminance and low for high illuminance levels. If the level of illuminance and glare are satisfactory then target contrast can be ignored as it will not affect the performance to a great extent.

Inspection task

Complexity. According to Harris and Chaney (1969), complexity of the inspection task has a significant effect on inspection performance. This has been shown by a study of the effect of the complexity of electronic equipment on inspection performance by Harris (1966). Complexity was rated on a scale of 1 to 100 by a panel of experts and was a function of the number of parts that comprised an equipment item and the way the parts were interrelated or packaged. The objective of the study was to find a relationship between performance and complexity measures. Ten items of electronic equipment were inspected by 62 inspectors. Each inspector had an unlimited amount of time to make his inspections. The measure of inspection performance was the percentage of defects detec-ed. The results indicated that complexity has a significant negative effect on inspection performance which cannot be overcome simply by providing inspectors with an unlimited amount of inspection time. This relationship obtained in the experiment is shown in Figure 3.

Defect rate. When a new product or a manufacturing process is introduced in a shop floor the defect rates are very high. Then the defect rates stabilize to a smaller value. Other situations such as variations of production schedules cause the defect rate to change in a predictable way. Whether inspection should be conducted in the same way, regardless of defect rate depends on the relationship between defect rate and inspection accuracy.

Harris (1969) conducted a study to examine the effect of defect rate on inspection performance. A representative scanning type inspection task was developed and materials prepared to include four different rates. Performance on the inspection task employed had been found to be significantly correlated with performance on the inspection of inertial instruments, module assemblies, electronic circuit boards, microelectronic devices, and photographic materials. The four defect rates considered were 0.25%, 1.0%, 4% and 16%. Inspections were made under the 4 defect rates by a total of

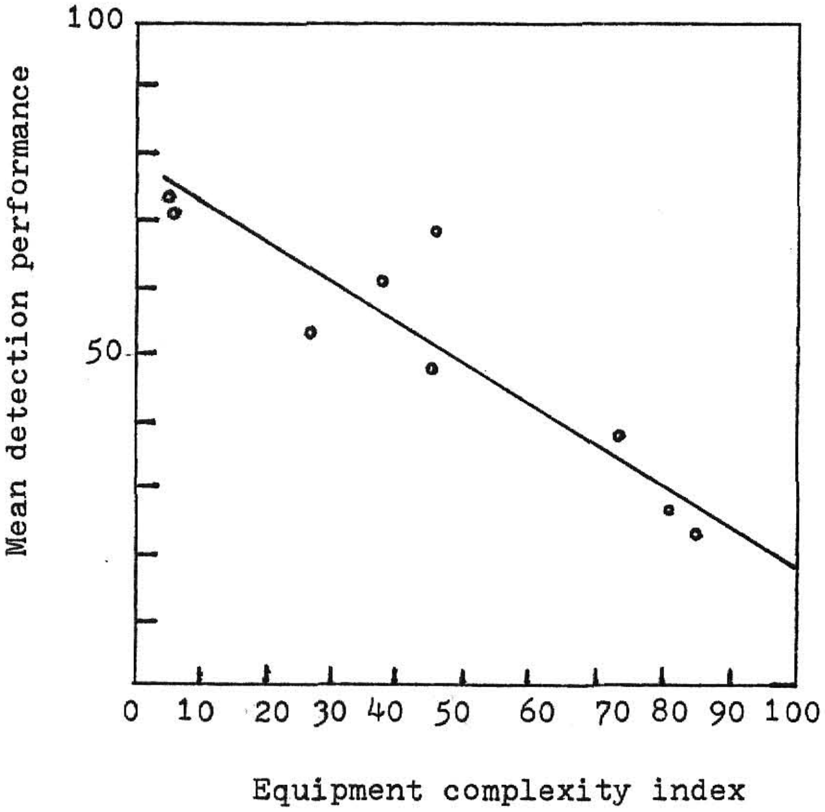


Figure 3. Inspection performance as a function of equipment complexity (cited from Harris and Chaney 1969).

80 naive inspectors, 20 per condition. Inspection accuracy was determined on the basis of percentage of defects detected and false reports made. The number of defects detected was divided by the total number of defects present to give a fraction of defects detected. The percentage of false reports was calculated by dividing the defects detected which were not defects by the total number of defects present. The results showed that inspection performance improved with higher defect rates; percentage of defects detected increased and percentage of false alarm rate decreased with increase in defect rates. The difference in the four defect rates for the percentages of false reports was found statistically significant beyond the 0.05 level for both cases.

Fox and Haselgrave (1969) performed studies on inspection performance under varying defect rates. They used the same two performance measures as Harris (1969) : percentage of defects detected and percentage of false alarms. No significant differences in performance were observed when subjects inspected defect rates of 0.005, 0.01 and 0.025 when items moved on a conveyor. On the other hand, inspectors working in paced condition at 0.01, 0.02 amd 0.05% defect rates showed an improvement in defects detected as defect rate increased as shown in Figure 4, but the false alarms varied widely for each subject as shown in Figure 5.

Repeated inspections. Harris and Chaney (1969) suggest repeated inspections improve inspection performance. The assumption is that the chance of detecting defects will increase

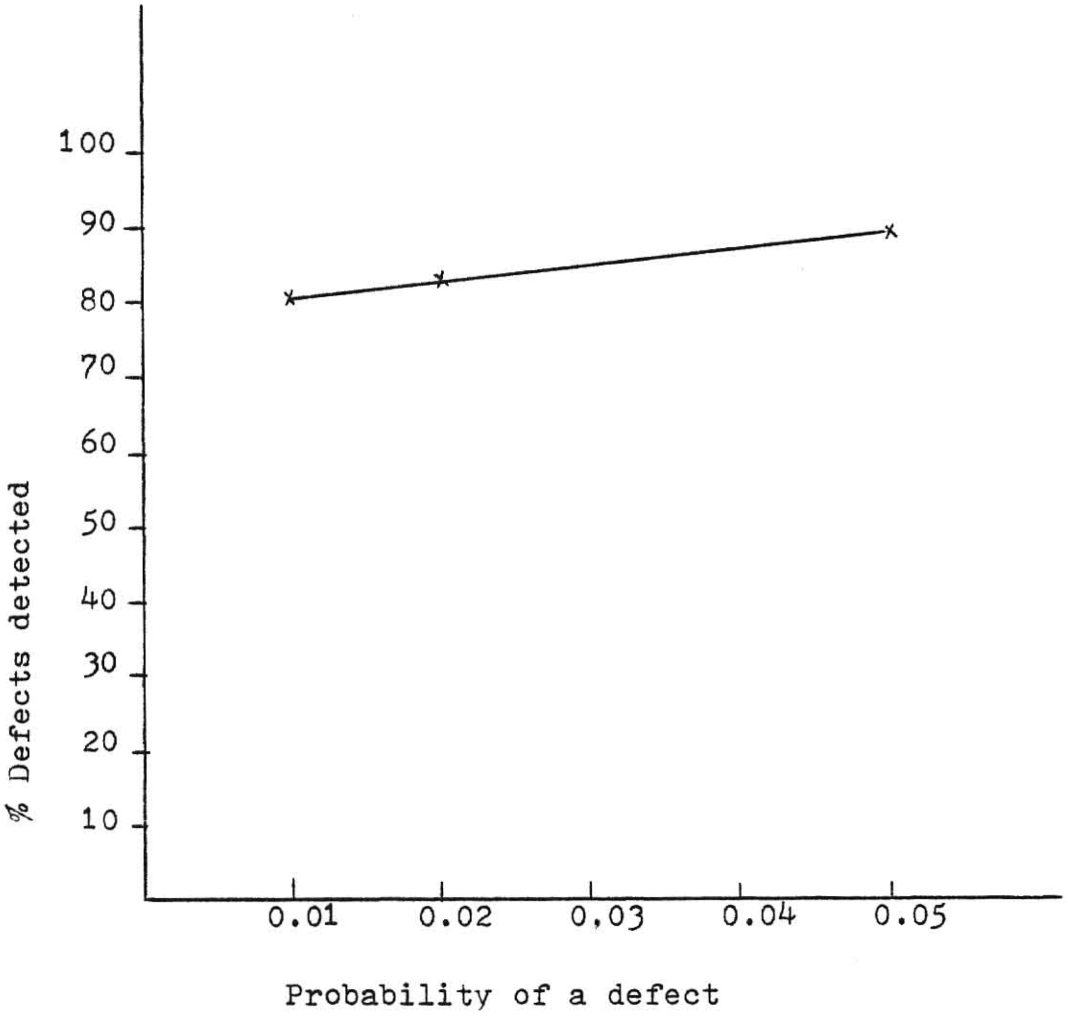


Figure 4. Variation of detection efficiency with probability of a defect in unpaced visual inspection (cited from Fox 1969)

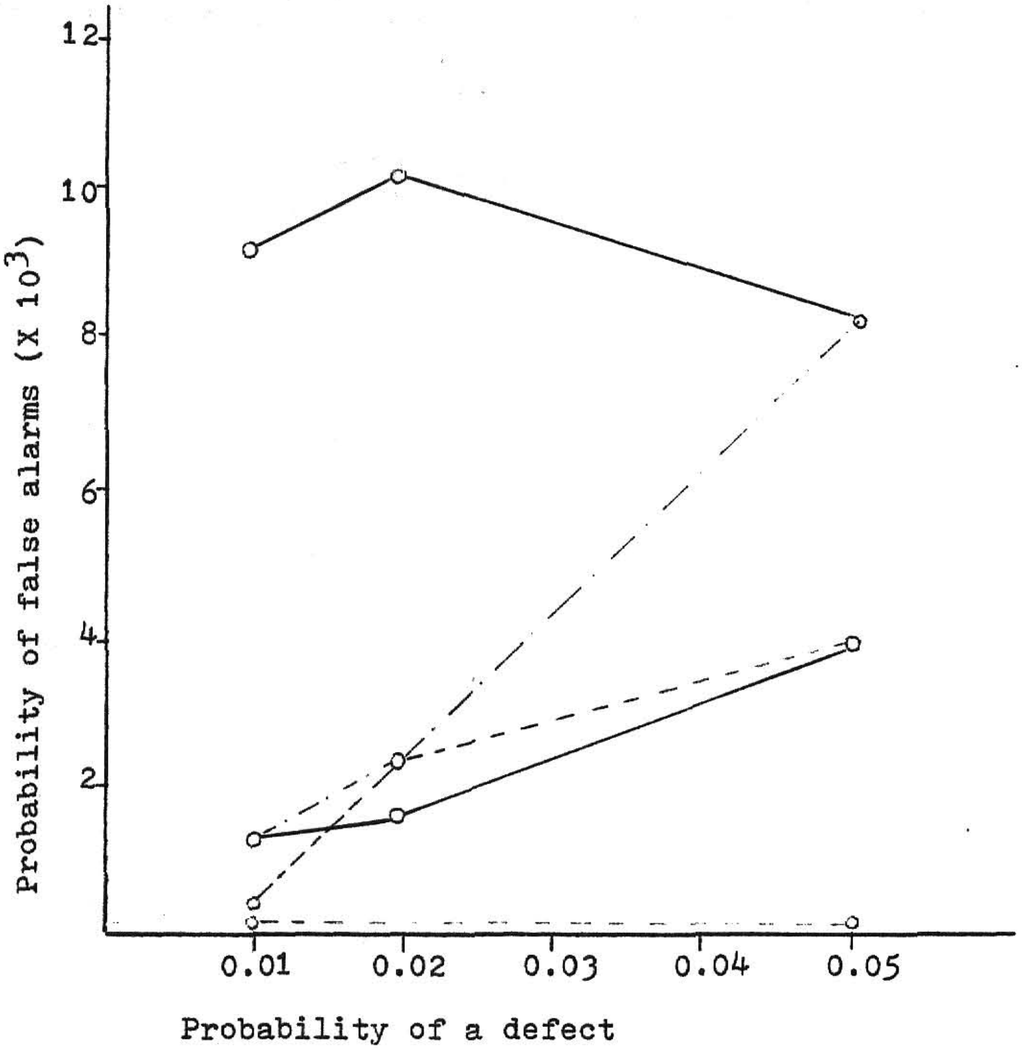


Figure 5. Variation in number of false detected with varying probabilities of defects for individual inspectors (5 subjects) in unpaced condition (cited from Fox 1969).

with the number of different inspections made. A study conducted at the Autonetics Division of the North American Rockwell Corporation was carried out to find the effect of repeated inspections on inspection accuracy. The results showed that repeated inspections increased the inspection accuracy upto a point. The critical defects showed a lesser increase in detection than the non-critical defects. This has been shown in Figure 6.

