PART VI (i)

VISUAL AND TELEVISUAL DETECTION STUDIES

Mintech contract PD/170/04/AT

PART VI(i)

BRIEFING MATERIALS FOR LOW-LEVEL TARGET DETECTION: A COMPARISON OF FIVE BRIEFING TYPES

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OCTOBER 1969

SUMMARY

This report describes the final experiment in a series of studies intended to investigate performance at a target detection task, simulated statically by means of aerial photographs. The purpose of the present experiment was to evaluate the effect on four measures of performance, detection probability, search time, confidence level and briefing time, of five different types of briefing: map only, map + 'target circles', map + diagrams, map + drawings and map + photographs. The 'target circles' briefing indicated only the position of the target on the display, whereas the drawings and diagrams were oblique views of the target and surrounding terrain prepared from the information on the map, (scale 1" = 1 mile). The drawings were carried out by a freehand technique and the diagrams by means of standardised shading materials.

The ranges at which the targets were shown in the four types of additional briefing material were (a) 2 miles and (b) 4 miles. Each of these briefing ranges was tested independently, and their combined effect was also studied, giving rise to three briefing range conditions. The map only condition, which was not associated with any briefing range, was treated as the control condition. Eight targets and four target ranges were used to study the effect of the briefing conditions, and a total of 74 unskilled subjects took part.

A summary table showing the main results of this experiment is given on the following page. These results indicate that, although the drawings and the diagrams were not as effective as the photographs, they do result in considerable improvement in detection probability, especially at longer ranges. This suggests that part of the difficulty of the target detection task lies in accurately visualising an oblique view of the terrain from the plan view information given on the map.

SUMMARY OF THE MAIN RESULTS

	DETECTION PROBABILITY	SEARCH TIME	CONFIDENCE LEVEL	BRIEFING TIME
BRIEFING TYPE	Highly significant ($p < 0.01$) Only the photographs resulted in significantly higher detection probability than the map only condition, but the drawings and diagrams both brought about improvements whereas the 'target circles' briefing resulted in a deterioration in detection probability. (36-37)	Highly significant ($p < 0.001$) All briefing types except the photographs resulted in significantly longer mean search times than the map only condition, but there was evidence that this latter value was unexpectedly low. (66-67)	Highly significant ($p < 0.001$) Photographs resulted in significantly higher mean confidence level than the map only condition but no improvement in confidence levels was found for the drawings and diagrams. (79-80)	Significant ($p < 0.05$) All types of additional briefing resulted in significantly longer briefing times than the map only condition, photographs being the longest. (94)
BRIEFING RANGE	Non-significant 2 + 4 mile briefing was more effective than 2 mile or 4 mile briefing but none of the values were significantly different from the map only condition. (38)	Non-significant 4 mile range briefing resulted in the longest mean search time, significantly greater than that for the map only condition. (68)	Significant ($p < 0.025$) 2 + 4 mile briefing gave rise to significantly higher mean confidence level than 4 mile briefing, but none of the values were significantly different from the map only value. (81)	Highly significant ($p < 0.01$) 2 mile briefing resulted in shorter briefing times than 4 mile or 2 + 4 mile briefing. (95)
BRIEFING TYPE x TARGET RANGE	Non-significant Diagrams, drawings and photographs improved detection probability, relative to the map only condition, at target ranges of 2, 3 and 4 miles but at the 1 mile range a deterioration occurred. (39-41)	Non-significant Search times increased with increasing range under all briefing conditions, with the exception that the 1 mile range resulted in longer search times than the 2 mile range. (69-70)	Non-significant ($p < 0.10$) Confidence levels tended to fall with increasing range under all briefing conditions. At the 1 mile range confidence levels were lower when additional briefing was used than under the map only condition. (82-83)	Non-significant (No interaction would be expected since the target range was not known to the subjects during briefing.)
BRIEFING RANGE x TARGET RANGE	Non-significant ($p < 0.10$) Detection probability was particularly favourably affected when the briefing range coincided with the target range but improvements also occurred at other target ranges, except 1 mile. (42-43)	Non-significant No analyses carried out since the main factors were also non-significant. (71)	Non-significant Confidence levels tended to be higher when briefing range coincided with target range. (84)	Non-significant (No interaction would be expected since the target range was not known to the subjects during briefing.)
Comparison of the drawings and diagrams using the replicated data (excluding data from the 1 mile range)	No significant differences between the drawings and diagrams. Both resulted in highly significant improvements in detection probability, relative to the map only, particularly at longer ranges. The drawings and diagrams interacted with briefing range and with target size. 2 + 4 mile briefing was consistently more effective than 2 mile or 4 mile briefing separately. (48-62)	No significant differences between the drawings and diagrams. The mean search times for the drawings and diagrams were not significantly higher than the map only value. Some evidence of an interaction between briefing range and target range. (72-75)	No significant differences between the drawings and diagrams. The mean confidence levels were not significantly different from the map only value. There was a significant interaction between the drawings and diagrams and the briefing ranges. (87-90)	Significantly longer briefing times were required for the diagrams than for the drawings. Both values were significantly longer than the map only value. (97-99)

NOTES (i) The significance levels quoted are taken from the analyses of variance carried out on the basic data for all additional briefing conditions, the map only data being excluded as these data were not associated with any briefing range. (ii) The briefing types referred to - target circles, diagrams, drawings and photographs were each used together with the map for briefing purposes, the control condition being the map only condition. (iii) The numbers shown in brackets at the bottom right-hand corner of each block refer to the relevant pages of the report.

ACKNOWLEDGEMENTS

The Department of Ergonomics and Cybernetics, University of Technology, Loughborough would like to acknowledge the financial support provided for this research by the Ministry of Technology under Contract No. PD/170/04/A.T.

Photographic material was provided by Weapons Department, Royal Aircraft Establishment, Farnborough and the author would particularly like to thank Mr. R. E. Cousens, Mr. F. I. Reynolds and Dr. E. B. Davies for advice and assistance during this investigation.

Facilities for carrying out this study were provided by Professor W. F. Floyd, Head of the Department of Ergonomics and Cybernetics. The work was supervised by Dr. N. S. Kirk, also of the Department of Ergonomics and Cybernetics, and the author is most grateful for his help and encouragement.

Throughout this series of experiments the author has received valuable technical assistance from Mr. J. Rennocks and she would like to thank him for the substantial contribution he has made.

The author is also grateful to all those concerned in the production of this report, particularly the staff of the University Photo-Printing Unit, and Miss V. Smith who was responsible for the typing.

Finally the author wishes to thank the many students who acted as subjects in these experiments.

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1. INTRODUCTION

This report describes the final experiment in a series of studies intended to investigate some aspects of performance at a target detection task, simulated statically by means of a series of aerial photographs. The present experiment is concerned with the effect of different types of briefing information on performance and, in particular, with the use of perspective drawings of the target and surrounding terrain as aids to target detection when suitable oblique photographs are not available.

The nature of the briefing information available to the pilot both prior to and during a high-speed, low-level mission is an important factor in determining its success. Under VFR conditions the pilot must maintain a continuous awareness of his geographic position by relating the information given on maps and other briefing materials to the terrain features visible either directly from the aircraft, or by means of a television viewing system. Positive identification of a number of checkpoints along the route is necessary to obtain accurate fixes which can be used to update the navigation system. As the pilot approaches the target area he must use this knowledge of his geographic position, together with time-to-go information and the available briefing materials, to detect and subsequently recognise the target as early as possible.

The actual target recognition task is liable to be considerably more difficult than the recognition of a checkpoint. When a flight is planned it is possible to select as checkpoints features which are likely to be conspicuous and readily recognised. The target, on the other hand, may be small, partially masked or situated in cluttered terrain. Therefore the nature of the briefing materials provided for this final phase of the mission is of particular importance and the present work is primarily concerned with this problem.

The standard form of briefing for high-speed, low-level VFR missions is a map or chart, showing a symbolic representation of the earth's surface as seen from vertically above each point. Various types of photographic briefing material which give a realistic view of the terrain, either from a vertical or an oblique viewing angle, may also be provided. For other sensor systems, e.g. side-looking radar, appropriate imagery may be available but the present work is confined to the television viewing mode. In addition to these forms of visual briefing information, which are considered in more detail below, verbal descriptions of the target and surrounding area, and other intelligence information, may be provided.

(a) MAPS

During pre-flight briefing, and during the actual flight, the pilot or navigator will normally have one or more maps of the route to be flown, marked with the planned track and a number of pre-determined checkpoints, in addition to the target area. It should be noted, however, that detailed map coverage of the world is far from complete, only 20% of the world being mapped at $\frac{1}{4}$M scale, and only 10% at 1:50,000, (Burton, 1966)

Much research has been carried out into the design of navigation aids and map display techniques are becoming increasingly sophisticated. Some recent developments in this area are described in a JANAIR symposium report 'Aeronautical charts and map displays' (1966). Considerations of particular relevance to present work are the choice of a map scale and the closely related question of the amount of detail shown. McGrath, Osterhoff and Borden (1964) have shown that a 2:1 increase in map scale (from 1M to $\frac{1}{2}$M) improves visual navigation performance only if it is accompanied by an increase in the amount of detail shown.

Heap (1965) has shown that, whereas a $\frac{1}{2}$M scale map of Southern England shows 1.3 useful features per mile, the corresponding $\frac{1}{4}$M map shows 3.0, and the 1" = 1 mile map shows 3.9. Although these values appear to

favour large scale maps, the problems of handling and storing such maps during flight must also be taken into account. From this point of view the number of useful features shown per inch of map is of importance. On this basis, the $\frac{1}{4}$M is favoured over both larger and smaller scale maps.

The values given above relate to standard Ordnance Survey maps which are primarily designed for use on the ground, rather than in the air, although aeronautical information may be overprinted. Some of the information shown on these maps, for instance county and parish boundaries, positions of milestones, etc., is useless for the purposes of high-speed, low-level flight and simply gives rise to unnecessary clutter. Progress is being made in the design and production of more suitable maps, for instance the JOG series, but the specialised requirements of different groups of military users make it virtually impossible to include all the information that these users might require on one map. Attempts to produce a multi-purpose map are liable to result in the inclusion of too much detail which may make the map difficult to read. On the other hand, if highly specialised maps are produced to serve a single purpose with maximum efficiency, then the total number of maps required for different purposes becomes excessive. The development of automated display systems, that would allow the information required for any specific purpose to be retrieved when necessary, could to some extent overcome this problem.

Pelton (1968) summarises the information required on maps for high-speed, low-level navigation as: (i) 'information regarding the planned route', (ii) 'checkpoints which can be acquired and accurately located from the aircraft', and (iii) 'general terrain shape and hydrologic information with significant, recognisable terrain features, readily interpreted'. He suggests a number of topics relating to the design of high-speed, low-level maps which should be further studied, including the best way to convey terrain information so that the pilot can quickly and

accurately visualise what he can expect to see; how much information is needed; whether one map can be used for flight in several directions across the terrain with equal effectiveness; which types of checkpoints can be readily detected; whether the utility of particular checkpoints depends on the direction of flight; the effects of terrain type, weather conditions, seasons, etc. in different parts of the world; the map scale to be used, and whether it depends on terrain type. It is clear that further research is required into these and related topics in order to achieve an optimum format for high-speed, low-level maps.

(b) PHOTOGRAPHS

(i) Vertical photographs

Medium or high-altitude vertical photographs are often used to provide additional briefing information. Such photographs show a realistic plan view of the target area and/or selected checkpoints along the route. The scale of these photographs depends on the altitude from which they were taken, the field of view of the camera and the actual size of the print. The use of high-resolution satellite photography has resulted in increasingly widespread coverage of important land areas being obtained.

For some missions continuous photographic coverage along the entire track may be available, and it is then possible to build up a photomosaic which provides a realistic representation of the terrain vertically below the aircraft at any point along the track. Photomosaics of this type are normally used as pre-flight briefing material, as their size makes in-flight use impractical.

Vertical photographs show considerably more detail than would be shown on a map, even one of relatively large scale. They also show textures, shades and patterns and provide some indication of which terrain features are likely to show up conspicuously on a television display.

However, this information must be interpreted cautiously since the appearance of some features may be substantially changed by differences in lighting and visibility, and by seasonal variation. Briefing photographs taken during a reconnaissance mission may be misleading when compared with the appearance of the terrain some weeks or months later. The variation in tree foliage, or the seasonal flooding of low-lying areas provide examples of this. The coded symbolism with which features are shown on maps largely avoids this problem since little attempt is made to convey the realistic appearance of the features.

(ii) Oblique photographs

During high-speed, low-level flight the observer must view the terrain several miles ahead of the aircraft and he therefore sees it obliquely. The lower the altitude of the aircraft the more oblique the observer's view becomes, and consequently the more marked the distortion due to perspective effects. Maps and vertical photography show the earth's surface in plan view, whereas forward-oblique photographs show perspective effects as well as details of the target and surrounding terrain. Such photographs provide the most realistic type of representation of the target area as seen during a low-level approach and are therefore particularly valuable for briefing purposes, although the problems of lighting and seasonal variation discussed in relation to vertical photographs also apply to oblique photographs.

The use of oblique photographs as briefing material also involves a number of additional problems. Firstly, low-level oblique reconnaisance photographs are less likely to be available than vertical imagery, since it is difficult to obtain low-level photographs over hostile territory. Secondly, the view of the target shown in a forward-oblique photograph depends critically on the altitude from which it was taken, the depression angle of the optical axis of the camera lens and the direction of approach.

Differences in altitude and depression angle result in changes in the apparent convergence of the terrain due to perspective effects. Differences in track cause differences in the position of features appearing within the field of view, and in their apparent spatial relationship to the target. Thus, unless these parameters coincide closely with those during the actual mission, oblique briefing photographs are liable to lose some of their value and could prove misleading.

If appropriate ground coverage is available it is possible to build up an oblique photomosaic which shows each point along the track as it would appear when seen from a fixed range; altitude and camera depression angle being kept constant. Mosaics of this type, which are prepared by taking corresponding strips from successive oblique photographs, exposed at regular intervals along the track, are not normally used for briefing purposes. Although these photomosaics show perspective and masking effects accurately as they appear at one fixed range, at other ranges, particular the longer ones, perspective is greatly distorted.

The quantity and quality of the briefing information available for any particular mission varies widely. For highly pre-planned missions a complete range of photographic and other sensor imagery may be available, together with information about terrain profiles, masking, vegetation heights, etc., verbal descriptions of the target and other intelligence information. However, it is sometimes necessary to carry out missions under conditions in which the available briefing information is very incomplete, consisting perhaps of nothing more than a map and a verbal description of the target. It is therefore important to know what levels of success are likely to be associated with different levels of briefing information.

One study intended to investigate the effects of different types of briefing information is reported by Rusis and Rawlings (1966). They used a cine-film simulation technique to compare five different briefing conditions: (i) ground-track map + oblique target photographs + vertical target

photographs, (ii) ground-track map + oblique target photographs, (iii) ground-track map + vertical target photographs + notes from briefing on a 10,000 ft. altitude vertical photomosaic of ground track, (iv) ground-track map + vertical target photographs, and (v) ground track map + notes from briefing on written descriptions of the targets. The oblique photographs were taken from an altitude of 500 ft., corresponding to that of the simulated flight, and the vertical photographs from 1000 ft. altitude.

The main performance measures made were the probability and range of correct recognition. For both these measures condition (ii) in which a ground-track map and oblique target photographs were provided for briefing was found to be superior to all the other conditions, although condition (i) in which vertical target photographs were provided in addition to a ground-track map and oblique photographs, resulted in only marginally worse performance. This result suggests that if optimum briefing information, i.e. oblique photographs, is available there is no advantage to be gained from providing additional, less useful information, in this case vertical photographs. The other three briefing conditions, in which oblique photographs were not used, resulted in considerably lower levels of performance. The vertical target photographs did not improve performance significantly over the levels achieved when only verbal information was provided in addition to the ground-track map.

This study indicates the superiority of oblique photographs of the target area, as compared with other forms of briefing which might be available, particularly for targets that are difficult to recognise. For conspicuous targets the probability of recognition was high and was little affected by the form of briefing used. It would seem therefore that efforts to improve performance by providing more appropriate briefing material should be concentrated on targets that are liable to be difficult to recognise, since it is for these targets that the greatest gains can be expected.

The use of oblique photographs, or any other form of oblique representation of the target area, raises a number of problems, in particular, that of deciding the optimum range at which the target should be depicted. A photograph taken at a relatively close range will show details of the target more clearly but it will not show the terrain features leading up to the target. A study carried out by LaPorte and Calhoun (1966) indicates the importance of the terrain features in the vicinity of the target in providing clues to the target position. They used a cine-film simulation technique to analyse the target/background clues used in target recognition. The film was stopped periodically and the subjects were asked to designate the target, to indicate their confidence in the designation, and to describe the most important clues leading to the designation. The most significant finding of the study was that, for most of the targets, non-target clues were more important to successful target recognition than were target clues. The nature of these non-target clues varied with the type and location of the target but, where available, roads were the most frequently reported clues. It was also found that target recognition was related to the observer's ability to encode the visual world, i.e. to memorise elements of the environment and to describe them verbally.

These two studies suggest that for maximum effectiveness the briefing material provided should enable the pilot to accurately visualise the main features in the vicinity of the target area, and their spatial relationship to the target, as seen obliquely during a low-level approach. There are a number of ways in which this may be achieved. The obvious way is to provide the pilot with at least one oblique photograph of the target area taken from a range long enough to show the features leading up to the target. However, as already discussed, the altitude, approach direction and camera depression angle from which the photograph was taken should correspond closely to those of the actual mission. Obtaining photographs of this type poses considerable problems since it necessitates low-level penetration of hostile territory over areas which are likely to be strongly defended.

For this reason, low-level oblique photographs will be much less readily obtainable than high-altitude vertical photography. For many missions the problem will be how to make the best use of briefing materials which show the target area in plan view when oblique photographs are not available. The pilot has therefore to accurately visualise the low-level oblique view from the plan information given either on a map or a vertical photograph, and it is necessary to consider how this can be most effectively brought about.

Pilots regularly flying high-speed, low-level missions learn to visualise from the information on the map, the appearance of terrain features as seen obliquely from different altitudes, but there is evidence that their preconceptions as to how a particular feature will appear are frequently inaccurate, and may therefore be misleading. McGrath (1963) found that of 109 pilots interviewed, 84% said that they regularly attempted to obtain a preconceived idea of how a particular checkpoint would appear during the approach and, of these, 92% said that their preconceptions had on occasion turned out to be wrong. Possible reasons for this failure to correctly visualise the oblique view of the checkpoint and surrounding terrain are inadequacy of the information given on the map, or inability on the part of the pilot to accurately deduce the spatial relationship between different features, and their apparent size and shape when seen obliquely.

Two different approaches are possible to the problem of overcoming this difficulty of mentally transforming plan information into oblique perspective information. Firstly, appropriate training in perspective geometry could be included in a standard training course. Secondly, by applying the rules of perspective, drawings could be prepared from a plan view of the target area to represent the target as seen from any required range, altitude and direction of approach. For television viewing systems the appropriate field of view and depression angle could also be taken into account. These drawings could then be used as a substitute for oblique

photographs. Although they could only show the information available in the source material, whether maps or vertical photographs, the apparent convergence due to perspective would be accurately represented, thus eliminating the necessity of the pilot mentally carrying out this perspective transformation.

An experiment to assess the value of training in perspective geometry on a subject's ability to locate target areas was carried out by Hagen, Larue and Ozkaptan (1966). Twelve subjects, randomly assigned to two groups, underwent conventional training in target area location. In addition, the experimental group received specialised training in perspective geometry, which took place before the conventional training, and required an average of 10 hours for each subject. The specialised training was entirely static and was intended to teach the subject to deduce the exact spatial relationship between a checkpoint and a target area as it would appear on the TV display. This was carried out by means of a series of overlays which indicated the range and cross-range values at various levels on the simulated TV monitor. Using these overlays the subject was required to locate the target area in relation to a particular checkpoint. The level of difficulty was progressively increased by reducing the amount of information shown on the overlays.

During the conventional training the target area and suitable checkpoints were indicated to the subject on a 1:20,000 scale photomosaic, showing $3\frac{1}{2}$ n.m. of terrain on either side of the planned track. When he was able to produce a rough sketch showing the checkpoints in correct relationship to the target area he viewed the same terrain on the TV monitor as many times as he felt was necessary. The simulation technique used during the conventional training was the same as that used during the subsequent experimental sessions.

The simulated altitude was 2000 ft., the field of view 28° x 21°, and the depression angle of the lens axis approximately 6°. Each route was

approximately 7 n.m. long and the simulated speed was 650 knots. Offset errors of ± 2.5 n.m., ± 1.25 n.m. and zero were simulated so that the target area did not always appear down the centre of the TV monitor. These offset values were such that on some occasions the target area did not appear on the monitor during any part of the simulated flight, and the subjects were told that this might occur. They were required to mark the target area, as early as possible during the run, either on the monitor itself or on the surrounding screen.

The results of the study showed that correct target area designations improved significantly from 68% to 81% as a result of the specialised training. The accuracy of these correct designations improved from an average error of 3.35 n.m. for the control group to 2.95 n.m. for the experimental group. These values, which were not significantly different, give some idea of the wide areas within which designations were counted as correct. The experimental group designated the target area in a significantly shorter average time than the control group, the average times before designation being 0.32 and 0.39 minutes respectively.

In considering the results of this experiment it should be noted that the subjects who underwent only conventional training did not have any additional learning activity while the second group of subjects underwent specialised training in perspective geometry. Thus, the experimental group received more than twice as many hours of training altogether, although both groups had equal training in conventional techniques, including film training. In spite of this, the results suggest that training in perspective geometry is of value in target area location and the techniques used in the experiment could be further developed to apply to a wider range of operational conditions.

The present experiment set out to investigate the possibility that an improvement in performance could be achieved if, in addition to providing a plan view of the target area, an oblique representation derived from the

plan view, was also presented as briefing information. This would eliminate the necessity for the subject to mentally visualise the appropriate oblique view while studying the map. Previous experiments had suggested that this gave rise to a major difficulty in utilising the map information to orientate the main features shown in the photographic display, and hence to locate the target.

The majority of the subjects used in these earlier experiments had been unskilled, although they were given detailed training for the purposes of the experiment, and it would be expected that such subjects would find greater difficulty in mentally transforming a plan view of the target area into an oblique view than would skilled subjects. However, it appeared that this problem was by no means confined to unskilled subjects and the result found by Rusis and Rawlings (1966), that oblique photographs were more effective as briefing material than vertical photographs, tends to confirm this. Furthermore, during informal interviews with pilots experienced in high-speed, low-level flight, some of them mentioned that they did attempt to make rough forward-oblique sketches as an aid to target recognition.

Although it would not be expected that perspective representations, even if accurately drawn, would be as effective as oblique photographs, it was thought likely that they would improve performance relative to that achieved when only plan view briefing information was provided. Since vertical photographs of the relevant target areas were not available, standard 1" = 1 mile Ordnance Survey maps were used to provide the plan information from which the oblique representations were prepared. Drawings prepared in this way could not show as much detail as would be available on vertical photographs, but Ordnance Survey maps had the advantage of providing a standardised source of plan view information for an initial investigation of the effectiveness of the technique.

The feasibility of this approach was confirmed by the production of several prototype drawings and this led to the appointment of a consultant artist to further develop the technique and to prepare a complete set of drawings for the twenty targets used in this series of experiments. A detailed account of the technique used and some of the difficulties encountered is given in the second part of this report (Parkes and Crook, 1969). Some of the more general points are considered below:

(a) Range of briefing drawings

At an early stage of this work it was necessary to decide at what range or ranges the briefing drawings should depict the target. The series of photographs used to simulate the TV display in previous experiments showed each target at ranges of 1, 2, 3 and 4 miles, and it had been found that performance, in terms of detection probability, search time and confidence level, deteriorated markedly as range increased from 1 to 4 miles. Under operational conditions it is important that the target should be detected and identified as early as possible, and therefore in considering at which range or ranges the target should be depicted the need to improve performance at longer ranges was of primary importance.

Another consideration was the type of targets studied. A small target might be difficult to detect at a range of, say, 2 miles, whereas a large, conspicuous target might be readily detected at ranges considerably greater than this. It seemed possible that the optimum briefing range would be different for the two types of targets. It was finally decided that in the present experiment the briefing range, i.e. the range at which the target was shown in the briefing drawings, should be 2 miles and 4 miles, and in addition to testing the effect of each briefing range independently, their combined effect, i.e. presenting both 2 and 4 mile briefing drawings simultaneously, would also be tested.

(b) Specification of drawings

The following parameters were specified to the consultant who prepared the drawings:

(i) Altitude: 2,000 ft.

(ii) Field of view 30° (horizontal) x $22\frac{1}{2}^{\circ}$ (vertical).

(iii) Depression angle of camera lens axis: 10°.

(iv) Range of target: 2 miles and 4 miles.

(v) Finished size of drawing: 4.8" x 3.6".

The appropriate section of 1" = 1 mile scale map was provided for each target. The grid reference of the target was given and the approach track marked to correspond accurately with the photographs. Thus the points of origin of the 2 mile and the 4 mile range briefing drawings coincided as closely as possible with the points from which the corresponding photographs had been taken.

At no stage during the preparation of the drawings did the artist see the actual photographs used in the experiment, either for subject training or in the test sequence, although some sample photographs not used for experimental purposes were provided initially to allow him to make a preliminary assessment of the problem.

(c) Drawing technique

Although the sizes and shapes of the various different features were fixed by the information given on the map and the principles of perspective geometry, the most appropriate way in which to portray the features had to be considered. Several methods were possible:

(i) A freehand technique could be used, the artist drawing each feature in the way he thought to be most realistic. This method had the advantage of flexibility but the disadvantage of lack of standardisation.

(ii) Using commercially available shading materials, it would be be possible to produce representations that did not depend

on the artist's skill at freehand drawing. Each area feature, e.g. woodland or built-up area, would be represented by a particular type of shading, and the line features, e.g. roads or railways, by lines of standard form and thickness. This standardisation would be an advantage but these representations would be less realistic and it would be necessary for subjects to learn the code.

(iii) A combination of (i) and (ii), combining flexibility with some degree of standardisation, could be used.

After a preliminary investigation of different techniques, it was eventually decided that the type of presentation should be a factor studied in the experiment. Two types of representations were prepared for each target at each briefing range. The first type, designated drawings, used an entirely freehand technique, which was maintained as constant as possible from one drawing to another. The second type, designated diagrams, was composed of mechanical shading materials and lines of standard width. It was carried out according to a fixed code. In each case the target was marked by a red circle, $\frac{1}{4}$" in diameter. Important implications of the differences between these two techniques are further considered in the Discussion, Section 8. Examples of the finished diagrams and drawings are shown in Figures 5.2.3 and 5.2.4, (Section 5).

For each of the 20 targets used in the experiment, 12 for subject training and 8 for the experimental sequence, four briefing pictures were prepared, i.e. drawings and diagrams at 2 and 4 mile ranges. For some targets the correspondence between briefing pictures and the actual photographs was very good. For others it was less close, either because of the inadequacy of the information shown on the map, or because the photographs had not been taken under the specified conditions of altitude, and camera depression angle. For instance, a slight variation in depression angle makes a noticeable difference to the apparent perspective and, in particular, to the distance between the aircraft and the terrain shown at the lower edge of the display.

The primary purpose of this experiment was to test the effectiveness of these drawings and diagrams as briefing materials, relative to the use of a map alone. However, it was also of interest to determine how effective these specially prepared briefing materials were relative to oblique photographs. For this reason the experiment included photographic briefing conditions in which 2 and/or 4 mile range photographs were used, together with the map, as briefing material. These photographs were identical to those used subsequently to simulate the TV display, except that on the briefing photographs the target position was marked as in the drawings and diagrams. The use of these photographs for briefing represented the highest level of briefing information, and when the range of briefing photograph coincided with the range at which the target was subsequently presented, briefing information was virtually perfect. It was of interest to determine whether this would give rise to 100% correct detection.

One further type of briefing was also investigated. This briefing gave the subject information about the position of the target in the photographic display, but no information about the appearance of the target and the terrain features surrounding it. It consisted of the outline of the display in which a $\frac{1}{4}$" diameter circle marked the position of the target at 2 miles range or 4 miles range. The type of briefing, designated 'target circles', was intended to determine whether the effect of the pictorial briefing materials, if any, resulted from the information they provided about target position or the information relating to the appearance of terrain features in the vicinity of the target.

The static simulation technique used in this experiment was clearly unrealistic in terms of the dynamic nature of the visual environment during high-speed, low-level flight. Nevertheless, it was hoped that the experiment would indicate whether the use of perspective drawings as a possible substitute for oblique briefing photographs would merit further investigation under dynamic simulation conditions.

2. PURPOSE OF THE EXPERIMENT

The experiment was intended to study the effects of different types of briefing information on target detection performance. In previous experiments in this series subjects had only been provided with a section of an Ordnance Survey map (scale 1" = 1 mile), marked with the target and aircraft track, for briefing purposes. The primary aim of the present experiment was to determine whether pictorial representations of the target and surrounding terrain, prepared by transforming the information on the map into an oblique perspective view of the target area, improved detection performance when used as additional briefing material.

These pictorial briefing materials, which were of two types, drawings and diagrams, are described in more detail in Section 5.2. They represented the target as seen from a ground range of (a) 2 miles and (b) 4 miles. This 'briefing range' was a further variable studied in the experiment, either the 2 mile or the 4 mile or both 2 and 4 mile representations being provided.

Two other types of briefing material were also studied for comparison purposes. One of these provided information about the position of the target in the display but no information about terrain features. The other, which represented the highest level of briefing information, involved the use of the actual target photographs (ranges 2 and 4 miles) as briefing material. Under each briefing condition the map was provided in addition to the appropriate type of briefing material. A control condition in which only the map was provided for briefing was also studied.

Eight targets, each at four ranges (1, 2, 3 and 4 miles), were used to test these briefing type and briefing range conditions and a total of 74 unskilled subjects took part. The performance measures recorded were (a) detection probability, (b) search time, (c) confidence level and (d) briefing time.

3. EXPERIMENTAL DESIGN

This experiment was intended to investigate detection performance under twelve different conditions of briefing information, one of which involved the use of a map alone, and the others the use of different forms of pictorial briefing information, in addition to the map. This pictorial briefing represented the target as seen from (i) 2 miles and (ii) 4 miles. The following factors were studied:

(a) Type of briefing:	5 levels	map + photographs map + drawings map + diagrams map + target circles map only
(b) Range of briefing:	3 levels	2 miles 4 miles 2 + 4 miles
(c) Range of target:	4 levels	1 mile 2 miles 3 miles 4 miles
(d) Targets:	8 levels	8 targets

The map only briefing was different from the other briefing types in that it was not associated with a particular range or ranges. Each of the other four briefing types were associated with the three different briefing ranges giving rise to 12 possible briefing conditions in addition to the map only condition, eleven of which were tested in the present experiment, no data being obtained for the map + target circles (2 + 4 miles) condition.

In considering possible designs for an experiment to test the effect of the different briefing conditions as compared with the map only condition, it was decided that each subject should only be exposed to a single briefing condition. This had the advantage of allowing the subject to become thoroughly familiar with the appropriate briefing condition during initial training. A group of 4 subjects

was assigned to each of the 12 briefing conditions (1 map only condition and 11 map + additional briefing conditions). The four subjects were arranged in an 8 targets x 4 target ranges matrix in such a way that each subject saw each target once and once only, and each target range twice and twice only. Order of presentation of the target and target range combinations was randomised for each subject. This procedure was repeated for each of the briefing conditions and details of the experimental schedules used are given in Appendix I. Care was taken to ensure that the mean and s.d. of the intelligence scores, as measured by Heim's A.H.5 test, for each group of 4 subjects was approximately equal since previous work had shown that there was a positive correlation between an individual's score on this test and the accuracy of his performance at the experimental task.

The experimental design outlined above required a total of 48 subjects (4 subjects for each of 12 briefing conditions) and gave rise to 32 readings per briefing condition. Time did not allow the entire experimental schedule to be replicated using a further 48 subjects, but in order to obtain more data about the conditions of particular interest in the present experiment, further groups of four subjects were assigned to the map only condition, the map + diagrams conditions (2, 4 and 2 + 4 mile briefing ranges) and the map + drawings conditions (2, 4 and 2 + 4 miles ranges). For these seven briefing conditions a further 32 readings per condition were thus obtained, giving a total of 64 readings per condition.

4. DISPLAY AND RECORDING EQUIPMENT

The display and recording equipment used in this experiment has been described in detail in the first of this series of reports. No changes were made to this equipment for the purposes of the present experiment as the additional briefing materials used did not require any special display facilities. They were simply mounted on card and placed on the table alongside the map display. The time taken for briefing using both the map and additional briefing, if provided, was recorded when the subject closed the lid of the map display.

The photographic display was 4.8" x 3.6" in size, the viewing distance being 13". The time the subject spent searching for the target (i.e. the time between the subject operating the 'start' button, which illuminated the display, and the 'stop' button which indicated that he was ready to designate the target) was recorded by means of a print-out device linked to a Decatron timer. The subject's confidence in his response, on a scale of 1-7, was also recorded automatically. Thus the experimenter only had to record whether or not the target had been correctly identified when the subject pointed it out.

5. EXPERIMENTAL MATERIALS

The target photographs and the briefing materials used in this experiment are described below:

5.1 Target photographs

The photographic material used was the same as that used in previous experiments. It consisted of a series of 8" x 8" aerial

photographs taken from an altitude of 2,000 ft. with a camera field view of 50° x 50°. For display purposes these photographs were masked so that only a central portion 4.8" x 3.6" was shown, representing a camera field of 30° (horizontally) x $22\frac{1}{2}^{\circ}$ (vertically). In each case the horizon appeared $\frac{1}{4}$" below the top of the displayed portion, the depression angle of the camera being 10°. For each of the 20 targets there were four photographs taken at ranges of 4, 3, 2 and 1 mile respectively along the approach route. Eight sets of target photographs were required for the experiment, the remaining 12 sets being used for training purposes.

5.2 Briefing materials

Examples of the briefing materials used are shown in Figures 5.2.1 - 5.2.5. These represent a complete set of briefing materials for one of the eight test targets studied. Short descriptions of the briefing materials are given below.

5.2.1 Map sections

The maps used were $6\frac{1}{4}$" x $6\frac{1}{4}$" sections of the 1" = 1 mile Ordnance Survey map, Sheet 169. Each map showed the target position and surrounding terrain with the approach route marked. The maps were displayed in the 'track-up' orientation, as shown in Figure 5.2.1.

5.2.2 'Target circle' briefing material

The 'target circle' briefing material was intended to give subjects information about the position of the target on the display, without giving him any information about terrain features. For each target briefing material was produced showing the outline of the display in which a small circle indicating the position of the target in (a) the 2 mile range photograph and (b) the 4 mile range photograph, was marked. This briefing material is shown in Figure 5.2.2.

5.2.3 Diagrams and drawings

The diagrams and drawings used as briefing materials in this experiment were perspective representations of the information shown on the map section prepared according to the appropriate altitude, camera field of view, depression angle and target range. Both drawings and diagrams were produced to represent the target as seen from (a) 2 miles and (b) 4 miles range. In each of the diagrams and drawings the target was marked with a small circle. Examples of these briefing materials are shown in Figures 5.2.3 and 5.2.4. The two types of representation both show the same information but, whereas the drawings were carried out using a freehand technique, only mechanical shading materials together with a fixed code for linear features were used for the diagrams. A detailed account of the development and preparation of these pictorial briefing materials is available (Parkes and Crook, 1969).

5.2.4 Photographs

The photographs used as briefing materials were identical to those described in Section 5.1 but only the 2 mile and 4 mile range photographs were used for briefing purposes. Thus on some occasions a subject would be provided with, say, a 2 mile range photograph for briefing purposes and subsequently be asked to identify the target in an identical photograph. This represented virtually perfect briefing information, although the subject did not know while he studied the briefing photograph at which range the target would subsequently be presented. Examples of the photographs used for briefing are shown in Figure 5.2.5.

FIGURE 5.2.1

Map section

Target 13 Cross roads at Borden Camp

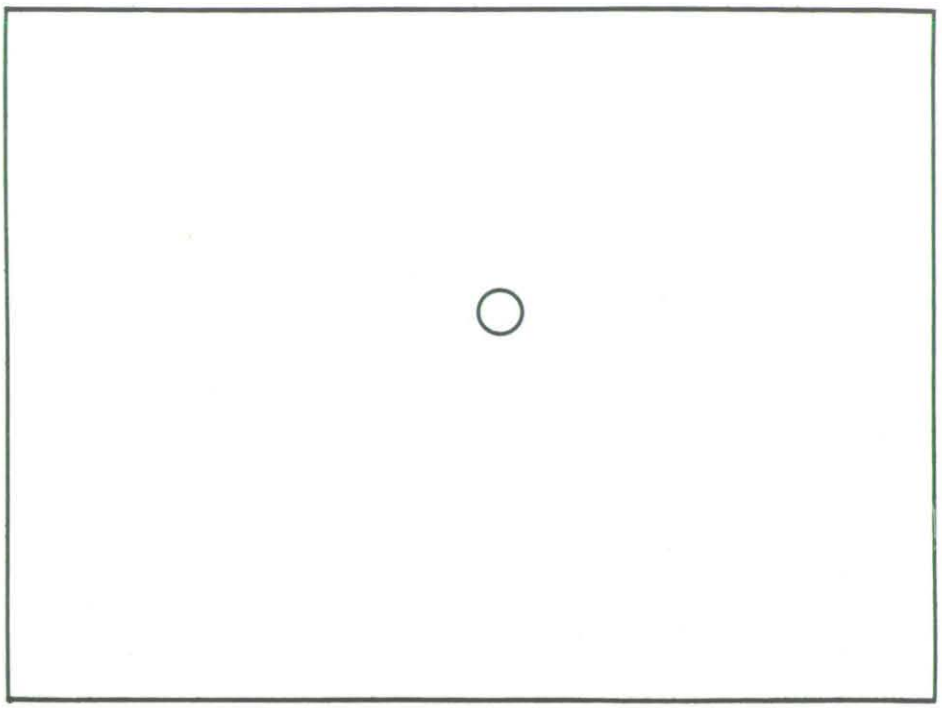
Map scale: 1" = 1 mile

The target is marked with an arrow on the map. The rectangle represents the final 4 miles of the aircraft track to the target, allowing for a possible offset error of $\pm\frac{1}{4}$ mile.

