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# EFFECTS OF A VARYING ENVIRONMENT ON THE PERFORMANCE OF AN INSPECTION TASK

Kenneth D. Gurley

Army Materiel Command
Texarkana, Texas

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# EFFECTS OF A VARYING ENVIRONMENT
# ON THE
# PERFORMANCE OF AN INSPECTION TASK

RESEARCH REPORT

Presented in Partial Fulfillment of the Requirements of the
AMC Production Design Graduate Engineering
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by

Kenneth D. Gurley

July 1971

PRODUCTION DESIGN ENGINEERING DIVISION
DEPARTMENT OF ENGINEERING
USAMC INTERN TRAINING CENTER - USALMC
Red River Army Depot
Texarkana, Texas

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ABSTRACT

Previous research has shown that the decrement associated with a vigilance task can be reduced and sometimes completely eliminated. However, some of the techniques used to reduce this vigilance decrement are not practical for industrial use.

An experiment, utilizing a technique that could be adapted for use in industry, was designed and performed by the writer. Subjects were tested in two groups, Control and Experimental. The Control Group was tested in a normal white light environment, whereas, the Experimental Group was tested in an environment of varying color illumination.

It was hypothesized that the Experimental Group would perform better than the Control Group. However, analysis of the experimental data did not allow acceptance of this hypothesis.

While this particular study is of no singular benefit to the Army Material Command, it does present a different approach to the visual inspection task. With further research it should be possible to improve the design of the many visual inspection tasks in the Army Material Command.

## ACKNOWLEDGMENTS

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# CHAPTER I

## INTRODUCTION

Since the time of the Industrial Revolution man has been confronted with the task of inspecting products manufactured for public use. Prior to the Industrial Revolution, most of these inspection tasks were relatively easy to perform and done by the man actually making the item or component. However, mass production, introduced by the Industrial Revolution, coupled with today's ever-increasing rate of technological accomplishments and demands for products of better quality, higher reliability, etc., has changed the inspection task immensely. In all likelihood, two of the greatest changes in the inspection task have been the quantity of goods that must be inspected and the variety of possible inspection tasks. The wide variety of possible inspection tasks can be classified relatively well into three basic categories. These categories are: scanning, measuring, and monitoring (Harris, 1969). Probably the most common task with respect to inspection is the scanning task. In this type of inspection, the inspector searches for defects by making a point-by-point examination of an item. Typically, this examination is performed visually. This visual inspection can be classified as a monotonous perceptual task (Ayoub and Badalamente, 1969). Essentially the inspector scans the moving items in search of a critical but infrequent signal, a defective product.

In monotonous perceptual tasks of this kind, research studies have shown that inspectors do not perform with sustained efficiency (Lucaccini and Smith, 1969). One form of this loss in efficiency is the decrease in per cent of defectives detected with respect to time. This decrease is attributed to the vigilance decrement due to the monotonous inspection task (Mackworth, 1968). The elimination of or at least a reduction in this decrement in the inspection task can be very benefical to management - reduce costs, increase job as well as customer satisfication. Numerous studies have been conducted in which this decrement has been reduced. However these studies utilized the techniques of feedback to the subject of his performance (knowledge of results), defect rate (signal rate), time between defectives (regularity of the intersignal interval), and as such are not very compatible with inspection practices of industry. It was, however, the objective of this research project to investigate the effects of the color illumination of the visual environment on the performance of an inspection task. This technique could conceivably be utilized in industry. The concluding chapter, Chapter V, presents conclusions, summarizes results of the project and briefly discusses the possibility of application to industry.

Chapter II contains a literature survey of similar studies. As such it serves to discuss and state conclusions of some past studies and their differences.

The design of the experiment is the topic of Chapter III. Also in this chapter are comments on the apparatus used in the experiment, and measures of inspector accuracy.

The analysis of the experimental data is presented in Chapter IV.

## CHAPTER II

## LITERATURE REVIEW

Since the classic Mackworth "clock-test" (1950) in the field of vigilance, there have been many more studies. Briefly, the majority of these studies served as further verification of Mackworth's "vigilance decrement" and/or other findings relating to theories of vigilance. This "vigilance decrement" may rather simply be defined as some loss in operator efficiency. However some studies have been performed whereby this "vigilance decrement" was decreased considerably and in some cases, eliminated completely.

Mackworth, for example in one of his studies, called each subject by telephone midway in the test period to ask him to "do even better for the rest of the test" (Smith and Lucaccini, 1969). Performance, which prior to the telephone message had shown a substantial decrement, recovered to a level higher than initial levels. However performance again declined. This technique can be thought of as a motivational factor influencing the subject's performance, at least momentarily.

One technique often used in demonstrating a decrease in this "vigilance decrement" during an inspection task is the varying of the rate of defective items, in the number of items being inspected. Harris (1969) used a respresentative scanning type inspection task to illustrate this decrease. In Harris' study the experiment employed four different defect rates. They were 0.25%, 1%, 4%, and 16%. Inspections were made under these rates utilizing 80 inspectors. Inspectors were randomly assigned to the four defect rates, 20 per rate. The inspectors were not told how many defects to expect; however, they were instructed to ask for clarification on any item about which they were undecided. In this manner, the monitor performed a role similar to that of an inspection supervisor on the job. Also, inspectors were encouraged to take as much time as possible to perform accurate inspections. Measures of accuracy were the percentage of defects detected and percentage of false reports (defects reported which were not actually defects). Results of this study showed that inspection accuracy decreased with a reduction in defect rate. The percentage of defects detected decreased slightly between defect rates of 16% and 1%, but declined very sharply between 1% and 0.25%. The percentage of false reports, however, increased at an accelerated rate as the defect rate approached zero. Although this study made no mention of time or the vigilance decrement, it does indicate that inspectors tested under the high defect rates did better and showed less of a decrement than did those tested at the lower defect rate. The differences among the four defect rates for the percentages of defects detected and for the percentages of false reports were found to be statistically significant at better than 0.05 level in both cases. Also, a study performed by Paladino (1970) indicates similar results to that of Harris.

Another method, as summarized by Frankman and Adams (1962), is knowledge of results (KOR). They note that this variable, KOR, prevents the decrement by allowing an accurate perception of sequence of stimuli. In their paper, they note that in one study the decrement was completely eliminated when the subject was informed of his success or failure in detecting a signal. Also summarized were the results of a study utilizing three groups of subjects. One group was given no KOR, another complete information on correct, missed and false signals, and the third repetition of a missed signal at five-second intervals until detected. The task was visual detection, with an observation time of one hour and signal rate of

24 an hour. Only the group with no KOR had a significant decrement.

