Validation of a Visual Perception Laboratory and Modeling Using the Fuzzy Logic Approach

by
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ABSTRACT

The purpose of this test is to compare the visual detection of military targets in the TARDEC Visual Perception laboratory (VPL) with detection performance in the field. Thirty 35mm color slides were used from a Marine Corps field test to validate the test procedures used in the TARDEC Visual Perception Laboratory (VPL). The color slides were of seven military vehicles positioned at tactical range in the desert. The correlation of the laboratory to the field ranged from 0.5 to 0.95 depending on the variables analyzed and questions asked of the subjects. ***The highest correlation, 0.95, was obtained when comparing identification rates*** of the vehicles between the field and the lab.

VPL PROCEDURAL SETUP

The test subjects were positioned in front of a rear-projection screen. The distance from the screen to the subject was 259cm. The AAV (Assault Amphibian Vehicle) in image 4-1 was used to check the distance from the projector to the screen. The actual length of the AAV is 7.943m and at a distance of 1 km, the vehicle subtense 0.0078 radians. With the subject to the screen distance of 259 cm, the AAV size was 2 cm high on the screen. The projector was placed so as to project the correct size of the AAV, see Fig. 2.

Figure 1: Current experimental setup in the VPL

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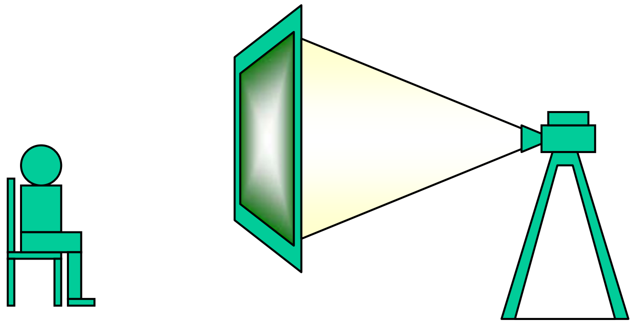


Figure 2: Schematic of procedural setup

SCORING METHOD

At the field location, the correct positioning of the target was considered an identification. In the VPL experiment, just pointing out the target and correctly naming the target was considered as identification. A description of the field and lab definitions is described in Table 1 below. See the following tables for the scoring of individual responses.

Table 1: Locations in the field and VPL lab

	Field	LAB
ID	A target was considered identified if it was indicated in the correct position (grid square) and with the correct target name.	A target was considered identified if it was pointed out and named correctly.
DET	A target was considered detected if it was indicated in the correct position (grid square) but with the incorrect target name.	A target was considered detected if it was pointed out but named incorrectly.
UN	A target was considered undetected if it was not indicated at all.	A target was considered undetected if it was not pointed out at all.
FA	A target was considered a false alarm if it was indicated on the map, when actually, no target was there. An example of a FA is when sage brush, or bushes, are mistaken as vehicles.	A target was considered a false alarm if it was pointed out which is bush or junk pile actually.

LIMITATION ON THE VPL TESTS

Three-dimensional search was compressed to a two dimensional search. The resolution and luminance of the projected scene was lower than the field. Luminance was the hardest factor to control. See Appendix B for a luminance plot. There were some images in which the target were located at the right or left edge of the slide. These may have been harder for the subjects to search.

DISTANCE definition

The target range was divided into bands of distance, each 300 meters deep. The entire target range was 3000 meters deep with the closest target at 600 meters and 500 meters wide. The distance variable is referred to as DIST-1 through DIST-8 and the specific ranges for each DIST are listed below.

DIST-1: 600 - 900 meters
DIST-2: 900 - 1200 meters
DIST-3: 1200 - 1500 meters
DIST-4: 1500 - 1800 meters
DIST-5: 1800 - 2100 meters
DIST-6: 2100 - 2400 meters
DIST-7: 2400 - 2700 meters
DIST-8: 2700 - 3000 meters

AVAILABLE DATA

The original primary purpose of the field test was to compare the performance of the laser eye protection systems (1). Data was collected by the Survivability Vehicle Damage Reduction Team as part of a comparison of laser filters for eye protection. In the VPL, only the baseline, naked eye visual perception test was done.

RESULTS

The tables and graphs on the following pages show the data that was collected in the lab versus the field partitioned in different ways.

I. LAB DATA and NAKED EYE (Lens type X) versus distance

In Table 2 below, the lab data and field data are compared.

Table 2A: Data for lens X and distance X in the field

Field	Lens		
Dist	%ID	%DET	%UN
1	67.4	5.8	26.8
2	69.2	9.1	21.7
3	70.5	9.4	20.1
4	53	12.8	34.2
5	47.7	19.5	32.9
6	46.3	24.8	28.9
7	35.3	19.3	45.3
8	37.1	16.1	46.9

Table 2B: Data for distance X and all subjects

LAB	All		
Dist	%ID	%DET	%UN
1	32.9	36.9	30.2
2	32.6	40.6	26.9
3	43.7	47.3	9.0
4	40.8	45.4	13.8
5	37.3	49.6	13.1
6	36.4	43.3	20.2
7	18.1	53.3	28.6
8	14.7	38.7	46.7

Figure 3 shows plots of the data in Table 2A and 2B. The reader can see there are high correlations at many points, up to 0.84.

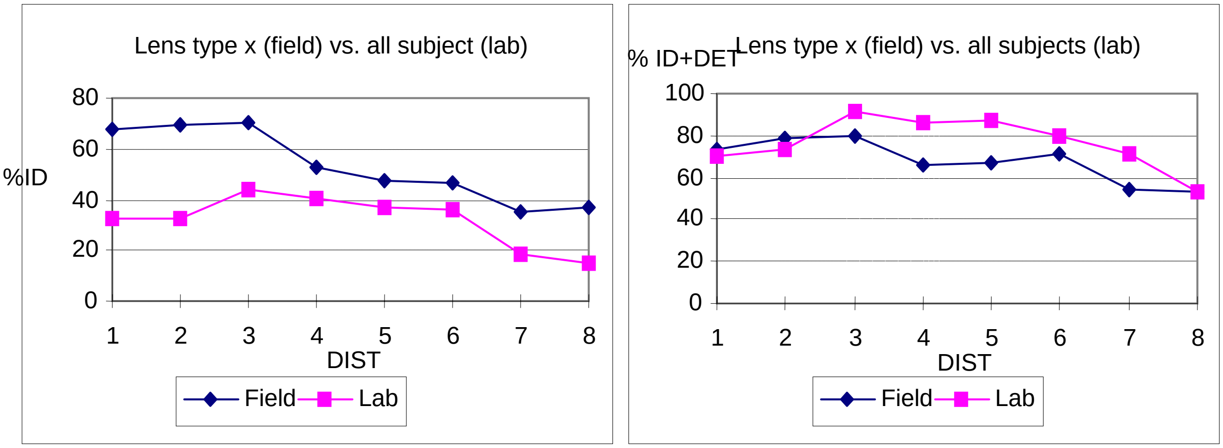


Figure 3: Plots of field and lab data versus all subjects

Correlation values
From dist-1 through dist-8: 0.67
From dist-3 through dist-8: 0.85

Correlation values
From dist-1 through dist-8: 0.58
From dist-3 through dist-8: 0.84

II. Lens type X field test vs. lab data separated by scene size and distance

Subject response was divided according to the projector distance setup. Subject 1-9 saw smaller target size than the actual size but in brighter image than the second setup (subject 10 through 30).

