Geometric Radar Symbology: Static Cathode Ray Tube Testing

Gary G. Sarli and Richard J. Carter
US Army Research Institute for the Behavioral and Social Sciences (ARI),
Fort Bliss Field Unit, Ft Bliss, Texas

Many air defense (AD) systems use geometric symbols to indicate aircraft on system displays and different shapes to encode friend-or-foe information. The purpose of ARI's AD symbology research was to identify sets of geometric symbols associated with high discriminability and quick response times.

It was felt that AD personnel would respond fastest and most accurately to symbols with stereotyped meanings. Phase 1 of this research (Carter, in press) identified nine such symbols:

FRIEND: Circle (○), 5-Pointed Star (☆), Heart (♡), Flag (⚐)
HOSTILE: Swastika (卐), Collapsed Box (▣), The letter "X" (X)
UNKNOWN: Question Mark (?), 6-Sided "U" (∪)

Phase 2, using paper displays, tested these symbols in sets of three (1 of each type) and five (2 friend, 2 hostile, and 1 unknown) symbols. The three-symbol set with the quickest response time (RT) was Star-Box-U; the one with the least errors was Heart-Box-U. RTs for the five-symbol sets were not significantly different, but set Heart-Flag-Swastika-Box-Question Mark had the least errors. (Carter, 1980)

This paper deals with Phase 3, in which the symbol sets were presented upon a cathode ray tube (CRT) display. Symbol shape was the independent variable; RT and errors were the dependent variables. The hypotheses were that some sets would have lower RTs and errors, and that the results of Phases 2 and 3 would agree.

Experiments 1 and 2: Three-Symbol Sets

Method

Subjects. For each experiment, 30 subjects were drawn from a pool of enlisted personnel (grades E2-E6) in AD console operator Military Occupational Specialties (16C, E, H, J) at the US Army Air Defense Center at Fort Bliss, TX.

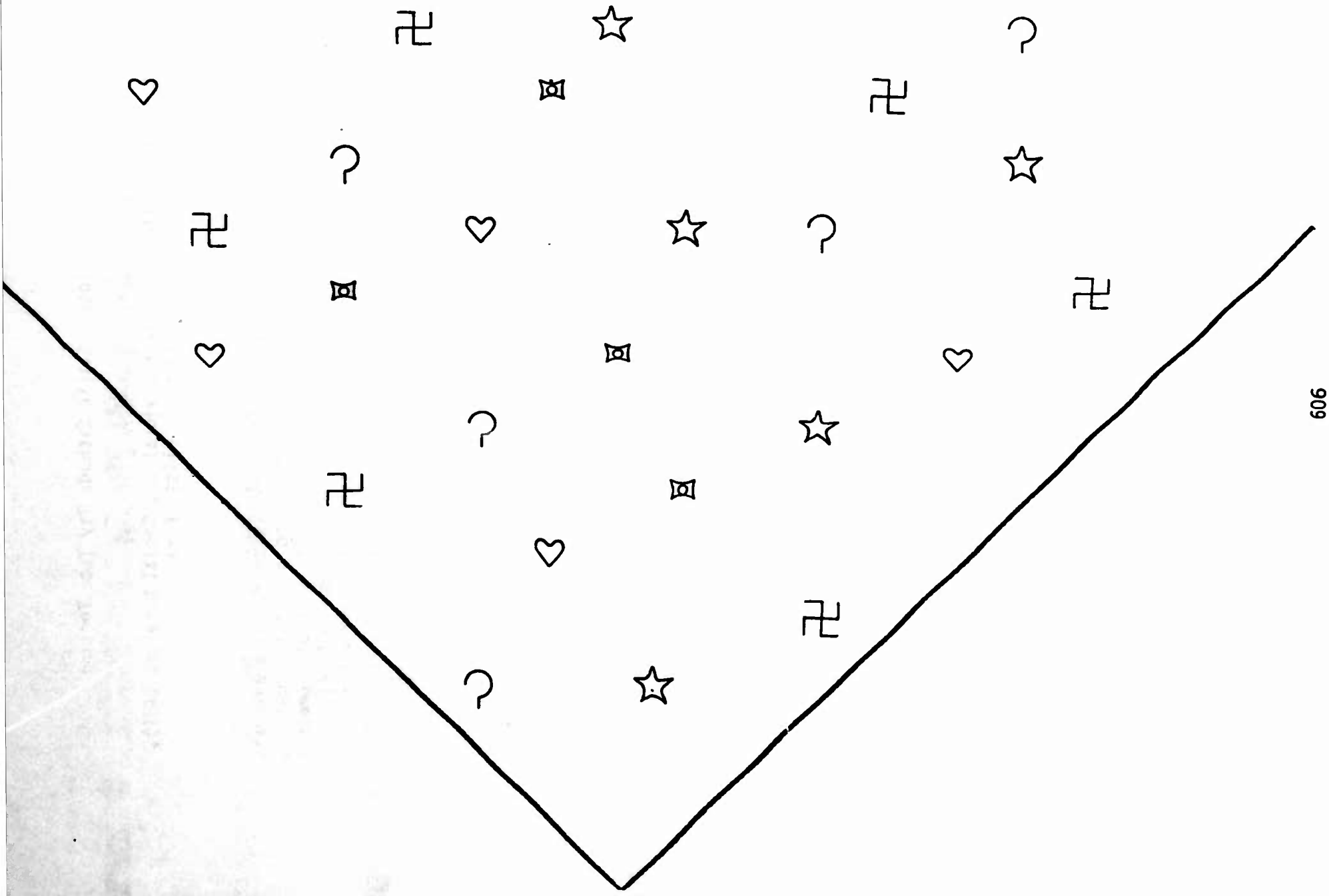
Apparatus. A PATRIOT Tactical Operations Simulator/Trainer (TOS/T) provided a 36.2 cm diameter, round CRT, as well as necessary switches and controls, including an isometric joystick. A FORTRAN program was used to generate 64mm-wide symbols on the CRT and to record the data.

