THE EFFECT OF DECREASING DEFECT PROBABILITIES
ON QUALITY CONTROL INSPECTION

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Jo Ann Segal, B.A.
Denton, Texas
May, 1998
Segal, Jo Ann. The effect of decreasing defect probabilities on quality control inspection. Master of Science (Behavior Analysis), May, 1998, 64 pp., 7 tables, 18 figures, references, 22 titles.

This study was a follow up to P. C. Dams' (1996) unpublished University of North Texas masters thesis, The effect of defect probability during training on inspection accuracy in a quality control simulation. Graphics of computer circuit boards were presented in dyads with an error free sample on the left and a comparison on the right. Comparisons had either a rotation or transposition defect, or were error free. Subjects had 10-s to accept or reject the comparison as identical to the sample. They were trained using two different stimulus fading procedures (using descending defect probabilities) and immediate feedback. Defect probabilities for the Tens were 0.60, 0.50, 0.40, and 0.30 and for the Twenties were 1.00, 0.80, 0.60, and 0.40. The last 4 pretraining and posttraining sessions were compared and the posttraining performance of the Twenties, as compared to the Tens, demonstrated greater improvement over pretraining performance. No firm conclusions could be drawn as to the effectiveness of either training procedure. The significance of the current investigation and suggestions for future research are discussed.
THE EFFECT OF DECREASING DEFECT PROBABILITIES
ON QUALITY CONTROL INSPECTION

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Jo Ann Segal, B.A.
Denton, Texas
May, 1998
ACKNOWLEDGMENTS

I want to thank Dr. Janet Ellis, my Thesis Chair, for her enduring support throughout my tenure in the department of behavior analysis. Without her, many of the invaluable opportunities that I have experienced while at the University of North Texas would have never come to pass, including this thesis. She graciously provided the computer program on which this thesis is based.

I would like to also thank Drs. Cloyd Hyten and Sigrid Glenn for their time and careful editing of the content of this thesis. For editorial, and, especially, for statistical help, I thank Dr. Joel Greenspoon. Thanks to Jocelyn Moore for entering all the data generated by this study. Furthermore, I would like to thank all my friends in the department because they helped keep me on the track to thesis completion.

Two people deserve a special thanks for this thesis actually being completed. I thank my significant other, Jim Tupper, for putting up with my very late nights, encouraging me to follow my dreams and allowing me the freedom to do so. My biggest thank you goes to my mother, Joyce Segal. She is my biggest fan, my strongest supporter, and my best friend. Without her, my experiences at North Texas would never have come to pass.

This thesis was completed in the memory of my father and champion, Harry Mark Segal.
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Dams (1996)</td>
<td>1</td>
</tr>
<tr>
<td>The Current Investigation as Compared to Dams</td>
<td>2</td>
</tr>
<tr>
<td>Stimulus Fading and Stimulus Control in Quality</td>
<td>5</td>
</tr>
<tr>
<td>Control Inspection</td>
<td>6</td>
</tr>
<tr>
<td>Feedback as a Reinforcer</td>
<td>7</td>
</tr>
<tr>
<td>Applicability to Industrial Inspection</td>
<td>8</td>
</tr>
<tr>
<td>Research Question</td>
<td>8</td>
</tr>
<tr>
<td>METHOD</td>
<td>8</td>
</tr>
<tr>
<td>Subjects</td>
<td>8</td>
</tr>
<tr>
<td>Pay Instructions</td>
<td>9</td>
</tr>
<tr>
<td>Setting and Apparatus</td>
<td>10</td>
</tr>
<tr>
<td>Independent Variable</td>
<td>10</td>
</tr>
<tr>
<td>Dependent Variables</td>
<td>10</td>
</tr>
<tr>
<td>Procedure</td>
<td>11</td>
</tr>
<tr>
<td>RESULTS</td>
<td>14</td>
</tr>
<tr>
<td>Pretraining</td>
<td>15</td>
</tr>
<tr>
<td>Topic</td>
<td>Page</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Training</td>
<td>17</td>
</tr>
<tr>
<td>Posttraining</td>
<td>22</td>
</tr>
<tr>
<td>Active and Passive Errors in the <strong>Tens</strong> Group</td>
<td>24</td>
</tr>
<tr>
<td>Active and Passive Errors in the <strong>Twenties</strong> Group</td>
<td>25</td>
</tr>
<tr>
<td>Mean Latencies for Correct and Incorrect Defect Detections in <strong>Tens</strong> Group</td>
<td>25</td>
</tr>
<tr>
<td>Mean Latencies for Correct and Incorrect Defect Detections in the <strong>Twenties</strong> Group</td>
<td>25</td>
</tr>
<tr>
<td>Pretraining Versus Posttraining Defect Detection Summary</td>
<td>26</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>28</td>
</tr>
<tr>
<td>Significance of the Current Study</td>
<td>29</td>
</tr>
<tr>
<td>Suggestions for Future Research</td>
<td>31</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>33</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>62</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1.
Experimental conditions and phases from Dams (1996) .................. 38

Table 2.
Experimental conditions and phases in the current study .................. 39

Table 3.
Subject TF 10's frequency of correct defect detections for session 7 ........ 40

Table 4.
Subject TF 10's frequency of active and passive errors for session 7 ........ 40

Table 5.
Subject TF 10's mean latencies (in s) of both correct and incorrect defect
detections for session 7 .................................................. 40

Table 6.
Comparisons between the maximum possible score for the last 4 sessions
of pretraining and posttraining to the maximum possible for these sessions .. 41

Table 7.
Percent of correct defect detections for the last 4 sessions of pretraining and
posttraining ................................................................. 42
LIST OF FIGURES

Figure 1.
Display of sample and comparison boards ........................................ 44

Figure 2.
Display of sample and comparison boards overlaid with feedback message 45

Figure 3.
Frequency of correct defect detections across all phases for
ES 10 and MM 10 .................................................................................. 46

Figure 4.
Frequency of correct defect detections across all phases for
PJ 10 and TF 10 .................................................................................... 47

Figure 5.
Frequency of correct defect detections across all phases for
AS 20 and KF 20 .................................................................................... 48

Figure 6.
Frequency of correct defect detections across all phases for
NW 20 and PO 20 .................................................................................. 49

Figure 7.
Frequency of active and passive error for all defect types across phases for
ES 10 and MM 10 .................................................................................. 50
Figure 8.
Frequency of active and passive error for all defect types across phases for
PJ 10 and TF 10 .......................... 51

Figure 9.
Frequency of active and passive error for all defect types across phases for
AS 20 and KF 20 .......................... 52

Figure 10.
Frequency of active and passive error for all defect types across phases for
NW 20 and PO 20 .......................... 53

Figure 11.
Mean latencies of correct defect detections for all boards across phases for
ES 10 and MM 10 .......................... 54

Figure 12.
Mean latencies of correct defect detections for all boards across phases for
PJ 10 and TF 10 .......................... 55

Figure 13.
Mean latencies of correct defect detections for all boards across phases for
AS 20 and KF 20 .......................... 56

Figure 14.
Mean latencies of correct defect detections for all boards across phases for
NW 20 and PO 20 .......................... 57
Figure 15.
Mean latencies of incorrect defect detections for all boards across phases for ES 10 and MM 10 .......................................................... 58

Figure 16.
Mean latencies of incorrect defect detections for all boards across phases for PJ 10 and TF 10 .......................................................... 59

Figure 17.
Mean latencies of incorrect defect detections for all boards across phases for AS 20 and KF 20 ....................................................... 60

Figure 18.
Mean latencies of incorrect defect detections for all boards across phases for NW 20 and PO 20 ....................................................... 61
INTRODUCTION

Behavior analysis has developed techniques that may prove useful in improving the accuracy of quality control inspection. Some of these techniques include stimulus fading, the development of stimulus control, and feedback as a reinforcer. Although these techniques have been investigated in other applications (Ducharme & Worling, 1994, Birnie-Selwyn & Guerin, 1997, & Leung, 1988, respectively), none has been studied extensively in the area of improving quality control inspection. The current investigation is a follow-up to Dams (1996) and focuses on the aforementioned techniques as these apply to the quality control inspection training process.

