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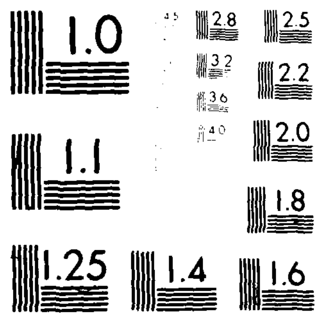
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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: AFOSR-TR-80-0965	2. GOVT ACCESSION NO.: AD-A089 945
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): The Influence of Figural Complexity on the Detection, Recognition, and Identification of Targets in Computer Generated Image Displays	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Moira K. LeMay	8. CONTRACT OR GRANT NUMBER(s): AFOSR-79-0103
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Montclair State College, Upper Montclair, New Jersey 07043	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F 2313D9
11. CONTROLLING OFFICE NAME AND ADDRESS: AFOSR (AFSC/NL) Bolling, AFB, D.C. 20332	12. REPORT DATE: Jul[redacted]80
	13. NUMBER OF PAGES: 40
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

LEVEL II

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Complexity
Detection
Recognition
Identification
Electrooptical Displays
Computer Generated Displays

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Computer-generated images (CGI) or displays in simulators provide a cost-effective approach to training pilots in the use of infra-red and other types of electrooptical (E/O) displays for night flying. The cost of simulating objects on a CIG display is proportional to the amount of display complexity. The present investigation attempted to assess the amount of complexity in simulation necessary for the detection, recognition, and identification of targets in a scene.

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20. Abstract

Complexity was manipulated by modeling six targets (airstrip, plane, hangar, factory, house, water tower) in full detail and then removing detail until there was just enough to model a three-dimensional object. Six levels of complexity were used, and internal and external detail were separated. Two levels of noise were also included, as well as a clear display. This made a total of 108 targets (6x6x3) which were embedded in a CIG scene, photographed, and made into slides.

The slides were shown to three groups of subjects in three experiments. In the first one, subjects were asked simply to detect the presence or absence of a target. In the second, they were asked to recognize which of the six possible targets it was and in the third they were asked to identify which of four possible targets of the same type this particular target was, i.e., they were shown four pictures of a hangar and asked to name which of these hangars was the one portrayed in the slide. Slides were shown for a very brief interval of time. Detection and recognition were group experiments, while identification subjects were run individually.

Neither complexity nor noise had any effect on detection or recognition of targets. However, more complex targets were much easier to recognize, especially when complexity was in the form of internal detail. Noise increased identification errors, and identification was the most difficult task, recognition was next, and detection was the easiest task.

AFOSR-TR- 80-0965

The Influence of Figural Complexity on the Detection, Recognition, and Identification of Targets In Computer Generated Image Displays

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Montclair State College

Contract No. AFOSR-79-0103

CONTENTS

The Influence of Figural Complexity on the Detection, Recognition, and Identification of Targets in Computer Generated Image Displays

Low level night flying of high performance aircraft depends for its success on the amount and interpretability of information about the terrain below and in front. Direct visual information may be severely limited and night sensing devices such as Low Light Level Television (L3TV) and Forward Looking Infra-Red (FLIR) are essential aids in missions such as damage assessment.

These electrooptical (E/O) displays, now installed in some aircraft, require training in their use and, for this purpose, computer generated images (CGI) have been developed for simulations of them. The level of transfer of training in using such images has often been assumed to be a function of realism which in turn is seen to be related to scene complexity. Complexity in this context is defined as the addition of features to the display, each of which increases the fidelity to the E/O sensor display by a small amount and at an increasing cost (Bunker & Heeschen, 1975).

The question then arises as to the extent of complexity necessary to permit positive transfer of training to the task being simulated. Smode, Gruber, and Ely (1963) point out that a high degree of transfer of training to the real task can be achieved without precise physical similarity and, in fact, transfer may be enhanced by introducing departures from realism such as feedback or the simulation of emergencies. The simulation of E/O displays by computer generated images, however, presents some rather unique problems.

The CIG simulations normally give a "cartoon-like" quality which is quite different from the E/O sensor displays. Moreover, the CIG pictures are made up of a large number of elements or edges which go to depict each object in the scene. If every detail of an object were to be represented, an extremely large number of edges would be required, and the cost of such image generation would be increased commensurately. It is clear, however, that objects can be represented in a recognizable way using only a moderate number of edges. The necessary number of edges for the completion of several tasks is the subject of this report.

In addition to the number of edges, the addition of visual noise to the simulated scenes was also studied, since the FLIR and L3TV images are extremely "fuzzy" in appearance, with very blurred edges. In a previous study (LeMay and Reed, 1980), the addition of an edge transfer function as well as visual noise was tried in an attempt to simulate the blurred edges. The transfer function had no effect on subjective judgments of scene complexity, while noise had a significant and rather large effect, so it was decided to include only noise in the present study.

The effect of such variables as the number of edges in a scene and visual noise on task performance may be expected to depend, of course, on the task being performed. With this in mind, three tasks representative of those performed by users of the FLIR and L3TV displays were examined in the present study. They are the detection, recognition, and identification of objects in a simulated scene.

Detection is here defined as the ability of an operator to discriminate between the presence and absence of a target; *recognition* is the assignment of a detected target to a class of possible targets; and identification is the selection of one individual target from a class of targets.

Numerous studies have been done on these three tasks under various conditions, and almost as many measures of performance have been devised. However, performance measures generally involve some consideration of the completeness (number of correct responses divided by the number of possible targets) and accuracy (number of correct responses divided by the total number of responses, correct and incorrect) of performance, and often of the time required for the task. These measures can be and have been applied to all three of the tasks under investigation. It is appropriate here to review some of the studies that have been done on the detection, recognition, and identification of targets in applied settings.

Detection

Studies on the detection of just barely visible (or audible) targets in a background of noise have been extremely numerous since the inception of the work on the theory of signal detection (TSD) described by Green and Swets (1966), and TSD has been applied to the problem of visual search for targets in aircraft and simulators, as well as in other situations.

The general problem of visual search for complex targets was reviewed by Teichner and Mocharnuk (1979). They defined complexity in terms of stimulus dimensionality, i.e., the number of attributes such as form, direction, color, etc., which a stimulus may have. They reviewed the findings of 9 earlier studies, and came to the conclusion that the time required to detect a target decreases as the number of stimulus dimensions (complexity) increases and that the rate of stimulus processing increases (i.e., the time per stimulus decreases) as the number of stimulus dimensions increases. In other words, complex targets are more easily detected and processed (recognized?) than simpler targets.

Uttal and Tucker (1977) present a multi-stage model of perception in which each stage can be explored only if thresholds for previous stages have been exceeded. They measured performance in a detection task by the percent of correct detections, and found that performance declined with increasing stimulus complexity. They also used a masking noise condition, and concluded that complexity was a powerful determinant of susceptibility to masking by noise.

Curran (1975) used a latency measure in a detection task, and found that it increased as a function of "relevant target characteristic symbol density", which is probably related to stimulus complexity.

The finding that signal uncertainty produces a substantial and reliable decrement in detection performance was again confirmed by Swets and Birdsall (1978). Uncertainty was manipulated using the frequency of an expected auditory signal in a fixed, random, or patterned manner which may be related to stimulus complexity.

Two very applied studies were done by Sternberg and Banks (1970) and MacLeod and Hilgendorf (1973). The former found very poor performance as measured by the percentage of targets detected and the time required to detect a target for passive night vision devices. Performance was not influenced by several independent variables. The latter study produced similar findings for three infra-red devices.