Table 3: Data for distance X for the lab and field separated by scene size

Lab	subject 1 ~ 9			subject 10 ~ 44		
Dist	%ID	%DET	%UN	%ID	%DET	%UN
1	40.7	31.1	28.1	29.5	39.4	31.1
2	37.0	37.0	25.9	30.7	42.1	27.2
3	52.9	41.2	5.9	39.8	49.9	10.4
4	52.1	35.0	12.8	35.9	49.8	14.3
5	43.1	40.3	16.7	34.8	53.6	11.6
6	39.3	38.5	22.2	35.2	45.4	19.4
7	27.8	43.7	28.6	13.9	57.5	28.6
8	13.3	37.8	48.9	15.2	39.0	45.7

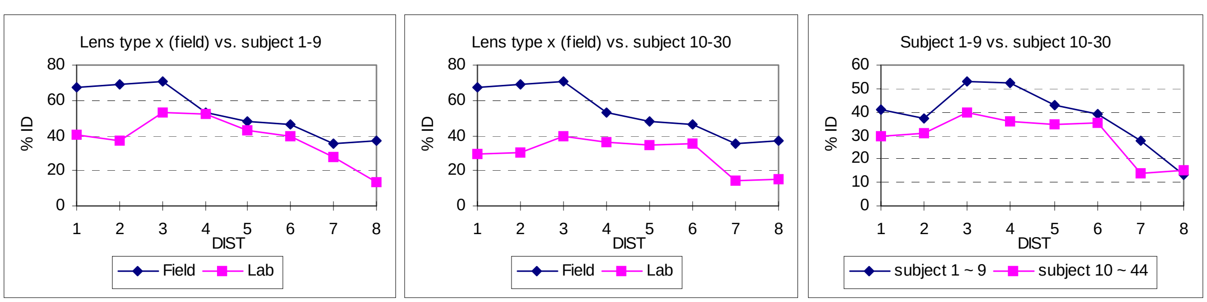


Figure 4: Plots for distance X for the lab and field separated by scene size

Correlation value of % ID | Subj. 1-9 | Subj. 10-30
From dist-1 through dist-8: | 0.64 | 0.66
From dist-3 through dist-8: | 0.82 | 0.83

Correlation value of % ID	Subj. 1-9	Subj. 10-30
From dist-1 through dist-8:	0.64	0.66
From dist-3 through dist-8:	0.82	0.83

III. Lens type X field test vs. lab data partitioned by 20/20 acuity and higher vision ability.
There are 15 subjects with 20/20 vision and 15 subjects with higher vision acuity.

Table 4: Data for lens and X distance with 20/20 or better

Lab	20/20 vision			better than 20/20 vision		
Dist	%ID	%DET	%UN	%ID	%DET	%UN
1	31.6	39.6	28.9	34.2	34.2	37.0
2	30.4	40.7	28.9	34.8	40.4	25.9
3	41.2	47.5	11.4	46.3	47.1	5.9
4	35.9	49.2	14.9	45.6	41.5	9.4
5	35.8	48.8	15.4	38.8	50.4	11.1
6	32.9	46.2	20.9	40.0	40.4	18.5
7	17.1	51.9	31.0	19.0	54.8	31.7
8	15.1	35.6	49.3	14.2	41.8	45.2

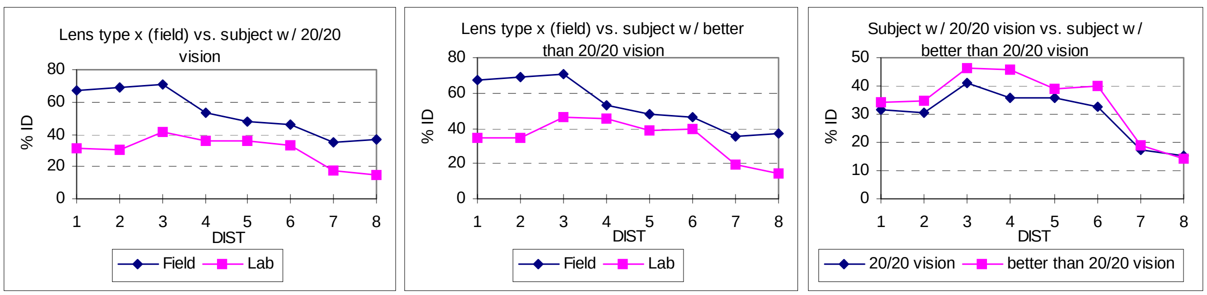


Figure 5: Plots of data for x distances in the field and lab with subjects having 20/20 vision or better than 20/20 vision

Correlation value of % ID	Subj. 20/20	Subj. better than 20/20
From dist-1 through dist-8:	0.7	0.64
From dist-3 through dist-8:	0.87	0.82

IV. Lens type X field test vs. lab data partitioned by normal and corrected vision acuity levels
There are 22 subjects with normal vision and 8 subjects with corrected vision.

Table 5: Data at distance X for subjects with normal and corrected vision

Lab	normal vision			corrected vision		
Dist	%ID	%DET	%UN	%ID	%DET	%UN
1	32.1	40.6	31.6	34.8	28.1	27.3
2	33.1	39.7	24.8	31.5	42.6	27.2
3	42.0	47.6	6.7	47.7	46.4	10.4
4	38.1	46.2	12.8	47.0	43.6	15.8
5	36.0	50.0	10.8	40.3	48.6	14.0
6	35.6	43.5	19.6	38.5	43.0	21.0
7	16.7	56.1	26.2	21.4	46.8	27.2
8	14.6	38.1	44.0	14.8	40.0	47.3

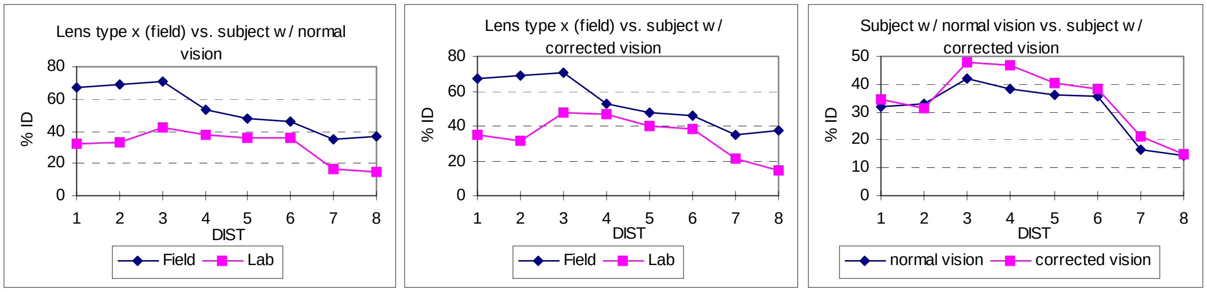


Figure 6: Plots at distance X for subjects with normal and corrected vision

Correlation value of % ID	Subj. normal	Subj. corrected vision
From dist-1 through dist-8:	0.7	0.58
From dist-3 through dist-8:	0.85	0.84

V. Lens type X field test result vs. lab data partitioned by normal color and color blind subjects

There are 28 subjects with normal color vision and 2 subjects with color blindness.

