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THE PSYCHOLOGICAL DIMENSIONS OF CAMOUFLAGED IMAGERY

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October 1975

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U. S. ARMY HUMAN ENGINEERING LABORATORY
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The major purpose of this research project was to develop a methodology for evaluating the effectiveness of camouflaging techniques. The present research approached the problem from a psychological perspective and incorporated a recent, sophisticated procedure, multidimensional scaling, for data analysis. The focus of this report concerns an actual methodology to be applied in a field (or laboratory) setting with later computer analysis of the data. The present research was restricted to visual (as opposed to IFR or radar) observations. The methods described in this report are applicable to virtually all types of camouflaged objects or soldiers in any setting which is sufficiently stable for repeated judgments to be made on the objects over a period. Both direct field observations or second-order observations of photographic materials provided suitable data.

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20. Abstract (Continued)

Of the numerous variables (as the project bibliography indicated) which influence camouflage the two most distinct tasks are identification and detection. Thus hindering detection and increasing the difficulty of identification are the two purposes considered in this report.

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1.0 INTRODUCTION

The major purpose of this research project was to develop a methodology for evaluating the effectiveness of camouflaging techniques. Although the evaluation of camouflage effectiveness is not a novel issue, the present research approached the problem from a psychological perspective and incorporated a recent, sophisticated procedure, multidimensional scaling, for data analysis. The focus of this report will concern an actual methodology to be applied in a field (or laboratory) setting with later computer analysis of the data. Experimental work underlying the development of the methodology will also be presented, but in a summary fashion.

The methods described in this report will apply to virtually all types of camouflaged objects or soldiers in any setting which is sufficiently stable for repeated judgments to be made on the objects over a period of a few minutes. Both direct field observations or second-order observations of photographic materials can provide suitable data. The present research is, however, restricted to visual (as opposed to IFR or radar) observations.

As the bibliography for the project indicates, there are a number of variables which influence camouflage effectiveness, particularly those related to the observer, the target, the context or surround and the task. To our knowledge, none of these variables are confounded with (biased by) the proposed methods except for "task" since application of any method involves assigning a specific task to the observers. There are at least two distinct tasks associated with camouflage evaluation, detection, and identification. The detection problem involves distinguishing the presence of some type of object from a noisy background. Once the object is detected, then the observer can attempt to identify or classify it. Since camouflage can be used to increase the difficulty of either or both tasks an evaluation of the effectiveness of a camouflage technique depends on a knowledge of its purposes. Hindering detection and increasing the difficulty of identification are the two purposes considered in this report.

2.0 OBSERVER CHARACTERISTICS

There is ample evidence to indicate that there are large differences in perceptual abilities that would influence performance on camouflaged objects or imagery. Thornton, Barrett and Davis (1968) and Bircklin (1971) demonstrated that performance on the Embedded Figures Test was positively related to the ability of observers to identify targets. Paivio and Ernest (1971) showed that individuals with high imagery ability were better in an identification task than observers with less imagery ability. Johnston (1965) found that people who typically have large visual fields do much better at scanning-detection tasks than people with smaller fields. Also, not too surprisingly, individuals with good vision and normal color sensitivity do well in detection and identification tasks.

Two perceptual tasks were administered to our observers prior to the tasks involving camouflage imagery, a visual search task and the Embedded Figures Test. The visual search was selected because of its accepted usage in the psychological literature as a measure of perceptual skill and because of its obvious relation to an image detection task. The embedded figures test was used because of its demonstrated utility (see above) as a perceptual measure correlated with performance in real-life detection and identification problems. Procedures followed in administering these two tasks are described below.

2.1 Visual Search Task

For this task two samples of 10 matrices with the following dimensions were generated on the computer:

Rows		Columns
10	X	10
18	X	25
25	X	40
33	X	55
40	X	70

One matrix of each size consisted of members of the set of all angular letters (AEFHIKLMNTVWXY). The letters were randomly positioned throughout the matrix with the letter Z designated as the embedded target letter. The other matrix for each dimension size was composed of the set of curved letters (BCDGJOPRSU), again randomly positioned, with Q as the embedded target letter. The matrices were printed, one to a page, on 11" x 14-7/8" line printer paper by an IBM 2741 terminal.

The observers were shown the matrices one at a time, in increasing order of dimension size. Angular and curved letter problems were alternated in the sequence. The dependent measure was time-to-detection of the embedded character, which was indicated by both a verbal response (for example, "here") and by pointing to it on the page. The greater the total response time, the longer it took for a subject to find the embedded characters.

2.2 Embedded Figures Test

The Witkin, Oltham, Raskin, Karp (1971) Group Embedded Figures Test (GEFT) was used, as a second measure of the observers' ability to disembed figures. The subjects' task in the GEFT was to locate a previously seen simple figure within a larger complex figure which is designed to obscure the simple figure. The GEFT was administered according to the procedure outlined in the accompanying GEFT manual and took approximately 20 minutes.

2.3 Prediction of Performance

Observer's scores on the Embedded Figures Test and the Visual Search Task were correlated with performance measures on a variety of detection and identification tasks (described in detail later) with camouflaged and uncamouflaged vehicles. Surprisingly, no relationship was found between perceptual measures and detection-identification performance measures for our observers. This result could perhaps be explained by the limited range of individual differences between our subjects or limited variability in the sample of stimuli since previous research has demonstrated the relevance of performance on the Embedded Figures Test.