These studies offer somewhat contradictory, and not always relevant, predictions for the present study. It seems that complexity sometimes aids and sometimes hinders detection performance. The most directly relevant is the study by Uttal and Tucker (1977), which found that complexity hindered detection, especially in the presence of noise. However, the findings of the two applied studies in which the manipulation of some independent variables similar to complexity made no difference may point to a difference between laboratory-generated and real-life targets. The present study uses simulations of real-life targets, and subjects them to a controlled analysis in the laboratory. It is expected that complexity will either have a slight hindering effect on detection performance, or no effect at all, and that the presence of noise will hinder performance, perhaps interacting with complexity. This expectation is based on the Uttal and Tucker (1977), Sternberg and Banks (1970), and MacLeod and Hilgendorf (1973) studies, as well as on the observation that the present targets should be well above threshold even in the presence of noise, and that the simple presence or absence of a target should not be influenced by any of its characteristics.

Recognition

The distinction between recognition and identification has not always been clearly made in the literature, and the term "discrimination", suggested by Gibson (1969) has sometimes been used for both tasks. Indeed, the distinction is not always easily made and, for present purposes, a somewhat arbitrary division has been made between those studies which ask subjects to recognize one of a class of targets, such as letters of the alphabet, and those which ask subjects to identify a particular target which has usually been constructed by the experimenter.

Pasnak (1971) used a same-different recognition task with simple and complex random polygons. The overall errors were greater for simple than for complex figures, and the experimental design made it possible to conclude that subjects were responding to the whole contour for simple random shapes, and to the distinctive parts of the outlines of more complex shapes.

Several studies have been done using letters of the alphabet as stimuli in a recognition task. Dolan and Mayzner (1978) compared detection and recognition of alphabetic characters using visual backward masking by noise, and found different functions for each task. Recognition required longer viewing time and was affected by complexity of the task, while detection performance was not so effected. Targets which were more easily confused with one another were harder to recognize.

Home (1978) also used letters of the alphabet in a recognition task, comparing it with a detection and an acuity task in a study of binocular summation. He found sensitivities lower for recognition than for detection, and less evidence of binocular summation for the recognition task.

An interesting experiment involving same-different judgments was done by Staller and Sekuler (1977). They asked subjects to respond to mirror-image and nonmirror-image stimulus pairs in a two-choice reaction time situation. They found that, in general, the more complex the pattern, the slower the response and complexity seemed to influence the quality of pattern processing, in that particular targets were responded to with significant differences in reaction time.

Frowein and Sanders (1978) looked at the effect of stimulus degradation in the form of added visual noise on a 4-choice reaction time task, finding that the more degraded stimuli led to longer reaction times. Similarly, Nygard, et al (1964) found that a more complex background resulted in more difficulty in recognition, and Berkhout and Phillips (1979) found background images interfered with target perception as measured by acuity with a Landolt ring.

Guttman, Snyder, Farley, and Evans (1979) studied the effect of image quality on target search, using the modulation transfer function area (MTFA) as a measure of image quality. They found that, as the MTFA increases (image quality improves), performance on a recognition task with a terrain model improves and search time and fixation duration decreases.

These studies seem to indicate a number of relevant generalizations that are possible. First, the more complex task of target recognition is more difficult and takes a longer time than that of detection. Second, degradation of a target image by the addition of noise makes it more difficult to recognize in terms of time and errors. Third, the findings on the effect of complexity on recognition are not clear. However, there is some evidence that simple patterns may be harder to recognize, at least when they are the unfamiliar, laboratory-generated random polygons, and that target degradation leads to longer search time, although longer search time was also reported for more complex targets. In the present study, target degradation refers to the simplification of a target. Fourth, several studies seemed to indicate that complexity influences the quality of pattern processing, so that there are differences among particular targets.

In the present study, the stimuli are constructed so that they are increasingly degraded by the subtraction of edges, both in outline and in internal detail, and this is defined as decreasing target complexity. They are further degraded by the addition of visual noise to the target scene, and these conditions are applied to 6 different targets. On the basis of a consideration of both the relevant literature and the unique aspects of this research (the definitions of target complexity and degradation), it may be expected that recognition will be affected by noise in the display, the particular target displayed, and target complexity. Noise should result in more errors of recognition, some targets should be harder to recognize than others, and the simpler, more degraded targets should be harder to recognize.

Identification

Studies of the identification of patterns have frequently made the distinction among detection, recognition and identification. Rosell and Willson (1973) defined the three tasks as they are defined here and found that detection probability rises with the S/N ratio of a video tube, i.e., noise lowers detection rate. Snyder (1973) reviewed a number of studies on detection, recognition, and identification, and elucidated several measures for use in studying them. Most relevant here is the percent or probability correct, which can be a measure of completeness (number of correct responses divided by the number of possible targets) or accuracy (number of correct responses divided by the total number of responses, correct and incorrect). The former is the measure used in the present study. Snyder also introduced the MTFA as a measure of overall image quality, and found that it was related to judged quality and information extraction as measured by responses to a series of questions about a scene.

Seman, Pasnak, and Zyer (1976) quantified photographs of human hands in a manner similar to that suggested by Attneave (1954), and asked subjects to identify the handmate for each hand. They found that the complexity of the thumb area influenced identifiability, and that lower complexity in this region was associated with an increase in correct identification. This was in contradiction, however, to an earlier finding by Pasnak (1969) which found lower complexity associated with a decrease in correct identifications for faces. The earlier finding was interpreted as support for Gibson's (1969) "distinctive feature hypothesis", in which a distinctive part or detail becomes the discriminative stimulus for that form. Presumably, the more details in the form, the easier it is to identify. The result for hands was not a large effect, and the author suggests that the contour of the human hand may have insufficient freedom to vary, thus reducing the probability of the appearance of a distinctive feature.

Thurmond, Menzer, and Rebbin (1974) studied two pattern classes with a paired-comparison identification technique and found that the pattern class (histoform or polygon) influenced the accuracy and speed of identification.

Dewar, Ells, and Mundy (1976) measured reaction time for the classification and identification of traffic signs and found shorter times for classification than for identification. Curran (1975) found that target characteristics affected detection latency and number of false alarms.

Brainard and Caum (1965) studied target detection, two types of recognition (gross and fine), and identification. They used four performance indices: completeness (number of correct responses/ number of targets in image); accuracy (number of correct responses/ time of exposure to task); and conditional accuracy (number of correct responses/number of correct detection responses). They found that the image enhancement technique they were studying improved performance significantly, particularly as the task difficulty increased.

Swets, Green, Getty and Swets (1978) studied the relationship between identification and detection in a series of experiments in which a visual stimulus was exposed in progressively more complete form in successive observation intervals. After each interval, the observer made both detection and identification responses. They compared detection accuracy, indexed by the area under an ROC curve, with identification accuracy, indexed by the percentage of correct responses, and found that the two processes proceed simultaneously as successive amounts of information in the form of successive glimpses of the target are presented. Thus, the processing of information for detection and identification take place at the same time, rather than in succession, and functions relating stimulus characteristics to detection and identification, such as the complexity studies in the present experiments, need not be identical, since the two simultaneous processes should be independent.

On the basis of these studies as well as a consideration of the tasks in the present study, several expectations may be advanced. It would seem that more complex targets would be more easily identified, since this was as actual finding in earlier studies, and because better images led to easier identification in some studies. The concept of "distinctive features" may prove useful here. One of the variables in the present study which has not been isolated in previous studies is that of the internal details of a target, as exemplified by the surface details of buildings, such as doors and windows. A previous study (LeMay and Reed, 1980) found these to be important determinants of the judged complexity of a scene, and they may constitute more salient "distinctive features" of a target that its outline shape. Therefore, it might be expected that targets that are more complex in terms of internal detail will be more easily identified than targets with simplified or missing internal details.

On the basis of both the distinctive feature hypothesis and of previous findings, it is further expected that the particular target being studied will have an effect on ease of identification. Some targets (those with more "distinctive features"?) will be more easily identified than others.

It would also seem that the functions relating target complexity to detection, recognition, and identification should be independent of one another, based on Swets, Green, Getty, and Swets (1978), and that detection of these targets which are well above threshold should result in the fewest errors, while identification should result in the most errors.