Table 6: Data for distance X for subjects with normal color vision and color blindness

Lab	normal color vision			color blindness		
Dist	%ID	%DET	%UN	%ID	%DET	%UN
1	32.6	36.7	30.7	36.7	40.0	23.3
2	31.7	41.1	27.2	44.4	33.3	22.2
3	42.9	48.3	8.8	55.9	32.4	11.8
4	39.8	45.9	14.3	53.8	38.5	7.7
5	37.1	49.3	13.6	40.6	53.1	6.3
6	35.5	43.6	21.0	50.0	40.0	10.0
7	18.4	52.6	29.1	14.3	64.3	21.4
8	14.0	39.3	46.7	23.3	30.0	46.7

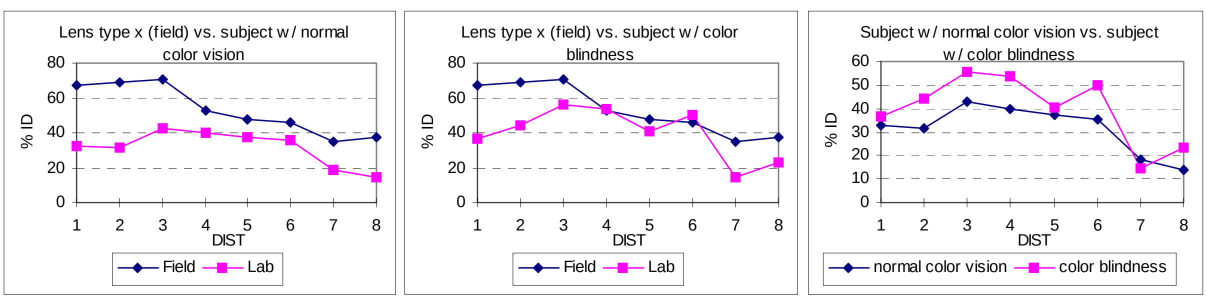


Figure 7: Plots at distance X for subjects with normal color vision and color blindness

Correlation value of % ID	Subj. normal color	Subj. color blindness
From dist-1 through dist-8:	0.67	0.65
From dist-3 through dist-8:	0.84	0.84

2) By target and distance. Target DIST, (for all lens types) field vs. Lab data

The following data is for a 5 Ton vehicle.

Table 7: Data at distance X for all lens types for a 5 Ton vehicle

5TON	Field		
Dist	%ID	%DET	%UN
1	85.1	1.2	13.7
2	69.3	10.1	20.6
3	73.2	10.7	16.1
4	51.4	18.1	30.6
5	45.7	18.3	36.0
6	41.8	16.4	41.8
7	34.8	23.2	42.0
8	32.7	18.2	49.1

5TON	Lab		
Dist	%ID	%DET	%UN
1	40.8	30.8	28.3
2	47.5	50.0	2.5
3	47.3	47.3	5.3
4	15.6	45.6	38.9
5	30.0	54.0	16.0
6	55.3	44.0	0.7
7	47.5	51.7	0.8
8	14.0	73.3	12.7

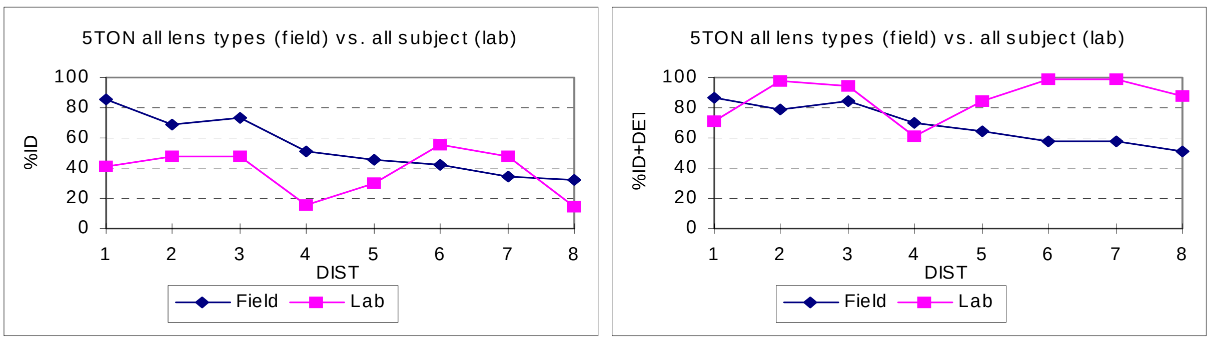


Figure 8: Plots at distance X for all lens types for a 5 Ton vehicle

The following data is for an AAV.

Table 8: Data at distance X for all lens types for an AAV

AAV	Field		
Dist	%ID	%DET	%UN
1	81.9	7.6	10.4
2	76.4	10.4	13.2
3	66.7	10.9	22.4
4	35.0	16.8	48.3
5	57.1	21.5	21.5
6	55.7	8.9	35.4
7	41.7	22.2	36.1
8	37.0	12.0	51.0

AAV	Lab		
Dist	%ID	%DET	%UN
1	52.2	47.8	0.0
2	36.7	52.2	11.1
3	35.6	61.1	3.3
4	20.0	76.7	3.3
5	30.0	56.7	13.3
6	40.0	56.7	3.3
7	23.3	70.0	6.7
8	15.6	65.6	18.9

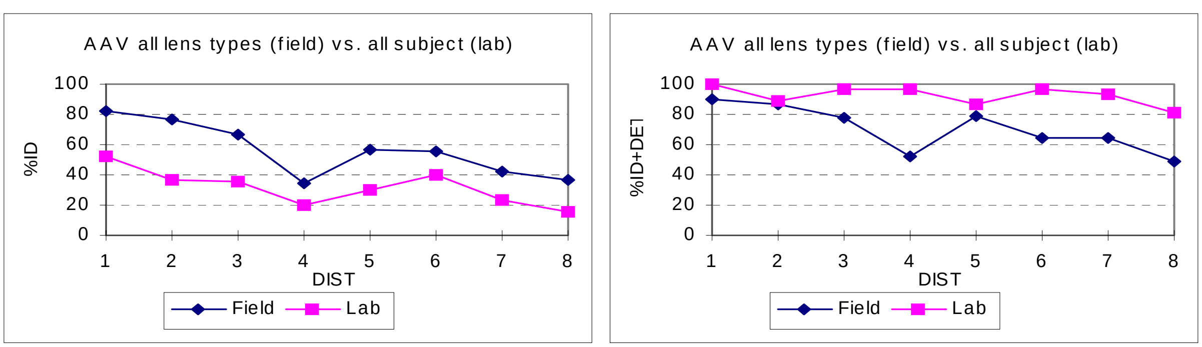


Figure 9: Plots at distance X for all lens types for an AAV

Correction value: 0.9 0.3

The following data is for a HMMWV.