Dams (1996)

The current investigation was an extension of Dams' preliminary study. His research question was, "Will a gradual decrease from high to low defect probabilities during training lead to higher percentages of defect detection and lower percentages of false rejections during posttraining?" (p. 14).

Defect probability was first used by Colquhoun (1961). It was calculated by dividing the number of defects presented by the total number of presentations. For example, if there were 40 presentations of which 30 had defects, the defect probability would be 0.75. Dams used a match-to-sample task, along with manipulation of the defect probability to answer his research
question; subjects inspected simulated circuit boards and could accept or reject the comparison board. See Figure 1.

Dams divided his subjects into 3 training conditions: "High" (and constant) defect probabilities, "Low" (and constant) defect probabilities, and "Decreasing" defect probabilities. The High condition consisted of 0.60 defect probability for 8 consecutive training sessions and the Low condition consisted of 0.20 defect probability for 8 consecutive training sessions. The Decreasing condition consisted of 0.60 defect probability for 3 training sessions, 0.40 defect probability for the next 2 training sessions, and 0.20 defect probability for the last 3 sessions of training. See Table 1. The current investigation, as well as Dams, used a 0.20 defect probability during both pretraining and posttraining phases.

Dams' study did not appear to answer affirmatively the research question posed. However, the data generated by Dams did indicate that the decreasing defect probability condition had the potential for differentiating itself from the other two training conditions.

The Current Investigation as Compared to Dams

Similarities. The current investigation was a replication and extension of Dams' behavior analytic answer to the industrial question of how best to train persons for a quality control inspection task. All procedures in this study replicated Dams' procedures, including using the same experimental apparatus and in the same setting. Furthermore, like Dams, pretraining and posttraining
defect probabilities were set at 0.20. Likewise, both studies included 8 posttraining sessions.

**Differences.** Dams ran 3 conditions with 4 subjects in each, while the current investigation involved 2 conditions with 4 subjects each. Dams’ pretraining phase at 0.20 defect probability included 4 sessions, and this study included 8 pretraining sessions. Whereas, Dams compared all 4 sessions of pretraining to all 8 sessions of posttraining, in this study, the last 4 pretraining sessions were compared to the last 4 posttraining sessions to exclude possible outlier data when the task was first introduced to subjects.

Each of Dams’ subjects participated in 20 sessions over 5 days; however, in this study, subjects were engaged for 48 sessions over 12 days. Dams divided sessions into 4 pretraining, 8 training, and 8 posttraining; this study was comprised of 8 pretraining, 32 training, and 8 posttraining sessions.

The most significant methodological difference between the two studies was the difference in the training conditions. Dams included 3 training conditions: High, Low, and Decreasing versus 2 training conditions in the present study: the **Tens** and the **Twenties**. The **Tens** and **Twenties** extended Dams’ Decrease condition.

Training in the **Tens** group was divided into 8 consecutive sessions of each of the following decreasing defect probabilities: 0.60, 0.50, 0.40, and 0.30. The **Twenties** condition involved 8 consecutive sessions of decreasing defect probabilities, which were 1.00, 0.80, 0.60, and 0.40. Other differences between
the decreasing defect probabilities in this study and Dams' Decrease condition were: (1) subjects were never trained at the same defect probability at which they were tested, (2) each training defect probability was represented at equal lengths (8 sessions each), and (3) subjects were trained overall for a longer period of time. See Table 2 for description of conditions in the current investigation.

Changes from the Dams' study. In addition to extending Dams' Decrease condition, in this study, all defects were faded out at equal defect decrements and after equal time periods. Dams' subjects trained under 0.60 defect probability for 3 sessions; 0.40 defect probability for 2 sessions, and 0.20 for 3 sessions. Thus, his subjects were trained under unequal number of sessions per decreasing defect probabilities. These gradual changes in exposure to decreasing defect probabilities could be viewed as stimulus fading in that the defect probabilities consistently decreased, albeit these conditions were predetermined and not performance-based. Colquhoun and Baddeley's (1964; 1967) studies trained defect detection at 0.18 defect probability and tested at 0.02 defect probability. Dams' research was the first wherein frequency of defects was faded (i.e., stimulus fading) as training progressed.

The current investigation faded out defect probability for all subjects during training. Performance differences were compared based on the rate at which defects were faded. For 4 subjects, defects were faded out in 0.20 defect probability decrements during training and for the other 4 subjects defects were faded out in 0.10 probability decrements during training. (See Table 2.)
Stimulus Fading and Stimulus Control in Quality Control Inspection

While stimulus fading is a procedure to establish stimulus control, stimulus control, per se, has not been featured prominently in the inspection training literature. Badalamente and Ayoub (1969), Mason and Redmon (1992), and Dams (1996) concluded that defect detection, per se, may function as a reinforcer for quality control inspection tasks. This implies that the defect itself may be functioning as the discriminative stimulus, the $S^D$ evoking detection behavior. However, if this conclusion is accurate, the question arises, why has it been difficult to demonstrate stimulus control in prior studies?

Some possible answers to this question might be 1) during the actual quality control inspection process, the schedule of reinforcement for defect detection could be too lean because product quality could be too high (i.e., too few defects present) or 2) the reinforcement schedule could be too low to maintain, or even generate, the operants involved in establishing stimulus control. Consequently, the defects might not come to exert stimulus control over critical inspecting behaviors. Therefore, a training technique that initially exposes inspectors to a high frequency of defects and a low frequency of error free comparisons and then gradually reduces defect frequency and increases frequency of error free parts may prove to be a more effective quality control inspection training procedure than have traditional procedures. Having discussed stimulus fading and stimulus control as dimensions of effective quality control inspection training, there was one other aspect of the behavior analytic
quality control inspection literature that has received some attention—the use of feedback as a reinforcer for accurate defect detection.

**Feedback as a Reinforcer**

Feedback commonly refers to the performance information a person receives following a given performance. According to Balcazar, Hopkins, and Suarez (1986), "...[feedback] will be effective to the extent that it is related to functional, differential reinforcement" (p. 65). Two previous quality control studies involved an element of feedback during the training of inspectors. In the first study, Mason and Redmon (1992) tested for the effects of the timing of feedback delivery during a quality control inspection simulation.

The simulation consisted of a computer monitor displaying a schematic of a computer hard drive. Subjects were divided into 4 conditions that varied both stimulus presentations and latency to performance feedback. They found that inspection accuracy was the highest for self-paced stimulus presentations with immediate feedback, followed second by self-paced stimulus presentations with delayed feedback, then by machine-paced presentations with immediate feedback, and finally machine-paced presentations with delayed feedback. In all conditions, feedback consisted of an on-screen cumulative correct percentage counter which either increased for a correct response or decreased for an incorrect response. However, in the immediate feedback conditions, this percentage was displayed following each inspection response and in the delayed
feedback conditions, it was displayed only after the 200th response (i.e., the last response in a session).

In the second study, Dams (1996) used immediate feedback only during training. A graphical display overlaid the sample and comparison boards and it read either "Correct!" or "Incorrect!" depending on the accuracy of the subject's response. See Figure 2. All subjects received the immediate feedback and no cumulative feedback was provided. Based on Balcazar, et al., there may be some divergence expected between correct and incorrect responding if feedback was effective. This study uses the same feedback procedure as did Dams; however, it is not a variable under investigation in this study.