Vigilance factors. Although vigilance is necessary in the successful performance in inspection tasks, most of the research on vigilance has been done on monitoring tasks. The research on vigilance has not simulated a real industrial situation according to Harris and Chaney (1969) and therefore results from vigilance research should be approached with great caution when applying them to industrial situations. Jerison (1963) carried out a study in which the task used was a simple clock-like apparatus in which a hand moved ahead in single jumps at infrequent and irregular intervals. The task of the inspector was to detect the double jumps of the clock hand. The complexity of the task was increased by having two additional clocks. The results of the experiment are shown in Figure 7. The performance was the lowest for the 3 clocks condition follow-by the 2 clocks condition with the 1 clock condition yielding the best performance. And also that the inspection performance is best initially and drops significantly between 15-30 minutes. This confirms with the relatively consistent finding in vigilance research that percentage of signals or defects detected decreases with the passage of time.

Type of pacing. Murrell (1965) explains the concept of

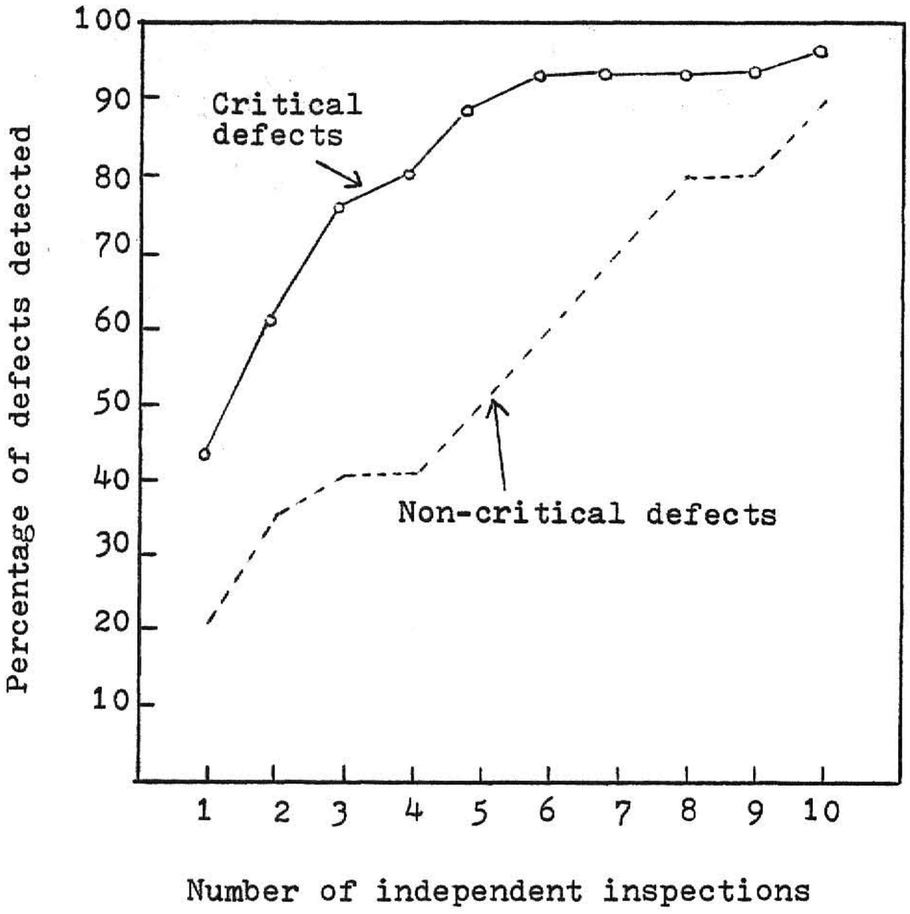


Figure 6. Inspection accuracy as a function of number of independent inspections (cited from Harris and Chaney 1969)

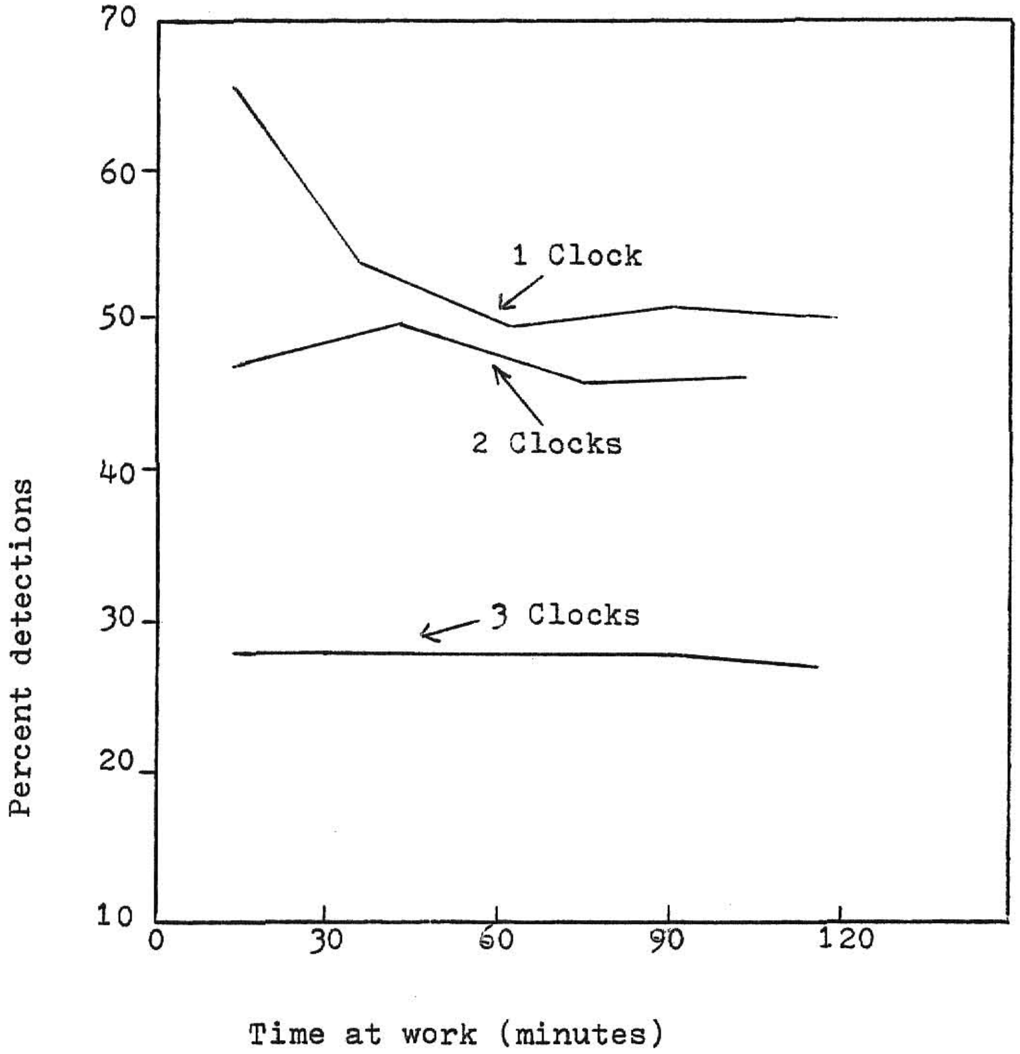


Figure 7. Percentage of detections during successive time periods with one, two, or three clocks in the monitored display (cited from Harris and Chaney 1969).

pacing, semi-pacing and self-pacing as applicable to industrial tasks. Pacing is when operator is presented only one task at a time and is made to keep a certain pace. Semi-pacing is when a number of tasks are presented to the operator to complete in a given time. Self-pacing is when the operator is given his own time to complete the job. Paced work will be influenced by variability of the operators. In all performance there will be variability about a mean performance and this does not disappear just because an operator is paced by a machine.

Applying this concept to inspection one can expect a high inspection performance when an operator is given his own time to inspect. On the other hand when the operator inspects under a pacing condition a low inspection performance might be expected. The inspection under semi-pacing condition should yield performance between the levels achieved under pacing and self-pacing.

Williges and Streeter (1971) conducted an experiment to study the effects of static (inspector-paced) versus dynamic (machine-paced) displays on inspection performance. The task consisted of detecting pin-hole defects in small plastic discs. The discs were displayed in two ways- a static display with discs mounted on a flat table, and a dynamic display with discs placed on a moving belt displaying 100 discs at a time with 600 discs being displayed in 20 seconds. Subjects were given only two 20 second trials in each condition. The results showed that the subjects performed significantly better in the static and as such did not complete inspecting all 600 items within the allotted 20 seconds.

In another study Williges and Streeter (1972) conducted a similar experiment with some modifications. Subjects were given orientation trials under two conditions of static and dynamic displays and tested under both static and dynamic displays. The experiment data obtained supported the major hypothesis of the study because inspectors who were given orientation on dynamic displays and then transferred to static experimental displays detected more defects. Also the subjects committed more false alarm errors during the dynamic display mode but this did not transfer when they performed under the static mode of experimental display. The authors say that this is possibly because errors during orientation were a result of subjects emphasizing a speed criterion when using a dynamic display because they were forced to scan at rapid rates. When the subjects were transferred to static experimental displays, they were no longer forced to emphasize speed but rather, chose to emphasize accuracy. The results of performance as a function of orientation and experimental display mode is shown in Figure 8.

McFarling and Heimstra (1975) studied the effect of pacing and product complexity on inspector performance. The experimental task consisted of inspecting 225 slide representations of printed circuits, and indicating whether the circuit was an acceptable or defective product. Three different circuits were chosen to represent three levels of product complexity, based on the absolute amount of circuitry present and the general appearance of the circuits. Acceptable products were defined by the presence of only partial disruptions in the uniformity of the circuits. Circuits containing defects that completely severed a circuit path were defined as defective or unaccept-