D. C. Fraser (1953) performed a study relating an environmental variable to a visual task. Basically the experimental task consisted of a subject visually searching a roll of film for a total of 20 holes approximately 3 millimeters in diameter interspersed at long but random intervals throughout a series of 2 millimeter holes. The subjects were tested under two conditions. These were the presence and the absence of the experimenter. With the experimenter absent, a total of 39 signals were missed, but with the experimenter present only 16 signals were missed. Utilizing the t-distribution, this is significant at better than the 1 per cent level.

Badalamente and Ayoub (1969) simulated an assembly-line visual inspection task using a rotating disk to convey the products to the subject. The products were simulated printed circuits. The experiment was run in a randomized block design with each subject being tested on four schedules, with a high and low level each. The basic schedules were fixed ratio, variable ratio, fixed interval and variable interval. The observed response was the number of times the subject pressed a limited hold button that stopped the rotating disk for a period of 1 second only. The briefing of the subject was designed to encourage button-pressing. The subject was instructed to stop the disk (by pressing the button) if he wished to inspect a circuit more closely. When the subject discovered what he thought was a defective he was told to call "reject" and remove the circuit from the disk. Generally the conclusions of this study were

1. presentation of a high signal rate (defect rate) is akin to differentially reinforcing a high response rate (button pressing) in maintaining attentive behavior throughout the task, thus preventing a vigilance decrement, both in terms of missed signals and false signals
2. variable schedules in both the ratio (number of times subject pressed the button to the detection of a defective) and interval (time between defectives) categories are superior to fixed-ratio and fixed interval in maintaining attentive behavior throughout the task, thus preventing a vigilance decrement in terms of a higher percentage of signals detected.

Thus this study supports not only that the defect rate influences the "vigilance decrement" but the intersignal interval as well.

A varied sensory environment as discussed by Frankman and Adams (1962) appears to be another approach to decreasing the "vigilance decrement". To quote

> "When background stimuli are at a minimum and often low key critical stimuli are present, rapid deterioration should be expected. The more unchanging are the critical stimuli, the sooner deterioration will occur. Rest periods and introduction of extraneous stimuli serve to increase the variety of stimulation needed to maintain or restore efficient behavior."

This quote is in one sense a description of an assembly-line visual inspection task and performance of the inspector. It was the purpose of this research project to investigate the effects of colored illumination of the visual environment on the performance of an inspection task. It was hypothesized that by the introduction of some outside stimulus, the colored illumination of the visual environment, that the "vigilance decrement" associated with a visual inspection task could be eliminated or at least reduced. Variations of this technique could then be adapted to the visual inspection of products in industry. The design of this experimental technique and equipment used is the subject of Chapter III.

CHAPTER III

# APPARATUS, TASK DESIGN AND EXPERIMENTAL PROCEDURE

## Apparatus

To accomplish the objectives of this research project, it was necessary to simulate the inspection task complete with the assembly-line and products to be tested. There is presently in existance in the Industrial Engineering Department an apparatus that encompasses the features required for such a simulation (Smurthwaite, 1970). This device includes a bench type working surface, a conveyor transportation system to move the products through the inspection area and necessary control equipment. Provisions are built into the apparatus that allow the viewing time for inspection of products to be varied and the automatic detecting of errors and coded defective products. Also, included in the apparatus is a system allowing feedback to the subject (inspector).

Also, feedback can occur quite inadvertantly from the apparatus control center. Due to the design of the apparatus control center, a characteristic electrical noise and light are introduced when the error detection system is activated. It was necessary to conceal the control center on the floor away from the subject. An event recorder, connected in parallel with the apparatus control center and placed outside the Environmental Chamber, served the dual purpose of recording a subject's response and the presentation of defective products. Information concerning the test apparatus and its utility furnished this experimenter by a previous user (Paladino, 1970), indicated the need for modifications of the track to facilitate a smooth continuous movement of the product. Needed repairs and modifications to the track were performed by this experimenter and proved quite satisfactory for the test apparatus. Although this device was primarily designed to simulate the assembly-line inspection of small printed circuits, other items of similiar size could be used.

The printed circuits are actually small amplifier type circuits. These were chosen for two reasons. First, they were readily available and secondly, are representative of actual products of industry that are visually inspected. As previously commented the viewing time for inspection can be varied, (by varying the conveyer speed), thus permitting a great degree of flexibility in the characteristics of an assembly-line inspection task simulated.

## Task Design and Experimental Procedure

For the purposes of this research, a viewing time of five seconds per item for inspection was chosen. This time allows each subject to be presented with 720 products per hour. The defect rate in this experiment was approximately seven per cent with the defectives, a total of 54, being presented in a predetermined random sequence to the subject. Each participant, whether in the Control Group or the Experimental Group, received the same pattern of defective products.

Sixteen subjects, fourteen male and two female, participated in this research project and were randomly assigned to either the Control Group or the Experimental Group. Each group contained eight subjects and rather coincidently one female in each group. Each participant was tested for one hour with no rest period. Also those participating in the experiment were tested for color vision defects with the Dvorine Pseudo-Isochromatic Plates. This test was conducted in order to maintain as much homogeneity as feasible between the two groups and was especially necessary for the Experimental Group. Potential subjects exhibiting color vision defects were not allowed to participate, but those normally requiring corrective glasses for vision defects were utilized.

Since the independent variable in this research was the visual environment of an inspection task, the testing of all subjects was conducted in the Environmental Chamber of the Industrial Engineering Department. Quite naturally the Environmental Chamber allows the experimenter to control those aspects of the environment such that he is certain each subject is tested under the same conditions. In this experiment the illumination level, color of the visual environment, temperature and humidity were controlled. Another factor of considerable importance to research projects of this type is noise.

The illumination level (reflected light) of the surround (track, inspection area, etc.) for both groups was maintained as near as practical at 130 foot-candles. However, due to the colored lighting equipment of the Environmental Chamber and the printed circuits, the illumination level (reflected light) of the printed circuits was less than the surround (Appendix A). Also, the temperature and relative humidity were held at 76° Fahrenheit and 31 to 35 per cent respectively. The Control Group was tested in the normal white light environment, similiar to that of industry, whereas the Experimental Group was subjected to the varying colored illumination schedule called for by the experimental procedure.

The visual environment of the Experimental Group was controlled by use of the colored lights in the Environmental Chamber. Thus, the variation in the visual environment was the color predominant in the chamber at various intervals during the testing of the subject. The color sequence was fixed, but the times between color changes, that is duration of each color, was varied in accordance with a predetermined random pattern (Appendix B). The color sequence and duration were of course the same for each participant in the Experimental Group. The defect pattern presented to the Experimental Group was identical with that of the Control Group, both in time and quantity. This was done to insure that the measures of inspector accuracy employed for data analysis should be as consistent as possible between the two groups.