On the basis of the available literature a descriptive profile of an observer who is likely to do well in a camouflage detection-identification task would contain at least the following characteristics: (a) Above average intelligence, (b) Good visual acuity and color sensitivity, (c) High score on the Embedded Figures Test, (d) Good imagery ability particularly with respect to the objects to be detected or identified, and (e) Generally makes use of large visual fields in a scanning situation.

3.0 UNIDIMENSIONAL DETECTION METHODS

3.1 Experimental Materials

The stimulus materials which were used to evaluate the effectiveness of camouflage consisted of 35 mm slides of vehicles taken at Fort Hood. These slides were prepared according to the specifications required by our experimental design. They consisted of scenes with a constant background containing six different vehicles at varying distances. The six vehicles were:

Tank, with standard paint
Tank, with camouflage paint
2-1/2 Ton Truck, with standard paint
2-1/2 Ton Truck, with camouflage paint
Jeep, with standard paint
Jeep, with camouflage paint

A careful examination of the materials indicated that because of the distances involved and the fact that the vehicles were "in the open" the effectiveness of the camouflage pattern paint was less than anticipated. Also, despite our knowledge of the position of the vehicles, they could not be detected in the slides at distances beyond 1000 meters. For these reasons we decided to use a subset of the total sample of stimulus slides available for our experimental work. The subset selected includes the range of variation in camouflage and distance conditions which can be meaningfully observed in the vehicles slides. The subset consists of the 14 scenes denoted in Table 1 by a circle around the X.

The methods to be described below would apply equally well to actual camouflaged objects in a natural setting as well as 35mm slides. In a later section a list of specific procedures to be followed for evaluating camouflage in the field will be presented.

Table 1

Schematic Description of the 35mm Slides Obtained from Fort Hood[a]

Vehicle type	Body Paint	100	200	500	1000	1500	2000
JEEP	Standard		(X)[b]	(X)	(X)	X	X
	Camouflage Pattern		(X)		(X)	X	X
TRUCK	Standard	X	(X)	(X)		X	X
	Camouflage Pattern	X	(X)	X	(X)	X	X
TANK	Standard		(X)	(X)	(X)	X	X
	Camouflage Pattern		(X)	X	(X)	X	X

Note.

[a] An X denotes the availability of a stimulus item for that particular experimental cell.

[b] A circle around the X indicates that this stimulus item was used in the detection, identification and similarity tasks.

3.2 Experimental Procedure

The 14 slides were randomly ordered for presentation to each subject and shown using a Kodak 850 carousel projector. The observers were shown the slides, one at a time, and for each slide were asked to make a vehicle detection-difficulty rating using a 10 point scale, where a rating of "1" indicated "no difficulty in detection", and a "10" rating indicated that the vehicle was not located.

If the evaluations were to be made in a field setting then the vehicles would be placed in appropriate positions relative to the observer who would utilize the rating scale described above. If a vehicle was not detected, then it would receive a scale value of 10 for that observer.

3.3 Scaling Method

The straightforward detection rating task is based on Thurstone's categorical scaling model (Torgerson, 1958) which assumes that individuals are able to use the categories of detectability on a 1-10 scale in a consistent manner. If we assume that the variability in ratings for each object is approximately the same as is the variability in the perceived location of the category boundaries, then estimates of the detection scale values of each object can be obtained by simply averaging responses across subjects. The detection scale values obtained in the manner for the 14 objects are given in Table 2. For application in a field setting once the objects are arranged all that is needed is a blank response form.

Table 2

Detection Scale Values for the 14 Vehicles

Slide	Vehicle Description	Detection Scale Value
1	Camouflaged tank at 200 meters	2.77
2	Tank at 200 meters	2.00
3	Camouflaged truck at 200 meters	2.00
4	Truck at 200 meters	1.36
5	Camouflaged jeep at 200 meters	5.00
6	Jeep at 200 meters	4.28
7	Tank at 500 meters	8.36
8	Truck at 500 meters	6.86
9	Jeep at 500 meters	7.14
10	Camouflaged tank at 1000 meters	9.23
11	Tank at 1000 meters	8.32
12	Camouflaged truck at 1000 meters	8.45
13	Camouflaged jeep at 1000 meters	8.50
14	Jeep at 1000 meters	8.59

A second scaling method method not used would follow the same task format except that only the responses "yes, I detected the object" and "no, I did not detect the object" would be recorded. For this latter task, the object's detection scale value would be given by the percentage of times it was correctly detected. This alternate procedure was not used because of two disadvantages: (a) A large number of observers is required, and (b) useful information may be discarded since observers can typically judge the difficulty of detection as well as whether the object is detectable or not.

3.4 Results

Table 2 contains the detection scale scores for the 14 vehicles. We note that detection difficulty increases directly with distance and also that camouflaged vehicles were more difficult to detect than vehicles with standard paint at a given distance. These results are consistent with our expectations and confirm the effectiveness of the camouflage paint as a device for reducing detection probability.

4.0 UNIDIMENSIONAL IDENTIFICATION METHODS

4.1 Experimental Materials

The same 14 slides described previously were used in this research. The method described below would apply as well to objects located in a field setting.