Table 9: Data at distance X for all lens types for a HMMWV

HMMWV	Field		
Dist	%ID	%DET	%UN
1	27.4	16.7	56.0
2	27.1	20.5	52.4
3	50.9	15.5	33.6
4	38.6	25.6	35.8
5	45.8	25.3	28.9
6	43.8	30.1	26.2
7	27.2	21.2	51.6
8	16.4	16.4	67.2

HMMWV	Lab		
Dist	%ID	%DET	%UN
1	15.0	19.2	65.8
2	46.1	26.7	27.2
3	21.7	20.8	57.5
4	8.3	23.3	68.3
5	37.3	28.0	34.7
6	48.9	17.8	33.3
7	42.7	28.0	29.3
8	16.7	12.5	70.8

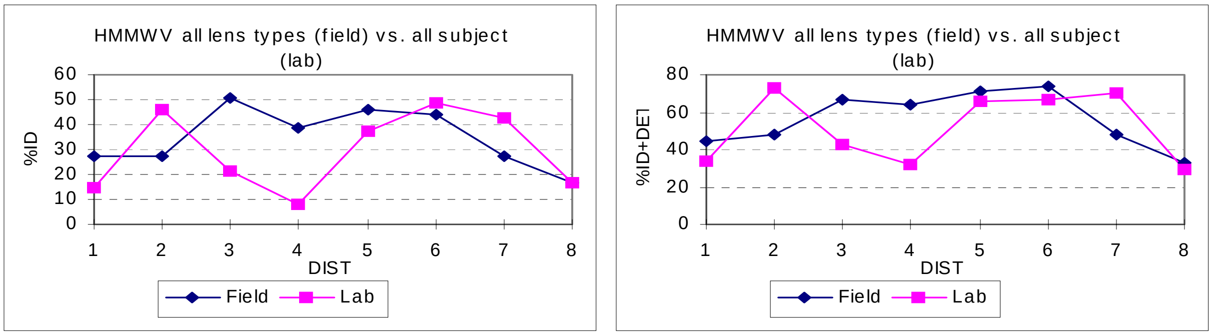


Figure 10: Plots at distance X for all lens types for a HMMWV

Correlation value: 0.1 0.3

The following data is for a LAV.

Table 10: Data at distance X for all lens types for a LAV

LAV	Field		
Dist	%ID	%DET	%UN
1	74.3	9.7	16.0
2	78.6	4.7	16.7
3	70.1	11.1	18.8
4	64.6	16.7	18.8
5	38.2	21.5	40.3
6	35.6	29.8	34.6
7	41.4	26.2	32.5
8	23.6	23.6	52.8

LAV	Lab		
Dist	%ID	%DET	%UN
1	30.0	66.7	3.3
2	30.0	50.8	19.2
3	35.6	57.8	6.7
4	37.5	50.8	11.7
5	31.7	55.0	13.3
6	10.0	46.7	43.3
7	20.0	76.7	3.3
8			

Empty data at distance 8 represents no data available from the lab.

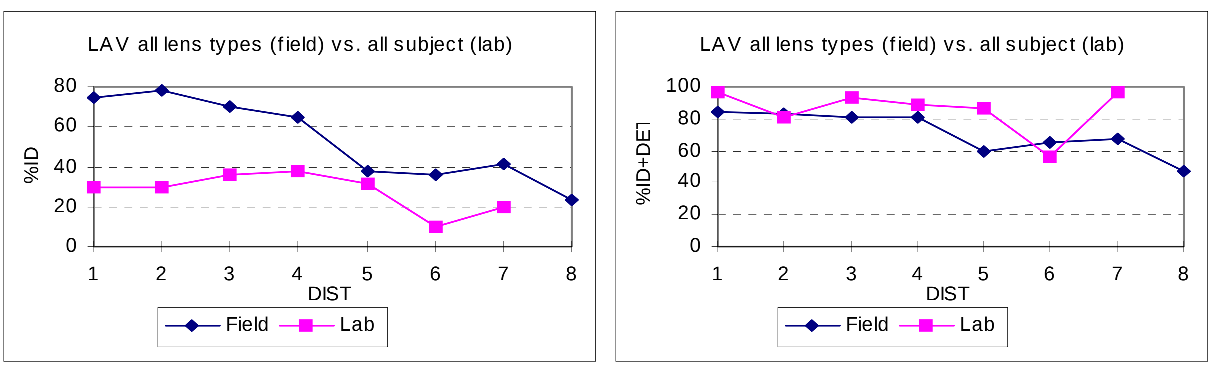


Figure 11: Plots at distance X for all lens types for a LAV

Correlation value: 0.6 0.4

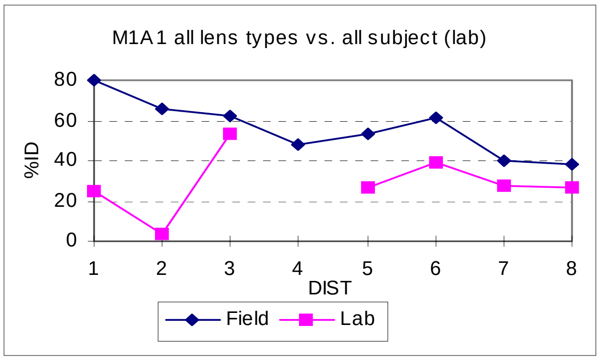
The following data is for a M1A1.

Table 11: Data at distance X for all lens types for a M1A1

M1A1	Field		
Dist	%ID	%DET	%UN
1	79.9	2.1	18.1
2	65.4	8.4	26.2
3	62.3	13.1	2.6
4	48.4	26.6	25.0
5	53.5	12.5	34.0
6	61.1	19.4	19.4
7	40.1	14.6	45.3
8	38.2	8.3	53.5

M1A1	Lab		
Dist	%ID	%DET	%UN
1	25.0	40.0	35.0
2	3.3	13.3	83.3
3	53.3	46.7	0.0
4			
5	26.7	62.2	11.1
6	38.9	56.7	4.4
7	27.5	50.8	21.7
8	26.7	48.9	24.4

Empty data set at distance 4 at the lab represents no data availability.



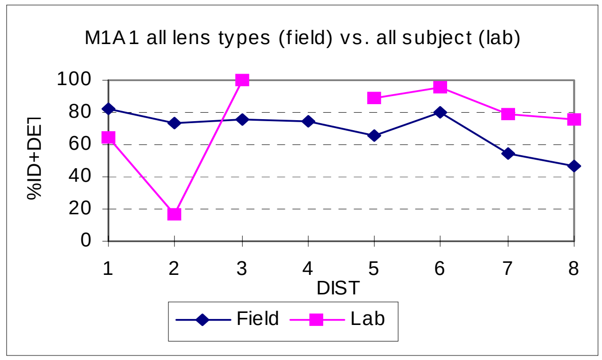


Figure 12: Plots at distance X for all lens types for a M1A1

Correlation value: 0.0 0.0

The following are the recognition of a vehicle at different distances

Table 12: Vehicle ID rate comparison at different distance

		% ID								%ID + DET							
		DIST								DIST							
	Target	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Field	5Ton	85.1	69.3	73.2	51.4	45.7	41.8	34.8	32.7	86.3	79.4	83.9	69.5	64.0	58.2	58.0	50.9
	AAV	81.9	76.4	66.7	35.0	57.1	55.7	41.7	37.0	89.5	86.8	77.6	51.8	78.6	64.6	63.9	49.0
	HMMWV	27.4	27.1	50.9	38.6	45.8	43.8	27.2	16.4	44.1	47.6	66.4	64.2	71.1	73.9	48.4	32.8
	LAV	74.3	78.6	70.1	64.6	38.2	35.6	41.4	23.6	84.0	83.3	81.2	81.3	59.7	65.4	67.6	47.2
	M1A1	79.9	65.4	62.3	48.4	53.5	61.1	40.1	38.2	82.0	73.8	75.4	75.0	66.0	80.5	54.7	46.5
Lab	5Ton	40.8	47.5	47.3	15.6	30.0	55.3	47.5	14.0	71.7	97.5	94.7	61.1	84.0	99.3	99.2	87.3
	AAV	52.2	36.7	35.6	20.0	30.0	40.0	23.3	15.6	100.0	88.9	96.7	96.7	86.7	96.7	93.3	81.1
	HMMWV	15.0	46.1	21.7	8.3	37.3	48.9	42.7	16.7	34.2	72.8	42.5	31.7	65.3	66.7	70.7	29.2
	LAV	30.0	30.0	35.6	37.5	31.7	10.0	20.0		96.7	80.8	93.3	88.3	86.7	56.7	96.7	
	M1A1	25.0	3.3	53.3		26.7	38.9	27.5	26.7	65.0	16.7	100.0		88.9	95.6	78.3	75.6
Correlation (field vs. lab)		0.7	-0.3	0.6	0.8	-0.4	0.3	-0.8	0.3	0.9	0.2	0.8	-0.1	-0.2	-0.1	0.8	1.0

The one with best correlation value is at distance 1 (600 - 900 meters)

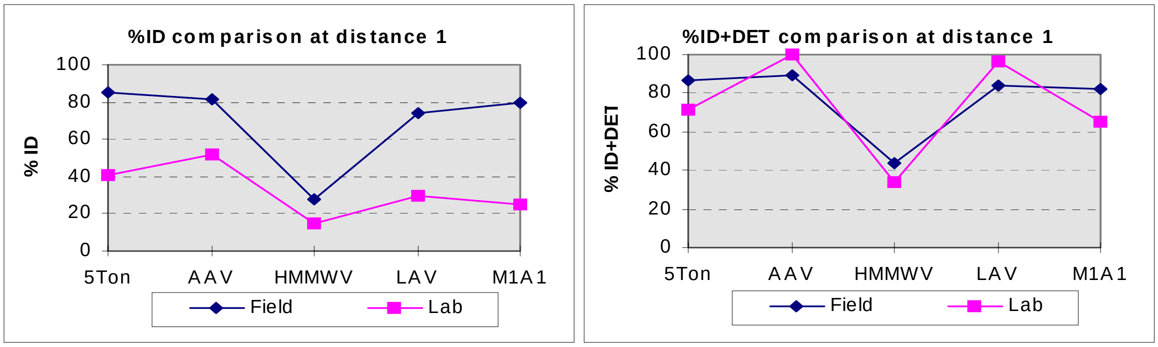


Figure 13: Plots of vehicle ID rate comparison at different distances

Correlation value: % ID = 0.7 %ID+DET = 0.9

The following tables and figures are the ID rate comparison of different vehicles.

Table 13: Comparison with all subject data

	Field			All subject		
Vehicle	%ID	%DET	%UN	%ID	%DET	%UN
M1A1	55.8	13.5	30.7	29.0	49.8	21.2
AAV	56.1	13.7	30.2	33.3	58.8	7.9
LAV	53.6	18.1	28.3	31.2	55.7	13.1
5TON	54.1	14.5	31.3	36.1	49.9	14.0
HMMWV	34.9	21.5	43.6	29.8	23.3	46.9

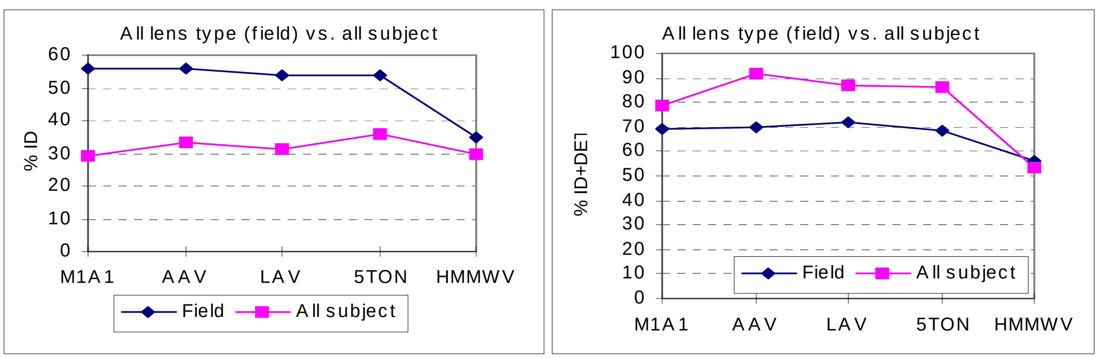


Figure 14: Plots of vehicle comparisons with all subject data

Correlation value: %ID only = 0.37 %ID + DET = 0.95

Table 14: Comparison with subjects 1-9 and 10-30

	Subject 1 ~ 9			Subject 10 ~ 44		
Vehicle	%ID	%DET	%UN	%ID	%DET	%UN
M1A1	37.3	39.9	22.9	25.5	54.1	20.4
AAV	47.2	43.1	9.7	27.4	65.5	7.1
LAV	53.6	34.6	11.8	21.6	64.7	13.7
5TON	36.0	52.3	11.7	36.1	48.9	15.0
HMMWV	30.2	21.3	48.6	29.7	24.2	46.1

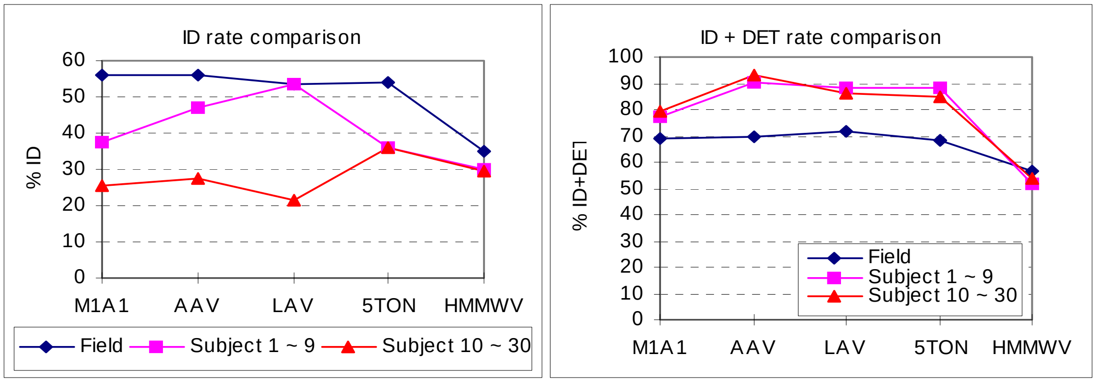


Figure 15: Plots of subjects 1-9 and 10-30

Correlation value:
Subj. 1 -9 : % ID = 0.61 %ID + DET = 0.95
Subj. 10 - 30 : % ID = 0.17 %ID + DET = 0.95

Table 15: Data comparison for subjects with 20/20 vision and better than 20/20 vision

	20/20 vision			Better than 20/20		
Vehicle	%ID	%DET	%UN	%ID	%DET	%UN
M1A1	28.2	47.5	24.3	29.8	52.2	18.0
AAV	36.7	52.9	10.4	30.0	64.6	5.4
LAV	23.5	63.9	12.5	38.8	47.5	13.7
5TON	33.0	52.1	14.9	39.1	47.7	13.2
HMMWV	28.6	22.5	49.0	31.0	24.2	44.8