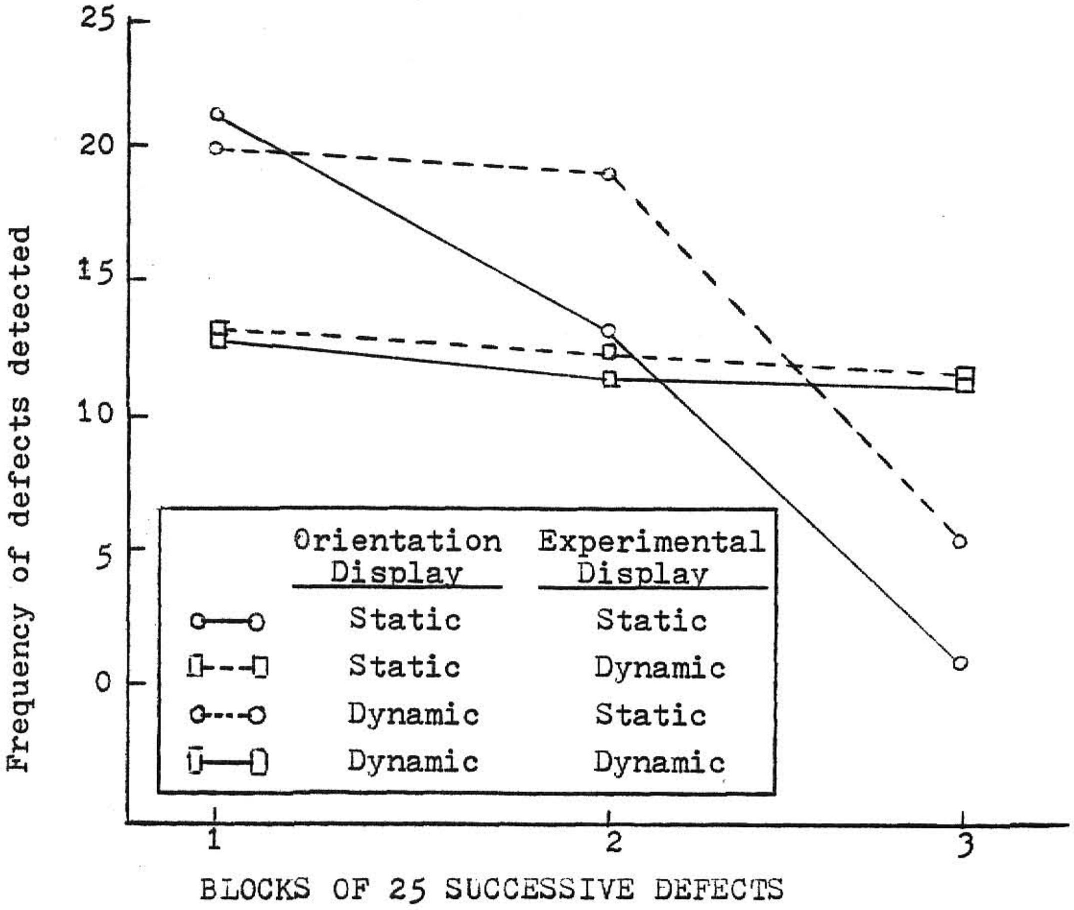


Figure 8. <u>Frequency of defect detection in successive thirds of experimental trials as a function of orientation and experimental display mode (cited from Williges and Streeter 1972).</u>

able products.

The circuits were presented for inspection under two conditions of task pacing. In the machine-paced condition, the subject was automatically presented a circuit for inspection every 14 seconds. Each circuit was displayed for 8 seconds during which the subject visually inspected the circuit and determined whether it was acceptable or defective. In the self-paced condition, circuit presentation rate was inspector controlled. Table 2 shows the results obtained. For all levels of circuit complexity, self-paced inspection took longer but resulted in a higher level of defect detection. Correct acceptance of nondefective circuits was maintained at a high level for both pacing conditions at all levels of circuit complexity. Subjects were also given a task discriptor rating sheet to fill out. It was found that subjects in both pacing conditions showed general agreement on the task being continuous and constant and reflecting a high degree of monotony, routine, and tedium. There was a tendency for all subjects to rate the task as not being pleasant, desirable, difficult, or active. Subjects in the self-paced condition rated the task as more controllable, interesting, and important than did the machine-paced subjects. Subjects in the machine-paced task condition rated the task as slightly more demanding and repetitive than did their self-paced counterparts. Overall, the task discriptor ratings indicate that both self-paced and machine-paced subjects perceived the inspection task as being relatively unpleasant, but the machine-paced subjects tended to have more negative perception of the task.

TABLE 2

Inspection Performance Comparing Machine and Self-Paced Conditions (cited from McFarling and Heimstra 1975)

	Circuit	Complexity	Level
	One	Two	Three
Mean Decision Time			
Machine-Paced	4.61 sec	4.99 sec	5.36 sec
Self-Paced	6.22	6.75	7.78
Defects Detected			
Machine-Paced	95.3 %	89.3%	89.6%
Self-Paced	99.2	93.8	89.6
Good Circuits Accepted			
Machine-Paced	98.0%	99.0%	98.8%
Self-Paced	99.7	99.3	99.3

Measurement of Inspection Performance

According to Drury (1978) any inspection device and especially human inspectors can make two errors:

Type 1 error: a good item is rejected

Type 2 error: a faulty item is accepted

One can define the probabilities of these two errors as :

e_1 = probability of Type 1 error

e_2 = probability of Type 2 error

The performance of the inspection device can then be defined by three indices:

$p_1 = 1-e_1 =$ probability of accepting a good item

= 1-probability of a false alarm

$p_2 = 1-e_2 =$ probability of rejecting a faulty item

= probability of a hit

and t = time (cost) required to inspect an item

The effect of Inspection Error. Once performance is measured by p_1, p_2 and t, the effect of these on quality control system performance can be found. If the system consists of 100% inspection, then obviously the output of good and faulty output can be predicted directly. If p' is the probability of a faulty item reaching the inspection stage, one can classify all decisions as shown in Table 3.

If the inspection relies on a sampling plan, then the effect of imperfect inspection (as measured by p_1 and p_2) can be calculated because the effective defective rate is not p' but the probability of an inspector rejecting an item, that is:

$$p'\text{effective} = (1-p_1) - p'(1-p_1-p_2)$$

Collins and Case (1976) have shown that using marginal

TABLE 3

Probabilities of Outcomes of Attributes Inspection

(cited from Drury 1978)

Inspector Decision	Item Good	Item Faulty	Total
Accepts	$p_1(1-p')$	$(1-p_2)p'$	$p_1+p'(1-p_1-p_2)$
Rejects	$(1-p_1)(1-p')$	p_2p'	$(1-p_1)-p'(1-p_1-p_2)$
Total	$(1-p')$	p'	1

distributions in this way is a valid substitute for considering all relevant combinations of events in a Bernoulli process. For example, if a batch is actually 5% defective, then an inspector with $p_1=p_2=0.90$ will cause the sampling plan to behave in the same way as it would with a batch of 14% defective and a perfect inspector.

PROBLEM

The problem is to study the effect of defect rate and type of pacing on inspector performance and to find how the inspectors perceive the task under different pacing conditions: paced, semi-paced and self-paced. Specifically, the following hypotheses shall be tested:

The first hypothesis in this study is that the greater the percentage of defectives, the better the inspection performance. This means that the inspector will detect more defects and fewer false alarms for higher defect rates.

The second hypothesis is that the inspection performance will be best in the self-paced condition followed by that in the semi-paced condition and worst in the paced condition.

The third hypothesis is that the subjects will have the best perception of the task in the self-paced condition followed by that in the semi-paced condition and the least of the task in the paced condition.

METHOD

The method of this research is divided into the following five sections:

1. Subjects
2. Task
3. Procedure
4. Performance
5. Data analysis

Subjects

Thirty six college students were used as subjects, four for each of the nine combinations of defect rates and pacing conditions. The subjects were recruited on whoever-was-available basis. Age ranged from 18 years to 39 years, with a mean of 23.8 years. All subjects possesed a visual acuity of at least 20/20 corrected. None of the subjects had any previous inspection experience and were paid for their participation.

Task

A variety of inspection tasks have been used in past research. Williges and Streeter (1972) used pin-hole defects in 1/4 inch diameter black printed discs in an experiment to study the influence of static and dynamic displays on inspection performance. Purswell (1972) used black and white photographs of 5X5 and 7X7 grids containing geometric figures to study the effect of item spacing, velocity and complexity of visual search on inspection performance. Williges and Streeter (1971) used pin-hole defects in 1/4 inch diameter transparent yellow plastics to study the effect of display type (static or dynamic) and display arrangement (random or ordered) on inspection performance.

McFarling and Heimstra (1975) used an experimental task consisting of 225 slide representations of printed circuits to study the effect of pacing and product complexity on inspection performance.

Harris (1964) developed an aptitude test for inspectors of electronic equipment. This test was developed under the assumption that a paper and pencil task could be developed to incorporate the elements of typical tasks involved in the inspection of electronic equipment. This test was validated by four studies involving a total of 65 inspectors. In each study, the relationship between test score and inspection performance was determined. This has been shown in Table 4. Harris (1964) used the same task to study effect of defect rate on inspection accuracy.

In the research the task developed by Harris was used. This paper and pencil task is made up of two forms. Form AB is made up of sheets A and B and form CD is made up of sheets C and D. Sheets A and B are shown in Figures 9 & 10 respectively. In this study only one sheet (sheet B of Harris inspection test with very minor modifications) has been used. This is shown in Figure 11.

<u>Task preparation.</u> The task was prepared by making copies of Form B of Harris Inspection Test (Figure 10). This Form B contains both defective and non-defective items. The non-defective items were cut out from copies of Form B. A defect free

TABLE 4

Summary of Inspection Test Validation Results

Inspection Department	Number of inspectors	Validity coefficients	
		Form AB	Form CD
Electronic Chassis	11	.39	—
Inertial Instruments	8	.86*	—
Module Assemblies	19	.58*	—
Circuit Boards	27	.51*	.64*

* Statistically significant at the .05 level

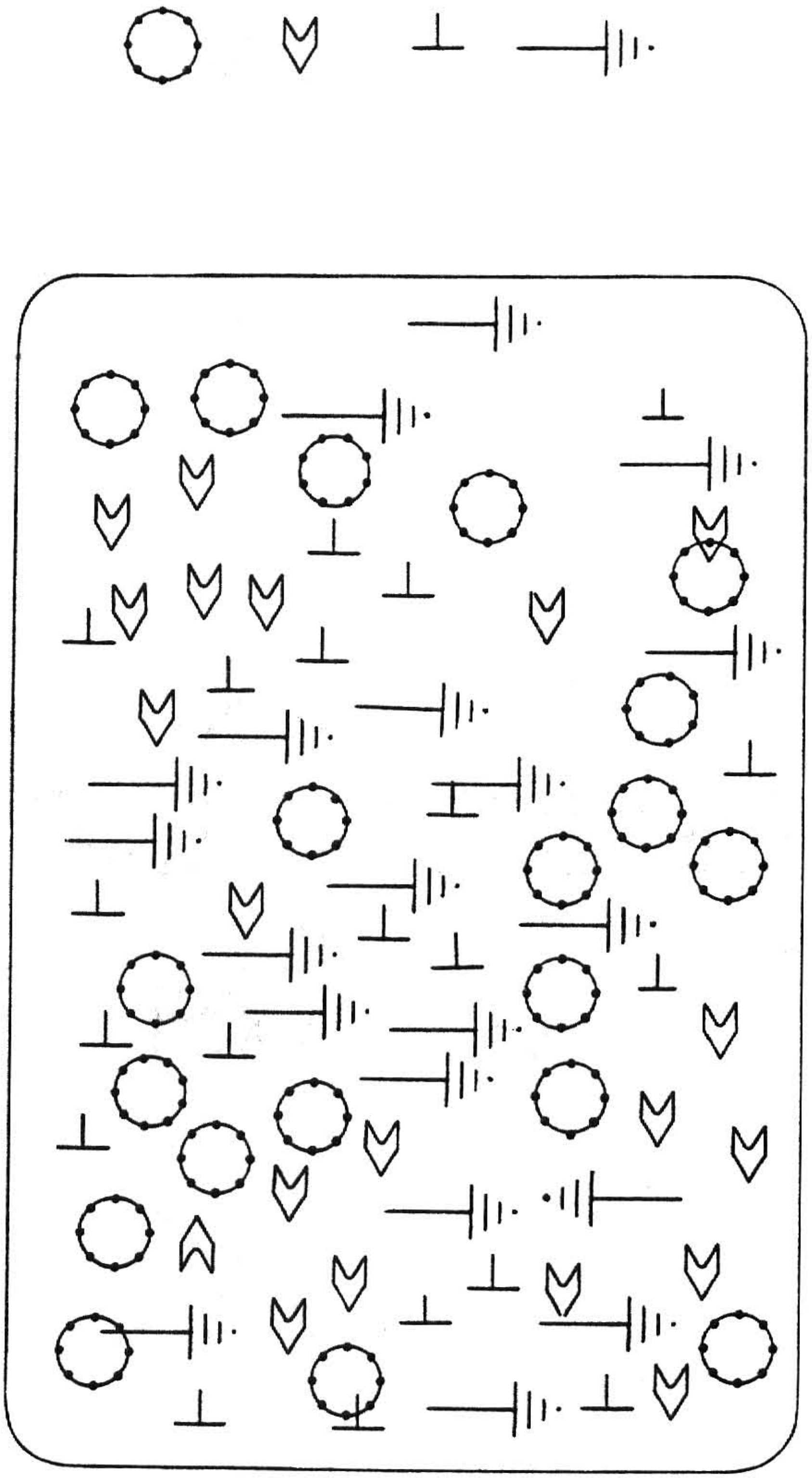


Figure 9. <u>Form A of Harris Inspection Test</u>.

