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MEMORANDUM REPORT

COMPARISON OF MANUAL AND STANDARD METHODS OF TARGET INDICATION

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COMPARISON OF MANUAL AND STANDARD METHODS OF TARGET INDICATION

SUMMARY

Purpose — The present experiment compares the efficiency of two methods of target-indication on a simulated search radar: (1) the present method in which the operator estimates range and bearing with the aid of a bearing cursor and range marks, and makes a verbal report; and (2) an experimental method in which the position of each target is indicated by the use of a pointing device in the hands of the operator.

Speed and Accuracy — The manual method of indication proved equally accurate in indicating bearing, and more than twice as accurate in indicating range as the oral report of estimation. In speed of indication, the experimental method exceeded the present method more than three times. It was further shown that, using manual indication, no change in performance occurs as a result of increasing the number of targets to be indicated from 5 to 30. These findings lead to the conclusion that a system of target indication based upon pointing would give better results in terms of the performance of the operator at the search radar.

Size of PPI — An incidental result with important practical implications is that large (20 inch) PPI's yielded no better accuracy or time score than smaller (7 inch) PPI's, using the present estimation method of indication. With manual indication, the large scopes gave no faster performance than the small ones, but did improve considerably the accuracy of the reported position.

PROBLEM

At any given time the presentation visible on the PPI of a search radar is of little use to an observer unless he also has available a graphic plot showing the previous movements of the targets represented on the PPI, or has been watching their progress on the scope for some time. Since this latter condition often cannot be fulfilled by those whose responsibility it is to take action on the basis of the information from the radar, this information is ordinarily relayed to a plotting board so that a graphic time representation can be made. The steps at present involved in obtaining such a plot are: observation of the radar scope; determination of coordinates of the position of the targets represented; communication, usually verbal, of the coordinates; reception and recording of the coordinates; and finally plotting of the coordinate position, thus translating the verbal coordinates back into graphic form.

The experiment reported here deals primarily with the estimation of target position, the second step above. As accomplished now, this is a mental calculation on the part of a trained operator who judges the bearing of each target with the aid of a bearing cursor which he moves into alignment with the center of the target, and the range by means of fixed range rings between which he must interpolate. He then reports these estimations to a recorder, either directly, by telephone, or by a synchro system.

These operations are both time-consuming and susceptible of error. As an alternative to the entire series of steps between observation and plotting, involving two or three people, it has been suggested that a physical system be designed which would automatically transmit and plot target positions indicated by the operator of the search radar, whose task would then be reduced to a manual indication of the place of each target, instead of the mental calculation described above.

Using speed and accuracy of indication as criteria of evaluation, the specific problem of this experiment is to compare such a manual indication with the estimation and report system now in use. Neither the advantages of operation which might result from automatic transmitting and plotting equipment, nor the difficulties of design of such equipment, is considered; this paper deals only with the task of the operator, although it is recognized that the two problems are interdependent. The ultimate practicability of a manual indication system such as the one here investigated presupposes the successful development of automatic transmitting and plotting mechanisms. Before attempting such a design, however, it is considered of primary importance to determine whether such a system would improve the performance of the operator at the search radar. This man would be the only person needed, and the only human source of error and delay in the entire chain of activities from observation to plotting.