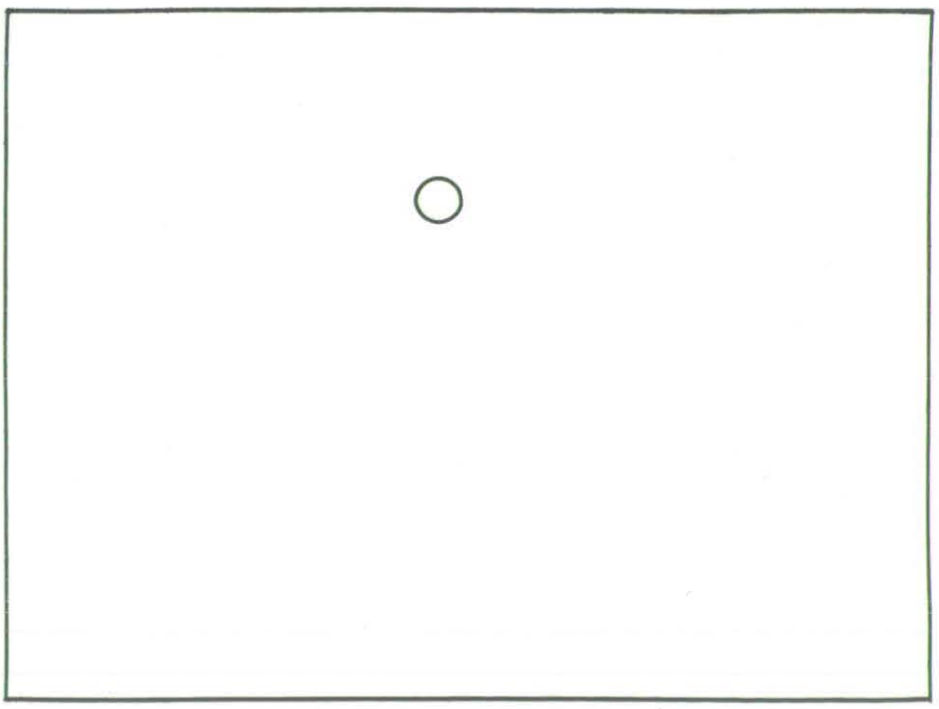
FIGURE 5.2.2

Target circles

Target 13 Cross roads at Borden Camp



2 mile range

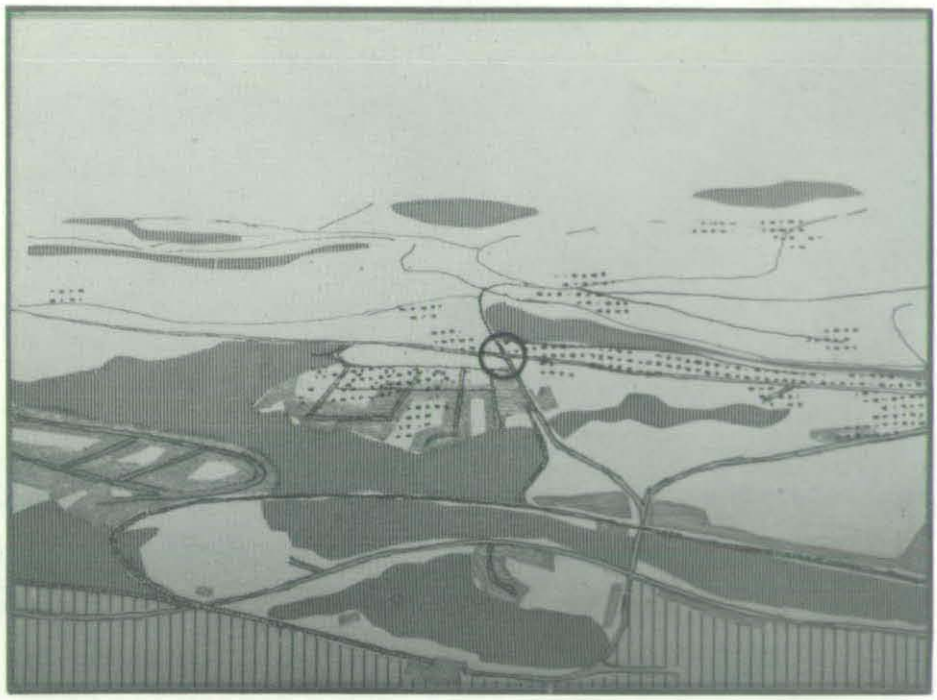


4 mile range

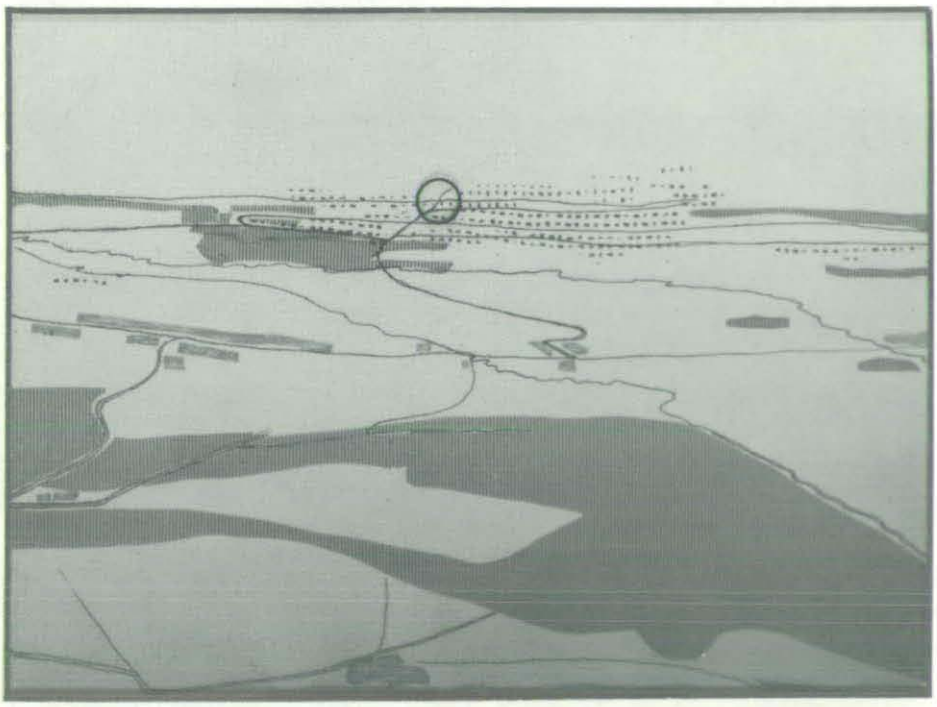
FIGURE 5.2.3

Diagrams

Target 13 Cross roads at Borden Camp



2 mile range

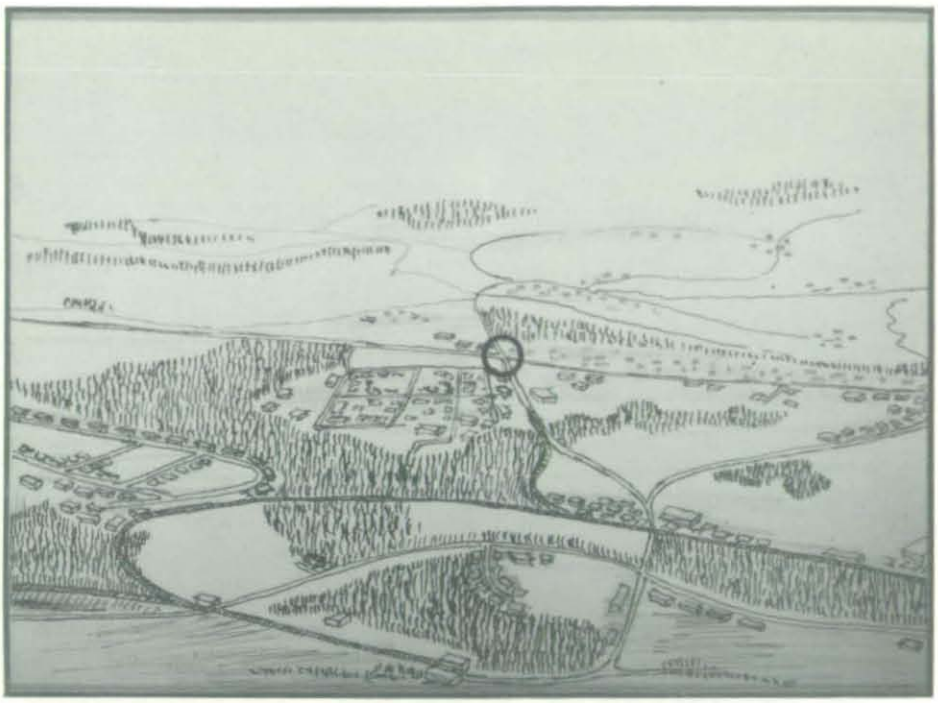


4 mile range

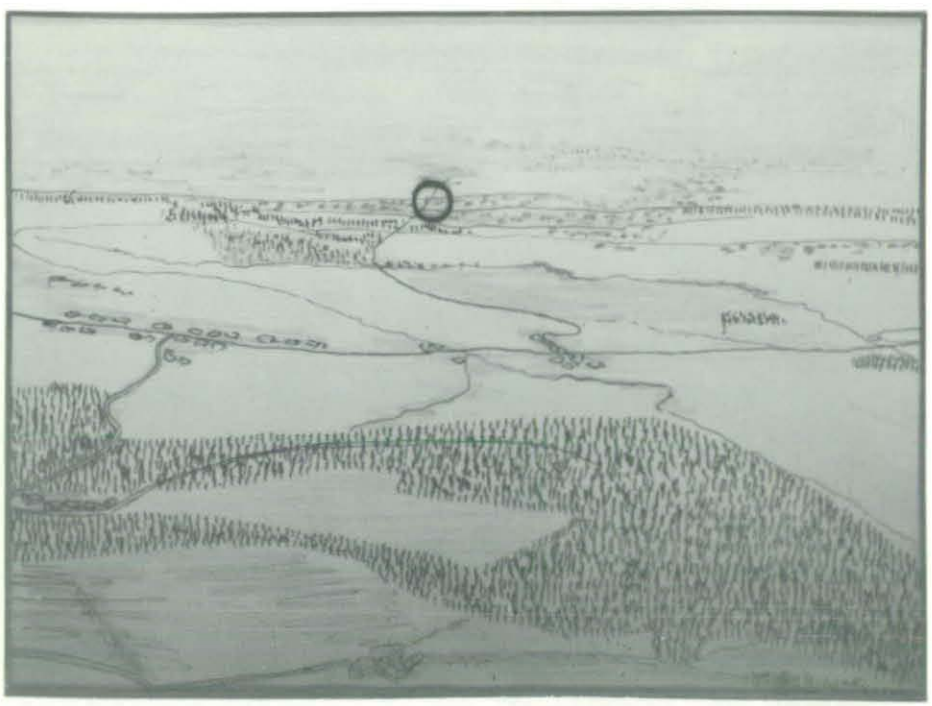
FIGURE 5.2.4

Drawings

Target 13 Cross roads at Borden Camp



2 mile range



4 mile range

FIGURE 5.2.5

Photographs

Target 13 Cross roads at Borden Camp

2 mile range

4 mile range

6. EXPERIMENTAL PROCEDURE

The training and test procedures used in this experiment were similar to those used in previous experiments. The only change was that subjects assigned to conditions in which additional briefing materials were used, were introduced to the appropriate type of briefing material at an early stage in training and all further practice took place using this briefing material.

Each subject was tested individually and the session lasted approximately 3 hours. Preliminary tests of intelligence (Heim's A.H.5 test), personality (Eysenck personality inventory) and memory (digit-span test) were carried out. This took approximately $1\frac{1}{4}$ hours. Training and practice at the detection task took a further $\frac{3}{4}$ hour. The subject was then shown how to operate the display and recording apparatus and a series of targets was presented for further practice. After each presentation the subject was told whether or not he had correctly located the target and, if not, he was given a further opportunity to do so.

Finally a series of eleven targets was presented during which the subject was given no knowledge of results. The last eight of these targets constituted the test run. In order to prevent the subjects placing undue reliance on the pictorial briefing materials they were required to study the map section for 90 seconds before the additional briefing materials were presented. They were then allowed as much further time as they required to study the briefing materials. The subjects tested under the map only condition also had to study the map for a minimum of 90 seconds, this being the approximate mean time which subjects had required for map-briefing in the previous experiments. For each presentation four measures of performance were obtained (a) whether or not the target was correctly detected, (b) search time, (c) confidence level and (d) briefing time.

7. RESULTS

The numbers of readings obtained for each of the briefing conditions tested in this experiment are shown in Table 7.0.

TABLE 7.0.

Numbers of readings obtained for each experimental condition.

BRIEFING TYPE	BRIEFING RANGE (miles)					
	2		4		2 + 4	
Map + target circles	32	-	32	-	-	-
Map + diagrams	32	(32)	32	(32)	32	(32)
Map + drawings	32	(32)	32	(32)	32	(32)
Map + photographs	32	-	32	-	32	-

MAP ONLY	32	(32)

The basic data consisted of 32 readings (on each of four performance measures) for the map only condition, and for each of eleven conditions in which additional briefing materials were used. These eleven conditions arose from four briefing types (map + target circles, map + drawings, map + diagrams and map + photographs), each being associated with 3 briefing ranges (2 miles, 4 miles and 2 + 4 miles). These gave rise to twelve conditions, one of which, target circles at 2 + 4 miles ranges, was not tested in the present experiment. Each set of 32 readings was obtained from 4 subjects, each of whom saw each of the eight targets once and each of the four target ranges twice, i.e. one reading per cell was obtained.

For the map only condition, the three map + diagrams conditions and the three map + drawings conditions an additional 32 readings per condition were obtained from further groups of four subjects. These are shown in brackets in Table 7.0. Thus for these conditions a total of two readings per cell was obtained. The time available for this experiment did not allow replicated data to be obtained for all the conditions tested. Additional data were therefore obtained only for the conditions of particular interest.

In deciding the most appropriate way of analysing these data a number of factors had to be taken into account.

(a) Different numbers of readings were available for different conditions.

(b) One block of data was missing completely (map + target circles, 2 + 4 miles range).

(c) The map only condition which was, in effect, the control condition, was not associated with any specific briefing range. This meant that it could not conveniently be included in any analysis of variance in which briefing type and briefing range were treated as separate factors. It was therefore not possible to determine directly from an analysis of variance whether there were significant differences between the map only, map + target circles, map + diagrams, map + drawings and map + photographs briefing types, or between the map only, map + 2 mile range briefing, map + 4 mile range briefing and the map + (2 + 4) miles ranges briefing. However, the map only data could be included if the eleven conditions using additional briefing materials were treated as independent and the briefing type and briefing range factors not considered separately.

In view of these difficulties, the analysis of the data was carried out in two parts:

(i) The basic 32 readings per condition for the map only condition and the eleven conditions using additional briefing materials were analysed for each performance measure. On account of the small numbers of readings available, it was not expected that highly significant results would be obtained, but these analyses were intended to provide an overall picture of the relative effectiveness of the different briefing conditions tested. These analyses are described in Sections 7.1 (detection probability data), 7.3 (search time data), 7.5 (confidence level data) and 7.7 (briefing time data).

(ii) The second part of the analysis was concerned only with the effects of different methods of presenting map information, i.e. with the map only condition, the 3 map + diagrams conditions and the 3 map + drawings conditions. The replicated data were used in these analyses and it was of particular interest to determine, more reliably than was possible using only a single set of data, whether there were any differences between the effects of the diagrams and drawings, and between the effects of the different briefing ranges studied. For reasons outlined at the beginning of Section 7.2 these analyses were carried out on the data from target ranges 2, 3 and 4 miles only, data from target range 1 mile being excluded. These analyses are described in Section 7.2 (detection probability data), 7.4 (search time data), 7.6 (confidence level data) and 7.8 (briefing time data).

In order to overcome the difficulties arising from the fact that the map only data were not associated with any particular briefing range two analyses of variance were carried out on each set of data. In the first analysis the twelve briefing conditions (map only + 11 conditions using additional briefing) were treated as independent and, for all performance measures, it was found that briefing conditions had a significant effect on performance. Further analyses of variance were therefore carried out in each case to investigate the separate effects of briefing type and briefing range, and interactions involving these factors. This was made possible by exclusion of the map only data and, where necessary, by taking account of the missing data for the target circles, (2 + 4 miles ranges) condition.

Subsequent analyses were carried out to determine by multiple comparison tests whether the map only condition resulted in significantly different performance from the briefing type and briefing range conditions tested. Significant interactions involving these factors were also analysed. The interactions of briefing type and briefing range with target range were of particular importance, even if they were not found to be significant in the analyses of variance from which the map only data had to be excluded. It was of interest to determine how the effect of target range on performance, for each briefing type and each briefing range, compared with that under the map only condition. The overall effects of targets and target ranges were not analysed in detail as they had been fully investigated in previous experiments.

The detailed analyses of the data obtained in this experiment are given in Sections 7.1 - 7.8 and a summary of the main results found is given in Section 7.9.

7.1 DETECTION PROBABILITY - ANALYSIS OF BASIC DATA FOR ALL BRIEFING CONDITIONS

The basic detection probability data obtained in this experiment is given in Table 7.1.1. This table shows the initial 32 readings per briefing condition used in the first part of this analysis. Two analyses of variance were carried out on these data. In the first, given in Table 7.1.2, the twelve briefing conditions (i.e. map only + 11 conditions using additional briefing material) were treated as independent and a 12 (briefing conditions) x 4 (target ranges) x 8 (targets) factorial analysis was carried out. In the second analysis of variance, given in Table 7.1.3, the map only data were excluded and a 4 (briefing types) x 3 (briefing ranges) x 4 (target ranges) x 8 (targets) analysis was carried out. In this analysis it was necessary to allow for the missing values associated with the 2 + 4 miles target circles briefing condition which was not tested in this experiment.

In the analysis shown in Table 7.1.2 the effect of the twelve different briefing conditions is significant at the 1% level and the effect of targets is significant at the 0.1% level, as is the interaction between the targets and target ranges. The overall effect of target range fails to reach the 5% level. The analysis of variance given in Table 7.1.3 shows very similar results for the main factors and also indicates that within the 11 briefing conditions the effect of briefing type is highly significant. The effect of briefing range, and the interaction between briefing range and target range, both fail to reach the 5% level, although the latter effect reaches the 10% level.

In the following sections the effects of briefing type and briefing range, and the interactions of these factors with target range are considered in more detail, the map only condition being treated as the control condition.

Basic detection probability data for all briefing conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	1	1	1	0	1	1	1	1
		2	0	1	1	0	0	1	0	1
		3	0	1	1	0	0	1	0	0
		4	0	0	0	0	0	1	0	1
MAP + TARGET CIRCLES	2	1	0	1	0	0	0	1	1	0
		2	0	0	0	1	0	1	0	1
		3	0	0	1	0	0	1	1	1
		4	0	0	0	0	1	0	0	1
	4	1	0	1	0	1	0	1	1	0
		2	1	0	0	0	0	1	1	1
		3	1	1	0	0	1	1	0	0
		4	0	0	1	0	0	1	0	1
MAP + DIAGRAMS	2	1	0	1	0	0	1	1	1	1
		2	0	1	0	1	1	1	1	1
		3	0	1	1	1	1	1	0	1
		4	0	1	0	0	1	1	0	1
	4	1	0	1	0	0	1	1	1	0
		2	1	1	0	1	0	1	0	1
		3	0	1	1	0	1	1	1	1
		4	0	1	1	0	1	1	0	0
	2 + 4	1	0	1	0	0	0	1	1	0
		2	1	1	0	1	0	1	0	1
		3	0	1	1	0	0	1	0	1
		4	1	1	1	0	1	1	1	0

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	0	1	0	0	0	1	1	1
		2	1	1	0	1	0	1	1	1
		3	0	1	0	0	0	1	0	0
		4	0	1	0	0	0	0	0	1
	4	1	0	1	0	1	0	1	1	1
		2	0	1	0	0	0	1	1	1
		3	0	1	1	0	1	1	0	1
		4	0	1	0	1	1	1	0	1
	2 + 4	1	1	1	0	1	0	0	1	0
		2	0	1	0	0	0	1	1	1
		3	1	1	1	1	0	1	0	1
		4	0	1	0	1	1	1	0	1
MAP + PHOTO-GRAPHS	2	1	0	0	0	0	1	1	1	1
		2	1	1	1	1	1	1	1	1
		3	1	1	1	0	1	1	1	1
		4	0	1	1	0	0	0	0	1
	4	1	0	1	0	1	0	1	1	1
		2	0	1	0	1	0	1	0	1
		3	0	0	1	0	0	1	0	1
		4	1	0	1	1	0	1	1	1
	2 + 4	1	0	1	0	1	1	1	1	1
		2	1	1	0	1	1	1	1	1
		3	1	1	1	0	1	1	1	1
		4	0	1	1	0	1	1	0	1

These data relate to four subjects per briefing condition. 1 = correct response 0 = incorrect response

TABLE 7.1.2

Analysis of variance on detection probability data shown in Table 7.1.1

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions (C)	11	4.43	0.40	2.61	$p < 0.01$
Target ranges (R)	3	0.97	0.32	2.10	N.S. ($p < 0.10$)
Targets (T)	7	19.66	2.81	18.24	$p < 0.001$
C x R	33	7.34	0.22	1.44	N.S.
C x T	77	13.16	0.17	1.11	N.S.
R x T	21	13.11	0.62	4.06	$p < 0.001$
Residual	231	35.57	0.15		
TOTAL	383	94.24			

TABLE 7.1.3

Analysis of variance on detection probability data shown in Table 7.1.1, excluding data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing types (B)	3	2.69	0.90	5.63(b)	$p < 0.01$
Briefing ranges(P)	2	0.70	0.35	2.19(b)	N.S.
Target ranges (R)	3	0.97	0.32	2.00(b)	N.S.
Targets (T)	7	17.67	2.52	15.75(b)	$p < 0.01$
P x B	*5	0.88	0.18	1.13(b)	N.S.
P x R	6	1.83	0.30	1.88(b)	N.S. ($p < 0.10$)
P x T	14	1.71	0.12	-	N.S.
B x R	9	0.49	0.05	-	N.S.
B x T	21	4.01	0.19	1.19(b)	N.S.
R x T	21	13.99	0.67	4.19(b)	$p < 0.01$
P x B x R	*15	3.28	0.22	1.57(a)	N.S.
P x B x T	*35	5.92	0.17	1.21(a)	N.S.
P x R x T	42	5.71	0.14	1.00(a)	N.S.
B x R x T	63	11.10	0.18	1.29(a)	N.S.
Residual (a)	105	15.13	0.14		
Residual (b) (Residual (a) + PBR, PBT, PRT, BRT)	260	41.14	0.16		
TOTAL	351	86.06			

*These values are reduced to take account of the missing data for the map + target circles (2 + 4 miles ranges) conditions.

7.1.1 Detection probability: the effect of briefing conditions.

The analysis of variance given in Table 7.1.2 shows that the twelve different briefing conditions tested had a highly significant effect on detection probability. However, rather than consider these twelve briefing conditions individually it is more meaningful to consider the separate effects of briefing type and briefing range. The effects of these factors are shown in the analysis of variance in Table 7.1.3 but the map only data had to be excluded from this analysis in order to conveniently analysis the briefing type and briefing range factors separately. In order to compare the map only condition with the briefing type and briefing range conditions further analyses were necessary.

In the analysis shown in the following sections, the map only condition is treated as the control condition and the effect of the briefing types and ranges compared with that of the map only condition. These multiple comparisons were made by means of Dunnett's t test, the appropriate value of t being selected according to the number of comparisons being made. When comparisons were made between briefing conditions other than the map only condition, Student's t could be used since, in general, it was possible to predict a priori the effect on detection probability of the various briefing types and briefing ranges tested.

7.1.2 Detection probability: the effect of briefing type

The analysis of variance given in Table 7.1.3 shows that briefing type has a highly significant effect on detection probability. The mean values obtained under each of the four briefing types included in this analysis are given in Table 7.1.4. For comparison purposes the value relating to the map only condition is also given.

TABLE 7.1.4

Detection probability values for each briefing type

Briefing type	Detection probability	N
MAP ONLY	0.50	32
Map + target circles	0.42	64
Map + diagrams	0.60	96
Map + drawings	0.54	96
Map + photographs	0.68*	96

N = Number of readings on which each value is based.
* Significantly higher than map only condition at 5% level.

Dunnett's t test (one-tail) was used to determine whether the use of additional briefing material resulted in significantly higher detection probabilities than the map only condition. Only for the map + photographs condition was a significant improvement found, but it can be seen from Table 7.1.4 that both the diagrams and the drawings conditions resulted in higher detection probabilities than the map alone, whereas the target circle condition resulted in an overall deterioration in performance.

Comparisons within the four conditions using additional briefing material, carried out by means of Student's t test, showed that the map + photographs condition resulted in a significantly higher detection probability than the map + drawings and map + target circles conditions. In addition, map + diagrams were significantly more effective than map + target circles, but otherwise differences were non-significant. It is of particular interest to note that the use of photographs as additional briefing material did not result in significantly better performance than the use of diagrams.

7.1.3 Detection probability: The effect of briefing range.

The effect of briefing range on detection probability fails to reach the 5% significance level in the analysis of variance given in Table 7.1.3. The mean detection probabilities achieved under each of the three briefing range conditions are shown in Table 7.1.5. The value obtained under the map only condition is also shown for comparison purposes.

TABLE 7.1.5

Mean detection probabilities under each briefing range condition

	Detection probability	N
MAP ONLY	0.50	32
Briefing range:		
2 miles	0.54	128
4 miles	0.56	128
2 + 4 miles	0.65	96

N = Number of readings on which each value is based.

For each briefing range the mean detection probability was higher than that for the map only condition but none of these differences reached the 5% significance level, as determined by Dunnett's t test. However, the difference between the map only condition and the 2 + 4 miles briefing range condition, 0.15, only just failed to reach significance. These results suggest that simultaneous presentation of briefing information at both the 2 and the 4 mile ranges is more effective than at either of these ranges alone.

7.1.4 Detection probability: the interaction between briefing type and target range.

The analysis of variance given in Table 7.1.3 shows that the interaction between range and briefing type is not significant, indicating that target range has the same effect on performance under each of the four briefing conditions included in this analysis. This effect can be seen in Figure 7.1.1 in which the data given below in Table 7.1.6 are displayed graphically. The four lines corresponding to the four briefing conditions do not differ substantially in form.

TABLE 7.1.6

The effect of range on detection probability under each type of briefing

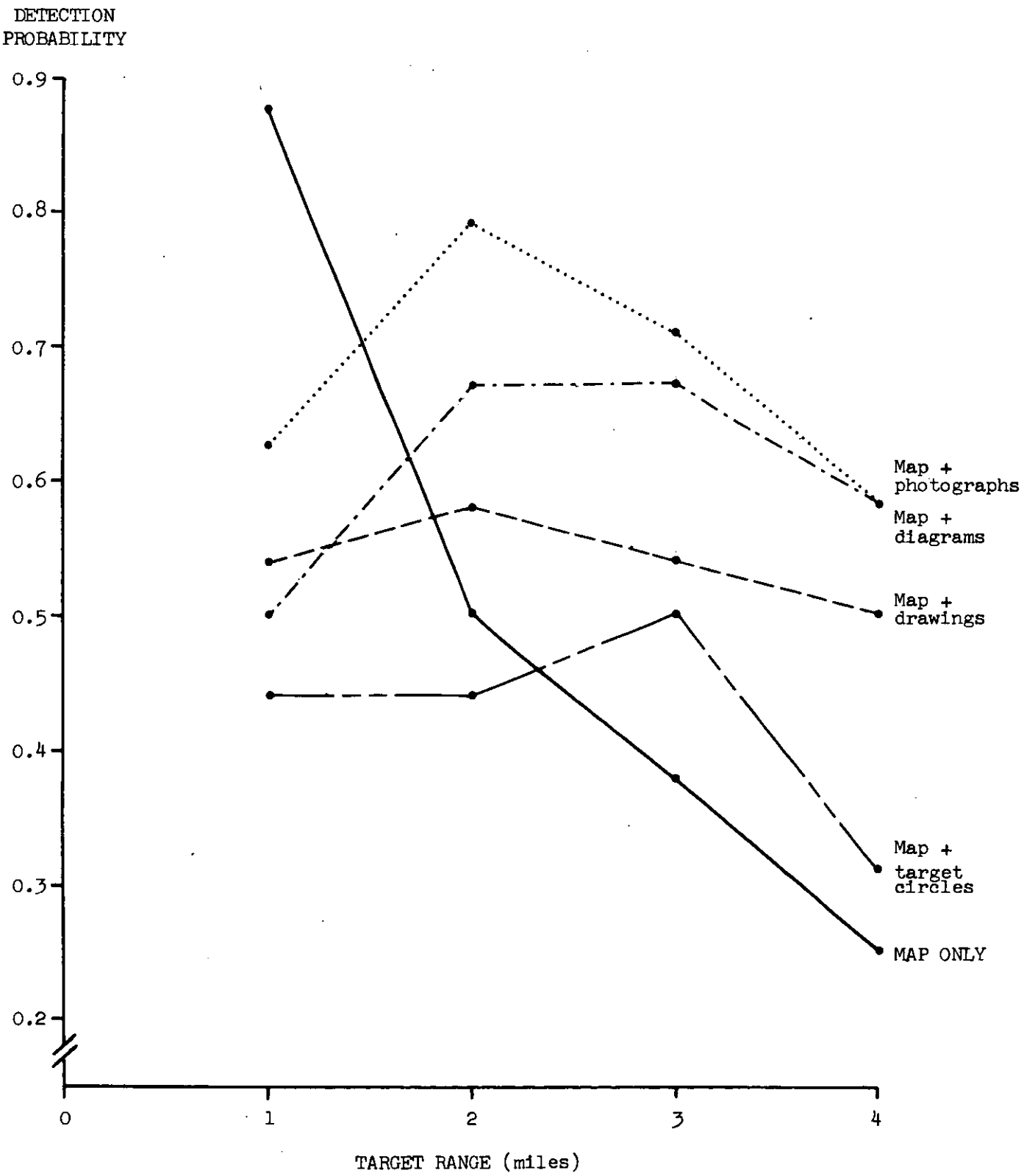
	TARGET RANGE (miles)				N
	1	2	3	4	
MAP ONLY	0.87	0.50	0.37	0.25	8
Map + target circles	0.44	0.44	0.50	0.31	16
Map + diagrams	0.50	0.67	0.67	0.58	24
Map + drawings	0.54	0.58	0.54	0.50	24
Map + photographs	0.63	0.79	0.71	0.58	24

N = Number of readings on which each value is based.

In this table, and also in Figure 7.1.1, the data relating to the map only condition are also shown. It can be seen that the form of these map only data is very different from those relating to the conditions using additional briefing materials. Under the map only condition the effect of range is to produce a consistent and marked deterioration in performance as range increases from 1 to 4 miles. When photographs, drawings or diagrams are used as additional briefing material detection probability increases from 1 to 2 miles and then deteriorates slowly as range is further increased to four miles. As a result, under each of these briefing conditions detection probability

FIGURE 7.1.1

The interaction between briefing type and target range



is lower than that for the map only condition at range 1 mile but higher for each of the longer ranges. Possible reasons for this marked reversal of effect are considered in the discussion.

Dunnett's t test was used to determine whether within any particular range condition, significantly higher detection probabilities resulted from the use of any of the additional briefing materials as compared with the map only condition. To reach the 5% significance level on a one-tail test the values relating to the diagrams, drawings and photographs conditions at each range had to be higher by 0.35 than the corresponding value for the map only condition. It can be seen in Table 7.1.6 that none of the values reached this level although one value for the map + photographs condition (3 miles range) was very close to it. The relatively large value necessary to reach significance resulted from the fact that the range means, particularly those for the map only condition, were based on small numbers of readings.

Using Student's t independent comparisons were made between the mean values for each of the four conditions using additional briefing material. The results showed that there were no significant differences between the photographs, drawings and diagrams condition at any of the four ranges, but at each range the map + photographs condition, which provided the most additional information, resulted in significantly higher detection probability than the map + target circles condition that provided the least additional information.

7.1.5 Detection probability: The interaction between briefing range and target range

The analysis of variance given in Table 7.1.3 shows that the interaction between briefing range and target range fails to reach the 5% level, although $p < 0.10$ indicating some tendency for these two factors to interact. This analysis did not include the data from the map only condition, but in Table 7.1.7 which shows the effect of target range on detection probability under each briefing range condition, the corresponding values for the map only condition are also given for comparison purposes.

TABLE 7.1.7

The interaction between briefing range and target range

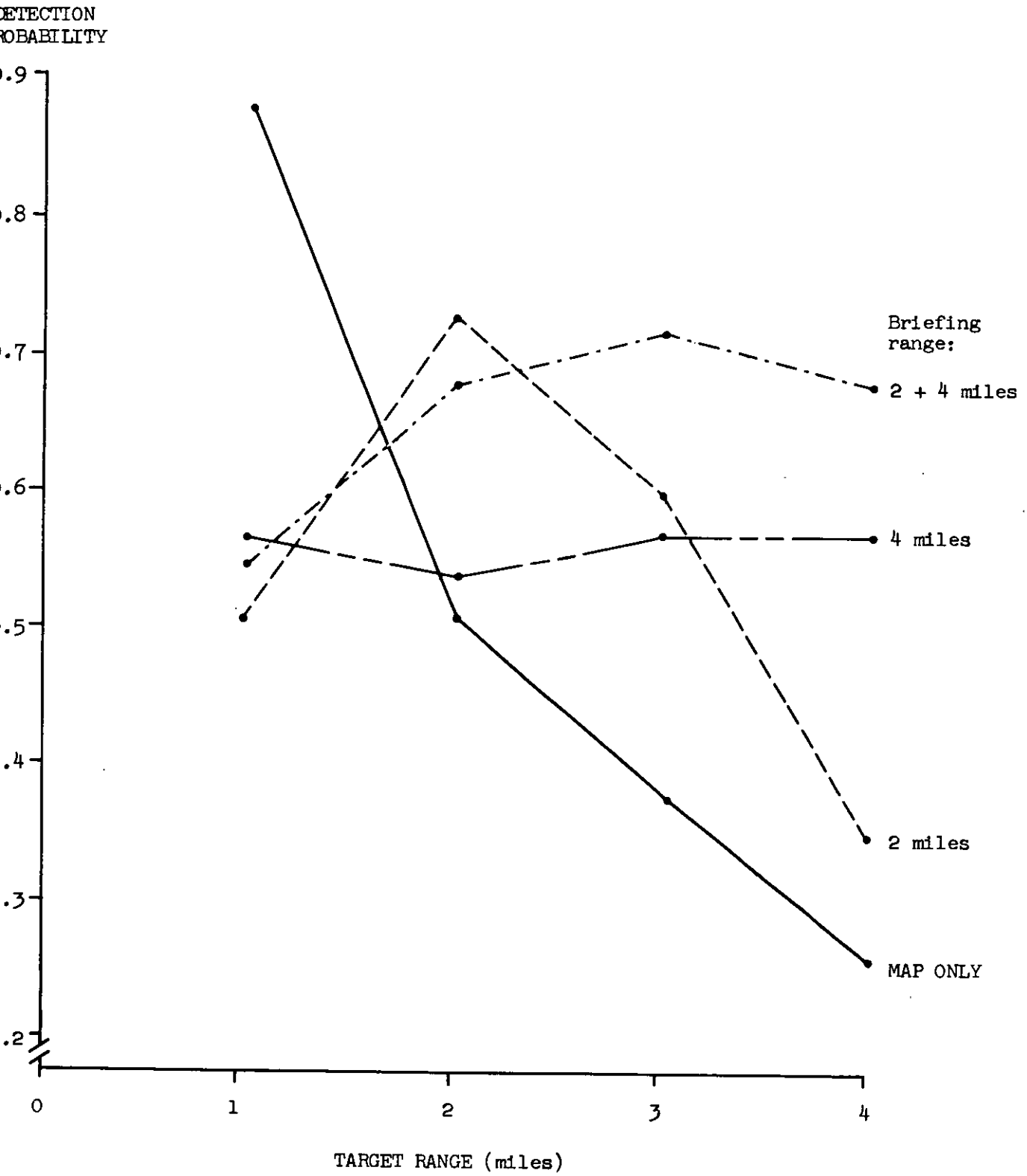
	TARGET RANGE (miles) 1	2	3	4	N
MAP ONLY	0.87	0.50	0.37	0.25	8
BRIEFING RANGE (miles)					
2	0.50	0.72	0.59	0.34	32
4	0.56	0.53	0.56	0.56	32
2 + 4	0.54	0.67	0.71*	0.67*	24

N = Number of readings on which each value is based.
* Significantly higher than the corresponding value for the map only condition at the 5% level.

The data shown in Table 7.1.7 are displayed graphically in Figure 7.1.2. It can be seen that, as would be expected, the 2 mile briefing range results in enhanced performance when the target range is also 2 miles, but has relatively little effect when the target range is 4 miles. Conversely, the 4 mile briefing range is particularly effective when the target range is 4 miles but has only a small effect when the target range is 2 miles. The 3 mile target range is favourably affected by both the 2 mile briefing condition and the 4 mile briefing condition. Under the third briefing condition, both 2 and 4 mile briefing was presented simultaneously and, as shown in Figure 7.1.2, this had the effect of substantially improving performance at target ranges of 2, 3 and 4 miles, the improvement, relative to the map only condition, being greater the greater the target range. Under each briefing range condition, performance for the 1 mile target range deteriorated markedly relative to the map only condition. In spite of the fact that the improvement at longer ranges was in some cases quite large, only those values marked with an asterisk in Table 7.1.7 were significantly greater than the corresponding map only condition.

FIGURE 7.1.2

The interaction between briefing range and target range



7.2 DETECTION PROBABILITY - ANALYSIS OF REPLICATED DATA FOR MAP ONLY, MAP + DIAGRAMS AND MAP + DRAWINGS CONDITIONS.

The results described in Section 7.1 related to four types of briefing in addition to the map only condition. This section is concerned with a more detailed analysis of two of these types of briefing, map + diagrams and map + drawings. The analyses described previously indicated that these pictorial briefing materials, which were derived solely from the information given on maps, tended to increase the probability of detection as compared with the map only condition. The purpose of this further analysis was to use the replicated data available for these seven conditions (map only, map + diagrams at 2, 4 and 2 + 4 miles, and map + drawings at 2, 4 and 2 + 4 miles) to determine, more reliably than was possible using a single set of data, whether there were any significant differences between the diagrams and the drawings, and between the three briefing ranges tested. In addition to providing more specific and reliable information of the effects of these experimental briefing materials under the static simulation conditions used in this study, it was hoped that this analysis would indicate which type and range (or ranges) of briefing could most usefully be developed for further investigation under dynamic simulation conditions.

The results described in Section 7.1 indicated that the use of briefing materials representing the target as viewed from 2 and/or 4 miles ranges had a favourable effect on performance, relative to the map only condition, at target ranges of 2, 3 and 4 miles. This was an encouraging result in that the pictorial briefing material had been developed primarily to facilitate the detection of targets at longer ranges. At the 1 mile target range, however, the use of briefing material which emphasised longer ranges proved detrimental to performance to such an extent that the detection probability at the 1 mile target range was lower than that at the 2 mile target range. This result is of some interest in the context of the static simulation technique used in this experiment but it is of less importance in relation to the possible use of these pictorial briefing materials under dynamic

conditions, which allow the observer a continuous view of the terrain as he approaches the target. If he correctly recognises the target at, say, a range of 2 miles, it is very unlikely that he would be unable to recognise it at shorter ranges. The anomalous results obtained at the 1 mile target range in the present static experiment therefore distorted the overall results in a manner which was misleading in that it would not occur under dynamic conditions. For this reason it was decided that the analyses described in this section should be carried out on the data relating to target ranges of 2, 3 and 4 miles only, the 1 mile range data being excluded except where specifically mentioned.

The complete set of raw data for the map only condition, the map + diagrams conditions and the map + drawings conditions is shown in Table 7.2.1. The analyses of variance carried out on the data taken from Table 7.2.1 (ranges 2, 3 and 4 miles only) are shown in Tables 7.2.2 and 7.2.3. In the first of these analyses the seven briefing conditions have been treated as independent and a 7 (briefing conditions) x 3 (target range) x 8 (targets) factorial analysis has been carried out, the results being shown in Table 7.2.2. The second analysis of variance, shown in Table 7.2.3, did not include the map only data, a 2 (type of briefing) x 3 (range of briefing) x 3 (target range) x 8 (targets) analysis being carried out. In each analysis target range and target differences, and the interaction between them are significant but, whereas Table 7.2.2 shows that briefing conditions are highly significant, Table 7.2.3 indicates that when map only data are excluded neither type of briefing nor range of briefing is significant. In the following sections the effects of these main factors, as compared with the map only condition are considered in more detail, together with the more important interactions. The overall effects of target range, and targets, and the interaction between these two factors, is not further discussed as, although these effects were significant, they have been fully investigated in previous experiments.

Replicated detection probability data for map only, map + diagrams and map + drawings conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	1	1	1	0	1	1	1	1
			0	1	0	1	0	1	1	1
		2	0	1	1	0	0	1	0	1
			0	1	0	1	0	1	1	1
		3	0	1	1	0	0	1	0	0
			0	0	1	0	0	1	0	1
		4	0	0	0	0	0	1	0	1
			0	0	1	0	0	1	0	0
MAP + DIAGRAMS	2	1	0	1	0	0	1	1	1	1
			0	1	0	1	0	1	1	1
		2	0	1	0	1	1	1	1	1
			1	1	1	0	1	1	1	1
		3	0	1	1	1	1	1	0	1
			0	1	1	0	1	1	0	0
		4	0	1	0	0	1	1	0	1
			0	1	1	0	1	0	0	1
	4	1	0	1	0	0	0	1	1	1
			0	1	0	1	0	0	1	1
		2	1	1	0	1	0	1	0	1
			0	1	0	1	0	1	1	0
		3	0	1	1	0	1	1	1	1
			0	0	0	0	0	0	0	1
		4	0	1	1	0	1	1	0	0
			0	0	1	0	1	1	0	1
	2 + 4	1	0	1	0	0	0	1	1	0
			0	1	0	1	1	1	1	1
		2	1	1	0	1	0	1	0	1
			1	1	1	0	0	1	0	1
		3	0	1	1	0	0	1	0	1
			0	0	1	0	1	1	1	1
		4	1	1	1	0	1	1	1	0
			0	1	1	0	1	1	0	1

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	0	1	0	0	0	1	1	1
			0	1	1	1	0	0	1	1
		2	1	1	0	1	0	1	1	1
			1	1	1	1	0	0	0	1
		3	0	1	0	0	0	1	0	0
			0	1	1	0	0	1	0	1
		4	0	1	0	0	0	0	0	1
			0	1	0	0	0	1	0	1
	4	1	0	1	0	1	0	1	1	1
			0	1	0	0	1	1	1	0
		2	0	1	0	0	0	1	1	1
			1	1	1	1	0	1	0	1
		3	0	1	1	0	1	1	0	1
			1	0	0	0	1	1	0	1
		4	0	1	0	1	1	1	0	1
			1	1	0	1	0	1	0	1
	2 + 4	1	1	1	0	1	0	0	1	0
			0	1	0	0	0	1	1	0
		2	0	1	0	0	0	1	1	1
			1	1	1	1	0	1	0	1
		3	1	1	1	1	0	1	0	1
			1	0	1	1	1	1	0	1
		4	0	1	0	1	1	1	0	1
			0	1	0	0	1	1	0	1

NOTES 1 = correct response 0 = incorrect response

These data were obtained from eight subjects per briefing condition, giving rise to 2 readings per cell. The first value in each pair relates to the first group of four subjects per briefing condition, as given in Table 7.1.1.

TABLE 7.2.2

Analysis of variance on detection probability data shown in Table 7.2.1*

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions(C)	6	2.94	0.49	3.06(b)	$p < 0.01$
Target ranges (R)	2	1.50	0.75	4.69(b)	$p < 0.05$
Targets (T)	7	20.16	2.88	18.00(b)	$p < 0.001$
C x R	12	1.92	0.16	1.00(b)	N.S.
C x T	42	7.98	0.19	1.19(b)	N.S.
R x T	14	7.28	0.52	3.25(b)	$p < 0.001$
C x R x T	84	14.62	0.17	1.06(a)	N.S.
Residual (a)	168	27.14	0.16		
Pooled residual (b) (Residual (a) + CRT)	254	41.76	0.16		
TOTAL	335	83.54			

TABLE 7.2.3

Analysis of variance on detection probability data shown in Table 7.2.1*, excluding the data from the map only condition

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing types (B)	1	0.03	0.02	- (c)	N.S.
Briefing ranges (P)	2	0.44	0.22	1.29(c)	N.S.
Target ranges (R)	2	0.92	0.46	2.71(c)	N.S. ($p < 0.10$)
Targets (T)	7	16.41	2.34	13.76(c)	$p < 0.001$
P x B	2	1.09	0.55	3.24(c)	$p < 0.05$
P x R	4	1.11	0.28	1.65(c)	N.S.
P x T	14	1.21	0.09	- (c)	N.S.
B x R	2	0.02	0.01	- (c)	N.S.
B x T	7	2.89	0.41	2.41(c)	$p < 0.05$
R x T	14	7.08	0.51	3.00(c)	$p < 0.01$
P x B x R	4	0.61	0.15	- (b)	N.S.
P x B x T	14	1.92	0.14	- (b)	N.S.
P x R x T	28	5.74	0.21	1.31(b)	N.S.
B x R x T	14	3.06	0.22	1.38(b)	N.S.
P x B x R x T	28	4.13	0.15	- (a)	N.S.
Residual (a)	144	23.50	0.16		
Pooled residual (b) (Residual (a) + PBRT)	172	27.63	0.16		
Pooled residual (c) (Pooled residual (b) + PBR, PBT, PRT, BRT)	232	38.96	0.17		
TOTAL	287	70.16			

*The data from target range 1 mile are not included in these analyses.