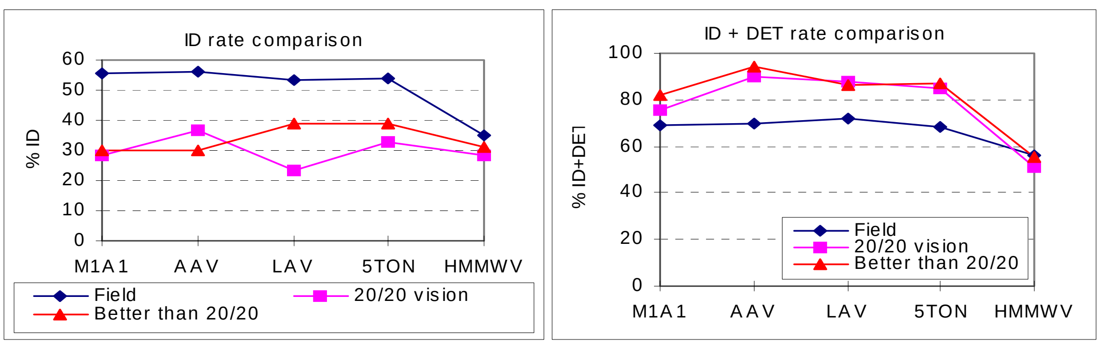


Figure 16: Plots comparing subjects with 20/20 vision and better than 20/20 vision

Correlation value:
Subj. 20/20 : % ID = 0.23 %ID + DET = 0.95
Subj. better than 20/20 : % ID = 0.21 %ID + DET = 0.94

Table 16: Data comparing subjects with normal vision and corrected vision

	Normal vision			Corrected vision		
Vehicle	%ID	%DET	%UN	%ID	%DET	%UN
M1A1	30.3	51.0	18.8	26.1	47.1	26.8
AAV	32.1	60.4	7.4	36.1	54.9	9.0
LAV	27.2	57.7	15.1	40.5	51.0	8.5
5TON	36.1	49.6	14.3	36.0	50.6	13.5
HMMWV	28.2	24.1	47.8	33.7	21.6	44.8

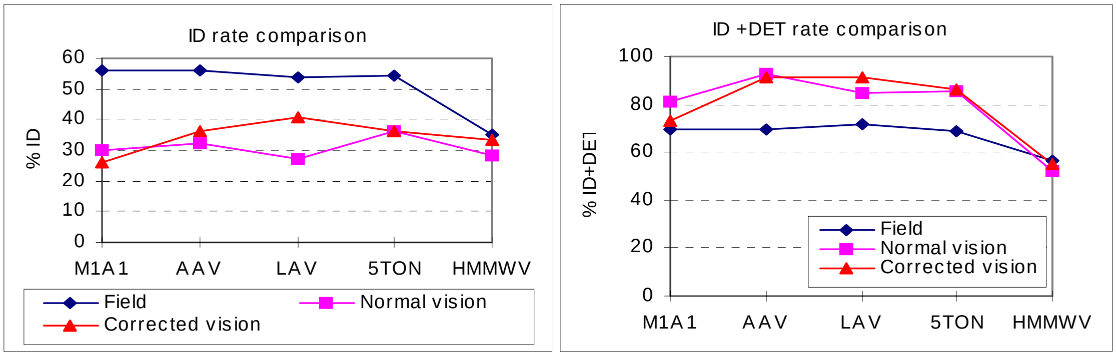


Figure 17: Plots comparing subjects with normal vision and corrected vision

Correlation value:
Subj. normal vision : % ID = 0.42 %ID + DET = 0.95
Subj. corrected vision : % ID = 0.01 %ID + DET = 0.91

(note: only 2 data sets are available for the colorblind data)

Table 17: Data comparing subjects with normal color vision and color blindness

	Normal color			Color blind		
Vehicle	%ID	%DET	%UN	%ID	%DET	%UN
M1A1	29.4	48.5	22.1	23.5	67.6	8.8
AAV	32.1	59.8	8.0	50.0	43.8	6.3
LAV	32.4	54.2	13.4	14.7	76.5	8.8
5TON	34.8	50.9	14.3	53.9	35.5	10.5
HMMWV	29.0	23.9	47.1	41.4	15.7	42.9

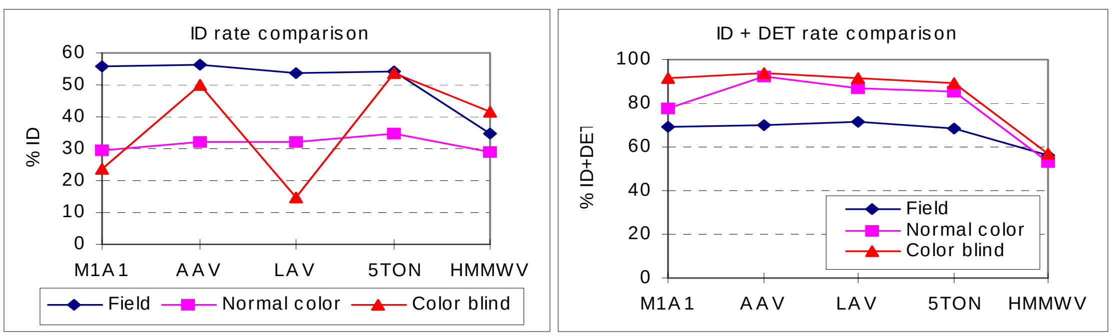


Figure 18: Plots comparing subjects with normal color vision and color blindness

Correlation value:
Subj. normal color vision : % ID = 0.54 %ID + DET = 0.94
Subj. color blindness: % ID = 0.12 %ID + DET = 0.98

USE OF THE FUZZY LOGIC APPROACH

It is of interest to use laboratory data both for the purposes of interpolating between collected data points and for extrapolating beyond the data points. Recently the authors have had great success in using the

Fuzzy Logic Approach [2,3,4] to model the search time and detectability of vehicles in the field and the laboratory. Typically a correlation of 0.9 between laboratory or field and computed search time can be achieved.

More than three decades ago Prof. L. A. Zadeh proposed the concept of fuzzy logic [1]. Following Mamdani and Assilian's seminal work in applying the fuzzy logic to the control of a steam engine in 1974 [2], the FLA has been finding a rapidly growing number of applications throughout industry and science. These applications include, transportation (subways, helicopters, elevators, traffic control, and air control for highway tunnels), automobiles (engines, brakes, transmission, and cruise control systems), washing machines, vacuum cleaners, rice cookers, VCRs, air conditioners, microwave ovens, video cameras, and other industries including steel, chemical, aerospace, medical diagnosis systems, information technology, and data analysis, ...etc. [3, 4, 5, 6, 7].