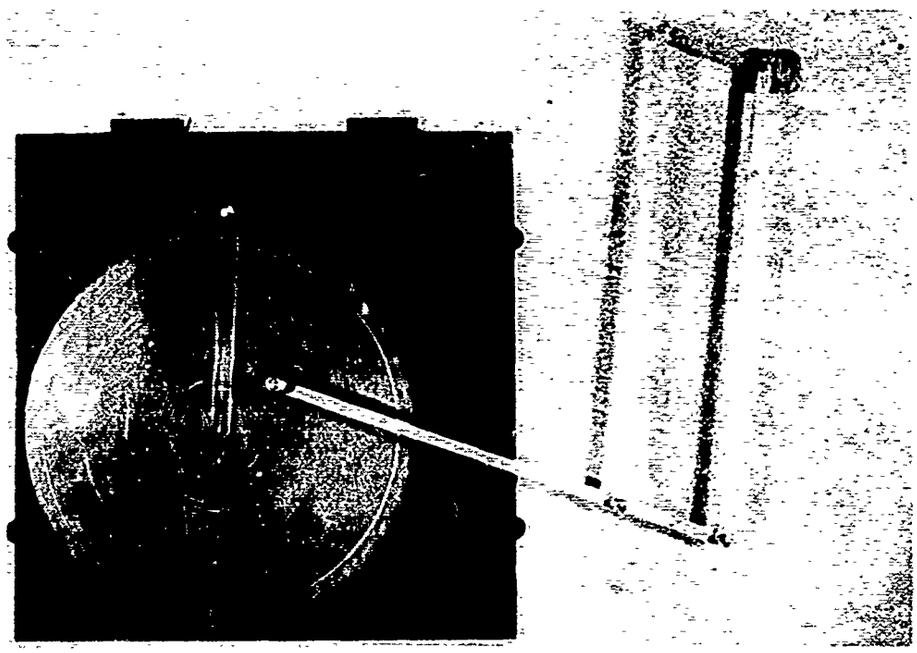
EQUIPMENT

PPI — Blueprints of drawings representing a generalized search radar scope with targets on it were used to simulate PPI's. They were laid out upside down on a ground glass screen and trans-illuminated with orange light to neutralize the blue color. The targets were invisible until the lights were turned on, when the effect was remarkably convincing.

Three diameters of PPI's were used: 7, 10, and 20 inches. The targets represented two lobe widths: 6° (as on the SG) and 20° (as on the SR). The pulse length equivalent of the targets was on the order of one-half mile (6.25 microseconds). Each PPI contained 5, 15, or 30 targets.

Pointer The pointer, as may be seen in the accompanying figure, was attached to a specially constructed pantograph. This arrangement had no special use in the experiment, but had a freely moving unattached pointer been used rather than the pantograph-pointer, the results of the experiment might have been quite different, and it was realized that any future practical use of a pointer-method of target indication would probably require a pantograph or similar arrangement for the automatic plotting or transmission of target indications.

The pointer was a heavy tubular lettering pen mounted on the end of a piece of transparent plexiglass which extended two inches beyond an aluminum bar. A round handle about one inch in diameter, secured to the bar, was used to guide the point. The point was normally held 1/8 inch above the surface of the paper by springs.



Mounting The paper PPI's were laid face down upon a piece of ground glass and held correctly in position by two pins outside the edge of the scope. A square sheet of plexiglass 3/16 inches thick, containing four range rings and a bearing rose marked off in degrees, was so hinged that it could be exactly positioned over the paper PPI. Three different plexiglass sheets were used, with markings corresponding to the three sizes of PPI's. The range rings were inscribed on the back of the plexiglass next to the targets so that there was no parallax, while the bearing marks were printed on the front, so that parallax was present. These conditions conform with those generally found in radar scopes.

A bearing cursor was designed so that it could be attached when the operator was estimating and removed when he was pointing.

EXPERIMENTAL METHOD

Estimations

Instructions The following instructions were given to each operator before he began the series of estimations.

> "This is a paper PPI which represents what you see on an ordinary radar scope. Your task is to designate bearing and range of each target, using the center of the target. This is a bearing cursor to help determine the exact bearing, and the range rings will help you determine the range. Since this is an 80-mile scope, every range ring will be 20 miles. This target, for example, has a bearing of 264 (showing the use of the cursor) and its range is about 38 miles. You should read bearings to the nearest degree (except on a 20-inch PPI, bearings were read to the nearest half degree) and range to the nearest mile. Call the bearing first and range second. You can drop the miles: 351, 70, and so on. Go around the scope clockwise, starting with the first target past North, (indicating which target) taking every target in order of increasing bearing. Take the knob of the bearing cursor in your hand and tell me when you are ready. When you are ready, I will switch on the light and that means that you are to start with the first target and proceed in a clockwise fashion. Do this as accurately and as fast as you can."

The operators were given two practice periods using 15 targets each before the first records were taken, and one practice period each time the diameter of the PPI was changed.

Recording and Error Measurement An assistant to the experimenter recorded the estimated range and bearing of each target. The time required to designate all the targets on each PPI was recorded to the nearest 1/5 second. After the series was completed, the experimenter determined accurately the position of each target to the nearest mile in range and the nearest half degree in bearing, and the deviations in the operator's estimations were measured.

Manual Indications

Instructions The operators were given the following instructions for the series of manual indications:

"This is a paper PPI which we are using in an experiment to determine the feasibility of indicating positions by using some such device as this pantograph, which you see here. This is a means for repeating the position of a target at some other point. Your task is to place a small drop of ink (showing use of pen) in the center of each target with respect to bearing and range. You will have to press down on the handle whenever you wish to indicate the target because a spring normally holds the pen off the surface. Do this as accurately and as fast as you can. When I switch on the light behind the scope place your hand on the pantograph arm. You are to start with the first target past North and proceed clockwise around the scope, that is, picking targets of increasing bearing."