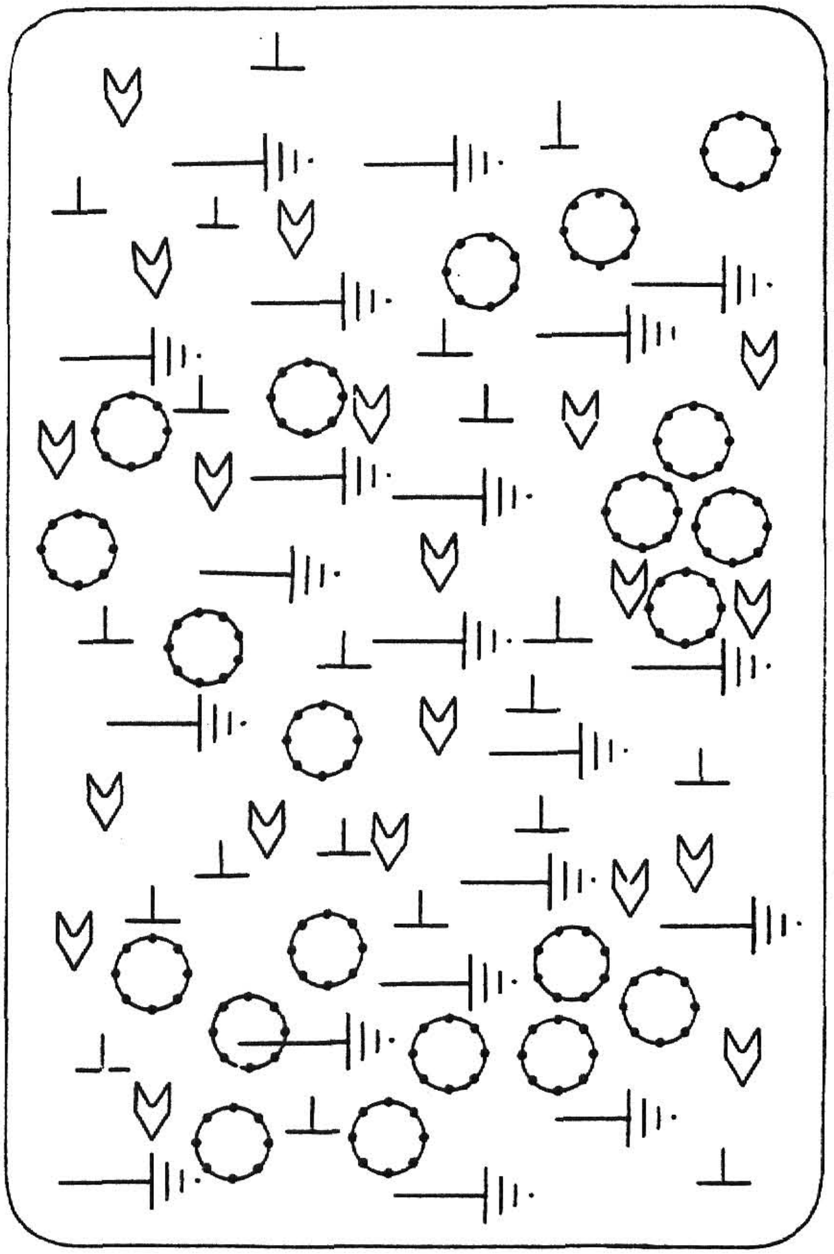


Figure 10. Form B of Harris Inspection Test.

sheet (like the one shown in Figure 11) was made by pasting non-defective items over all defective items in a sheet containing both. Then copies of this defect-free sheet were made. Defective items were then pasted in locations(selected using random number tables) on these defect-free sheets to form master sheets for a particular defect rate. The same process was repeated for other defect rates. These master sheets were copied to make sheets for the experiment.

The defects are shown in Figure 12. The defects were that some of the objects may not have the correct shape, some may be slightly out of line. For example, in Figure 12, the object crossed out on the left has a dot out of place. The crossed-out object in the center is out of line and the one on the right has two lines which are not properly joined.

Procedure

The subject was led into a room having a table and chair. The table had a digital clock which had a least count of one-thousandth of a minute. Upon arrival the subject was asked to sit on the chair and requested to sign a consent form shown in Figure 13. The subject was assigned randomly to one of the nine combinations of pacing condition and defect rate, shown in Table 5. Then the subject was given four sheets. The first sheet gave general instructions on how the task in actual experiment was to be administered and depended on whether the subject was to perform in the paced, semi-paced or self-paced condition, shown in Figures 14, 15 and 16 respectively. The second sheet was instructions on the nature of defects, shown in Figure 17. The third sheet shown in Figure 18 was a task perception sheet

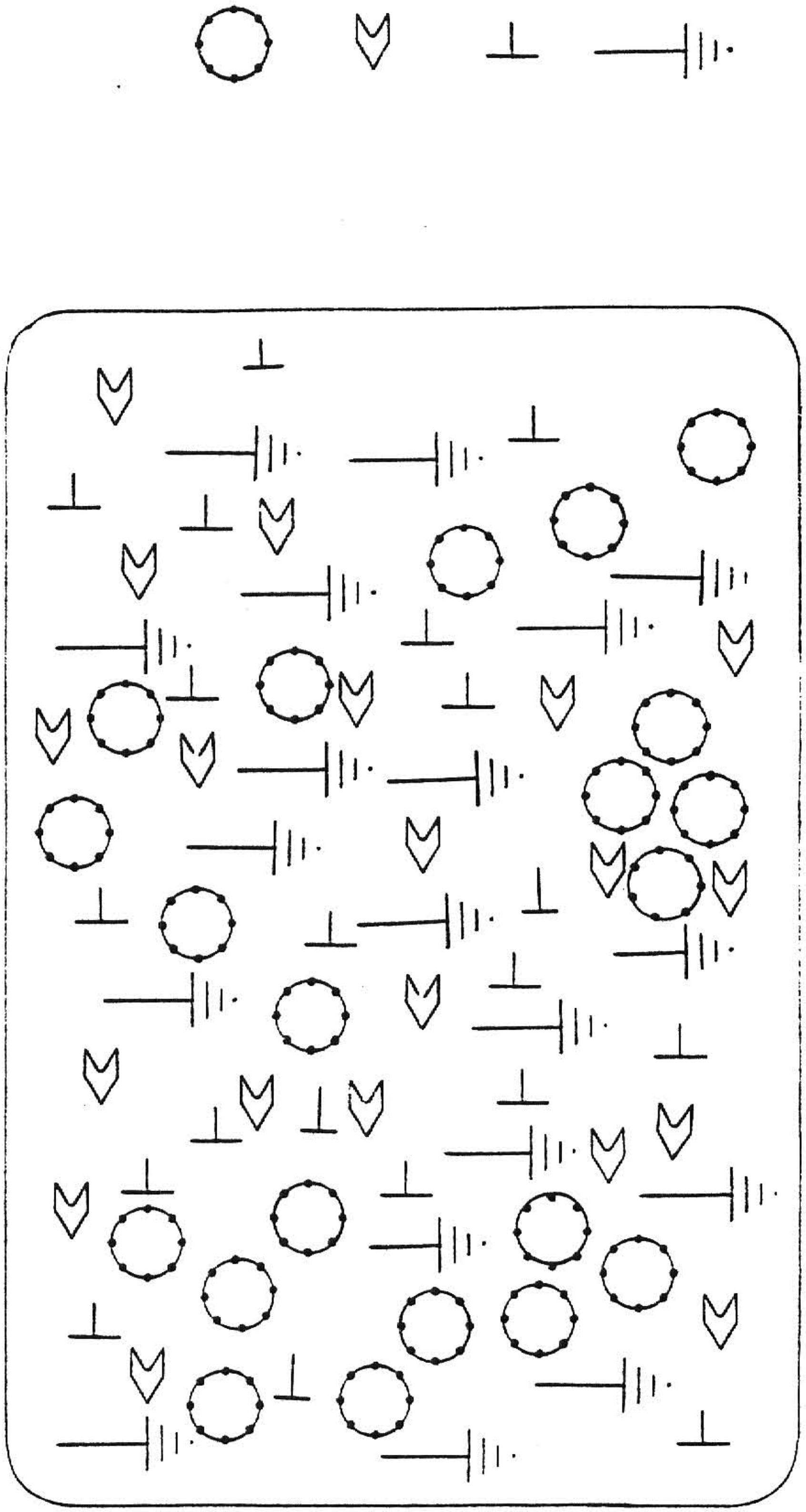


Figure 11. <u>Actual task used in the experiment</u>.

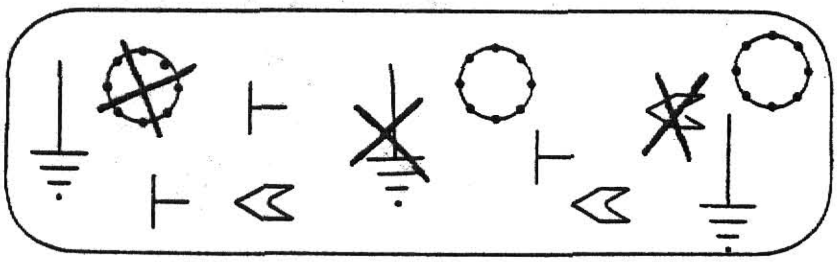


Figure 12. Nature of defects.

Subject consent form

The experiment you are about to participate in studies inspection performance. There are no dangers involved. However, you are free to stop the experiment any time you wish. If you agree to participate as a subject in this experiment, please sign your name below. Thank you.

Devendra Singh Negi

Figure 13. Subject consent form.

TABLE 5

Experimental conditions in the experiment

		DEFECT RATE IN EXPERIMENT		
		1%	4%	16%
PACING CONDITIONS	Paced	4 subjects per cell		
	Semi			
	Self			

INSTRUCTIONS

You will be given 1 sheet to inspect in 2.5 minutes. The sheet contains 20 each of 4 different items. The correct ones are shown on top of each sheet. You are to mark the incorrect ones with an X.

You are encouraged to inspect until you are 100% confident of accuracy and as fast as possible. The clock in front of you shows how much time you have spent on the task. If you finish before 2.5 minutes are over, please let me know immediately.

I will take the sheet you have just completed and give you another sheet when the 2.5 minutes are over. If you have not completed the sheet in 2.5 minutes, I will take it away and give you another sheet to inspect. In this way you shall inspect 9 sheets.

Enclosed are instructions which explain defects and also a trial sheet containing defects. You are to mark the defects in this sheet and also have some idea of the time involved in the task of inspecting the sheet.

After studying the sheet explaining defects, please let me know when you are ready to inspect the trial sheet.

I will give you a task rating sheet to be filled up after you have completed inspecting 9 sheets under test condition.

Figure 14. Instructions for paced condition.

INSTRUCTIONS

You will be given 3 sheets at a time to inspect in a total time of 7.5 minutes. Each sheet contains 20 each of 4 different items. The correct ones are shown on top of each sheet. You are to mark the incorrect ones with an X.