Applicability to Industrial Inspection

Previous research on the development of training methods for increasing the accuracy of critical inspection behaviors stressed the need for simulations to more closely resemble real-world inspection tasks (Craig & Colquhoun, 1975, Embrey, 1975, & Harris, 1968; 1969). Early studies had experimental stimuli that were too simple and future recommendations included the use of more complex stimuli (Craig & Colquhoun, 1975 & Embrey, 1975).

Harris (1966) and Schoonard, Gould, and Miller (1973) increased stimulus complexity by using actual or simulated electronic components. Harris' study concluded that the more complex the components, the more likely there would be detection errors. In behavior analytic research, stimuli to be inspected have included a variety of graphic symbols on a pen and paper simulation (Thorne,
1991) and computer simulated schematics of computer hard drives (Mason & Redmon, 1992). The current study presented subjects with computer-generated graphics of 30-component electronic circuit boards.

**Research Question**

This study will compare and evaluate two quality control inspection training methods. The first method involves a gradual decrease in defect probability using decrements of 0.20 (similar to Dams’ procedures). The second training method involves gradual decrements of 0.10 defect probability. The purpose of this research was to determine which training series of descending defect probabilities would result in more accurate detection of defects in a simulated quality control task—i.e., which stimulus fading procedure, a 0.20-defect probability decrement or a 0.10-defect probability decrement, will be most effective in generating and maintaining accurate defect detection?

**METHOD**

**Subjects**

Eight participants from the University of North Texas volunteered as subjects following signing of the informed consent form. Each was given base pay of $3.50 for all daily sessions and was able to earn up to an additional $2.50 in performance-based pay for all daily sessions on a computer-simulated quality control inspection task.
Performance pay was calculated by adding the frequency of correct defect detections for all daily trials and multiplying that total by $0.015625 ($2.50 divided by 160). Thus, a subject with correct defect detection over 160 trials for the 4 daily sessions could earn the maximum of $6.00. A split payment schedule was implemented such that performance pay plus $1.50 of the base pay was given to the subject at the conclusion of each day’s fourth session. The remaining $2.00 was paid to the subject at the conclusion of the experiment. (For example, a subject who correctly responded to 130 comparison boards earned $1.50 base pay, performance pay of $2.03--130 x $0.015625--and the experimenter retained $2.00 of base pay until the conclusion of the study.)

Pay Instructions

Prior to entering the experimental chamber on the first day, each subject received a copy of pay instructions. The subject read this copy silently as the experimenter read the instructions aloud:

You may earn up to $6.00 per day. Of that, $3.50 will be paid to you for attending the daily session. This pay will be disbursed so that $1.50 will be given to you each day you attend and the remaining $2.00 will be banked and given to you at the conclusion of the experiment. You may also earn up to $2.50 per day based on your performance on the computer task. This performance pay will be disbursed concluding daily sessions along with the $1.50 of
the base pay. You may take home a maximum of $4.00 for attending daily sessions. (Dams, 1996)

The experimenter retained both copies of these pay instructions.

**Setting and Apparatus**

All experimental sessions were conducted in a room approximately 3 m x 1.5 m. The apparatus consisted of a Windows 3.1 platform personal computer with a 486 DX-50 CPU, 32 MB of RAM, 1 MB of display memory, and a 38.1 cm SVGA monitor. The apparatus was programmed to control all experimental events and collect all data.

**Independent Variable**

The independent variable was the defect probability parametrically manipulated for two groups of 4 subjects each. Pretraining and posttraining sessions for both groups was conducted at 0.20 defect probability. In the **Twenties** group, defect probability decreased in decrements of 0.20 during the training phases. Defect probabilities included 8 sessions of each of the following: 1.00, 0.80, 0.60, 0.40. In the **Tens** group, defect probability decreased in decrements of 0.10 during the training phrases. Defect probabilities included 8 sessions of each of the following: 0.60, 0.50, 0.40, 0.30.

**Dependent Variables**

There were three dependent variables (DV): DV1 was frequency of correct defect detection for error free comparisons, transposition defects, and rotation defects. A correct defect detection response was defined as rejecting a
comparison board with a defect or accepting an error free comparison board. DV2 was the frequency of occurrence of active and passive errors. Active errors were defined as incorrectly rejecting an error free comparison board or incorrectly accepting a comparison board with either a rotation or transposition defect within a 10-s limited hold. A passive error was failing to make a response to a comparison board within the 10-s limited hold. DV3 was mean latency of correct and incorrect defect detection responses for all comparison boards.

Procedure

Quality control task. This involved viewing computer-generated circuit boards. Each board was composed of 30 items varying in size, shape, and color. Sample and comparison stimuli were presented side-by-side on the computer monitor. The "Sample" board appeared on the left side of the monitor, and the "Comparison" board, on the right, did or did not match the "Sample" board. The comparison board contained either a single defect or was error free. See Figure 1.

There were two types of defects: transposition defects and rotation defects. Transposition defects occurred when two components on the circuit board exchanged locations. Rotation defects occurred when one component on the comparison board was rotated 180 degrees.
To initiate a session, the subject single-clicked the left mouse button (indicated with a blue sticker) on the word "Start" as an orientation response. This was followed by the first dyad to be examined.

Subjects could make one of two active responses. They could single-click either the "Reject" button or the "Accept" button; both were located below the comparison board. If the subject did not respond within a 10-s limited hold, the dyad disappeared, and 750 ms later, a new dyad appeared. This protocol was followed for 4 daily sessions with 40 trials per session. Maximum session length was 7 min and the subject concluded all 4 daily sessions within approximately 35 min.

Following each session, a message appeared on the computer screen instructing the subject to leave the room and inform the lab attendant. The investigator entered the experimental room and exited the program, collected the data, and reset the program for the next session. This took approximately 90 s.

**Experimental design.** The experimental design was an A-B-A reversal design (Barlow & Hersen, 1984) with pretraining at 0.20 defect probability, training (defect probability either in the Tens group or Twenties group), and posttraining at 0.20 defect probability. Training consisted of a combination of instructions, parametrically manipulated defect probabilities, and feedback. However, only the effect of the parametrically manipulated defect probabilities was investigated. Subjects received their performance pay plus $1.50 of their base pay after the 4th (i.e., last) daily session.
Pretraining. Prior to the first experimental session, the investigator read aloud the following instructions to each subject as the subject followed along on a copy:

WELCOME! You are training to be a quality control inspector.

Your task is to detect defects in a computer circuit board. You will see two boards on the computer screen: The board on the left is labeled SAMPLE and is a board without defects. The board on the right is the comparison board you are inspecting for defects. If you see a defect on the right board, move the cursor to the "Reject" button and press the blue dot on the computer mouse. If you do not see a defect on the right board, move the cursor to the "Accept" button and press the blue dot on the computer mouse. When you are through, follow the instructions on the screen. (Dams, 1996)

Defect probability was 0.20 for all subjects. Pretraining occurred for the first 8 sessions.

Training. Subjects were assigned randomly to one of 2 training conditions. The investigator read the following instructions aloud as the subject read silently from another copy. These instructions included a description of the defect types and the introduction of on-screen feedback.

Training starts today. You will now receive feedback on the screen after each response. If the comparison board has a defect, it will either be (1) two parts have switched location or (2) one part may
be rotated. For instance, the colored stripes on the small parts may be reversed. (Dams, 1996)

Feedback consisted of “Correct!” and “Incorrect!” displayed across the center of the dyad for 2s following each response (see Figure 2). A passive error (no response within the 10-s limited hold), was scored as “Incorrect!” The feedback component added 1.3 min to each session. Defect probabilities during training depended on the condition to which the subject was assigned. Total training consisted of 32 sessions. The 4 daily sessions took approximately 40 min to complete.