Method

Subjects

The subjects for the detection experiment were 14 students in an experimental psychology class at Montclair State College.

There were 10 females and 4 males. Subjects were tested in a group for this experiment.

Thirteen of the same subjects also served in the recognition experiment, as this gave them a familiarity with the stimuli which fostered recognition without further instruction. This was also a group experiment.

The subjects for the identification experiment served individually. They were 11 volunteers from classes at Montclair State. None of them had served as subjects for the previous two studies.

Stimuli

The stimuli for all three studies were composed of 108 slides of various scenes generated on a computer according to the methods described by Bunker and Heeschen (1975). The scenes were of 6 targets at each of 6 levels of complexity and 3 levels of visual noise. They were used in a 6 x 6 x 3 factorial design with repeated measures on the same subjects (Kirk, 1968).

The 6 targets were embedded in a scene as they would be likely to appear when viewed from an aircraft. The targets consisted of a(n):

aircraft hangar
factory
water tower
single house
airstrip and
single aircraft on the ground

Only one target appeared on each slide. The scene consisted of surface features such as several roads, with mountains in the background. Some of the slides are illustrated in Figures 1 through 8. The same scene was used throughout the 108 stimuli, and the various targets were placed in it at appropriate places. One scene was generated with no targets in it for use in the detection experiment, and one scene was generated with all the targets in it, for use in instructing the subjects.

Each target was presented at each of 6 levels of complexity. Since a previous study (Lemay and Reed, 1980) had shown that the number of internal details was an important determinant of subjective complexity, while the number of external edges or details was relatively unimportant, the 6 complexity levels were chosen so that there were only two levels of complexity of figure outline, and three of added internal detail. These are illustrated for one target (the factory) in Figures 1 and 2. The simple outline consisted of the barest minimum number of edges to outline two dimensions of an object, so that the basic building facade is a rectangle. The more complex outline consisted of the greatest detail in the outline of that particular building. Thus, the many-peaked factory roof is presented, along with each of three smokestacks. The simple outline had only a flat roof and the smokestacks were represented by a single rectangle.

The three levels of internal edges consisted of, first, an outline with no internal detail at all. In the second level, the doors and windows were represented by blocks or rectangles. At the third level, windows and doors were articulated.

When the most complex level of internal and external edges were combined, the resulting stimulus was a fairly realistic picture of the object represented. The other levels of complexity should be thought of as degradations of this representation. The question addressed here, then, is: How much degradation can be tolerated for the performance of the tasks involved?

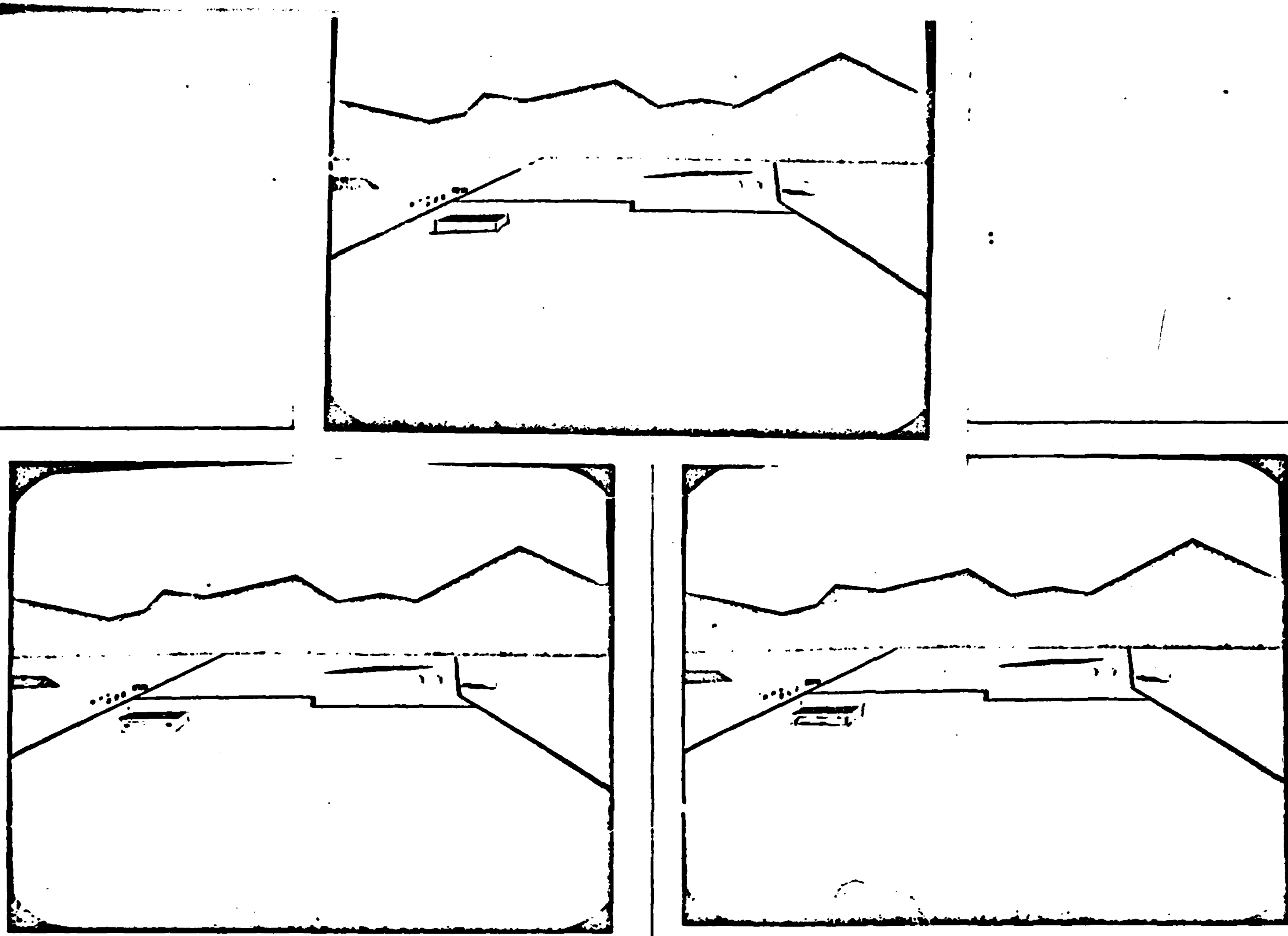

Figure 1. Simple outline of the "factory" target at three levels of internal complexity with no visual noise.