You are encouraged to inspect until you are 100% confident of accuracy and as fast as possible. The clock in front of you shows how much time you have spent on the task. If you finish before 7.5 minutes are over please let me know immediately. I will take the 3 sheets you have just completed and give you another set of 3 sheets to inspect. If you have not completed the 3 sheets in 7.5 minutes, I will take them away and give you another set of 3 sheets. In this way you will inspect 9 sheets. Enclosed are instructions which explain defects and also trial sheet containing defects. You are to mark the defects in this sheet and also have some idea of the time involved in the task of inspecting one sheet.

After studying the sheet explaining defects please let me know when you are ready to inspect the trial sheet.

I will give you a task rating sheet to be filled up after you have completed inspecting 9 sheets under test condition.

Figure 15. Instructions for semi-paced condition.

INSTRUCTIONS

You will be given 9 sheets to inspect. Each sheet contains 20 each of 4 different items. The correct ones are shown on top of each sheet. You are to mark the incorrect ones with an X. You are encouraged to inspect until you are 100% confident of accuracy and as fast as possible. Please let me know <u>immediately</u> when you finish all the 9 sheets provided.

Enclosed are instructions which explain defects and also a trial sheet containing defects. You are to mark the defects in this sheet.

After studying the sheet explaining defects, please let me know when you are ready to inspect the <u>trial</u> sheet.

I will give you a task rating sheet to be filled up after you have completed inspecting 9 sheets under test condition.

Figure 16. <u>Instructions for self-paced condition</u>.

NAME ______ LAST ______ FIRST ______ MIDDLE ______ DATE ______

COMPANY ______

PLANT ______ DEPT. ______

SCORES

	RAW	%-ILE
R		
W		

JOB TITLE ______

APPLICANT? ______ EMPLOYEE? ______ AGE ______ SEX ______ M. OR F.

EDUCATION 6 7 8 9 10 11 12 13 14 15 16 16+
ENCIRCLE NUMBER OF LAST GRADE COMPLETED

HARRIS INSPECTION TEST

FORM B

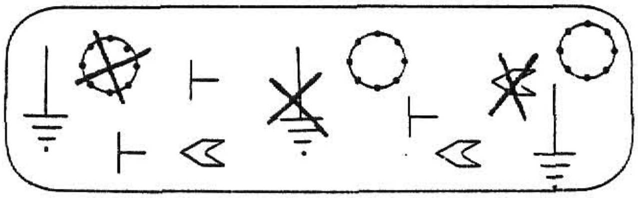
Developed by:
Douglas H. Harris

This is a test of how well you can inspect objects for defects.

The enclosed area on the back of this sheet contains a number of objects. There are four different kinds of objects—one of each kind is shown in its correct form below. A correct example of each one is also shown on the back of the sheet.

Your task will be to inspect the enclosed area and put an "X" through each object which is not like the correct one shown.

Some of the objects may not have the correct shape, some may not be of the correct size, some may not have the correct number of parts or the parts may be out of place, others may be slightly out of line. For example, the object crossed out on the left below has a dot out of place. The crossed-out object in the center is out of line and the one on the right has two lines which are not properly joined.



One object may overlap another. Overlapping is NOT to be counted as a defect. Your score will be based upon the number of defective items you mark. However, be careful not to mark any correct items—a penalty will be subtracted for each one marked.

PSYCHOLOGICAL SERVICES, INC.
LOS ANGELES, CALIFORNIA

Figure 17. Instructions on nature of defects.

In your opinion the task you just completed was

Relaxing____________________________Strenuous
1 2 3 4 5 6 7 8 9 10

Boring____________________________Interesting
1 2 3 4 5 6 7 8 9 10

	Very, very easy		Very easy		Fairly easy		Somewhat hard		Hard		Very hard		Very, very hard	
6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 18. Task perception rating sheet.

which was to be completed after the experiment. The fourth sheet was the trial sheet which had the same percentage of defects which the subject was to inspect in the actual experiment. After reading the instructions, the subject performed one practice trial in 2½ minutes. Feedback was given to the subject as to how his/her performance was and provided with further clarifications on the nature of defects.

The actual task was examining one sheet in 2½ minutes in the paced condition, three sheets in 7½ minutes in the semi-paced condition and as much time as the subject desired in the self-paced condition. The subjects informed the experimenter when they had finished inspecting the sheets provided so that the actual time on the task could be noted. At the end of the experiment, the subject completed a task perception rating sheet.

Performance measures

Data was collected to determine the percentage of total defects detected, the percentage of false alarms and the time required for each of the nine combinations of pacing and defect rate. The time a subject took in inspecting nine sheets was noted down as the decision time. Subject ratings of the task were also collected. These ratings were made to make comparisons between pacing conditions on the basis of the task perception.

Data analysis

A two factor randomized design was used for the analysis of variance of the three performance measures (defect detection rate, false alarms and decision time) and three task perception ratings with four subjects in each combination of pacing condition and defect rate.

RESULTS

Inspection performance is measured in terms of percentage of hits (percentage of correct defects reported to the actual number of defects), percentage of false alarms (percentage of false alarms to the number of correct items), decision times for inspecting nine sheets, rating on the "relaxing-strenuous" scale, rating on the "boring-interesting" scale and rating on the Borg scale.

Analysis of variance for all six dependent variables (percentage of hits, percentage of false alarms, decision time and the three task perception ratings) was done using the Statistical Analysis System at the Kansas State University. Duncan's Multiple Range Test was done at the alpha level of 0.05.

Percentage of hits

The performance of individuals (four subjects per cell) is shown in Table 6. The means are 87.7, 89.2 and 94.2% for the paced, semi-paced and self-paced conditions respectively. The means are 86.9, 91.3 and 92.7% for the 1, 4 and 16% defect rates respectively. The overall mean is 90.3% with a standard deviation of 7.2%.

The analysis of variance is shown in Table 7. Neither of the main effects of pacing condition and defect rate were significant at the 0.05 level. But a one way t-test (0.05 level) shows the performance in the self-paced condition to be significantly better than the performance in the paced condition. The t-test also shows a significantly higher percentage of hits in the 16% defect rate than the 1% defect rate. The means for the

TABLE 6

Percentage of hits for individuals in various cells

		Pacing conditions			
		Paced	Semi	Self	Mean
Defect Rate	1%	71.4 85.7 (82.1) 100.0 71.4	85.7 85.7 (85.7) 85.7 85.7	100.0 85.7 (92.9) 100.0 85.7	86.9
	4%	92.9 89.3 (89.3) 92.9 82.1	85.7 96.4 (91.1) 82.1 100.0	92.9 92.9 (93.8) 96.4 92.9	91.4
	16%	97.4 88.7 (91.6) 87.1 93.1	89.6 92.2 (90.7) 94.9 86.1	87.0 99.1 (95.9) 99.1 98.3	92.7
	Mean	87.7	89.2	94.2	90.3

TABLE 7

Analysis of variance for Hits

Source of variation	DF	Mean square	F value	PR>F
Pacing condition (A)	2	139.23444	2.93	0.0706
Defect rate (B)	2	111.66194	2.35	0.1147
AXB	4	15.54236	0.33	0.8574
Error	27	47.53667		
Total	35			

pacing conditions are shown in Figure 19 and the means for the defect rates are shown in Figure 20.

Percentage of false alarms

The performance of individuals is shown in Table 8. The means are 1.02, 0.45 and 0.23% for the paced, semi-paced and self-paced conditions respectively. The means are 0.26, 0.63 and 0.80% for the 1, 4 and 16% defect rates respectively. The overall mean is 0.57% with a standard deviation of 0.87%.

The analysis of variance is shown in Table 9. Neither of the main effects of pacing conditions and defect rate were significant. However, a t-test showed the percentage of false alarms to be significantly lower in the self-paced condition as compared to that in the paced condition. The t-test showed the performance in the 1% defect rate to be better than the performance in the 16% defect rate. The means for the pacing conditions are shown in Figure 21 and the means for the defect rates are shown in Figure 22.

Decision time

The decision time taken by individuals is shown in Table 10. The means are 1213, 1304 and 1333 seconds for the paced, semi-paced and self-paced conditions respectively. The means are 1144, 1300 and 1405 seconds for the 1, 4 and 16% defect rates respectively. The overall mean is 1284 seconds with a standard deviation of 388 seconds.

The analysis of variance is shown in Table 11. The main effects of pacing conditions and defect rates were not significant. However, a t-test showed that the 16% defect rate took a longer time than the 1% defect rate. The means for the defect

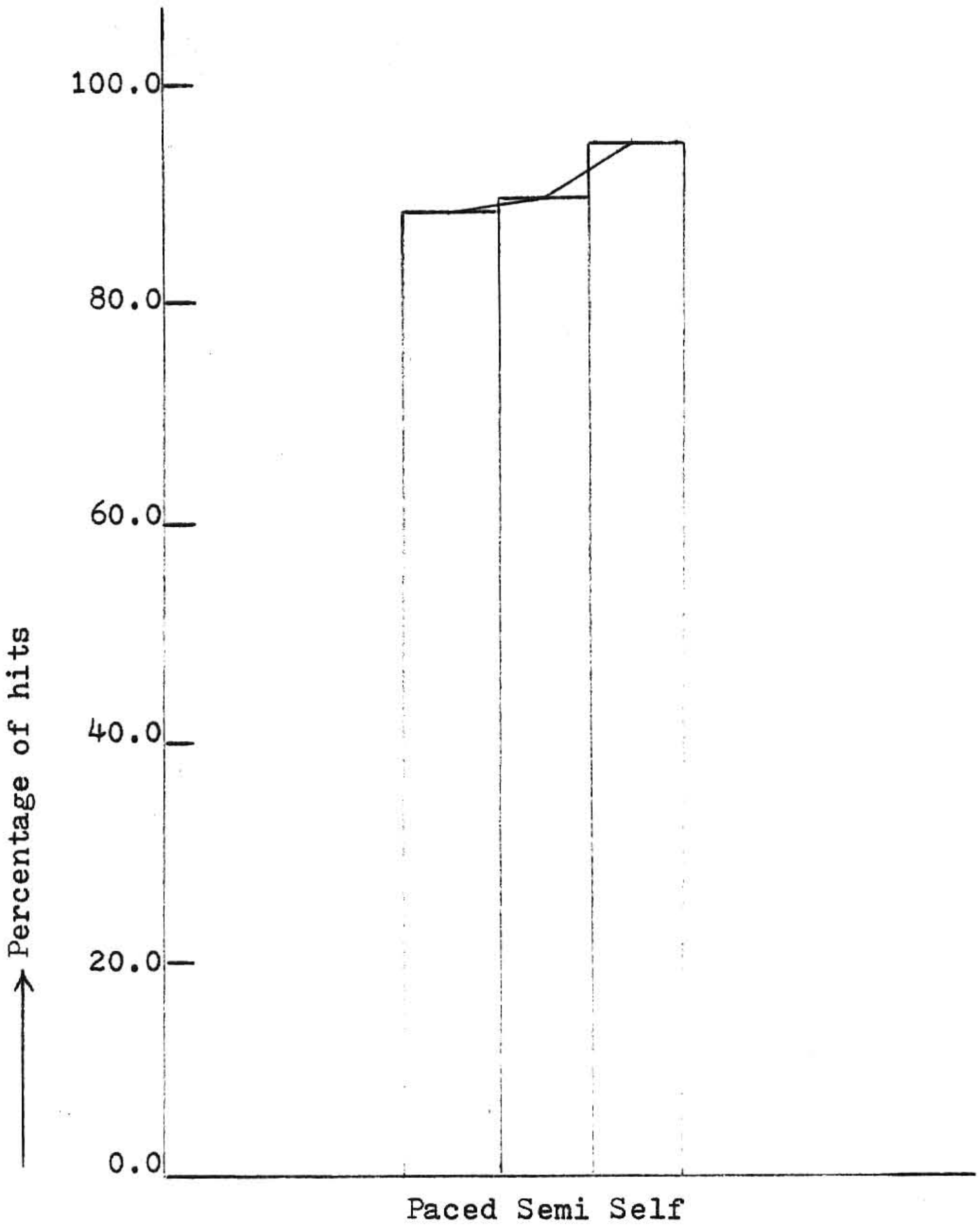


Figure 19. Mean percentage of hits for different pacing conditions.

