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Designing Multi-media to Train the Thermal Signatures of Vehicles

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Guidelines for using multi-media technology to train the thermal signatures of combat vehicles were developed from training effectiveness experiments with a prototype multi-media program and the instructional design literature. The guidelines specify requirements for a database of thermal images. The database must be constructed to support vehicle recognition/identification exercises as well as in basic instruction on thermal technology and on thermal cues. Factors to consider in developing vehicle recognition exercises are presented, to include the exercise format, establishment of vehicle sets, selection of part-task training schedules, and the type of feedback needed for soldiers and instructors. How to generate training strategies that adapt to the skill level of the soldier is described. Flexibility in the instructional design is stressed as the primary means of meeting the varied training requirements within the military. The need for an instructor's guide describing how to maximize the training features in a flexible training program is emphasized. The guidelines were applied to a multi-media, thermal training program developed in conjunction with the Night Vision and Electronic Sensors Directorate and the Product Manager for Forward Looking Infrared.

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FOREWORD

As the Army changes from a reliance on classroom instruction to multi-media training tools, the quality of these computer-based products becomes critical. These new training formats should be effective, efficient, and motivating. The training techniques embedded in the software should be appropriate to the domain of interest. Guidelines for designing a multi-media, thermal combat vehicle recognition program are presented in this report. They are based on a series of training effectiveness experiments on prototype thermal training programs and related research using nonthermal (visible) images of vehicles and aircraft. Viewed in a broader context, the guidelines apply to designing drill and practice programs where the content to be learned is primarily a perceptual one.

In 1995, the Product Manager for Forward Looking Infrared (PM-FLIR) sponsored the development of a multi-media, target acquisition training program for second-generation FLIR sights. The Army's Night Vision and Electronic Sensors Directorate (NVESD) developed the training software and obtained imagery on a large number of combat vehicles for inclusion in the program. The Infantry Forces Research Unit (IFRU) of the Army Research Institute, in coordination with PM-FLIR and NVESD, conducted training effectiveness experiments on prototype versions of the program. The recommendations reported here were incorporated in the thermal program, and continue to affect the program as it is refined by the NVESD.

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In summary, the training programs reflect contributions from individuals with expertise in thermal technology, instructional design, and military training, as well as empirical data on training effectiveness. To a great extent, the unique features of these programs resulted from this collaborative effort.

DESIGNING MULTI-MEDIA TO TRAIN THE THERMAL SIGNATURES OF VEHICLES

EXECUTIVE SUMMARY

Research Requirement:

As the Army changes from a reliance on classroom instruction to using multi-media training tools, the quality of these computer-based products becomes critical. Lessons learned from research with multi-media training need to be documented so others can profit from what was accomplished. Guidelines for designing a multi-media, thermal combat vehicle recognition program are presented in this report. Viewed in a broader context, the guidelines apply to designing drill and practice programs where the content to be learned is primarily perceptual.

Procedure:

The guidelines were derived from two sources. First and foremost was a series of training effectiveness experiments on prototype thermal training programs. The second source was research on vehicle and aircraft recognition training programs using nonthermal (visible) images and research literature on instructional design.

Findings:

Several areas were found critical in program design. Careful attention must be paid to the imagery, as the images constitute the content to be learned. A large data base with actual thermal images was recommended. Instruction on thermal technology, the features that distinguish vehicle classes, and the unique signatures of individual vehicles are needed. This instruction must achieve an appropriate balance between perceptual learning and verbal descriptions. An analytic technique had to be developed to analyze the thermal features of vehicles to be taught. Central to training soldiers to discriminate vehicles was the establishment of training sets containing vehicles with the appropriate degree of similarity. Training also had to employ suitable exercise-feedback formats within the context of appropriate part-task training schedules. Pretests, embedded tests, and posttests were needed. Tests had to be carefully designed so they were rigorous, yet fair, as the difficulty of any test depended on the similarity of the vehicles it contained. Flexibility in the instructional design was key to its success both in terms of addressing individual differences and in meeting the varied requirements in the military training settings where such programs are used. Coupled with program flexibility came the need to show instructors how to use the training features in the software with skill and creativity.

Utilization of Findings:

The recommendations were used to revise the prototype thermal program and later versions. The report provides guidance for training developers and instructors on developing vehicle identification training programs. The lessons learned also have implications for multi-media training that involves perceptual learning.

DESIGNING MULTI-MEDIA TO TRAIN THE THERMAL SIGNATURES OF VEHICLES

CONTENTS

Page

INTRODUCTION 1

COMPUTER-BASED TRAINING VERSUS TRADITIONAL TRAINING 2

THE TRAINING STRATEGY: "THE BIG PICTURE" 4

THE IMAGERY DATABASE: "WHAT SOLDIERS SHOULD SEE" 4

Imagery 6
Database Size 12
Accessing the Database Through a Library of Images 12

INSTRUCTION: "THE BASICS COME FIRST" 14

Knowledge of Thermal Technology 14
Knowing Thermal Features of Vehicle Classes 15

TRAINING: "REPEATED EXPOSURE, PRACTICE, AND FEEDBACK ARE KEY" 15

Presentation of Specific Vehicles and Their Cues 16
How to Establish Vehicle Sets 22
Training Exercise Formats and Strategies 29

ASSESSMENT: "WHEN DO SOLDIERS REALLY KNOW VEHICLES?" 39

Types of Assessments 39
Performance Standards and Conditions 41

INSTRUCTOR CONTROLS: "REDUCING THE INSTRUCTOR'S LOAD" 43

GROUP INSTRUCTION: "FLEXIBILITY FOR THE CLASSROOM" 44

ADDITIONAL MODULES 45

SUMMARY AND CONCLUSIONS 46

REFERENCES 53

Page

APPENDIX A. ADDITIONAL TRAINING MODULES AND IMAGES FROM THE PROTO-FLIR PROGRAMS A-1

LIST OF TABLES

Table 1. S^4HEET Framework for Thermal Cues 21

2. Illustration of a Vehicle Confusion Matrix: Vehicle Presented by Vehicle Named (% responses) 28

3. Recommended Summary Feedback on Each Soldier 38

4. Factors Influencing the Difficulty of Vehicle Identification Exercises and Tests 42

LIST OF FIGURES

Figure 1. Illustrations of the M1 Abrams and LAV-25 at the four ranges in the Proto-FLIR programs 9