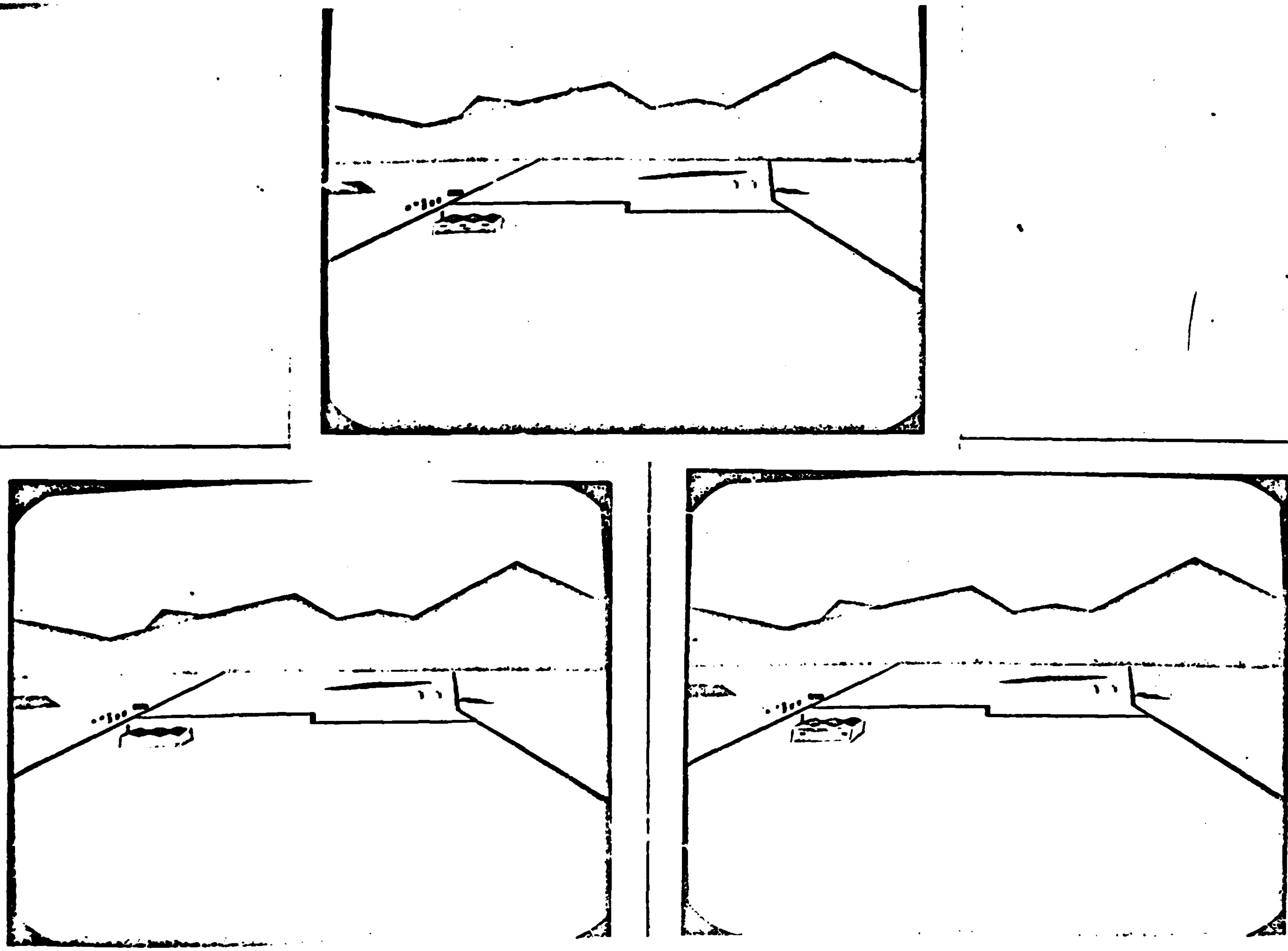

Figure 2. Complex outline of the "factory" target at three levels on internal complexity with no visual noise.

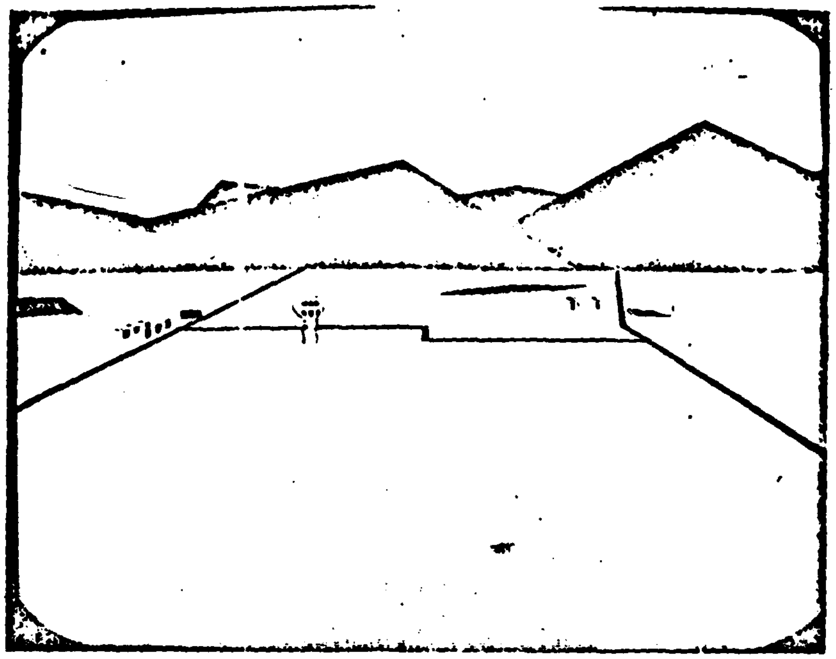

Figure 3. The most complex water tower.

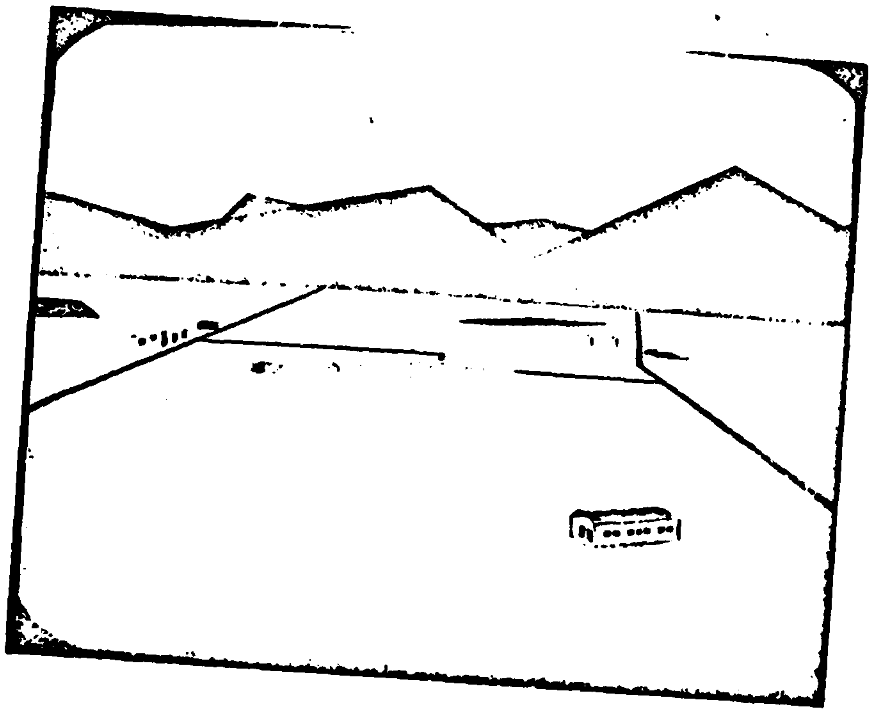

Figure 4. The most complex hangar.

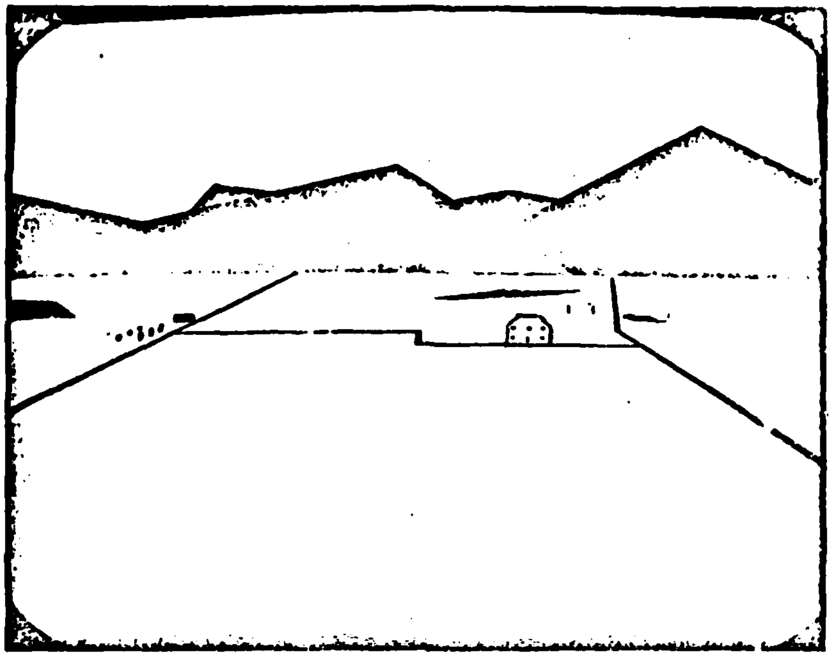

Figure 5. The most complex house.