7.2.1. Analysis of replicated detection probability data: the effect of briefing conditions.

The analysis of variance given in Table 7.2.2 indicates that the effect of the seven briefing conditions on detection probability is highly significant. The effects of briefing type (diagrams and drawings) and briefing range (2, 4 and 2 + 4 miles), which give rise to six of these briefing conditions, are considered below, in comparison with the map only condition. The significant interaction between these factors in considered in Section 7.2.6.

7.2.2 Analysis of replicated detection probability data: the effect of briefing type.

The mean detection probabilities achieved under each of the briefing type conditions considered in this section are given in Table 7.2.4. The analysis of variance in Table 7.2.3 shows that the effect of briefing type (drawings and diagrams only) is non-significant but, as can be seen in Table 7.2.4, the map only condition resulted in considerably lower detection probability.

TABLE 7.2.4

Detection probabilities for each briefing type

Briefing type	Detection probability	N
MAP ONLY	0.40	48
Map + diagrams	0.59**	144
Map + drawings	0.57**	144

N = Number of readings on which each value in based.
** Significantly higher than the map only value at 1% level.

Dunnett's t test was used to determine whether the map + diagrams and the map + drawings conditions resulted in significantly higher detection probabilities than the map only condition. The results showed that both briefing types resulted in highly significant improvements in detection probability as compared with the map only condition ($p < 0.01$ in each case). As can be seen in Table 7.2.4 there was virtually no difference in effectiveness between the drawings and diagrams conditions, confirming the results of the analysis of variance.

7.2.3 Analysis of replicated detection probability data: the effect of briefing range

The detection probabilities achieved under each condition of briefing range are shown in Table 7.2.5. The map only value is also shown. As stated previously, these data relate to target ranges of 2, 3 and 4 miles only.

TABLE 7.2.5

Detection probabilities for each briefing range

Condition	Detection probability	N
MAP ONLY	0.40	48
Briefing range:		
2 miles	0.55*	96
4 miles	0.55**	96
2 + 4 miles	0.64**	96

N = Number of readings on which each value is based.
* Significantly higher than map only condition, 5% level.
** Significantly higher than map only condition, 1% level.

The mean detection probability associated with the map only condition was compared with each of the three values associated with the different briefing ranges by means of Dunnett's t test. It was found that each briefing range value was significantly higher than that for the map only condition, the 2 mile and the 4 mile values at the 5% significance level, and the 2 + 4 miles value at the 1% level.

Although the analysis of variance given in Table 7.2.2 indicated that briefing range did not have an overall significant effect on detection probability, independent comparisons between the three briefing range conditions showed that the 2 + 4 miles briefing range condition resulted in a significantly higher detection probability than either the 4 mile or the 2 mile briefing range condition (Student's t, one-tail tests at 5% level). As shown in Table 7.2.5, there was no difference between the 2 mile and the 4 mile briefing range values.

7.2.4 Analysis of replicated detection probability data: the interaction between briefing type and target range.

The analysis of variance given in Table 7.2.3 shows that the interaction between briefing type and target range (2, 3 and 4 miles) is not significant. The relevant data are given in Table 7.2.6 and shown graphically in Figure 7.2.1, together with the map only data for comparison purposes. It can be seen that, at each of the three target ranges included in the analysis of variance, differences between the drawings and the diagrams conditions are very slight, which is in accordance with the extremely small variance associated with the briefing type x target range interaction in Table 7.2.3.

TABLE 7.2.6

The interaction between target range and briefing type

	Target range (miles)				N
	(1)	2	3	4	
MAP ONLY	(0.75)	0.56	0.37	0.25	16
Map + diagrams	(0.56)	0.67	0.56	0.54*	48
Map + drawings	(0.52)	0.65	0.56	0.50*	48
Mean for maps + diagrams and maps + drawings	(0.54)	0.66	0.56	0.52**	96

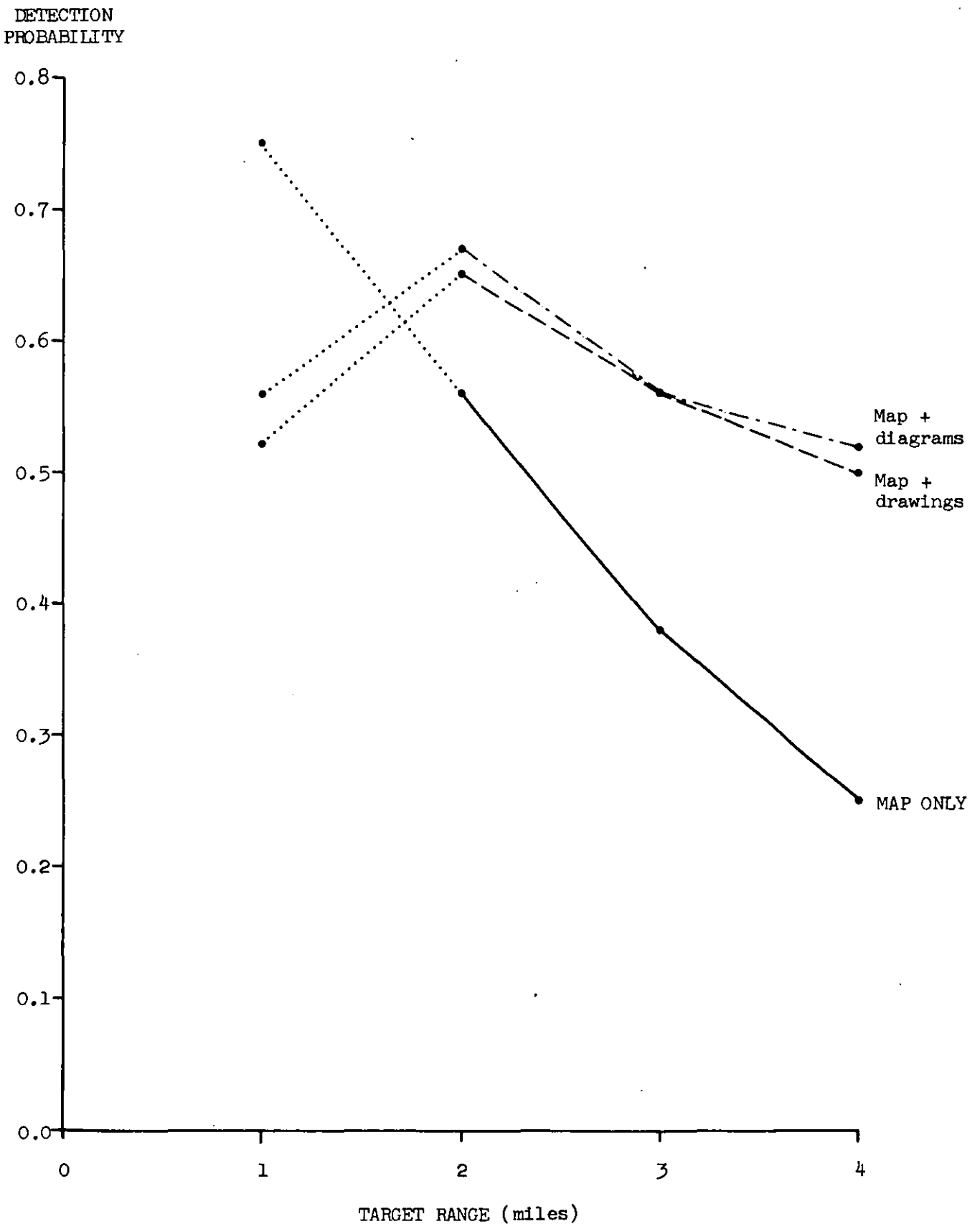
N = Number of readings on which each value is based.
* Significantly higher than corresponding value for map only, 5% level.
** Significantly higher than corresponding value for map only, 1% level.

As shown in Figure 7.2.1, under both the drawings and diagrams conditions, detection probability deteriorates less rapidly with increasing range than under the map only condition, although this could not be shown by the analysis of variance in Table 7.2.3, in which the map only data had to be excluded.

FIGURE 7.2.1

The interaction between briefing type and target range.

(replicated data)



Dunnett's t test was used to compare the detection probability at each target range under the map only condition with the corresponding values under the drawings and diagrams conditions. Only the values relating to the 4 mile target range were found to be significantly higher than the corresponding map only value. In addition, the mean detection probability at each range for the drawings and diagrams combined was calculated and these values compared with the corresponding map only values by means of Student's t test. Significant improvements were found at 3 miles and at 4 miles but not at 2 miles.

Since the data given in Table 7.2.6 is broken down into individual target range values the data for the 1 mile range is also shown although, for reasons discussed previously, these data have not been included in the main analyses described in this section. It can be seen that, as shown by the analyses in Section 7.1, the drawings and diagrams conditions have a detrimental effect on performance at the 1 mile target range.

7.2.5 Analysis of replicated detection probability data: the interaction between briefing range and target range.

The analysis of variance given in Table 7.2.3 shows that the interaction between target range and the range at which the briefing material was presented is not significant. The map only condition, which was not associated with a particular briefing range, was not included in the analysis. The relevant data are shown in Table 7.2.7, together with the map only data for comparison purposes.

TABLE 7.2.7

The interaction between range of briefing and range of target

Briefing condition	Range of target (miles) 1	2	3	4	N
MAP ONLY	(0.75)	0.56	0.38	0.25	16
Briefing range:					
2 miles	(0.59)	0.75	0.50	0.41	32
4 miles	(0.53)	0.59	0.53	0.53*	32
2 + 4 miles	(0.50)	0.63	0.66*	0.63*	32

N = Number of readings on which each value is based.
* Significantly higher than the corresponding value for the map only condition, 5% level.

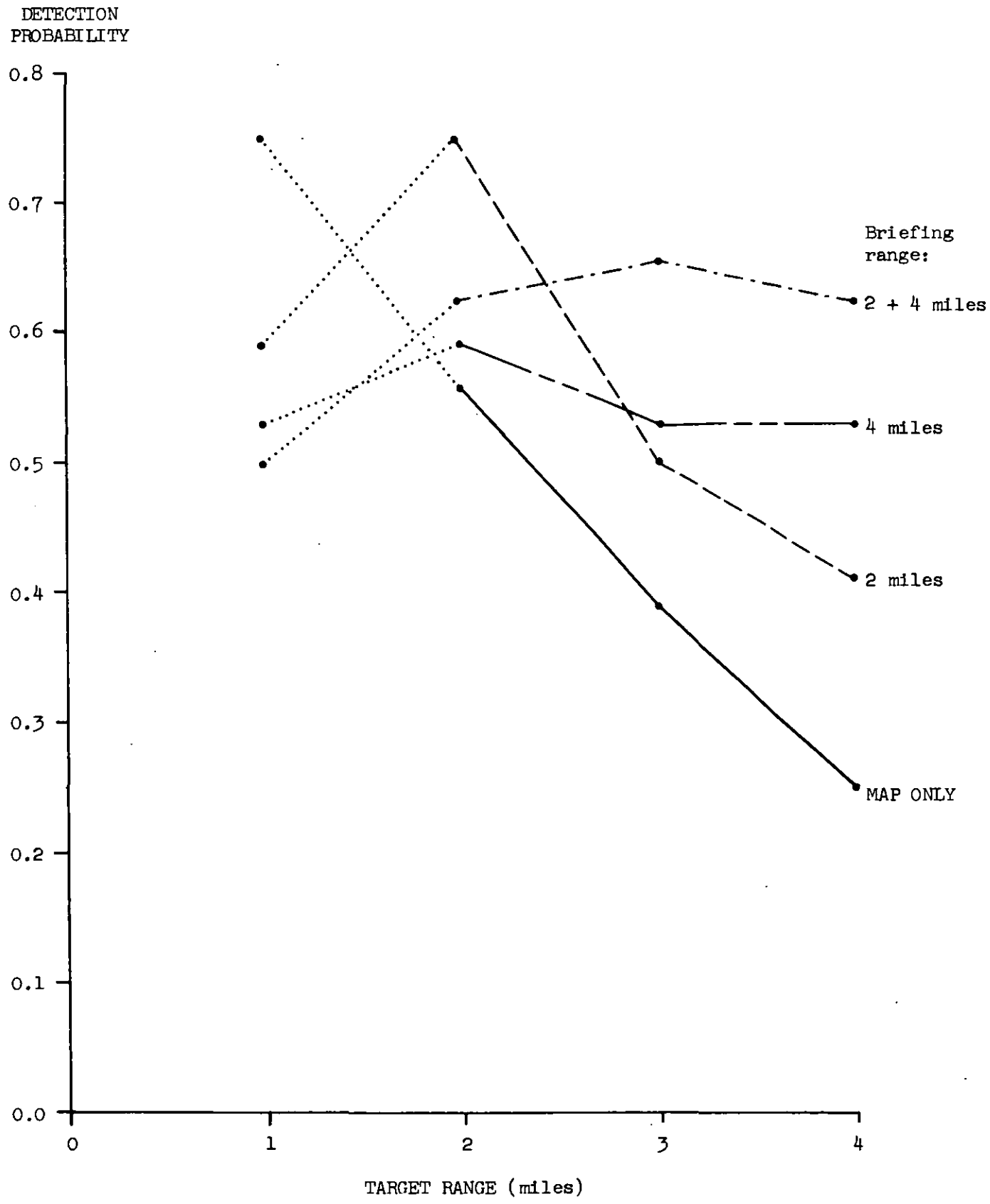
In Table 7.2.7, and in Figure 7.2.2 which shows the data graphically, the values for the 1 mile range condition are included to complete the set of data, but as indicated previously these 1 mile range values have not been included in the other analyses in this section.

Dunnett's t test was used to determine whether any of the values shown in Table 7.2.7 relating to the three briefing range conditions were significantly higher than the corresponding values for the map only condition. For the 4 mile target range both the 4 mile briefing

FIGURE 7.2.2

The interaction between briefing range and target range.

(replicated data)



and the 2 + 4 mile briefing resulted in significantly higher detection probability. For the 3 mile target range, briefing at 2 + 4 miles significantly improved detection probability. Otherwise none of the values reached the 5% significance level although,as can be seen in Figure 7.2.2, the 2 mile briefing produced a considerable improvement in performance at the 2 mile range.

7.2.6 Analysis of replicated detection probability data: the interaction between briefing type and briefing range.

The analysis of variance in Table 7.2.3 shows that the interaction between briefing type and briefing range is significant at the 5% level. Mean detection probability values for each briefing type and briefing range are given in Table 7.2.8, together with the value obtained under the map only condition. These data are shown graphically in Figure 7.2.3.

TABLE 7.2.8

The interaction between briefing type and briefing range

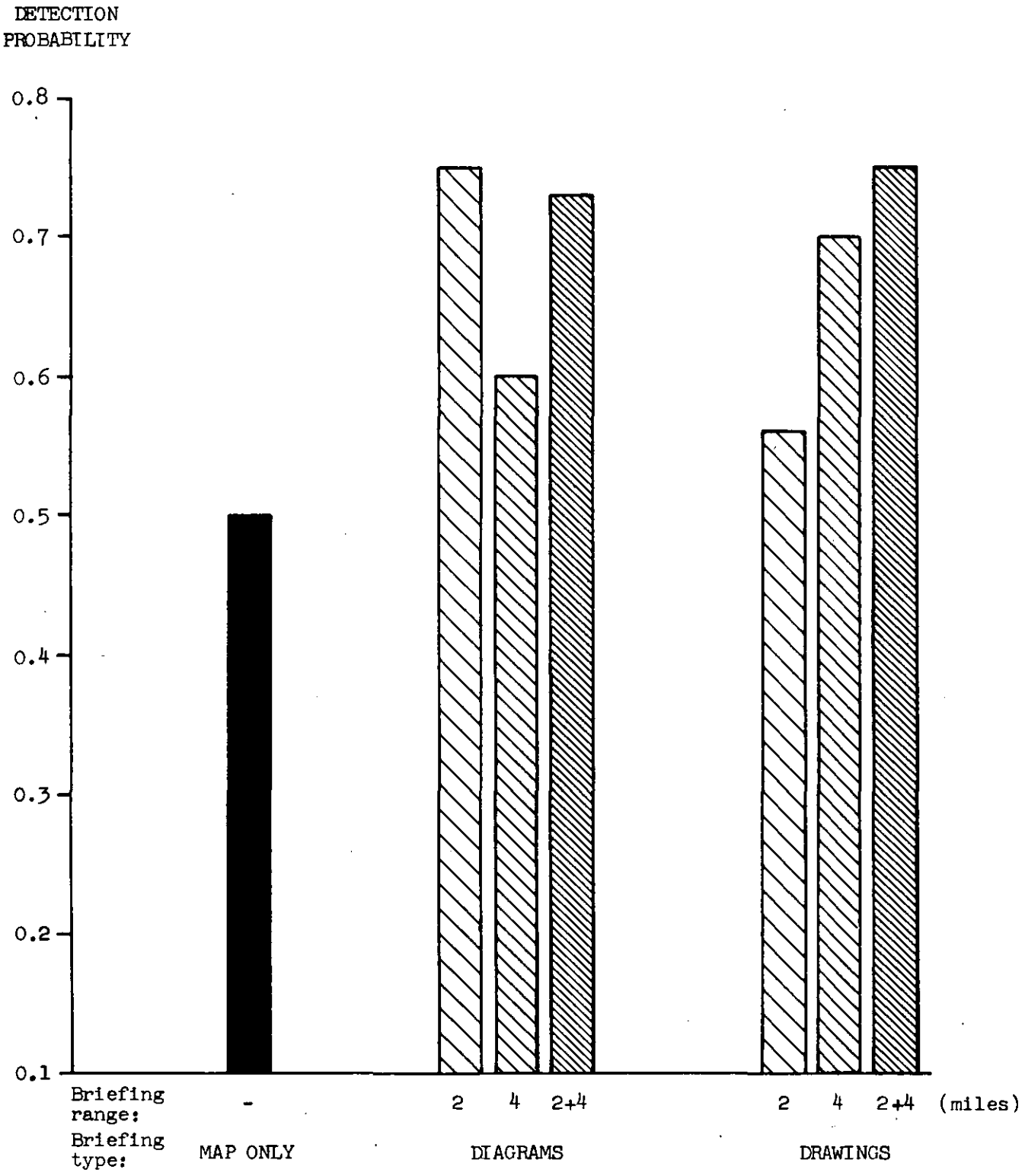
Briefing type	Briefing range			N
	2 miles	4 miles	2 + 4 miles	
Map + diagrams	0.65**	0.50	0.63*	48
Map + drawings	0.46	0.60*	0.65**	48
MAP ONLY	0.40			48

N = Number of readings on which each value is based.
* Significantly higher than map only value, 5% level.
** Significantly higher than map only value, 1% level.

FIGURE 7.2.3

The interaction between briefing type and briefing range.

(replicated data)



The data from target range 1 mile are not included in this analysis.

Dunnett's t test was used to determine whether the detection probabilities achieved under the drawings and diagrams conditions at each briefing range were significantly higher than that for the map only condition. It can be seen in Table 7.2.8 that only in two cases, map + diagrams at 4 miles, and map + drawings at 2 miles, did the values fail to reach significance. It was also found that the map + diagrams at 2 miles resulted in a significantly higher detection probability than the map + drawings at 2 miles. At the 4 mile briefing range the effect was reversed, the map + 4 mile drawings resulting in a considerably higher detection probability than the map + 4 mile diagrams, although this difference did not reach the 5% level using Student's t test.

This reversal of effect gave rise to the interaction between briefing type and briefing range found in the analysis of variance in Table 7.2.3 and shown graphically in Figure 7.2.3. There is no obvious explanation of this interaction. Inspection of the raw data in Table 7.2.1 showed that the difference between the effects of drawings and diagrams at the 2 mile briefing range arose largely from one target, Target 15. Detection probability for this target (ranges 2, 3 and 4 miles only) using 2 mile briefing was 0.00 for the drawings as compared with 1.00 for the diagrams. However, in the case of the 4 mile briefing range the detection probabilities achieved with the drawings were higher than those for the diagrams for six out of the eight targets. Therefore the interaction cannot be ascribed entirely to the anomalous results for one target.

7.2.7 Analysis of replicated detection probability data: the interaction between briefing type and targets.

Although the analysis of variance given in Table 7.2.2 does not show a significant interaction between briefing conditions and targets, there is a significant interaction, shown by the analysis of variance given in Table 7.2.3, between briefing types and targets. This indicates that the drawings and diagrams differ in their effect on individual targets. The mean detection probabilities for each target under the diagrams and drawings conditions are shown in Table 7.2.9, together with the corresponding values obtained under the map only condition. These data are shown graphically in Figure 7.2.4.

TABLE 7.2.9

The interaction between targets and briefing types

	TARGETS								N
	1	3	6	13	15	16	17	20	
MAP ONLY	0.00	0.50	0.67	0.16	0.00	1.00	0.16	0.67	6
Map + diagrams	0.28	0.83	0.67	0.28	0.67*	0.89	0.33	0.78	18
Map + drawings	0.44*	0.89*	0.38	0.50	0.33	0.89	0.17	0.94	18

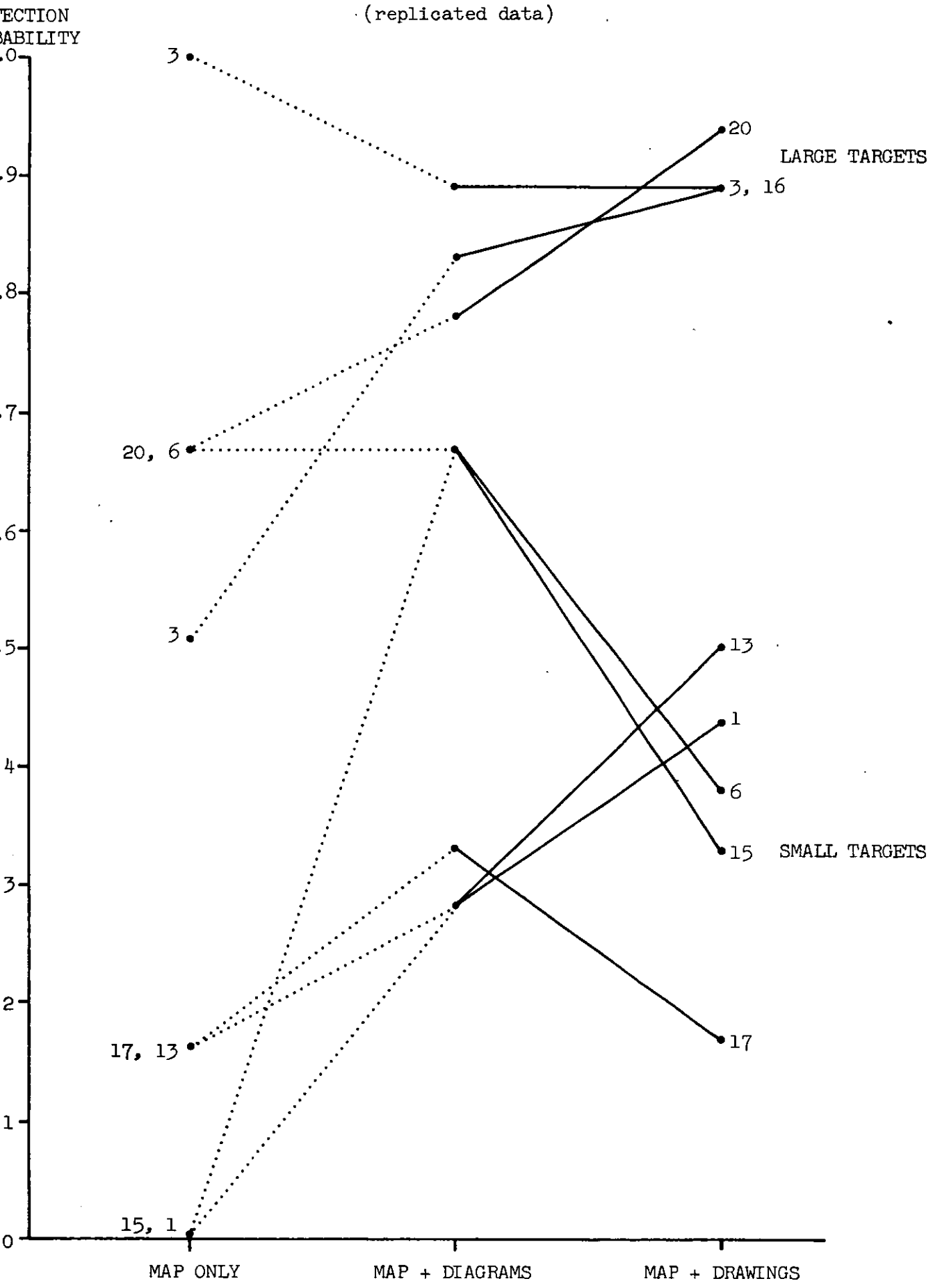
N = Number of values on which each reading is based.
* Significantly higher than corresponding map only value, 5% level.

Dunnett's t test was used to determine for which targets either the drawings or the diagrams conditions resulted in significantly higher detection probabilities than the map only condition. Calculations showed that to reach the 5% level the improvement in detection probability had to reach 0.36 and, as shown in Table 7.2.9, only three values reached this level although considerable improvement occurred for several other targets. For Target 16 the detection probability

FIGURE 7.2.4

The interaction between targets and briefing types

(replicated data)



For greater clarity these data have been shown graphically rather than in the form of a histogram.

The data from target range 1 mile have been omitted from this analysis.

achieved under the map only condition was 1.00, thus leaving no scope for improvement under the drawings and diagrams conditions and, in fact, a slight deterioration took place. The only other target to show no improvement under the additional briefing conditions was Target 6. There is no apparent reason why the pictorial briefing material for this target should be less effective than that for the other targets, but there was some evidence from a previous experiment that the map only value was unexpectedly high for this relatively difficult target.

The interaction between targets and briefing conditions was further investigated by dividing the eight targets into two groups, Targets 3, 16 and 20 comprising the group of large targets, and Targets 1, 6, 13, 15 and 17 the group of small targets. The variation due to the targets x briefing types interaction was then partitioned to determine whether target size interacted with briefing type. This analysis is shown in Table 7.2.10.

TABLE 7.2.10

Partition of targets x briefing types interaction

Source	D.F.	S.S.	M.S.	V.R.	Significance
B x T*	7	2.89	0.41	2.41	$p < 0.05$
B x Target size	1	0.49	0.49	2.89	N.S. ($p < 0.10$)
B x T (within small targets)	4	2.32	0.58	3.42	$p < 0.01$
B x T (within large targets)	2	0.08	0.04	-	N.S.
RESIDUAL*	292	50.55	0.17		

*These values are taken fron the analysis of variance in Table 7.2.3.

This analysis shows that the interaction between targets and briefing types occurs only in the group of small targets. This can be seen in Figure 7.2.4 which shows that the three lines representing the large targets are virtually coincident whereas of the five lines representing small targets, two slope upwards from diagrams to drawings and two slope downwards, thus giving rise to the highly significant interaction between small targets and briefing types.

The interaction between type of briefing and target size fails to reach the 5% significance level, although $p < 0.10$ which suggests a tendency for targets of different sizes to be differently affected by the briefing types. This can also be seen from Table 7.2.11.

TABLE 7.2.11

The interaction between target size and briefing type

	Large targets (3)	N	Small targets (5)	N
MAP ONLY	0.72	18	0.20	30
Map + diagrams	0.83	54	0.45**	90
Map + drawings	0.91	54	0.36*	90

N = Number of readings on which each value is based.
**Significantly higher than map only value at 1% level.
*Significantly higher than map only value at 5% level.

As shown in this table, the improvement in detection probability due to the pictorial briefing materials is proportionately much greater for the small targets than for the large ones. This improvement is also greater in absolute terms, but it should be noted that the low detection probability values obtained for the small targets under the map only condition allow greater possibility of improvement than the relatively high values obtained for large targets under map only condition. Dunnett's t test showed that both the drawings and the diagrams resulted in

significantly higher detection probabilities than the map only for small targets but neither of the values for large targets reached significance, although that for drawings was very close to it. It can be seen from Table 7.2.11 that, whereas diagrams proved to be the more effective form of briefing for small targets, for the large targets drawings were more effective. This apparent interaction should not be over-emphasised since it failed to reach the 5% significance level but it is perhaps worth further investigation.

Analyses were carried out to determine whether target size interacted with briefing range, i.e. whether the optimum briefing range for large targets was different from that for small targets. No such interaction was found and the data suggested that for both large and small targets the 2 mile and the 4 mile briefing ranges were equally effective. In each case the 2 + 4 mile briefing ranges resulted in greater improvement than either of these briefing ranges separately.

7.3 SEARCH TIMES - ANALYSIS OF BASIC DATA FOR ALL BRIEFING CONDITIONS.

The analysis of the search time data was analogous to that of the detection probability data, i.e. the effects of the five different types of briefing materials were compared using the basic data obtained from four subjects per condition, and subsequently a further analysis of the map only, map + diagrams and map + drawings conditions (excluding target range 1 mile) was carried out using the replicated data from 8 subjects per condition.

The basic raw data are shown in Table 7.3.1. Two analyses of variance were carried out on these data. In the first, given in Table 7.3.2, each of the twelve briefing conditions was treated as independent and a three-way analysis of variance carried out. Two of the main factors, briefing conditions and targets, were highly significant but the effect of target range failed to reach the 5% level. None of the interactions was significant. In the second analysis of variance, shown in Table 7.3.3, the map only data were excluded and the remaining eleven briefing conditions partitioned into briefing type (4 levels) and briefing range (3 levels), with due allowance being made for the missing data relating to the map + target circles (2 + 4 miles) condition. This analysis showed that the effects of briefing type and targets were highly significant, but the effects of briefing range and target range, and all interactions, were non-significant.

Basic search time data for all briefing conditions

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	9.0	16.6	1.0	3.0	6.4	3.2	3.2	14.2
		2	4.4	6.6	7.2	5.4	6.4	6.0	7.6	2.4
		3	14.8	8.0	22.6	11.6	11.6	2.6	9.8	3.2
		4	19.2	4.2	13.4	12.4	4.0	10.4	18.8	6.0
MAP + TARGET CIRCLES	2	1	11.8	8.0	11.0	27.2	8.4	5.2	4.0	27.8
		2	27.4	4.8	18.8	8.2	29.8	4.6	11.0	3.6
		3	11.4	15.2	3.0	18.0	35.8	26.2	6.2	7.0
		4	31.4	3.6	46.8	7.6	14.2	17.2	29.6	7.2
	4	1	16.2	3.0	42.6	16.2	7.2	17.2	10.4	17.4
		2	30.4	10.8	19.2	12.2	35.0	7.2	24.2	7.4
		3	13.2	17.0	8.8	26.4	10.0	16.2	15.6	22.2
		4	8.8	7.2	10.4	24.2	23.8	40.6	15.8	2.8
MAP + DIAGRAMS	2	1	29.8	3.8	15.4	10.6	3.4	9.2	1.2	4.0
		2	15.0	12.4	7.6	10.4	15.8	4.8	7.2	2.8
		3	25.2	13.0	26.2	6.8	9.4	13.2	7.6	14.8
		4	9.6	8.6	9.2	13.6	34.0	9.2	12.8	9.6
	4	1	6.6	7.8	27.0	6.8	56.4	23.0	2.8	27.8
		2	16.4	17.0	42.4	1.6	4.6	4.6	6.4	29.0
		3	31.6	8.8	9.8	21.2	6.6	5.4	31.8	6.4
		4	8.0	3.8	5.4	50.4	18.2	21.8	27.4	11.0
	2 + 4	1	5.0	3.0	12.8	9.6	37.6	11.4	3.0	4.2
		2	24.4	10.6	7.0	4.6	21.2	2.2	5.2	5.6
		3	21.4	3.2	7.8	41.6	7.0	22.8	25.2	3.6
		4	6.0	3.4	20.2	4.2	6.2	4.2	18.4	15.0

All the search times are given in seconds.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	15.8	19.8	3.0	8.0	13.6	11.0	5.4	5.4
		2	13.4	8.0	25.8	10.0	5.4	2.6	20.8	4.0
		3	28.6	3.0	16.0	5.2	18.4	3.8	27.0	2.0
		4	6.6	12.2	47.8	13.8	15.4	7.0	19.6	12.8
	4	1	11.6	12.0	11.0	11.8	6.2	11.4	6.8	13.2
		2	7.0	4.6	14.4	11.0	18.2	8.2	15.8	3.6
		3	5.2	6.6	9.2	16.6	7.4	18.8	7.2	7.6
		4	36.2	6.6	28.4	5.4	25.8	7.6	12.6	4.8
	2 + 4	1	26.0	13.2	12.8	20.0	10.4	48.2	3.2	9.0
		2	18.6	11.8	13.0	5.8	12.4	2.4	17.2	2.8
		3	20.4	27.6	25.0	7.6	23.2	16.8	7.8	13.0
		4	8.8	2.0	9.0	9.4	17.2	21.8	29.2	21.4
MAP + PHOTO-GRAPHS	2	1	15.0	17.2	12.2	9.8	8.6	9.8	5.0	9.2
		2	6.8	2.2	2.6	4.8	4.4	8.8	4.2	2.6
		3	4.6	4.2	4.0	14.0	5.2	9.4	3.2	2.0
		4	20.8	5.6	7.0	14.4	5.8	11.6	18.2	6.2
	4	1	10.4	4.2	3.6	13.0	13.0	14.2	1.2	8.4
		2	9.8	1.6	8.8	2.6	21.8	6.4	18.2	2.8
		3	3.4	10.0	3.2	9.6	4.8	3.4	10.4	13.4
		4	9.0	4.2	11.2	2.8	10.2	3.2	8.4	1.2
	2 + 4	1	19.0	2.8	7.8	8.8	26.0	7.2	4.0	3.6
		2	5.4	1.2	7.4	5.4	1.6	2.8	4.0	1.6
		3	2.2	2.4	5.4	4.4	2.6	15.6	4.6	4.6
		4	7.4	2.8	4.0	11.8	5.0	4.8	4.6	4.0

The values underlined relate to incorrect responses

TABLE 7.3.2

Analysis of variance on search time data shown in Table 7.3.1

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions (C)	11	5086.40	462.40	6.20(b)	$p < 0.001$
Target ranges (R)	3	505.59	168.53	2.26(b)	N.S. (p 0.10)
Targets (T)	7	2256.10	322.30	4.32(b)	$p < 0.001$
C x R	33	1833.81	55.57	- (a)	N.S.
C x T	77	2889.04	37.52	- (a)	N.S.
R x T	21	2192.82	104.42	1.20(a)	N.S.
Residual (a)	231	20062.35	86.85		
Pooled residual (b) (Residual (a) + CR, CT, RT)	362	26979.86	74.53		
TOTAL	383	34826.11			

TABLE 7.3.3

Analysis of variance on search time data shown in Table 7.3.1, excluding data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing type (B)	3	3620.25	1206.75	15.08(c)	$p < 0.001$
Briefing range (P)	2	241.40	120.70	1.51(c)	N.S.
Target range (R)	3	419.16	139.72	1.75(c)	N.S.
Targets (T)	7	2302.51	328.93	4.11(c)	$p < 0.001$
B x P	*5	819.95	163.99	2.03(b)	N.S. (p <0.10)
B x R	9	440.01	48.89	- (b)	N.S.
B x T	21	976.50	46.50	- (b)	N.S.
P x R	6	761.88	126.98	1.57(b)	N.S.
P x T	14	587.72	41.08	- (b)	N.S.
R x T	21	2273.25	108.25	1.34(b)	N.S.
B x P x R	*15	557.09	37.14	- (a)	N.S.
B x P x T	*35	1140.34	32.58	- (a)	N.S.
B x R x T	63	6275.75	99.62	- (a)	N.S.
P x R x T	42	3026.10	72.05	- (a)	N.S.
Residual (a)	105	10024.75	95.47		
Pooled residual (b) (Residual (a) + BPR, BPT, BRT, PRT)	260	21024.03	80.86		
Pooled residual (c) (Pooled residual (b)+ BP, BR, BT, PR, PT, RT)	336	26883.34	80.01		
TOTAL	351	33466.66			

*These values are reduced to take into account the missing data for the map + target circles, 2 + 4 miles ranges, condition.

7.3.1 Search times: the effect of briefing conditions.

As shown in Table 7.3.2, the effect of briefing conditions on search time is highly significant but, as in the case of the detection probability data, it is more meaningful to consider the separate effects of briefing type and briefing range, the two factors that give rise to the briefing conditions. The effects of these factors are shown in the analysis of variance in Table 7.3.3. This analysis does not include the map only condition which was not associated with any briefing range. In the analyses that follow the map only condition is treated as the control condition and the effects of briefing types and ranges are compared with that for the map only condition. These multiple comparisons were made by means of Dunnett's t test, the appropriate value of t being selected according to the number of comparisons being made.

7.3.2 Search times: the effect of briefing types.

Briefing type has a highly significant effect on search time as shown in Table 7.3.3. The mean search times for each of the four briefing types are shown in Table 7.3.4, together with the map only value for comparison purposes.

TABLE 7.3.4

The effect of briefing type on search time

Briefing type	Search time (seconds)	N
MAP ONLY	8.6	32
Map + target circles	16.1*	64
Map + diagrams	13.6*	96
Map + drawings	13.5*	96
Map + photographs	7.3	96

N = Number of readings on which each value is based.
* Significantly different from map only condition at 5% level.

It can be seen in Table 7.3.4 that, with the exception of the photographs, all the types of additional briefing resulted in higher mean search times than the map only condition. These differences were significant at the 5% level. The map + photographs condition resulted in a marginally lower mean search time than the map only condition butthe difference was not significant. The low value resulting from the use of photographs for briefing can be explained by the fact that one third of the 96 readings obtained for this condition related to presentations in which subjects were required to find the target in a photograph identical to one shown to them for briefing purposes. As can be seen in the raw data, Table 7.3.1, these presentations resulted in exceptionally low search times. The mean search time for the map + photographs condition was also oonsiderably lower than those for the other types of briefing material, these differences being highly significant (Student's t test).

These results clearly suggest that the use of additional briefing materials, with the exception of photographs, increases the time required to locate the target. However, this result must be regarded with some caution as the results of previous work suggest that the mean search time obtained in the present experiment for the map only condition is unexpectedly low. Six of the targets used in the present experiment had also been used under closely comparable conditions in two previous experiments. The mean search time values obtained in these experiments were 13.4 seconds and 15.7 seconds respectively, as compared with 8.5 seconds for the same targets and target ranges in the present experiment under the map only condition. This indicates that it may be misleading to use the map only value obtained in the present experiment as a basis for comparisons with other briefing conditions. The higher mean values found in previous experiments are closely comparable with the values obtained under the drawings and diagrams briefing conditions in the present experiment. These briefing conditions are further analysed using the replicated data in Section 7.4 From the above results it can be concluded

that, with the exception of photographs, additional briefing materials do not reduce the mean search time required and appear, in fact, to increase it although this latter result must be interpreted cautiously.

7.3.3 Search times: the effect of briefing range.

The effect of briefing range on search time is non-significant in the analysis of variance given in Table 7.3.3. The relevant mean search times are given in Table 7.3.5, together with the map only value for comparison purposes.

TABLE 7.3.5

The effect of briefing range on search time

	Search time (seconds)	N
MAP ONLY	8.6	32
Briefing range:		
2 miles	12.0	128
4 miles	13.3*	128
2 + 4 miles	11.3	96

N = Number of readings on which each value is based.
* Significantly different from map only condition at the 5% level.

It can be seen that the mean search times at each briefing range are all higher than the value for the map only condition, but only one of the values is significantly different from the map only value. In comparing the three briefing range values with that for the map only condition exactly the same considerations apply in relation to the unexpectedly low value for this condition as were discussed in the previous sections.

There were no significant differences between the values for the three different briefing ranges, confirming the results of the analysis of variance.

7.3.4 Search times: the interaction between briefing type and target range.

The analysis of variance given in Table 7.3.3 shows that the interaction between briefing type and target range is non-significant. The mean search time values for each briefing type at each target range are shown in Table 7.3.6. The map only values are given for comparison purposes although these data were not included in the analysis of variance in Table 7.3.3.

TABLE 7.3.6

The effect of target range on search time for each briefing type

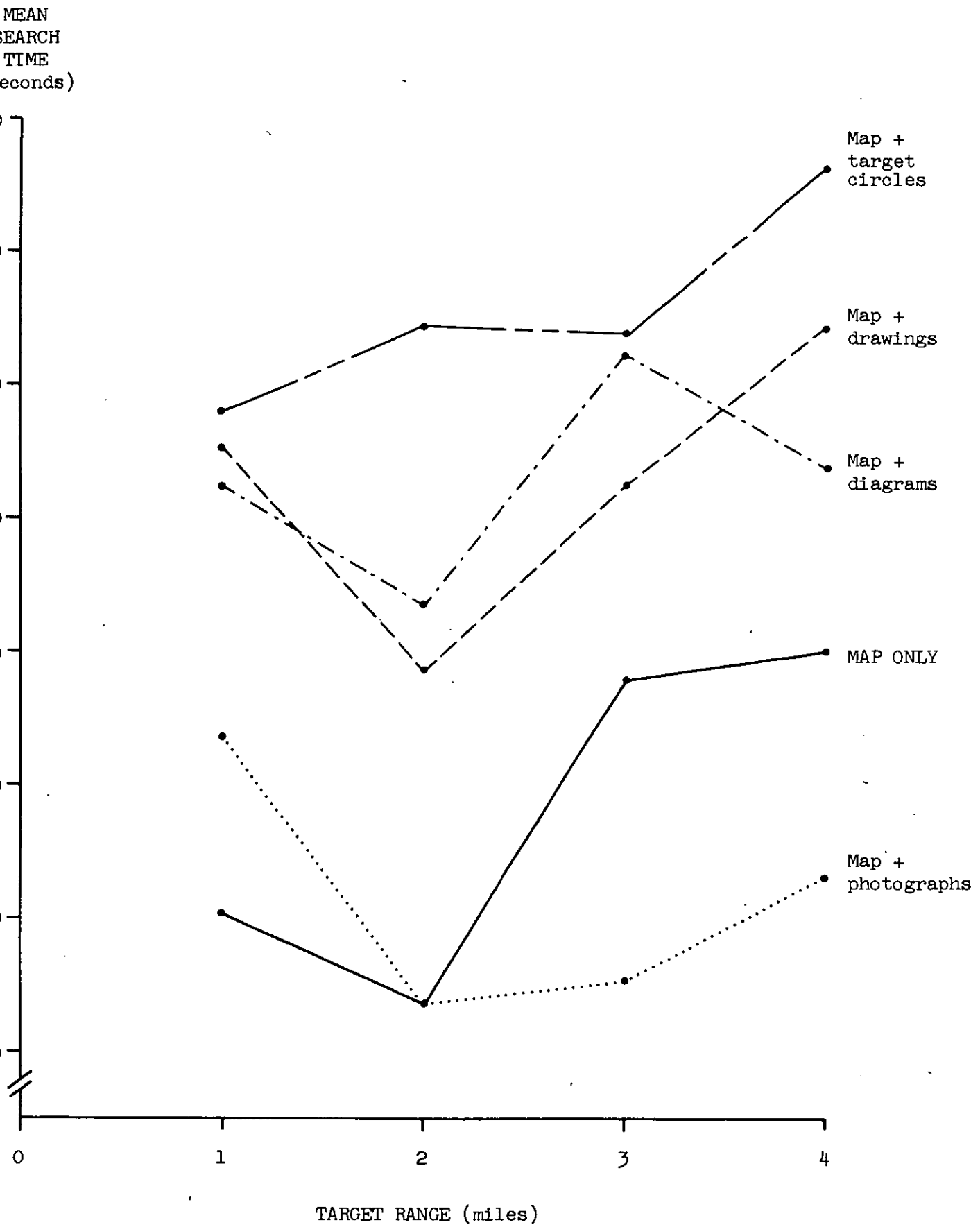
Briefing type	Target range (miles) 1	2	3	4	N
MAP ONLY	7.1	5.8	10.5	11.1	8
Map + target circles	14.6	15.9*	15.8	18.2	16
Map + diagrams	13.4	11.6	15.4	13.7	24
Map + drawings	14.0	10.7	13.5	15.9	24
Map + photographs	9.7	5.7	6.1	7.7	24

N = Number of readings on which each value is based.
All the search time values are given in seconds.