2. Night and day thermal imagery of the BTR-80 in white-hot and black-hot from the Proto-FLIR database. 10

3. Image Library with two- and three-display formats 13

4. Eight aspects of the BTR-80 from the Proto-FLIR database 18

5. Eight aspects of the BMP-2 from the Proto-FLIR database 19

6. Illustration of pure-part training schedule 23

7. Illustration of repetitive-part training schedule 24

8. Illustration of progressive-part training schedule 25

9. Graphic representation of potential overlap (degree of similarity) in the thermal signatures of vehicles from different classes 26

Page

LIST OF FIGURES (continued)

10. Illustration of a training sequence that addresses the vehicle confusions depicted in Table 2 28

11. Aspect Matching exercise from the Proto-FLIR programs 31

12. Vehicle Identification exercise displays of the response format and of the corrective visual feedback after responding 33

13. Signature Challenge exercise displays with feedback for correct and incorrect responses 34

14. Feedback matrix: Vehicles by aspects 38

Designing Multi-Media to Train the Thermal Signatures of Vehicles

Introduction

Military training is affected by the combat system being trained and by the training technologies available at the time the system is fielded. This report focuses on applying multi-media technology to training soldiers to recognize and identify vehicles using thermal sights. This skill (i.e., vehicle recognition and identification) is not new to the military. But the application of multi-media as the training technology to this domain and to thermal signatures in particular is relatively new. The guidelines in this report can assist training developers and instructional designers in developing software for future tactical systems and can assist instructors in making the best use of the multi-media instructional software available to them.

Identifying vehicles quickly and accurately on the battlefield is acknowledged as an essential combat skill. Soldiers with this skill are less likely to fire on the wrong target and less likely to hesitate when firing. Consequently, combat vehicle recognition and identification training can curtail fratricide and increase combat effectiveness.

Today's soldier uses many sensors for target acquisition. A common technology used for the sensors in modern weapon systems is forward looking infrared (FLIR, also known as thermal). FLIR sensors turn infrared energy produced by the heat emanated from an object into visible light (Palmer, D'Agostino, & Lillie, 1982). FLIR images contain information foreign to the untrained eye. "Seeing" heat with FLIR is a unique experience. In vehicles, this infrared energy results from the vehicle's temperature, its surface reflectivity, and its structural properties. Fuel combustion heat generated by engines and frictional heat generated by moving parts (e.g., tracks) often create distinctive thermal signatures for different combat vehicles. When the vehicle's armor heats up from the sun, the thermal signature changes. Because the heat profile or thermal signature of a vehicle is dynamic, the thermal image seen by the soldier is also dynamic. As thermal images may bear only a distant resemblance to a visual representation of the object, soldiers must learn how to recognize, integrate, and use this information. Skill with thermal imagery does not necessarily flow directly from prior experience with photographs or drawings of vehicles. In conclusion, vehicle recognition and identification, a skill commonly viewed as difficult to train and sustain, is made harder and more complex with thermal imagery.

The use of multi-media technology to train this skill has some notable advantages over the traditional classroom approaches. More instructional options can be provided. Computer-assisted training gives trainers the flexibility to tailor lessons to each individual. Soldiers can learn at a pace and skill level best suited for them, and they can learn in an efficient and entertaining way. Feedback can be tailored to the unique vehicle confusion errors of each individual. This flexibility is important, particularly as there are substantial individual differences in vehicle recognition skill. Computers can easily handle a large imagery database of vehicles. The software can be designed to focus on high-level comprehension of thermal signatures, not rote memorization of the imagery. Exercises can be designed to create a high level of interactivity on part of the soldier, and to test for transfer to new images. The software

can aid the instructor in customizing the instruction and in keeping track of individual and group progress. Both classroom and individual training modes can be created.

On the other hand, the flexibility provided by computers raises instructional design issues. There are, perhaps, as many ways to teach a skill to a learning audience as there are audience members. In addition, there is a need to keep the structure of an instructional program relatively simple and easy for all to understand and use. However, much has been learned about developing an effective vehicle recognition program, which reduces the instructional design options for the training developer.

The training guidelines and suggestions in this report integrate findings from several sources. The primary source is a series of experiments conducted by the authors (Dyer, Westergren, Shorter, & Brown, 1997), using a prototype multi-media program for training the thermal signatures of vehicles called CVI*Plus* (Night Vision & Electronic Sensors Directorate [NVESD], 1996). More lessons were learned from additional experience with variations of this program when it was used in an ongoing course at the Infantry School. Further modifications have been and are being made to this program, which has been called 2nd Gen FIRST (NVESD, 1997a) and is now called ROC-V (recognition of combat vehicles, NVESD, 1997b). In addition, other vehicle and aircraft recognition training programs, prior research with photophic images, diagrams, and scaled models, and the learning literature in general were examined in compiling training guidelines.

Throughout this report, we use the acronym "Proto-FLIR" to refer to the variations of these prototype FLIR training programs (CVI*Plus,* 2nd Gen FIRST, and ROC-V). We also use "thermal" and "FLIR" interchangeably. Lastly, the terms vehicle "recognition" and "identification" are used interchangeably, although we acknowledge that they are formally distinguished from each other (e.g., Joint Chiefs of Staff, 1987). Recognition refers to determining that a vehicle belongs to a certain category of vehicles (e.g., tank, tracked armored personnel carrier [APC], wheeled APC), and identification refers to naming the vehicle (e.g., M1 Abrams, T-72). However, in the aviation literature, naming of the aircraft is often referred to as aircraft recognition (Air Defense Artillery [ADA] School, 1993; Jane's Information Group, 1993). In the Proto-FLIR programs we used, soldiers had to name the vehicle.

Computer-Based Training versus Traditional Training

To be cost-effective, computer-based training must take advantage of the capabilities offered by computers. However, one of the problems we encountered in some computer-based, visual aircraft recognition training programs is that they often had little training value beyond the simple, non-interactive, presentation of information. This raises the question of "What real benefit does a non-interactive computer program have over a book?" The answer is "none." A book containing pictures and specifications of vehicles is more portable than software and a computer. Books require no power to run. Books do not have glitches or bugs. Books do not require continuing support. Books are, in many ways, more economical than the same information presented on a computer. Finally, educated persons are trained to use books virtually from infancy, whereas, in many training populations, the lack of computer experience

and skill may interfere with the ability to use computer-assisted training. Therefore, there must be some justification for changing from traditional book-based learning to computer-assisted training. The primary justification for this shift should always reflect the ability of the computer to interact with individuals for the purpose of substantially increasing their skills, not simply to have a computer-based program.