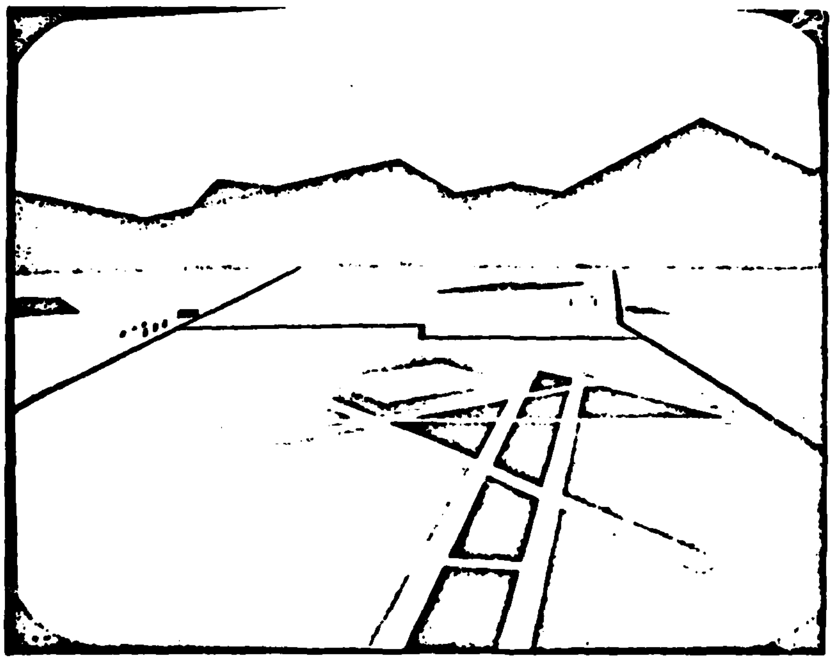

Figure 6. The most complex airstrip.

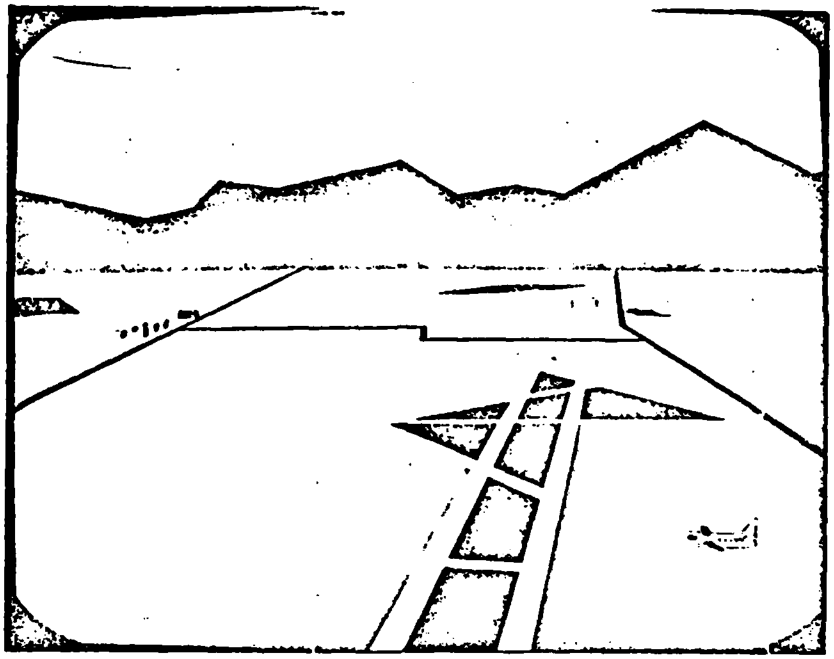

Figure 7. The most complex plane.

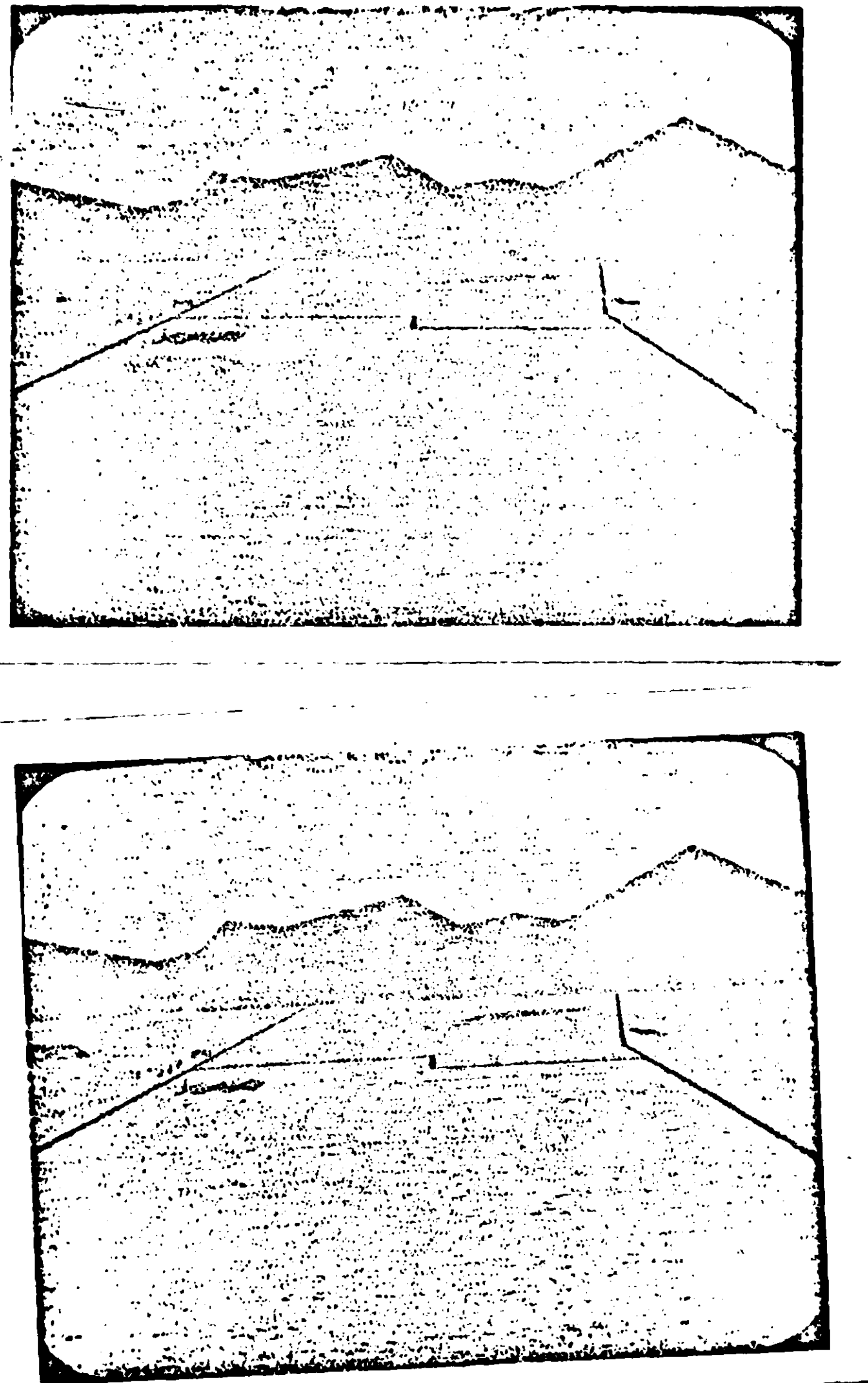

Figure 8. The two levels of visual noise (the first level is no noise).