The data given in Table 7.3.6 are shown graphically in Figure 7.3.1. It can be seen that, except for the target circles condition, mean search times are lower, i.e. performance is better, for the 2 miles range than for the 1 mile range. This result is analogous to that found in the analysis of the detection probability data for the conditions in which additional briefing materials were used. For the map only condition it would be expected, on the basis of previous experiments, that search time would increase consistently with increase in target range. However, the slight decrease that occurs in mean search time for the 2 mile range under the map only condition in the present experiment is non-significant and therefore likely to be due to random effects.

FIGURE 7.3.1

The interaction between target range and briefing type



It can be seen in Figure 7.3.1 that the general form of the data is similar for each of the four conditions using additional briefing materials. This is in accordance with the fact that the interaction between briefing type and target range is non-significant. Dunnett's t test showed that only one of the individual range means (target circles at 2 miles range) differed significantly from the corresponding map only value.

7.3.5 Search times: the interaction between briefing range and target range

The analysis of variance given in Table 7.3.3 indicates that the interaction between briefing range and target range is non-significant. Since the overall effects of each of these factors individually are also non-significant, the interaction beteeen them need not be considered in detail.

7.4 SEARCH TIME - ANALYSIS OF REPLICATED DATA FOR MAP ONLY, MAP + DIAGRAMS AND MAP + DRAWINGS CONDITIONS

This analysis, which was carried out on the replicated data obtained for seven of the briefing conditions, (map only; map + diagrams, 2, 4 and 2 + 4 miles; map + drawings, 2, 4 and 2 + 4 miles), was primarily intended to determine more reliably whether there were any significant differences between drawings and diagrams and whether these additional briefing materials resulted in significantly different search times from the map only condition. The raw data are shown in Table 7.4.1. This table includes the data from target range 1 mile but, for the same reasons as outlined in Section 7.2, these data were excluded from the analyses described in this section. Two analyses of variance were carried out on the data for target ranges 2, 3 and 4 miles. In the first, given in Table 7.4.2, the seven briefing conditions were treated as independent and the results showed that briefing conditions had no significant effect on search time. In the second analysis of variance, given in Table 7.4.3, the map only data were excluded and the effects of briefing type (i.e. drawings or diagrams) and briefing range (i.e. 2, 4 or 2 + 4 miles) were analysed separately. The results showed that neither of these factors significantly affected search time.

The significance of the three-way interaction in the analysis of variance in Table 7.4.2 and the four-way interaction in the analysis in Table 7.4.3 is of some interest. These interactions represent the variance of the two readings in each cell and the fact that they are significant suggests that, in terms of search time, there were differences between the subjects in the two groups.

In the following section the effects of diagrams and drawings on search time, and the effects of briefing range, are considered briefly but no other analyses were carried out.

Replicated search time data for map only, map + diagrams and map + drawings conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	9.0 8.4	16.6 22.0	1.0 11.6	3.0 7.2	6.4 14.8	3.2 8.8	3.2 14.0	14.2 5.4
		2	4.4 13.2	6.6 11.6	7.2 21.4	5.4 11.6	6.4 7.2	6.0 7.2	7.6 16.2	2.4 5.8
		3	14.8 15.4	8.0 4.6	22.6 11.2	11.6 5.4	11.6 11.6	2.6 5.4	9.8 22.0	3.2 16.0
		4	19.2 11.8	4.2 11.6	13.4 10.0	12.4 9.6	4.0 29.4	10.4 13.2	18.8 5.4	6.0 19.2
MAP + DIAGRAMS	2	1	29.8 10.8	3.8 2.4	15.4 16.8	10.6 5.4	3.4 6.2	9.2 5.6	1.2 4.4	4.0 3.6
		2	15.0 31.6	12.4 3.8	7.6 5.0	10.4 8.0	15.8 16.6	4.8 5.2	7.2 3.2	2.8 9.4
		3	25.2 16.6	13.0 1.6	26.2 18.0	6.8 5.6	9.4 7.8	13.2 8.2	7.6 4.4	14.8 4.2
		4	9.6 4.4	8.6 9.4	9.2 23.2	13.6 28.2	34.0 5.4	9.2 17.4	12.8 21.4	9.6 10.4
	4	1	6.6 3.6	7.8 4.6	27.0 6.4	6.8 29.0	56.4 2.0	23.0 50.8	2.8 6.0	27.8 7.8
		2	16.4 32.2	17.0 5.8	42.4 9.4	1.6 8.2	4.6 9.4	4.6 1.4	6.4 32.4	29.0 8.6
		3	31.6 4.4	8.8 36.2	9.8 5.6	21.2 5.6	6.6 7.4	5.4 11.2	31.8 2.2	6.4 18.4
		4	8.0 8.0	3.8 10.4	5.4 23.6	50.4 3.2	18.2 36.2	21.8 8.8	27.4 4.8	11.0 1.4
	2 + 4	1	5.0 14.0	3.0 6.0	12.8 18.6	9.6 5.4	37.6 19.6	11.4 12.6	3.0 2.4	4.2 10.4
		2	24.4 14.0	10.6 8.6	7.0 10.4	4.6 11.0	21.2 13.0	2.2 4.8	5.2 18.6	5.6 10.2
		3	21.4 44.0	3.2 4.8	7.8 2.8	41.6 10.6	7.0 16.0	22.8 8.6	25.2 15.2	3.6 6.6
		4	6.0 27.2	3.4 7.2	20.2 12.0	4.2 12.8	6.2 13.0	4.2 18.8	18.4 18.4	15.0 13.8

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	15.8 6.4	19.8 6.4	3.0 8.0	8.0 15.8	13.6 14.6	11.0 7.2	5.4 9.6	5.4 2.6
		2	13.4 27.0	8.0 4.6	25.8 5.0	10.0 3.8	5.4 4.8	2.6 12.0	20.8 6.2	4.0 4.4
		3	28.6 5.4	3.0 8.4	16.0 8.0	5.2 8.0	18.4 9.4	3.8 5.8	27.0 16.8	2.0 4.8
		4	6.6 7.2	12.2 5.0	47.8 17.2	13.8 5.6	15.4 7.2	7.0 6.0	19.6 4.0	12.8 15.0
	4	1	11.6 18.2	12.0 12.6	11.0 12.0	11.8 12.5	6.2 10.2	11.4 11.8	6.8 3.0	13.2 7.4
		2	7.0 6.0	4.6 5.6	14.4 5.0	11.0 8.4	18.2 21.8	8.2 4.6	15.8 12.0	3.6 10.8
		3	5.2 8.6	6.6 9.6	9.2 13.2	16.6 15.6	7.4 5.8	18.8 3.8	7.2 13.6	7.6 5.4
		4	36.2 15.2	6.6 9.4	28.4 22.6	5.4 8.0	25.8 11.4	7.6 11.2	12.6 10.2	4.8 7.4
	2 + 4	1	26.0 13.4	13.2 2.4	12.8 11.2	20.0 8.0	10.4 9.2	48.2 6.2	3.2 3.0	9.0 14.6
		2	18.6 11.8	11.8 6.4	13.0 9.0	5.8 15.2	12.4 18.2	2.4 6.2	17.2 12.0	2.8 7.8
		3	20.4 12.2	27.6 7.2	25.0 13.0	7.6 5.4	23.2 5.2	16.8 6.2	7.8 9.8	13.0 3.2
		4	8.8 13.8	2.0 3.0	9.0 12.4	9.4 18.0	17.2 4.0	21.8 3.4	29.2 8.2	21.4 3.4

NOTES All the search time values are given in seconds. These data were obtained from eight subjects per briefing condition, giving rise to 2 readings per cell. The first value in each pair relates to the first group of four subjects per briefing condition, as given in Table 7.3.1. The values underlined relate to incorrect responses.

TABLE 7.4.2

Analysis of variance on the search time data shown in Table 7.4.1*

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions (C)	6	435.74	72.62	1.19	N.S.
Target ranges (R)	2	308.43	154.22	2.52	N.S. ($p < 0.10$)
Targets (T)	7	2630.73	375.82	6.15	$p < 0.001$
C x R	12	740.51	61.73	-	N.S.
C x T	42	1155.03	22.50	-	N.S.
R x T	14	1453.86	103.81	1.70	N.S.
C x R x T	84	8037.56	95.69	1.56	$p < 0.05$
Residual	168	10261.45	61.08		
TOTAL	335	25023.31			

TABLE 7.4.3

Analysis of variance on the search time data shown in Table 7.4.1* excluding the data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Type of briefing (B)	1	153.42	153.42	2.37	N.S.
Range of briefing (P)	2	76.83	38.41	-	N.S.
Target range (R)	2	226.58	113.29	1.75	N.S.
Targets (T)	7	2257.93	322.56	4.99	$p < 0.001$
P x B	2	101.89	50.94	-	N.S.
P x R	4	514.89	128.72	1.99	N.S. ($p < 0.10$)
P x T	14	334.46	23.89	-	N.S.
B x R	2	73.27	36.63	-	N.S.
B x T	7	277.48	39.64	-	N.S.
R x T	14	1802.38	128.74	1.99	$p < 0.05$
P x B x R	4	125.21	31.30	-	N.S.
P x B x T	14	521.60	37.26	-	N.S.
P x R x T	28	2303.14	82.25	1.27	N.S.
B x R x T	14	1159.50	82.82	1.28	N.S.
P x B x R x T	28	3934.22	140.51	2.17	$p < 0.01$
Residual	144	9308.82	64.64		
TOTAL	287	23171.62			

*The data from target range 1 mile are not included in this analysis.

7.4.1 Analysis of replicated search time data: the effects of briefing type and briefing range.

The mean search times for the drawings and diagrams conditions are given in Table 7.4.4 and the mean search times for each briefing range condition in Table 7.4.5. In each case the mean value for the map only condition is also given.

TABLE 7.4.4

Mean search times for each briefing type

	Mean search time (seconds)	N
MAP ONLY	10.4	48
Map + diagrams	12.7	144
Map + drawings	11.3	144

TABLE 7.4.5

Mean search time for each briefing range

	Mean search time (seconds)	N
MAP ONLY	10.4	48
Briefing range (miles)		
2	11.4	96
4	12.7	96
2 + 4	11.9	96

N = Number of readings on which each value is based.
Data relate to target ranges of 2, 3 and 4 miles only.

Dunnett's t test showed that there were no significant differences between the map only condition and the drawings and diagrams conditions, or between the map only condition and the three briefing ranges. There were also no significant differences between the drawings and diagrams conditions, or between the briefing ranges, confirming the results of the analysis of variance given in Table 7.4.3.

7.5 CONFIDENCE LEVELS - ANALYSIS OF BASIC DATA FOR ALL BRIEFING CONDITIONS.

The basic confidence level data obtained from the initial group of 4 subjects per condition are shown in Table 7.5.1. Two analyses of variance were carried out on these data. In the first, given in Table 7.5.2, the twelve briefing conditions were treated as independent and the analysis showed that each of the main factors, briefing conditions, target ranges and targets, had a highly significant effect on confidence level. The interaction between targets and ranges was also significant. In the analysis of variance given in Table 7.5.3, the map only data were excluded, and briefing type and briefing range treated as separate factors. The results of this analysis showed that both briefing type and briefing range were highly significant, while the interaction between them reached the 5% level. Targets and target ranges were also highly significant.

In the following sections the effects of briefing types and ranges, and the interactions of these factors with target range, are considered in more detail. In each case the effects are compared with that of the map only condition.

Basic confidence level data for all briefing conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	4	6	4	5	6	6	7	7
		2	3	6	5	4	6	6	5	5
		3	3	5	3	5	3	7	5	3
		4	3	6	6	5	4	4	5	6
MAP + TARGET CIRCLES	2	1	5	7	3	3	6	7	7	4
		2	3	6	5	6	3	6	5	7
		3	5	5	7	3	2	5	5	6
		4	3	2	2	4	4	3	2	6
	4	1	5	6	3	6	5	5	6	6
		2	2	6	3	5	2	5	3	4
		3	5	5	6	2	7	6	4	3
		4	2	6	5	3	2	2	5	7
MAP + DIAGRAMS	2	1	4	7	4	4	7	5	7	7
		2	3	5	5	6	4	6	6	7
		3	4	7	6	7	6	6	5	5
		4	2	7	6	3	5	4	4	7
	4	1	7	4	2	4	2	4	6	4
		2	2	6	4	6	4	6	3	3
		3	3	4	3	2	5	5	5	7
		4	4	6	4	4	2	3	2	3
	2 + 4	1	5	6	6	5	4	4	5	5
		2	6	6	5	5	4	6	3	7
		3	2	6	5	4	4	5	3	5
		4	3	6	3	4	4	5	5	3

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	2	6	6	7	3	3	6	7
		2	5	6	2	5	4	7	3	6
		3	2	7	4	6	4	5	3	5
		4	6	7	1	2	5	5	4	5
	4	1	5	7	4	5	3	5	5	5
		2	5	7	6	3	3	5	6	6
		3	5	6	3	2	3	5	7	6
		4	2	5	5	5	4	5	4	6
	2 + 4	1	4	6	3	7	6	3	7	5
		2	5	7	4	6	4	6	3	7
		3	2	5	6	2	4	4	5	6
		4	4	6	4	3	6	5	4	6
MAP + PHOTO-GRAPHS	2	1	3	4	3	2	5	5	7	7
		2	5	7	7	7	7	7	7	7
		3	6	7	7	4	6	5	7	7
		4	2	7	6	4	4	2	4	5
	4	1	4	7	4	5	6	4	6	7
		2	3	7	6	6	5	7	4	6
		3	5	4	7	5	5	7	6	5
		4	7	4	3	7	3	5	7	7
	2 + 4	1	5	7	5	6	3	7	7	6
		2	6	7	6	6	6	7	7	7
		3	6	7	7	6	7	4	5	7
		4	5	7	6	4	6	6	6	6

The confidence level scale ranges from 1 to 7, high values indicating high confidence in a correct response. Values underlined relate to incorrect responses.

TABLE 7.5.2

Analysis of variance on confidence level data shown in Table 7.5.1.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions (C)	11	102.74	9.34	5.40	$p < 0.001$
Target ranges (R)	3	32.64	10.88	6.29	$p < 0.001$
Targets (T)	7	149.59	21.37	12.35	$p < 0.001$
C x R	33	69.30	2.10	1.21	N.S.
C x T	77	80.85	1.05	-	N.S.
R x T	21	70.56	3.36	1.94	$p < 0.01$
Residual	231	399.63	1.73		
TOTAL	383	905.31			

TABLE 7.5.3

Analysis of variance on the confidence level data shown in Table 7.5.1, excluding the data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing type (B)	3	66.27	22.09	13.15(b)	$p < 0.001$
Briefing range (P)	2	15.02	7.51	4.47(b)	$p < 0.025$
Target range (R)	3	33.21	11.07	6.59(b)	$p < 0.001$
Targets (T)	7	137.06	19.58	11.58(b)	$p < 0.001$
B x P	*5	21.50	4.30	2.56(b)	$p < 0.05$
B x R	9	27.63	3.07	1.83(b)	N.S. ($p < 0.10$)
B x T	21	17.22	0.82	- (b)	N.S.
P x R	6	16.26	2.71	1.61(b)	N.S.
P x T	14	12.46	0.89	- (b)	N.S.
R x T	21	72.66	3.46	2.06(b)	$p < 0.01$
B x P x R	*15	17.20	1.15	- (a)	N.S.
B x P x T	*35	44.07	1.26	- (a)	N.S.
B x R x T	63	93.60	1.49	- (a)	N.S.
P x R x T	42	78.12	1.86	- (a)	N.S.
Residual (a)	105	202.95	1.93		
Pooled residual (b) (Residual (a) + BPR, BPT, BRT, PRT)	260	435.94	1.68		
TOTAL	351	855.23			

*These values are reduced to take account of the missing data for the target circles (2 + 4 miles) condition.

7.5.1 Confidence levels: The effect of briefing conditions.

The analysis of variance given in Table 7.5.2 shows that the effect of briefing conditions on confidence level is highly significant. As in the case of the detection probability data, this effect is analysed in terms of briefing type and briefing range, and the map only condition is treated as the control condition.

7.5.2 Confidence levels: The effect of briefing type.

The analysis of variance given in Table 7.5.3 shows that briefing type has a highly significant effect on confidence level. The relevant values are given in Table 7.5.4, together with the mean value for the map only condition for comparison purposes.

TABLE 7.5.4.

The effect of briefing type on confidence levels.

Briefing type	Mean confidence level	N
MAP ONLY	4.9	32
Map + target circles	4.5	64
Map + diagrams	4.7	96
Map + drawings	4.8	96
Map + photographs	5.6*	96

N = Number of readings on which each value is based.
* Significantly different from map only value at 5% level.

It can be seen in Table 7.5.4 that only the map + photographs briefing results in a higher mean confidence level than the map only condition. Dunnett's t test showed that this difference reached the 5% significance level. None of the other values were significantly different from the map only value, indicating that, apart from the photographs, the additional briefing materials tested did not affect the subject's overall confidence in their responses.

The mean confidence levels given in Table 7.5.4 relate to all responses, regardless of whether they were correct or incorrect. Although the target circles, diagrams and drawings tested had no significant effect on confidence level relative to the map only condition, it was of interest to determine whether these additional briefing materials enabled the subjects to judge more accurately whether or not their responses were correct. This would result in higher mean confidence levels being assigned to correct responses made under the additional briefing conditions relative to the corresponding map only value, and lower mean confidence levels to the incorrect responses, again relative to the corresponding map only value. Such an effect would not be apparent from the data given in Table 7.5.4.

The data given in Table 7.5.5. show the mean confidence levels for correct and incorrect responses under each briefing type condition.

TABLE 7.5.5.

Mean confidence levels of correct and incorrect responses for each briefing type

Briefing type	Mean confidence level			
	Correct responses	N	Incorrect responses	N
MAP ONLY	5.4	16	4.4	16
Map + target circles	5.4	27	3.8	37
Map + diagrams	5.2	58	3.8	38
Map + drawings	5.3	52	4.1	44
Map + photographs	6.3*	65	4.3	31

N = Number of readings on which each value is based.
* Significantly higher than corresponding map only value at 5% level.

There is no conclusive evidence in Table 7.5.5 that subjects were better able to assess the accuracy of their responses when additional briefing materials were provided, although it appears that under the target

circles, diagrams and drawings conditions mean confidence levels for incorrect responses decreased slightly, while those for the correct responses remained effectively equal to that recorded under the map only condition. For the map + photographs condition the mean confidence level for correct responses increased significantly, relative to the map only condition, while that for incorrect responses was not affected.

7.5.3 Confidence levels: The effect of briefing range.

Briefing range had a significant effect on confidence level as shown in Table 7.5.3. The mean values for each briefing range condition are given in Table 7.5.6, together with the value for the map only condition.

TABLE 7.5.6

The effect of briefing range on confidence level

	Mean confidence level	N
MAP ONLY	4.9	32
Briefing range:		
2 miles	5.0	128
4 miles	4.7	128
2 + 4 miles	5.2	96

N = Number of readings on which each value is based.

Dunnett's t test showed that none of the mean confidence levels for the three briefing ranges were significantly different from that of the map only value. Within the three briefing range conditions the value for the 4 miles briefing range was significantly lower than that for the 2 + 4 miles condition but otherwise differences were non-significant.

7.5.4 Confidence levels: the interaction between briefing type and target range

The interaction between briefing type and target range failed to reach the 5% level in the analysis of variance given in Table 7.5.3 but $p < 0.10$ indicating some tendency for the effect of target range on confidence level to depend on the type of briefing material used. This analysis of variance did not include data from the map only condition, but these data are shown in Table 7.5.7, which gives the mean confidence levels for each briefing type at each target range.

TABLE 7.5.7

The interaction between briefing type and target range

	Target range (miles) 1	2	3	4	N
MAP ONLY	5.6	5.0	4.3	4.9	8
Map + target circles	5.3	4.4	4.8	3.6	16
Map + diagrams	4.9	4.9	4.8	4.1	24
Map + drawings	4.9	5.1	4.5	4.5	24
Map + photographs	5.2	6.3*	5.9*	5.1	24

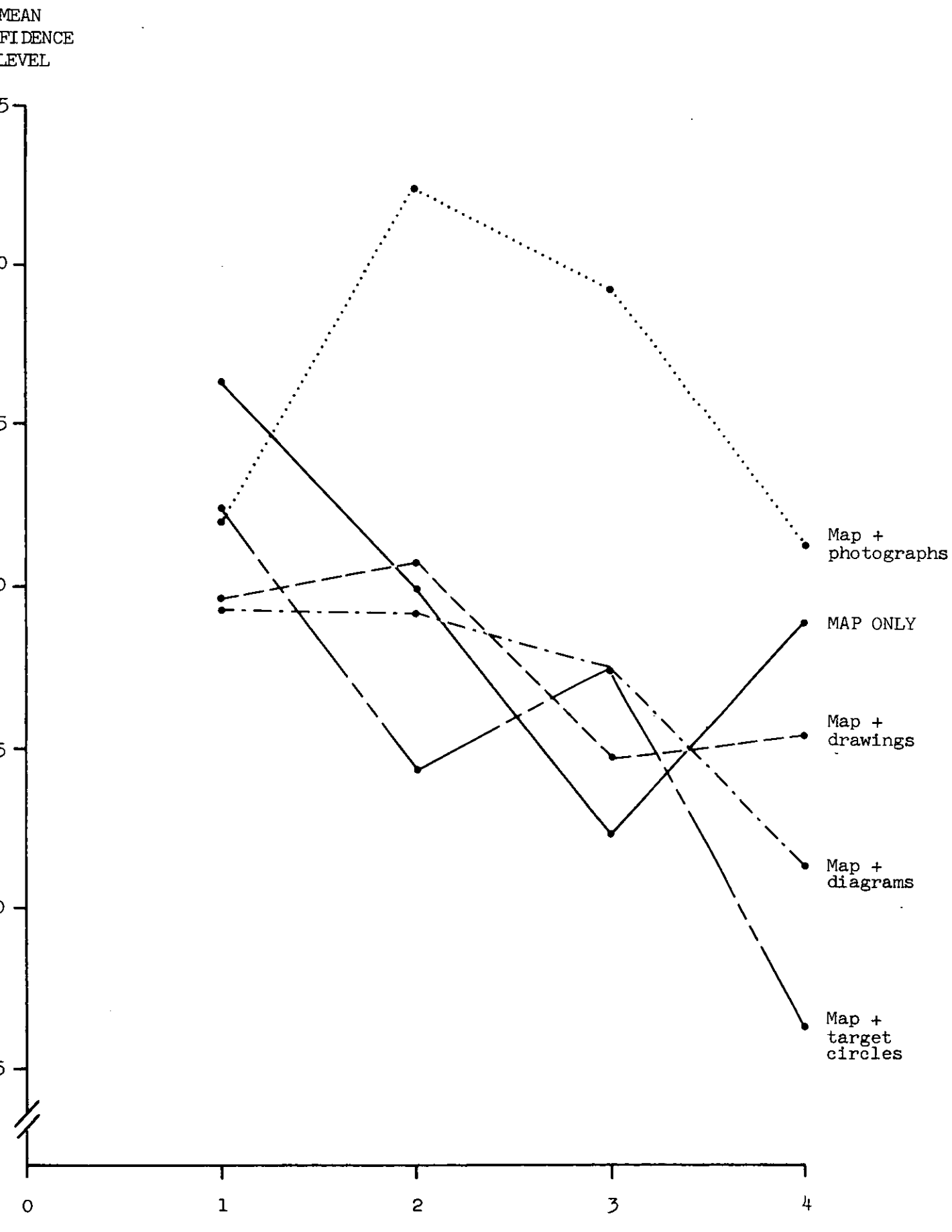
N = Number of readings on which each value is based.

* Significantly different from map only value at 5% level.

These data are shown graphically in Figure 7.5.1. At all target ranges, except 1 mile, the map + photographs condition resulted in higher confidence levels than all the other types of briefing, including map only. At the 1 mile target range all the additional briefing materials resulted in lower mean confidence levels than the map only condition but none of these differences reached the 5% level. This deterioration in performance at the 1 mile range when additional briefing materials were provided was also seen for both the detection probability and search time measures (see Figures 7.1.1 and 7.3.1).

FIGURE 7.5.1

The interaction between briefing type and target range



As can be seen in Figure 7.5.1, the drawings, diagrams and target circles briefing types did not have any consistent effect on mean confidence levels at each target range, and none of the differences between the briefing conditions and the map only condition were significant. The apparent increase in mean confidence level at the 4 mile target range relative to the 3 mile range for the map only condition is unexpected but this difference does not reach significance.

7.5.5 Confidence levels: the interaction between briefing range and target range.

The interaction between briefing range and target range was non-significant, as shown in Table 7.5.3, and need not be considered in detail. It is of interest to note, however, that there was a tendency for higher confidence levels, relative to the map only condition to be associated with conditions in which the briefing range coincided with the target range.

7.5.6. Confidence levels: the interaction between briefing type and briefing range

The interaction between briefing type and briefing range was significant at the 5% level as shown by the analysis of variance given in Table 7.5.3. The mean values for each type of briefing at each briefing range are given in Table 7.5.8.

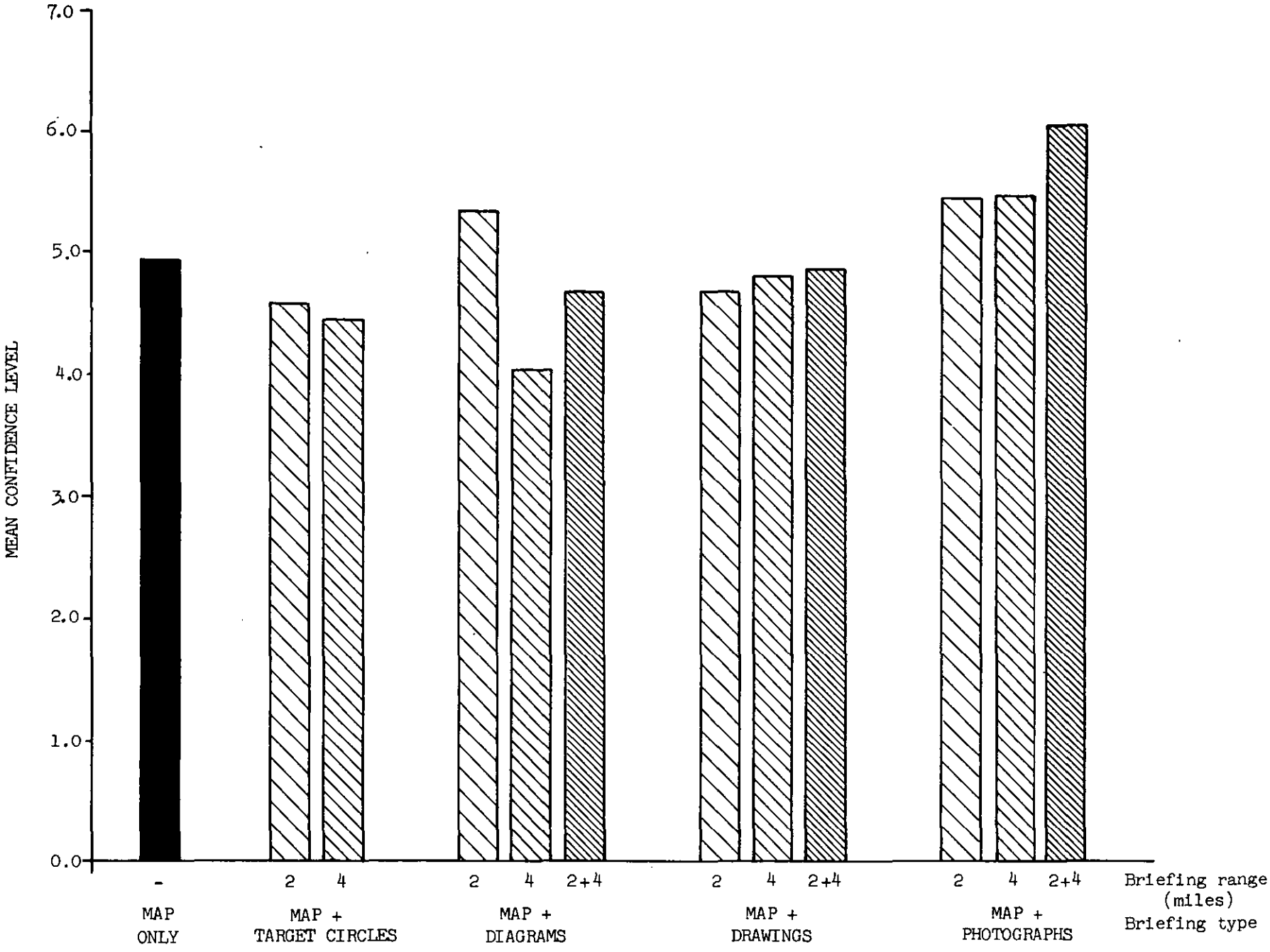
TABLE 7.5.8

The interaction between briefing type and briefing range

	Briefing range (miles) 2	4	2 + 4	N
Map + target circles	4.6	4.4	-	32
Map + diagrams	5.3	4.0	4.7	32
Map + drawings	4.7	4.8	4.8	32
Map + photographs	5.4	5.4	6.0*	32
MAP ONLY	4.9			32

N = Number of readings on which each value is based.
* Significantly different from corresponding map only value at the 5% level.

The data given in Table 7.5.8 are shown in the form of a histogram in Figure 7.5.2. It can be seen that the significance of the interaction between briefing type and briefing range is largely due to the high mean confidence levels associated with the map + diagrams (2 miles) and map + photographs (2 + 4 miles) briefing conditions, together with an unexpectedly low value for the map + diagrams (4 miles) condition. Only one value, map + photographs (2 + 4 miles) is significantly higher than the map only value. This high value is readily explicable since under this condition in 50% of the presentations the subject was required to find the target in a photograph identical to one which he had previously been given for briefing purposes.


7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
MEAN CONFIDENCE LEVEL
-
2
4
2
4
2+4
2
4
2+4
2
4
2+4
MAP ONLY
MAP + TARGET CIRCLES
MAP + DIAGRAMS
MAP + DRAWINGS
MAP + PHOTOGRAPHS
Briefing range (miles)
Briefing type

7.6 CONFIDENCE LEVELS - ANALYSIS OF REPLICATED DATA FOR THE MAP ONLY, MAP + DIAGRAMS AND MAP + DRAWINGS CONDITIONS.

The effects of the map only condition, the map + diagrams conditions (2, 4 and 2 + 4 miles) and the map + drawings conditions (2, 4 and 2 + 4 miles) on confidence level were further analysed using the replicated data, shown in Table 7.6.1. In the analyses described in this section the data from target range 1 mile were excluded for the same reasons as indicated in Section 7.2. The analysis of variance given in Table 7.6.2 shows that confidence level was significantly affected by the seven different briefing conditions but the analysis given in Table 7.6.3, which does not include the data from the map only condition, shows that neither range of briefing nor type of briefing are significant. However this analysis does show that the interaction between these two factors is significant at the 5% level.

Replicated confidence level data for the map only, map + diagrams and map + drawings conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	4 / 5	6 / 7	4 / 5	5 / 6	6 / 4	6 / 7	7 / 3	7 / 5
		2	3 / 4	6 / 7	5 / 6	4 / 5	6 / 4	6 / 6	5 / 7	5 / 6
		3	3 / 5	5 / 6	3 / 4	5 / 6	3 / 4	7 / 5	5 / 2	3 / 6
		4	3 / 5	6 / 6	6 / 3	5 / 6	4 / 4	4 / 5	5 / 4	6 / 5
MAP + DIAGRAMS	2	1	4 / 5	7 / 7	4 / 3	4 / 7	7 / 5	5 / 6	7 / 7	7 / 7
		2	3 / 4	5 / 5	5 / 4	6 / 5	4 / 5	6 / 6	6 / 7	7 / 5
		3	4 / 3	7 / 7	6 / 5	7 / 5	6 / 4	6 / 6	5 / 7	5 / 6
		4	2 / 4	7 / 6	6 / 6	3 / 4	5 / 4	4 / 3	4 / 3	7 / 7
	4	1	7 / 3	4 / 6	2 / 4	4 / 5	2 / 5	4 / 5	6 / 3	4 / 5
		2	2 / 4	6 / 7	4 / 4	6 / 2	4 / 4	6 / 4	3 / 6	3 / 4
		3	3 / 3	4 / 6	3 / 3	2 / 5	5 / 4	5 / 5	5 / 6	7 / 7
		4	4 / 5	6 / 4	4 / 6	4 / 5	2 / 4	3 / 2	2 / 5	3 / 5
	2 + 4	1	5 / 5	6 / 7	6 / 5	5 / 6	4 / 5	4 / 5	5 / 7	5 / 5
		2	6 / 3	6 / 7	5 / 7	5 / 6	4 / 3	6 / 7	3 / 5	7 / 4
		3	2 / 3	6 / 6	5 / 5	4 / 6	4 / 5	5 / 5	3 / 4	5 / 7
		4	3 / 2	6 / 7	3 / 5	4 / 4	4 / 5	5 / 3	5 / 3	3 / 5

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	2 / 4	6 / 4	6 / 3	7 / 5	3 / 6	3 / 3	6 / 3	7 / 5
		2	5 / 6	6 / 6	2 / 6	5 / 6	4 / 5	7 / 4	3 / 5	6 / 5
		3	2 / 4	7 / 7	4 / 3	6 / 4	4 / 2	5 / 4	3 / 3	5 / 7
		4	6 / 3	7 / 7	1 / 5	2 / 4	5 / 5	5 / 4	4 / 5	5 / 5
	4	1	5 / 4	7 / 6	4 / 5	5 / 6	3 / 6	5 / 5	5 / 7	5 / 7
		2	5 / 6	7 / 7	6 / 7	3 / 6	3 / 5	5 / 6	6 / 6	6 / 5
		3	5 / 5	6 / 7	3 / 4	2 / 6	3 / 5	5 / 7	7 / 2	6 / 7
		4	2 / 6	5 / 5	5 / 2	5 / 5	4 / 6	5 / 4	4 / 5	6 / 6
	2 + 4	1	4 / 2	6 / 7	3 / 6	7 / 4	6 / 5	3 / 6	7 / 7	5 / 5
		2	5 / 4	7 / 6	4 / 6	6 / 7	4 / 2	6 / 5	3 / 5	7 / 6
		3	2 / 5	5 / 4	6 / 4	2 / 7	4 / 6	4 / 5	5 / 4	6 / 6
		4	4 / 5	6 / 6	4 / 4	3 / 5	6 / 5	5 / 7	4 / 4	6 / 4

NOTES The confidence level scale ranged from 1 to 7, high values being associated with high confidence of a correct response.

The values underlined relate to incorrect responses.

These data were obtained from eight subjects per briefing condition, giving rise to 2 readings per cell. The first value in each pair relates to the first group of four subjects per briefing condition, as given in Table 7.5.1.

TABLE 7.6.2

Analysis of variance on the confidence level data shown in Table 7.6.1*

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions (C)	6	23.89	3.98	2.73(c)	$p < 0.05$
Target ranges (R)	2	19.83	9.91	6.79(c)	$p < 0.005$
Targets (T)	7	151.60	21.66	14.84(c)	$p < 0.001$
C x R	12	16.54	1.38	- (b)	N.S.
C x T	42	45.80	1.09	- (b)	N.S.
R x T	14	27.30	1.95	1.30(b)	N.S.
C x R x T	84	132.44	1.58	1.08(a)	N.S.
Residual (a)	168	244.84	1.46		
Pooled residual (b) (Residual (a) + CRT)	252	377.28	1.50		
Pooled residual (c) (Pooled residual (b) + CR, CT, RT)	320	466.92	1.46		
TOTAL	335	662.36			

TABLE 7.6.3

Analysis of variance on the confidence level data shown in Table 7.6.1,* excluding the data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Type of briefing (B)	1	2.35	2.35	1.57(c)	N.S.
Range of briefing (P)	2	2.53	1.26	- (c)	N.S.
Target range (R)	2	17.53	8.76	5.84(c)	$p < 0.005$
Targets (T)	7	133.83	19.12	12.75(c)	$p < 0.001$
P x B	2	18.78	9.39	6.26(c)	$p < 0.005$
P x R	4	1.49	0.37	- (c)	N.S.
P x T	14	14.08	1.01	- (c)	N.S.
B x R	2	6.69	3.35	2.23(c)	N.S.
B x T	7	14.93	2.13	1.42(c)	N.S.
R x T	14	30.75	2.20	1.47(c)	N.S.
P x B x R	4	5.24	1.31	- (b)	N.S.
P x B x T	14	12.94	0.92	- (b)	N.S.
P x R x T	28	59.90	2.14	1.47(b)	N.S. ($p < 0.10$)
B x R x T	14	19.69	1.41	- (b)	N.S.
P x B x R x T	28	35.37	1.26	- (a)	N.S.
Residual (a)	144	215.00	1.49		
Pooled residual (b) (Residual (a) + PBRT)	172	250.37	1.46		
Pooled residual (c) (Pooled residual (b) + PBR, PBT, PRT, BRT)	232	348.14	1.50		
TOTAL	287	591.10			

*The data from target range 1 mile are not included in these analyses.

7.6.1 Analysis of replicated confidence level data: the interaction between briefing type and briefing range

The mean confidence levels for the drawings and diagrams at each briefing range are shown in Table 7.6.4, together with the mean value obtained under the map only condition.

TABLE 7.6.4

Mean confidence level under each briefing condition

	Briefing range (miles)			N
	2	4	2 + 4	
Map + diagrams	5.2	4.3	4.7	48
Map + drawings	4.7	5.1	4.9	48
MAP ONLY	4.9			48

N = Number of readings on which each value is based.

The analysis of variance in Table 7.6.2 indicates that the seven values in this Table, which relate to the seven briefing conditions, are significantly different. The analysis of variance given in Table 7.6.3 indicates that there is a significant interaction between briefing type and briefing range, i.e. between the data in the top two lines of this Table, the map only value being excluded. None of the six values were significantly different from the map only value, but for the 2 mile briefing range diagrams resulted in significantly higher mean confidence level than drawings, whereas for the 4 mile briefing range the opposite was true. Comparison with Table 7.2.8 shows a similar pattern of results for the detection probability data.

7.7 BRIEFING TIMES - ANALYSIS OF BASIC DATA FOR ALL BRIEFING CONDITIONS

The briefing time data were analysed in the same way as the other three performance measures. The basic data obtained from four subjects per condition are shown in Table 7.7.1. It should be noted that the conditions under which the experiment was carried out resulted in all the briefing times being greater than 90 seconds since, in order to prevent undue reliance on the additional briefing materials, all subjects were required to study the map for 90 seconds before the additional briefing was presented. They were then allowed to take as much further time as they needed. Subjects tested under the map only condition were also required to study the map for a minimum of 90 seconds.

Two analyses of variance were carried out on the data given in Table 7.7.1. The first, given in Table 7.7.2, showed that the effect of the twelve briefing conditions was highly significant. The second analysis of variance, given in Table 7.7.3, from which the map only data were excluded, showed that the effects of briefing type, briefing range and the interaction between them were significant. In both analyses the effect of targets was significant. No effects due to target range were found and none would be expected since, while studying the briefing materials, the subjects did not know at what range the target would subsequently be presented.