4.2 Experimental Procedure

The 14 slides were randomly ordered for presentation to observers and shown using a carousal slide projector. The subjects were shown the slides one at a time and instructed to classify each vehicle (if they could detect it), as a jeep, tank or truck, and to indicate how sure they were of their classification by placing a subjective probability rating (from 2% to 100%) on the response sheet under the columns labeled jeep, tank, or truck. The subjective probabilities for each judgment did not have to equal 100%. The Ss were given 10 seconds to look at each slide. The screen was blank for 10 seconds following the presentations, and at the same time Ss were instructed to make their judgments for the previous slide.

4.3 Scaling Method

The estimation of subjective probabilities constitutes a magnitude scaling task (Stevens, 1956) and the resulting averages of the probability estimates represent a magnitude scale of the vehicles identifiability. This identifiability or recognition scale can be used directly to evaluate the effectiveness of camouflage since camouflage objects would in general have lower recognition scale values than objects not camouflaged. There is no strong reason for preferring a magnitude scaling task over a categorical procedure (as was employed with the detection scale) except that from our experience individuals have a good intuitive grasp of the meaning of probability estimates and can give consistent ratings using a 1-100 scale.

4.4 Results

Table 3 contains the Identification Scale Values for each of the 14 objects. Since the objects could belong to one of three identification scale values (unless the identification was not disputed as with objects 3 and 4). The "correct" identification (from the observer's perspective, regardless of ground truth) is defined by the vehicle class with the highest scale value for an unknown object. A comparison of the identification scale values with ground truth for the objects indicates that 11 of 14 identifications were correct for this sample of observers. The three incorrect identifications were all for vehicles at a distance of 1000 meters.

For each observer the identification task was scored by counting as correct classifications all cases in which the highest identification probability was given to the vehicle represented in a particular slide. If the probability estimates were 0.0 or identical for all three vehicles, the slide was not counted in the final score.

Table 3

Identification Ratings for the 14 Vehicles

Slide	Vehicle Description	Identification Scale Rating		
		Truck	Jeep	Tank
1	Camouflage tank at 200 meters	5.91	5.00	83.18
2	Tank at 200 meters	-	-	92.05
3	Camouflaged truck at 200 meters	95.45	-	-

Table 3

(continued)

Slide	Vehicle Description	Identification Scale Rating		
		Truck	Jeep	Tank
4	Truck at 200 meters	100.00	-	-
5	Camouflaged jeep at 200 meters	13.86	58.64	14.64
6	Jeep at 200 meters	11.36	64.09	11.07
7	Tank at 500 meters	10.00	6.36	22.95
8	Truck at 500 meters	37.05	7.50	2.86
9	Jeep at 500 meters	5.23	45.00	2.50
10	Camouflaged tank at 1000 meters	7.27	10.23	6.36
11	Tank at 1000 meters	10.23	15.23	3.93
12	Camouflaged truck at 1000 meters	16.36	9.55	8.64
13	Camouflaged jeep at 1000 meters	8.18	5.49	23.93
14	Jeep at 1000 meters	10.23	18.41	1.36

Table 4 contains the number of correct identifications for each observer. We note that no single observer had as many correct identifications as implied by the identification scale given in Table 3. Such variability in individual judgments suggests that a fairly large number of observers is necessary in order to provide a reliable estimate of camouflage effectiveness. This comment is especially appropriate for work in field settings where the number of uncontrollable extraneous variables is likely to be large.

Table 4

Detection and Identification Scores for the 22 Observers

Observer Number	Total Number of Objects Detected			Number of Correct Identifications
	Cutoff Criterion			
	6	8	10	
1	6	7	11	9
2	6	9	10	8
3	4	6	7	6

Table 4

(continued)

Observer Number	Total Number of Objects Detected Cutoff Criterion 6	8	10	Number of Correct Identifications
4	5	5	10	5
5	6	8	11	8
6	7	6	8	8
7	6	7	10	7
8	7	9	9	9
9	9	10	13	8.5
10	4	11	14	8.5
11	4	5	7	6
12	3	4	9	6
13	7	8	8	9
14	7	8	9	9
15	3	6	11	6
16	13	13	13	9.5
17	9	5	9	9
18	6	6	9	5
19	6	9	10	8
20	5	5	10	5
21	5	8	12	7
22	6	8	11	10

5.0 MULTIDIMENSIONAL IDENTIFICATION METHODS

5.1 Experimental Materials

5.1.1 The 14 slides described previously were used for one of the multidimensional studies.

5.1.2 A set of 9 slides of three vehicles (and a rock) similar to the above slides except that camouflaged nets rather than paint were used for concealment was used for a second study.

5.2 Experimental Procedure

Essentially identical experimental procedures were followed for both the set of 14 slides and the set of 9 slides. Every possible pair of slides were presented to the observers who were given the following instructions:

You will be shown some slides of military vehicles, at various distances and in different degrees of camouflage. In most of these scenes you will have some difficulty in identifying the vehicle because of distance, concealment, position of the vehicle, and other factors. All of these factors act to "camouflage" the vehicle and decrease the ease of identification.