The other common means of teaching vehicle recognition skills is classroom instruction. Here too, a computer-based program that does little more than present pictures and specifications has no advantages over classroom instruction. In fact, one of the challenges to computer-based instruction in this domain is to develop software that can function as a tutor; that can replicate the instructor's knowledge of vehicles and the instructor's ability to react to soldiers' errors and questions. On the other hand, the classroom instructor cannot adapt easily to individual differences in learning rate, progressing too slowly for some and too quickly for others (Whitmore, Cox, & Friel, 1968), whereas instructional software can easily adapt to these differences. Well-designed computer software can also help the instructor develop additional training exercises and tests tailored to individual learning problems and to mission requirements.

Finally, critical to deciding whether computer-based training should be used is the nature of the task itself. Vehicle recognition is a perceptual skill (Liebowitz as cited in Cockrell, 1978, p. 3) with cognitive components, as opposed to a cognitive skill with perceptual components. As such, computers are an ideal medium for training soldiers to understand thermal signatures and to discriminate vehicles, given the computer's capability to present images and to generate images and graphics. Computer-based training can present images in a multitude of formats: randomly or in a predetermined order; single images to study; multiple images to compare; images of a vehicle at different distances; displays that provide a 360° view of a vehicle; etc. The computer, by selecting images from a large database, randomly or through some form of stratified sampling procedure, can offer almost unlimited exercises requiring soldiers to discriminate vehicles. When errors are made, the computer can immediately provide side-by-side displays of the correctly- and incorrectly-identified vehicles, tailoring feedback to the unique confusions of each soldier. These training techniques, easily executed via computer, exploit the use of images. They are consistent with Liebowitz's stress on the perceptual nature of the task and his assertion that perceptual learning is accomplished by perceiving, not by talking, as in traditional lecture formats.

What role should verbal descriptions have in a training program? Can identification occur despite, rather than because of, verbal representations (Gregory, 1984)? With a large imagery database, we believe that text (or audio) which draws soldiers' attention to distinctive thermal features is a valuable supplement to vehicle images. This attention to thermal features is consistent with Biederman's (1987) recognition-by-components theory. But verbalization should not be incorporated in such a fashion that it interferes with learning to make the required discriminations. Exploiting a large database of images during initial and remedial instruction on distinctive components keeps the focus on the perceptual nature of the task. Words can also emphasize basic concepts and principles that serve to differentiate vehicles and classes of vehicles. However, many thermal signatures, forms, and shapes are very difficult to describe. Even when words can describe features, those features constitute only part of the basis for the

discrimination. Consequently, letting soldiers examine and compare vehicle images remains integral to vehicle recognition training.

As implied above, while computer-based training can look flashy and impressive, it has no inherent value over and above in-situ or traditional training. The software must be designed well. And some challenges remain even with well-designed software. Yet multi-media training for vehicle recognition and identification has notable advantages. It can resolve the weaknesses with traditional modes of instruction and can add unique instructional and training features.

The Training Strategy: "The Big Picture"

The generic training strategy recommended for vehicle recognition and identification skills is similar to most other training strategies. The core elements of this strategy are:

- Pretesting to determine where training should start.
- Teaching critical concepts and information that underlie the skill to be acquired.
- Training that starts at the soldier's skill level (basic or advanced) as determined by pretests, includes performance feedback and spaced practice, and progresses from general to specific and from easy to difficult.
- Checking on skill progression with embedded or spot tests.
- Continuing with training as indicated by skill status.
- Conducting assessments of performance that include testing for transfer of skill.
- Providing spaced review of vehicles learned previously in conjunction with training on new vehicles.

So what makes a training program on the thermal signatures of vehicles distinct or unique from training other skills? As indicated in the remainder of the report, the difference is "in the details" and the perceptual nature of the task.

The Imagery Database: "What Soldiers Should See"

The success of vehicle recognition and identification training depends greatly on the images available for the training. By success, we mean that soldiers acquire skills transferable to new imagery in the database itself and ideally to field settings with real vehicles as well.

Training success does not mean that soldiers simply memorize the images presented during training. To accomplish this goal, a large database must be established, which can be a very costly part of the development process.

What type of FLIR imagery should training developers require? At a minimum, the following factors should be considered:

- General Considerations

  - High-fidelity images with respect to the sensor(s) under consideration
  - Imagery with few, if any, incidental cues
  - Vehicles consonant with the soldiers' mission (e.g., soldiers with anti-tank weapons need to see tanks; long-range surveillance teams need an extremely large database that includes vehicle variations such as commander's vehicles)
  - Diurnal cycle of vehicles

- Vehicle-Specific Considerations

  - Images of each vehicle from different aspect angles
  - Images of each vehicle at different ranges; from a close distance to distances where target detection should occur
  - Images scaled by actual vehicle size at different ranges
  - Stationary and moving views
  - Day and nighttime views
  - Black-hot and white-hot views
  - Non-tactical views
  - Tactical views (e.g., defilade, through smoke or dust, live-fire, turret facing forward regardless of the aspect)
  - Imagery taken at different times of the year, in different climates, or both
  - Imagery showing thermal signature changes as a function of vehicle operating time
  - Imagery for test purposes
  - Color photos of each vehicle for comparison with the thermal images

An image database with these factors provides soldiers with a wide variety of examples. Soldiers need many examples in order to learn "the vehicle," and not "the image" or "the picture." In addition, they are more likely to transfer their skill to field conditions if they have seen vehicles in a variety of conditions during training.