Three measures of inspector accuracy are used in this experiment:

1. The per cent of defective items accepted and is defined mathematically by the following equation:

$$A_1 = \frac{\text{defective items accepted}}{\text{defective items presented}} \times 100\%.$$

2. The per cent of good items rejected, that is judging a good item as a defective one, is the second measure of accuracy, $A_2$. The equation for this is

$$A_2 = \frac{\text{good items rejected}}{\text{good items presented}} \times 100\%.$$

3. The final measure of interest is known as Juran's Special Measure. This was developed to provide for good products rejected as well as bad products accepted in evaluating inspector accuracy. It is computed as follows:

$$A_3 = \frac{\text{defective items rejected} - \text{good items rejected}}{\text{defective items presented} - \text{good items rejected}} \times 100\%.$$

It was the experimental hypothesis that the first two of these measures for the Experimental Group would be less than those for the Control Group and the third measure for the Experimental Group would be greater than that of the Control Group.

Each subject was given verbal instructions, shown representative samples of defective products, and allowed a trial run of approximately four minutes. After the trial run the participant had the opportunity for further clarifications if required. Testing of the subject was then begun and his performance recorded.

Data for analysis was recorded utilizing Data Formats 1 and 2 shown respectively in Tables 1 and 2. The performance of a Control Group subject was recorded on Data Format 1 and for an Experimental Group subject on both Data Formats 1 and 2. The analysis of this data is presented in Chapter IV.

## CHAPTER IV

## ANALYSIS OF EXPERIMENTAL DATA

The analysis of the data was performed utilizing the three measures of inspector accuracy as defined in Chapter III. The cumulative measure, $A_1$, $A_2$, and $A_3$, are plotted against time on watch in Figures 1, 2, and 3 respectively, for both the Control Group and the Experimental Group. Also shown in each respective figure is a plot of that measure's cumulative per cent versus color during the watch for the Experimental Group. Figures 4, 5, and 6 are respectively the non-cumulative curves of measures $A_1$, $A_2$, and $A_3$ against time on watch for each group. Figure 7 is the non-cumulative normalized data for defects accepted versus time on watch for each group and Figure 8 is a similar curve for good items rejected. The normalized pattern of defectives presented is also shown in Figure 7. No similar curve for good items presented is shown in Figure 8 since it would be the exact opposite of that in Figure 7.

Generally, for each measure of inspector accuracy, the Control Group performed much better than the Experimental Group. However, two statistical tests, analysis of variance (F test) and a t-test, indicated no significant difference between means for the two groups within each measure, $A_1$, $A_2$, and $A_3$. Also, the same was true for homogeneity of variance utilizing the Hartley F Max test and Cochran C test for the two groups within each measure, $A_1$, $A_2$, and $A_3$. The level of significance was 0.01 for all statistical tests. Although the samples were homogenous and the curves for a particular measure are very similar, there are varying degrees of differences in the performances of the two groups. In a research project of this type, one would suspect some learning as an influencing factor. However, in this case, learning cannot account for the performance differences between the two groups.

The performance differences are attributed to the fact that the Experimental Group was tested under a different visual environment than that of the Control Group. That is, the varying color illumination of the visual environment hampered those Experimental Group subjects in their abilities to inspect the products efficiently. Only one subject in the Control Group accepted more defectives than the worst subject in the Experimental Group and each of the three best subjects in the Experimental Group accepted only two defectives less than the two third best subjects in the Control Group. The average number of defectives accepted by a Control Group subject was 15.5 versus 19.5 for an Experimental Group subject. It should be noted, however, in Figures 1 and 4 the significant increase in the performance of the Experimental Group from the 30 minute time period to the 50 minute time period. This increase in performance can be attributed to some unknown combination of four factors. These four factors are:

1. of the 10 times that the color illumination of the visual environment changed, only 2 of these occured in approximately the 30 to 50 minute time interval,
2. one of the colors illuminating the visual environment during this time interval is red, under which, according to half of the Experimental Group subjects, it was relatively easy to detect the defective circuits,
3. over 46% of all defectives presented were done so in approximately the 30 to 50 minute time interval,
4. although the subjects had no explicit knowledge of duration of the test, etc. most seemed to sense that the experiment was near termination.

Although the cumulative per cent of good items rejected was less than 0.3% for both groups, the cumulative per cent rejected by the Experimental Group was almost three times that of the Control Group. The curves for $A_2$, Figures 2 and 5, as generally noted, show that the Control Group performs better, again with a high degree of similarity. As before the varying degree of differences can be attributed to the color illumination of the visual environment of the Experimental Group. The better performance of the Control Group and the similarity of the curves for a particular $A_3$ form, cumulative or non-cumulative, are already accounted for since $A_3$ is a combination of $A_1$ and $A_2$ for their respective cumulative or non-cumulative forms. The final cumulative form of $A_3$ for the Control Group was over 8 percentage points higher than the Experimental Group.

As can be readily seen in Figure 7, both groups followed very nearly the normalized pattern of defectives presented except for the fifth data point for the Experimental Group. Although the curves in Figure 8 are similar for the two groups, their general pattern appears to be somewhat opposite of the normalized pattern.

Aside from the preceding statements, no proper interpretation can be made concerning the results of this experiment.

In conclusion, the two groups showed very similar pattern of results for each measure of inspector accuracy. However, the Experimental Group performed worse in each measure than did the Control Group. Also in this experiment, no vigilance decrement was detected. This is attributed to the length of the experiment. Thus, the experimental hypothesis of this research project cannot be accepted. Concluding remarks and suggested future research is discussed in Chapter V.