Recording and Error Measurement In order to evaluate this method of indicating target position, the operators' indications were recorded in the following manner: The lettering pen was filled with mimeograph ink. When the pen was pressed down, it left a small dot on the plexiglass covering the chart which carried the targets. As soon as the series was completed, the paper PPI was removed from beneath the plexiglass, laid face down on top of it, and smoothed down so that the spots of ink were printed on the face of the PPI. The correct relationships were preserved because the original position of the PPI on top of the ground glass screen was face downward. Exact alignment on top of the plexiglass was possible by means of the two positioning pins which protruded from the surface of the plexiglass. After this printing, the plexiglass was wiped off for subsequent use, and the deviations of the operator's indications from the true range and bearing were measured.

System of Presentation

A balanced series of four operators, all trained radar men, was used. Each man was given a different order of presentation of each diameter of the paper PPI's so that practice and interaction effects could be balanced for the four operators together. The men alternated the methods of indicating so that whatever fatigue occurred would be equalized. To insure that the possible distorting effect of the specific target pattern would be minimized, two of the operators indicated manually the patterns which the other two estimated verbally, and vice versa. No pattern was ever repeated for any operator.

The total number of trials given each man included: eight PPI's each containing 5 targets; four PPI's, each containing 15 targets; and four PPI's, each containing 30 targets. Half of the above were indicated orally, the other half manually. This number of trials was repeated for each of the three diameters used. In each group of patterns, half contained 6^{o} targets and the other half 20^{o} targets.

RESULTS

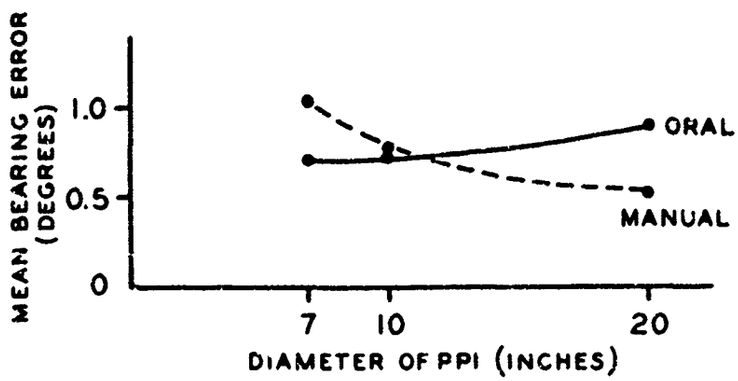
The results have been tabulated in terms of accuracy of bearing and range and time required for the two methods of target indication. They will be considered in that order.

Accuracy

Intrusion of Gross Errors In the analysis of inaccuracies of oral indication, notice must be taken of the intrusion of gross errors of reporting caused by too great concentration on the problem of interpolation between markers, at the expense of the general orientation of the markers themselves. For example, range reports which were mistaken by 20 miles occurred because of inattention on the part of the operator to the specific range ring from which he was estimating. Similarly, bearing errors of 10 degrees occur. Out of a total of 5280 targets presented, there were 24 such intrusions. Eighteen of these mistakes occurred with respect to range, and six with respect to bearing. In one case, a bearing error of 100 degrees occurred.

Naturally, errors such as these never occur in the pointing method.

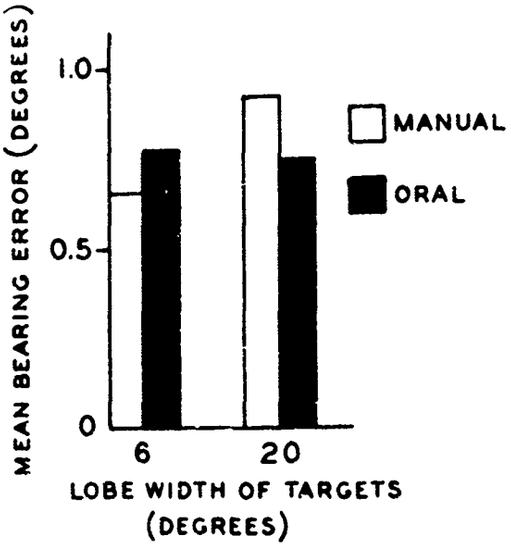
Bearing Errors There is little difference with respect to bearing accuracy between manual indication and cursor-aided oral indication; the estimations prove about 10% more accurate. Relative accuracy of the two methods is dependent largely upon the size of the PPI used, since increasing the scope diameter has little effect on estimation, but decreases the error on manual indication.



Change in bearing accuracy with change in diameter

Effect of More Targets There is no appreciable change in accuracy with either method as the number of targets to be designated increases.