What was done for the Proto-FLIR programs? Actual thermal imagery was taken of a variety of combat vehicles with a commercial FLIR camera during daytime and nighttime. These vehicles were tanks, and tracked and wheeled APCs, plus air defense artillery, field artillery, engineer, and logistics vehicles. The countries of origin were US and nonUS. Eight vehicle aspects were photographed (stationary views). The aspects were the two flanks, the front and rear views, and the four oblique aspects between these cardinal aspects. Vehicles were also shown at four different ranges, ranging from close-up views, where the heat profile of the vehicle was clearly evident, to tactical ranges typically less than the maximum effective range of the

weapon system. Imagery was available in both white-hot and black-hot polarities. All vehicles were exercised prior to being photographed, and were idling during the photography process itself. Therefore, the vehicles were "hot, not cold." Of necessity, different sites were used for this imagery collection. But in each case, the background was kept neutral (i.e., wood line) to minimize incidental cues. There were at least 128 thermal images per vehicle.

In addition, colored photographs of the eight aspects of each vehicle were taken, but for only the closest of the four ranges displayed in the program. Of the other factors cited above, the database did not contain views of each vehicle moving, of vehicles in various tactical positions, of vehicles going from a cold to a hot image after their engines started, live-fire, etc. This imagery was available, however, for some vehicles in some of the instructional modules. Some vehicles were photographed at different times of the year as well. The latest versions of the program had about 40 vehicles.

Imagery

Image fidelity. There is consensus that the thermal image should be representative of the vehicle and maintain as much realism as possible. Although simulations of thermal images exist, real imagery is needed to train vehicle recognition and identification. Soldiers must understand and appreciate the dynamics of thermal imagery and the heat profile of different vehicles. This cannot be accomplished well via current simulation techniques, as computer-generated imagery typically depicts only nighttime conditions; it is not dynamic (e.g., does not change with range); and it does not depict the temperature gradations in the vehicle's thermal signature that are critical to its identification[1]. Furthermore, line drawings and photographs do not portray the thermal signature. And we found that ability to identify vehicles with photographs did not guarantee ability to identify vehicles via their thermal signature.

Vehicle aspect. Aspect is important as it strongly influences the ease with which a vehicle can be identified. Consistent with other research, we (Dyer, et al., 1997) found vehicle identification easiest with flank views, more difficult with oblique aspects, and hardest with front and rear views. The four oblique aspect angles, in conjunction with the four cardinal views, produced a three-dimensional appearance to the training stimuli. Together these views also increased the element of battlefield realism, which has often been absent in training materials. Although training on eight aspect angles can be time-consuming, training in this manner provides a more informed understanding of the vehicles to be learned.

We also found that encouraging soldiers to think in terms of vehicle orientation had beneficial results. Those who practiced determining the vehicle's aspect, as well as its identity, were more likely to correctly determine aspect on transfer than soldiers who did not have aspect training (Dyer et al., 1997). Appreciation for aspect angle has an interdependent effect on vehicle identification. It contributes to the understanding of the thermal heat signature of a vehicle and it is also a reflection of that understanding. For example, if soldiers can determine that they are looking at the left front oblique of a vehicle, this has important implications for ascertaining the identity of that vehicle. They can use their knowledge about this angle to

[1] One of the reasons for simulations failing to be realistic has been the lack of a comprehensive database of thermal images of vehicles on which to base the simulation.

narrow their response options. They know that Soviet T-series tanks have exhaust flumes on the left side. So if none are present, they can eliminate these tanks from their response repertoires. Similarly, if soldiers are aware of key heat signature elements, they can use this knowledge to determine which aspect angle they are viewing. For example, awareness that the M1A1 Abrams tank has a large turbine engine that manifests itself in FLIR as a large round circle allows soldiers to determine they are looking at the rear of the M1A1.

Knowing the aspect angle also allows soldiers to evaluate the level of risk present in a combat situation and to prioritize their attention. If soldiers see the front aspect of a T-72 at 500 meters (with turret facing forward) and a rear view of a T-80 at a range of 400 meters (with turret facing away), they must decide which vehicle deserves their most concentrated efforts.

Although training can proceed more quickly and it is likely that soldiers will obtain high levels of performance if presented with fewer aspect angles, especially if the aspects presented are flank views, this type of abbreviated training is not recommended. Because of the benefits just cited, we recommend that soldiers be trained on a variety of aspect angles on all vehicles. A concerted effort should be made to photograph at least eight aspects during imagery collection when the vehicles are stationary.

Range. As with aspect, range is critical. The thermal signature changes with range. More detail is visible at closer ranges. Fewer gradations in vehicle temperatures are visible at longer ranges although the hottest spots still stand out. There has been a debate regarding the most appropriate method for training vehicle cues. Some suggest that training must occur with imagery at close ranges in order to insure soldiers gain a full understanding of the structural characteristics of the vehicle which generate its thermal signature. Such a conceptual understanding is thought to be a prerequisite for interpreting the thermal signature at farther ranges. Others debate this point, suggesting that training on cues visible at close distances may be counterproductive to learning. Using this line of reasoning, soldiers may look for cues that do not exist when vehicles are viewed at range.

Both approaches assume that far ranges are more difficult than closer ranges. Regardless of which viewpoint you take, the database should contain far and near images. We verified the greater difficulty in discriminating thermal signature at range in our research (Dyer et al., 1997). Soldiers took twice as long to learn to discriminate vehicles at the far as opposed to the near ranges. Once all soldiers learned to discriminate vehicles at the far ranges, they were successful at the near ranges without further training. On the other hand, skills developed from training with vehicles presented at the near ranges did not transfer as well to the far ranges.

In combat, soldiers and leaders should engage targets at the farthest range possible, maximizing their weapon's stand-off capability. Our findings suggest that soldiers can identify vehicles at tactical distances, particularly with flank and oblique views. But the most efficient training is on close-up images first, particularly with soldiers who have low initial skills. Advanced skill training should involve vehicles at greater and greater distances. Therefore, the image database must contain images of vehicles at different ranges. The Proto-FLIR programs used 4 ranges, but 5 would work as well. More ranges would probably yield unnecessarily

redundant information with each increment in range; fewer ranges would probably provide too great a change in the thermal signature with each increment.

How the images at different distances are generated is important. Previous research on non-FLIR imagery, using models, drawings, or photographs often did not find substantial differences in vehicle identification performance as a function of range (Haverland & Maxey, 1978; Kottas, Bessemer & Haggard, 1980; Smith, Heuckeroth, Warnick, & Essig, 1989). But these presentation techniques failed to display degradations in distant images resulting from atmospheric haze. Therefore, it was easier to identify vehicles in the training setting than in an operational environment. With today's computer software, it is possible to simulate atmospheric haze, making photographs more realistic. Nevertheless, because of these limitations in previous studies, training developers had no data to help them decide at what ranges and under what conditions which specific vehicle cues should be taught (Foskett, Baldwin, & Kubala, 1978).