Posttraining. The investigator read aloud the following instructions prior to the first posttraining sessions as the subject read from a copy:

CONGRATULATIONS! You have completed quality control inspection training. You will no longer receive on-screen feedback.

(Dams, 1996)

Defect probability was reset to 0.20 and the experiment concluded after 8 posttraining sessions.

RESULTS

Each dependent variable is reported separately. Figures 3 through 6 illustrate the frequency of correct defect detections for error free comparisons, rotation defects, and transposition defects across all phases. Figures 7 through 10 show the frequency of active and passive errors for all defect types across
phases. Figures 11 through 14 depict mean latencies for correct defect
detections across phases and Figures 15 through 18 depict mean latencies for
incorrect defect detections across phases.

Pretraining

The frequency of correct defect detections for subjects in the Tens group
is displayed in Figures 3 and 4 and the frequency of correct defect detections for
subjects in the Twenties group is displayed in Figures 5 and 6. Figures are
divided into frequencies of overall correct defect detections, error free
comparison board detections, rotation defect detections, and transposition defect
detections. The results of each type of defect detection per group is discussed
separately. To preclude possible acclimation-to-task effects, only the last 4 data
points in the pretraining phase are discussed.

Overall correct defect detections in the TENS group. As shown in Figure
3, Subject ES 10's overall correct defect detections ranged from 32 to 36 and
subject MM 10's ranged from 32 to 35. In Figure 4, Subjects PJ 10 and TF 10\textsuperscript{1}
demonstrated the greatest variability in overall correct defect detections. TF 10
correctly detected 37 of 40 defects in session 6; whereas, PJ 10 detected 29 of
40 in sessions 3 and 4. No subject in the Tens group reached the maximum
overall correct score of 40.

\textsuperscript{1} Due to an error in the setup of the experimental apparatus, TF 10's data
for session 7 was not depicted on Figures 4, 8, 12, and 16. Instead, this data is
represented in Tables 3, 4, and 5.
Overall correct defect detections in the TWENTIES group. In Figure 5, subject AS 20's detection range was 31 to 35. KF 20, whose scores ranged from 29 to 35, had the greatest variability in the Twenties group. Figure 6 shows subject NW 20's consistently overall correct score of 31 across the last 4 pretraining sessions and subject PO 20's overall correct defect detection range of 16 to 21. No subject in the Twenties group reached the maximum overall correct defect detection score of 40.

Error free comparison board detections in the TENS group. While subjects ES 10 and TF 10 correctly accepted 15 of the 16 error free comparison boards in the last 4 sessions of pretraining, MM 10 correctly accepted all error free boards in these same last 4 sessions. On the other hand, PJ 10's detection of error free comparisons ranged from 22 to 26. It may be concluded from these results that at the outset of this study, 3 of 4 subjects in the Tens group either had an accept bias or a failure-to-reject bias since most of their detection errors occurred on comparison boards with a defect. See Figures 3 and 4.

Error free comparison board detections in the TWENTIES group. A response bias was less evident in the Twenties group. AS 20 correctly accepted all error free comparisons in 2 of the last 4 pretraining sessions. On the other hand, KF 20's acceptance of error free comparisons ranged from 26 to 30, and NW 20, from 29 to 31. PO 20, the outlier of the group, had an acceptance range from 15 to 19.
Rotation detections in the TENS group. None of the Tens group subjects correctly identified all rotation defects during training. TF 10 was the only subject who correctly detected 2 of 4 rotation defects in any of the last 4 sessions of pretraining. See Figures 3 and 4.

Rotation detections in the TWENTIES group. As shown in Figure 5, AS 20 and KF 20 correctly detected 3 of 4 rotation defects in one of the last 4 sessions of pretraining; whereas, NW 20 and PO 20 detected 2 of 4 rotation defects in the last 4 sessions of pretraining (Figure 6).

Transposition detections in the TENS group. ES 10 and TF 10 detected all transposition defects in pretraining session 6. MM 10's rotation detection range was 0 to 2 and PJ 10's range was 0 to 3, as shown in Figures 3 and 4.

Transposition detections in the TWENTIES group. No subject in the Twenties group detected all 4 rotation defects. AS 20's session 5 was the group high: 3 of 4 correctly detected rotation defects.

Training

Overall correct defect detections in the TENS group. As ES 10, MM 10, and PJ 10 (Figure 3 and Figure 4, top) progressed through the training phases from 0.60 to 0.30 defect probabilities, overall correct defect detection scores consistently increased after an initial dip following pretraining; however, TF 10's performance (Figure 4, bottom) did not follow this pattern. The range for all overall correct data points was 26 to 36 throughout training.
Overall correct defect detections in the TWENTIES group. Throughout training, AS 20 and KF 20 produced similar response patterns: a reject bias when defect probability was at 1.00; a substantial drop in frequency for correct defect detections throughout the 0.80 defect probability; and almost total performance recovery from that drop by the conclusion of training. NW 20, on the other hand, did not exhibit a reject bias at 1.00 defect probability and, subsequently, did not have as steep a decrease in frequency when entering the 0.80 defect probability phase. However, at 0.60 defect probability, NW 20's responding became unstable with a range from 18 at session 29 to 36 at session 26. The range narrowed during the 0.40 defect probability phase from 32 to 36. (See Figure 4.) PO 20's responses did not reflect either a reject or accept bias at the 1.00 defect probability; that may explain why there is a slight increase—from 24 in session 16 to 28 in session 17—in frequency of correct defect detection at the introduction of the 0.80 defect probability. PO 20's performance continually improved throughout the rest of the training phases.

Error free comparison board detections in the TENS group. A high frequency of correctly accepting error free comparison boards throughout all training phases appeared to be the pattern for all subjects except PJ 10. Subject PJ 10 did accept more error free boards as the training progressed; however, performance levels never reached to the levels of other group members. (Figures 3 and 4).
Error free comparison board detections in the TWENTIES group. There were no error free comparison boards presented to the Twenties group in their first 8 training sessions during 1.00 defect probability. Once error free comparison boards were re-introduced at the 0.80 defect probability level, approximately half of these comparison boards were correctly accepted. At the conclusion of training, all subjects in the Twenties group had correctly accepted 24 of 24 error free comparison boards in at least 3 sessions at the 0.40 defect probability level.

Rotation detections in the TENS group. No subject in the Tens group detected all rotation defects presented in a given session at any training defect probability. ES 10's (Figure 3) best rotation detection training score for any session in each probability under each training condition was as follows: 8 of 12 correct at 0.60 defect probability, 6 of 10 at 0.50 defect probability, 7 of 8 correct at 0.40 defect probability, and 4 of 6 correctly rejected rotations at the 0.30 defect probability. MM 10's (Figure 3) correct rotation defect detections at each training defect probability were 7 of 12 at 0.60 defect probability, 2 sessions of 3 of 10 at 0.50 defect probability, 5 of 8 correct at 0.40 defect probability, and 3 of 6 at 0.30 defect probability. PJ 10's best scores were 7 of 12 correct at 0.60 defect probability, 2 sessions of 6 of 10 at 0.50 defect probability, 4 sessions of 4 of 8 correct at 0.40 defect probability, and a session frequency score of 4 of 6 at 0.30 defect probability. (See Figure 4.) Finally, TF 10's best scores (Figure 4) were as follows: 9 of 12 correct at 0.60 defect probability in session 12, 9 of 10 at
0.50 defect probability in session 24, 5 of 8 correct at 0.40 defect probability in session 27, and 5 of 6 in the second session at 0.30 defect probability.