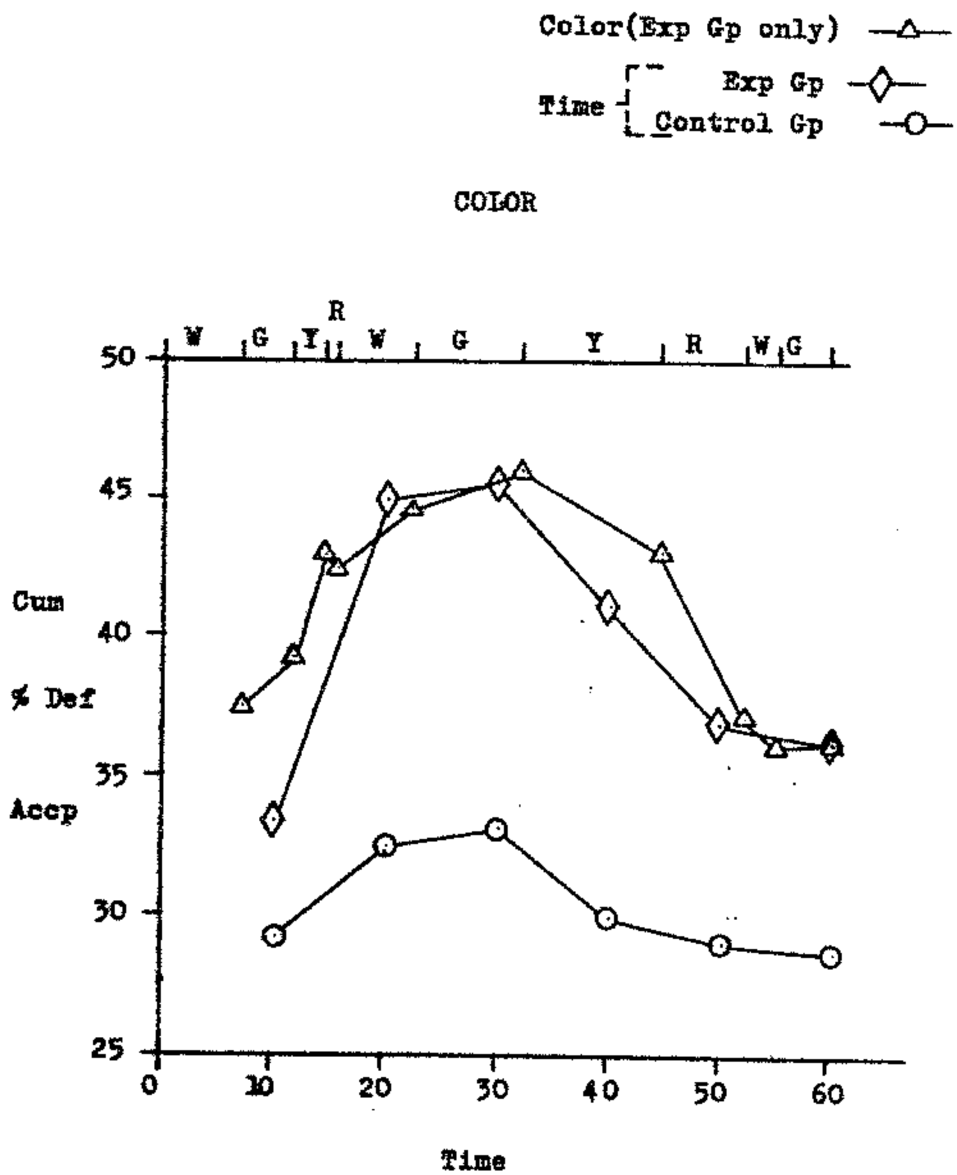


FIGURE 1

CUMULATIVE PERCENT OF DEFECTS ACCEPTED
VERSUS TIME ON WATCH AND COLOR DURING WATCH

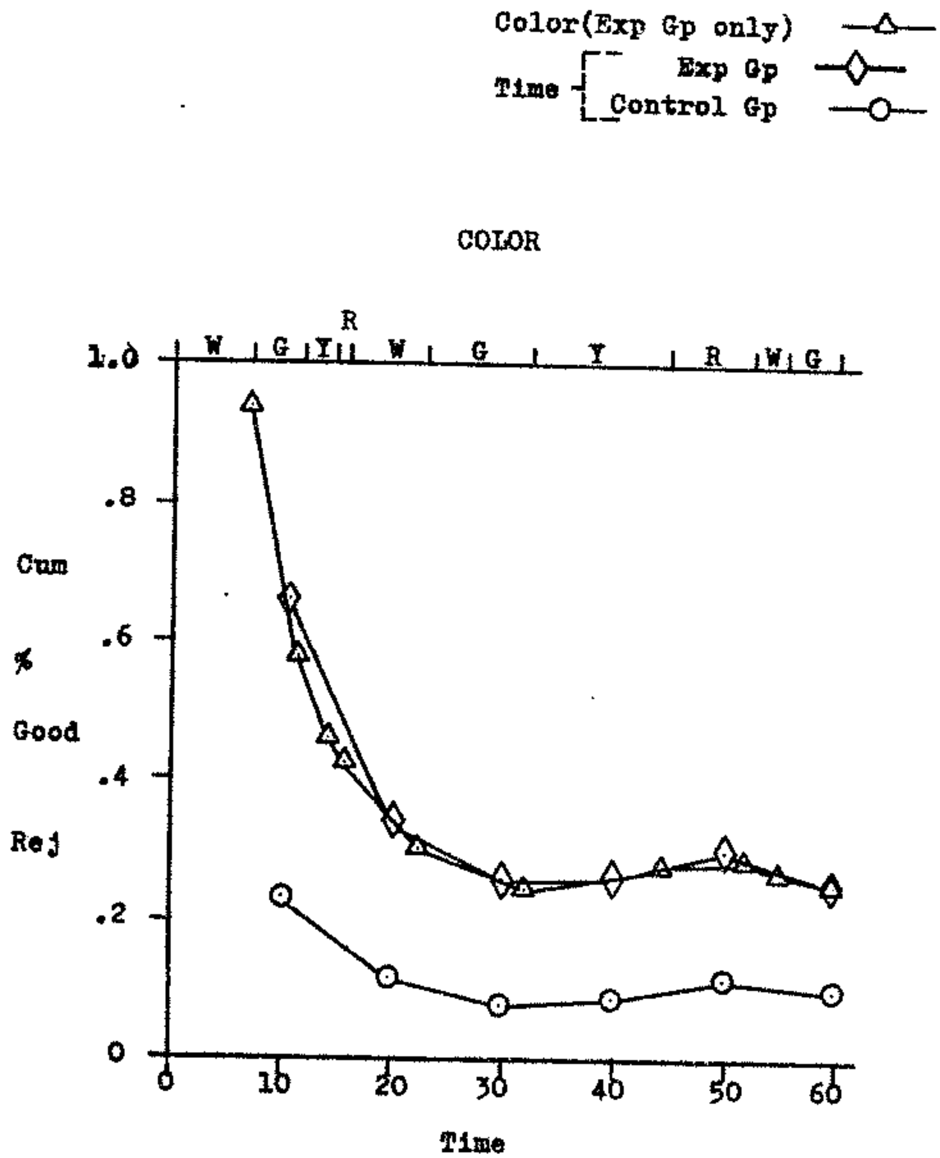


FIGURE 2

CUMULATIVE PERCENT OF GOOD ITEMS REJECTED VERSUS TIME ON WATCH AND COLOR DURING WATCH

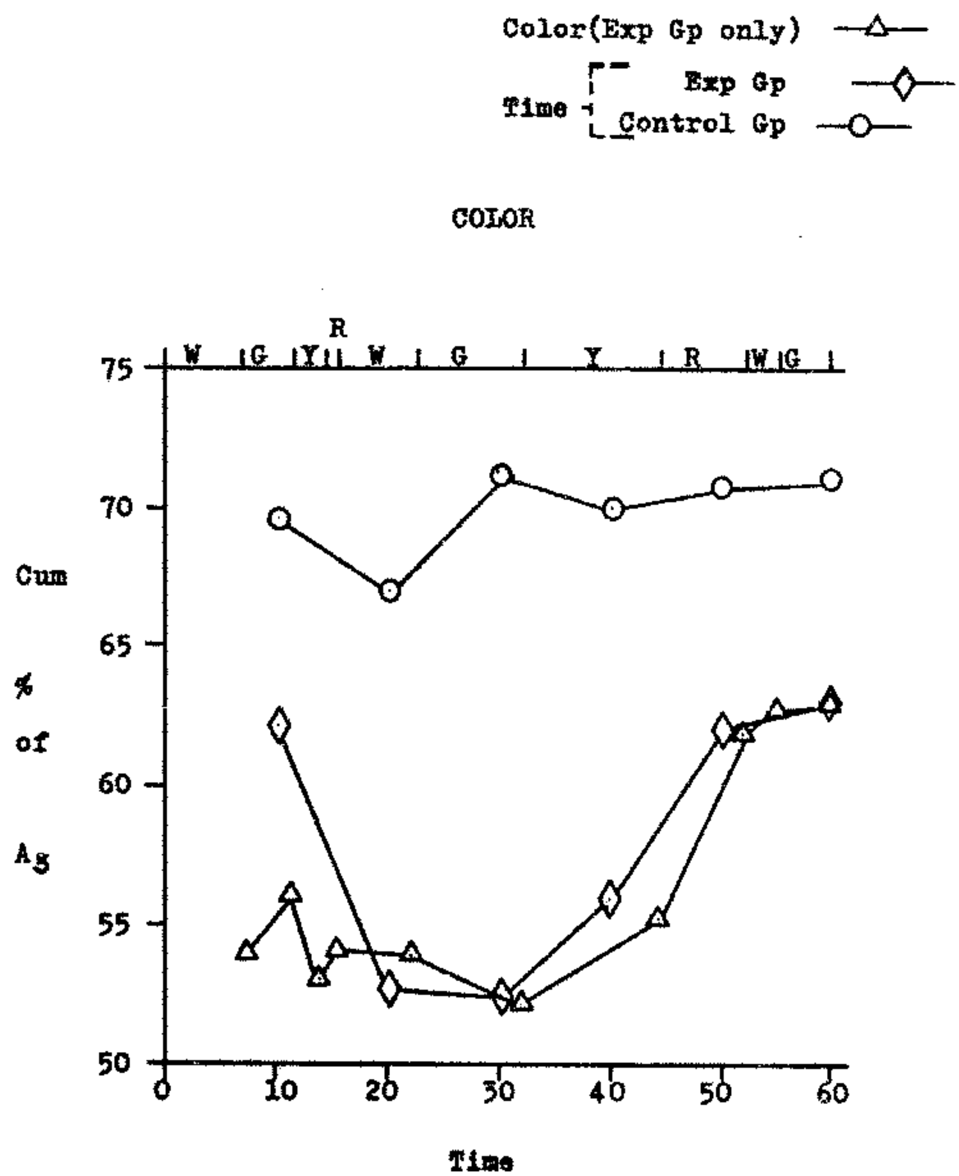


FIGURE 3