Procedure. A 90° top oriented search sector was plotted on the CRT (Figure 1). Each soldier, seated at the TOS/T console, was given 2 practice

The authors wish to thank CPT David Smull, SP6 David Arvieux, Jeri Price, and John Davis for their valuable assistance.

Figure 1

Example of CRT Display of Test Symbols



606

and 8 test sets (see Table 1) which each consisted of 1 friend, 1 hostile, and 1 unknown. On each set, the soldier was shown 27 scenes; each scene contained 24 symbols (7 to 9 of each type). The 27 scenes were divided into 3 groups of 9 scenes; the soldier was told to locate and "hook" either the friend, hostile, or unknown symbols in each group. The soldier hooked each symbol by using the joystick to superimpose a plus-sign-shaped cursor upon the symbol and then pressing the "hook" button. Feedback was provided by causing a PATRIOT "hold fire" modifier to appear around the hooked symbol.

Results

Experiment 1. The RTs for the eight symbol sets were significantly different: $F(7,203) = 2.391$, $P=.0225$. A Newman-Keuls' test showed that the soldiers hooked the symbols in the Star-Box-Question Mark and Heart-Swastika-Question Mark sets significantly faster than the two slowest sets. The number of errors made on the symbol sets were also significantly different, $\chi^2(7)=49.37$, $p<.001$, as were the numbers of errors made on the two hostile symbols, $\chi^2(1)=7.13$, $p < .001$. Symbol set Star-Box-Question Mark had the fewest errors among sets and the Collapsed Boxes had fewer errors than the Swastikas.

Experiment 2. The RTs for the symbol sets differed significantly: $F(7,203)=2.283$, $p=.029$; set Circle-Box-Question Mark was significantly faster than the slowest sets. The times for the friend symbols were also different, $F(3,87)=5.993$, $p=.0012$, with the Circle being significantly faster than the Flag. The number of errors were significantly different for sets ($\chi^2(7)=14.87$, $p < .025$), friends ($\chi^2(3)=17.16$, $p < .001$), and unknowns ($\chi^2(1)=7.13$, $p < .01$). Set Circle-Box-Question Mark, friend symbol Heart, and unknown symbol Question Mark had the fewest errors in their respective groups (see Table 1).

Experiments 3 and 4: Five-Symbol Sets

Method

Subjects. For each experiment, 24 subjects were selected in the same way as subjects in Experiments 1 and 2.

Apparatus. The apparatus was the same as that used in Experiments 1 and 2.

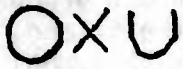
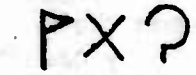
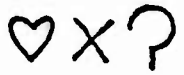
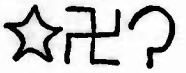
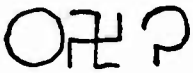
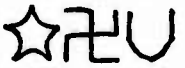
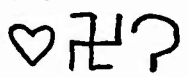
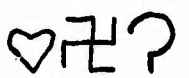
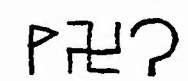
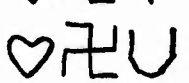
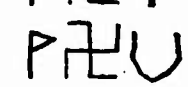
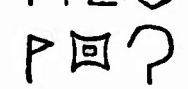
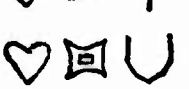
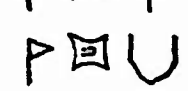
Procedure. Each soldier was given 1 practice and 6 test sets (see Table 2) which each consisted of 2 friends, 2 hostiles, and 1 unknown. On each set, the soldier was shown 50 scenes; each scene contained 25 symbols (4-6 of each shape). The 50 scenes were divided into 5 groups of 10 scenes each. The rest of the procedure was the same as in Experiments 1 and 2.