**Rotation detections in the TWENTIES group.** When training began, subjects in the Twenties group were presented with comparison boards, all of which were to be rejected. This may have led to the “Reject” button clicking bias evident in 3 of the 4 subjects’ performances. AS 20 (Figure 5) correctly rejected all but 8 of the 160 presentations of rotation defects at the 1.00 defect probability and the 8 that were incorrectly accepted occurred in the first session. AS 20’s subsequent best scores at detecting rotation defects were 15 of 16 at 0.80 defect probability, 11 of 12 at 0.60 defect probability, and 8 of 8 at 0.40 defect probability. KF 20 (Figure 5) missed only 14 of the 160 possible rotation defect presentations at 1.00 defect probability. The best scores following that were 14 of 16 at 0.80 defect probability, 10 of 12 at 0.60 defect probability, and 8 of 8 during session 37, at 0.40 defect probability. NW 20’s (Figure 6) best rotation detection scores were 2 sessions of 19 of 20 at 1.00 defect probability, 13 of 16 at 0.80 defect probability, 2 sessions of 10 of 12 at 0.60 defect probability, and 6 of 8 at 0.40 defect probability. PO 20 demonstrated a positively sloped trend with a range from 2 of 20 to 10 of 20 in rejecting rotation defects at 1.00 defect probability. PO 20’s best scores during the other training defect probabilities: 10 of 16 at 0.80, 2 sessions of 6 of 12 at 0.60, and 3 sessions of 5 of 8 at 0.40.

**Transposition detections in the TENS group.** For all subjects in the Tens group, transposition defects were easier to detect than rotation defects. ES 10’s
best transposition detection training score (Figure 3) for any session under each probability in the training condition was as follows: 11 of 12 under 0.60 defect probability, 2 sessions of 10 of 10 correct responses under 0.50 defect probability condition, 8 of 8 in 0.40 condition, and 3 sessions of 6 of 6 correct detection responses under 0.30 defect probability condition. In Figure 3, MM 10's highest transposition defect detection scores were 10 of 12 at 0.60, 4 sessions of 8 of 10 at 0.50, 7 of 8 at 0.40, and 4 of 6 at 0.30 defect probability. In Figure 4, PJ 10's highest transposition detection scores were 9 of 12 at 0.60 defect probability, 2 sessions of 7 of 10 at 0.50 defect probability, 7 of 8 at the 0.40 defect probability, and in session 37, 6 of 6 at 0.30 defect probability. Figure 4 displays TF 10's transposition defect detection scores. At 0.60 defect probability, TF 10's highest score was 12 of 12 in session 13. Best scores on transposition defect detections, thereafter, were 9 of 10 at 0.50, 8 of 8 in session 30 at 0.40, and 3 perfect 6 of 6 sessions at 0.30 defect probability level.

**Transposition detections in the TWENTIES group.** AS 20 (Figure 5) correctly rejected all but 5 of the 160 total presentations of transposition defects at 1.00 defect probability and all the detection errors occurred in the first 3 sessions entering training. AS 20’s subsequent best scores at transposition detection were 16 of 16 in session 20 at 0.80 defect probability, 7 of 12 at the 0.60 defect probability, and 2 sessions of 7 of 8 at the 0.40 defect probability. KF 20 (Figure 5) missed only 7 of the 160 transposition defect presentations at 1.00 defect probability, and KF 20's best scores following that were 3 sessions of
14 of 16 at 0.80 defect probability, 11 of 12 at 0.60 defect probability, and 8 of 8 in session 40 at 0.40 defect probability. NW 20 (Figure 6) had 2 sessions at 1.00 defect probability with a perfect transposition detection score. NW 20's best transposition detection scores for the remaining training defect probabilities were 19 of 20 at 1.00 defect probability, 15 of 16 at 0.80 defect probability, 4 sessions of 11 of 12 at 0.60 defect probability, and 5 sessions of 7 of 8 at 0.40 defect probability. The following are PO 20's (Figure 6) best transposition detection scores throughout all training sessions: 3 sessions of 17 of 20 at 1.00, 15 of 16 at 0.80, 4 sessions of 10 of 12 at 0.60, and 2 sessions at 8 of 8 at 0.40.

Posttraining

Posttraining occurred in sessions 41 through 48. To provide a fair comparison with the pretraining phase, only the last 4 data points (sessions 45 through 48) in the posttraining phase will be discussed.

Overall correct defect detections in the TENS group. Subject ES 10's overall correct defect detection range during the last 4 sessions of posttraining indicated slight improvement with a range of 35 to 38 as compared to the last 4 pretraining sessions. (See Figure 3). MM 10's posttraining range of 33 to 35 was virtually unchanged from pretraining. PJ 10 (Figure 4) demonstrated the greatest increase in the frequency of correct defect detections compared to the pretraining condition. The bottom of PJ 10's range rose from 23 to 34 while the top of the range rose from 29 to 36. Subject TF 10 showed virtually no change
in the frequency of correct defect detections with a posttraining range of 32 to 37.

**Overall correct defect detections in the TWENTIES group.** Only the ranges for KF 20's pre- and posttraining scores overlapped. For all the other subjects in the Twenties group (AS 20, NW 20, and PO 20) the ranges of posttraining and pretraining scores did not overlap. See Figures 5 and 6. AS 20 (in session 46) was the only subject in either the Tens or the Twenties group who responded correctly to all defects in a posttraining session.

**Error free comparison board detections in the TENS group.** Subjects ES 10 and TF 10 had 32 of 32 correctly accepted error free comparison boards in 3 of their last 4 sessions of posttraining. PJ 10 had 2 sessions of 32 of 32 correct and MM 10 had 1 session of correctly accepting all error free comparisons (Figures 3 and 4).

**Error free comparison board detections in the TWENTIES group.** NW 20 (Figure 6) was the only subject in either group who achieved a perfect final 4 sessions of correctly accepting all error free comparison boards. AS 20 (Figure 5) detected all error free comparison boards in 3 of 4 last posttraining sessions. KF 20 correctly accepted 31 of 32 on 2 of the last 4 sessions; whereas, PO 20's scores ranged from 25 to 31 correctly accepted error free comparisons in the last 4 sessions of posttraining.
Rotation detections in the TENS group. Subject ES 10 had 3 sessions at 2 of 4, MM 10 had 1 session of 2 of 4, PJ 10 had 2 sessions of 1 of 4, and TF 10 had 2 sessions of 2 of 4 (Figures 3 and 4).

Rotation detections in the TWENTIES group. AS 20 and PO 20 had 1 session of 4 of 4 correctly rejected rotation defects in the last 4 sessions of posttraining. KF 20 and NW 20's best scores were 2 of 4 correct rotation defect detection. See Figures 5 and 6.

Transposition detections in the TENS group. All subjects except TF 10 had at least 1 session of 4 of 4 correctly rejected transposition comparisons. ES 10 had 2 sessions of 4 of 4 and MM 10 and PJ 10 had 1 session of 4 of 4. TF 10's best was 3 of 4, in session 47.

Transposition detections in the TWENTIES group. Figures 5 and 6 depict that AS 20, KF 20, and NW 20 all having 1 session of perfectly detecting all transposition defects in the last 4 sessions of posttraining. PO 20's best transposition detection score was 3 of 4 in session 48.

Active and Passive Errors in the TENS Group

Across all sessions and subjects, there was a definite delineation between active and passive errors. With few exceptions, all subjects committed more active errors than passive errors (i.e., they responded to the comparison boards by either clicking on the accept button or the reject button and not by waiting for the dyad to disappear after the 10-s limited hold had expired). See Figures 7 and 8.
Active and Passive Errors in the TWENTIES Group

AS 20, KF 20, and NW 20 responded to a presented dyad in much the same way as their counterparts in the Tens group. PO 20 had a unique responding pattern. For the first 16 sessions, PO 20's made more passive errors than active errors; however, once training phase of 0.40 defect probability commenced, PO 20's responding resembled that of the other 7 subjects (Figures 9 and 10).

Mean Latencies for Correct and Incorrect Defect Detections in the TENS Group

Figures 11 and 12 display the mean latencies for correct defect detections. Correctly accepting an error free comparison board resulted in longer latencies than did correctly rejecting a comparison board with defects.

Figures 15 and 16 display the mean latencies for incorrect defect detections and error free comparison boards. Incorrect defect detection latencies were differentiated at the 10-s limited hold mark where error free comparison boards were withdrawn and scored as incorrect. There were no differences between either correct or incorrect defect detection latencies based on type of defect.

Mean Latencies for Correct and Incorrect Defect Detections in the TWENTIES Group

Figures 13 and 14 depict the mean latencies of correct defect detections. Differentiation in correct defect detection latencies only appeared when subjects
entered the 0.80 defect probability phase, where error free boards took longer to accept than defects took to reject.

Figures 17 and 18 display the mean latencies of incorrect defect detections. AS 20 and KF 20 had similar results whereby error free comparison boards resulted in subjects exceeding the 10-s limited hold. Error free comparison boards also resulted in NW 20 exceeding the 10-s limited hold. However, this subject appeared to show a trend of making faster incorrect defect detections as the study progressed. PO 20 fell prey to the limited hold for every type of comparison board in the first 16 sessions. After training at 0.80 defect probability began, better differentiation occurred and only error free comparisons were scored as incorrect due to no response before the expiration of the limited hold.

Pretraining Versus Posttraining Defect Detection Summary

Tables 6 and 7 summarize training effects by comparing pretraining to posttraining. Table 6 compares maximum possible scores to the sum total of correct responses per defect type in the last 4 sessions of pretraining and posttraining. Table 7 displays the conversion of these scores as percent correct.

Overall correct defect detections. All subjects, whether in the Tens or Twenties group displayed some, even if negligible, improvement. Subject TF 10 demonstrated the least amount of improvement (only 1%) and PO 20 showed the greatest improvement with a 37% increase. However, excluding for PJ 10's 21% gain, all of the Twenties subjects did markedly better during posttraining.
Therefore, it may be concluded that even though both groups improved, the Twenties group learned the task better than did the Tens group.

Error free comparisons. Only PJ 10 and PO 20 demonstrated any sizeable improvement (23% and 37%, respectively) in accepting error free comparisons. The rest either got worse (MM 10), stayed the same (ES 10), or only marginally improved. This may have been because of a possible "accept" bias by most subjects, even as the study progressed.

Total defects. All subjects improved, except TF 10, when both rotation and transposition defects were grouped together.

Rotations. Two of the Tens subjects either did not improve (PJ 10) or actually got worse (TF 10) at detecting rotation defects. However, all of the Twenties subjects improved anywhere from 25% to 43%. This was the more difficult of the two types of defects to detect in this study because it involved only one component being rotated 180 degrees. These improvements may or may not support the claim of defects functioning as S^D's.

Transpositions. All subjects improved in the detection of transposition defects. These defects were more easily detected because they involved two components exchanging locations, therefore a subject actually only had to detect one of transposed components to reject the comparison board. Transposition defects did come to exert stimulus control over subject responding.

Error free comparisons. Only PJ 10 and PO 20 demonstrated any sizeable improvement (23% and 37%, respectively) in accepting error free
comparisons. The rest either got worse (MM 10), stayed the same (ES 10), or only marginally improved. This may have been because of a possible “accept” bias by most subjects, even as the study progressed.

DISCUSSION

The purpose of this research was to determine which training series of descending defect probabilities would result in the most effective and accurate detection of defects in a simulated quality control inspection task and to determine at what rate or step-size (i.e., stimulus fading rate) might increase inspection accuracy. If training quality control inspectors is to be considered successful, trainees must learn to reject boards with defects and to accept error free boards.

This training program was implemented using a previously defined stimulus fading procedure. The goal was to arrange the task so that defects would exert stimulus control over detection responses (i.e., function as S^D_s for rejecting defects). The performance of all subjects in both groups improved, as evidenced by the difference between the overall correct scores for the last 4 pretraining sessions compared to the last 4 posttraining sessions. (See Tables 6 and 7.) However, at best, the evidence is mixed as to whether defects actually functioned as S^D_s because as the defect probability during training decreased, subjects’ overall correct defect detection performances improved. Therefore,
defects appear to have functioned as S^D's only when their frequency of occurrence was very low.

Neither the Tens nor the Twenties group performed better than the other at overall correct defect detections. However, when pretraining and posttraining scores for the specific defect types were compared, some improvements in detecting transpositions and rotations could be seen. This was exemplified by the performances of all 8 subjects in accurately detecting transposition defects and 6 of 8 subjects when detecting rotation defects.

The Twenties group accurately detected more defects than did the Tens group. There are two possible explanations for this finding. First, the Twenties group were exposed to a higher total number of defects (1024) compared to the Tens group (704), and, therefore, had more practice at detecting defects. Second, all of the subjects in the Twenties group started with lower pretraining performances than the subjects in the Tens group, therefore they had more room for improvement during posttraining.

**Significance of the Current Study**

This study addresses earlier concerns about the complexity of simulated quality control inspection tasks and their applicability to real-world quality control inspections. This was accomplished by using a 30-component computer simulated circuit board as the stimulus under inspection. Thirty components for inspection made the task complex and using a computer simulation allows for its applicability for real-world training. Previous studies that used computer simulations include Craig and Colquhoun (1975), Embrey (1975), and Harris
(1968; 1969). Some of the complex stimuli under study included Badalamente and Ayoub's (1969) use of simulated circuit boards and Schoonard et al.'s (1973) use of slide presentations of printed circuit boards. Other complex electronic stimuli under study were computer line-printer patterns representing computer chips and filmed images of electronic circuit boards projected on a screen (Tsao, Drury, & Morawski, 1979; Eskew & Riche, 1982; respectively).

To this point, behavior analytic quality control inspection studies used either simple stimuli (Thorne, 1991) or complex stimuli comparable to the current study (Mason & Redmon, 1992). Thorne used pen-drawn graphic symbols on paper and Mason and Redmon used computer-generated schematics of computer hard drives. However, Mason and Redmon included omission defects in their comparison schematics; whereas, the current study did not use omissions because of the relative ease of detecting this defect type (Ellis & Greenspoon, 1996).

This study compared two possibly viable and real-world training methods. The only conclusion that may be drawn is that exposure to more defects and, possibly, longer training periods (32 sessions in the current study versus 8 in Dams' study) may enhance accuracy of quality control inspection. Separating out which of these variables, if not both, is the most critical will be left for another study.

The findings in this study support Wang, Sharit, and Drury's (1991) statement, "Large individual differences in inspection performance is one of the
most consistent findings in inspection studies" (p. 587). To reach the goal of designing highly effective quality control inspection training programs appears to require finding a training program that will minimize or eliminate these individual differences to the extent that defect detection will occur at consistently high accuracy across all inspectors.

Suggestions for Future Research

The major limitation in answering the research question in this study was lack of funds. Adequate funding would have allowed for more subjects and more comparison groups. More subjects and comparison groups would have eliminated the differences in the range of defect probabilities to which the two groups in this study were exposed. For example, it may have been more beneficial to compare groups in which the defect probability range during training started at 1.00 for both the Tens and the Twenties group and, consequently, ended at 0.40 for each group.