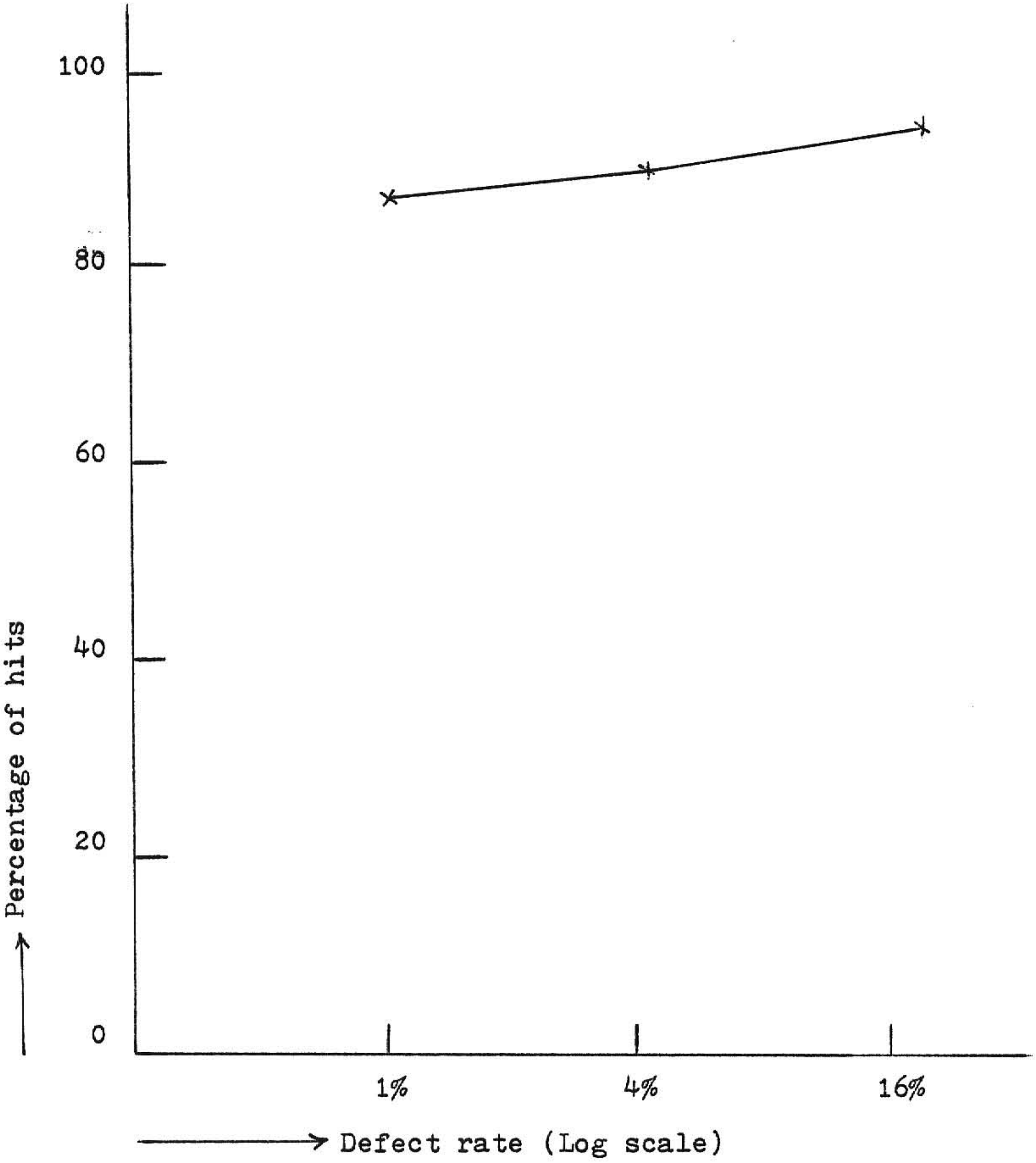


Figure 20. Mean percentage of hits for different defect rates.

TABLE 8

Percentage of false alarms for individuals in various cells

	Pacing conditions			
Defect rates	Paced	Semi	Self	Mean
1%	0.28 0.42 (0.39) 0.56 0.28	0.00 0.28 (0.61) 0.42 0.28	0.14 0.14 (0.36) 0.14 0.28	0.26
4%	2.02 0.58 (0.94) 0.72 0.43	0.14 0.72 (0.61) 1.59 0.00	0.14 0.29 (0.36) 0.43 0.58	0.63
16%	1.49 0.33 (1.74) 0.17 4.96	0.17 0.83 (0.50) 0.66 0.33	0.17 0.17 (0.17) 0.33 0.00	0.80
Mean	1.02	0.45	0.23	0.57

TABLE 9

Analysis of variance for False alarms

Source of variation	DF	Mean square	F value	PR>F
Pacing condition (A)	2	1.97569	2.86	0.0747
Defect rate (B)	2	0.89235	1.29	0.2912
AXB	4	0.57312	0.83	0.5180
Error	27	0.69070		
Total	35			

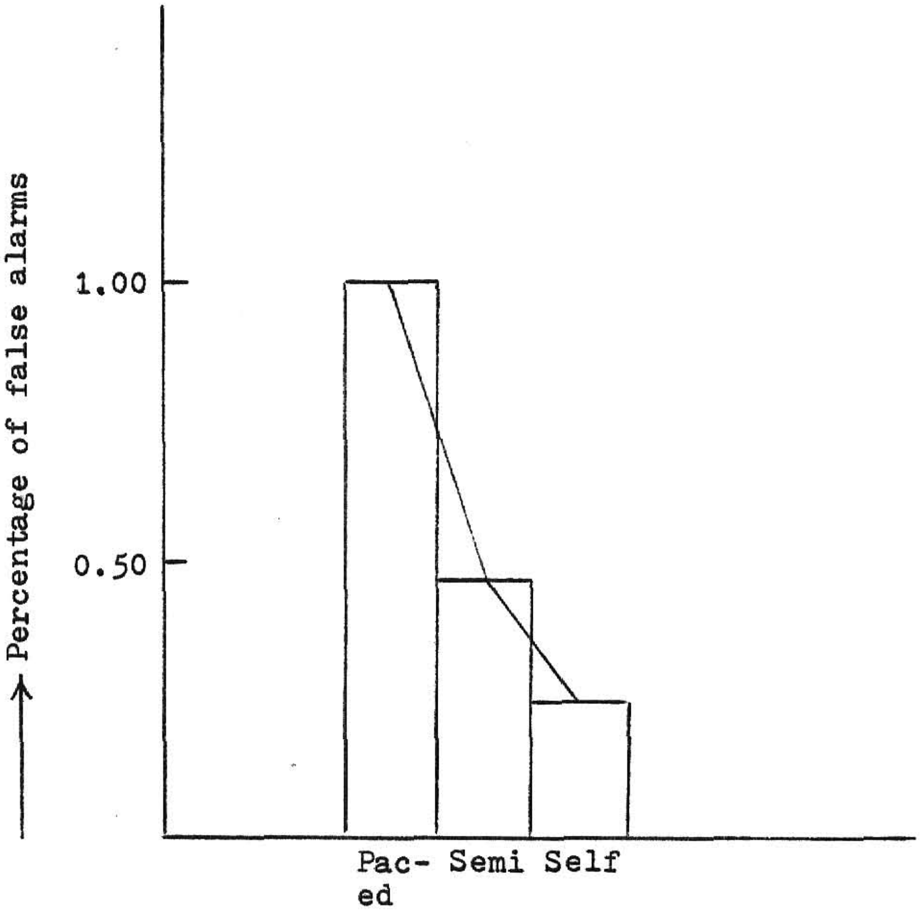


Figure 21. Mean percentage of false alarms for pacing conditions.

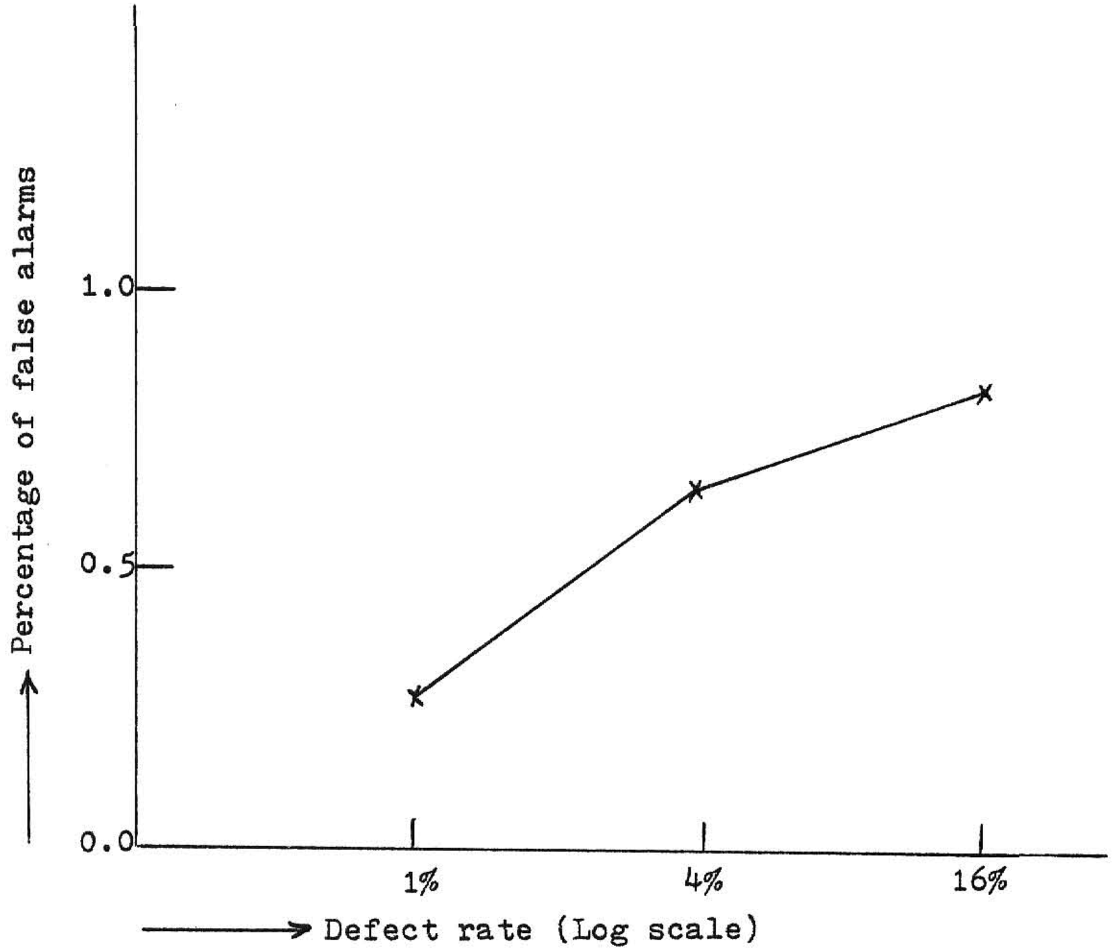


Figure 22. Mean percentage of false alarms for defect rates.

TABLE 10

Decision times (seconds) for individuals in various cells

		Pacing conditions						
		Paced		Semi		Self		Mean
Defect rates	1%	1164	1350	1085	1305	1350	870	
		(1172)		(1224)		(1027)		1144
		1077	1097	1205	1302	836	1050	
	4%	1248	1280	1350	893	1190	1370	
		(1208)		(1236)		(1459)		1300
		1275	1028	1350	1350	1087	2190	
	16%	1223	1224	1245	2190	1085	1730	
		(1262)		(1440)		(1513)		1405
		1323	1278	1166	1160	912	2325	
	Mean	1213		1304		1333		1248

TABLE 11

Analysis of variance for Decision times

Source of variation	DF	Mean square	F value	PR>F
Pacing condition (A)	2	46253.361	0.39	0.6821
Defect rate (B)	2	206041.690	1.73	0.1966
AXB	4	71257.777	0.60	0.6674
Error	27	119202.720		
Total	35			

rates are shown in Figure 23.

"Relaxing-strenuous" task perception rating

The subjects rated the task on a 1 to 10 scale with 1 corresponding to the task being relaxing and 10 corresponding to the task being strenuous. The task perception ratings given by the subjects are shown in Table 12. The means are 5.6, 6.3 and 5.8 for the paced, semi-paced and self-paced conditions respectively. The means are 6.0, 6.0 and 5.75 for the 1, 4 and 16% defect rates respectively. The overall mean is 5.9 with a standard deviation of 1.68.

The analysis of variance is shown in Table 13. The main effects of pacing conditions and defect rates were not significant.

"Boring-interesting" task perception rating

The subjects rated the task on a 1 to 10 scale with 1 corresponding to the task being boring and 10 corresponding to the task being interesting. The task perception ratings given by the subjects are shown in Table 14. The means are 7.0, 5.6 and 4.6 for the paced, semi-paced and self-paced conditions respectively. The means are 5.8, 5.9 and 5.8 for the 1, 4 and 16% defect rates respectively. The overall mean is 5.8 and the standard deviation is 2.45.

The analysis of variance is shown in Table 15. Only the pacing condition main effect was significant. Duncan's Test shown in Table 16 groups the performance in the paced and semi-paced condition and also performance in the semi-paced and self-paced condition. But a t-test shows that the paced condition is significantly more interesting than the self-paced condition.

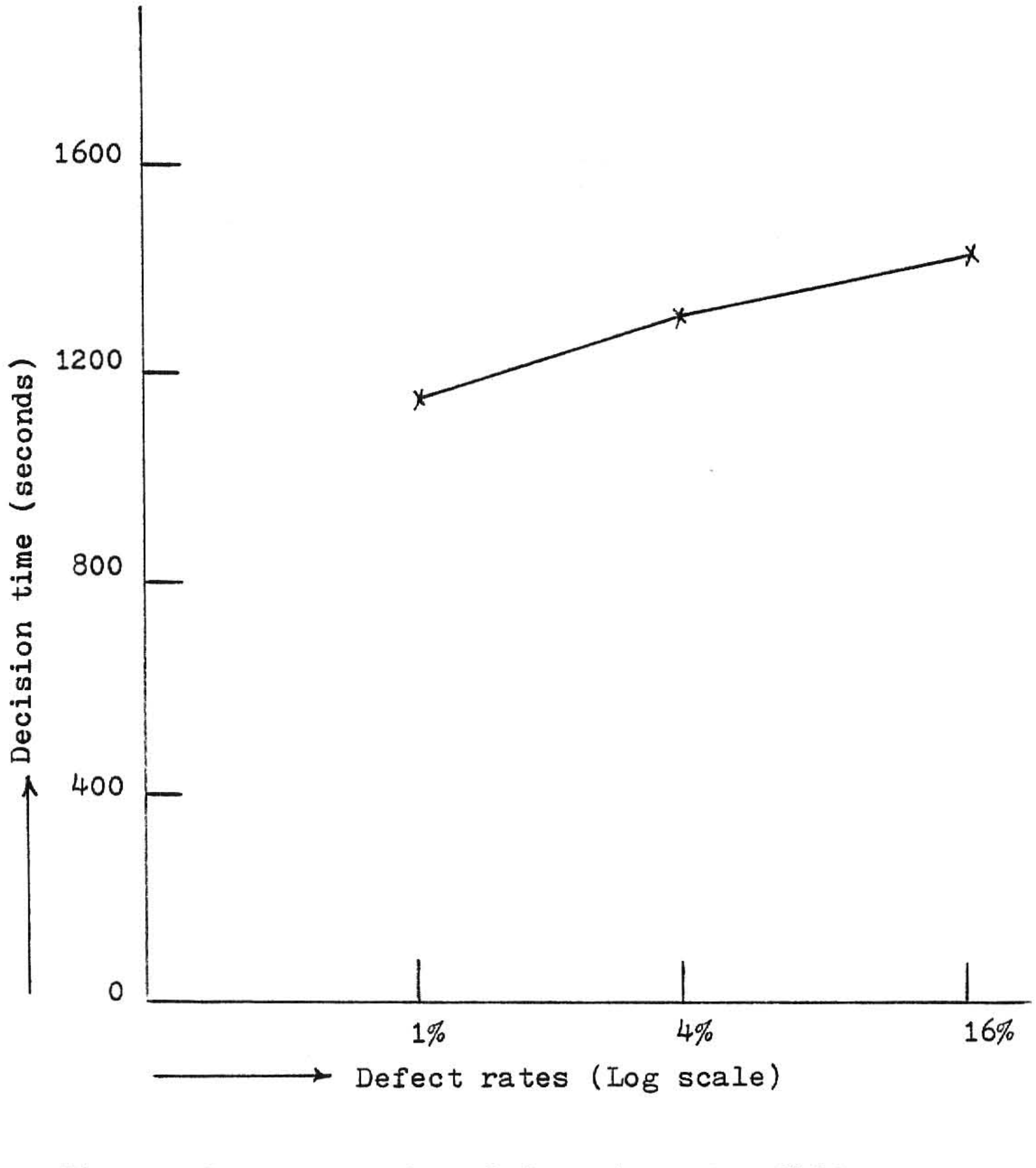


Figure 23. Mean of decision times for different defect rates.

TABLE 12

"Relaxing-strenuous" task perception ratings for various cells*

	Pacing conditions			
Defect rates	Paced	Semi	Self	Mean
1%	6 6 (5.5) 5 5	7 7 (7.0) 8 6	5 5 (5.5) 5 7	6.0
4%	3 4 (5.5) 9 6	6 4 (6.3) 7 8	6 5 (6.3) 6 8	6.0
16%	7 6 (5.8) 3 7	7 8 (5.8) 6 2	6 5 (5.8) 3 9	5.8
Mean	5.6	6.3	5.8	5.9

* A rating of "1" means the task is relaxing, a rating of "10" means the task is strenuous.

TABLE 13

Analysis of variance for "relaxing-strenuous" task perception rating

Source of variation	DF	Mean square	F value	PR>F
Pacing condition (A)	2	1.75000	0.52	0.6000
Defect rate (B)	2	0.25000	0.07	0.9285
AXB	4	1.00000	0.30	0.8770
Error	27	3.36111		
Total	35			

TABLE 14

"Boring-interesting" task perception ratings for various cells*

		Pacing conditions			
		Paced	Semi	Self	Mean
Defect rates	1%	8 7 (5.8) 3 5	9 5 (6.8) 3 10	5 6 (4.8) 6 2	5.8
	4%	8 6 (6.8) 6 7	2 6 (5.5) 8 6	6 8 (5.5) 6 2	5.9
	16%	9 10 (8.8) 8 8	4 2 (4.8) 7 6	3 2 (3.8) 8 2	5.8
	Mean	7.0	5.6	4.6	5.8

* A rating of "1" means the task is boring, a rating of "10" means the task is interesting.

TABLE 15

Analysis of variance for "boring-interesting" task perception rating

Source of variation	DF	Mean square	F value	PR>F
Pacing condition (A)	2	17.69444	3.38	0.0489
Defect rate (B)	2	0.11111	0.02	0.9790
AXB	4	8.19444	1.57	0.2118
Error	27	5.23148		
Total	35			

TABLE 16

Duncan's Multiple Range Test for "boring-interesting" task perception scale

Alpha=0.05

Grouping		Mean	Observations	Pacing condition
	A	7.08	12	Paced
B	A	5.67	12	Semi
B		4.67	12	Self

The means for the pacing conditions are shown in Figure 24.

Borg scale task perception rating

The subjects rated the task difficulty on the Borg scale from 6 to 20. The task perception ratings given by the subjects are shown in Table 17. The mean ratings are 14.3, 12.8 and 12.8 for the paced, semi-paced and self-paced conditions respectively. The mean ratings are 13.8, 13.7 and 12.6 for the 1, 4 and 16% defect rates respectively. The overall mean rating is 13.3 with a standard deviation of 2.14.

The analysis of variance is shown in Table 18. Both the main effects of pacing conditions and defect rates are not significant. Significant interaction between the main effects of pacing conditions and defect rates is observed. Data of cell means indicates that the subjects perceive the task as relatively less hard when in self-paced and higher defect rate condition. Also a t-test shows the self-paced condition to be significantly less hard than the paced condition. The means for the pacing conditions are shown in Figure 25.

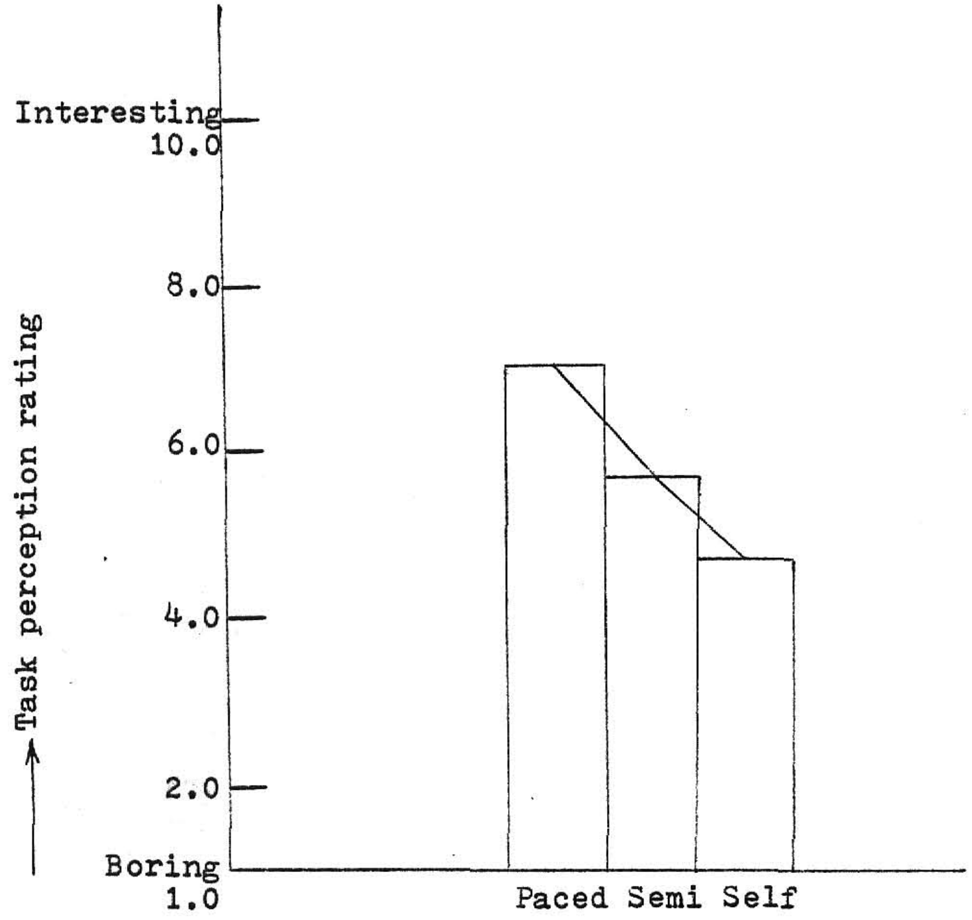


Figure 24. Mean of "Boring-interesting" task perception rating for different pacing conditions.