A strong point of the FLA is that it permits the encoding of expert knowledge directly and easily using rules with linguistic labels. A week point is that it usually takes some time to design and tune the membership functions, which quantitatively define these linguistic parameters of interest. It has been found that artificial neural network learning techniques can automate this process and substantially reduce development time while improving performance. To enable a system to deal with cognitive uncertainties in a manner more like humans, researchers have incorporated the concept of fuzzy logic into these systems using a neural network approach. The integration of these two techniques is the Neuro-Fuzzy Approach (NFA) [8]. The NFA has potential to capture the benefits of both the fuzzy and the neural network methods in a single model. A new approach to the computation of the probability of target detection in infrared and visual scenes containing clutter and other psychometric metrics is presented here. Our understanding of the visual world is a result of the perception, not merely detection, of the spatio-temporal, spectra-photometric stimuli that is transmitted onto the photoreceptors on the retina [9]. The computational processes involved with perceptual vision can be considered as the process of linking generalized ideas or concepts to retinal, early vision data. These ideas or concepts may be represented in software using various clutter or edge metrics [10] as well as luminance attributes of a military vehicle or automobile. From a system theoretic point of view, human perceptual vision involves the mapping of early vision data onto one or more concepts, and then inferring a meaning of the stimuli based on prior experience and knowledge. The approaches of fuzzy and neuro-fuzzy systems provide a robust alternative to complex semi-empirical models for predicting observer responses to visual and IR cluttered scenes. The fuzzy-based approaches have been used to calculate the probability of detection (Pd) and search times of vehicles in different infrared and visual scenes.

PROBABILITY OF DETECTION (Pd) FOR GROUND TARGETS

During the past three decades there has been an increasing interest in the development and use of computational models to compute the static and dynamic probability of detection of a target in visual and infrared images that include a known or unknown amount of clutter [10,11,12,13]. Clutter and the idea of the probability of detection play a very important role in the area of machine vision and human-in-the-loop target acquisition.

The problem of modeling electro-optical (EO) systems for the purpose of ground vehicle countermeasures development and system performance modeling is an old problem [14]. There are many algorithms used for the computation of the probability of detection of a target in clutter currently used in the literature of image processing and target acquisition modeling. During the past twenty years there has been an increasing interest in the modeling community to adapt the methods and results of recent research in the area of neurophysiology and human vision research into multiresolution target acquisition modeling [15,16].

Implementation

The novel application of the FLA in this problem was the inclusion of seven experimental parameters to be modeled as effecting the mean search time for human observers scanning the presented imagery for the vehicles. A picture of the MATLAB [17] Fuzzy Inference System (FIS) used to analyze and model the data from this experiment is shown below in Fig. 18. On the left hand side of the system diagram in Fig. 18 are the seven input variables, range, aspect angle, height, area, and three luminance measures. The center block of Fig. 18 shows the type of Fuzzy Logic Model used to represent the data. The far right hand side of Fig. 18 shows the output parameter, which in this case was the mean search time for detection of the vehicles.

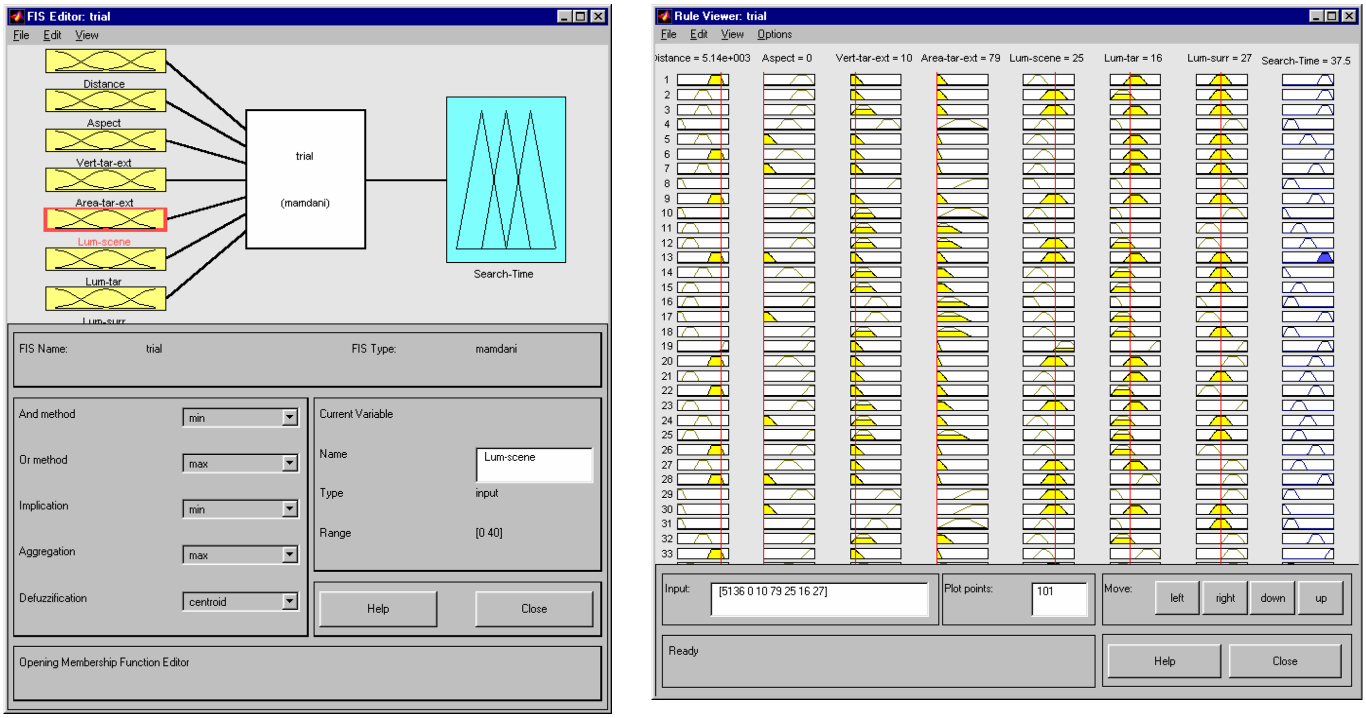


Figure 19: A picture of MATLAB Fuzzy Inference System (FIS)

The plot below shows the experimental versus fuzzy logic predicted values and the 0.9 correlation. In this model, 36 images and their associated metrics, were used for training the model and 6 images were left out. The correlation of 0.9 between field and model predicted is for all 44 images.

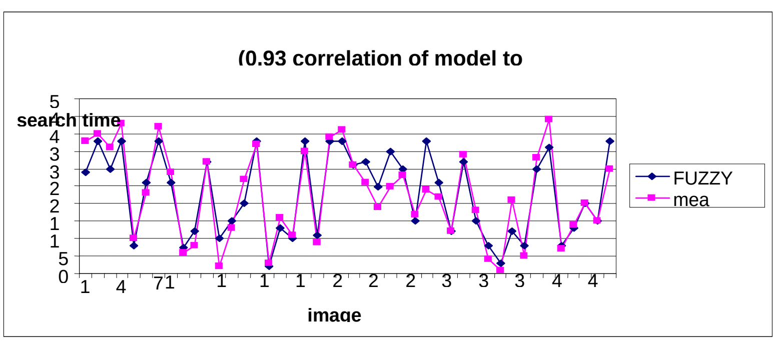


Figure 20: Plot showing the comparison of fuzzy logic predicted versus lab search times

CONCLUSIONS

35mm color slides were used from a laser protection filter field test to help validate the overall test procedures used in the Visual Perception Laboratory (VPL). The color slides were of seven military vehicles positioned at tactical range in the desert. The correlation of the laboratory to the field ranged, surprisingly high, from 0.5 to 0.95 depending on the variables analyzed and questions asked of the subjects. The highest correlation, 0.95, was obtained when comparing identification rates of the vehicles between the field and the lab. This is understandable in light of the fact that detection is strongly controlled by local luminance conditions, which are hard to replicate in the lab, and identification rates are more a function of the target size, shape, texture and target/background color differences, which are easily replicated in the lab using various projection techniques.