A second modification would be to add a third, fourth, and/or possibly a fifth training group. The third group could be exposed to the same defect probability throughout pretraining, training (including feedback), and posttraining as in Dams' "Low" condition and possibly be used as a "control" group. If a fourth group were added, a second "control" group where 0.20 defect probability was implemented just like the third group except there would be no feedback during training sessions. The third or fourth group would help to determine whether practice would be sufficient to lead to the high accuracy levels observed
in posttraining. Finally, if a fifth group were added, random defect probabilities during the training phase could be implemented as this procedure has not been reported in any of the quality control inspection literature.

A third modification to possibly support the research question would be to eliminate the 1.00 defect probability altogether, because, no marketed consumer product has a manufacturing defect probability of 1.00. This is suggested because in the current study the 1.00 defect probability appeared to lead to a "reject" response bias for 3 of the 4 subjects in the Twenties group that disrupted subsequent training at lower defect probabilities. On the other hand, despite a possible reject response bias, retaining a 1.00 defect probability phase during training mirrors what occurs in some actual defect detection training situations, according to Hyten (personal communication, September 9, 1997).

Finally, there remains the issue of the importance of developing more inspection training procedures focusing on stimulus (antecedent) control rather than consequent control. A suggestion may be to have inspectors scan circuit boards for a given amount of time (as in the current study). After either any response (correct or incorrect) or no response within the time allotted, the defect would be highlighted so that the inspector could study it, become familiar with it, and know what to look for the next time that defect appeared. After repeated presentations, this should enable specific defects to function as S^D's. Therefore, if this suggestion were successful, defects would become an inspector's reinforcer and no artificial consequent control should be needed.
My Name is Jo Ann Segal. I am candidate for the Masters of Science degree from the Department of Behavior Analysis in the School of Community Service at the University of North Texas in Denton, Texas. This informed consent form pertains to research to fulfill my Master's thesis requirement.

INFORMED CONSENT FORM

I, ________________________________, agree to participate in a study designed to investigate human learning. I understand that my participation will involve using a personal computer. I have been informed that each participation session will last no longer than 40 minutes, and that my participation involves attending 12 participation sessions.

I understand that during the experiment I will have the opportunity to earn up to $6.00 per day. I will receive $3.50 base pay at the end of each session plus up to $2.50 based on my own performance at the learning task. The $3.50 base pay will be divided into two payments, $1.50 which will be given to me immediately concluding each session and $2.00 which will be banked and given to me only upon conclusion of all experimental sessions. All money earned based on performance will be paid immediately concluding each session.

I understand that all data collected in the experiment will be treated as confidential, kept in a locked file cabinet, and encoded in a computer database so as I am not identified. I agree to allow Jo Ann Segal or Dr. Janet Ellis to use the results of my experimental sessions in any way considered best for publication or education, keeping my identity associated with the data confidential. I understand that the results of the experimental sessions will be explained to me in a debriefing session after all the sessions have been concluded.

I have been informed that there is no personal risk or discomfort directly involved with this research. I understand that my participation in this study is voluntary and I may withdraw at any time without penalty. If I have questions that may arise in relation to my participation in this research, I should contact Jo Ann Segal at (940) 591-9491 (home) or (940) 565-2274 (Department of Behavior Analysis) or Dr. Janet Ellis at (940) 565-3318 (work) or (940) 566-6488 (home).

Date ________________________________
Signature of Participant

Date ________________________________
Signature of Investigator

THIS PROJECT HAS BEEN REVIEWED BY THE UNIVERSITY OF NORTH TEXAS COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS. (940) 565-3940
University of North Texas
Sponsored Projects Administration

July 11, 1997

Ms. Jo Ann Segal
3400 Joyce Lane, Apt #106
Denton, TX 76207

Institutional Review Board for the Protection of Human Subjects in Research (IRB)
Re: Human Subjects Application No. 97-148

Dear Ms. Segal:

As permitted by federal law and regulations governing the use of human subjects in research projects (45 CFR 46), I have conducted an expedited review of your proposed project titled “The Effect of Decreasing Defect Probabilities on Quality Control Inspection.” The risks inherent in this research are minimal, and the potential benefits to the subjects outweigh those risks. The submitted protocol and informed consent form are hereby approved for the use of human subjects on this project.

The UNT IRB must review this project prior to any modifications you make in the approved project. Please contact me if you wish to make such changes or need additional information.

If you have questions, please contact me.

Sincerely,

[Signature]
Rollie Schaier
Chair, Institutional Review Board

cc: IRB Members
Table 1. Experimental conditions and phases from Dams (1996).

<table>
<thead>
<tr>
<th>Day</th>
<th>Phase</th>
<th># of Sessions</th>
<th># of Trials</th>
<th>Defect Probability</th>
<th>Incorrect-Correct Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-training</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
</tr>
<tr>
<td>2</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.60</td>
<td>24:16</td>
</tr>
<tr>
<td>3</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.60</td>
<td>24:16</td>
</tr>
<tr>
<td>4</td>
<td>Post-training</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
</tr>
<tr>
<td>5</td>
<td>Post-training</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
</tr>
</tbody>
</table>

2 On day 2 in the decrease condition, there were 3 sessions at 0.60 defect probability and 1 session at 0.40 defect probability.

3 On day 3 in the decrease condition, there was 1 session at 0.40 defect probability and 3 sessions at 0.20 defect probability.
Table 2. Experimental conditions and phases in the current study.

<table>
<thead>
<tr>
<th>Day</th>
<th>Phase</th>
<th># of Sessions</th>
<th># of Trials</th>
<th>Defect Probability</th>
<th>Incorrect-Correct Ratio</th>
<th>Condition</th>
<th>Defect Probability</th>
<th>Incorrect-Correct Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pretraining</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
<td>TENS</td>
<td>0.20</td>
<td>8:32</td>
</tr>
<tr>
<td>2</td>
<td>Pretraining</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
<td>TWENTIES</td>
<td>0.20</td>
<td>8:32</td>
</tr>
<tr>
<td>3</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.60</td>
<td>24:16</td>
<td>TENS</td>
<td>1.00</td>
<td>40:0</td>
</tr>
<tr>
<td>4</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.60</td>
<td>24:16</td>
<td>TWENTIES</td>
<td>1.00</td>
<td>40:0</td>
</tr>
<tr>
<td>5</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.50</td>
<td>20:20</td>
<td>TENS</td>
<td>0.80</td>
<td>32:8</td>
</tr>
<tr>
<td>6</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.50</td>
<td>20:20</td>
<td>TWENTIES</td>
<td>0.80</td>
<td>32:8</td>
</tr>
<tr>
<td>7</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.40</td>
<td>16:24</td>
<td>TENS</td>
<td>0.60</td>
<td>24:16</td>
</tr>
<tr>
<td>8</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.40</td>
<td>16:24</td>
<td>TWENTIES</td>
<td>0.60</td>
<td>24:16</td>
</tr>
<tr>
<td>9</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.30</td>
<td>12:28</td>
<td>TENS</td>
<td>0.40</td>
<td>16:24</td>
</tr>
<tr>
<td>10</td>
<td>Training</td>
<td>4</td>
<td>40</td>
<td>0.30</td>
<td>12:28</td>
<td>TWENTIES</td>
<td>0.40</td>
<td>16:24</td>
</tr>
<tr>
<td>11</td>
<td>Posttraining</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
<td>TENS</td>
<td>0.20</td>
<td>8:32</td>
</tr>
<tr>
<td>12</td>
<td>Posttraining</td>
<td>4</td>
<td>40</td>
<td>0.20</td>
<td>8:32</td>
<td>TWENTIES</td>
<td>0.20</td>
<td>8:32</td>
</tr>
</tbody>
</table>
Table 3. Subject TF 10's frequency of correct defect detections for session 7.

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Frequency of Corrects</th>
<th>Possible Maximum Correct</th>
<th>Defect Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Correct</td>
<td>30</td>
<td>40</td>
<td>N/A</td>
</tr>
<tr>
<td>Error Free Comparisons</td>
<td>20</td>
<td>20</td>
<td>0.50</td>
</tr>
<tr>
<td>Rotations</td>
<td>3</td>
<td>8</td>
<td>0.20</td>
</tr>
<tr>
<td>Transpositions</td>
<td>6</td>
<td>8</td>
<td>0.20</td>
</tr>
<tr>
<td>Omissions</td>
<td>1</td>
<td>4</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Table 4. Subject TF 10's frequency of active and passive errors for session 7.

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>10</td>
</tr>
<tr>
<td>Passive</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5. Subject TF 10's mean latencies (in s) for both correct and incorrect defect detections for session 7.

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Correct Detections</th>
<th>Incorrect Detections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Free Comparisons</td>
<td>6.3</td>
<td>no incorrect detections</td>
</tr>
<tr>
<td>Rotations</td>
<td>6.5</td>
<td>6.6</td>
</tr>
<tr>
<td>Transpositions</td>
<td>3.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Omissions</td>
<td>5.4</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Table 6. Comparisons between the maximum possible score for the last 4 sessions of pretraining and posttraining to the maximum possible for these sessions.

<table>
<thead>
<tr>
<th></th>
<th>Total Defects</th>
<th>Rotations</th>
<th>Transpositions</th>
<th>Error Free</th>
<th>Overall Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
</tr>
<tr>
<td>Maximum</td>
<td>Possible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-</td>
<td>Post-</td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
<td>Pre- Post-</td>
</tr>
<tr>
<td>TENS</td>
<td>32</td>
<td>32</td>
<td>16</td>
<td>16</td>
<td>128</td>
</tr>
<tr>
<td>ES 10</td>
<td>11</td>
<td>20</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>MM 10</td>
<td>5</td>
<td>14</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>PJ 10</td>
<td>9</td>
<td>14</td>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>TF 10⁴</td>
<td>8 (11)</td>
<td>11</td>
<td>4 (5)</td>
<td>4 (5)</td>
<td>4</td>
</tr>
<tr>
<td>TWENTIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS 20</td>
<td>12</td>
<td>23</td>
<td>6</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>KF 20</td>
<td>12</td>
<td>19</td>
<td>4</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>NW 20</td>
<td>4</td>
<td>18</td>
<td>3</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>PO 20</td>
<td>8</td>
<td>19</td>
<td>4</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

⁴ Due to the error in data collection in session 7 of pretraining, TF 10's pretraining data has been altered to insure fair comparisons between the last 4 sessions of pretraining and the last 4 sessions of posttraining. Altered scores are in parentheses.
Table 7. Percent of correct defect detections for the last 4 sessions of pretraining and posttraining. This data is a conversion of the data in table 6. Furthermore, denominators are not constant between defect categories.

<table>
<thead>
<tr>
<th></th>
<th>Total Defects</th>
<th>Rotations</th>
<th>Transpositions</th>
<th>Error Free</th>
<th>Overall Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-</td>
<td>Post-</td>
<td>Pre-</td>
<td>Post-</td>
<td>Pre-</td>
</tr>
<tr>
<td><strong>Maximum Possible</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TENS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ES 10</td>
<td>34%</td>
<td>63%</td>
<td>13%</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>MM 10</td>
<td>16%</td>
<td>49%</td>
<td>6%</td>
<td>16%</td>
<td>25%</td>
</tr>
<tr>
<td>PJ 10</td>
<td>28%</td>
<td>44%</td>
<td>13%</td>
<td>13%</td>
<td>44%</td>
</tr>
<tr>
<td>TF 10(^{6})</td>
<td>33%</td>
<td>34%</td>
<td>33%</td>
<td>25%</td>
<td>33%</td>
</tr>
<tr>
<td><strong>TWENTIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS 20</td>
<td>38%</td>
<td>72%</td>
<td>38%</td>
<td>81%</td>
<td>38%</td>
</tr>
<tr>
<td>KF 20</td>
<td>38%</td>
<td>59%</td>
<td>25%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>NW 20</td>
<td>13%</td>
<td>56%</td>
<td>19%</td>
<td>44%</td>
<td>6%</td>
</tr>
<tr>
<td>PO 20</td>
<td>25%</td>
<td>56%</td>
<td>25%</td>
<td>63%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Due to the error in data collection in session 7 of pretraining, TF 10's pretraining data has been altered to insure fair comparisons between the last 4 sessions of pretraining and the last 4 sessions of posttraining. Actual scores have been calculated using the frequency of correct responding divided by the maximum possible of responses for 3 sessions. Altered scores were calculated by dividing the frequency of correct responses by the maximum possible frequency of responses for 4 sessions and are in parentheses.
Figure 1. Display of sample and comparison boards. The comparison board on the right contains a transposition defect (Dams, 1996).
Figure 2. Display of sample and comparison boards overlaid with feedback message (Dams, 1996).
Figure 3. Frequency of correct defect detections across all phases. The top graph is ES 10 and the bottom graph is MM 10.
Figure 4. Frequency of correct defect detections across all phases. The top graph is PJ 10 and the bottom graph is TF 10. See Table 3 for TF 10's data for session 7.
Figure 5. Frequency of correct defect detections across all phases. The top graph is AS 20 and the bottom graph is KF 20.
Figure 6. Frequency of correct defect detections across all phases. The top graph is NW 20 and the bottom graph is PO 20.
Figure 7. Frequency of active and passive errors for all defect types across phases. The top graph is ES 10 and the bottom graph is MM 10.
Figure 8. Frequency of active and passive errors for all defect types across phases. The top graph is PJ 10 and the bottom graph is TF 10. See Table 4 for TF 10's data for session 7.
Figure 9. Frequency of active and passive errors for all defect types across phases. The top graph is AS 20 and the bottom graph is KF 20.
Figure 10. Frequency of active and passive errors for all defect types across phases. The top graph is NW 20 and the bottom graph is PO 20.
Figure 11. Mean latencies of correct defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no correct defect detection for that board type occurred in that session. The top graph is ES 10 and the bottom graph is MM 10.
Figure 12. Mean latencies of correct defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no correct defect detection for that board type occurred in that session. The top graph is PJ 10 and the bottom graph is TF 10. See Table 5 for TF 10's data for session 7.
**Figure 13.** Mean latencies of correct defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no correct defect detection for that board type occurred in that session. The top graph is AS 20 and the bottom graph is KF 20.
Figure 14. Mean latencies of correct defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no correct defect detection for that board type occurred in that session. The top graph is NW 20 and the bottom graph is PO 20.
Figure 15. Mean latencies of incorrect defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no incorrect defect detection for that board type occurred in that session. The top graph is ES 10 and the bottom graph is MM 10.
Figure 16. Mean latencies of incorrect defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no incorrect defect detection for that board type occurred in that session. The top graph is PJ 10 and the bottom graph is TF 10. See Table 5 for TF 10's data for session 7.
Figure 17. Mean latencies of incorrect defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no incorrect defect detection for that board type occurred in that session. The top graph is AS 20 and the bottom graph is KF 20.
Figure 18. Mean latencies of incorrect defect detections for all boards across phases. When points do not connect within phases, the missing points indicate that no incorrect defect detection for that board type occurred in that session. The top graph is NW 20 and the bottom graph is PO 20.
REFERENCES