Your task will be to evaluate the identifiability of the vehicles in the slides that will be shown to you. The slides will be presented in pairs. For each pair you are to estimate how similar the two objects are in their identifiability. That is, if it is easier to identify one of the vehicles, for example, a tank, (because it is closer, clearer, less concealed, etc.) than is the other vehicle, then your judgment will be an estimate of "how much easier" since this will reflect the similarity of the tanks in their identifiability. Two vehicles that are identifiable or recognizable to the same degree are obviously very similar in identifiability and should receive a rating of 1. If one tank is very easy to identify and the other cannot be identified, then they are very different in identifiability and should receive a rating of 10. Intermediate degrees of similarity between 1 and 10 should be used accordingly.

Within a field setting it is not possible to "present pairs" of objects for viewing as with the slides; however, the requirement that the observer be able to view and compare both objects can be satisfied adequately in another manner. The entire set of objects must be viewable from a central location so that by turning the head or moving a few feet any object can be observed. Under these conditions the multidimensional scaling task can be completed in a field setting. Also, a "reference" or standard set of photographs might prove very useful for field evaluations.

5.3 Scaling Method

The multidimensional scaling (MDS) model assumes that the similarity judgments comparing the degree of concealment of the objects correspond (via a monotonic transformation or in the case of the model used for this report, a linear transformation) to distances between the objects as represented in a multidimensional attribute space. For our task the attributes represent the characteristics of the objects which influence their degree of concealment. The MDS procedure used for the analysis of our data, the INDSCAL (Carroll and Chang, 1970), not only determines the dimensions or features used by observers in evaluating the identifiability of vehicles but also defines the relative importance or salience of each dimension to the observers. This latter capability makes the INDSCAL program an extremely useful and powerful method for studying differences between observers in their performance with camouflaged objects.

5.4 Results

5.4.1 Set of 14 vehicle slides.

The "similarity of identifiability" data obtained for the 14 slides was analyzed using the INDSCAL. An examination of the INDSCAL results revealed that a two dimensional scaling solution explained 63% of the variance in the original similarity judgments. Adding a third dimension increased the variance explained by only 3%. Also, the third dimension could not be interpreted. Figure 1 illustrates the two dimensional solution. An examination of the ordering of the vehicles along the two dimensions suggests the following interpretations:

(a) Dimension I is basically a near-far distance axis separating those vehicles that were close enough to be clearly observed and identified from all others. Only the trucks and tanks at 200 meters were regarded as "close." The jeeps at 200 meters were not clearly identified and were between the other vehicles at 200 meters and the cluster of vehicles lumped together at 500 and 1000 meters on this dimension. These data are consistent with the identification probabilities given in Table 3.

(b) Dimension II also orders the vehicles according to distance; however, it is probably best described as a "detection dimension" since it separates those vehicles (at 200 and 500 meters) which were nearly always detected (and usually identified) from those vehicles (at 1000 meters) which were seldom detected and almost never identified. Neither dimension was related in any direct way to the camouflage condition of the vehicle. Although we might have expected a "camouflage" dimension to emerge, its absence is not surprising in view of the limited variation present in the slides.

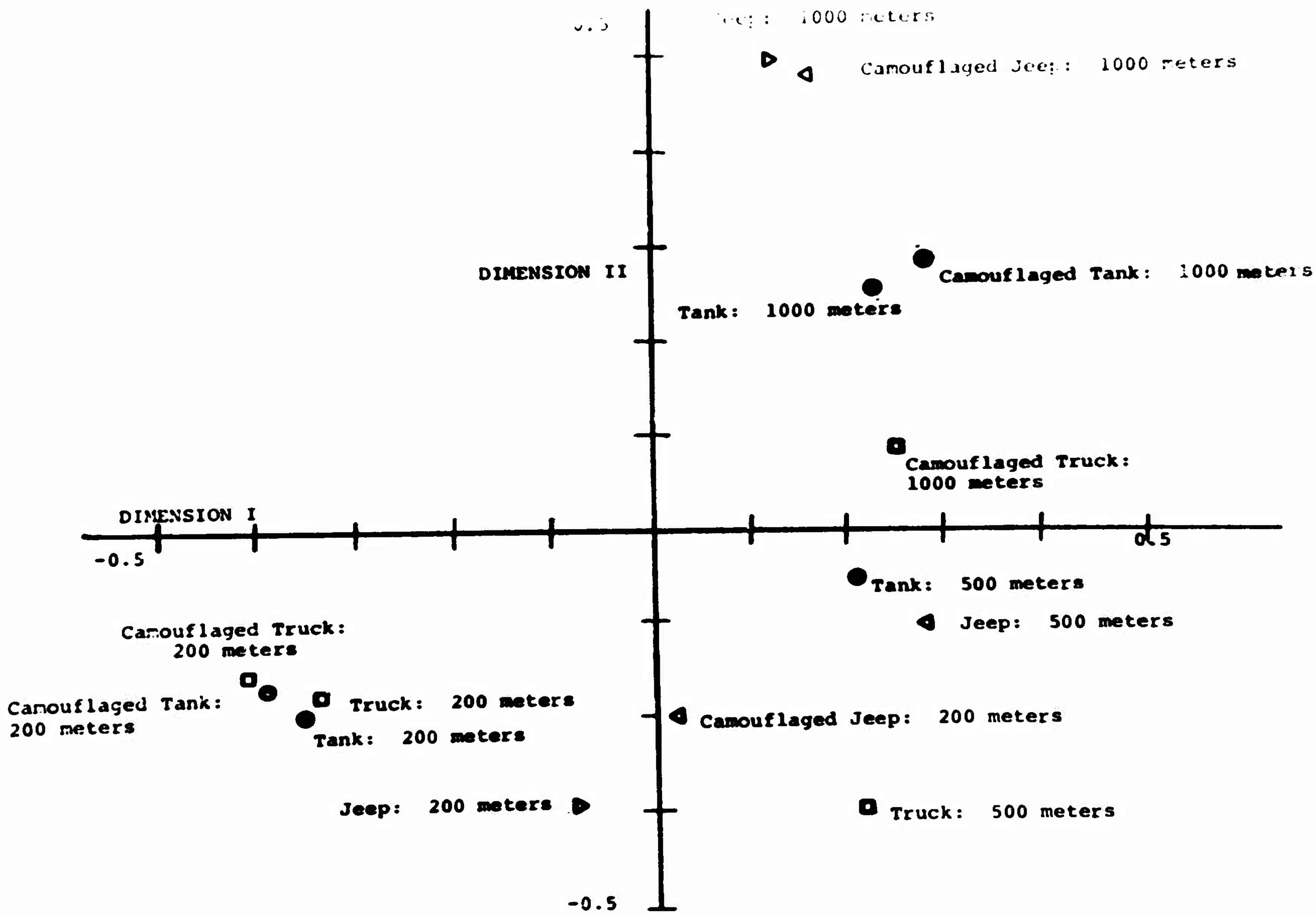


Figure 1

Two-dimensional INDSCAL Solution for the 14 Vehicles

The fact that we obtained a two dimensional solution indicates that our observers differed somewhat in the importance they attached to the two dimensions as predictors of vehicle interpretability. An examination of the subject weights contained in Table 5 confirms this fact. Several individuals, including 7, 12, 18, and 22 used Dimension I almost exclusively as a basis for their similarity of interpretability judgments while others, including 2, 6, and 17 strongly favored Dimension II. The large differences in the weighting patterns for subjects across the two dimensions indicates that individuals have strategies for evaluating the effectiveness of camouflage which vary considerably.

Table 5

Variance Explained Estimates and Observer Weights for the Two-dimensional INDSCAL Solution

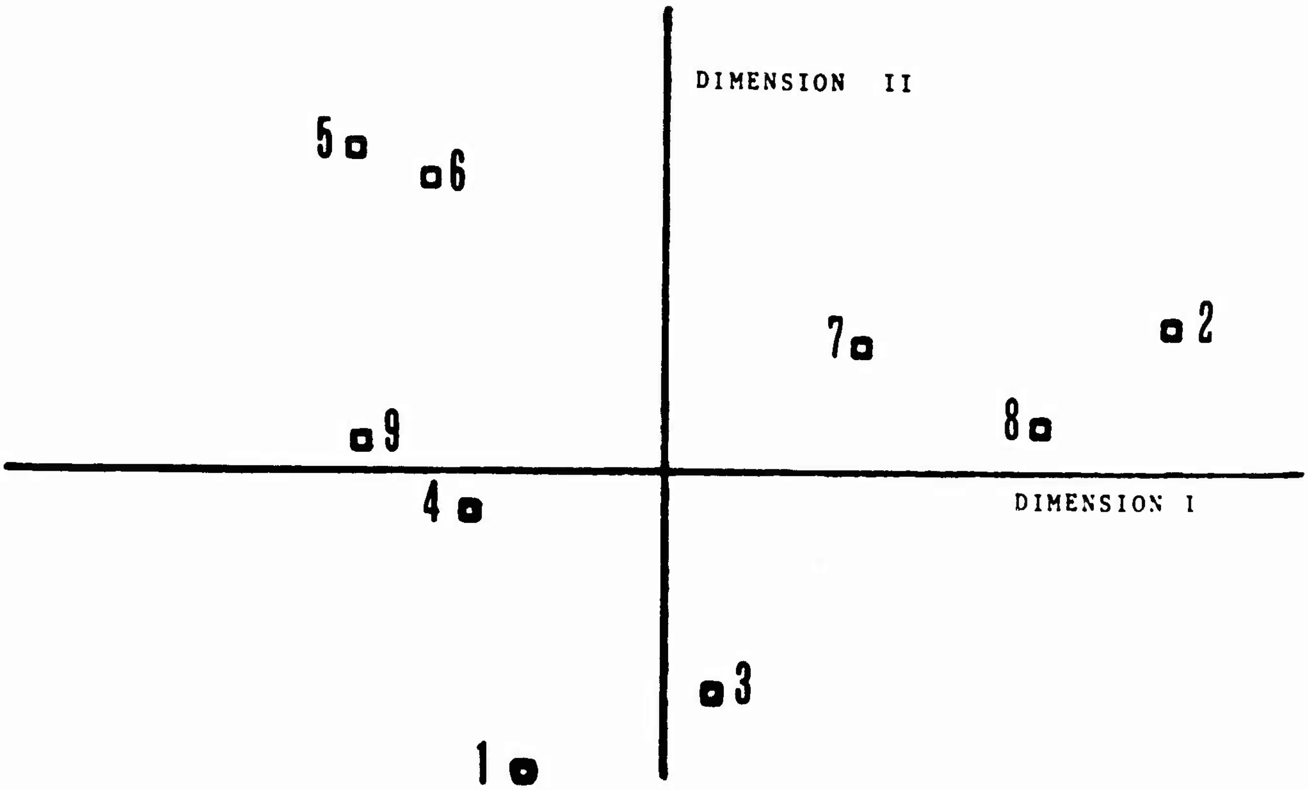
Observer	Weights		Correlation of Solution with Original Data
	Dimension I	Dimension II	
1	.471	.570	.842
2	.308	.720	.865
3	.650	.462	.905
4	.703	.385	.898
5	.282	.641	.775
6	.413	.530	.764
7	.723	.298	.861
8	.532	.487	.831
9	.271	.368	.519
10	.393	.573	.788
11	.560	.508	.895
12	.802	.113	.844
13	.503	.259	.632
14	-.101	.273	.260
15	.611	.499	.899
16	.348	.534	.721
17	.250	.696	.809
18	.742	.035	.753
19	.547	.439	.800
20	.482	.483	.780
21	.614	.384	.817
22	.706	.304	.849

The quality of the observers' performance is illustrated by the variance estimates given in Table 5 and by the similarity judgment reliabilities presented in Table 6. The variance estimates are the correlations between each observer's original judgments and the distances in the two-dimensional scaling solution. These correlations are in general extremely high, demonstrating that the "similarity of interpretability" judgments could be consistently and meaningfully given for the vehicles. Subject 14, whose judgments did not fit the scaling solution, was also highly unreliable as indicated by the reliability coefficients in Table 6. Although there are a number of moderate (.500 to .700) reliability coefficients for observers shown in Table 6 these are "lower bound" reliabilities since they are based on the correlations between the similarity judgments on the first 10 pairs and the corresponding judgments as these pairs are repeated in the stimulus series.

Table 6

Reliability Coefficients for Similarity of Interpretability Judgments

Observer	Reliability
1	.768
2	.920
3	.961
4	.766
5	.558
6	.507
7	.773
8	.614
9	.435
10	.760
11	.865
12	.614
13	.939
14	-.272
15	.752
16	.538
17	.427
18	.174
19	.751
20	.516
21	.886
22	.927



Vehicles

1. Jeep at approximately 3/4 mile
2. Jeep at approximately 100 yards
3. Tank at approximately 2/3 mile
4. Rock at approximately 2/3 mile
5. Tank with camouflage net: 20 yards
6. Jeep with camouflage net: 50 yards
7. Tank at approximately 1/4 mile
8. Truck at approximately 1/4 mile
9. Jeep with camouflage net: 200 yards

Figure 2

The two-dimensional INDSCAL solution for nine vehicles used in the Similarity of Identifiability Task.

5.4.2 Set of 9 vehicle slides

The similarity data were analyzed using the INDSCAL and a two-dimensional solution was determined to be optimal. A description of the nine vehicles and their locations on the two measured dimensions is given in Figure 2.

The ordering of vehicles on Dimension I ranges from camouflaged vehicles or non-vehicle (4,5,6,9), to non-obscured, clear vehicles (2, 7, 8). Dimension 1 clearly represents a "degree of camouflage" or "degree of obscuration" feature. The ordering of vehicles on Dimension II ranges from far vehicles (1, 3) to moderately distant vehicles (2, 7, 8, 9) to close vehicles (5, 6). Clearly this dimension represents the proximity of the objects to the observers. The results then indicate that the observer used two features in judging the identifiability of the objects. These two features were degree of camouflage and distance of vehicle. An analysis of the observer's similarity judgments and the distances between the vehicles in Figure 2 was .87. This high correlation definitely indicates that the observer was able to perform the Similarity Task consistently and in a predictable manner.

5.5 Advantage of Multidimensional Methods

Despite the fact that the multidimensional procedure is more difficult to administer and analyze than the unidimensional methods, it offers at least one important advantage. By breaking identifiability judgments into the distinct components or attributes underlying camouflage effectiveness, the method serves as a powerful analytical tool for describing and controlling the psychologically important dimensions of concealment. The scales generated with the unidimensional methods cannot offer this advantage since all of the factors which contribute to camouflage effectiveness are "confounded" within each scale value. In other words, with the unidimensional scales it is impossible to separate (and hence evaluate the relative importance of the effects of point, distance, surround and so forth.

6.0 INFORMATION METRIC SCALES

A final type of scale used to evaluate camouflage effectiveness is based on information metric analysis. Such an analysis is particularly useful for determining the success of an experimental manipulation in the field (for example, comparing two types of paint) since it provides both an absolute and relative criterion for evaluating performance. Information metrics determined the degree to which the observers' identifications of the camouflaged and uncamouflaged vehicles were correct by measuring the extent of overlap between the ideal distribution of identification responses and the subjects' actual distribution. Since we would normally expect the camouflage condition to make identification more difficult, the responses in this condition should, on the average, contain less information than in the uncamouflaged conditions. The greater the difference between the two conditions, the more effective the camouflage.

Table 7 contains a summary of an information metric analysis for the 14 camouflaged and uncamouflaged vehicles used above in the detection-identification analysis. With three response categories available optimum classification performance is 1.59 bits of information transmitted. The observers made fewer errors (see number 4 in Table 7) in identifying uncamouflaged vehicles than they did with camouflaged vehicles, resulting in a total difference (see number 5 in Table 7) of 1.09 bits of information transmitted between the two conditions. While this is not a large difference it does demonstrate that the camouflage paint did have some effect on identification performance as measured by the information metric.

Table 7

Information Metric Analysis

	Camouflaged Vehicles	Uncamouflaged Vehicles
1. Total amount of information present in the stimuli potentially	2.59 Bits	3.00 Bits
2. Maximum information which could be transmitted given the number of response categories	1.59 Bits	1.59 Bits

Table 7

(continued)

	Camouflaged Vehicles	Uncamouflaged Vehicles
3. Maximum information which could be transmitted given the observers' use of the response categories	1.50 Bits	1.52 Bits
4. Information lost due to errors in the observers' identification	0.50 Bits	0.43 Bits
5. Total information transmitted	1.00 Bits	1.09 Bits

7.0 DISCUSSION OF EXPERIMENTAL RESULTS

7.1 Correlational Data

The intercorrelations between the various rating measures for vehicles and performance measures for observers are presented in Table 8. Several important conclusions can be reached by examining this table. First, there is apparently no relationship between performance on the "perceptual measures" (Visual Search Task, Embedded Figures Task) and either detection or identification performance. At least for the present experimental situation, performance on these two sets of tasks was not related. Secondly, performance on the detection task was moderately correlated with identification performance (R = .656) as might be predicted. Thirdly, ratings of the detectability of the vehicles were highly correlated (R = 0.984) with identification probability estimates, and identification probabilities were highly correlated (R = 0.931) with the vehicles' scale values on the first dimension of the multidimensional scaling solution. This information corroborates our earlier interpretation of this dimension as a "near-far" distance dimension since the largest differences in detection ratings and identification probabilities were between the 200 meter range and longer distances.

Table 8

Correlations Between Detection, Identification and Scaling Measures for Observers and Vehicles

Observers' Performance	Detection Score[a]	Identification Score
Visual Search Task	0.178	-0.076
Embedded Figures Task	-0.185	-0.145
Detection Score	-	0.656[b]

Vehicle Ratings and Scale Values	Detection Rating	Identification Probability
MDS Dimension I	0.964[b]	-0.931[b]
MDS Dimension II	0.680[b]	-0.729[b]
Detection Rating	-	-0.984[b]

Note.

a Although three different detection scores were presented in Table 4, because they were highly intercorrelated and none correlated significantly with other measures only one (criterion = 8) is included in the present table.

b $p \leq .05$

7.2 Evaluation of Scaling Analyses

The major purpose of our research effort was to develop scaling methodologies that could be used to evaluate the effectiveness of camouflage techniques. The previous sections of the report describe these methodologies and demonstrate that they can be successfully applied to evaluate vehicle imagery. We had hoped that the application of the different scaling methods would also generate some useful information about the effectiveness of camouflage in the two sets of slides available to us. Because of the restricted range of variation present in our slides, however, the results were not as conclusive as expected. This range of variation was probably not adequate to constitute either an operationally normal detection-identification task for a military observer. With these cautions, however, some inferences can be drawn from our data.

First, in both sets of slides the camouflage used was effective for increasing the difficulty of detection and identification. In the slide set using camouflage nets, the effect of covering a vehicle with a net was considerable especially for detection but also for identification. In the set of 14 slides using camouflage paint the results are not as clear. Table 2 illustrates that all except one of the camouflaged vehicles (paint) had higher (more difficult to detect) detection scores than their uncamouflaged counterparts. The exception was the jeep at 1000 meters which was very difficult to locate because of its small size. The identification ratings presented in Table 3 also illustrate that the vehicles with camouflage paint were harder to identify although the number of correct identifications was approximately the same for both vehicles. These ratings suggest that the camouflage paint was probably more effective in preventing detection since it reduced the distributions of vehicle features from characteristics of the surround than it was in preventing correct identifications. In order to be effective in the latter task, the paint would have to mask those features which permit vehicle discriminations, and these features are evidently somewhat different from the dimensions necessary for detection. We suggest then in designing camouflaging materials it should be noted that different techniques are required depending on whether one is attempting to prevent detection or confuse identification.

Second, despite the fact that performance on detection and identification tasks did not correlate with the perceptual measures such as the embedded figures test, we would recommend that such perceptual guides (and other criteria described in Section 2.0) be used to select or train observers for object detection either in the field or with photographic imagery.

Third, we note in Table 8 the high correlation between the first and second dimensions in the multidimensional scaling task and the detection and identification ratings. Although the dimensions are not as distinct as we would prefer, it is clear that the features in these objects used for detection and identification overlap to a large extent. Also, judgments of identifiability apparently have at least two underlying dimensions.

8.0 FUTURE DIRECTIONS

As we mentioned in the introduction, the camouflage problem has at least two major divisions, the detection problem and the identification problem. Paint or nets or other techniques which prevent an object from being detected will not necessarily represent the optimum techniques for preventing or confusing identifications. In fact, a blotched paint pattern which resembles an object surround may, when that object is clearly detected, actually accentuate vehicular differences that would improve the probability of correct identification. If the vehicles or other objects are located in a position where it is difficult to prevent detection then painting to increase the similarity of objects on those features used for identification may be the most effective strategy.

Although the authors do not pretent to be experts with camouflage paint we have employed a very simple technique to enhance the naturalness of man made objects (such as chairs) or environments (such as a room). We take a slide photograph of the object's surround, the project the photographic image on the object as a guide for painting. The result (generally more abstract than the original) is quickly produced and quite effective "camouflage" for a limited set of backgrounds.

While our research project dealt only with usual imagery, the scaling methods proposed would apply equally well to IR, radar or other types of object representations. In fact, a sophisticated scaling analysis is probably even more critical with these "non-visual" techniques since the important parameters which influence detection or identification are less well known and not as likely to be intuited correctly from our visual experience.

9.0 APPLICATIONS

This section presents an outline guide detailing the steps to be followed in using the three scaling methods. Since the computational routines used in the multidimensional scaling program are somewhat complicated no details will be given. The reader should refer to the article by Carroll and Chang (1970) for additional information.

9.1 Unidimensional Detection Task

9.1.1 Arrange the set of objects to be viewed with the types of camouflage, backgrounds and orientations desired.

9.1.2 Designate viewing positions for each of the objects covering the range of distances desired. It is important to have some objects viewed at distances too great for detection and others at easily detected distances in order to generate a good detection scale.

9.1.3 Designate the areas to be scanned by observers in attempting to detect the vehicles. Ideally the observer might be situated on a hill with 360 degrees viewing radius.

9.1.4 Do not inform the observers of the number of objects present in the designated scan area.

9.1.5 Instruct the observers to examine the designated area for the class of objects being studied (e.g., vehicles) and for each object sighted estimate the "detection difficulty" on a 10 point scale where a rating of "1" indicates that the observer had no difficulty in detecting the object and a "9" rating indicates the objects were extremely difficult to detect. The rating value of "10" is reserved for those objects not detected by the observers.

9.1.6 Ratings for each object are simply averaged across all observers to obtain detection scale scores. These scale values represent a direct measure of the effectiveness of the camouflage or other object variables.

9.2 Unidimensional Identification Task

9.2.1 Arrange the objects to be viewed with the types of camouflage, backgrounds and orientation desired.

9.2.2 Designate viewing positions for each of the objects covering the range of distances desired. All objects should be sufficiently close to the observers to be detected, however, the distances should vary so that at one extreme the objects are "detectable but not identifiable" and at the other extreme the objects are "easily detectable and identifiable."

9.2.3 Designate the positions of the objects to the observers and make sure all objects are detectable.

9.2.4 Identify for the observers the classes of objects they will be attempting to discriminate.

9.2.5 Instruct the observers to examine each object and estimate the probability that the object belongs to each of the possible classes of objects being used. If the classes are Truck, Tank, and Jeep then the observer must estimate the probability that an unknown vehicle belongs to each of these classes. For this last example the probability estimates can be represented as P_{TANK}, P_{TRUCK}, P_{JEEP}.

9.2.6 The probability estimates for each object can be averaged across observers to obtain identification scales for each of the classes. An overall scale indicating the certitude of identification can then be obtained with the following equation:

$$SV = \begin{array}{c}\text{Pooled Information}\\ \text{Scale Value}\end{array} = \frac{P_{TRUE}}{P_{JEEP} + P_{TANK} + P_{TRUCK}}$$

where P_{TRUE} represents the scale values of the correct object class. If the object being classified was a truck then the above equation would be:

$$SV = \frac{P_{TRUCK}}{P_{JEEP} + P_{TANK} + P_{TRUCK}}$$

The final pooled identification scale values will vary between 0 and 1 with the smaller numbers representing confusion and classification errors and the scale values near 1 representing accurate discrimination.

9.2.7 The final SV scale values can be used directly to evaluate the effectiveness of camouflage in reducing identifiability. Scale values for individual classes can be used to determine the effectiveness of camouflage in confusing one class with another (e.g., to what extent can tanks be made to look like trucks).

9.3 Multidimensional Identification Task

9.3.1 Arrange the objects to be viewed with the types of camouflage, backgrounds, and orientations, desired. All objects must be observable from one central location such as a hill.

9.3.2 Situate the objects so that they cover the desired range of distances, however, all objects should be sufficiently close to be detectable. Unlike the unidimensional task the distances do not have to go from the extreme of "object just detectable" to "object easily identified".

9.3.3 No specific instructions about classes of objects present need to be used with the multidimensional scaling task, however, to obtain the best possible information we recommend that whenever the multidimensional identification procedure is employed that its unidimensional counterpart also be used.

9.3.4 All possible pairs of objects to be viewed are randomly ordered on the response sheet. For each pair, the observer is asked to examine the two objects and then estimate how similar they are in their degree of identifiability.

9.3.5 These similarity estimates are input directly into the multidimensional scaling procedure which generates the underlying identification scales used by observers for their judgments. These scale values can be used directly as estimates of the objects identifiability (since the signs on these scales are arbitrary a sign reversal is sometimes necessary to make large numbers correspond to high probabilities of identification).

9.3.6 Additional details on multidimensional scaling are given in Section V of this report.

9.4 Utilization of Methods

The three methods outlined above can be applied equally well to visual photographs, IR imagery, radar scans or other representations of scenes. Rather than manipulating distances and orientation by moving the observer, the scanning instrument must be moved. Also, in the multidimensional task it is not necessary to have all the objects viewed from a single vantage point.