TABLE 17

Borg scale task perception ratings for various cells*

		Pacing conditions			
		Paced	Semi	Self	Mean
Defect rates	1%	17 18 (15.8) 13 15	11 16 (13.3) 13 13	13 12 (12.3) 11 13	13.8
	4%	12 11 (13.0) 16 13	14 11 (14.5) 16 17	11 16 (13.5) 12 15	13.7
	16%	14 15 (14.3) 13 15	11 10 (10.8) 11 11	12 13 (12.8) 11 15	12.6
	Mean	14.3	12.8	12.8	13.3

* A rating of "7" means the task is very, very easy, a rating of "13" means the task is somewhat hard, a rating of "19" means the task is very, very hard.

TABLE 18

Analysis of variance for Borg scale

Source of variation	DF	Mean square	F value	PR F
Pacing condition (A)	2	9.00000	2.57	0.0950
Defect rate (B)	2	5.08333	1.45	0.2517
AXB	4	9.33333	2.67	0.0539
Error	27	3.50000		
Total	35			

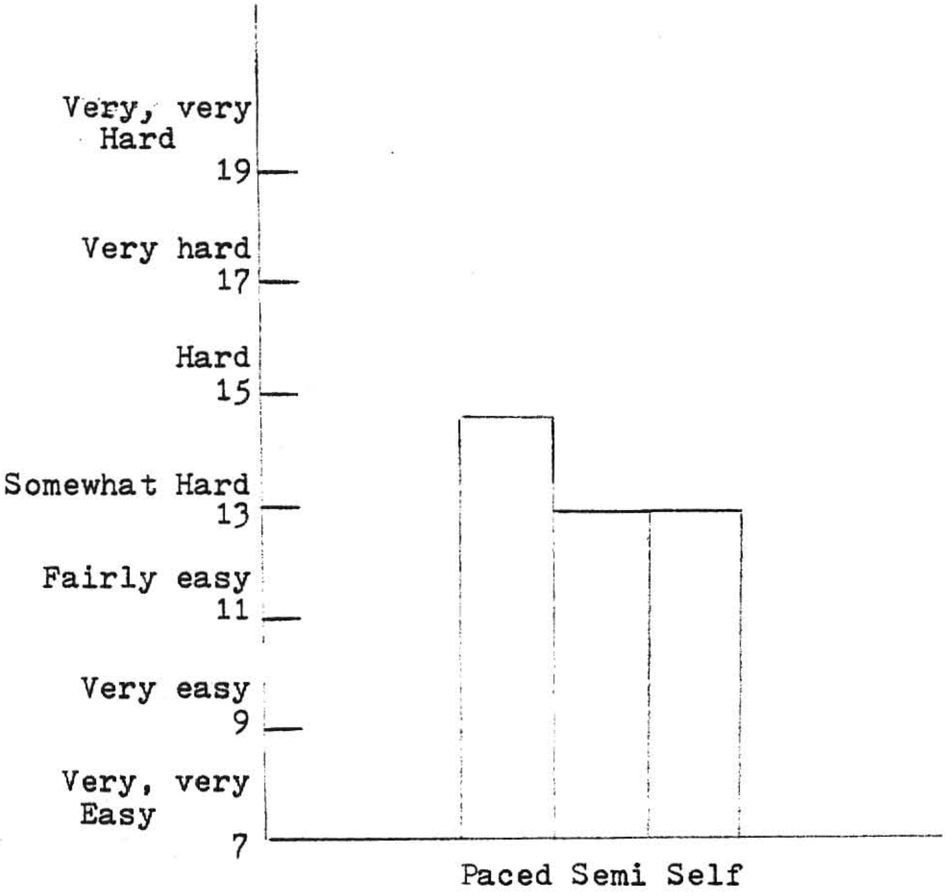


Figure 25. Mean of Borg scale rating for different pacing conditions.

DISCUSSION

It was hypothesized that the greater the percentage of defectives, the better the inspection performance. Specifically, this meant that the inspector would detect more defects and produce fewer false alarms for a higher percentage of defects. The other hypothesis was that the inspection performance would be best in the self-paced condition followed by that in the semi-paced condition and worst in the paced condition. The third hypothesis was that the subjects have the best perception of the task in the self-paced condition followed by that in the semi-paced condition and the least in the paced condition.

Effect of pacing condition on performance

Hits (and misses). The subjects performed significantly better in the self-paced condition as compared to the paced condition. This is consistent with the findings of McFarling and Heimstra (1975) who reported a greater percentage of hits in a self-paced condition as compared to a paced condition. Performance in the semi-paced condition was not significantly better than in the paced condition. This is contrary to what was hypothesized. This is probably because the operator variability was not reduced by a semi-paced condition of three at a time. Another experiment with more than three sheets at a time might bring out a significantly better performance in the semi-paced condition.

False alarms (and correct acceptances). The subjects had a significantly higher percentage of false alarms when in the paced condition as compared to the self-paced condition. This is consistent with the findings of McFarling and Heimstra (1975) who reported lesser percentage of false alarm errors in the self-paced condition as compared to the paced condition. Significant differences in the performance in the semi-paced condition as compared to that in the paced condition could not be obtained. This is probably because the semi-paced condition of three sheets at a time could not reduce the operator variability to improve the performance. A semi-paced condition with more than three sheets at a time might bring out a better performance in the semi-paced condition.

Decision time. No significant differences in the three pacing conditions were observed. This is contrary to what was hypothesized where significantly higher decision times were expected in the self-paced condition as compared to the semi-paced condition and significantly higher times in the semi-paced condition as compared to the paced condition. The results obtained might be due to operator variability. Another reason might be that the trial before the experiment was made for 2½ minutes for one sheet might have influenced the subjects to perform at a rate not significantly different in the three pacing conditions.

"Relaxing-strenuous" task perception rating. No significant differences in the three pacing conditions were observed. This is contrary to what was hypothesized. It might be that the task involved was for such a short period of time that the subjects never really felt the pressure of doing this task and as such reported no significantly different ratings for the three pacing conditions. A similar experiment with a longer task period might bring out significant differences on this task perception scale.

"Boring-interesting" task perception rating. The paced condition was perceived as significantly better compared to the self-paced condition. This is completely contrary to what was hypothesized. It might be that because of the short task time, the subjects found racing against the time more interesting than being given their own time to finish the task. Another experiment with a longer task time needs to be carried out to say anything conclusively.

Borg scale rating. The paced condition was perceived as significantly harder than the self-paced condition. However, the paced condition was not perceived harder than the semi-paced condition. It is felt that a semi-paced condition with more than three sheets at a time and an increase in task duration might bring out significant differences, if any, between the paced and the semi-paced conditions. Another reason can be that the task was not hard enough to bring out significant differences in the semi-paced condition as compared to those in the paced and self-paced condition.

Effect of defect rates on performance

Hits (and misses). The subjects performed significantly better in the 16% defect rate as compared to the 1% defect rate. This supports the findings of Harris (1968). Fox and Haselgrave (1969) reported similar findings. Lin (1980) also reported that an inspector would detect a higher percentage of defects with a higher percentage of lot defectives. But, the performance in the 4% defect rate was not significantly better than that in the 1% defect rate. It might be that because of the low power of the experiment, differences in performance among smaller ranges of defect rates (1%, 4% and 4%, 16%) could not be detected. Another similar experiment with more than four subjects per cell might bring out this difference more significantly.

False alarms (and correct acceptances). A completely contrary result to what was hypothesized, was obtained. Subjects performed significantly better in the 1% defect rate as compared to the 16% defect rate. This might be due to the effect of trials before the experiment. In order to make the subjects aware of the percentage of defects in the actual experiment (without actually telling them), the subjects worked on a trial sheet which had the same percentage of defects as their actual experimental condition. It is possible that at this trial stage, the subjects developed a tendency to miss defects than to report false alarms for lower defect rates. Nothing, however, can be said conclusively. Further study needs to be carried out with more number of subjects per cell, a longer task and a trial which contains a completely different defect rate than the experimental condition in order to make definite conclusions.

Harris (1968) studied the effect of defect rate on inspection performance and defined the percentage of false alarms as the percentage of false alarms to the total number of defects reported. Using this definition for percentage of false alarms in this study showed that the percentage of false alarms were significantly highest for the 1% defect rate, less for the 4% defect rate and least for the 16% defect rate. This is consistent with the findings of Harris (1968).

Decision time. The subjects took significantly less time while operating in the 1% defect rate as compared to the 16%

defect rate. This is as expected because more time is required to compare more defects with correct items on top of every sheet and then mark those items as defects. However, this time in the 4% defect rate was not significantly different from that in the 1 or 16% defect rate. This might be due to subject variability.

"Relaxing-strenuous" task perception rating. No significant differences in the three defect rate condition were observed. This is as expected.

"Boring-interesting" task perception rating. No significant differences were observed. This is as expected.

Borg scale. No significant differences in the three defect rate conditions were observed. This is as expected.

Future research

This study did not bring out significant performance differences between the semi-paced and paced conditions and between semi-paced and paced conditions. It might be that the semi-paced condition of three sheets at a time were not sufficient to reduce the operator variability to bring out significant improvement in performance over the paced condition. A similar study with more than three sheets at a time for the semi-paced condition might bring out this difference. Another reason can be that as the experimental design for this study was for an alpha level of 0.05 and power of 0.5, another experiment with an increased power might show the semi-paced condition to be significantly different from both the paced and the self-paced conditions. For a similar experimental design, increasing the number of subjects per cell will increase the power of the experiment. Further research is needed to study whether the semi-paced condition can form a good compromise between the extreme conditions of paced and self-paced.

Factors such as the nature of the inspection task, complexity of the task, task time and the way the trials are administered before the experiment remain to be researched. In fact it is felt that even elimination of trials might be considered to remove any possible biasing in performance during actual experiment.

Further research is needed to confirm the findings of this study that the inspection performance is better in the self-paced condition as compared to that in the paced condition at least for measures such as hits (and misses) and false alarms (and correct acceptances).

Practical implications

This study points that inspection performance improved in the self-paced condition as compared to the paced condition. Management might consider using self-pacing if higher detection rate and less false alarms outweigh increased costs due to more inspection time.

Another finding of this study is that defects detected are more in higher percentage of defect rates. Supervisors might use this feedback to check the process as defects detected increase.

Although it cannot be said conclusively from this study, there are indications that semi-pacing inspection might result in improved inspection performance as compared to the paced condition. Management might consider semi-paced inspection as a possible alternative to paced inspection.

This study suggests that the subjects perceive the task as more difficult while operating in the paced condition as compared to the self-paced condition. This might also be considered alongwith improved performance for hits and false alarms while deciding between paced and self-paced inspection.

CONCLUSIONS

1. Defects detected decreased with lower defect rates.

2. Defects detected are highest for the self-paced condition, followed by those for the semi-paced and paced condition.

3. False alarms are lowest for self-paced condition, followed by those for the semi-paced and paced conditions.

4. Decision time is higher for higher defect rates.

5. On the Borg scale, the task was perceived as the most difficult for the paced condition, followed by the task in the semi-paced and the self-paced condition.

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PACING, DEFECT RATE AND TASK PERCEPTION
IN SIMULATED INSPECTION

by

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ABSTRACT

This study investigated the effects of pacing conditions and defect rates on inspection performance. The three pacing conditions were paced (inspection task presented one at a time every 2½ minutes), semi-paced (inspection task presented three at a time every 7½ minutes) and self-paced (inspection task presented nine at a time for as much time as the subject desired). The three defect rates were 1%, 4% and 16%. Thirty six subjects were tested and each one was assigned randomly to one of the nine combinations of pacing conditions and defect rates. Measures of inspection performance were hits, false alarms, decision time and task perception ratings on "relaxing-strenuous" scale, "boring-interesting" scale and the Borg scale. It was found: hits were highest in the self-paced condition; false alarms were lowest in the self-paced condition; on the Borg scale the task was perceived as the easiest in the self-paced condition; in general it was better to inspect in the self-paced condition. Although the semi-paced condition was not shown to be statistically different from either the paced or the self-paced condition, there are indications that it might be used as a compromise between the extreme conditions of paced and self-paced.