If actual FLIR imagery is used, the effect of distance on the thermal signature will be reflected in the images. Real imagery was used in the Proto-FLIR programs. That probably accounts, to a large extent, for the significant differences in time to learn and in ability to transfer skill found as a function of range (Dyer et al., 1997). Figure 1 shows the LAV-25 and the M1 Abrams at each of the four ranges in the Proto-FLIR programs. These pictures show clearly how the distinctness of the thermal image changes with range. These pictures also show why instruction on thermal cues may need to be tailored to the range displayed.

In the closest view of the rear of the M1, you can see the central exhaust and engine heat, the "comma" to the left of this heat, and the tracks. Some of the features start disappearing as the range increases, until at the farthest range you see only a circular glow from the exhaust. The rest of the vehicle is substantially cooler than the exhaust, making the hull and turret almost impossible to discern at range. With the LAV-25, the externally-mounted, muffler-shaped exhaust is visible at all ranges, and heat from the right-front engine and wheels is most distinct at the two closest ranges. The heat signature takes on a less distinct form at distance. Training on close imagery will give soldiers a concept of the vehicle's shape and what hot spots the thermal image will project at range.

Night and day images and sensor polarity. For thermal signature training, it is critical to have imagery taken during the night and the day. Thermal sensors are often the primary target acquisition system regardless of time of day, and day and night signatures differ dramatically due to solar loading during the day. For example, parts of the hull or turret may be cool at night and very difficult to detect, whereas during the day these components are quite visible because they have been heated from exposure to the sun (see Figure 2). During the day, tracks and wheels often appear less hot relative to the rest of the vehicle. If the vehicle has been operating, the engine and exhaust will still be hot, but their signatures will not be as distinct when the hull and turret are also hot.

Most thermal sensors have reverse polarity, where the hotter spots can be displayed as black (black-hot) or as white (white-hot). Thus the database must have this capability as well. Switching from one polarity to the other helps the soldier to discern critical features. As indicated in Figure 2, perceptually these images are not strict complements of each other. By

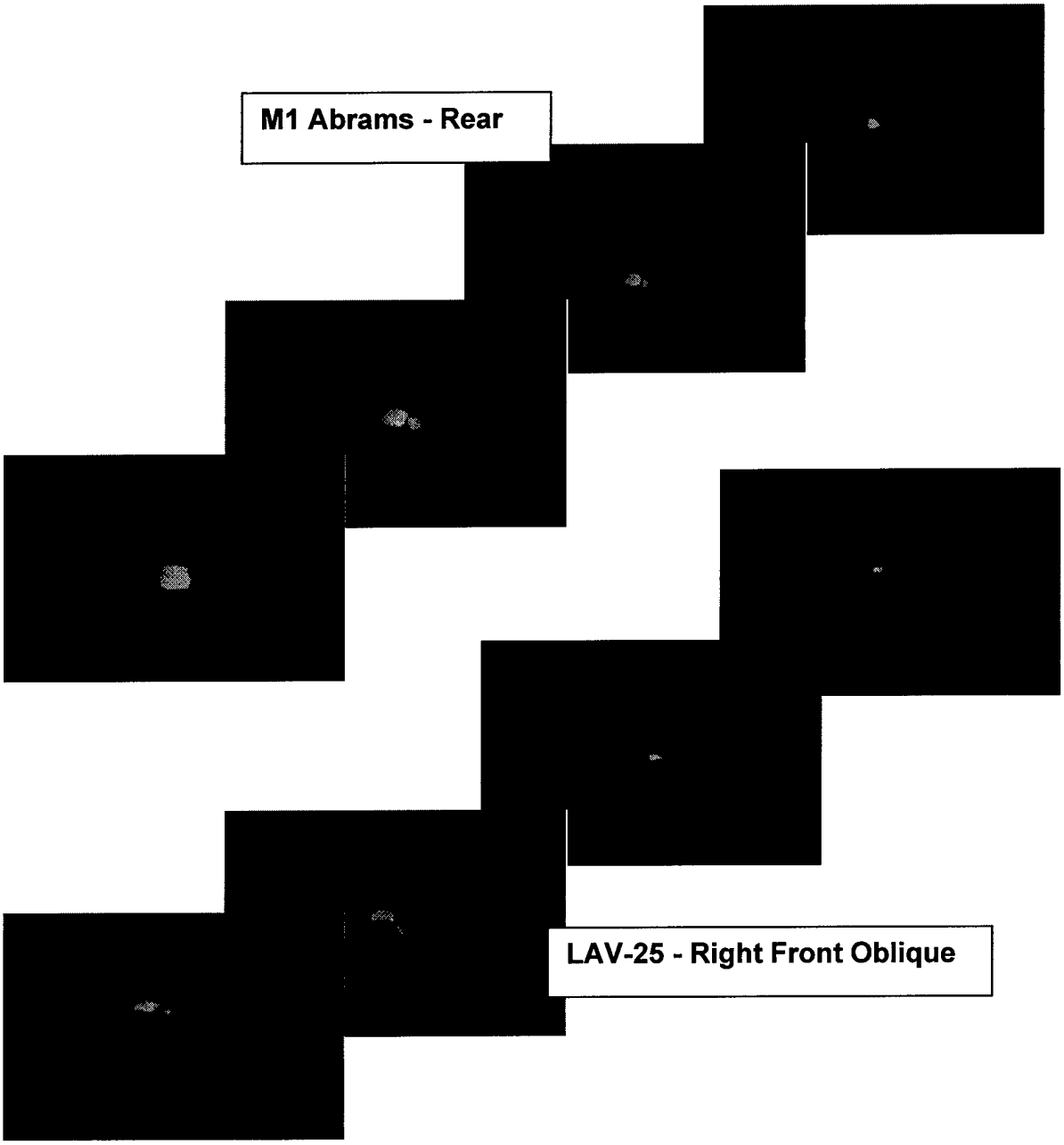


Figure 1. Illustrations of the M1 Abrams and LAV-25 at the four ranges in the Proto-FLIR programs.

