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Abstract

Visual inspection plays a very important role ensuring quality in manufacturing and service industries. Visual search and decision-making are two determinants of inspection performance. Any improvement in any one of the components will have an impact on system performance. Job-aids, accompanying with training, have been proven to be effective in enhancing accuracy and reducing search time in visual inspection systems. One of the important issues is to help inspectors adopt the appropriate search strategy. This research aims to investigate effects of search strategy along with task complexity and pacing on inspection performance using a job-aiding tool. Results from this study will help to design a better inspection system.

Keywords
Search strategy, Inspection performance, Job-aiding

1. Introduction

Customer needs for high quality goods and the risk of product liability litigation across businesses have made inspection a very important part of manufacturing [6]. Although there are many inspection techniques, the process often tends to be visual in nature. There are two primary functions of visual search inspection, namely, visual search and decision-making [1]. Between these two essential determinants, visual search is the major step in a visual inspection because it is more time- consuming and error-prone [2].

Even though inspection by humans tends to be less than 100% accurate, it continues to be one of the common techniques used for the examination of defect severity. This research will focus on human inspection, which is more flexible and economically attractive. More specifically, this research will concentrate on the search components of human inspection systems. One of the most important issues in human inspection is training inspectors to search for defects more efficiently and effectively. Prior studies have shown that training is an effective method of improving inspection performance [4] [7] [8].

One of the purposes of training inspectors is to help them adopt the appropriate strategy. Typically, there are two extremes of search strategy: a random strategy (i.e., sampling with replacement) or a systematic strategy (i.e., sampling without replacement). Studies have shown that inspectors who adopt a systematic search strategy perform better than those adopting a random approach [9] to improve inspection performance. Hence, it is important to train inspectors to adopt a systematic search strategy. One approach in achieving this objective is to use job-aiding tools. Besides training and search strategy, other factors that
affect search performance, include subject, task, and organizational factors [5]. In this research, task
complexity, pacing, and search strategy were studied using a job-aiding tool.

2. Methodology

2.1 Subjects
The subjects for this experiment were 14 students selected from a population of undergraduate and graduate
students enrolled in the College of Engineering at North Carolina A&T State University. The subjects were
between 19 and 40 years of age. They were screened for 20/20 vision (correction if necessary). Visual
acuity was measured in Snellen decimal units from two different distances using a standard reading table
[3]. The subjects were not compensated for participating in the study.

2.2 Equipment
The experiment was conducted on Pentium IV computers with a Windows XP operating system. The
subjects viewed the screen from a distance of approximately 500 mm. The input devices were a Microsoft
standard keyboard and a two-button mouse.

2.3 Stimulus Material
The inspection task consisted of examining a screen filled with a set of eight characters (“T”, “Y”, “W”,
“R”, “U”, “G”, “H’, “P”) in the background as shown in figure 1, and searching for a possible target
color character “X”. The locations of the characters were randomly generated.

![Figure 1. Horizontal Search Strategy](image1)

![Figure 2. Diagonal Search Strategy](image2)

2.4 Experimental Design
A 2 x 2 x 2 factorial design was used. The three factors were task complexity, search strategy and pacing.
The search strategy had two levels: horizontal (Figure1) and diagonal (Figure2). Two levels were used for
task complexity, which was measured by the background density: 75% (high density) and 25% (low
density). Pacing also had two levels: machine-paced (the simulator automatically moved to the next search
area in the sequence once the defined time was reached), and self-paced (the subjects had the latitude to
advance to the next screen when their inspection was completed before the assigned length of time had elapsed). Both pacing options had a three-second delay between the changes of the screens. Twenty-three
seconds, which was generated from a pilot study of five subjects, was used as the standard time for both
pacing options. The fourteen subjects were randomly assigned to each of the eight possible treatment
groups. Hence, the experiment was a within-subject factorial design.

2.5 Procedure
First, the participants were briefed on the nature and objectives of this experiment. Next, they were required
to complete a consent form and a demographic questionnaire. Then, an overview of the experiment was
presented to the subjects, which was followed by a demonstration program to familiarize them with the
inspection tasks. After that, the subjects performed the criterion visual search task that consisted of 20 randomly-ordered screens with a total of 18 targets. The subjects were informed that each screen might or might not have the target character. They took an average forty-five minutes to complete the tasks with a break offered at the end of each task.

3. Results

Studies in visual inspection have shown that there is a trade-off between speed and accuracy. If an inspector spends less time in inspection, the accuracy tends to be decreased. In other words, speed and accuracy have a negative correlation ($r = -0.28813$, $p<0.05$).

3.1. Multivariate Analysis of Variance (MANOVA)

**Interaction Effects:** Since speed and accuracy measures have a negative correlation, we have to study these two measures simultaneously. As result, a Multivariate Analysis of Variance (MANOVA) was used. Multivariate Analysis of Variance (MANOVA) indicated no significant interaction effects between pacing, strategy and complexity (Wilks’ Lambda=0.9999, $F(2,87)=0.01$, $p=0.99$). There was no indication of a significant interaction effect between pacing and strategy as well (Wilks’ Lambda=0.9866, $F(2,87)=0.59$, $p=0.55$). Also, the results showed no significant interaction between pacing and complexity (Wilks’ Lambda=0.9963, $F(2,87)=0.16$, $p=0.85$). Furthermore, there was no significant interaction between strategy and complexity (Wilks’ Lambda=0.9984, $F(2,87)=0.07$, $p=0.93$).