Overall, the lower luminance in the VPL of the projected image resulted in a lower identification rate and higher detection rate than the field test. This study shows that the vehicle identification rate aggregated by the distance gives the best correlation.

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APPENDIX A – LUMINANCE MEASUREMENTS

VPL projected scene luminance was measured with SpectraScan 650 spectrophotometer at a distance of 1m from the screen. The spectrophotometer was set up so as to point at the center of the white portion of the black and white calibration tarp in the slides. Measurements units were in Cd/m^2 and compared to the field measurements. The VPL measurement was multiplied by correction factor to have a reasonable comparison. Run number 4, 6,7, and 8 were eliminated due to high level of luminance difference.

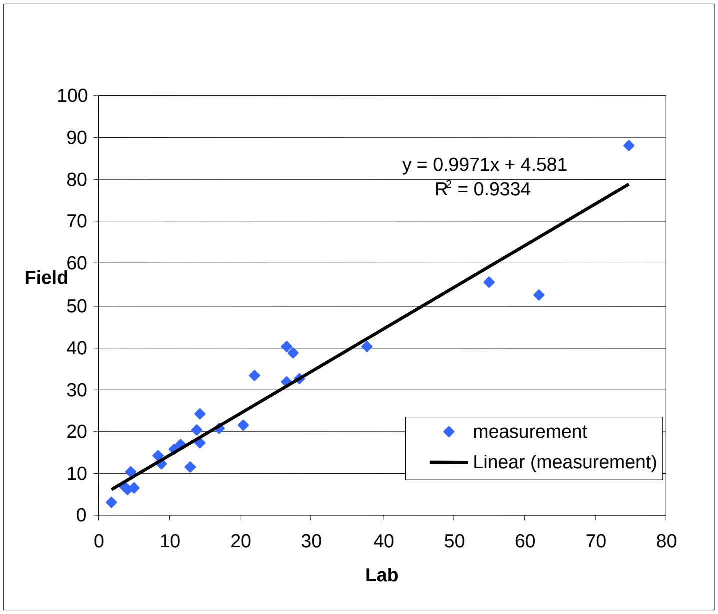

Figure 21: Luminance measure comparison

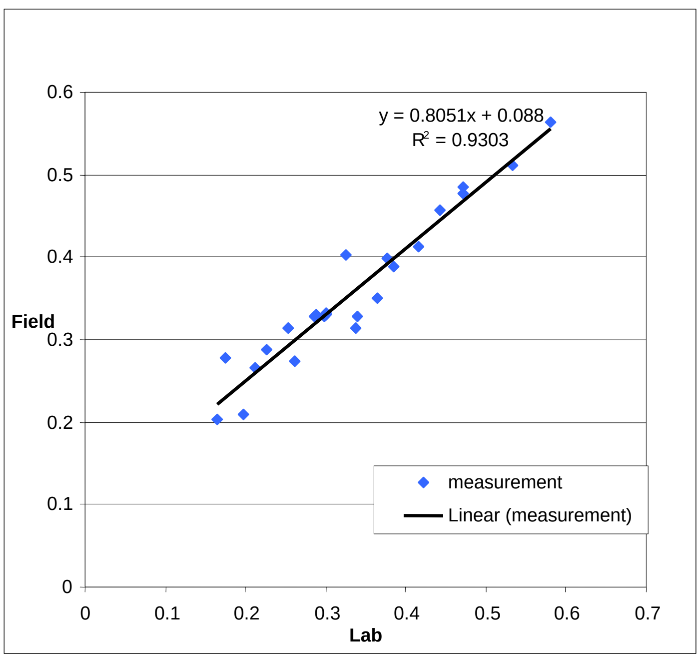

Figure 22: CIEx measurement graph

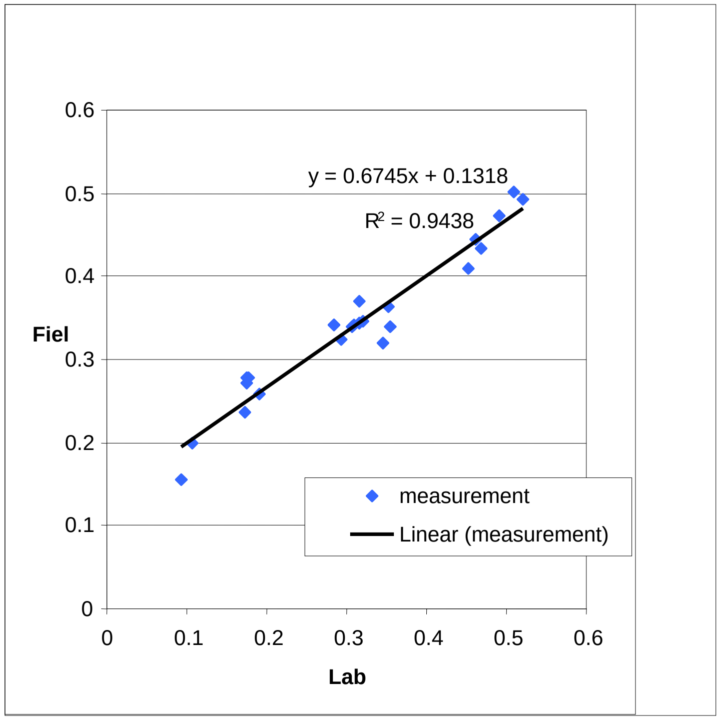

Figure 23: CIEy measurement chart

Figure 24: Macbeth color rendition chart

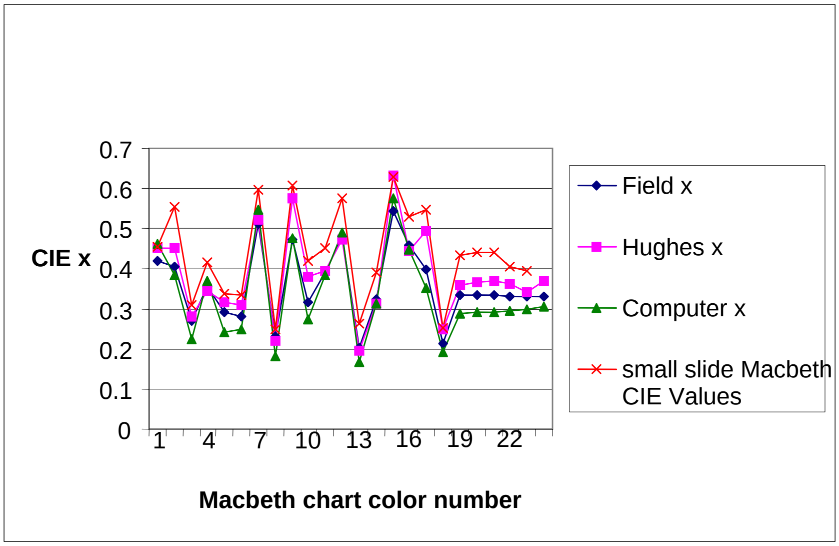

Figure 25: Field versus lab comparison

Note: 0.96 correlation of field to lab