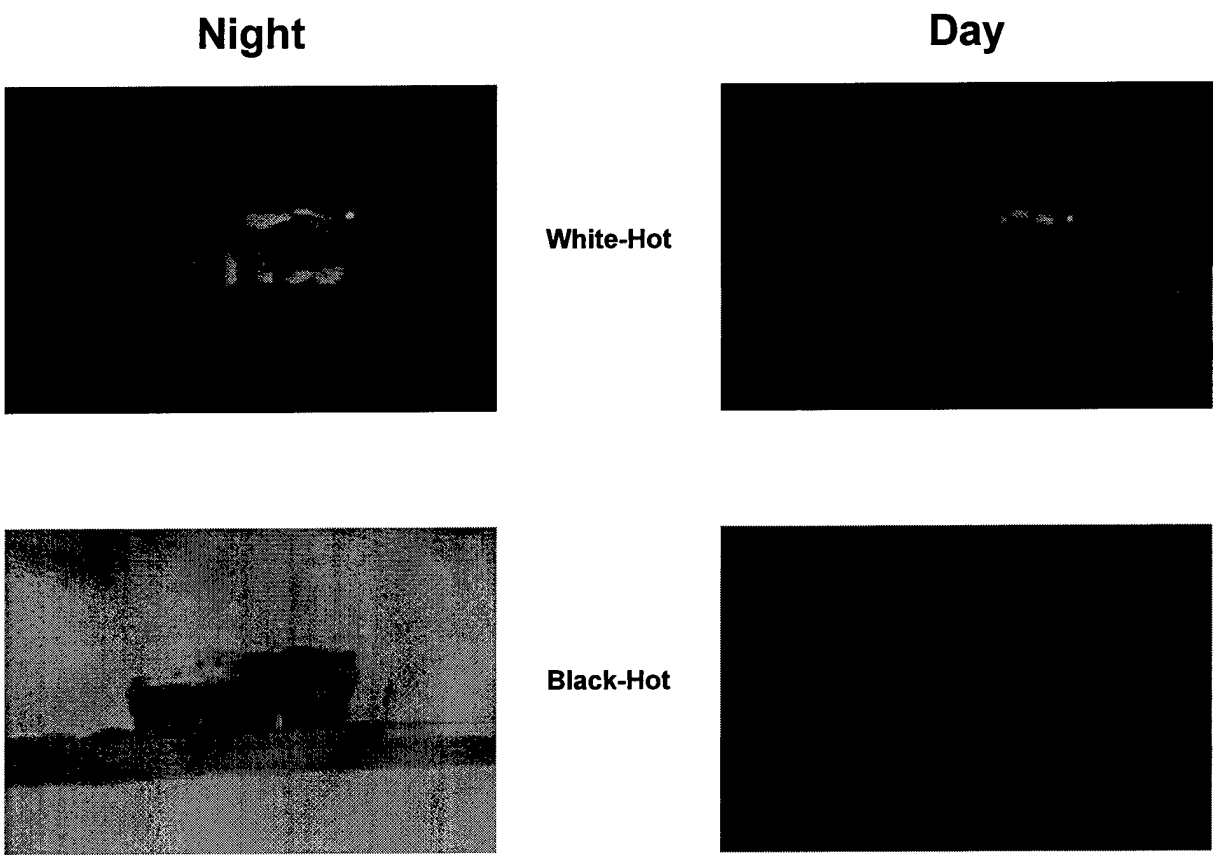


Figure 2. Night and day thermal imagery of the BTR-80 in white-hot and black-hot from the Proto-FLIR database.

using both polarities, soldiers frequently are able to discern different pieces of information, which, collectively, help them identify the vehicle. Ideally, the program software should allow soldiers to easily switch between white-hot and black-hot in training exercises as they would with their tactical systems.

Tactical images. To reflect battlefield conditions, training programs should include moving vehicles, partially-exposed vehicles (defilade and enfilade), vehicles as seen through varying types of obscurants (dust and smoke), vehicles in different climates (temperature, arctic, desert), tanks with turrets directed forward regardless of aspect angle, and so on. Vehicles can present different signatures under these conditions. Movement is common on the battlefield, and the exhaust and dust-cloud signatures associated with movement are critical to vehicle identification. Sometimes additional instruction is required on the cues that discriminate vehicles under these conditions. For example, during Desert Storm/Desert Shield, the NVESD published a special training guide (Orentas, Zegel, & Gonzalez, 1991) on thermal signatures. The very hot climate in conjunction with combat conditions produced signatures that differed from what soldiers encountered in field exercises at home station. Although tactical conditions make a vehicle more difficult to detect and identify, this very fact makes their inclusion in a training program all the more important.

Test imagery. Because the training goal is to prepare soldiers for combat, the trainer needs to give tests with imagery that differs from the imagery used in the practice exercises and instruction. Can soldiers identify vehicles under conditions they have never seen before? This is the primary means of determining whether the soldiers have in fact learned "the vehicle" as opposed to "the image." There are many ways transfer or generalization of skill can be assessed: a different range, day as opposed to night images, different aspects, images taken under different climatic conditions, moving images, etc. But the critical issue is that testing for transfer must be considered in the data collection process as well as during training and testing. The larger the database, the easier it is for the instructor to assess soldiers' abilities to transfer skills.

Incidental cues. Incidental cues in the training imagery present a great threat to ensuring that soldiers can identify vehicles in an operational environment. An obvious attempt is often made to conceal any incidental markings or cues such as insignias, an atypical vehicle configuration, the presence of a soldier, and distinctive backgrounds in the scene. Soldiers are likely to focus on these incidental cues rather than the vehicle's thermal signature. For example, suppose that all of the pictures of a particular vehicle have a tree-lined background, while all others are presented against a desert environment. The ability of the soldier to identify the vehicle with the odd background may simply be an artifact of irrelevant features in the scene rather than characteristics of the vehicle itself. Or one vehicle may have the driver's hatch open, presenting a unique thermal image because of the body heat of the driver.

Obtaining standardized imagery is a big challenge in the construction of a database of real images. Incidental cues in the background are often eradicated by removal of the background itself. However this type of presentation often appears very artificial. If the background remains, incidental cues are impossible to eliminate totally, as the photography must usually be collected at different locations and the field of regard is large when vehicles are photographed at a distance. However, obvious differences in background scenes can be

controlled in most imagery collection efforts. Another means of helping reduce the likelihood of incidental cues affecting the learning is to create a very large database, with multiple, varied backgrounds and conditions for all vehicles. This creates an ideal learning environment, but is costly.