**Main Effects:** A significant main effect was found for strategy (Wilks’ Lambda=0.9166, $F(2,87)=3.96$, $p<0.05$). Specifically, results indicated that inspectors who adopted the horizontal strategy performed better than those who adopted the diagonal strategy. Both speed and accuracy were looked at simultaneously. Moreover, a significant main effect was found for task complexity (Wilks’ Lambda=0.5737, $F(2,87)=32.31$, $p<0.01$) indicating inspectors under machine-paced performed better than those under self-pacing. A significant main effect was found for pacing as well (Wilks’ Lambda=0.8259, $F(2,87)=9.17$, $p<0.01$).

3.2. Univariate Analysis of Variance (ANOVA)

Since significant results were found in the Multivariate Analysis of Variance (MANOVA) analysis, individual Univariate Analysis of Variance (ANOVA) was needed to further investigate the effect of pacing, strategy and task complexity.

**Mean Hit Rate**

**Interaction Effects:** No significant pacing x complexity x strategy effect ($F(1,88)=0.65$, $p=0.422$) was found. ANOVA results indicated no significant pacing x strategy interaction effect ($F(1,88)=0.04$, $p=0.84$). Also, there was no significant pacing x complexity interaction effect ($F(1,88)=0.82$, $p=0.367$). Additionally, there is no significant strategy x complexity interaction effect ($F(1,88)=0.09$, $p=0.763$).

**Main Effects:** Results showed a significant pacing effect $F(1,88)=7.38$, $p<0.05$) illustrated in Figure 3. The inspectors under machine-paced outperformed those under self-paced. A significant strategy effect $F(1,88)=4.47$, $p<0.05$) was also found as shown in Figure 4. Inspectors who adopted the horizontal strategy performed better than those who adopted the diagonal strategy. However, no significant complexity effect ($F(1,88)=0.65$, $p=0.422$) was found.
Interaction Effects: No significant pacing x complexity x strategy effect (F(1, 88) = 0.01, p = 0.98) was found. The ANOVA indicated no significant pacing x strategy interaction effect (F(1, 88) = 0.14, p = 0.70). No significant pacing x complexity effect (F(1, 88) = 0.30, p = 0.58) was found. In addition, no significant strategy x complexity effect (F(1, 88) = 0.13, p = 0.72) was found.

Main Effects: Results showed a significant strategy effect (F(1, 88) = 5.41, p < 0.05). Inspectors who adopted the horizontal strategy spent less time than those who adopted the diagonal strategy. In addition, there was significant complexity effect (F(1, 88) = 13.82, p < 0.05) as shown in figure 5. Inspectors who used the low density concentration performed better than those who used the high density concentration. Furthermore, pacing effect was not significant (F(1, 88) = 0.06, p = 0.81) illustrated in Figure 6.
4. Discussion

The main objective of this research was to study task complexity, pacing, and search strategy when a job-aiding tool was used. Previous studies showed that job-aiding tools are a very effective way to improve inspection performance. Studies have shown that inspection performance can be affected by task complexity, search strategy and complexity. However, with the help of a job-aiding tool, it is unclear whether these results will remain the same.

We were expecting to see an interaction between pacing and the other two factors. Surprisingly, no significant interaction was found between strategy, complexity and pacing on inspection performance when using a job-aiding tool. One of the possible reasons is that students were used instead of real inspectors. Although subjects were given the option to proceed should they complete inspecting a screen, they still used the maximum allowed time for a screen (just as in a machine-paced option). Hence, the potential interaction effect was not revealed.

Significant strategy effect was found for both performance measures (mean search time and mean hit rate). In both cases, inspectors who adopted a horizontal strategy performed better (higher hit rate and less search time) than the ones who adopted a diagonal strategy. A possible reason is that people read from left to right in their daily life. A significant task complexity effect was found for mean search time but not for mean hit rate. One possible cause is that subjects took their time in the inspection task. For a different task, they spent a longer time to detect the target letter. As a result, mean hit rate is almost the same. Surprisingly, a significant pacing effect was found for mean hit rate but not mean search time. As mentioned earlier, student subjects did not take advantage of the flexibility of self-pacing. Instead, they used the time allocated for each screen (just as in a machine-paced task). It seems that it took almost the same amount of time for them to search for a target as in the machine-paced option. Why this happened remains unknown.

Overall, this experiment verified that a horizontal strategy needs to be used for training inspectors using a job-aiding tool. Findings on task complexity and pacing are somewhat surprising. One of the possible reasons might be the use of student subjects instead of real inspectors.

Future studies are needed to investigate the effects of strategy, pacing and task complexity using real inspectors. Furthermore, potential benefits using different pacing options need to be clearly understood by the subjects, so that differences in inspection performance under different pacing options can be studied. Moreover, there are others factors (such as task and environment) that can impact inspection performance. These factors (i.e., contrast level, noise level and lighting level) can be implemented in inspection tasks using the job-aiding tool. Their impact on inspection performance can be studied in the future.

References