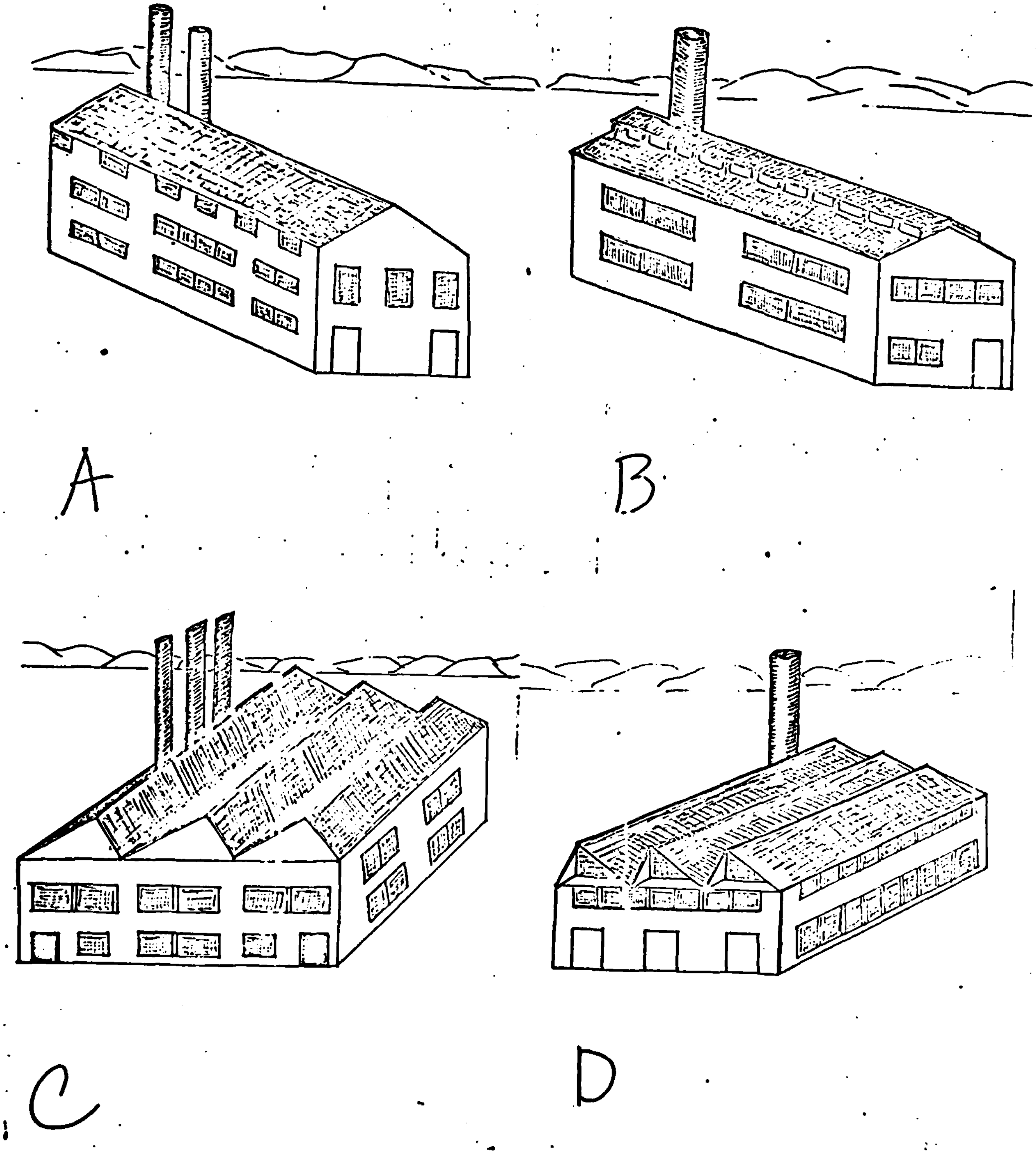

Figure 9. Four factories. The one labeled "C" is the one portrayed in the scene used in the experiment.

Since the FLIR and L3TV images are generally viewed in conjunction with a considerable amount of visual noise, each of the 36 combinations of target and complexity was subjected to two levels of noise, as well as being generated with a clear picture. This added a 3-factor variable, resulting in a 3 (noise level) x 2 (internal edges) x 3 (external edges) x 6 (targets) factorial design with 108 conditions. This was presented to all subjects in a repeated-measures design.

The scenes were generated and shown on a TV screen, and still pictures were taken of them and made into slides and into still pictures so that the scenes could be presented to subjects easily.

Procedure

For the detection experiment, three slides were taken of the basic scene with no targets in it, one for each noise level. These were interspersed with the slides on which there was a target and presented to the subjects in one random series of 216 slides on which there was a target 50% of the time. A Kodak Carousel projector was used to govern the interval of presentation on each trial. The "advance" button was held down so that the projector was advanced two spaces at once and the slide was presented in the first space. Thus, each slide was projected for an equal, and very short, interval of time, making a discrete trial and adding some stress to what would otherwise have been a very easy task for the subjects.

Subjects were instructed to record on an answer sheet whether or not there was a target in the scene, regardless of which target it was. Subjects were not informed of target probability.

In the recognition experiment, the slides were presented in a random series of 108. This time, however, subjects were instructed to mark on an answer sheet which one of the six possible targets was on the slide just shown. They were first acquainted with all of the targets, using the scene with all 6 targets in it, in full detail, i.e., with the maximum number of edges.

Subjects were run individually in the identification experiment. First they were acquainted with the appearance of the targets using a set of drawings mounted on the wall in front of them. These consisted of 4 drawings of each target type, one of which was the target in the scene, and three of which were of other, similar, targets. There were 24 drawings in all: 4 hangars, 4 water towers, 4 airstrips, etc. They were visible to the subjects at all times throughout the experiment. The drawings of the factory are reproduced in Figure 9.

Then, subjects were told they would be shown a set of slides in which one of the six pictured targets would appear. The slides were shown briefly, as before, and subjects informed the experimenter which target of the 24 pictured was in the slide. If the subject was uncertain, the slide could be shown again, as many times as the subject wished, although each time was of the same very short duration. Thus, two measures of subject performance were obtained. The first was the number of errors made in identifying the target and second was a time measure, that of the number of repetitions necessary for identification. The slide was not necessarily repeated until it was correctly identified, but only until the subject was satisfied that it was identified.

A short de-briefing session was held after each experiment. Subjects were informed of the target probability in the detection experiment, and had reached the conclusion that it was .50 before the experimenter so informed them. In the identification experiment, no subjects had been aware of the fact that there were only 6 possible targets; they all thought there had been more than one of each target type.

Results

The dependent variable for the detection and recognition experiments was whether or not the subject had made an error in each category. An error was scored as 1 and a correct response as 2. This was also used for identification and, in addition, the number of repetitions of each stimulus slide was scored. These data were subjected to a treatments by subjects analysis of variance (Kirk, 1968) to determine the effects of noise, target complexity, and target type on errors and, for identification, number of repetitions.

Detection

For the detection experiment, the only significant main effect was that of target type. Significant interactions were obtained between target type and noise, external edges and internal edges, and external edges and noise. The data for target type and noise are presented in Table 1. The house, the water tower, and the factory were difficult to detect, and this was especially so when noise was added to the display. It should be noted that these are relatively small targets.

The data for noise, external edges, and internal edges are presented in Table 2. The interaction between noise and external edges is accounted for by a very slight increase in difficulty of detection at both higher complexity and higher noise levels. In other words, the more complex a target is under noisy conditions, the harder it is to detect. The cause of the external edges by internal edges interaction is somewhat unclear; it simply seems to be the case that the more complex a target is in general, the harder it is to detect.

It should be borne in mind that, despite some significant interactions, the ability of subjects to detect targets is not

Table 1. Mean error for each target type at each noise level for the detection experiment.