Nonthermal daytime photographs. Thermal signature training programs can benefit from including daytime, color photographs of each vehicle, allowing soldiers to compare and contrast thermal and color displays. In many cases the external shape of an exhaust system or engine grating system translates into a unique thermal signature. The visible imagery allows soldiers to relate what they already know to something less well known. These color views should be taken at the same aspects and ranges as the thermal views.

Imagery for instruction on FLIR theory. Finally, consideration should also be given to collecting imagery for basic instruction on thermal technology. For instance, visual examples of how a vehicle's thermal signature changes as a function of the diurnal cycle, after the engine starts, and when the main gun fires all help the soldier understand the dynamics of thermal imagery and will help on the battlefield. Pictures that show the thermal properties of different material, both man-made and natural, are critical. Imagery depicting the effects of limited visibility conditions such as fog and smoke on thermal sights is valuable. Such imagery should precede formal training and practice on vehicle recognition and identification per se.

Database Size

Obviously, a very large database is generated when all the above factors are considered. This presents significant problems not only in terms of image procurement but also in terms of data storage space. One solution is to limit the total number of images. Another is to create simulated imagery, which takes less hard drive space and costs less money and time to collect. The data storage space problem will probably become less significant as computer capacity increases. If affordable, however, real imagery for thermal signature training should be obtained, as realism is a lofty goal for simulated images. We recommend that a training program be built around real imagery, even if the number of vehicles for which systematic imagery can be acquired is limited.

Accessing the Database Through a Library of Images

One you have a large database, it is essential that soldiers and instructors be able to view what is in it. For the Proto-FLIR programs, an Image Library was generated. This library was used in several significant ways: as a reference and study tool, and by instructors in group settings. It was available to the soldier at any time. Sample screens from the Image Library in the Proto-FLIR programs are shown in Figure 3. A soldier could access any vehicle, any aspect angle, day and night thermal imagery, any range, and also change polarity. The day color photographs (visible) were also accessible. The two- and three-display screens provided flexibility in comparing and contrasting images of the same vehicle and of different vehicles. In essence, any combination of images was possible. Soldiers used the library frequently in our try-outs of the program. If other images, such as moving and partially exposed vehicles, are in the database, they should also be accessible from the library.

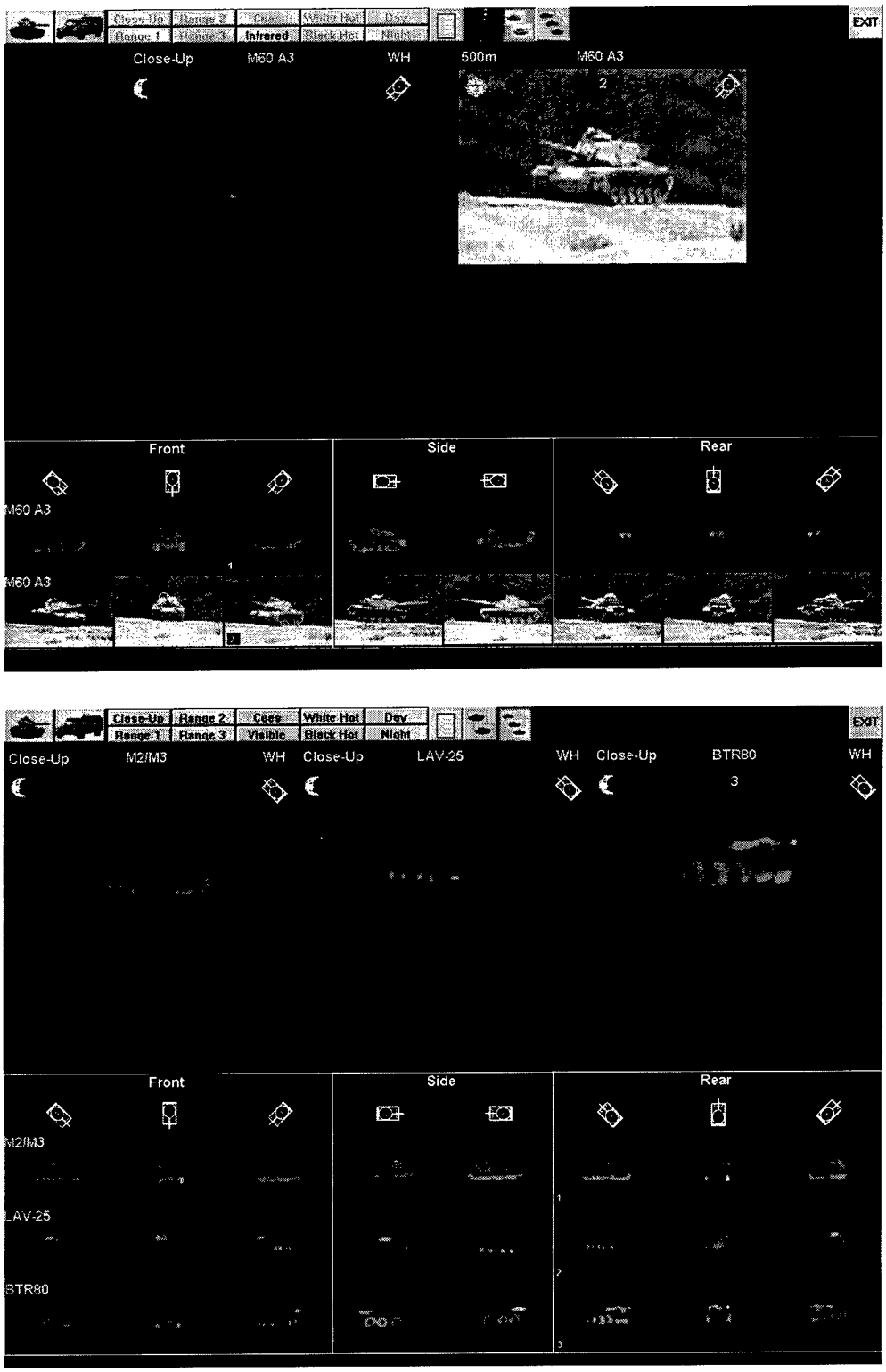


Figure 3. Image Library with two- and three-display formats (from the Proto-FLIR programs).