CUMULATIVE PERCENT OF $A_3$ VERSUS
TIME ON WATCH AND COLOR DURING WATCH

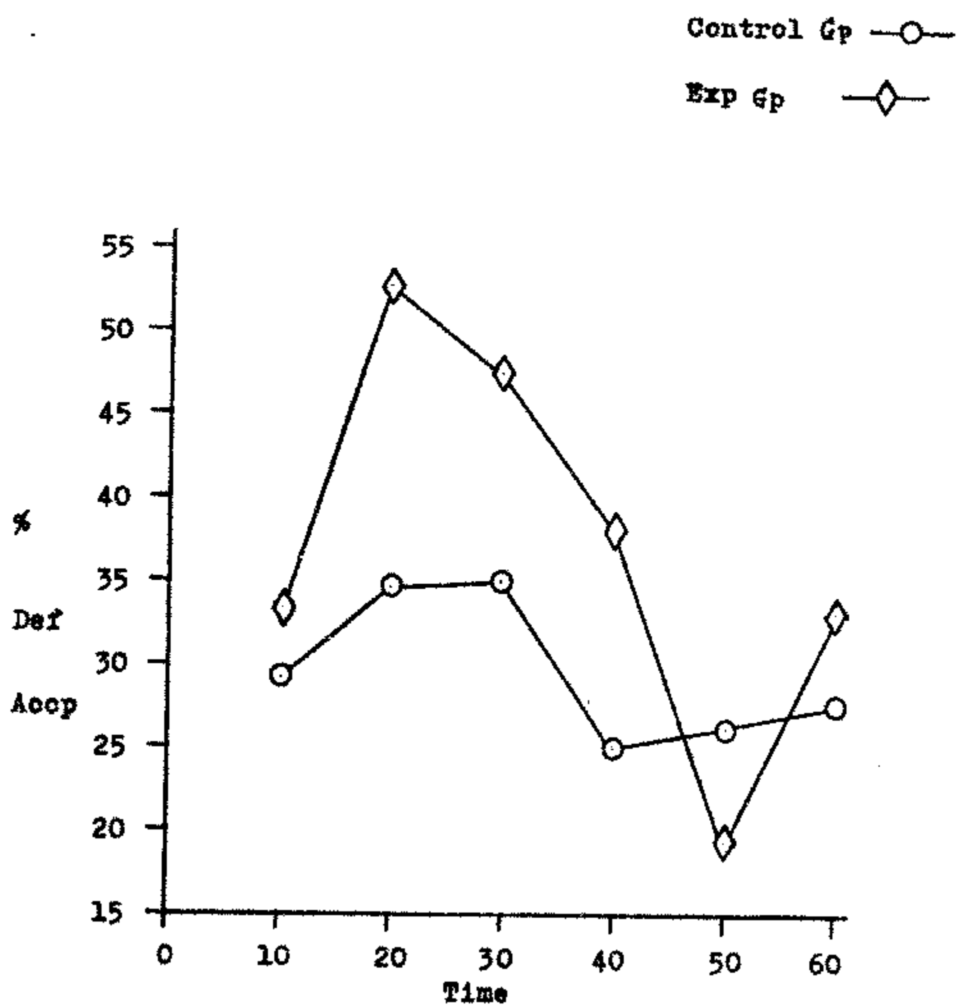


FIGURE 4

PERCENT OF DEFECTIVES ACCEPTED VERSUS
TIME ON WATCH

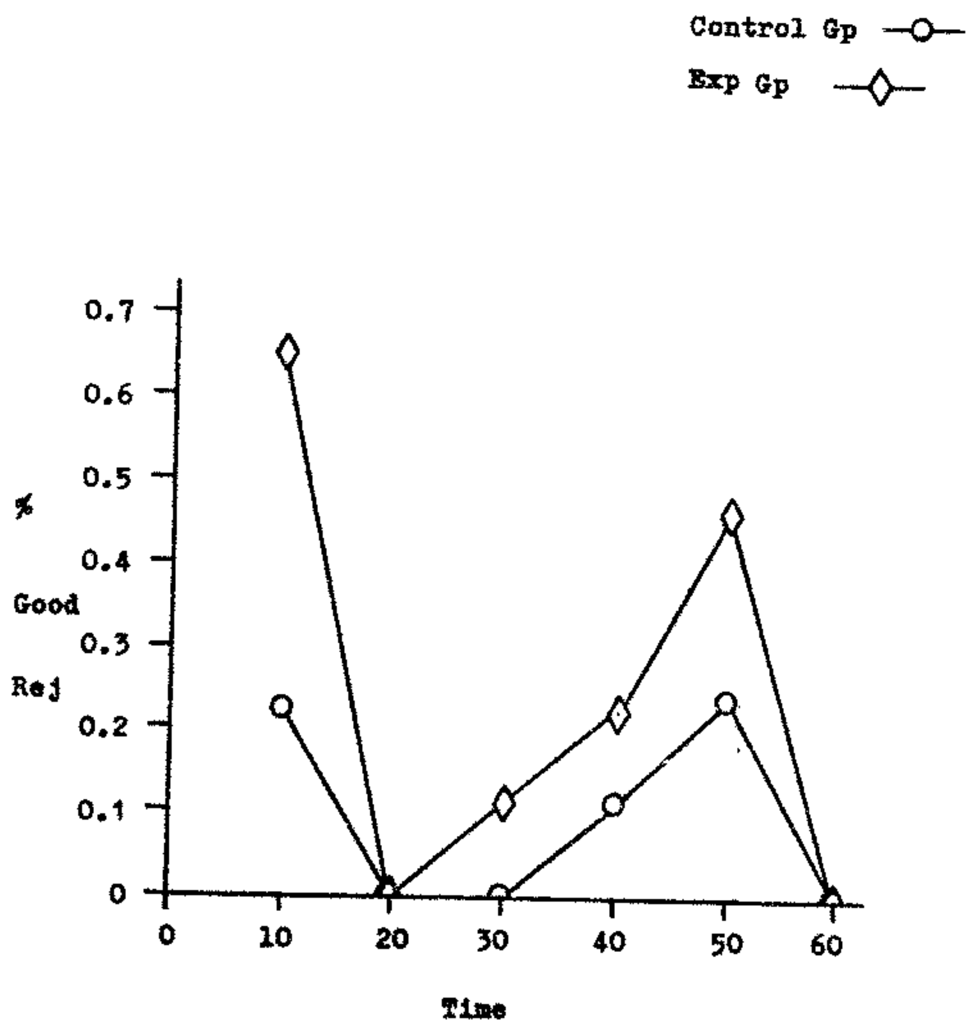


FIGURE 5

PERCENT OF GOOD ITEMS REJECTED
VERSUS TIME ON WATCH

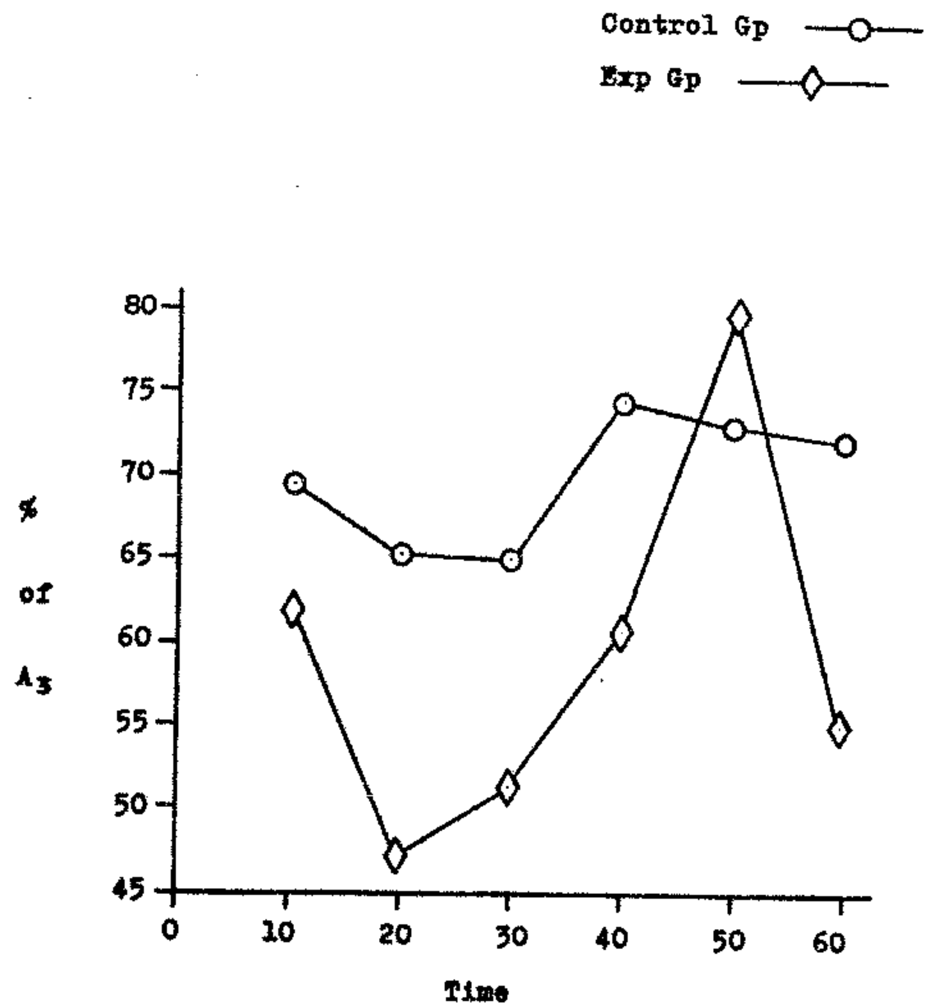


FIGURE 6