Results

Experiment 3. The RTs were significantly different only among friend symbols: $F(2,46)=6.707$, $p=.0031$. A Newman-Keuls' test revealed that the Hearts were significantly faster than the other friend symbols. The number of errors were significantly different for sets ($\chi^2(5)=9.51$, $p < .05$), and for friend ($\chi^2(2)=16.79$, $p < .01$) and hostile ($\chi^2(2)=12.52$, $p < .01$) symbols. Set Star-Heart-Box-X-Question Mark had the lowest error rate among sets. Hearts and

Table 1

Mean Response Times and Error Rates for Experiments 1 and 2

EXPERIMENT 1			EXPERIMENT 2		
Sets	RT	ERRORS	Sets	RT	ERRORS
	(PRACTICE)			(PRACTICE)	
	(PRACTICE)			(PRACTICE)	
	322.07	2.80		299.02	.83
	326.13	1.63		293.17	.34
	308.15	.90		308.54	1.03
	314.36	1.27		302.97	.37
	308.15	.97		312.81	.66
	319.02	1.73		309.12	.94
	315.71	1.72		311.95	.70
	327.66	1.27		302.77	.83
Friends			Friends		
	109.69	.55		99.54	.19
	109.14	.42		105.29	.60
Hostiles				105.08	.10
	102.31	.80		109.18	.42
	103.31	.44	Hostiles		
Unknowns				96.30	.16
	104.95	.42		96.29	.13
	105.96	.45	Unknowns		
				102.56	.18
				104.26	.37

Swastikas had the lowest error rates among friends and hostiles, respectively.

Experiment 4. Because only one unknown symbol was used, only sets, friend symbols, and hostile symbols were compared. The RTs for the sets were not significantly different, but the times for the friend ($F(2,44)=30.369$, $p < .00005$) and the hostile symbols ($F(2,44)=7.510$, $p=.0019$) were. Newman-Keuls' tests revealed that the Circle was significantly faster than the other friends and that the X was significantly faster than the Collapsed Boxes. The errors were significantly different for the sets ($\chi^2(5)=19.44$, $p < .01$) and the friend symbols ($\chi^2(2)=55.64$, $p < .01$). Set Circle-Star-Box-X-Question Mark and friend symbol Circle had the lowest error rates for their groups (see Table 2).

Discussion

The hypotheses that the symbols and symbol sets would have significantly different time and error rates was generally supported. Note that response time differences were found among 3-symbol sets but not among 5-symbol sets. Inasmuch as the total number of symbols displayed at one time were comparable across the experiments, it is assumed that the effect of any one symbol on response time decreases as the diversity of symbols displayed increases (Earl, in press).

The hypothesis that the same sets and symbols would be identified as best in Phases 2 and 3 was not supported. This may be due to slight differences in the symbol shapes as displayed on the CRT versus on paper, the fact that CRT symbols were white-on-black instead of black-on-white, or differences in hooking procedures and practice sets. In general, the subjects in Phase 2 performed better on the Flag and six-sided "U" but worse on the "X" and Question Mark than the subjects in Phase 3. Clearly, paper simulations of CRT screens must be interpreted with great care.

References

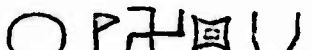
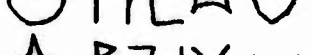
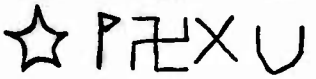
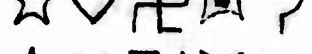
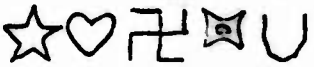
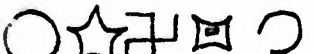
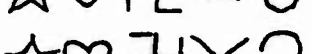
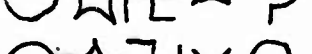
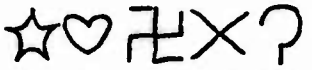
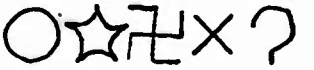
Carter, Richard J. Paper-and-pencil testing of geometric radar symbols. Proceedings of the Military Testing Association, 1980, 22(1), CAR2-1 to CAR2-10.

Carter, Richard J. An investigation of geometric radar shapes for stereotyping (ARI Technical Report). Alexandria, Virginia: US Army Research Institute for the Behavioral and Social Sciences, in press.

Earl, William K. Learning and recognition of US, Soviet, and pictorial military symbology. Alexandria, Virginia: US Army Research Institute for the Behavioral and Social Sciences, in press.

Table 2

Mean Response Times and Error Rates for Experiments 3 and 4

EXPERIMENT 3			EXPERIMENT 4		
Sets	RT	ERRORS	Sets	RT	ERRORS
	(PRACTICE)			(PRACTICE)	
	(PRACTICE)			(PRACTICE)	
	498.67	2.46		(PRACTICE)	
	493.49	2.83		501.58	2.65
	473.24	2.71		474.19	2.00
	479.26	1.71		477.46	1.57
	502.86	2.54		487.12	1.61
	484.99	2.00		491.77	1.57
Friends				480.04	2.35
	107.23	.80	Friends		
	100.32	.40		94.51	.17
	105.46	.52		105.07	.68
Hostiles				108.73	.86
	93.91	.30	Hostiles		
	94.74	.60		94.01	.33
	89.73	.40		97.44	.30
Unknowns				91.34	.39
	96.12	.31	Unknown		
	96.92	.38		94.90	.33