Noise level	airstrip	water tower	target plane	factory	hangar	house
no noise	1.02	1.09	1.00	1.07	1.09	1.03
first level	1.00	1.09	1.03	1.15	1.03	1.12
second level	1.04	1.14	1.04	1.08	1.09	1.34

Table 2. Mean error for each level of external and internal edges at each noise level for the detection experiment.

		Level of internal edges 1	2	3
No noise				
Level of external edges	1	1.06	1.02	1.10
	2	1.05	1.03	1.03
Moderate noise level				
		1.04	1.08	1.05
		1.16	1.05	1.02
Heavy noise level				
		1.12	1.10	1.14
		1.10	1.12	1.15

really affected by target complexity, or even much by noise. The actual overall error rate in the experiment was quite low. Subjects detected 91.88% of all the targets presented. This result is presented in Figure 10, where it can be compared with the data obtained for recognition and identification. The overall false alarm rate was 18.33%.

Recognition

The results of the recognition experiment were similar to those for the detection experiment, in that the only significant main effect was that for target type, and there was a significant interaction between target type and external edges. No other effects were significant.

These results are illustrated in Table 3, where it can be seen that smaller targets (the plane and the hangar) are difficult to recognize. The interaction seems to be the result of the data for the plane, where more external edges make it more difficult to recognize, and the factory, where the opposite is true. The reasons for this are mentioned later. The plane, the hangar and the factory were the most difficult targets to recognize.

The actual overall error rate for recognition was considerably higher than that for detection. Only 77.24% of all targets presented were recognized correctly. Although the number of errors declined as complexity increased, this result was not significant. It must therefore be concluded that increasing target complexity does not enhance recognizability.

Identification

The results for identification are quite different from those for detection and recognition. Here, all main effects except that

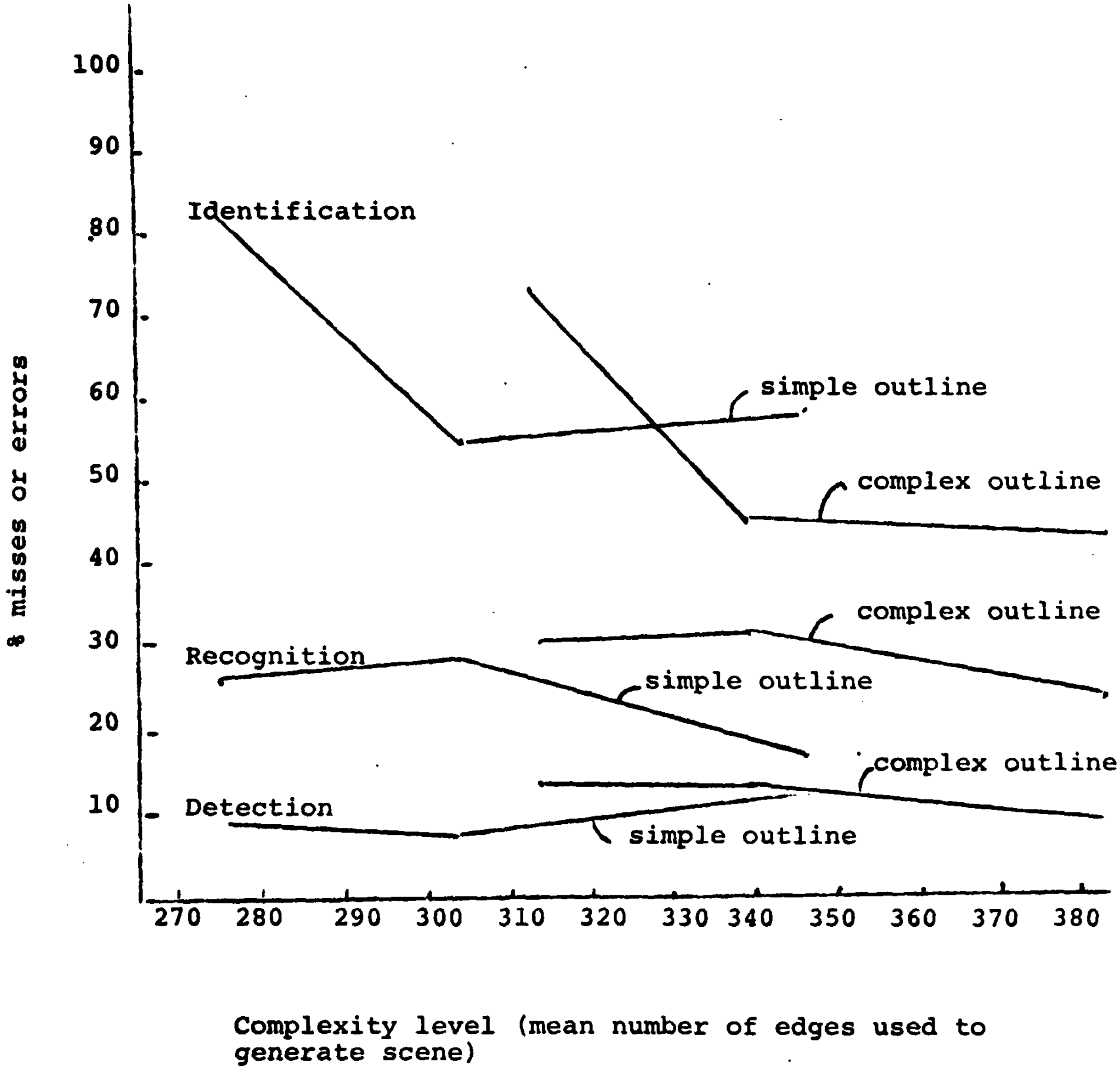

Figure 10. Percentage of errors in detection, recognition, and identification for six levels of complexity.

Table 3. The effect of external edges (complexity) on the recognizability of six target types. All three noise levels are combined.

Level of external edges		Airstrip	Water Tower	Plane	Factory	Hangar	House
	hi	1.03	1.16	1.33	1.32	1.42	1.04
	lo	1.08	1.15	1.59	1.19	1.44	1.04

of noise are significant, and there are no significant interactions.

The variable of most interest in the present study is that of complexity. Both internal and external edges had a significant effect on errors of identification (internal: $F=16.83$; $p<.001$; external: $F=6.13$; $p<.03$). These results are also presented in Figure 10, where it is clear that targets with more detailed, complex outlines are more easily identified than those in which the outline has been degraded by removal of some detail.

Degrading the target image by removal of internal detail has an even more drastic effect on identification. The complete absence of internal detail represented by the least complex targets results in an 80% error rate in identification. A Duncan multiple range test indicates a significant difference between the first and second level of complexity, but not between the second and third levels. In other words, absence of internal detail makes a target difficult to identify, but simply presenting some internal detail decreases the error rate significantly. Further articulation of detail does not result in additional improvement.

In short, both external and internal detail are important for target identification, with internal detail being somewhat more important, although only a small amount of it needs to be present.

The effect of target on identification errors was also significant. This data is presented in Table 4. The most difficult target to identify was the house. In addition to being confused with one of the other 3 possible houses, it was frequently not recognized, being confused with the factory. This accounts for the high error rate for the factory, as well. The next most

Table 4. Mean number of errors for each target in the identification experiment.

Airstrip	1.39
Water tower	1.38
Plane	1.73
Factory	1.61
Hangar	1.57
House	1.78

Table 5. Mean number of repetitions for each target at the three noise levels.

	Noise level		
Target Type	No noise	Moderate noise	Heavy noise
Airstrip	1.92	1.97	2.01
Water tower	2.08	2.16	2.74
Plane	2.26	2.12	2.28
Factory	2.27	2.04	2.82
Hangar	2.54	2.76	2.12
House	2.83	2.71	3.45

difficult target was the plane. This was presented on the air-strip, and was frequently not detected, despite the repeated presentations. The overall error rate for identification was 59%.