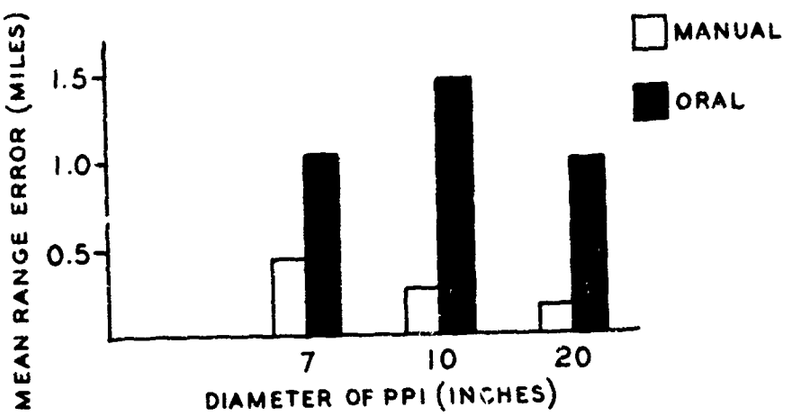
Effect of Lobe Width As the lobe width of targets is increased from 6° to 20°, there is a decrease in accuracy for both manual indications and estimations.



Range Errors The manual indication of range is more than twice as accurate as the method of estimation aided merely by the four range rings. The operators were required to judge target range to the nearest mile, which means that they had to interpolate 20 spaces between range markers. The addition of more range rings would probably improve the accuracy of estimation between markers, but would increase the number of errors involving the identity of the particular marker, thereby leading to mistakes of approximately the magnitude of the inter-marker distance. Manual indication does not present this problem, since the operator's only concern is that of centering the pointer.

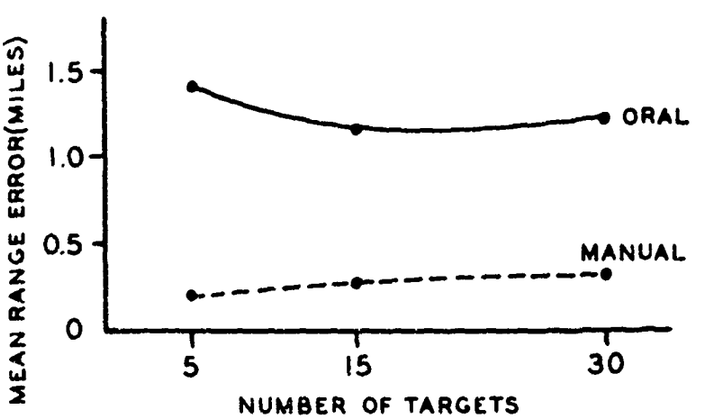
Effect of Larger Scope

There is no increase in accuracy of estimation of range as a function of the size of the PPI, but manual indications show improvement as the scope diameter is increased.



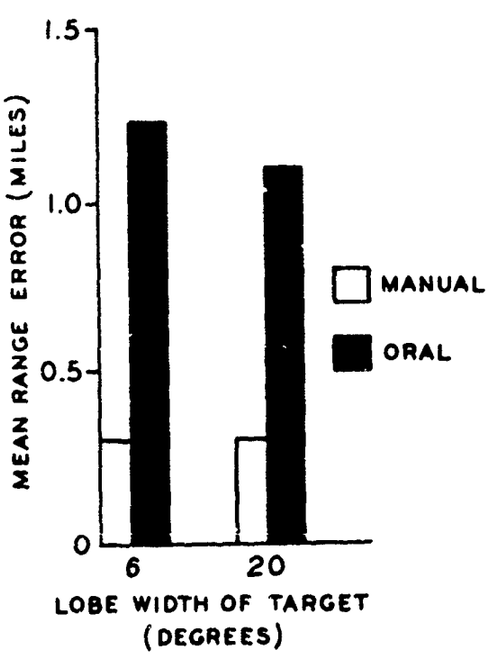
Effect of More Targets

The magnitude of the range error does not change as the number of targets is increased. This result corresponds to the finding for bearing error.



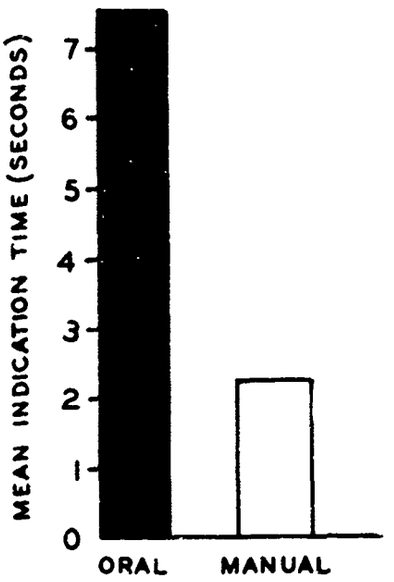
Effect of Lobe Width

The increase in lobe width has, as would be expected, no effect on the range estimation.

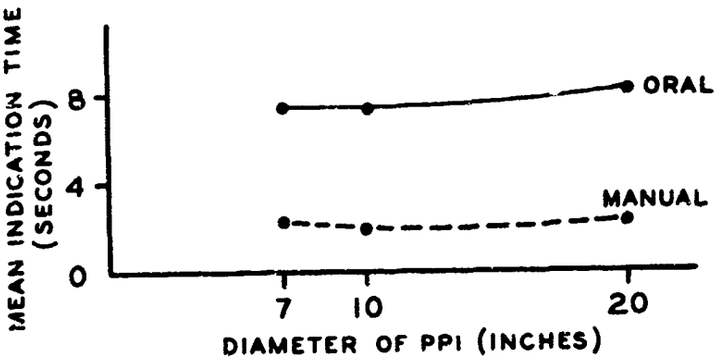


Speed

Overall Comparison The average time required to indicate targets manually is less than one-third that required by the standard method of estimation and report.

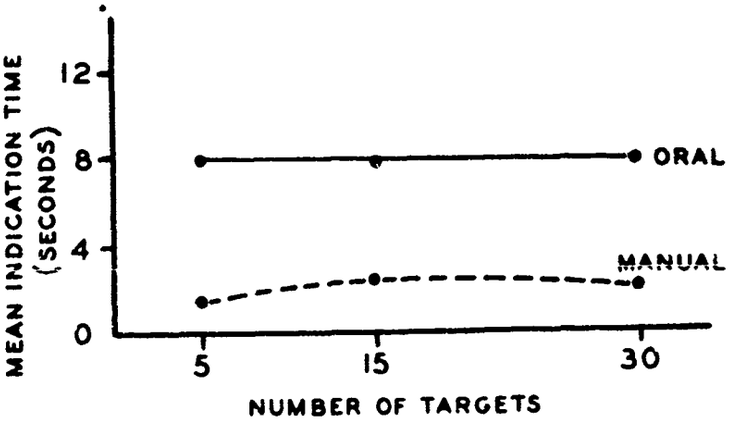


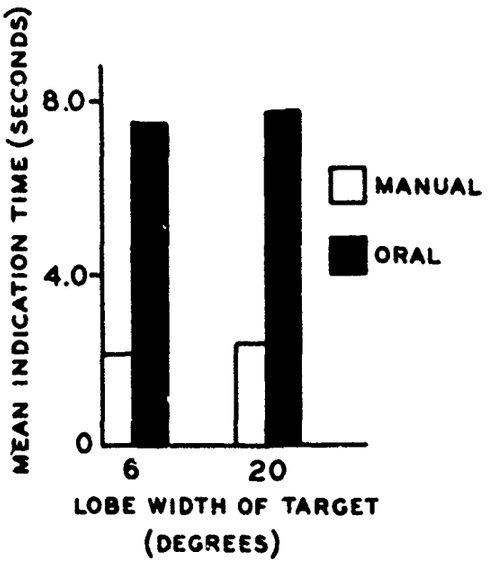
Effect of Larger Scope Neither method of indication showed any alteration in time required, as a function of the changed diameter of the PPI. This means that, within the limits used in this experiment, no increase or decrease in speed of performance can be expected as the size of the scope is increased.



Effect of More Targets

As the number of targets is increased from 5 to 15 to 30, the time spent on each target remains constant for each system of indication.





Effect of Lobe Width The difficulty of 20° targets as compared with 6° targets has little effect on the time required to judge them. There is a very small but consistent increase of the order of a few percent.

Comment on Speeds The time to report each target is from one-half to two seconds longer than that reported for similar conditions in some of the previous publications from this laboratory. This difference is attributed to two factors: 1) the operators were striving for maximal accuracy at the expense of speed, and 2) the operators had not previously seen the target positions and so could not benefit from the memory of their previous reports. However, the relative difference in speeds with the two techniques probably remains the same despite these two factors.

Conclusion

Manual indication of target position by the operator of a search radar shows an advantage of two times in accuracy and three times in speed over the present method of estimation and reporting. It may be inferred that any system of transferring the information from the PPI to the plotting board which made use of the technique of manual indication would give much more satisfactory results from the point of view of operator performance than are obtainable with present standard methods.