PERCENT OF $A_3$
VERSUS TIME ON WATCH

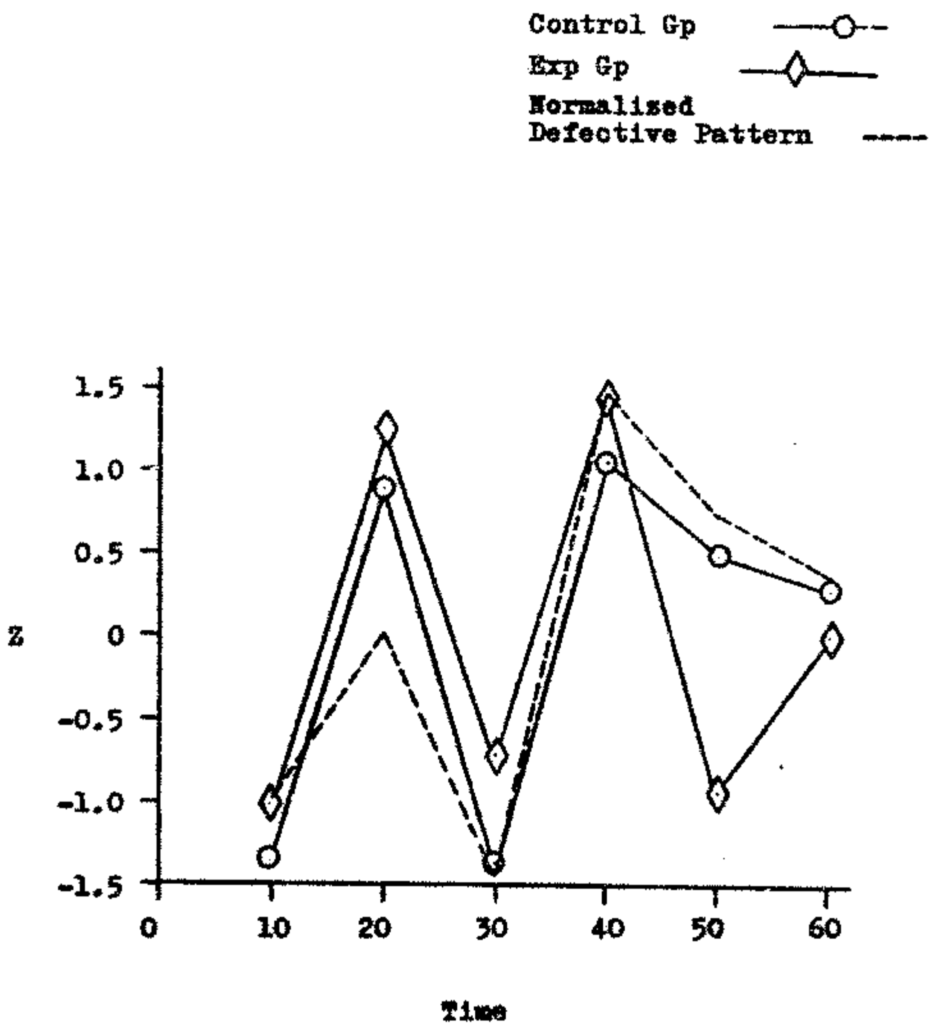


FIGURE 7

DEFECTS ACCEPTED (NORMALIZED)
VERSUS TIME ON WATCH

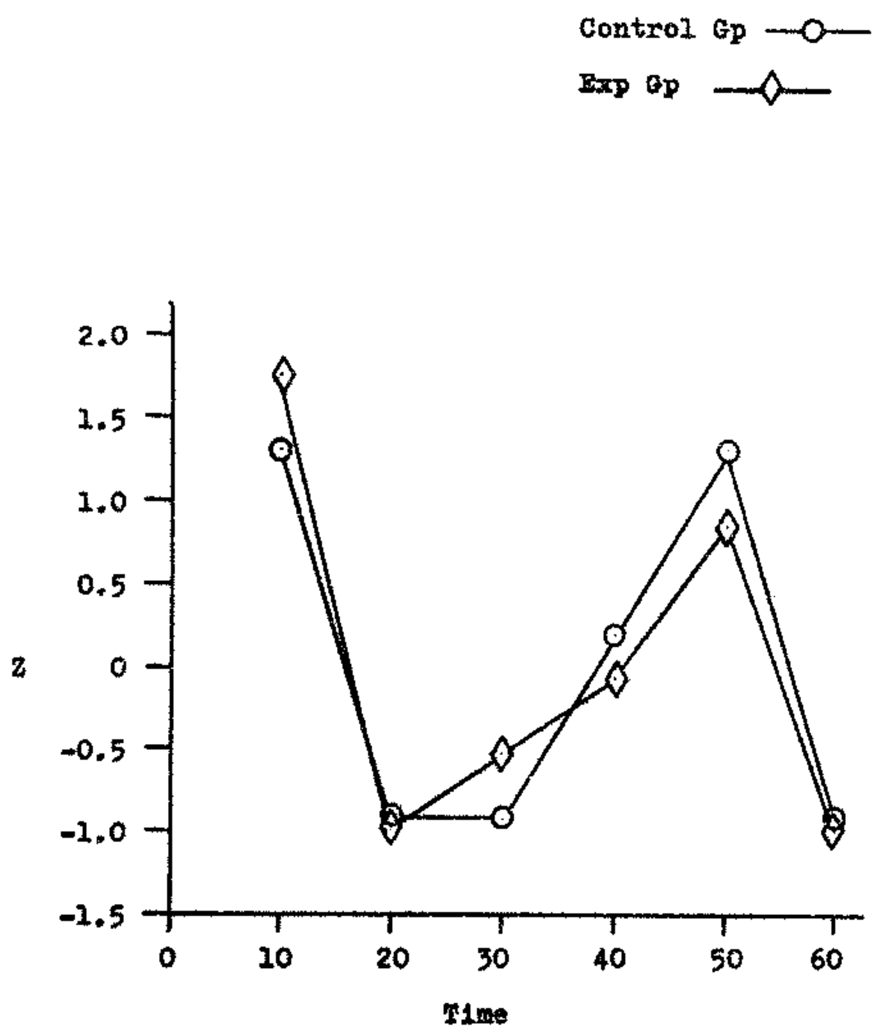


FIGURE 8

GOOD ITEMS REJECTED (NORMALIZED)
VERSUS TIME ON WATCH

# CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

Although the experimental hypothesis, that by varying the color illumination of the visual environment the "vigilance decrement" could be reduced, was not supported, future research is needed. As commented by some of the subjects that they felt the varying illumination of colors helped their attention level is in itself encouragement for future research.