The repeated presentations, of course, constituted a second dependent variable which was subjected to the same type of analysis of variance. In this case, however, noise and targets were the only significant main effects, and they interacted significantly with one another. There was also a significant interaction between external edges and targets.

The number of repetitions of target presentation for each target type at each noise level is presented in Table 5. The most difficult target to identify in terms of errors, the house, also required the highest average number of repetitions. Small targets with much internal detail, such as the house, the factory, and the water tower, required more repetitions under the high noise condition, thus accounting for the interaction.

Discussion

The most significant result of the present investigation from the point of view of the simulation of E/O displays is the finding that the complexity of a target, in terms of the number of external and internal edges which go to make it up, influences performance on an identification task but has no effect on the recognition and detection tasks used here. Thus, a high degree of complexity in simulation may be necessary only for training operators in the identification of particular targets and not for simply recognizing a class of possible targets or detecting the presence of a target.

It is also important to note the very large effect of the task itself. This effect is so large that it would be misleading to generalize about the effects of variables from one task to the other. Indeed, whether the processes of detection, recognition, and identification proceed simultaneously, as proposed by Swets, Green, Getty and Swets (1978) or successively, as suggested by Uttal and Tucker (1977), they seem to be affected by the target characteristics varied in the present study, complexity and target type, in very different ways. In applied situations such as this, it is clear that the task must be treated as an important independent variable. Hence, the three separate experiments reported here.

Considering the similarity of the experimental situations, the tasks produced markedly dissimilar results in terms of the number of errors. The overall error rate was only 8% for the detection task. It jumps to 23% for the recognition task, and to 59% for the identification task. Where they are affected by degradation in target complexity, identification errors jump to 80%. Detection is a relatively easy task, and is not affected by complexity.

It is not surprising that complexity did not enhance target detectability. In fact, the addition of detail to a target may, in a sense, add to a visual noise factor and thereby make it harder to detect. Evidence for a phenomenon like this was suggested by Teichner and Mocharnuk (1979) and Uttal and Tucker (1977). The surprising result here is that the addition of visual noise to the scene did not affect detectability. It is even more surprising that there was no interaction between noise and internal edges, since the addition of internal edges to a target in an already noisy scene would seem to make it more easily seen as part of the noisy background and thus harder to detect, as in the studies mentioned. Instead, however, there is an interaction between noise and external edges and noise and target type. These two are probably related to one another, in that those targets with some detail in their outlines (the house and the factory) were the most difficult to detect under noisy conditions. These results seem to indicate that target complexity may have a slight negative effect on detectability, but it is too small to have produced a main effect in this experiment, and is reflected only in the interactions. The major reason for such a small effect is the general ease with which subjects performed the detection task.

The detection task could have been made harder only by the addition of more detail to the scene itself in the form of other irrelevant targets, but the aim of this experiment was to deal with the complexity, as defined by the number of edges, of each individual target, and this does not seem to have an effect on how difficult it is to detect a target.

While it was to be expected that target complexity would not affect detectability, the lack of any main effects other than that of target type is surprising for the recognition experiment. In particular, it would seem that complexity of detail should affect the recognizability of a target, especially since several of the targets were chosen because of their rather unique shapes, such as the hangar with, the distinctively curved roof, or the airstrip with its rather characteristic projections in various directions. Both of these characteristics were missing in the simplified outlines, yet neither target was particularly difficult to recognize, and the factory was actually easier to recognize without the high level of external detail. If, as Gibson (1969) suggests, pattern recognition depends on the presence of "critical features", it is not evident in the recognition part of these experiments. It would seem that there is enough variability in the shapes of the objects chosen so that a fairly large degree of departure from either the outline or the internal features of a particular target does not render it unrecognizable as a member of a certain class of targets. Thus, while airstrips frequently have oddly projecting runways, it is not necessary that they do and, while factories often have many-peaked roofs, the basic building shape and a minimal indication of a smokestack is enough to make it recognizable as a factory.

It should also be pointed out for the recognition experiment that the subjects were aware that there were only six possible classes of targets so that, if an object looked like, for example, a hospital, it was not possible to call it a hospital, so it would have to be another large building such as the factory. In other words, the amount of uncertainty in the situation was clearly very limited. This, of course, affects the overall percentage of errors in the recognition experiment, but it should not influence the effect of complexity on recognition, since the various levels of complexity were distributed evenly over all the targets.

While the absence of details in outline or in internal features does not seem to affect target recognition where this is defined as the correct classification of targets, it has a very clear effect on the exact identification of a target as being one, and only one, of its general class. The application of Gibson's (1969) critical feature model would seem to be more relevant here. Both external and internal edges had a significant effect on identification. Degrading a target image by subtracting either external or internal critical features makes it more difficult to identify.

This is perhaps most readily apparent in the case of internal edges. The total absence of any internal edges, as in the most simple targets, results in an extremely high error rate (over 70% even for targets with a complex outline). Adding any amount of internal detail immediately brings the error rate down near 50% for both simple and complex outlines. Internal details certainly seem to act like critical features for the identification of targets. This observation is borne out by the significance of the difference between the first and second levels of internal detail (the presence or absence of any detail) and the lack of a significant difference between the second and third levels.

The effect of external edges is also significant, although it is not as large as that for internal edges. Completing the outline of a target aids in its identification, probably by adding critical details to the outline.

The absence of an interaction between external and internal edges is reflected in the relationship shown in Figure 10. The effect of internal edges with a complex outline is repeated for the simple outline, but at a lower error rate. Thus, internal and external detail act separately and additively to lower the error rate for target identification. There are also no other significant interactions, either with noise or with target type, indicating that the main effects of complexity apply across the various types of targets and levels of noise. In other words, where complexity is an important variable, as in the identification task, it acts by itself in a simple fashion regardless of other variables. This should make it easier to deal with in an applied situation.

The measure of number of repetitions may be considered analogous to the time required to identify a target. It was not significantly affected by complexity, but only by target type and noise. It is not surprising that some targets should require more time to identify than others, or that these targets should also be the most difficult to identify in terms of errors. The effect of noise is also to be expected, since noise increases uncertainty, thus requiring a longer time to produce a response. This would probably be true even if the error rate were not affected by the number of repetitions, i.e., even if they had guessed correctly, subjects would still prefer more time to examine a target under high noise than under low noise conditions, since their criterion for identification would be raised (Swets, Green, Getty & Swets, 1978).

It is interesting to note that, when subjects were questioned after participating in the identification experiment, none of them had realized that there were only six targets, with six different versions of each. They all thought that there was more than one airstrip, factory, house, etc. This, of course, reflects the high error rate, but it also emphasizes the importance of the complexity of figures for the identification process.

Conclusions and Recommendations

1. Since hits and false alarms in detection, and errors in recognition, are not affected by complexity either in external or internal detail, a very low level of such detail is probably all that is necessary for the simulation of these tasks. Bare outline

figures, such as those used at the simplest level in the present study, are probably sufficient in CIG simulation.

2. Errors in identification, on the other hand, are drastically affected by complexity, and it is probably necessary to simulate considerable detail if unacceptable levels (70-80%) of error are to be avoided. The best combination for use in identification training is probably the higher level of outline complexity with the middle level of internal complexity, since the third level of internal complexity does not seem to lower the error rate. In other words, a full outline with only the suggestion of internal detail will probably produce the lowest attainable error rate, other factors being held constant.

3. Error rates for recognition and identification are high, and may be unacceptable for practical application. They may be improved, however, with training, and training may interact with complexity, so that subjects may be trained to recognize and identify simpler targets. More research is needed in this area.

4. Noise is an important variable which has significant effects on all three tasks studied here, and interacts with various target characteristics which are not covered by the manipulation of target edges. This is shown by the interaction of noise with target type and other factors. The role of noise in CIG simulation should also be further investigated, especially as it pertains to the simulation of E/O displays.

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