Basic briefing-time data for all briefing conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	99.0	93.0	100.2	100.2	102.0	98.2	98.6	95.8
		2	98.4	101.2	98.0	101.4	103.8	101.2	104.0	103.6
		3	103.2	98.0	94.0	95.0	104.8	95.0	100.2	97.8
		4	100.8	101.6	97.8	93.6	101.6	106.6	98.2	98.8
MAP + TARGET CIRCLES	2	1	147.0	111.4	111.6	209.4	159.6	120.0	129.8	183.8
		2	211.4	139.2	137.8	108.6	210.0	140.4	117.2	100.6
		3	98.0	208.0	136.8	116.6	113.0	199.0	141.6	108.0
		4	140.8	94.8	253.2	169.8	107.4	106.2	235.6	142.6
	4	1	164.4	115.4	237.0	141.2	224.2	136.0	174.4	171.8
		2	128.4	112.2	135.0	230.8	153.4	207.6	127.6	128.8
		3	225.8	119.6	176.0	158.4	243.4	124.8	171.8	137.6
		4	127.8	193.6	155.8	165.8	141.2	149.6	165.0	222.6
MAP + DIAGRAMS	2	1	182.2	147.8	102.6	183.0	207.0	107.0	195.2	158.4
		2	191.4	104.6	173.8	148.8	105.6	195.6	213.6	158.8
		3	107.4	132.2	137.2	158.4	149.4	191.0	179.6	104.4
		4	211.6	136.6	168.0	97.8	198.8	145.4	105.4	178.4
	4	1	147.2	121.2	134.0	153.0	189.0	166.6	136.6	156.0
		2	188.6	136.2	151.4	151.2	147.8	148.6	156.8	188.2
		3	158.4	150.2	147.2	186.8	148.4	142.0	137.4	136.2
		4	161.8	134.8	143.6	146.4	207.0	147.4	162.8	137.0
	2 + 4	1	127.0	174.8	172.6	125.6	168.6	140.4	134.6	215.0
		2	161.6	167.4	149.4	187.6	161.8	121.8	183.6	167.4
		3	135.0	128.6	213.2	178.0	187.0	181.4	156.0	148.6
		4	184.0	146.0	128.0	116.4	143.0	194.0	175.4	156.8

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	186.8	139.6	115.4	137.8	179.4	125.2	141.2	110.6
		2	129.2	131.4	124.6	127.6	145.0	119.6	138.0	139.8
		3	126.4	147.4	131.2	118.6	137.8	138.2	119.0	121.2
		4	148.2	113.0	135.6	161.8	132.8	127.6	139.4	134.4
	4	1	142.4	124.8	156.2	185.4	129.2	125.0	196.6	149.0
		2	130.8	158.2	159.0	171.4	134.2	151.4	161.2	137.8
		3	148.8	158.2	157.0	134.2	244.6	206.0	162.2	130.2
		4	181.8	167.4	131.2	143.4	191.0	172.4	133.0	158.0
	2 + 4	1	121.6	174.8	153.0	109.8	178.2	138.6	117.4	153.6
		2	126.8	110.8	143.6	113.6	152.0	162.8	196.2	198.0
		3	216.2	131.4	118.4	186.4	147.4	182.6	178.8	117.0
		4	142.4	179.8	175.0	208.8	118.2	132.2	136.4	131.0
MAP + PHOTO-GRAPHS	2	1	170.8	121.4	162.0	138.6	141.4	160.4	171.2	134.6
		2	198.6	139.6	157.2	161.2	169.2	171.4	146.0	153.8
		3	171.2	145.6	164.0	159.4	159.4	133.4	153.6	140.0
		4	158.6	172.6	149.8	181.4	145.6	183.4	208.6	168.6
	4	1	156.4	164.4	153.8	140.2	182.8	125.4	162.4	182.6
		2	136.4	147.0	235.4	142.8	230.8	186.0	129.8	157.2
		3	158.2	145.6	208.0	222.8	155.2	203.6	222.0	163.0
		4	248.2	130.2	147.4	157.4	160.6	152.0	245.4	148.0
	2 + 4	1	130.0	115.2	177.4	158.4	143.3	111.6	123.4	171.2
		2	159.8	147.6	152.4	128.4	201.0	135.6	129.4	115.4
		3	119.2	126.0	151.6	156.2	135.2	158.2	206.0	145.4
		4	215.6	125.2	129.0	138.8	154.0	218.4	124.8	123.0

All the briefing-time values are given in seconds.

TABLE 7.7.2

Analysis of variance on the briefing-time data given in Table 7.7.1

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions(C)	11	120477.24	10952.54	13.01(b)	$p < 0.001$
Target ranges (R)	3	1553.61	517.87	- (b)	N.S.
Targets (T)	7	15221.29	2174.47	2.58(b)	$p < 0.01$
C x R	33	12352.13	374.31	- (a)	N.S.
C x T	77	22863.61	296.93	- (a)	N.S.
R x T	21	18745.65	892.65	- (a)	N.S.
Residual (a)	231	250729.71	1085.41		
Pooled residual (b) (Residual (a) + CR, CT, RT)	362	304691.78	841.69		
TOTAL	383	441943.94			

TABLE 7.7.3

Analysis of variance on the briefing-time data given in Table 7.7.1, excluding the data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing type (B)	3	7055.82	2351.94	2.35(b)	$p < 0.05$
Briefing range (P)	2	10527.78	5263,89	5.27(b)	$p < 0.01$
Target range (R)	3	1670.94	556.98	- (b)	N.S.
Targets (T)	7	16177.70	2311.10	2.31(b)	$p < 0.05$
B x P	*5	12911.85	2582.37	2.59(b)	$p < 0.05$
B x R	9	4732.02	525.78	- (b)	N.S.
B x T	21	7644.42	364.02	- (b)	N.S.
P x R	6	4800.30	800.05	- (b)	N.S.
P x T	14	5703.60	407.40	- (b)	N.S.
R x T	21	20655.18	983.58	- (b)	N.S.
B x P x R	*15	2653.19	176.88	- (a)	N.S.
B x P x T	*35	8483.00	242.37	- (a)	N.S.
B x R x T	63	74547.20	1183.29	- (a)	N.S.
P x R x T	42	45095.82	1073.71	- (a)	N.S.
Residual (a)	105	128950.47	1228.10		
Pooled residual (b) (Residual (a) + BPT, BPR, BRT, PRT)	260	259729.60	998.96		
TOTAL	351	351609.29			

*These values are reduced to take account of the missing data for the target circles (2 + 4 miles) condition.

7.7.2 The effect of briefing type on briefing time

The briefing times for each of the four types of additional briefing are given in Table 7.7.4, together with the mean value for the map only condition.

TABLE 7.7.4

The effect of briefing type on briefing time

Briefing type	Briefing time (seconds)	N
MAP ONLY	99.6	32
Map + target circles	155.9**	64
Map + diagrams	156.5**	96
Map + drawings	148.0**	96
Map + photographs	159.6**	96

N = Number of readings on which each value is based.
** Significantly higher than map only value at 1%.

Dunnett's t test was used to determine whether the additional briefing materials resulted in significantly longer briefing times than the map only condition. It was found that all four values were significantly higher than the map only value as would be expected from the procedure adopted in this experiment. Student's t test was used to determine whether there were significant differences between the briefing types and the results showed that the map + photographs condition resulted in significantly higher briefing times than the other briefing types. This is in accordance with the result shown in the analysis of variance in Table 7.2.3 that briefing type had a significant effect on briefing time.

7.7.3 The effect of briefing range on briefing time

The analysis of variance given in Table 7.7.3 shows that the effect of briefing range on briefing time is highly significant. The relevant mean values are given in Table 7.7.5, together with the value obtained under the map only condition.

TABLE 7.7.5

The effect of briefing range on briefing time

	Briefing time (seconds)	N
MAP ONLY	99.6	32
Briefing range:		
2 miles	149.3**	128
4 miles	161.9**	128
2 + 4 miles	153.2**	96

N = Number of readings on which each value is based.
** Significantly higher than map only value at 1% level.

As shown in Table 7.7.5, the mean briefing time for each briefing range was significantly higher than that for the map only condition. It was also found that the mean briefing time for the 2 mile briefing range was significantly lower than that for the 4 mile briefing range. The mean value for the 2 + 4 mile briefing range is also lower than that found when the briefing range was 4 miles. This can be regarded as indicating that the interpretation of the 4 mile briefing in relation to the map was easier if 2 mile briefing was also provided, and/or that if 2 mile briefing was provided the subjects tend to disregard the 4 mile briefing.

7.8 BRIEFING TIMES - ANALYSIS OF REPLICATED DATA FOR MAP ONLY, MAP + DIAGRAMS AND MAP + DRAWINGS CONDITIONS

The effects of the map only condition, the map + diagrams conditions (2, 4 and 2 + 4 miles) and the map + drawings conditions (2, 4 and 2 + 4 miles) on briefing times were further investigated using the replicated data given in Table 7.8.1. In the analyses described in this section the data from target range 1 mile were excluded so that the analyses were consistent with those for the other performance measures. However, as target range was not a meaningful factor in relation to briefing time it is unlikely that the omission of these data made any substantial difference to the results of this analysis.

The analysis of variance given in Table 7.8.2 shows that the seven briefing conditions had a highly significant effect on briefing time. The analysis of variance given in Table 7.8.3, from which the map only data were excluded, shows that both types of briefing and range of briefing were highly significant. In both analyses the effect of targets was found to be significant. In the following section the effects of briefing type and briefing range are considered in more detail but no further analyses were carried out.

Replicated briefing-time data for map only, map + diagrams and map + drawings conditions.

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP ONLY	-	1	99.0	93.0	100.2	102.0	100.2	98.2	98.6	95.8
			246.0	103.6	103.6	105.2	229.6	97.4	104.0	107.4
		2	98.4	101.2	98.0	101.4	103.8	101.2	104.0	103.6
			105.2	161.8	98.0	102.0	103.8	243.4	102.2	107.8
		3	103.2	98.0	94.0	95.0	104.8	95.0	100.2	97.8
			108.6	105.4	235.4	121.8	102.2	106.6	198.2	98.2
		4	100.8	101.6	97.8	93.6	101.6	106.6	98.2	98.8
			118.8	104.6	113.6	168.8	102.6	102.2	103.2	149.4
MAP + DIAGRAMS	2	1	182.2	147.8	102.6	183.0	207.0	107.0	195.2	158.4
			160.0	135.0	176.8	177.8	194.8	141.2	127.6	185.2
		2	191.4	104.6	173.8	148.8	105.6	195.6	213.6	158.8
			217.2	119.8	126.4	117.0	255.8	151.6	148.0	125.0
		3	107.4	132.2	137.2	158.4	149.4	191.0	179.6	104.4
			132.2	152.4	112.8	135.6	176.8	148.2	148.2	131.8
		4	211.6	136.6	168.0	97.8	198.8	145.4	105.4	178.2
			172.4	164.4	160.4	206.0	173.4	121.8	209.8	177.4
	4	1	147.2	121.2	134.0	153.0	189.0	166.6	136.6	156.0
			249.0	143.0	169.2	148.6	148.4	147.4	119.2	134.0
		2	188.6	136.2	151.4	151.2	147.8	148.6	156.8	188.2
			158.6	122.8	152.4	163.8	171.8	121.4	143.0	204.2
		3	158.4	150.2	147.2	186.8	148.4	142.0	137.4	136.2
			176.2	143.4	136.4	143.2	161.4	130.6	121.0	170.8
		4	161.8	134.8	143.6	146.4	207.0	147.4	162.8	137.0
			160.0	179.8	168.4	130.0	183.0	152.4	153.2	157.6
	2 + 4	1	127.0	174.8	172.6	125.6	168.6	140.4	134.6	215.0
			244.8	129.8	134.0	148.0	219.6	203.0	149.4	170.6
		2	161.6	167.4	149.4	187.6	161.8	121.8	183.6	167.4
			241.8	176.0	174.0	184.6	214.6	179.6	260.6	150.8
		3	135.0	128.6	213.2	178.0	187.0	181.4	156.0	148.6
			369.2	189.0	160.6	215.2	170.0	173.2	155.4	222.0
		4	184.0	146.0	128.0	116.4	143.0	194.0	175.4	156.8
			241.0	117.4	181.8	202.4	223.8	155.2	201.2	216.2

Briefing type	Briefing range (miles)	Target range (miles)	TARGETS 1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	186.8	139.6	115.4	137.8	179.4	125.2	141.2	110.6
			200.0	120.8	131.0	190.6	230.0	144.6	136.2	171.4
		2	129.2	131.4	124.6	127.6	145.0	119.6	138.0	139.8
			207.0	203.8	120.4	147.2	208.2	239.4	138.2	119.8
		3	126.4	147.4	131.2	118.6	137.8	138.3	119.0	121.2
			149.0	147.8	179.4	123.4	113.4	212.4	185.0	111.0
		4	148.2	113.0	135.6	161.8	132.8	127.6	139.4	134.4
			137.0	117.2	170.5	200.8	142.2	118.0	202.8	184.6
	4	1	142.4	124.8	156.2	185.4	129.2	125.0	196.6	149.0
			120.6	115.2	144.8	131.8	130.2	120.8	155.6	144.0
		2	130.8	158.2	159.0	171.4	134.2	151.4	161.2	137.8
			144.0	139.8	130.2	134.0	127.6	154.0	147.0	157.8
		3	148.8	158.2	157.0	134.2	244.6	206.0	162.2	130.2
			135.0	153.0	130.8	137.2	134.6	139.8	145.2	140.0
		4	181.8	167.4	131.2	143.4	191.0	172.4	133.0	158.0
			170.0	114.8	127.6	137.8	150.2	145.5	122.0	154.4
	2 + 4	1	121.6	174.8	153.0	109.8	178.2	138.6	117.4	153.6
			182.8	128.2	143.2	228.4	189.8	130.8	145.6	145.0
		2	126.8	110.8	143.6	113.6	152.0	162.8	196.2	198.0
			199.8	136.8	167.0	187.2	156.8	243.8	146.8	161.0
		3	216.2	131.4	118.4	186.4	147.4	182.6	178.8	117.0
			149.6	169.4	149.0	153.8	162.8	167.4	176.4	140.2
		4	142.4	179.8	175.0	208.8	118.2	132.2	136.4	131.0
			142.6	110.8	163.6	151.8	155.4	150.2	163.6	177.4

NOTES All the briefing time values are given in seconds.

These data were obtained from eight subjects per briefing condition, giving rise to 2 readings per cell. The first value in each pair relates to the first group of four subjects per briefing condition, as given in Table 7.7.1.

TABLE 7.8.2

Analysis of variance on the briefing-time data given in Table 7.8.1*

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing conditions(C)	6	112068.01	18678.00	18.83(c)	$p < 0.001$
Target ranges (R)	2	611.31	305.65	- (c)	N.S.
Targets (T)	7	14133.33	2019.05	2.04(c)	$p < 0.05$
C x R	12	7704.76	642.06	- (b)	N.S.
C x T	42	31233.28	743.65	- (b)	N.S.
R x T	14	11705.38	836.10	- (b)	N.S.
C x R x T	84	76861.64	915.02	- (a)	N.S.
Residual (a)	168	189867.22	1130.16		
Pooled residual (b) (Residual (a) + CRT)	252	266728.86	1058.45		
Pooled residual (c) (Poooled residual (b) + CR, CT, RT)	320	317372.28	991.79		
TOTAL	335	444184.93			

TABLE 7.8.3

Analysis of variance on the briefing-time data given in Table 7.8.1*, excluding the data from the map only condition.

Source	D.F.	S.S.	M.S.	V.R.	Significance
Briefing type (B)	1	9989.91	9989.91	10.36(d)	$p < 0.005$
Briefing range (P)	2	19038.96	9519.48	9.87(d)	$p < 0.001$
Target range (R)	2	784.10	392.05	- (d)	N.S.
Targets (T)	7	18072.59	2581.80	2.68(d)	$p < 0.05$
P x B	2	3991.32	1995.66	2.05(c)	N.S.
P x R	4	4996.22	1249.06	1.29(c)	N.S.
P x T	14	10083.52	720.25	- (c)	N.S.
B x R	2	555.08	277.54	- (c)	N.S.
B x T	7	10642.02	1520.29	1.56(c)	N.S.
R x T	14	9555.83	682.56	- (c)	N.S.
P x B x R	4	1633.12	408.28	- (b)	N.S.
P x B x T	14	3920.01	280.00	- (b)	N.S.
P x R x T	28	24658.39	880.66	- (b)	N.S.
B x R x T	14	10207.16	729.09	- (b)	N.S.
P x B x R x T	28	26813.89	957.64	- (a)	N.S.
Residual (a)	144	158194.51	1098.57		
Pooled residual (b) (Residual (a) + PBRT)	172	185008.40	1075.63		
Pooled residual (c) (Pooled residual (b) + PBR, PBT, PRT, BRT)	232	225427.08	971.67		
Pooled residual (d) (Pooled residual (c) + PB, PR, PT, BR, BT, RT)	275	265251.07	964.55		
TOTAL	287	313136.63			

*The data from target range 1 mile are not included in these analyses.

7.8.1 Analysis of replicated briefing-time data: the effects of briefing type and briefing range.

The mean briefing times for the drawings and diagrams conditions are given in Table 7.8.4 and the mean briefing times for the three briefing range conditions in Table 7.8.5. In each case the mean value for the map only condition is also given.

TABLE 7.8.4

Mean briefing time for each briefing type

	Mean briefing time (seconds)	N
MAP ONLY	113.8	48
Map + diagrams	163.5**	144
Map + drawings	151.7**	144

TABLE 7.8.5

Mean briefing time for each briefing range

	Mean briefing time (seconds)	N
MAP ONLY	113.8	48
Briefing range:		
2 miles	151.5**	96
4 miles	152.3**	96
2 + 4 miles	169.1**	96

N = Number of readings on which each value is based.
** Significantly higher than map only value at 1% level.

Each of the briefing type values shown in Table 7.8.4, and the briefing range values shown in Table 7.8.5, was significantly higher than the value for the map only condition. The difference between the mean briefing times for the drawings and diagrams was highly significant, subjects taking longer for the diagrams. This is of some interest as it is the only measure of performance for which a significant difference was found between the effects of drawings and diagrams. The difference between the 2 mile briefing condition and the 4 mile was not significant but both these values were significantly lower than that for the 2 + 4 mile condition.

TABLE 7.9.1

SUMMARY OF THE MAIN RESULTS

	DETECTION PROBABILITY	SEARCH TIME	CONFIDENCE LEVEL	BRIEFING TIME
BRIEFING TYPE	Highly significant ($p < 0.01$) Only the photographs resulted in significantly higher detection probability than the map only condition, but the drawings and diagrams both brought about improvements whereas the 'target circles' briefing resulted in a deterioration in detection probability. (36-37)	Highly significant ($p < 0.001$) All briefing types except the photographs resulted in significantly longer mean search times than the map only condition, but there was evidence that this latter value was unexpectedly low. (66-67)	Highly significant ($p < 0.001$) Photographs resulted in significantly higher mean confidence level than the map only condition but no improvement in confidence levels was found for the drawings and diagrams. (79-80)	Significant ($p < 0.05$) All types of additional briefing resulted in significantly longer briefing times than the map only condition, photographs being the longest. (94)
BRIEFING RANGE	Non-significant 2 + 4 mile briefing was more effective than 2 mile or 4 mile briefing but none of the values were significantly different from the map only condition. (38)	Non-significant 4 mile range briefing resulted in the longest mean search time, significantly greater than that for the map only condition. (68)	Significant ($p < 0.025$) 2 + 4 mile briefing gave rise to significantly higher mean confidence level than 4 mile briefing, but none of the values were significantly different from the map only value. (81)	Highly significant ($p < 0.01$) 2 mile briefing resulted in shorter briefing times than 4 mile or 2 + 4 mile briefing. (95)
BRIEFING TYPE x TARGET RANGE	Non-significant Diagrams, drawings and photographs improved detection probability, relative to the map only condition, at target ranges of 2, 3 and 4 miles but at the 1 mile range a deterioration occurred. (39-41)	Non-significant Search times increased with increasing range under all briefing conditions, with the exception that the 1 mile range resulted in longer search times than the 2 mile range. (69-70)	Non-significant ($p < 0.10$) Confidence levels tended to fall with increasing range under all briefing conditions. At the 1 mile range confidence levels were lower when additional briefing was used than under the map only condition. (82-83)	Non-significant (No interaction would be expected since the target range was not known to the subjects during briefing.)
BRIEFING RANGE x TARGET RANGE	Non-significant ($p < 0.10$) Detection probability was particularly favourably affected when the briefing range coincided with the target range but improvements also occurred at other target ranges, except 1 mile. (42-43)	Non-significant No analyses carried out since the main factors were also non-significant. (71)	Non-significant Confidence levels tended to be higher when briefing range coincided with target range. (84)	Non-significant (No interaction would be expected since the target range was not known to the subjects during briefing.)
Comparison of the drawings and diagrams using the replicated data (excluding data from the 1 mile range)	No significant differences between the drawings and diagrams. Both resulted in highly significant improvements in detection probability, relative to the map only, particularly at longer ranges. The drawings and diagrams interacted with briefing range and with target size. 2 + 4 mile briefing was consistently more effective than 2 mile or 4 mile briefing separately. (48-62)	No significant differences between the drawings and diagrams. The mean search times for the drawings and diagrams were not significantly higher than the map only value. Some evidence of an interaction between briefing range and target range. (72-75)	No significant differences between the drawings and diagrams. The mean confidence levels were not significantly different from the map only value. There was a significant interaction between the drawings and diagrams and the briefing ranges. (87-90)	Significantly longer briefing times were required for the diagrams than for the drawings. Both values were significantly longer than the map only value. (97-99)

NOTES (i) The significance levels quoted are taken from the analyses of variance carried out on the basic data for all additional briefing conditions, the map only data being excluded as these data were not associated with any briefing range. (ii) The briefing types referred to - target circles, diagrams, drawings and photographs were each used together with the map for briefing purposes, the control condition being the map only condition. (iii) The numbers shown in brackets at the bottom right-hand corner of each block refer to the relevant pages of the report.

8. DISCUSSION

The main results found from the analyses described in Section 7 can be summarised as follows:-

(a) Three of the additional briefing materials tested, diagrams, drawings and photographs, resulted in higher detection probabilities than the map only condition, the photographs being most effective. Search time decreased slightly and confidence level increased when photographs were used as additional briefing material but the drawings and diagrams did not result in improvements in these performance measures.

(b) The use of target circles as additional briefing material did not result in any overall improvement in detection probability, search time or confidence level.

(c) No differences were found between drawings and diagrams, except that longer briefing times were required when the diagrams were used.

(d) In spite of the overall improvement in detection probability brought about by the diagrams, drawings and photographs, each of these briefing materials caused a marked deterioration in detection probability, relative to the map only condition, when the target range was 1 mile. The same effect was noted for the target circles briefing.

(e) The 2 and 4 mile briefing ranges were equally effective in terms of overall detection probability, but the 4 mile range tended to result in longer search times and lower confidence levels than the 2 mile range. Simultaneous presentation of briefing at both ranges was more effective than at either of the briefing ranges alone. The greatest improvements in detection probability, relative to the map only condition, tended to occur when the briefing range coincided with target range.

In general, these results are in accordance with expectation. Although no definite predictions could be made as to the relative effectiveness of the drawings and diagrams, both of which showed the same amount of information, it would clearly be expected that the additional briefing materials

used in this experiment would increase in effectiveness as the amount of relevant information provided increased, i.e. in ascending order of effectiveness, target circles, diagrams/drawings and photographs. However, the magnitude of the improvement due to the successive increases in information could not be predicted. The more important comparisons between briefing types are considered in the following sections.

8.1 The effect of briefing type

(i) Comparison of map + target circles briefing with map only

The failure of the first level of additional briefing, target circles, to bring about any improvement in performance as compared with the map only condition is of importance in relation to the interpretation of the effects found for the other briefing materials. This result indicates that, under the conditions of the present experiment, detection performance was not improved when the subjects were given information about the position of the target on the display, but not about its appearance nor that of the surrounding terrain. In fact, an overall deterioration in performance, arising largely from a marked deterioration at the 1 mile target range, occurred with this type of briefing. This result implies that any improvement arising from the use of diagrams, drawings or photographs as additional briefing material must be due to the information they provide about the target and surrounding terrain, not to the fact that the target position is marked, thus allowing visual search to be concentrated on a relatively narrow area.

(ii) Comparison of map + drawings or diagrams briefing with map only

The fact that the use of drawings or diagrams in addition to a map improves detection probability relative to the map only condition indicates that at least part of the difficulty in interpreting the map information lies in the problem of accurately visualising a realistic perspective view of the terrain from the symbolically coded plan view given on the map. Although the initial analysis of the data showed that

the increase in overall detection probability due to the drawings and diagrams did not reach significance in either case, further investigation showed that comparing the overall mean values was in some respects misleading, as the substantial improvement occurring at longer ranges was partially off-set by a marked deterioration in performance at the 1 mile target range. The same effect was found for the other types of additional briefing material. The explanation of this effect lies in the briefing ranges chosen, 2 miles and 4 miles. Briefing materials showing the target at one or both of these ranges, tended to direct the subject's attention to the upper part of the display. In spite of the fact that the subject knew that the target might on some occasions be presented at relatively short ranges, it is clear from the results that the briefing materials tended to mislead the subject into expecting the target to be at longer ranges, and thus produced a deterioration in performance, as compared with the map only condition. It is perhaps surprising that this effect was so marked in spite of the fact that the majority of the targets were relatively conspicuous when viewed from 1 mile range. These results emphasise that misleading or inappropriate briefing material is liable to prove positively detrimental to performance.

Although this result is of some importance in the context of the static simulation technique used in the present experiment, it is of less relevance in considering the possible use of these briefing materials under dynamic conditions since under such conditions the navigator would have a continuous view of the target area as he approached, rather than, as in the present experiment, a single view from one unknown range.

Under these dynamic conditions the probability of correct detection at a range of 1 mile could only in exceptional circumstances be less than the probability of detection at greater ranges. The result obtained in the present experiment was therefore only applicable to the static simulation technique used. In this respect therefore the overall mean

detection probabilities, summed over all target ranges for each type of additional briefing give an artificially low estimate of their possible effect, relative to the map only condition, under dynamic conditions. For this reason data from target range 1 mile were excluded when a more detailed analysis of the effects of the diagrams and drawings was carried out. The results of this analysis showed that drawings and diagrams were equally effective, both resulting in highly significant improvements in detection probability as compared with the map only condition.

(iii) Comparison of map + photographs briefing with map only

As would be expected, photographs were found to be the most effective form of additional briefing, resulting in improvements in detection probability, search time and confidence level. However, it must be emphasised that, since the briefing photographs were in some cases identical to the target photographs and in other cases taken under identical conditions and different only in range, the results of this experiment tend to overestimate the effect of the photographs relative to the other types of briefing material. Under operational conditions it is unlikely that, even if oblique briefing photographs were available, they would have been taken under conditions such that cloud, lighting, visibility and seasonal effects corresponded exactly with those of the actual mission. The present experiment was therefore highly artificial in this respect and the data relating to the photographs briefing condition must be regarded as indicating an upper limit of performance. It is of interest to note that when the briefing range coincided with the target range, and thus the subject was required to locate the target in a photograph identical to one previously given him for briefing, the probability of correct response, although high, did not reach 100%.

(iv) Comparison of the map + photographs briefing conditions with the map + drawings or diagrams conditions

Comparison of the detection probabilities achieved when drawings or diagrams were used as additional briefing materials with that for the photographs conditions showed that at each range target photographs resulted in greater improvement than either drawings or diagrams but at the longer ranges there was very little difference between the effects of the diagrams and the photographs. The overall mean improvement (omitting the data from target range 1 mile) due to the use of photographs was 1.6 times as great as that achieved with the drawings and diagrams. However, this value would be reduced if, as in practice, the photographs were taken under different conditions from the views of the target subsequently displayed to the subjects. Nevertheless it is unlikely that, other things being equal, drawings or diagrams prepared from maps could be made as effective for briefing purposes as oblique photographs of the same area. In particular, important visual cues such as field patterns, hedgerows, different types of vegetation, masking effects, details of built-up areas, etc. cannot be derived from the information given on maps of the type used for this work, i.e. 1" = 1 mile Ordnance Survey maps. If maps of smaller scale are used, the problem becomes correspondingly greater. On account of these limitations perspective drawings prepared from maps must be regarded as essentially a substitute for use when suitable oblique photographs are not available. Other effects such as those due to seasonal changes, cloud, lighting, visibility, etc., also cannot be taken into account when preparing the drawings but these limitations apply equally to oblique photographs.

In spite of the fact that perspective drawings, prepared from maps, show less information than the corresponding photographs, they do have several important advantages. In particular, providing suitable maps are available, the drawings can be prepared to correspond to any required altitude, direction of approach, field of view, depression angle, target

range and offset. Oblique photographs taken during reconnaissance missions may not correspond exactly in these parameters to the conditions of the actual mission, and in many cases may not be available at all. It could be that the effectiveness of a photograph taken, say, from an approach direction several degrees different from that of the actual mission, is reduced to such an extent that it is no more effective and may be less, than a perspective drawing prepared according to the planned parameters of the actual mission.

This discussion of the effects of the different types of briefing has been concerned mainly with the most important performance measure, detection probability. The analysis of the search time and confidence level data showed less conclusive results. Whereas photographs slightly reduced mean search time and significantly increased confidence level, as compared with the map only condition, the drawings and diagrams did not result in improvements in these performance measures. The overall mean confidence levels for these briefing materials were effectively the same as for the map only condition, and mean search times appeared to increase. Although further analysis suggested that this result was apparently due to an unusually low value for the map only condition, it was clear that drawings and diagrams did not bring about any reduction in mean search time.

The conditions of the present experiment were such that no specific limit was set on time the subjects were allowed to search the display, although the importance of speed was strongly emphasised to them. Under these conditions it was difficult to ensure that subjects did in fact respond as quickly as possible, and it would perhaps have been more appropriate to have carried out the experiment under paced conditions so that the performance levels achieved in a given time with the different

types of briefing could have been compared. However, work currently being carried out using a dynamic simulation technique should show more conclusively whether, in fact, the different briefing materials tested do affect the time required to detect the target, and thus the detection range, as well as the probability that it will be correctly detected.

One possible explanation for the result obtained in the present experiment is that the small amount of experimental material available for training purposes did not allow the subject to become thoroughly familiar with the techniques of representation used in the drawings and diagrams, whereas photographs were a familiar form of representation. Furthermore the briefing photographs corresponded very closely to those in which the subject was subsequently required to locate the target, and as discussed previously, this artificial situation tended to result in an overestimate of the effect that might be obtained from photographs in practice.

These possible explanations could also account at least in part for the fact that, whereas photographs significantly increased mean confidence level as compared with the map only condition, drawings and diagrams had very little effect on confidence level. It is of interest to note that there was evidence in both the search time and the confidence level data of a deterioration in performance at the 1 mile target range, relative to the map only condition, similar to that which occurred for detection probability.

8.2 The effect of briefing range

The effect of briefing range as determined from the present experiment was very much as would be expected. The anomalous reversal of effect at the 1 mile target range noted previously occurred for each briefing range. At the other target ranges it was found that the 2 mile briefing enhanced

detection probability at the 2 mile target range but had little effect at the 4 mile range. For the 4 mile briefing range the reverse was true. When the 2 and 4 mile range briefing was used simultaneously the overall improvement in detection probability was greater than that for either of the briefing ranges alone. However, the improvement was not as great as the summated effects found for the 2 and 4 mile briefing ranges. This is understandable since subjects given both briefing pictures simultaneously had to memorise and process considerably more information than those given only a single briefing picture. Analysis of the search time data showed that 2 + 4 mile briefing resulted in slightly shorter search times than either briefing range singly. It was also found that the combined briefing gave rise to higher mean confidence levels. Briefing range also had a significant effect on the time required for briefing. The 2 mile briefing range resulted in shorter briefing times than either the 4 mile or 2 + 4 mile condition.

8.3 Comparison of the effects of the drawings and diagrams.

The analysis of the basic data for all briefing types, discussed in the previous sections, indicated that there were no significant differences between the effects of the drawings and diagrams. However, for reasons described below, it was necessary to determine, more reliably than was possible using the single set of data, whether there were any important differences between these two types of briefing which were not apparent in the initial analyses. Replicated data were therefore obtained for these conditions, together with the map only condition, in order to carry out more detailed analyses. Only the data from target ranges 2, 3 and 4 miles were included in these further analyses, the data from the anomalous target range 1 mile being omitted, in order to obtain a better indication of how effective these briefing materials might be, as compared with the map only condition, in a dynamic situation.

No overall differences were found between the drawings and the diagrams conditions in the analysis of the replicated data for the detection probability, search time and confidence level measures. This confirmed the results obtained from the initial analysis of the basic data. The analysis of this replicated briefing-time data showed that significantly longer briefing times were required for the diagrams conditions than for the drawings. This result can be explained by the fact that the use of the diagrams depended on the interpretation of a code whereas the drawings conveyed information directly. This was the only overall difference between the drawings and the diagrams and, although of some interest, it is not of practical importance since briefing-time, i.e. the time available for pre-flight study of the briefing materials, is not likely to be limited to such an extent that the difference between the two mean values (less than $\frac{1}{4}$ minute) would become critical.

The fact that there were no other significant differences between the overall effects of the drawings and diagrams has important implications for the further development of this work. Whereas the preparation of the freehand drawings requires some degree of artistic skill, the preparation of the diagrams is largely a routine process. Relatively little training would be required to enable a technical assistant, or the aircrew themselves, to use the special grids for transferring the plan view information on the map to the required perspective view, as described in the second part of this report (Parkes and Crook, 1969), and to apply the set coding for each type of feature. If these forms of briefing proved to be effective under dynamic conditions, then the question of whether it would be possible to use them in an operational situation would have to be considered. The preparation of diagrams could be carried out relatively easily in such a situation whereas the preparation of freehand drawings is much less likely to be feasible. The fact that the diagrams were found to be as effective as the drawings in improving performance was therefore of considerable importance.

Although the overall effects of these two types of briefing differed only in respect of the briefing times required, there were some significant interactions involving drawings and diagrams and/or range of briefing. The most important of these was the interaction between briefing type and briefing range which occurred in both the detection probability data and the confidence level data. In each case the data followed a similar pattern, the interactions arising from the fact that when diagrams were used as additional briefing material the 2 mile briefing range resulted in better overall performance than the 4 mile briefing range, whereas when when drawings were used the opposite was true. The low detection probability value for the 2 mile drawings as compared with the 2 mile diagrams was particularly striking and inspection of the raw data showed that this was largely due to one target, Number 15, for which the 2 mile diagrams resulted in 100% correct detection and the 2 mile drawings, 0%. Examination of the 2 mile range drawings and diagrams showed that for this particular target the diagrammatic technique had resulted in a much closer resemblance to the photographs than the drawings. This is the most likely explanation of the result found.

This example illustrates a more general point that the mechanical shadings used in diagrams have an advantage over freehand techniques if detailed information about the terrain is not available. The mechanical shading can be laid over the appropriate area without implying specific details about the structure of the area, whereas in freehand drawing it is difficult to avoid some indication of the detailed structure which may not be accurate, and may therefore be misleading.

On the other hand, the freehand technique is better suited to representing the way in which the appearance of a particular type of feature changes at different distances from the observer. The fixed code used for the diagrams could not take this into account. Thus, at the 4 mile briefing range, the relationship between the features in the immediate

vicinity of the target and those in the foreground could be better represented by drawings than by diagrams. This could perhaps explain why at this briefing range the drawings proved to be more effective than the diagrams for six out of the eight targets.

The analysis of the replicated detection probability data indicated a significant interaction between the drawings and diagrams and the targets. Further analysis showed that this interaction was confined to the group of five small targets, the interaction arising from the fact that drawings proved more effective than diagrams for two of these targets whereas the reverse was true for the other three. There was also some evidence of an interaction between target size and briefing type arising from the fact that drawings proved more effective than diagrams for large targets and diagrams more effective than drawings for small targets. These effects could have arisen by chance but it would be of interest to further investigate the apparent interactions using targets more closely controlled in terms of size.

The significance of these interactions suggests that under some circumstances the conclusion that the drawings and diagrams are equally effective may not be valid. However, this applies only to the conditions in which the two briefing ranges, 2 miles and 4 miles, were used separately. Under the combined briefing range condition, 2 + 4 miles, which was consistently more effective than either of the single briefing ranges, there was no evidence of an interaction between type and targets although, relative to the map only condition, the improvement brought about by the briefing materials for small targets was proportionately much greater than that for the large targets.

It was not possible to include in the analyses of variance from which these interactions were determined the data from the map only condition, since those were not associated with any particular briefing range. However, inspection of the data showed that, as noted previously,

whereas increasing target range brought about a marked deterioration in performance under the map only condition, when drawings and diagrams were used as additional briefing material performance improved markedly at the longer ranges. This was an encouraging result since the briefing materials had been developed primarily to facilitate target detection at these longer ranges. There was also evidence that performance was particularly favourably affected when the briefing range was equal to the target range. This latter effect was probably accentuated by the static nature of the simulation technique used in this experiment. Clearly it is of vital importance to determine whether the significant improvement in detection probability brought about by the drawings and diagrams under these static conditions is also found under dynamic conditions. Research currently being carried out is intended to investigate this.

8.4 Further work

Whilst any further development of these techniques must depend on the outcome of the experimental work currently being carried out under dynamic conditions, some possible directions in which the work could be extended are outlined below.

(a) Since maps of scale 1" = 1 mile, as used in the present experiment, are not available for many parts of the world, it would be of interest to determine whether perspective views prepared from smaller scale maps, particularly $\frac{1}{4}$M, would be of any value in target recognition. The main difficulty in the use of such maps is that the amount of detail shown is extremely limited and does not correspond well with the type of detail that is likely to be conspicuous when the terrain is viewed by television during a low-level approach. For instance, many small patches of woodland are omitted from $\frac{1}{4}$M maps but the size, shape and position of these features may provide important clues to the recognition of the target area. Conversely, roads shown conspicuously on the map may be completely masked by hedges, particularly if

they run perpendicular to the flight path. Current work suggests that drawings prepared from $\frac{1}{4}$M maps may confuse the observer by emphasising features which do not show up clearly on the television display, whilst omitting those that do.

(b) Vertical photography of the earth's surface is becoming increasingly widespread and in some areas may be more readily available than detailed maps. Such photographs could be used as an extremely effective source of information about the terrain from which oblique drawings could be prepared. The amount of detail on vertical photographs is very much greater than that on a map and, in addition, a photograph gives some indication of tones and textures. In preparing oblique drawings from vertical photographs it might be preferable to omit some of the detail, and select only those features which are likely to provide useful clues to the recognition of the target area.

(c) Although it is possible to prepare drawings corresponding to views of the terrain from any required altitude, it is doubtful whether such drawings would be of much value at very low altitudes since at these altitudes the effects of masking, which cannot be accurately estimated from maps, become of critical importance. The limits of altitude within which the drawings can be used as an effective substitute for oblique photographs should therefore be determined. Another aspect that could usefully be investigated is whether the field of view shown in the drawings should be the same as that of the simulated television display, as in the present experiment, or whether a slightly larger field of view should be shown. The larger field of view might be an advantage if there were small errors in the aircraft track as it approached the target area.

(d) In spite of the fact that there was no evidence of an interaction between briefing range and target size in the present experiment, it is possible that a further study carried out with a wider range

of targets under dynamic simulation conditions might indicate that the optimum briefing range depends on both target size and terrain type.

(e) Since a wider range of shading materials is now available commercially than when the diagrams used in the present experiment were prepared, the coding used to represent different types of feature could perhaps be improved. In particular, a greater difference between the tones would be an advantage, and it is possible that 'semi-symbolic' forms of coding, as described in the second part of this report, would be more readily interpreted than the coding used in the present experiment which was based on the matching of tones and/or textures. In discussing the question of coding a number of more general considerations arise such as the maximum number of shadings that can be readily interpreted and whether several graduations of each type of shading can be used. This would allow some attempt to be made to represent the way in which the appearance of a feature alters at different distances from the observer.

(f) Whilst the task of transforming the map information into oblique views of the target area was carried out by hand in the present work, it is possible to use automated techniques for carrying out this transformation. The standardised format of the diagrams is particularly suited to automated techniques but their use would only be justified for relatively large-scale applications.

9. REFERENCES

Burton, M.J.C. (1966). Brief comments on problems in the operational use of aeronautical charts and map displays. Janair symposium on aeronautical charts and map displays. (Ed. J. J. McGrath) 133-136.

Hagen, W.C., Larue, M.A., and Ozkaptan, H. (1966). Effect of perspective geometry training on target area location. Martin Marietta Corporation, Orlando, Florida. Report No OR8528.

Heap, E. (1965). Visual factors in aircraft navigation. Institute of Navigation Journal. 18 (3).

LaPorte, H.R., and Calhoun, R.L. (1966). Laboratory studies in air-to-ground target recognition. Part X: Clue utilization in target recognition. Autonetics, Anaheim, California. T6-1504/3111.

McGrath, J.J. and Borden, G.J. (1963). Geographic orientation in aircraft pilots: A problem analysis. Human Factors Research Inc. Technical report 751-1.

McGrath, J.J., Osterhoff, W.E., and Borden, G.J. (1964). Geographic orientation in aircraft pilots: Experimental studies of two cartographic variables. Human Factors Research Inc. Technical report 751-3.

Parkes, K.R., and Crook, J.M. (1969). Visual and televisual detection studies. Part VI (ii). Briefing materials for low-level target detection : techniques for preparing perspective drawings from maps. Ministry of Technology contract No. PD/170/04/AT. Loughborough University of Technology.

Pelton, F.M., and Magorian, T.R. (1966). Chart requirements for low-altitude, high-speed military missions. Janair symposium on aeronautical charts and map displays. (Ed. J.J. McGrath).

Rusis, G., and Rawlings, S.C. (1966). Laboratory studies in air-to-ground target recognition. Part IX: The effect of reconnaisance/intelligence information. Autonetics, Anaheim, California. T6-1164/3111.

APPENDIX

Briefing type	Briefing range (miles)	Target range (miles)	Targets							
			1	3	6	13	15	16	17	20
MAP ONLY	-	1	A E	D F	C G	B H	A E	B F	C G	D H
		2	B H	A E	D F	C G	D H	A E	B F	C G
		3	C G	B H	A E	D F	C G	D H	A E	B F
		4	D F	C G	B H	A E	B F	C G	D H	A E
MAP + TARGET CIRCLES	2	1	A	B	C	D	A	B	C	D
		2	D	A	B	C	D	A	B	C
		3	C	D	A	B	C	D	A	B
		4	B	C	D	A	B	C	D	A
	4	1	B	D	C	A	C	D	A	B
		2	A	B	D	C	B	C	D	A
		3	C	A	B	D	A	B	C	D
		4	D	C	A	B	D	A	B	C
MAP + DIAGRAMS	2	1	D E	C H	B G	A F	A E	B H	C G	D F
		2	C F	B E	A H	D G	B F	C E	D H	A G
		3	B G	A F	D F	C H	C G	D F	A E	B H
		4	A H	D G	C F	B E	D H	A G	B F	C E
	4	1	C G	D F	A E	C H	B G	A H	D E	B F
		2	A H	B G	B F	D E	D F	C G	C H	A F
		3	B E	A H	D G	A F	C E	D F	B G	C H
		4	D F	C E	C H	B G	A H	B E	A F	D G
	2 + 4	1	A E	B F	D G	C H	B G	D H	C E	A F
		2	C G	A H	B E	D F	A H	B E	D F	C G
		3	D H	C E	A F	B G	C F	A G	B H	D F
		4	B F	D G	C H	A E	D E	C F	A G	B H

Briefing type	Briefing range (miles)	Target range (miles)	Targets							
			1	3	6	13	15	16	17	20
MAP + DRAWINGS	2	1	B E	A F	C G	D H	B H	A G	C F	D E
		2	D H	C E	B F	A G	C E	D H	A G	B F
		3	A G	B H	D E	C F	A F	B F	D H	C G
		4	C F	D G	A H	B E	D G	C F	B E	A H
	4	1	C F	B G	D H	A E	D F	B G	C H	A E
		2	B G	D H	A E	C F	B G	C H	A E	D F
		3	D H	A E	C F	B G	C H	A E	D F	B G
		4	A E	C F	B G	C H	A E	D F	B G	C H
	2 + 4	1	D E	A G	B H	C F	A F	D H	C G	B E
		2	C F	C E	D G	D H	B E	B F	A H	A G
		3	A H	D H	C E	B G	D G	A E	B F	C H
		4	B G	B F	A F	A E	C H	C G	D E	D E
MAP + PHOTO-GRAPHS	2	1	B	A	D	D	A	B	C	C
		2	D	D	A	B	C	C	B	A
		3	A	B	C	C	B	A	D	D
		4	C	C	B	A	D	D	A	B
	4	1	B	D	C	A	B	A	C	D
		2	A	B	D	C	D	B	A	C
		3	C	A	B	D	C	D	B	A
		4	D	C	A	B	A	C	D	B
	2 + 4	1	C	D	B	A	C	D	A	B
		2	A	B	C	D	B	A	C	D
		3	D	C	A	B	D	C	B	A
		4	B	A	D	C	A	B	D	C

The tables above show details of the experimental design. The basic data were obtained from 48 subjects, four subjects being assigned to each of the 12 briefing conditions. The subjects in each group are designated A, B, C and D. It can be seen that each subject was exposed to each target once and once only, and to each range condition twice and twice only. For seven of the briefing conditions replicated data were obtained from further groups of four subjects. These subjects are designated E. F, G and H. The order of presentation of the 8 target and range combinations to each subject was randomised.

PART VI (iii)

V I S U A L A N D T E L E V I S U A L D E T E C T I O N S T U D I E S

Part VI(ii) Briefing materials for low-level target detection: Techniques for preparing perspective drawings from maps.

by

K. R. Parkes and J. M. Crook

The work described in this report was carried out by Mr. J. M. Crook, Lecturer in the Department of Educational Studies, Brighton College of Art, in co-operation with the Department of Ergonomics and Cybernetics, Loughborough University of Technology. Mr. Crook was also responsible for all the art-work reproduced in the report.

SUMMARY

This report is concerned with the development of techniques for preparing perspective drawings of target areas from the information given on a 1" = 1 mile Ordnance Survey map. These drawings were intended for use as experimental briefing material in a low-level target detection task. The altitude (2000 feet), camera field of view (30° x $22\frac{1}{2}^{\circ}$) and depression angle (10°), and the display size for the drawings were specified to correspond to the parameters of the simulated television viewing system.

An initial study of the problem was carried out and grids for transforming the plan view information on the map to the required perspective views were prepared. Possible techniques for representing the different types of features in the perspective views were investigated and two of these were chosen for the preparation of a complete set of briefing material for the experimental targets, The techniques chosen were: (a) drawings carried out using a freehand technique, and (b) diagrams carried out by means of commercially available shading materials and standardised lines. For each target drawings and diagrams were prepared showing the target and surrounding terrain as seen from two different ranges, 2 miles and 4 miles.

The report is illustrated with examples of some of the preliminary work carried out, and with a complete set of briefing material prepared for one of the series of experimental targets.

ACKNOWLEDGEMENTS

The Department of Ergonomics and Cybernetics, University of Technology, Loughborough, would like to acknowledge the financial support provided for this work by the Ministry of Technology, under contract No. PD/170/04/A.T.

The work was supervised by Dr. N. S. Kirk, Senior Lecturer in the Department of Ergonomics and Cybernetics and the authors are grateful for his advice and encouragement. Valuable technical assistance was provided by Mr. J. Rennocks, also of the Department of Ergonomics and Cybernetics.

Particular thanks are due to the University Photo-Printing Unit who were responsible for the reproduction of the many illustrations in this report.

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ILLUSTRATIONS

1. THE PURPOSE OF THE WORK

This report is concerned with work carried out in connection with a study of the effects of different types of briefing materials on performance at a simulated target detection task. The problem as outlined to the consultant who undertook this part of the work was to develop techniques for preparing oblique perspective drawings, derived from the information given on a 1" = 1 mile Ordnance Survey map, of specified target areas.

During low-altitude flight the terrain ahead of the aircraft is seen obliquely, whereas a map represents the terrain symbolically and in plan view. It was hoped that providing accurate drawings showing an oblique view of the target area would reduce the difficulty experienced by subjects in attempting to visualise the target and surrounding terrain, as seen during a low-altitude approach, solely from the information shown on the map. These drawings were initially intended for use as experimental briefing material in a televisual target detection task simulated statically by means of a series of aerial photographs. However, the underlying problem was dynamic target acquisition during high-speed, low-level flight under conditions in which only a map was available for briefing purposes. A more detailed account of the background to this work is given in Part VI(i) of this series of reports (Parkes, 1969).

The oblique view of the target, as seen on a television monitor during a low-level approach, depends on altitude, camera field of view, depression angle, display size and target range. For the present work the following values of these parameters were specified:

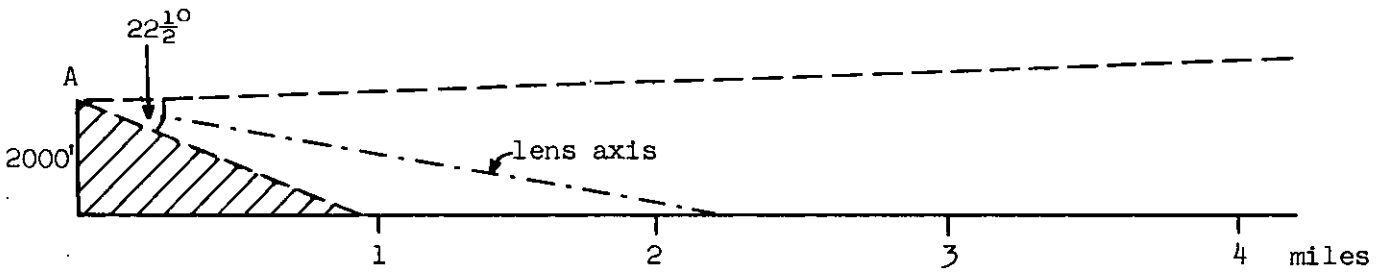
(i) Altitude: 2000 feet.
(ii) Camera field of view: 30° (horizontal) x $22\frac{1}{2}^{\circ}$ (vertical)
(iii) Depression angle of lens axis: 10°
(iv) Display size: 4.8" x 3.6"
(v) Range of target: (a) 2 miles, and (b) 4 miles

These parameters, some of which are shown graphically in Figure 1.1, correspond to the conditions under which the photographs used to simulate the television display in these experiments had been exposed.

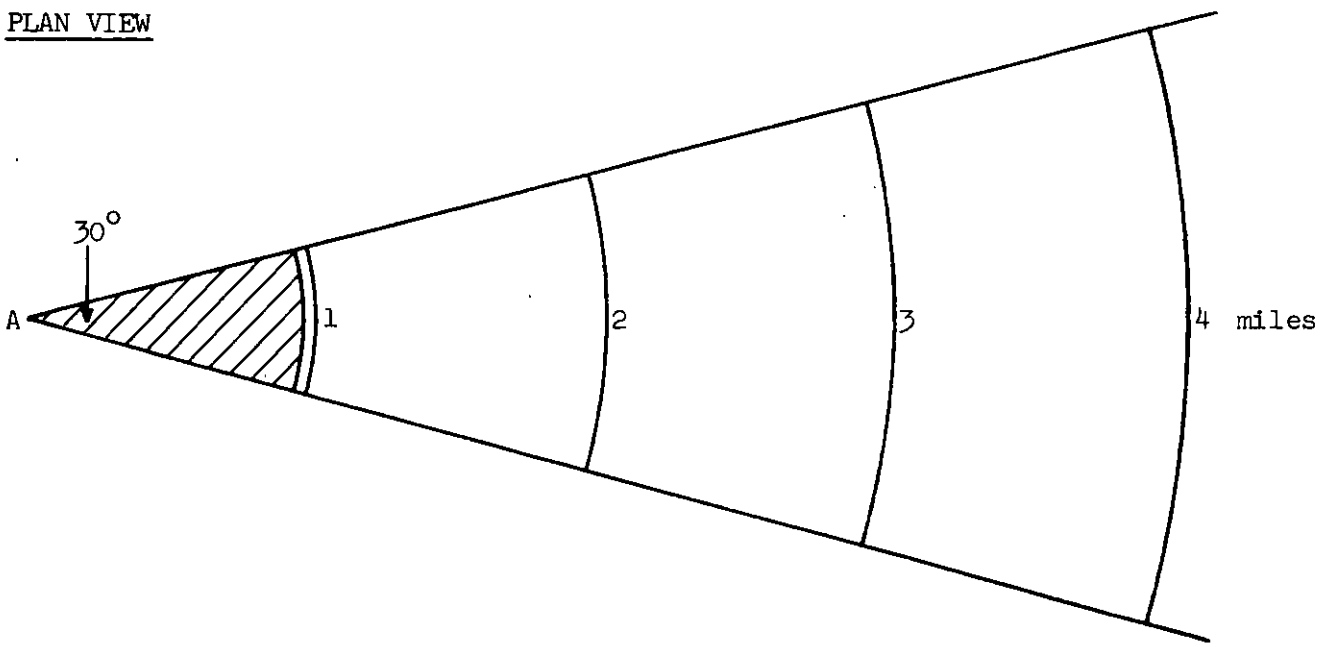
FIGURE 1.1

Photographic parameters.

SIDE VIEW



PLAN VIEW



Scale: 1½" = 1 mile

The point designated A represents the position of the camera, carried in the aircraft or missile, at an altitude of 2000 feet. The lens axis is depressed 10° below horizontal, and the shaded areas represent the space ahead of the camera but not in the field of view.

After some preliminary discussion it was decided that the work should be carried out in three stages:

(i) Initial investigation of the problem: a series of sample maps and photographs was provided to enable the relationship between them to be studied.

(ii) Preparation of drawings for two targets for which only maps were provided. This stage of the work would include preparing examples of various different techniques of representation as a basis for deciding the most satisfactory format.

(iii) Preparation of the complete set of drawings required, according to the detailed specification decided after the second stage of the work.

These three stages are described in more detail in the following three sections.

2. PRELIMINARY APPRAISAL OF THE PROBLEM

For the initial investigation of the problem a series of sample maps and photographs was provided. These were not used in the subsequent experiment, but were made available simply to allow detailed study of the relationship between the terrain features shown on the map and their appearance in the oblique photographs. This also enabled the tones, textures and lighting effects in the photographs to be studied. A sample map section is shown in Figure 2.1, marked with the approach track, and the points 2 and 4 mile distant from the target. The corresponding photographs, which represent a 30° horizontal field of view, are shown in Figure 2.2. The original photographs showed a 50° field of view but for the purposes of these experiments only the central portion, corresponding to the 30° field of view, was used, the remaining area being masked off.

FIGURE 2.1

Sample map

Target 22 - Road/rail bridge at Hook.

The small circle marks the position of the target and the two dots show the points from which the 2 mile and 4 mile range photographs were taken. The line represents the direction of approach to the target.

FIGURE 2.2

Sample photographs

Target 22 - Rail/road bridge at Hook.

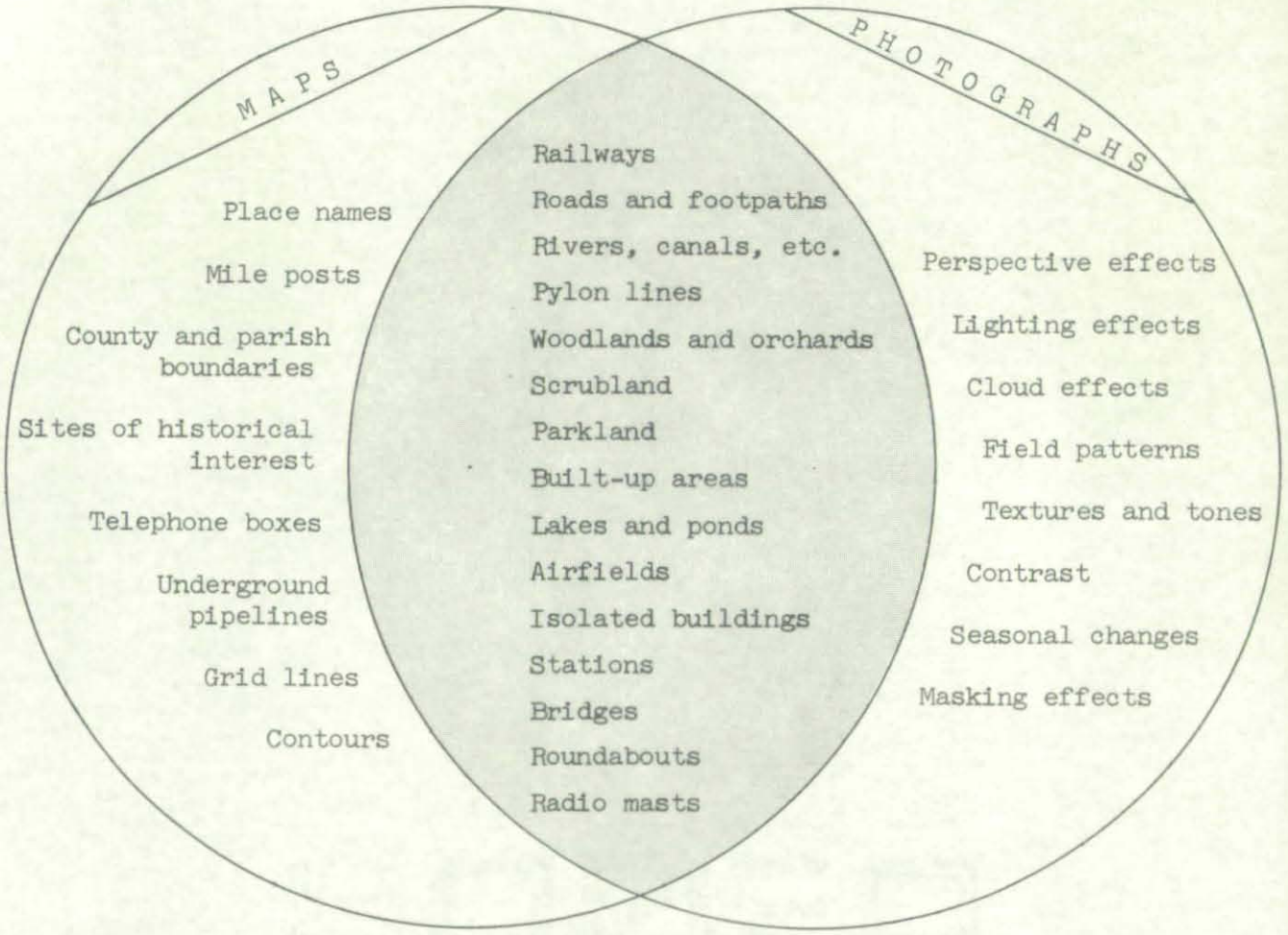
Range 2 miles

Range 4 miles

From the initial study of the relationship between the maps and photographs it was possible to determine which features were common to both the maps and photographs, which appeared only on the maps, and which appeared only on the photographs. These three categories are illustrated in Figure 2.3 in the form of a Venn diagram, in which one circle represents the information available on the maps, and the other circle represents the information shown on the photographs. The overlapping area, which is shaded, shows the information common to both.

FIGURE 2.3

The relationship between information given on maps and photographs



The information given in Figure 2.3 relates to cluttered terrain in Southern England. For other types of terrain the nature and density of conspicuous features might be very different. The inclusion of contour

lines in the category of information only apparent on the map requires further qualification. If changes in ground elevation, as indicated on the map by contour lines, are great enough they will be clearly visible in photographs taken at low altitudes. The present experiment was concerned with relatively flat terrain seen from an altitude of 2,000 ft. and under these conditions changes in ground elevation were only occasionally apparent in the photographs. It was therefore decided that for the purposes of the present work the terrain could, except in a very few instances, be treated as flat.

The basic aim of the work described in this report could be regarded as taking the information available on the maps, i.e. that shown in the left hand circle in Figure 2.3, and converting it as far as possible to the information shown in the right hand circle, thus simulating the appearance of the photographs. It followed that the basic rules for preparing the drawings would be (a) information occurring on the maps but not on the photographs would be omitted (b) information common to both maps and photographs would be included and (c) where possible, information shown on the photographs but not on the maps would be determined or estimated.

It was clear that it was this last requirement that would give rise to the greatest difficulties. The perspective effects could be accurately determined from a knowledge of range, depression angle, field of view, etc. Some other characteristics of the photographs, for instance, tone, texture and masking could be estimated to a limited extent but a number of effects such as those due to lighting, clouds, field patterns and seasonal changes were impossible to estimate and had to be disregarded in spite of the fact that they were clearly of importance in determining the overall appearance of the photographs.

Other difficulties which became apparent during this initial study were:

(i) The relationship between the maps and the photographs was not constant. While the symbol for a particular type of feature on the map was fixed, its appearance in the photographs could vary considerably. For instance, as can be seen in Figure 2.2, some roads appear dark grey against a paler edge, while others are almost white against a darker background. It was clear that variations of this kind would give rise to considerable problems in deciding how these features should be represented in the drawings. The roads and other linear features also varied widely in the ease with which they could be seen, those running perpendicular to the aircraft track being particularly difficult to see, often because of masking by hedges, and therefore of little value for briefing purposes.

(ii) In some cases, the maps, even the most recent editions, were not up-to-date. In particular the extent of built-up areas and woodland areas, as shown in the photographs were frequently greater than those shown on the maps. A further difficulty was that the standard Ordnance Survey maps used did not show military airfields although these were very conspicuous on some of the photographs.

(iii) Detailed inspection of the photographs indicated that in some cases they had not been exposed under the specified conditions, in particular, the depression angle and target range appeared to vary considerably around the nominal values of 10^{o} and 2 or 4 miles respectively, thus substantially altering the appearance of the photograph. This could not be taken into account when preparing the oblique drawings. The top photograph in Figure 2.2, in which the range appears to be considerably less than the nominal value of 2 miles, provides an example of this type of error.

3. PREPARATION OF SAMPLE DRAWINGS

The considerations discussed in the previous section indicated that the drawings should include the following features:

(i) Accurate representation of perspective effects in both tone and line.

(ii) Linear features: roads, rivers, railways. These features should be represented by lines of appropriate width, in such a way as to be readily distinguishable.

(iii) Area features: woodland, scrubland, marshland, built-up areas, areas of water and airfields are the most common area features. Shape, tone and texture are important characteristics of these features. Shape can be determined from the map with reasonable accuracy but tone and texture are impossible to estimate accurately, although previous inspection of sample photographs gave some indication of these effects.

(iv) Isolated buildings, radio masts, pylons, quarries, stations, bridges, etc.

(v) An overall decrease in tone from the lower edge to the top edge of the drawing to represent the observed decrease in tone in the sample photographs from foreground to background due to atmospheric attenuation.

(vi) A clear marking to indicate the actual target.

The next stage was to determine how the drawings should be executed. The following possibilities were considered:

(i) A freehand drawing technique could be used in which the general style would be maintained constant from one drawing to another, but the artist would be free to interpret the map information as realistically as possible. This would have the advantage of allowing maximum flexibility but would be difficult to standardise, particularly as the drawings produced would depend on the style of the individual artist.

(ii) The entire representation could be carried out by a 'mechanical' technique in which commercially available shading materials such as Letratone would be used to represent area features and standardised lines to represent linear features.

(iii) A combination of freehand and 'mechanical' techniques could be used. The main area features would be represented by commercial shading materials and linear features, and any other sketching needed to improve the realism of the drawing, added freehand.

(v) A combination of 'mechanical' shading techniques and map symbolism was also possible. The area features would be represented by commercial shading materials, the linear features by standardised lines, and conventional map symbols used to indicate churches, stations, bridges, level crossings, radio masts, etc.

Whatever type of representation was used, it seemed desirable that the overall graduation in tone from foreground to background should be included to give the appearance of distance. A further consideration, applying only to the 'mechanical' types of representation, was the number of shading types

used to represent the different features. Since the subjects would have to learn the type of shading representing each feature it seemed important that only a limited number of different types, say five, should be used, and that they should be readily discriminable.

At this stage of the work no decision was made as to which, if any, of the above techniques would be used for the final drawings but it was agreed that an example of each technique would be prepared as a basis for further discussion. For the preparation of these sample drawings two map sections, marked with the target, the direction of approach and the points from which the 2 mile range photographs had been taken were provided. During this part of the work no 4 mile range drawings were prepared. The work took place in two stages:

(a) Preparation of suitable grids for transforming the plan view information on the map into a perspective view, and subsequently using these grids to prepare master drawings for the two targets.

(b) Experimentation with different techniques for representing individual features and finally the production of sample drawings, based on the master drawings, according to the possible techniques outlined above.

These two stages are described in greater detail below.

(a) Preparation of master drawings

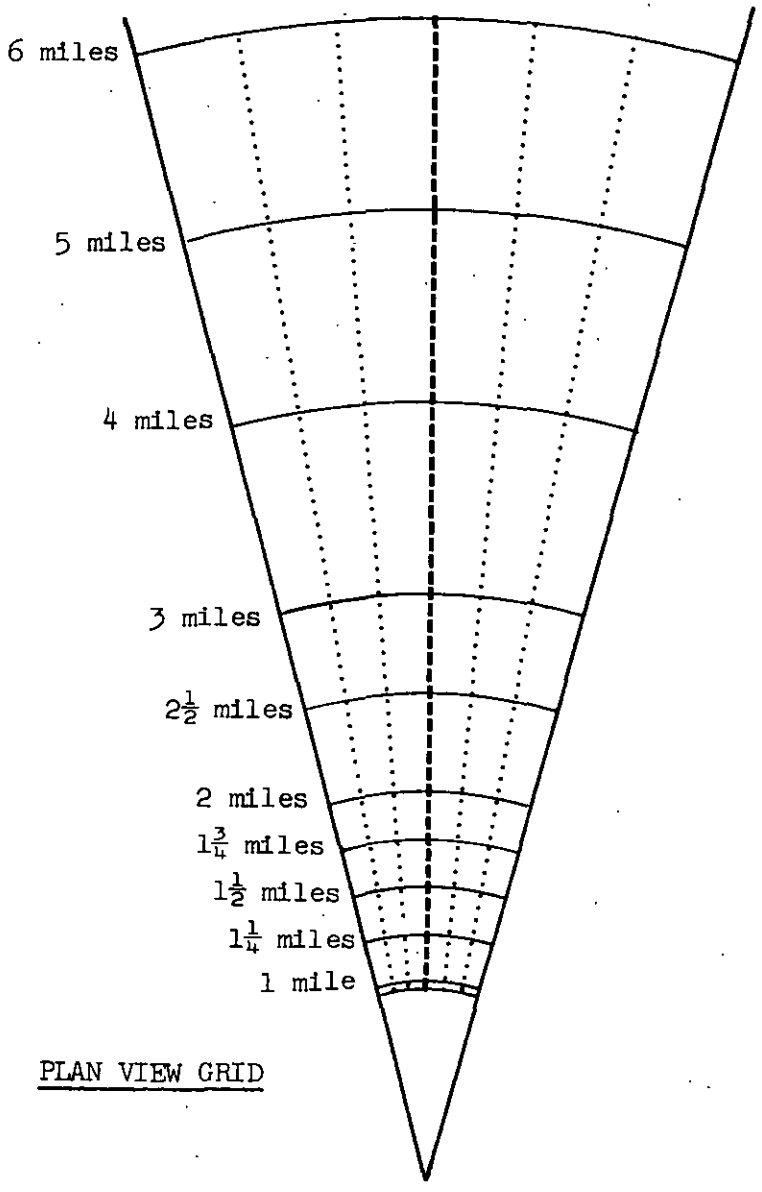
The initial step in the preparation of the master drawings for the sample targets was to prepare two grids, one corresponding to the plan view of the target area as shown on the map, and one corresponding to the perspective view. These grids are shown in Figure 3.1. The plan view grid represented the 30° horizontal field of view and was drawn to a scale

of 1" = 1 mile, the same as that of the map. Additional plotting lines were included to facilitate accurate transfer of the information. An initial attempt was made to draw the grid onto transparent cellophane which could then be positioned accurately on each map section in turn but it was eventually found that drawing the grid straight onto each map was more convenient.

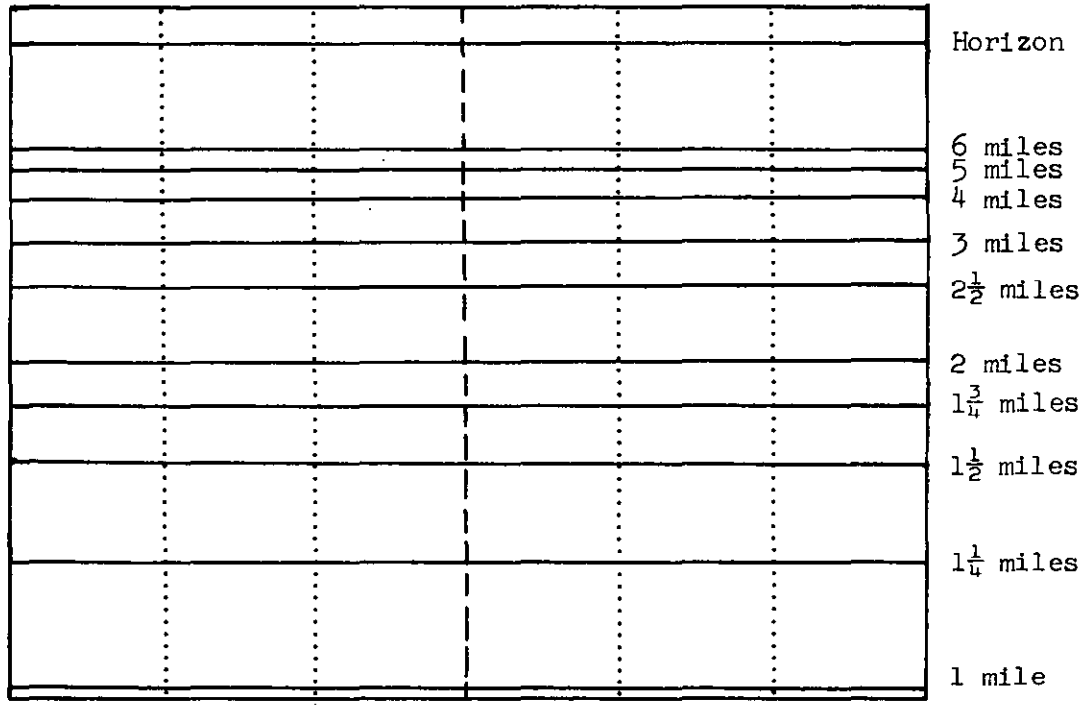
The perspective grid was prepared by determining, from the photographic parameters given, the levels at which points at various ground ranges from the camera would appear on the display. In the foreground $\frac{1}{4}$ mile range intervals were chosen, but at the longer ranges $\frac{1}{2}$ mile and, later, 1 mile intervals were adequate, as shown in Figure 3.1. A vertical centre line, corresponding to the camera axis, was drawn and additional plotting lines on each side. A simplified diagram showing how the shapes, lines and points which made up the drawing were actually transfered from the plan view grid to the perspective grid is given in Figure 3.2.

The map sections showing the sample targets for which the master drawings were prepared are shown in Figures 3.3 and 3.4. These drawings, shown in Figure 3.5, formed a basis from which other types of representation could be developed. The master drawings were drawn directly onto a perspective grid and later drawings were traced off these originals.

Plan view and perspective view grids



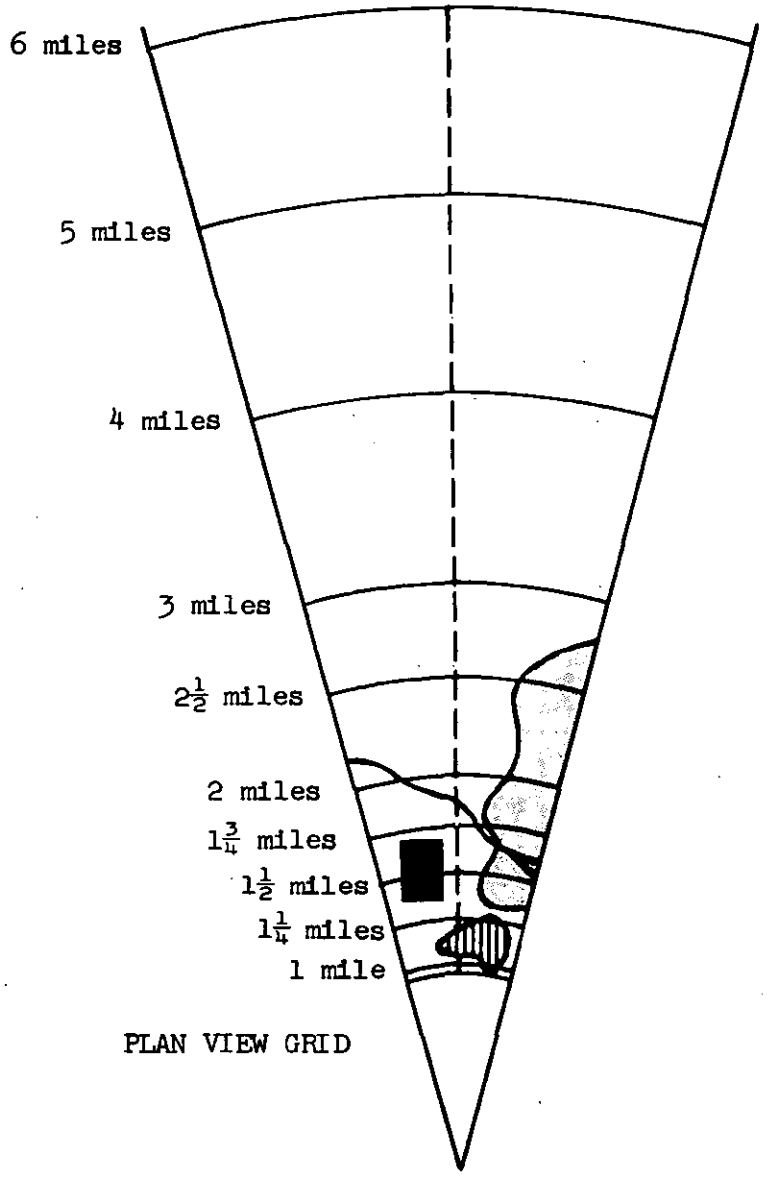
PLAN VIEW GRID



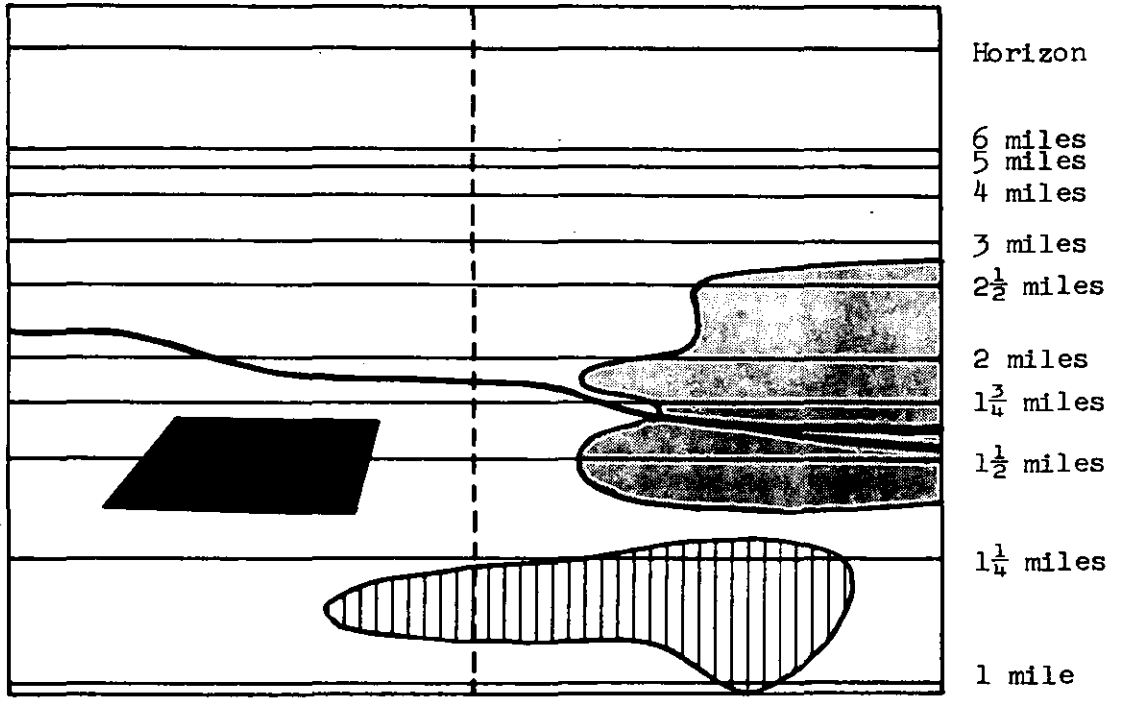
PERSPECTIVE GRID

The plan view grid is drawn directly onto the map section and the required terrain information is then transferred to the corresponding positions on the perspective grid.

Simplified diagram showing the transfer of information from the plan view grid to the perspective grid



PLAN VIEW GRID

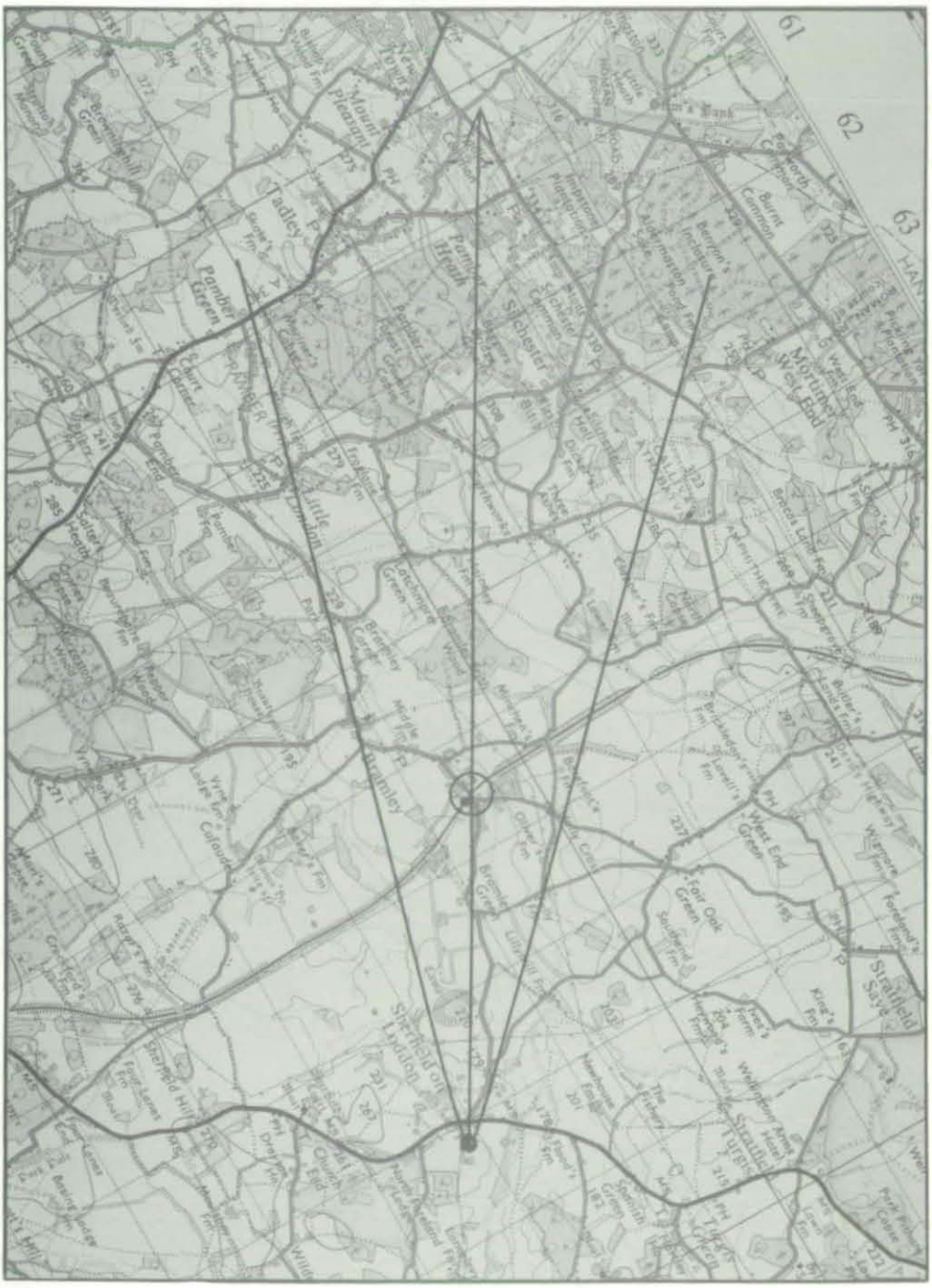


PERSPECTIVE GRID

FIGURE 3.3

Map section

Target 8. Bramley Station

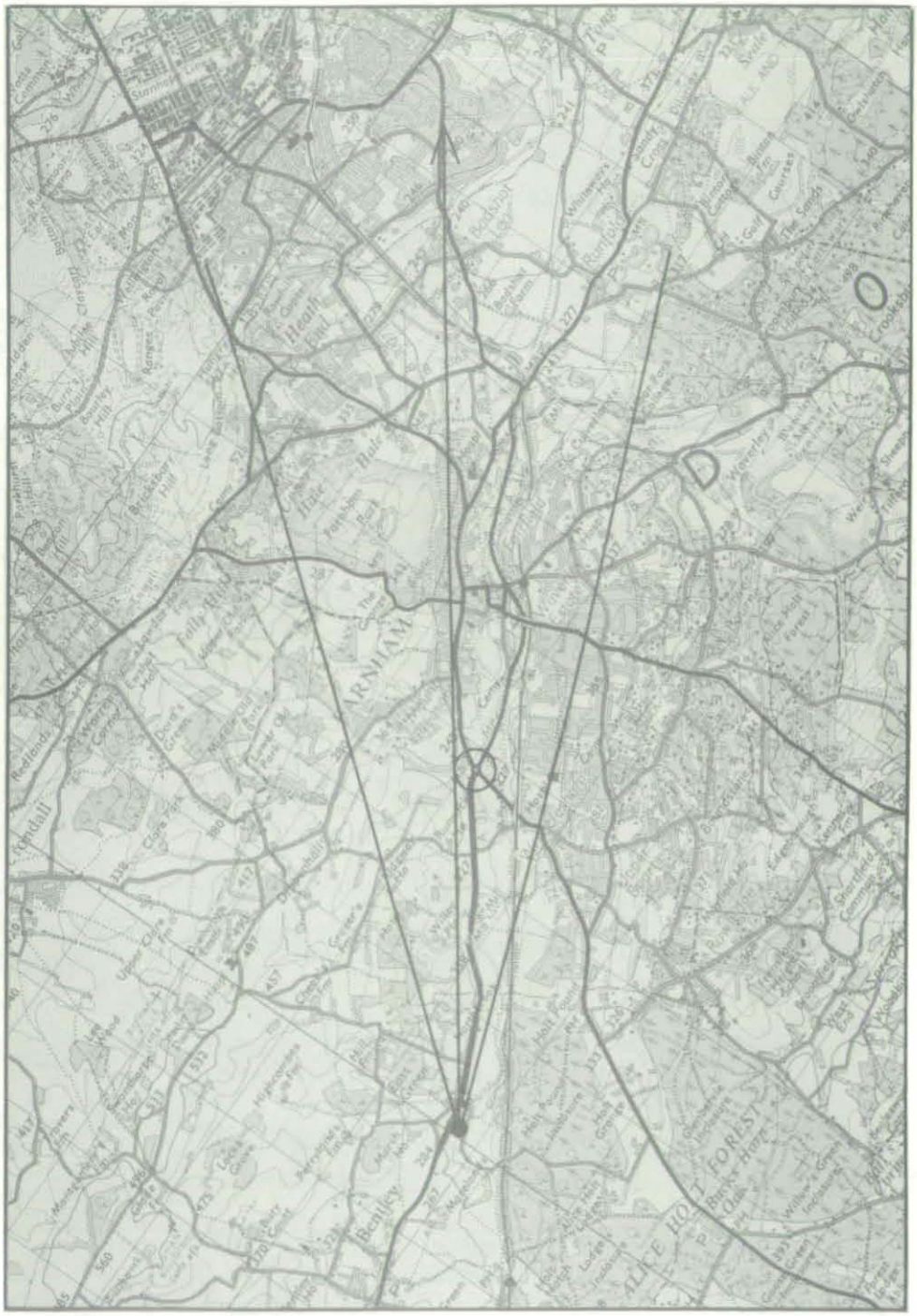


The target position is marked with a small circle. The arrowed line represents the direction of approach and the limits of the 30° field of view from the 2 mile range point are also shown.