There are many alternative procedures to this experiment. Some are as follows:

1. Rapidly varying the color of the environment by the use of 3 or more colors for a minute or less, but returning to the normal white light environment as inspection continues. This could be done at either random or fixed time intervals. Also, the manner in which the colors are varied could be fixed or random.
2. Testing under various color combinations that yield maximum contrast and minimum glare. conditions for the product being inspected.

3. Utilizing some form of psychological testing to attempt determination of a subject's color preferences. Test the subject then utilizing these color preferences in various combinations.

More research is required in this area to determine possible procedures that could eliminate this decrement. When these procedures are known, it should be relatively easy to apply them to the industrial inspection task.

These procedures would benefit the inspection of miniature and micro-miniature electronic components by reducing the number of defective products missed. Another area of application would be the fabrics industry, where the only approach to inspection of vast quantities is a visual scanning technique. However, in this case, the color of the visual environment would not be utilized to maintain inspector efficiency. This same approach could be used in the inspection of carpeting, wall paper, painted products, etc., any industry where the color of the product or location of flaws relative to the color of the product are of primary importance.

These are but a few of the many possible designs and areas of application of color illumination of the visual environment that should prove benefical to future researchers and industry.

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# APPENDIXES

Appendix A: Illumination Level of Reflected Light

Appendix B: Color Sequence and Duration for Experimental Group

Appendix C: Experimental Data

# APPENDIX A

## ILLUMINATION LEVEL OF REFLECTED LIGHT

| COLOR | SURROUND | CIRCUIT |
|---|---|---|
| White | 130 ft-c | 50 ft-c |
| Green | 130 ft-c | 50 ft-c |
| Yellow | 130 ft-c | 65 ft-c |
| Red | 130 ft-c | 65 ft-c |

# APPENDIX B

## COLOR SEQUENCE AND DURATION FOR EXPERIMENTAL GROUP

| COLOR | DURATION (seconds) |
|---|---|
| White | 427 |
| Green | 268 |
| Yellow | 180 |
| Red | 065 |
| White | 427 |
| Green | 564 |
| Yellow | 758 |
| Red | 445 |
| White | 180 |
| Green | 286 |

# APPENDIX C

## EXPERIMENTAL DATA

This appendix contains six tables. The data formats used to record a subject's performance are shown in Tables 1 and 2. Tables 3 and 4 summarize the defective items accepted by each subject and Tables 5 and 6 the good items rejected by each subject.

TABLE 1

DATA FORMAT 1

Group:__________
Subject No.__________
Age:__________
Sex:__________

| Time Period (10 min.) | Total Presented Good | Total Presented Defective | Defectives Accepted | Good Rej. |
|---|---|---|---|---|
| 1 | 114 | 6 | | |
| 2 | 111 | 9 | | |
| 3 | 115 | 5 | | |
| 4 | 107 | 13 | | |
| 5 | 109 | 11 | | |
| 6 | 110 | 10 | | |
| Totals | 666 | 54 | | |

Comments of the Subject:

TABLE 2

DATA FORMAT 2

Group:__________
Subject No.__________
Age:__________
Sex:__________

| Color | Total Presented | | Defectives Accepted | Good Rej. |
|---|---|---|---|---|
| | Good | Defectives | | |
| White | 81 | 4 | | |
| Green | 51 | 3 | | |
| Yellow | 34 | 2 | | |
| Red | 12 | 1 | | |
| White | 77 | 8 | | |
| Green | 109 | 4 | | |
| Yellow | 139 | 12 | | |
| Red | 76 | 13 | | |
| White | 34 | 2 | | |
| Green | 53 | 5 | | |
| Totals | 666 | 54 | | |

Comments of the Subject:

TABLE 3

DEFECTS ACCEPTED BY TIME PERIOD

Control Group

| Subject No. | Time Period 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 2 | 3 | 8 | 5 |
| 2 | 1 | 4 | 2 | 4 | 4 | 4 |
| 3 | 1 | 1 | 1 | 5 | 0 | 0 |
| 4 | 2 | 3 | 4 | 2 | 2 | 3 |
| 5 | 5 | 5 | 2 | 4 | 1 | 5 |
| 6 | 1 | 3 | 3 | 3 | 4 | 2 |
| 7 | 1 | 0 | 0 | 2 | 2 | 1 |
| 8 | 0 | 3 | 0 | 3 | 2 | 2 |

Experimental Group

| Subject No. | Time Period 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 2 | 5 | 4 | 5 | 3 | 3 |
| 2 | 4 | 5 | 2 | 5 | 2 | 4 |
| 3 | 1 | 4 | 1 | 3 | 1 | 4 |
| 4 | 2 | 4 | 3 | 6 | 4 | 5 |
| 5 | 3 | 6 | 2 | 9 | 2 | 1 |
| 6 | 1 | 4 | 2 | 4 | 2 | 1 |
| 7 | 3 | 6 | 3 | 5 | 3 | 3 |
| 8 | 0 | 4 | 2 | 3 | 0 | 5 |

TABLE 4

DEFECTS ACCEPTED BY COLOR
(EXPERIMENTAL GROUP ONLY)

| Subject No. | Color | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | W | G | Y | R | W | G | Y | R | W | G |
| 1 | 1 | 1 | 1 | 0 | 6 | 2 | 7 | 2 | 0 | 2 |
| 2 | 2 | 3 | 0 | 0 | 5 | 2 | 4 | 3 | 1 | 2 |
| 3 | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 2 | 0 | 3 |
| 4 | 2 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 0 | 3 |
| 5 | 3 | 2 | 2 | 1 | 3 | 3 | 7 | 2 | 0 | 0 |
| 6 | 1 | 0 | 1 | 0 | 4 | 2 | 3 | 2 | 0 | 1 |
| 7 | 2 | 2 | 1 | 1 | 5 | 1 | 6 | 4 | 1 | 0 |
| 8 | 0 | 0 | 2 | 0 | 3 | 2 | 2 | 1 | 1 | 3 |

TABLE 5

GOOD ITEMS REJECTED BY TIME PERIOD

Control Group

| Subject No. | Time Period | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 2 | 0 |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 0 | 0 | 1 | 0 | 0 |

Experimental Group

| Subject No. | Time Period | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 1 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 1 | 0 |
| 5 | 2 | 0 | 0 | 1 | 1 | 0 |
| 6 | 1 | 0 | 1 | 1 | 0 | 0 |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 1 | 0 |

TABLE 6

GOOD ITEMS REJECTED BY COLOR
(EXPERIMENTAL GROUP ONLY)

| Subject No. | Color | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | W | G | Y | R | W | G | Y | R | W | G |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 6 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |