

Naval Submarine Medical Research Laboratory



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TARGET DETECTION ON A WATERFALL DISPLAY
WITH THE TARGET BEARING DELINEATED WITH A STRAIGHT EDGE

by

S. M. Luria
J. DiVita
and
M. Shim

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R. G. Walter, CAPT, DC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

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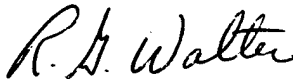
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S. M. Luria, Joseph DiVita, and Matthew Shim

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R. G. WALTER, CAPT, DC, USN
Commanding Officer
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SUMMARY PAGE

THE PROBLEM

To measure target detection on a waterfall display with and without the target bearing set off with a straight-edge.

THE FINDINGS

Target detection was not reliably improved when the target bearing was delineated with a straight-edge. The false-alarm rate and the percentage of incorrect rejections were significantly increased.

APPLICATION

This simple method of delineating the target bearing of interest apparently will not reliably improve performance of sonarmen using waterfall displays.

ADMINISTRATIVE INFORMATION

This investigation was conducted under Naval Medical Research and Development Command Research Work Unit 65856N-M0100.001-5003. It was submitted for review on 28 September 1989, approved for publication on, and has been designated as Naval Submarine Medical Research Laboratory Report No. 1160.

ABSTRACT

Simple, inexpensive, and easily implemented procedures can sometimes significantly improve performance. DiVita and Hanna (1987) have pointed out that target detection on the waterfall display suffers, because the observer has difficulty in keeping the relevant bearing isolated. Performance is improved if the target bearing is simply highlighted, so that there is no question in the observer's mind as to where he is supposed to be looking.

DiVita's procedure requires the computer to be programmed to highlight the bearing of interest. This may be simple enough to do with a vertical bearing. In practice, however, a target track on a waterfall display may occur at any angle. This greatly increases the programming difficulties.

The question arises as to whether or not a simple mechanical method of delineating a given bearing would also improve performance. In this study, we simply placed a straight-edge along the target bearing and compared target detection under that condition with performance without the straight-edge. Although the straight-edge presumably makes it easier for the operator to isolate the target bearing, target detection did not improve.

INTRODUCTION

Signals from passive sonar systems are typically presented as multiple-channel, time-history displays, such as the passive broad-band (PBB) display. Here, bearing is represented along the horizontal axis and time along the vertical axis. The signal strength is encoded as pixel intensity. The information from every bearing at any given moment is presented along a horizontal line, and this information is updated at regular intervals; the older information drops to the next lower line, and the current information is displayed just above it. This produces a display which appears to scroll downward and is, therefore, called a "waterfall" display. Random ocean noise appears as a random dot display ("snow" is a common description), and a target appears as a discrete track. If the target remains at the same bearing over time, it produces a vertical line through the display.

When the signal strength of the target is not much greater than that of the background, it is, of course, to be expected that the target will be difficult to detect. However, DiVita and Hanna (1987) found that operator performance was worse than would be expected from theory. One reason for the poor performance is the inability of the eye to follow the target bearing and the consequent uncertainty about its location. The random dot pattern of the background makes it very difficult to isolate visually a single column of the display from top to bottom. When, on the other hand, the target bearing is clearly delineated by, for example, encoding that bearing by color or brightness, performance improves. The observers no longer confuse information presented on adjacent bearings with that presented at the target bearing.

Unfortunately, it is not possible to have the computer "highlight" a target bearing on current sonar displays. Not only must the operator be able to pick a specific bearing to encode, but the critical bearing will probably not be the same from one time period to another. Programming the computer to handle the problem is probably not feasible at this time. This raises the question as to whether or not a more simple procedure of delineating the target bearing would improve performance in this case.

The experimental procedure tested was to delineate the target bearing with a straight-edge. In this study, target detection was compared with and without the straight-edge.

METHOD

Subjects

Seven staff members of the laboratory served as subjects. Two had had some experience as subjects with waterfall displays.

Apparatus

A VAX 750, a Ramtek 9400 graphics display generator, and a Matsushita standard phosphor color monitor (1024 by 1280 pixels; 100 pixels to the inch) were used to simulate the sonar display. The screen was illuminated to 0.25 fc by fluorescent lamps covered with neutral density filters located behind and above the observer. The luminance of the lit pixels was about .35 fc.

The Display

The display simulated one depression-elevation sector of a spherical array PBB short term averaging (STA) display. There were 60 columns and 128 rows. At a viewing distance of about two feet, the display subtended about 9 x 5 degree visual angle. Targets were presented at a signal strength of -5 dB. The target bearing (column) was approximately in the middle of the display, and a white cross-hair was placed directly above it.

The target column was delineated by a gray piece of cardboard taped to the face of the CRT just to the left of the target column. The cardboard was positioned by the experimenter. It approximated the mean brightness of the display and eliminated the left half of the display. The subject viewed the display with his head in a chin and forehead rest to reduce the parallax errors.

Procedure

The subjects had 10 practice trials in which they learned immediately if their responses were correct. Each subject then had 8 experimental trials with no feedback. Four trials were with the straight-edge, and four were without it, in a different random order for each subject.

One trial consisted of these events: The display scrolled at a rate of about 10 lines/sec until the complete block of data (128 lines) was presented; it then stopped and remained visible. The subjects had an unlimited amount of time to decide if the target was present at the bearing marked by the cross, although they could also respond while the display was still scrolling. After the response was entered, the display disappeared, and a new block of data began to appear. The probability that a target was present on any trial was 50%.

The subjects rated the confidence of their responses as either (1) relatively certain that no target was present, (2) target not present but not certain, (3) target present but not certain, (4) relatively certain that a target is present. The four response categories were grouped as follows to yield three points on the Receiver Operating curve (Egan, 1975). A strict criterion was defined by considering only response 1 (relatively certain that no target was present) as indicating no target, while the other three responses indicated that a target was present. A neutral criterion was defined by considering

responses 1 and 2 as indicating no target, and responses 3 and 4 as indicating a target. Finally, a lax criterion was defined by considering all three responses 1, 2, and 3 as indicating no target was present and only response 4 (relatively certain that a target is present) as indicating a target.

Table 1. Comparison of mean performance measures (percent) with and without a straight-edge.

| HIT-RATE | | |
|----------------------|-------------------------|----------------------|
| <u>Criterion</u> | <u>No Straight-edge</u> | <u>Straight-edge</u> |
| Lax | 79.7 | 80.1 |
| Neutral | 59.7 | 58.7 |
| Strict | 18.0 | 21.3 |
| Mean | 52.5 | 53.4 |
| FALSE-ALARM RATE | | |
| Lax | 54.1 | 56.9 |
| Neutral | 26.1 | 28.6 |
| Strict | 5.6 | 7.4 |
| Mean | 28.6 | 31.0 |
| INCORRECT REJECTIONS | | |
| Lax | 20.3 | 19.9 |
| Neutral | 40.3 | 41.3 |
| Strict | 82.0 | 78.7 |
| Mean | 47.5 | 46.6 |
| CORRECT REJECTIONS | | |
| Lax | 45.9 | 43.1 |
| Neutral | 73.8 | 71.4 |
| Strict | 94.4 | 92.6 |
| Mean | 71.4 | 69.0 |

RESULTS

Table 1 shows the mean percentages of correct and incorrect identifications of the presence of the target ("hit rate" and "false-alarm rate"), and the correct and incorrect rejections of the presence of the target both with and without the presence of the straight-edge. Each of these is given for each of the three criteria.

There were no significant changes in any of the four performance measures produced by the presence of the straight-edge. The mean hit-rate was unchanged with every criterion or when averaged across the three criteria; it was 52.5% without the straight-edge and 53.4% with it.

The mean false-alarm rate was 28.1% without the straight-edge and 31.5% with it when averaged across the three criteria.

The percentages of incorrect and correct rejections did not change significantly.

Another indication of performance is the signal-to-noise ratio for each condition relative to that with ideal performance. This can be calculated as follows (DiVita and Hanna, 1987). Each observer's hit rate was extrapolated from his Receiver Operating Curve at a false alarm rate of 5%. From this a value, $d_{.05}$ equal to $Z_{Hit} - Z_{FA}$, was calculated for each observer using the formula

$$d_{.05} = 10 [\log(d_{.05}(\text{observed})/d_{.05}(\text{ideal}))]$$

For the ideal detector, $d_{.05}$ is approximately proportional to signal energy; thus, increasing the signal strength by 3 dB doubles the $d_{.05}$ value (DiVita and Hanna, 1987).

Table 2 gives the values of the SNR losses for each observer both with and without the straight-edge. Again, we see that SNR loss was reduced -- i.e., performance improved -- with the straight-edge only for two observers (EN and BS), whereas performance was worse with the straight-edge for the other four observers. The mean values are virtually identical.

Table 2. SNR losses (dB) compared to the ideal detector with and without the straight-edge.

| Observer | No Straight-edge | Straight-edge |
|----------|------------------|---------------|
| LB | -3.77 | -6.81 |
| TB | -2.09 | -3.84 |
| EH | -4.55 | -6.81 |
| EN | -8.47 | -0.61 |
| BS* | -3.99 | -3.45 |
| WW* | -1.37 | -3.04 |
| MEAN | -4.04 | -4.09 |

* More experienced subjects

COMMENT

The presence of a straight-edge beside the target bearing on the waterfall display did not improve the ability of these observers to detect a target. All but two of the observers had had no experience with the display. It might be assumed that if such a procedure helped to read a display, an inexperienced observer would get more benefit than an experienced one. The latter would be expected to have less room for improvement. In any event, the two more experienced observers (BS and WW) did not seem to perform differently from the others.

These results indicate that for basically inexperienced observers target detection on the waterfall display is not improved by outlining the target bearing with a straight-edge.

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