FIGURE 3.4

Map section

Target 11. Farnham Roundabout

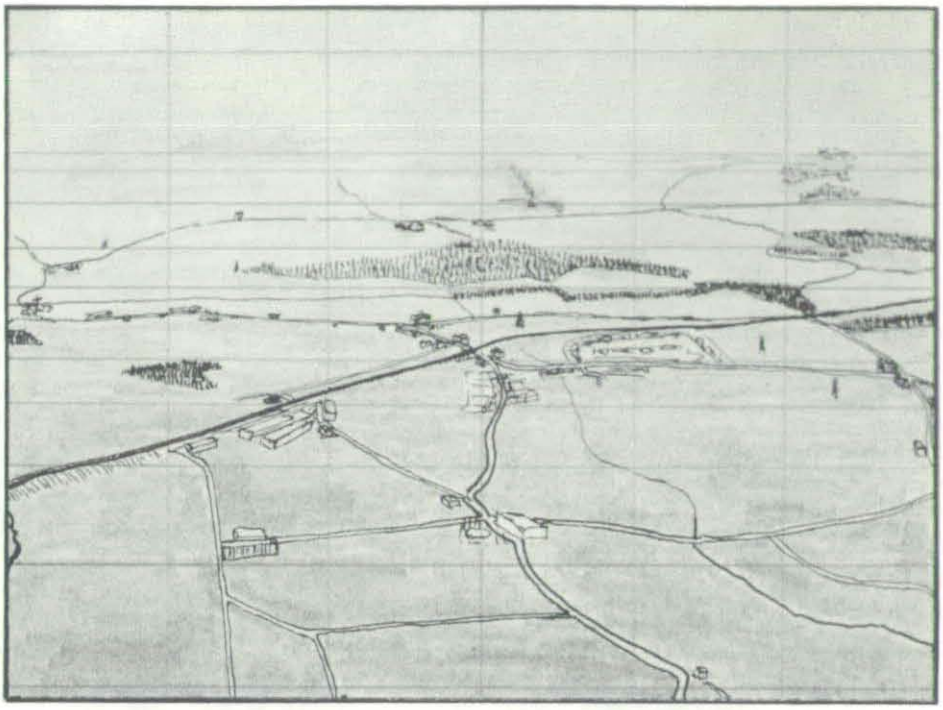


The target position is marked with a small circle. The arrowed line represents the direction of approach and the limits of the 30° field of view from the 2 mile range point are also shown. In this case the target is slightly offset from the centre of the field of view.

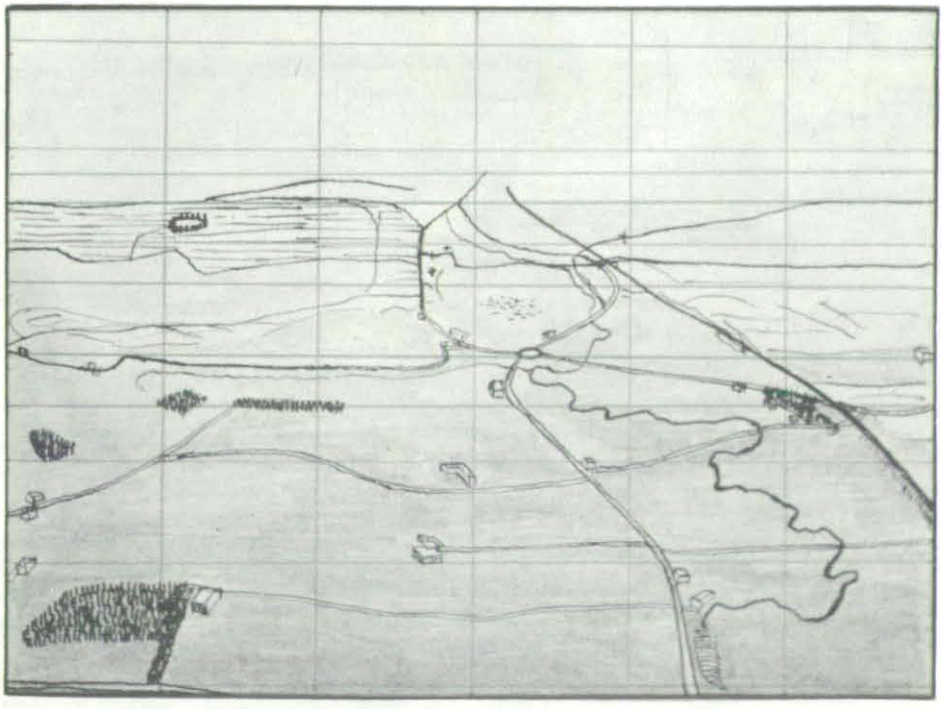
FIGURE 3.5

Master drawings

Range 2 miles



Target 8 - Level crossing at Bramley Station.
(target is central in the field of view)



Target 11 - Farnham Roundabout.
(target is offset slightly to the right)

(b) Development of presentation techniques

The second stage of the work was the development of possible techniques for representing terrain features in the final drawings. The intention was to produce drawings according to each of the techniques outlined earlier in this section, but some preliminary experimentation was necessary to determine the most effective methods of representation and, in particular, the code of shadings to be used in the mechanical representations.

Various possible types of freehand and mechanical shading techniques for representing the main area features are shown in Figures 3.6 and 3.7. The freehand drawings have the advantage of being more flexible and therefore better suited to the problem of representing the way in which the appearance of a particular type of feature changes as its distance from the viewer increases. The main disadvantage of freehand drawings is the difficulty of standardisation, both for successive drawings carried out by the same artist, and for different artists carrying out the same drawings.

Another problem in using freehand techniques is that the information on the map is not sufficiently detailed to allow accurate representation, particularly of built-up areas. Although some of the roads within built-up areas are shown on the map, and it is reasonable to assume that there will be buildings along them, there is a lack of information about smaller roads, housing areas, factories and large buildings, and other features which may be conspicuous. This is particularly serious if these features occur in the foreground of the display. The artist is therefore forced to rely partly on his idea of how the area might appear. This type of 'artist's impression' may be misleading. The same type of problem occurs with areas designated scrubland, parkland, woodland, etc., particularly as seasonal variation plays an important part in the appearance of these features.

If a mechanical shading technique is used it is possible to lay a single type of shading over the appropriate area, to represent, say, a patch of scrubland, and no further detail need be added. This is inevitably less realistic, particularly in the foreground, but has the advantage of avoiding the inadvertent inclusion of information that might be misleading.

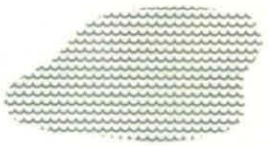
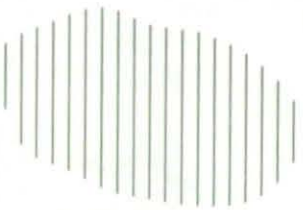
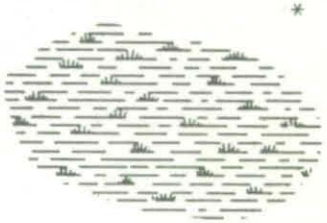
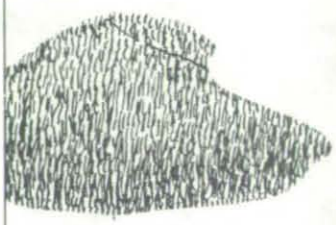
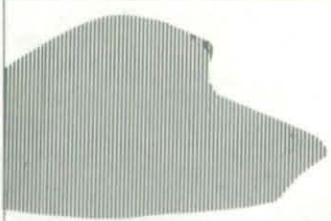
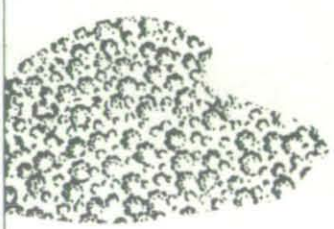
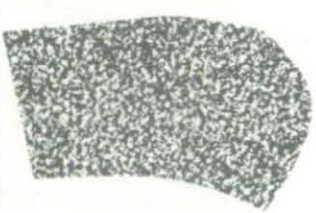
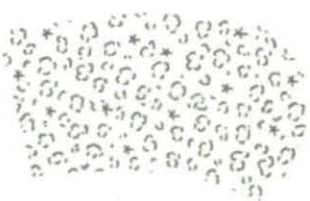
If this course is followed the important question of whether the shading used to represent a particular feature should approximate to the tone and texture of the feature when seen in the photographs, or whether it should suggest the feature by some form of semi-symbolic representation, similar to that used on maps, must be considered. Some examples of these two forms of coding are shown in Figure 3.6. The course chosen is to some extent dependent on the availability of suitable shading materials in a standard commercial range, such as Letratone, although for extensive work it would be possible to have shadings made up to order.

The representation of line features such as roads and railways presents less of a problem since they are easier to visualise from the map information. The normal rules of perspective apply in determining the width of these features at different distances from the viewer, but it is not possible to estimate the extent to which they may be masked by features not shown on the map, particularly hedges. For these line features there is not such a marked difference between freehand and standardised forms of representation as there is for area features. Standardisation of lines can be achieved by the use of a drawing pen with a nib of specified size and different line features, roads, railways and rivers, can be made readily distinguishable by giving each line a characteristic form appropriate to the feature represented.

One general consideration that affects the type of representation used is whether an overall grey covering tone, increasing in density towards the foreground, is used as a basis for the drawings, in order

FIGURE 3.6

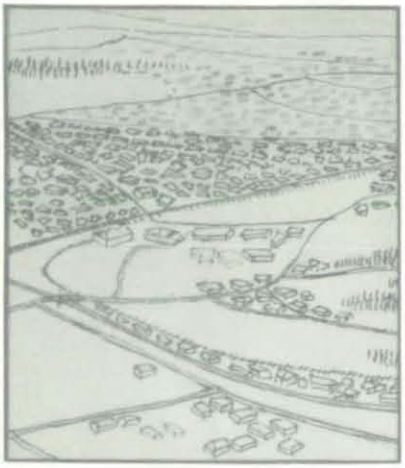
Examples of different techniques for representing common area features.

	FREEHAND	TONE/TEXTURE CODING	SEMI-SYMBOLIC CODING
WATER			
SCRUBLAND OR PARKLAND			* 
DENSE WOODLAND		 or 	* 
SPARSE WOODLAND OR ORCHARD			* 

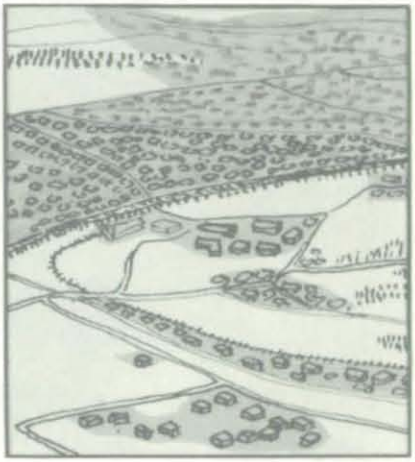
*These shadings were not available in the standard Letratone range when this initial development work was carried out, but they have been included in this chart to show the materials currently available.

FIGURE 3.7

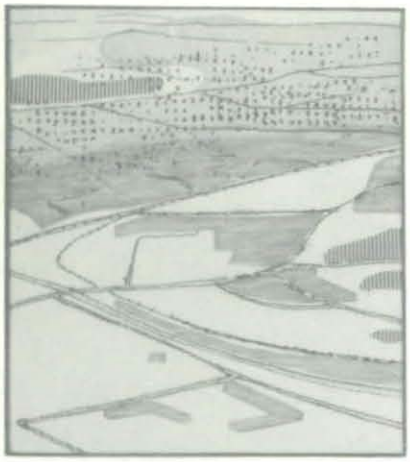
Examples of possible techniques for representing built-up areas in the foreground and the background.



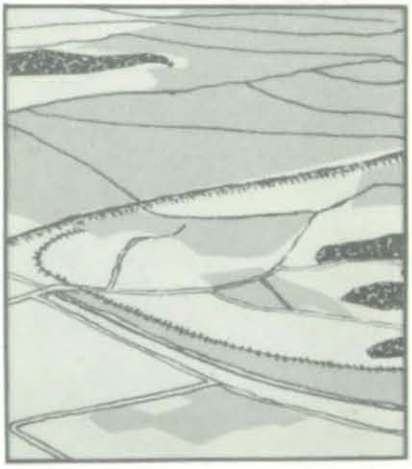
Freehand drawing



Freehand drawing + single tone mechanical shading



Complex mechanical shading technique using two different tones and a superimposed texture.



Simple mechanical shading technique using a single tone for all built-up areas.

Built-up areas indicated by partial removal of grey covering tone

to simulate the appearance of the photographs. Investigation showed that no suitable graduated shading materials were available commercially. The effects of such a tone and some attempts to build up a standardised tone so that a realistic decrease in density from foreground to background was achieved are shown in Figures 3.8 and 3.9. These examples are based on the master drawings for the two sample targets given in Figure 3.5. These attempts are not entirely satisfactory but it is clear that an overall tone of this type does simulate the basic appearance of photographs, or a television monitor, better than a plain white background.

If a graduated tone of this type is used then the possibility of removing this tone to represent certain types of features as lighter than the surrounding areas can be considered. This is particularly relevant in the case of roads and built-up areas which, as noted in Section 2, sometimes appear lighter than the surrounding terrain. An example of the use of this technique to represent built-up area is included in Figure 3.7. A comparison of two techniques for representing roads in open country is shown in Figure 3.10. In one case the roads are cut into the covering film, or drawn in white ink, thus appearing lighter than the surroundings, and in the other case they are drawn in black ink, and appear darker than the surroundings. Since it was not possible to predict how any particular road would appear in practice it was necessary to decide which of these techniques seemed most generally appropriate. For the preliminary work shown in this section the first technique, that of cutting into the shaded film, was chosen. This had the advantage of distinguishing more clearly between roads and other line features which were drawn in black ink.

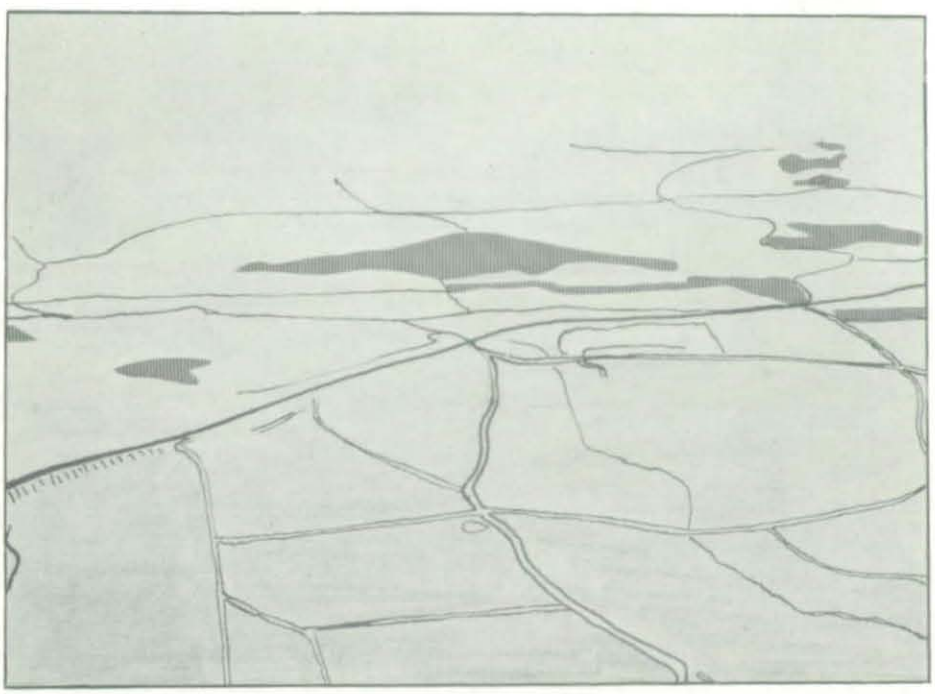
Figures 3.11 - 3.12 show examples of drawings prepared for the two sample targets (No. 8 and 11) according to four possible techniques; (i) freehand, (ii) mechanical shading, (iii) mechanical shading + freehand detail, and (iv) mechanical shading + map symbols.

FIGURE 3.8

The use of a graduated tone to give the illusion of perspective.

These two drawings show the difference that the application of a graduated tone can make to the illusion of perspective. The use of such a tone appeared to be a necessary part of the presentation. The main problem was one of standardisation since a suitable form of mechanical shading material was not available commercially.

Target 8 - without graduated tone

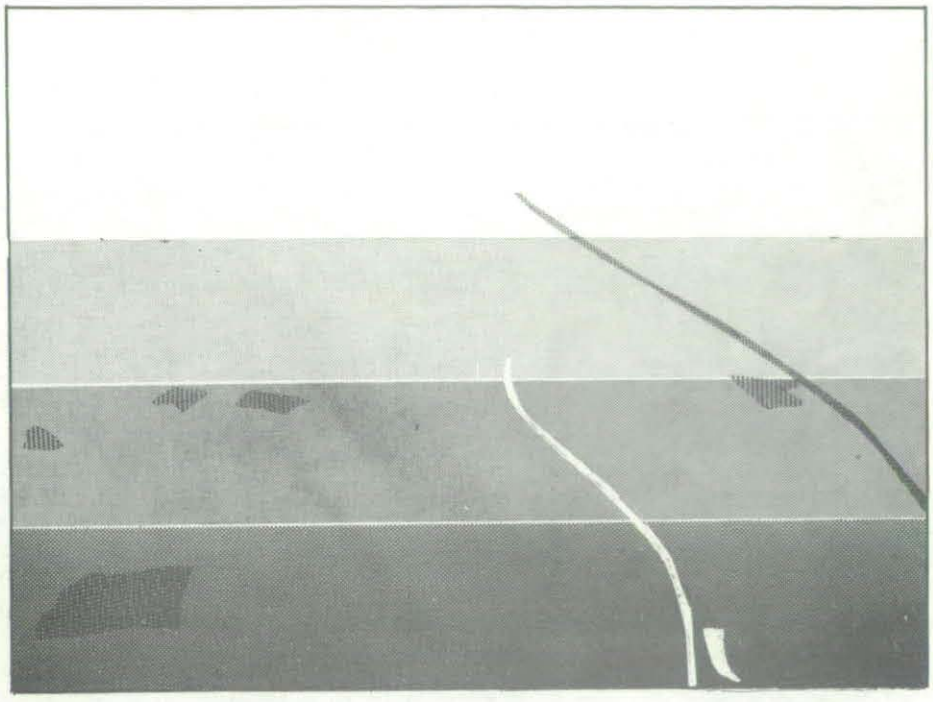


Target 8 - with graduated tone

FIGURE 3.9

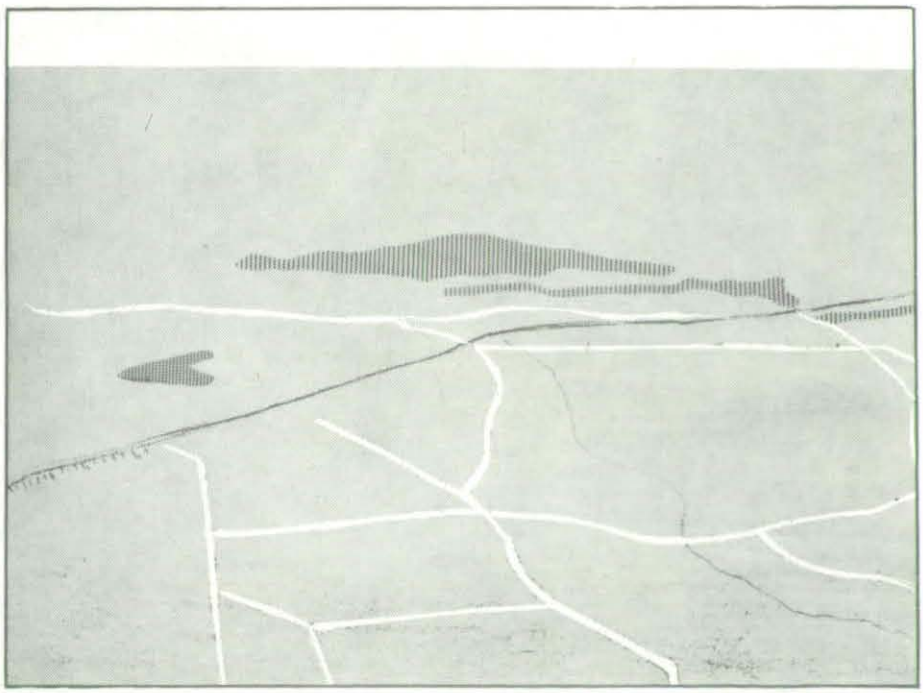
Attempts to build up a standard graduated tone to give an illusion of perspective in the presentation.

Target 11. Farnham Roundabout



Building up a graduated tone from strips of shaded film of different densities is not satisfactory as the changes in tone are too great.

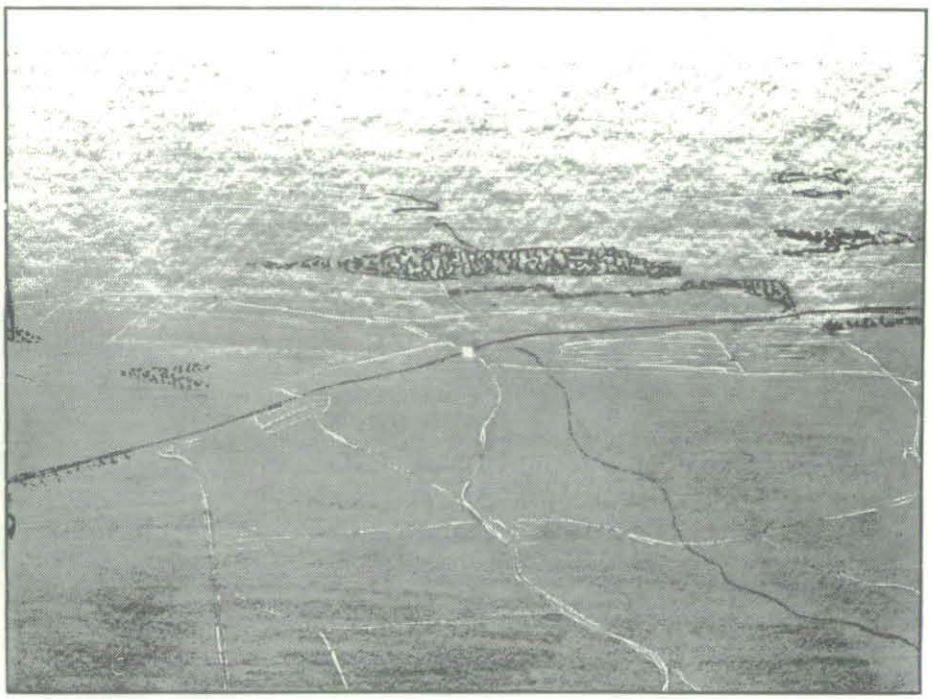
Target 8. Bramley Station



If a single tone is laid over the area there is no illusion of perspective unless a considerable amount of supportive drawing is done to increase the density in the foreground. This results in a more complex presentation and greater difficulties of standardisation.

FIGURE 3.9 (continued)

Target 8. Bramley Station

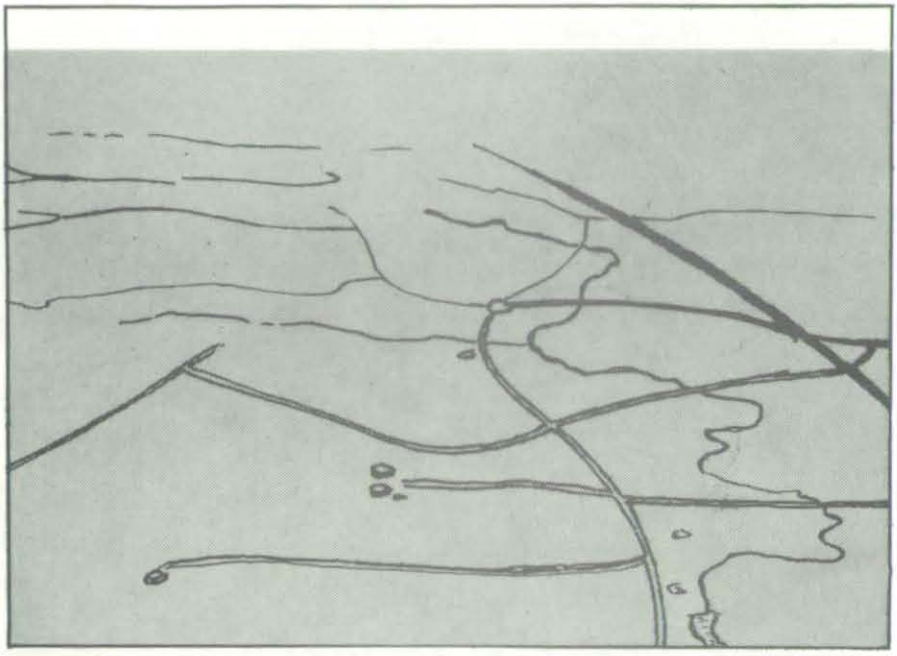


In this example a darker covering tone has been used. In the background the tone has been lightened with a razor and in the foreground it has been increased by pencil shading. This produces a more satisfactory effect but it would be very difficult to standardise the technique.

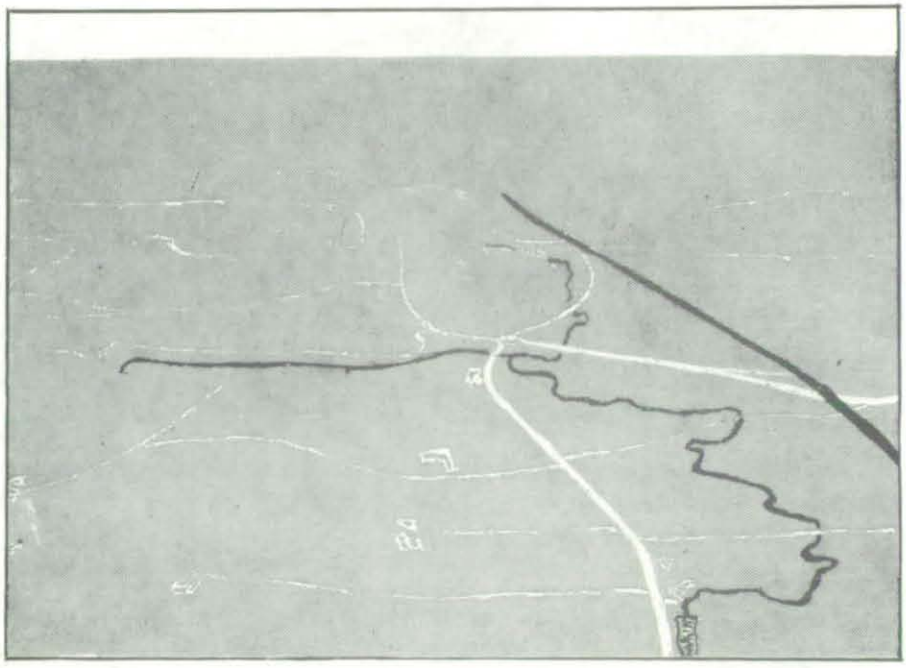
FIGURE 3.10

Examples of different techniques for representing roads.

Target 11. Farnham Roundabout.



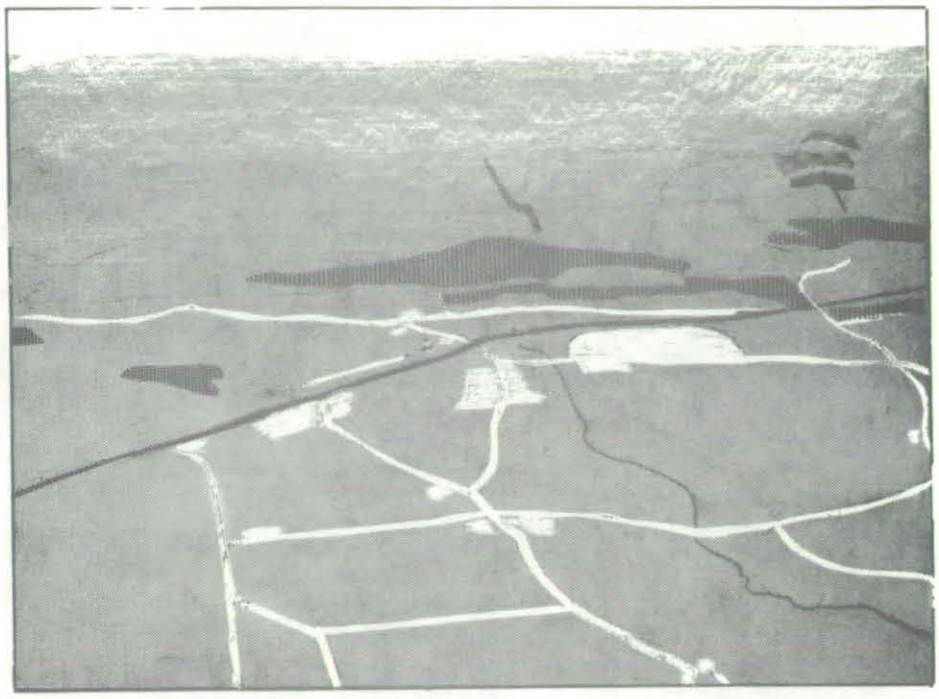
In this example the roads are drawn on top of the grey film in black ink.



In this example the roads are represented by cutting into the grey film, or drawing on top of it in white ink, so that they appear lighter than the surrounding terrain.

FIGURE 3.11

Two sample drawings prepared for Target 8

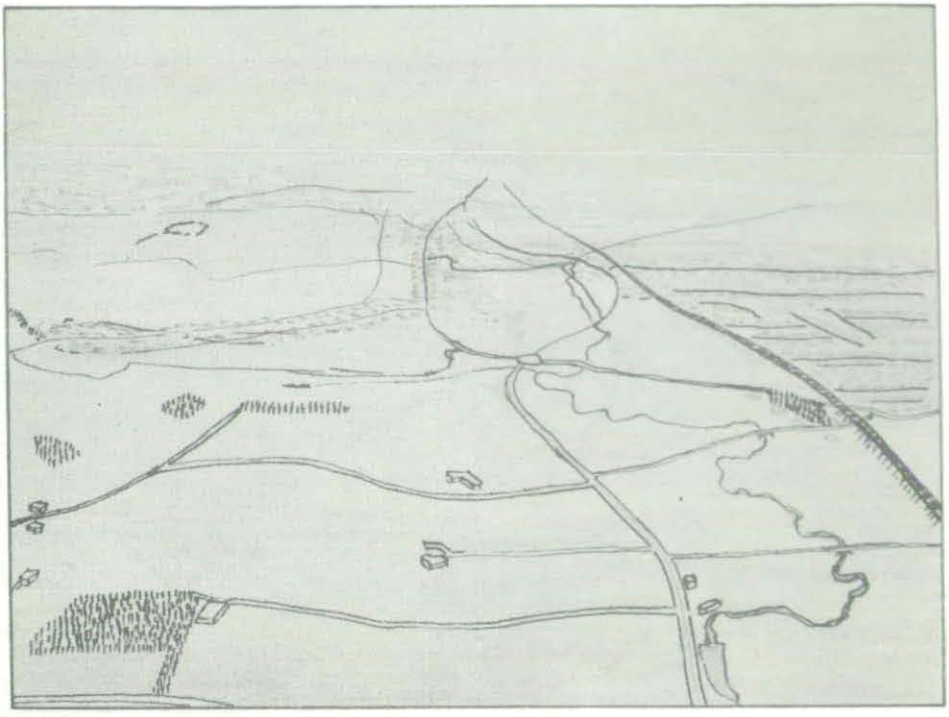


Mechanical shading technique

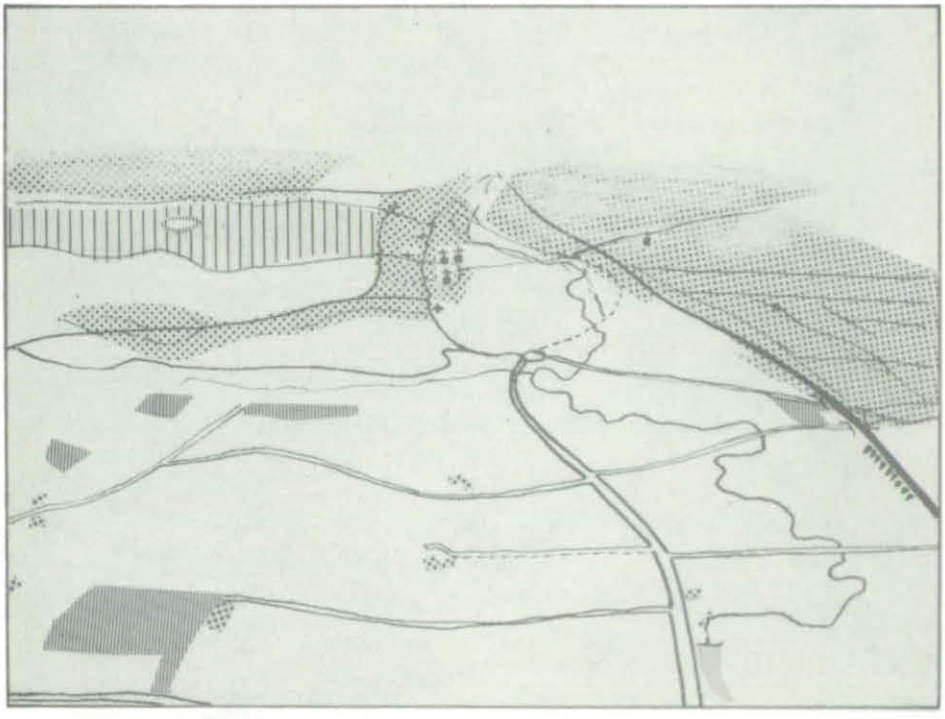
Mechanical shading with detail added freehand

FIGURE 3.12

Two sample drawings prepared for Target 11.



Freehand drawing



An attempt to combine the symbolic coding on the map with mechanical shading techniques

4. PREPARATION OF THE COMPLETE SET OF DRAWINGS

Detailed consideration of the preliminary work described in Section 3 led to the following decisions, taken before work on the complete series of drawings was started.

(i) Two types of representation would be used, one freehand and the other carried out entirely with mechanical shading materials and standardised lines. The first of these types was designated drawings, and the second diagrams.

(ii) The overall graduation in tone from foreground to background could not be adequately represented either by freehand shading, or by the shading materials available commercially. Instead it was decided that sheets of photographic film would be used to cover the completed drawings and diagrams. These sheets of film, which were prepared by Kodak Ltd., were exposed such that the density increased smoothly from 0% at the top edge, to 60% at the lower edge, the longer sides being horizontal. The size of the shaded film was 4.8" x 3.6", the same as that of the drawings and an additional $\frac{1}{4}$" border was left all round to facilitate fixing. The use of this type of film eliminated the difficulties of drawing on top of, or cutting into, the commercial shadings used in the preliminary studies. The film also acted as a protective covering for the drawings.

(iii) For the diagrams it was necessary to finalise the code of mechanical shadings and lines to be used to represent the different features. The use of the graduated film cover meant that some of the techniques considered during the preliminary work, those involving cutting into the grey

film, or drawing on top of it, were no longer applicable. Since very few shadings corresponding to 'semi-symbolic' coding were available when this work was carried out, the shadings were chosen to be as simple and readily distinguishable as possible and, where appropriate, to approximate to the tone of the feature in the photographs. The code used is given in Figure 4.1.

(iv) The target would be indicated by a red circle, $\frac{1}{4}$" in diameter, drawn to surround the target if it was small, or in the centre of it if it was large. (For reproduction in this report these circles were re-drawn in black.)

It was then possible to proceed with the preparation of the drawings and diagrams for the complete set of targets to be used in the experiment. Since oblique views from two different ranges were required, four representations (drawings and diagrams at 2 miles and 4 miles) had to be prepared for each of the twenty targets. For each target a section of map was provided on which the target itself, and the positions from which the 2 mile and 4 mile range photographs had been taken, were marked as accurately as possible. In some cases these three points were not exactly co-linear but for the purposes of the present work this was not of great importance. The direction of approach to the target was also given, assuming this to be coincident with the optical axis of the camera. This information enabled the artist to draw the appropriate grid, from which the terrain features could be transferred to the corresponding perspective grid.

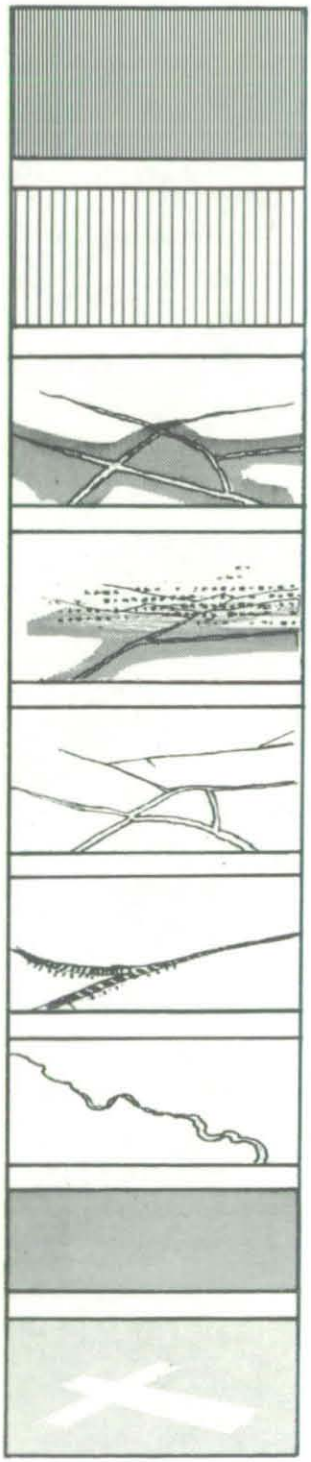
At no stage during this work did the consultant see any of the target photographs and, with two exceptions, he did not receive information about the terrain other than that on the standard Ordnance Survey maps used. The two exceptions were (a) military airfields not shown

on the standard maps but which would be shown on military maps, and (b) a few instances where the map proved to be very out-of-date and omitted large recently built-up areas. In these cases the necessary additions were made to the map.

Examples of the finished work prepared for one of the targets, together with the original master drawings, are shown in Figures 4.2 - 4.6. For comparison purposes the corresponding photographs are shown in Figure 4.7. Further examples are shown in Figures 5.2.3 - 5.2.5 in Part VI (i) (pages 25 - 27).

FIGURE 4.1

The code of shadings used for the diagrams

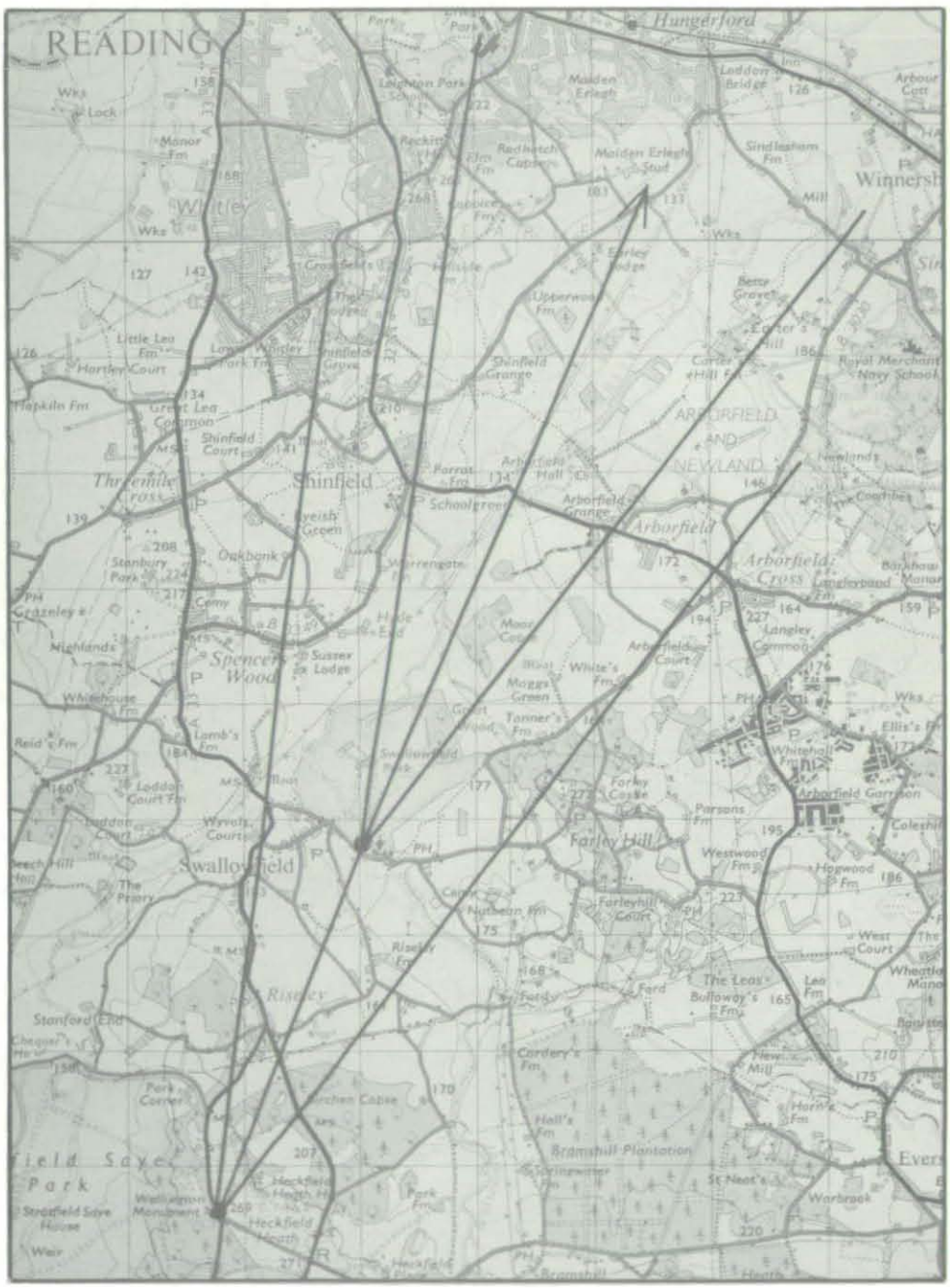


Both the diagrams and the drawings were completed by overlaying with sheets of photographic film graduated in density from 60% in the foreground to 0% in the background.

FIGURE 4.2

Target 6. Road/river bridge, East of Shinfield

Map section



Scale: 1 inch = 1 mile

The position of the target is marked with a small circle. The points from which the 2 mile and 4 mile photographs were taken are shown by dots and the limits of the 30° horizontal field of view at these points are also shown.

FIGURE 4.3

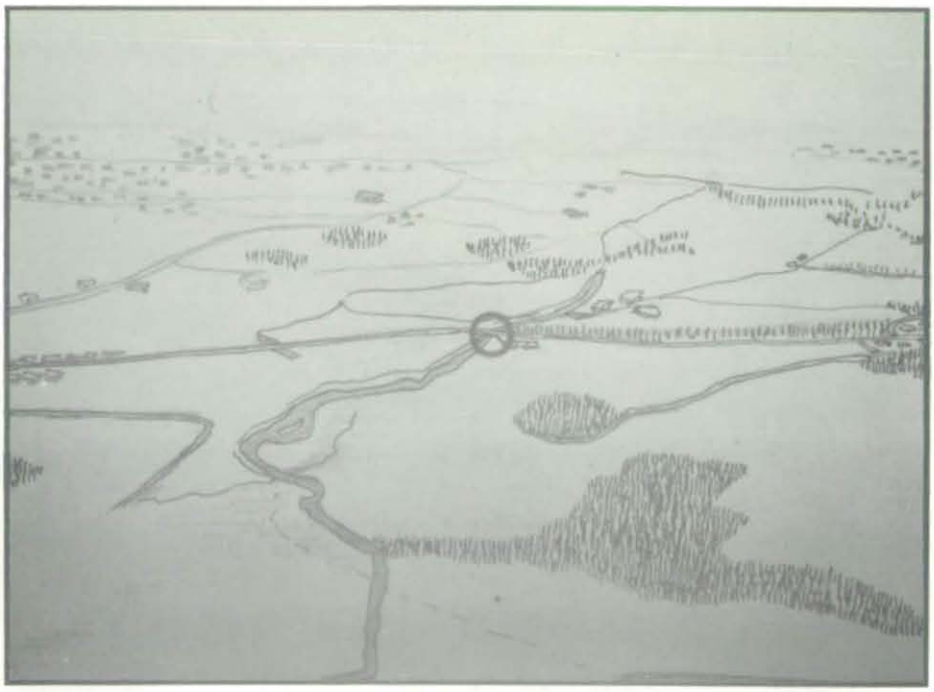
Target 6. Road/river bridge, East of Shinfield

Master drawing - range 2 miles

FIGURE 4.4

Target 6. Road/river bridge, East of Shinfield

Range 2 miles



Freehand drawing

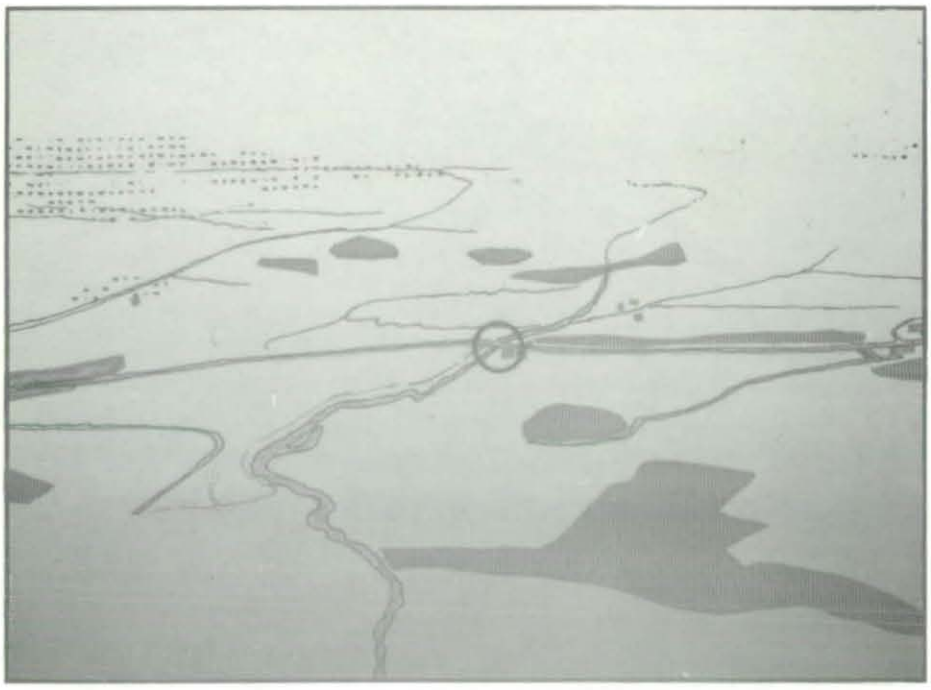


Diagram using mechanical shading materials

FIGURE 4.5

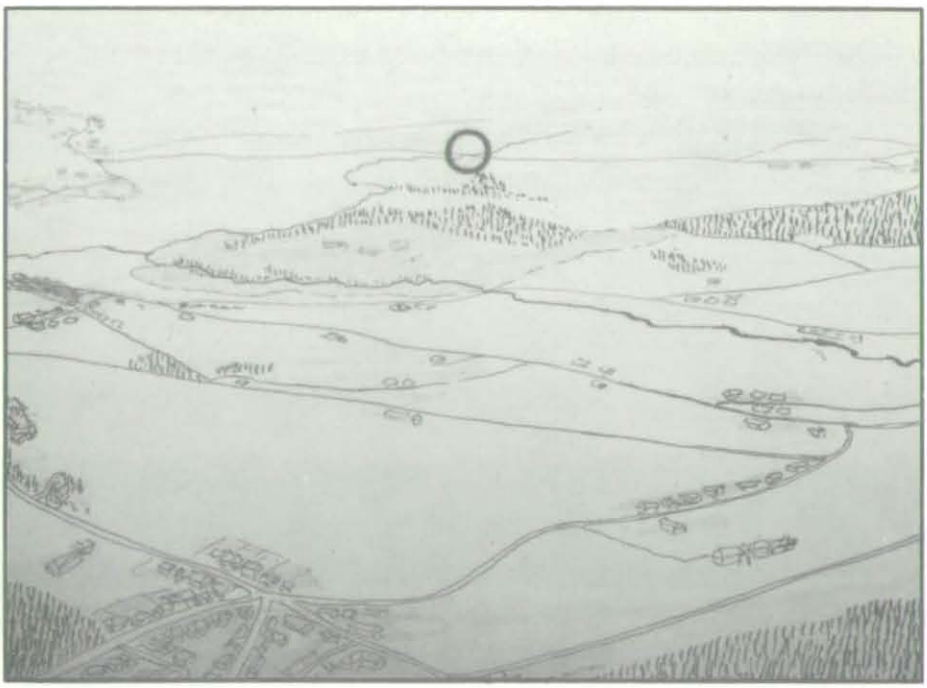
Target 6. Road/river bridge, East of Shinfield.

Master drawing - range 4 miles

FIGURE 4.6

Target 6. Road/river bridge, East of Shinfield

Range 4 miles



Freehand drawing

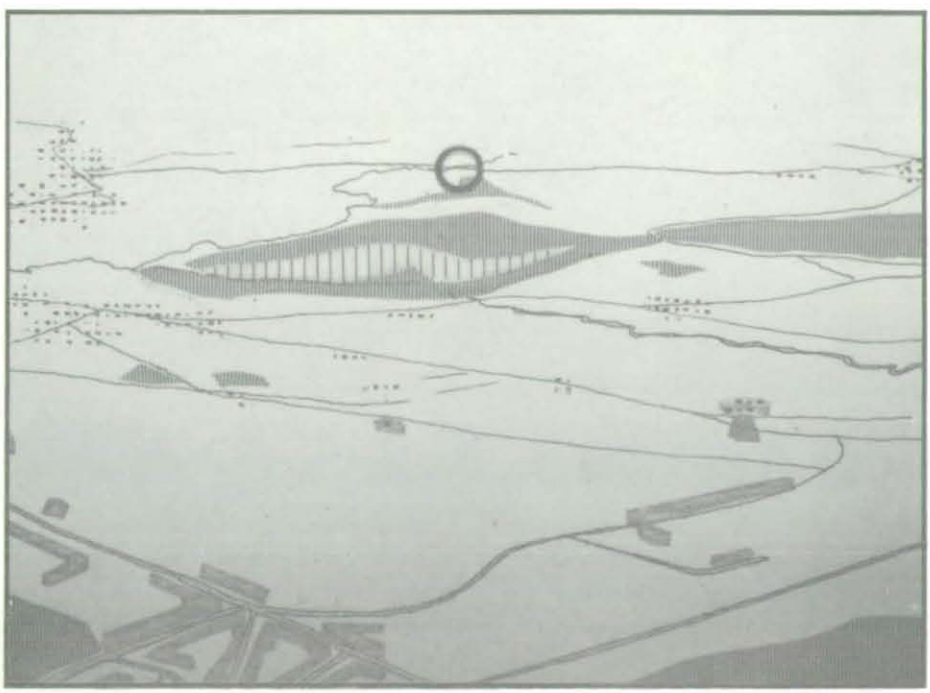


Diagram using mechanical shading materials

FIGURE 4.7

Target 6. Road/river bridge, East of Shinfield

Photographs

2 mile range

4 mile range

5. REFERENCE

Parkes, K. R., (1969) Visual and televisual detection studies. Part VI(i) Briefing materials for low-level target detection: a comparison of five briefing types. Ministry of Technology Contract No. PD/170/04/AT. Loughborough University of Technology.

STUDY
NOTE 1

VISUAL AND TELEVISUAL DETECTION STUDIES

Mintech contract PD/170/04/AT

STUDY NOTE I

THE EFFECT OF MAP ORIENTATION ON TARGET DETECTION PERFORMANCE

by
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Department of Ergonomics and Cybernetics,
University of Technology,
LOUGHBOROUGH.

APRIL 1969

SUMMARY

This experiment was intended to determine whether map orientation had a significant effect on performance at a statically simulated target detection task. Performance data had been obtained previously under conditions in which the map was presented in a fixed 'North-up' orientation. In the present experiment similar data were obtained under conditions in which the map was orientated 'track-up'. 21 unskilled subjects took part in each experiment.

Analysis of the combined results showed that map orientation had no significant effect on any of the four performance measures recorded: detection probability, search time, confidence level and map-briefing time. There were also no significant interactions between map orientation and either of the two other main factors tested, targets and ranges.

It can be concluded that map orientation is not an important factor in this static detection task, but these results cannot be regarded as applicable to a dynamic situation.

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1. PURPOSE OF THE EXPERIMENT.

This experiment was one of a series of studies intended to investigate factors affecting performance at an air-to-ground target detection task, simulated statically by means of a series of oblique aerial photographs. The subject was required to familiarise himself with the target area, and the approach to it, by reference to a section of a 1" = 1 mile Ordnance Survey map, on which the track of the aircraft was marked. He was then required to locate the target in the photographic display as rapidly as possible, without further reference to the map. Photographs taken at ranges of 4, 3, 2, and 1 miles along the approach track to the target were available, but the subject did not know at what range any particular target would be presented.

Throughout this series of experiments the map sections had been presented in a fixed 'North-up' orientation, i.e. regardless of the direction of the aircraft track, the map section was positioned so that the North-South axis was vertical, with North at the top. In an airborne situation it is more usual for a 'track-up' orientation to be used, i.e. the map is rotated until the track of the aircraft is vertical. For instance, if the track is due West, the map is rotated through an angle of 90° in a clockwise direction from the 'North-up' position to bring it to the 'track-up' position. In view of this difference it was of interest to determine whether map orientation had any effect on detection performance, under the static simulation conditions used in these experiments.

The present experiment was intended to obtain detection performance data under conditions which were identical to those used in the first experiment of this series (Parkes, 1967) except that new map sections orientated 'track-up' were used in place of the 'North-up'

maps used previously. Since the aircraft tracks were randomly orientated the angular differences between corresponding 'North-up' and 'track-up' positions for the seven targets were random values between 0° and 180°, direction of rotation not being taken into account.

The design of the present experiment, which was identical to that used previously, was based on a matrix of seven targets and seven conditions. The matrix was replicated three times, using 21 unskilled subjects. The four performance measures recorded for each target presentation were detection probability (whether or not the position of the target was correctly located), search time (the time taken by the subject in searching the photographic display), confidence level (the confidence, on a scale of 1 - 7, the subject had that his response was correct) and map-briefing time (the time taken by the subject to familiarise himself with the appropriate map area).

2. RESULTS

The data relating to each performance measure were analysed to determine whether there were any significant effects due to the two different map orientations. The other main factors studied, ranges and target differences, were analysed only to determine whether they interacted with map orientation. No detailed analyses were carried out on the navigational uncertainty factor as this had previously been shown to have no effect on performance. This limited analysis was intended only to investigate the effect of map orientation, the effects of the other main factors having been studied in detail in previous experiments.

The analyses outlined in the following sections were carried out on the data relating to ranges 1 - 3 miles, only half as many readings being available for the 4 mile range. This difference arose from the two levels of navigational uncertainty, one of which was associated with three ranges (1, 2 and 3 miles) and the other with four ranges (1, 2, 3 and 4 miles). This imbalance in the experimental design meant that it was not possible to include the range 4 miles data in the analyses of variance and, since range was not of primary importance in this experiment, they have also been excluded from most of the subsequent analyses.

The main results found from this experiment are outlined below and a summary of performance data for the two different conditions of map orientation is given in Table 2.0 at the end of this section.

2.1 Detection probability

Analysis of variance carried on the detection probability data showed that the effect of map orientation was not significant overall, and did not interact significantly with any of the other factors studied. The effects of ranges and target differences were highly significant as

was the interaction between them.

The overall detection probabilities for the 'North-up' and 'track-up' conditions were not significantly different, the values being 0.62 and 0.60 respectively. There were also no significant differences between corresponding detection probability means for individual ranges and targets under the two map orientation conditions. In the case of targets a further analysis was carried out to determine whether the small differences in detection probabilities for the individual targets under the two map conditions were correlated with the magnitude of the angular differences between the 'North-up' and 'track-up' conditions. The value of Kendall's tau was close to zero, indicating that there was no correlation.

These analyses indicated clearly that the different map orientations had no effect on detection probability. Indeed, the similarity of the data obtained in the present 'track-up' experiment to those obtained previously under 'North-up' conditions provides confirmation of these original results. A summary of the detection probability data under each map condition is given in Table 2.0.

2.2 Search time

Map orientation had no overall effect on search time and it did not interact significantly with ranges or targets. The overall mean search times were 11.9 seconds for the 'North-up' condition and 14.1 seconds for the 'track-up' condition. This marginal difference favouring the 'North-up' condition was not significant. Differences between range values for the two map conditions were not significant. Differences between mean search times for individual targets under the two map conditions were non-significant, but for all except one of the targets search times were marginally shorter under the 'North-up' condition.

2.3 Confidence level

The overall mean confidence levels for the two map orientation conditions were exactly equal, and map orientation did not interact significantly with ranges or targets. Individual range and target means were not significantly different under the two conditions.

2.4 Map-briefing time

Map orientation had no significant effect on the time taken for briefing, the overall means for the 'North-up' and 'track-up' conditions being 89.5 seconds and 90.4 seconds respectively. Target differences had a significant effect on map-briefing time, but there was no significant interaction with map-orientation.

The subject did not see the photographic display until he had familiarised himself with the appropriate map area, and therefore map-briefing times relate only to the map display whereas the other performance measures related to the actual detection task. Since the subject did not know at what range the target would subsequently be presented while looking at the map display, analysis of the range factor is not relevant for the map-briefing times.

Previous experiments had shown that map-briefing times were not correlated with any of the other performance measures for the seven targets, and since the subjects were allowed to take as long as they wished in map-briefing, it is possible that extraneous distractions could cause considerable random variation in these values. Analysis also showed that there was no apparent relationship, under either 'North-up' or 'track-up' conditions between the map times and the density of features in the relevant map area. It was also found that differences in map-briefing times for targets under the two map conditions were not related to the angular differences between the 'North-up' and 'track-up' orientations.

2.5 Psychometric measures

For subjects in both of the map condition groups it was found that an individual's performance, in terms of the number of correct detections made, was correlated with his score on the Heim test of intelligence. The mean values of the scores in each group were not significantly different.

TABLE 2.0

SUMMARY OF PERFORMANCE DATA

	DETECTION PROBABILITY		SEARCH TIME (seconds)		*CONFIDENCE LEVEL		MAP-BRIEFING TIME (seconds)		GENERAL NOTES
	'North-up'	'Track-up'	'North-up'	'Track-up'	'North-up'	'Track-up'	'North-up'	'Track-up'	
Overall mean	0.62	0.60	11.9	14.1	5.3	5.3	89.5	90.4	No significant differences
RANGE 1	0.74	0.74	9.7	12.2	5.7	5.7	Not applicable since the subject did not know at what range the target would be subsequently presented.		Detection probability, search time and confidence level are linearly related to range. Range 4 mile data are not included in the main analysis.
RANGE 2	0.62	0.63	12.1	14.6	5.4	5.2			
RANGE 3	0.52	0.43	14.0	15.5	4.7	4.9			
RANGE 4	(0.38)	(0.43)	(12.9)	(16.5)	(5.0)	(4.8)			
TARGETS 14	1.00	1.00	4.4	6.9	6.2	6.6	98.5	85.7	There are significant correlations between rank orders of the targets on each performance measure, except map-briefing time. For each performance measure, except map-briefing time, the target orders under 'North-up' and 'track-up' conditions are correlated.
TARGETS 16	0.94	1.00	9.3	13.1	5.3	5.3	89.2	82.2	
TARGETS 3	0.67	0.61	7.9	11.4	6.0	5.7	68.5	75.9	
TARGETS 17	0.67	0.56	13.4	15.8	5.7	5.3	89.6	93.5	
TARGETS 13	0.50	0.44	13.2	14.4	5.3	4.7	85.7	95.1	
TARGETS 15	0.33	0.33	18.1	15.7	4.4	5.3	100.7	97.2	
TARGETS 1	0.28	0.28	16.9	21.3	4.0	3.9	94.7	103.3	

*The confidence level scale ranged from 1 to 7, high values being associated with high confidence of a correct response.

3. DISCUSSION

The results outlined in the previous section show clearly that none of the four performance measures made in this experiment were significantly affected by altering the orientation of the map sections from 'North-up' to 'track-up'. Not only had map orientation no overall effect on any of the performance measures, but also there were no significant interactions between map orientation and targets or ranges.

Interactions might have been expected to occur between map orientation and targets since the aircraft tracks were orientated in random directions and thus the angular difference between the 'North-up' and the 'track-up' configurations was different for each of the seven targets. However, there was no correlation between the magnitudes of these angular differences and the differences in mean detection probabilities for the targets under the two map conditions. The same result held for the other performance measures.

Since these angular differences between 'North-up' and 'track-up' orientations were confounded with other differences between targets, further analyses were carried out to determine whether, by chance, target size (a predominant factor in determining detection performance) or density of features in the relevant map area (one factor which might affect map-briefing time) were correlated with the angular differences between the two map orientations. Correlations such as these could mask the interactions between map orientation and targets but no significant correlations were found and it is therefore reasonable to conclude from the above results that there are in fact no interactions between map orientation and targets for any of the performance measures studied.

The main result found in this experiment, that map orientation has no effect on detection performance should be considered in relation to the experimental task and the subjects used. Firstly, the subjects

who took part in this experiment were unskilled in that they had little or no flying experience, and none in high-speed, low-level flight, although most of them were familiar with Ordnance Survey maps of the kind used. During this experiment they were exposed to only one map orientation condition, and during the preliminary training and practice the maps were displayed only in this orientation. Thus the subjects had an opportunity to familiarise themselves with the map orientation used, and they were largely free from any negative transfer effects which might have arisen from frequent use of maps in an orientation different from that to which they were exposed during the experiment. These factors would tend to minimise any differences in performance due to differences in map orientation. Although some of the subjects tested under the 'North-up' condition commented that they would have preferred the maps to be displayed 'track-up', the majority of subjects did not appear to care either way and a few said that they preferred the 'North-up' orientation.

Had it been possible to obtain performance data for skilled subjects under both map conditions it is possible that differences in performance would have been found, since experienced pilots and navigators normally use maps in the 'track-up' orientation and those that took part in the first experiment of this series did not favour the 'North-up' orientation of the maps.

Secondly, it should be noted that this experiment was carried out under static conditions in which the area of the map that the subject was required to familiarise himself with was relatively small, and he was not allowed to refer back to the map while viewing the photographic display. Both these factors may have contributed to the absence of any effect due to map orientation. A study of map orientation in relation to static displays which has some relevance to the present experiment is reported by Layman (1968). In one part of this experiment Layman

compared the time taken by observers to locate the boundary of an aerial photograph on a map, and then to estimate the map coordinates of a designated object, under two different viewing conditions. Under the first condition both the map and the photograph were displayed in fixed orientations, whereas under the second condition the observer was free to orientate the photograph relative to the display. This experiment involved relating a photograph to a map, rather than a map to a photograph as in the present experiment, but the necessity of recognising corresponding elements in two different types of display, which may or may not be similarly orientated, is present in each case. However, the imagery used by Layman was vertical photography, whereas in the present experiment oblique photographs, which are complicated by perspective effects, were used. In spite of this the result found by Layman, that freedom to orientate a photograph relative to a map does not shorten the time taken to find the photographic area on the map or to determine the map coordinates of a designated object, is in accordance with the results of the present experiment.

It must be emphasised that the present experiment was carried out only to determine whether map orientation affected performance under the static conditions used in this series of experiments, and was not intended to be applicable to dynamic situations. The effect of map orientation on visual or televisual navigation performance is likely to be more marked since under dynamic conditions the navigator must maintain continuous geographic orientation along the aircraft track by looking alternately between the map and other cockpit displays, and the outside world as seen directly or on a TV monitor. McGrath et al (1964) have summarised some of the problems associated with the use of 'North-up', 'heading-up' and 'track-up' maps in airborne situations, and they conclude that since none of these systems will alone adequately meet display requirements optional map rotation will be required.

One important disadvantage associated with map rotation, which is necessary to maintain 'track-up' or 'heading-up' orientations, is the possibility, investigated by Upton, Willis and Dougherty (1964), of reading errors, particularly when the aircraft is travelling South and the map is upside down. Although on some occasions in the present experiment the direction of the aircraft track required 'track-up' maps to be presented upside down, there was no need for the subject to read or report place names and it is unlikely that this particular factor could have affected performance. Detailed consideration of this problem, and related ones such as the legibility of the type face used and the cluttered appearance of maps resulting from an excessive number of place names, although of considerable importance, is not relevant to this report.

The results of the present study showed clearly that under the static conditions studied, map orientation had no effect on detection performance and it is reasonable to conclude that, had 'track-up' maps been used throughout this series of experiments, the results obtained would have been no different from those obtained under the 'North-up' conditions. However, as indicated above, the dynamic situation involves considerations outside the scope of the present study and therefore it is not possible to draw any wider conclusions.

4. REFERENCES

Layman, R. S. (1968) An experimental comparison of two map display modes. Human Factors 10 (5)

McGrath, J. J., Osterhoff, W. E. and Borden, G. J. (1964) Geographic orientation in aircraft pilots: experimental studies of two cartographic variables. Technical report 751 - 3. Human Factors Research Inc., Santa Barbara, California.

Parkes, K. R. (1967) Visual and televisual detection studies. Part I. The effect of navigational uncertainty and target difficulty on detection performance. Ministry of Technology contract No. PD/170/04/AT. Loughborough University of Technology.

Upton, H. W., Willis, J. M., and Dougherty, D. J. (1964) JANAIR progress report. No. D228-100-009. Bell Helicopter Co., Fort Worth, Texas.

STUDY NOTE 2

VISUAL AND TELEVISUAL DETECTION STUDIES

Mintech contract PD/170/04/AT

STUDY NOTE II

THE EFFECT OF CAMERA FIELD OF VIEW ON TARGET DETECTION PERFORMANCE

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APRIL 1969

SUMMARY

This experiment was intended to compare the effects of two different camera fields of view, 30° x $22\frac{1}{2}^{\circ}$ and 50° x $37\frac{1}{2}^{\circ}$, on performance at a statically simulated target detection task. For the smaller field of view the display size was 4.8" x 3.6" and the viewing distance was 13"; for the larger field of view the display size was 8.0" x 6.0" and the viewing distance was 21". The angle subtended by the display at the observer's eye was thus kept constant at 21° x 16° .

The results showed that field of view had no overall effect on performance, as measured by detection probability, search time and confidence level. However, for small targets there was some evidence that the larger field of view resulted in higher detection probability, lower search time and higher confidence level. Map-briefing times were significantly longer for the larger field of view than for the smaller field of view, the increase in overall map-briefing time being proportional to the increase in the horizontal field of view.

In the Discussion section these results are considered in relation to the findings of other reported studies of field of view effects.

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1. PURPOSE OF THE EXPERIMENT

The experiment described in this report was one of a series of studies intended to investigate performance at an air-to-ground target detection task, simulated statically by means of aerial photographs. The present experiment was intended to determine whether increasing the camera field of view from 30° x $22\frac{1}{2}^{\circ}$ to 50° x $37\frac{1}{2}^{\circ}$ resulted in any significant differences in detection performance. The experiment was carried out under conditions in which the visual angle subtended by the display at the observer's eye remained constant. Thus, the effect of increasing the field of view was to increase the extent of the terrain shown, thus increasing the amount of information in the display, but to decrease the apparent size of the target.

The static display material used in this experiment consisted of a series of oblique photographs taken at ground ranges of 1, 2, 3 and 4 miles from each target. The camera field of view was 50° x 50°, the depression angle approximately 10°, and each photograph was 8" x 8" in size. The 30° x $22\frac{1}{2}^{\circ}$ field of view was produced by masking the photographs so that only a central portion 4.8" (horizontally) x 3.6" (vertically) was displayed, the viewing distance being 13". Under these conditions the horizon appeared approximately $\frac{1}{4}$" below the top of the display.

The larger field of view, 50° x $37\frac{1}{2}^{\circ}$, was produced by masking the photographs to display a portion 8.0" x 6.0", the horizon in this case appearing approximately $1\frac{1}{2}$" below the top edge, since the centre points of the two different size displays were coincident. The larger display was viewed from a distance of 21" so as to subtend at the observer's eye an angle equal to that of the smaller display, viewed at the shorter distance. This method of altering both viewing distance and display size avoided the need to reprint the photographs at reduced size which

would otherwise have been necessary. Such a procedure might have introduced extraneous processing variables. The viewing conditions described above are summarised in the following table:

TABLE 1.0

Summary of viewing conditions

Field of view	Actual size of display	Viewing distance	Angle subtended by display at eye	Angle subtended at the eye by 'large' and 'small' targets.	
				Large	Small
30° x $22\frac{1}{2}^{\circ}$	4.8" x 3.6"	13"	21° x 16°	197'	40'
50° x $37\frac{1}{2}^{\circ}$	8.0" x 6.0"	21"	21° x 16°	123'	25'

The last column in this table shows the mean values of the angles, in minutes of arc, subtended by large and small targets at the observer's eye under each field of view condition. The seven targets used in this experiment could be divided into two groups, one consisting of the three large, conspicuous targets and the other of the four small targets. However, since four range conditions were tested, there was considerable variation within these groups. The values given can only be regarded as approximate but they do give some idea of the variation between large and small targets and the extent to which the increase in field of view decreases the visual angle subtended by the targets.

The data relating to the smaller field of view condition had been obtained in the first experiment of this series (Parkes, 1967) and in the present experiment therefore it was only necessary to obtain data for the larger field of view 50° x $37\frac{1}{2}^{\circ}$. The conditions used were identical to those used previously, as was the experimental design, which was based on a matrix of seven targets and seven conditions.

The matrix was replicated three times using a total of 21 unskilled subjects. Each subject was tested on the Heim A.H.5 test of intelligence, and care was taken to ensure that the mean score of the group of subjects exposed to the larger field of view condition was not significantly different from that of the group of subjects used previously under the smaller field of view condition. The subject groups were balanced in this way since it had previously been shown that performance, in terms of the number of correct detections made, was highly correlated with an individual's score on the A.H.5 test.

Performance was measured by: detection probability (whether or not the position of the target was correctly located), search time (the time taken by the subject in searching the photographic display), confidence level (the confidence, on a scale of 1 - 7, that the subject had that his response was correct), and map-briefing time (the time taken by the subject to familiarise himself with the appropriate map area).

2. RESULTS

The data relating to each performance measure were analysed to determine whether there were any significant effects due to the different fields of view tested. The other main factors tested, ranges and target differences, were analysed only to determine whether they interacted with field of view. No analysis of the navigational uncertainty factor was carried out as the detailed analysis of the data relating to the smaller field of view, carried out previously, had shown that this factor had no effect on any of the performance measures made. There was no apparent interaction between navigational uncertainty and field of view and, therefore, in the analyses described in the following sections, data from the two uncertainty conditions were combined.

Since one uncertainty condition was associated with 3 range conditions (1 - 3 miles) and the other uncertainty condition with four ranges (1 - 4 miles) only half as many readings were available

for the range 4 mile condition as for the other ranges. As a result of this imbalance in the experimental design it was not possible to include the range 4 miles data in the analyses of variance. Since range was not of primary importance in this experiment these data have also been excluded from the subsequent analyses, except where specifically mentioned.

This limited analysis was only intended to investigate the effect of field of view, the overall effects of the other main factors having been studied in detail in previous experiments. The main results found are outlined below and a summary of performance data for the two different field of view conditions is given in Table 2.0 at the end of this section.

2.1 Detection probability

Analysis of variance carried out on the detection probability data showed that the effect of field of view was not significant overall, and did not interact significantly with any of the other factors studied. The effects of ranges and target differences were highly significant as was the interaction between them.

The overall detection probabilities for the 30° field of view and the 50° field of view were not significantly different, the values being 0.62 and 0.66 respectively. There were also no significant differences between corresponding detection probability means for individual ranges and targets under the two field of view conditions. For both these conditions, the relationship between range and detection probability was linear, but there was more variation about the regression line for the data relating to the larger field of view.

The mean detection probabilities for individual ranges and targets under each condition are shown in Table 2.0. This table also shows the mean values for large targets (Numbers 3, 14 and 16) and for small targets (Numbers 17, 15, 13 and 1) under each field of view condition. For the small target group there was a considerable improvement in detection probability under the 50° field of view condition, as compared with the 30° field of view, the relevant values being 0.53 and 0.44 respectively. The difference between these values is close to the 5% significance level. For the large target group there was no significant difference between the mean detection probabilities for the two field of view conditions. These results indicate that although there was no significant interaction between individual target and field of view conditions there does appear to be some difference between the effect of field of view on the large and the small targets groups, the detection of small targets being favourably affected by the increased field of view, whereas there are no significant differences for the the large target group.

2.2 Search times

Field of view had no overall effect on search time and there was no significant interaction with ranges or targets. The overall mean search times were 11.9 seconds for the 30° field of view and 10.5 seconds for the 50° field of view. Differences between range means for the two different field of view conditions were not significant. For both conditions the relationship between range and search time was closely linear for ranges of 1 - 3 miles. For the larger field of view this linear relationship continued to the 4 mile range, but for the smaller field of view an unexpectedly low value was obtained for this range condition.

There was no significant difference between mean search times for individual targets under the two conditions. When the four small targets were grouped together it was found that the mean search time for this group was significantly shorter ($p < 0.05$), under the 50° field of view condition, (11.7 seconds) than under the 30° field of view condition (15.4 seconds). There was no significant difference between the corresponding values for large targets.

2.3 Confidence level

The overall effect of confidence level was not significant and there were no significant interactions between field of view and ranges or targets. The mean confidence levels for the 30° field of view and the 50° field of view were 5.2 and 5.6 respectively, the difference between these values being non-significant. Differences between individual range means for the two field of view conditions were also non-significant.

The confidence level means for individual targets were consistently higher under the 50° field of view condition than under the 30° field of view condition, but none of these individual differences reached significance. However, for the group of small targets mean confidence level was significantly higher under the 50° field of view than under the 30° field of view but the corresponding values for large targets showed no significant difference.

2.4 Map-briefing time

Under the 50° field of view condition the map area with which the subjects had to familiarise themselves was proportionately larger than that for the 30° field of view and this difference had a significant effect on map-briefing time. The mean times for the 50° and 30° fields of view were 89.5 seconds and 135.1 seconds respectively. It is of interest to note that the ratio of these times, 1 : 1.51, is similar to the ratio of the fields of view, 1 : 1.67. Differences between individual target means for each field of view condition were all significant.

TABLE 2.0

SUMMARY OF PERFORMANCE DATA

		N	DETECTION PROBABILITY		SEARCH TIME (seconds)		CONFIDENCE LEVEL (1 - 7 scale)		MAP-BRIEFING TIME (seconds)		GENERAL NOTES
			Field of view 30^{o} x $22\frac{1}{2}^{o}$	50^{o} x $37\frac{1}{2}^{o}$	Field of view 30^{o} x $22\frac{1}{2}^{o}$	50^{o} x $37\frac{1}{2}^{o}$	Field of view 30^{o} x $22\frac{1}{2}^{o}$	50^{o} x $37\frac{1}{2}^{o}$	Field of view 30^{o} x $22\frac{1}{2}^{o}$	50^{o} x $37\frac{1}{2}^{o}$	
Overall mean		126	0.62	0.66	11.9	10.5	5.3	5.6	89.5	135.1	No significant differences
RANGE miles	1	42	0.74	0.86	9.7	7.1	5.7	6.1	Not applicable since the subject did not know at what range the target would be subsequently presented.		Detection probability, search time and confidence level are linearly related to range. Range 4 miles data are not included in the main analysis.
	2	42	0.62	0.60	12.1	10.2	5.4	5.5			
	3	42	0.52	0.52	14.0	14.3	4.7	5.3			
	4	21	(0.38)	(0.43)	(12.9)	(17.2)	(5.0)	(4.8)			
TARGETS LARGE	14	18	1.00	1.00	4.4	4.7	6.2	6.8	98.5	136.1	Field of view has a significant effect on detection probability, search time and confidence level for the small target group but not for the large target group. For each target map-briefing time is significantly longer for the larger field of view.
	16	18	0.94	0.94	9.3	9.8	5.3	5.4	89.2	122.5	
	3	18	0.67	0.55	7.9	10.3	6.0	5.9	68.5	108.7	
	Mean	54	0.87	0.83	7.2	8.3	5.8	6.0	86.0	122.4	
SMALL	17	18	0.67	0.56	13.4	10.9	5.7	6.0	89.6	131.6	
	13	18	0.50	0.72	13.2	11.2	5.3	5.9	85.7	134.8	
	15	18	0.33	0.50	18.1	11.7	4.4	5.2	100.7	155.1	
	1	18	0.28	0.28	16.9	12.9	4.0	4.4	94.7	162.2	
	Mean	72	0.44	0.53	15.4	11.7	4.9	5.4	92.7	145.8	

N = number of readings on which each value is based.

3. DISCUSSION

The results outlined in the previous section indicate that, under the conditions of this experiment, field of view had no overall significant effect on detection probability, search time or confidence level. However, there was some evidence that for the small targets mean detection probability increased and mean search time decreased when the field of view was increased from 30° to 50°, whereas for the large targets this increase in field of view had no significant effect.

Under the conditions of this experiment the increase in field of view was accompanied by an increase in both display size and viewing distance, such that the angle subtended by the display at the observer's eye remained constant. Thus the effects of increased viewing distance and increased field of view were confounded. However, in a previous experiment it had been shown that increasing the viewing distance to 21" while keeping the 30° field of view and the display size constant, thus reducing the angle subtended by the display at the observer's eye, had no effect on performance. Therefore the increase in detection probability found when field of view and viewing distance were simultaneously increased can be attributed solely to the change in field of view.

This effect could have resulted from the increase in the extent of the terrain shown under the larger field of view condition. Since the small targets studied in this experiment occupied an extremely small proportion of the total display, even in the smaller field of view, the subject's ability to orientate the main features in the display from his knowledge of relevant map information, was of considerable importance in locating the target area. It is likely therefore that the improvement in detection probability for these small targets

resulted from the fact that the larger area of terrain in the 50° field of view showed a greater number of conspicuous features which could be used in this orientation process.

In view of this it is perhaps surprising that the larger field of view resulted not only in higher mean detection probability for the small targets but also in significantly shorter mean search time. Data from the previous viewing distance experiment had shown that when viewing distance was increased to 21", without an increase in the 30° field of view, there was a marginal but non-significant increase in mean search time for the small targets. It can therefore be concluded that the significant reduction in search time under the larger field of view conditions was the direct result of the increased area of terrain shown. This could be due to the fact that the additional information shown enabled the subject to locate the general target area more quickly, and more accurately, thus reducing the time required for specific search of this area.

It should also be noted that when the field of view was increased the mean time taken for map-briefing also increased, indicating that the subjects did attempt to familiarise themselves with a wider area of terrain. For the large targets map-briefing time was the only performance measure significantly affected by field of view. The absence of any affect on detection probability can be accounted for by the fact that for these conspicuous targets overall orientation was very much less important than for small targets since in many of the presentations the target could be readily recognised without reference to other features in the display. Since these targets were conspicuous largely by virtue of their size the marginal deterioration in performance found for the larger field of view could have been associated with the decrease in the apparent size of the target.

Whilst the fact that an increase in the field of view appears to improve detection performance, as measured by detection probability, search time and confidence level, for small targets but not for large ones is of some interest, it should be noted that the effects were only of borderline significance and must therefore be regarded with caution. No overall significant effect due to the field of view was found in this experiment and some consideration should be given to the reason for this result, in view of the fact that a number of other reported studies clearly indicate that field of view has a highly significant effect on performance at various different types of target recognition task. The following two examples illustrate some of the results that have been obtained.

In a study of telescope field of view requirements for star identification, Allen and Hershberger (1966) found a highly significant inverse relationship between field of view and the time taken to identify a major navigation star in a simulated star field, and to center it in the telescope field. The field of view of the telescope was varied between 10° and 45° and the main result found was that acquisition time decreased markedly as field of view was increased to 30°, but remained relatively stable for fields of view larger than this. It was also found that the majority of star identification errors (81%) occurred for viewing fields of 25° or less. Both these results indicate that the smaller fields of view were not large enough to provide a readily recognisable pattern of stars by which the navigation star could be identified.

More closely related to present work is a study carried out by Rusis and Snyder (1965) who investigated the effects of TV camera field of view on air-to-ground target recognition. The three camera fields of view studied were 25° (vertical) x 34° (horizontal), 7.5° x 10° and 6.2° x 8.2°. The simulated altitude was 500 ft. and the simulated

ground-speed 198 knots. The main performance measures made in this study were the probability of correct recognition and the range of correct recognition.

It was found that the percentage of targets correctly recognised increased significantly as the field of view increased but there was no interaction between target size and field of view. Analysis of the range data showed that the mean range of correct recognition increased as the field of view decreased. There was a statistically significant interaction between field of view and the size of the targets, the increase in recognition range with decreases in field of view being greater for large targets than for small targets, but the general trend was similar for targets of both sizes.

The explanation Rusis and Snyder give for the first of these results is that as field of view is decreased the length of time the target is in the field of view is proportionately reduced. There is evidence that percent correct recognition is directly proportional to exposure time and, therefore, the smaller the field of view, the less likely the target is to be recognised. A second contributing factor is that the angular velocity of objects across the display increases as field of view decreases, which also tends to bring about a deterioration in performance. The effect of field of view on recognition range is due partly to the geometry of the viewing conditions since, if the horizon is kept within the field of view, the smaller the field of view, the greater the range of the target when it passes out of the lower edge of the display and is thus no longer available for recognition. Therefore, if recognition occurs, it must take place at longer ranges than would be necessary for a larger field of view. The fact that image magnification is inversely proportional to field of view may also tend to increase recognition ranges for smaller fields of view.

These results indicate that the optimum field of view for a particular situation will depend on whether recognition range or detection probability is the primary consideration. If, for instance, effective weapon delivery depends on recognition taking place at a relatively long range then a small field of view might be desirable. However, for general airborne orientation purposes a high probability of checkpoint recognition is more important than recognition range, and a larger field of view is therefore preferable.

The experiment described above was carried out under dynamic simulation conditions, whereas the present experiment used a much less realistic static simulation technique. The conditions under which this static experiment was carried out allowed the subject to view the photographic display for as long as he required, although the importance of speed in the detection task was emphasised. Therefore, the relationship between field of view and exposure time, which is inherent in a dynamic situation if ground-speed is kept constant, was not simulated in the present static experiment. Since this decrease in exposure time is a major factor causing the deterioration in detection probability for smaller fields of view under dynamic conditions, this at least partially explains why only a small effect due to field of view was observed under these static conditions.

In practice the present experiment was investigating detection performance under conditions in which, although changes in field of view and image magnification were realistically simulated, the associated effects such as changes in exposure time, angular velocity of objects moving through the display, and geometrical viewing constraints, were not simulated. However, in the experiment carried out by Allen and Hershberger, in which observers were required to identify navigation stars in a simulated star field, the nature of the experimental task was such that these dynamic effects were not present, since the observer was free to scan

the star field with the telescope as he wished. In spite of this a highly significant effect due to field of view was found, whereas in the present experiment there was no overall significant effect.

Whilst the experimental task studied in the star identification experiment, and that studied in the present experiment, are not directly comparable, they were both orientation tasks involving the recognition of complex patterns, by reference to a map, as a means of locating and confirming target position. The results obtained by Allen and Hershberger indicated that no significant improvement in identification performance occurred as field of view was increased beyond 30°. This suggests that the fields of view studied in the present experiment were both larger than a critical size below which a marked deterioration in performance would occur as the display would not show enough features for overall orientation purposes. The results obtained from the present experiment suggest that only marginal improvement occurs as field of view is increased from 30° to 50° although this improvement is more marked for small targets, the detection of which requires more detailed and accurate orientation.

It is clear from this discussion that the static simulation technique used in the present experiment was not entirely appropriate for a study of field of view since important effects associated with changes in field of view in the dynamic situation could not be reproduced. This, together with the fact that relatively large fields of view were studied, appears to have caused the relatively slight effects observed, as compared with those reported by other investigators.

4. REFERENCES

Allen, R. W. and Hershberger, M. L. (1966). Telescope field of view requirements for star recognition. Human Factors 8 (1) 41-47.

Parkes, K. R. (1967). Visual and televisual detection studies. Parts I-IV. Ministry of Technology Contract No. PD/170/04/AT. Loughborough University of Technology.

Rusis, G. and Snyder, H.L. (1965) The effects of T.V. camera field of view and size of targets upon air-to-ground target recognition. Human Factors 7 (5) 493-502.