To make the library a "one-stop shop" for the soldier, additional features are needed. Pull-down menus with text on vehicle characteristics and vehicle diagrams, similar to the approach used in the *Jane's*™ combat vehicle volumes (Foss, 1995; Foss & Gander, 1996), should be included. For thermal training, this information should be supplemented with descriptions of the location of the heat-producing parts of the vehicle (exhaust, engine) and the materials that compose the vehicle, as these materials affect the thermal signature. This technical information is often hard to obtain and is rarely in *Jane's*™, but greatly assists instructors and soldiers in understanding what is hot and what is cool on each vehicle. The thermal cues for each vehicle presented in the training modules of the program should also be included.

Another factor that helps soldiers identify vehicles on the battlefield is size. Some vehicles have similar signatures from some angles, but can be discriminated by their size. But size is difficult to estimate when a vehicle is displayed in isolation. The library reference materials could be used to demonstrate size. For example, as with the current vehicle recognition training aids (Department of the Army [DA], 1987), a line drawing of the vehicle could be included with a standard figure, such as a 6 foot tall man, beside it. Ideally, soldiers should be able to cut and paste these drawings to the screen for purposes of comparison. Or these drawings could be available in a separate training module. Another option is to generate the database so the vehicle's size is scaled appropriately at each range. Then whenever vehicles are compared in the Image Library at the same range, their relative sizes are depicted.

In summary, the image library should be the master reference. It should be the storehouse of all images and of information about all the vehicles in the training program.

Instruction: "The Basics Come First"

By "The Basics" we mean two things:

❶ FLIR technology
and
❷ The thermal features that distinguish different classes of combat vehicles

Training on these topics should precede training on individual vehicles. Training on specific vehicles will be more effective and efficient when soldiers understand FLIR technology and when they know some of the typical differences between vehicle classes.

Knowledge of Thermal Technology

An excellent reference on infrared technology is the *Infrared Recognition and Target Handbook* by Palmer et al. (1982). In the Proto-FLIR programs, a "Thermal Basics" instructional module stressed and illustrated these concepts. A short discussion of FLIR is given here to illustrate why this module was needed. Identifying an object using FLIR is complicated because the contrast in FLIR imagery is due to differences in relative temperature. For an object to be "visible" in FLIR, it must be significantly colder or warmer than its background or the objects around it.

The thermal signature of vehicles emanates primarily from the sun, fuel combustion, and friction. Since most combat vehicles have metal armor, the sun can heat up the deck plating, lending the vehicle a distinct signature. The sun's effects can often be detected long into the evening hours while the metal armor cools. When the vehicle is running, heat from the engine creates a very hot exhaust signature or spot and heats up the entire vehicle as well. The heat from the sun as well as from the engine typically make the vehicle hotter than its background (the ground, trees, etc.) and make its overall shape visible. When the vehicle is not operating and the sun has not heated up the vehicle, the vehicle is cold. Under these circumstances, vehicles are hard to detect as the thermal signature is very weak. Friction is another major heat source. Heat builds in the suspension and drive train systems as a result of friction. Generally, the heavier the vehicle, the more heat generated by the drive train. And, of course, when a weapon is fired, the gun barrel gets hot and is easily visible.

These dynamics must be explained and illustrated because they contribute to soldiers' understanding of FLIR images. The "Thermal Basics" module in the Proto-FLIR programs had an interactive training lesson on the FLIR technology. The following topics were presented, all illustrated with imagery.

- Basic thermal concepts: Definition of FLIR, seeing heat, typical hot spots on vehicles, thermal signatures generated by different objects, thermal cues used to identify vehicles, relating visible and thermal images
- Signature variability: Thermal signature changes over the day-night cycle, effects from moving vehicles, effects of obscurants, amount of vehicle exposed
- Brightness and contrast controls on the tactical sensor: Effects on the image when controls are adjusted
- Search techniques: Interactive demonstration

Knowing Thermal Features of Vehicle Classes

It so happens that vehicles within a certain class or certain type have similarities (e.g., tanks are tracked, have a main gun and a turret, and typically the engine is in the rear). In addition, there are some distinctions among classes or types (e.g., most APCs both tracked and wheeled have their engines toward the front and right and their exhausts relatively high on the right flank, where as tanks typically have their engines and exhausts in the rear). Basic instruction on vehicle types or classes should precede training on naming individual vehicles, as knowledge of these features helps narrow a soldier's choices considerably. For example, by determining that a vehicle is a wheeled APC, soldiers have available to them a volume of other information. They then know that the vehicle is not an M1, T-72 or Challenger and that it is more than likely a LAV, BTR, BRDM, etc. Lyons, Miller, and Bennett (1982) found that soldiers taught how to sort vehicles by class and to study them by these groupings did better than those who used flashcards with no specific study strategy.

Training: "Repeated Exposure, Practice, and Feedback are Key"

There are many ways to train vehicle recognition. Differentiating training methods in terms of effectiveness necessitates an analysis of the task being trained. For example, if the skill

a program is attempting to train requires speed, the optimal computer-based training for that skill would incorporate timed exercises. If accuracy is central to the skill being trained, then slower-paced components that emphasize corrective feedback and careful study might be used. Herein lies just one of the challenges in teaching combat vehicle recognition. Since speed and accuracy are both important, an effective training program needs to be versatile enough to incorporate these two different training objectives.

Another critical issue is how to break up and sequence the entire set of vehicles, because it is impossible to train all vehicles during a single session. How do you make training exercises challenging, but not frustrating? How do you make them motivational, but not perceived as "just a game?" How do you capitalize upon the prior experience and initial expertise of each soldier?

What we (Dyer et al., 1997) learned about designing instructional and training modules for vehicle recognition/identification using multi-media capabilities is included in this section. These guidelines are consistent with general recommendations on incorporating principles of cognitive psychology in computer-based training (Merrill & Salisbury, 1984; Salisbury, 1990). More specifically, these guidelines recognize the interference and confusion created when large numbers of vehicles or very similar vehicles are trained; the need for both spaced practice and spaced review; how the limitations of short-term memory impact the learning process; and how to make the vehicle identification task meaningful, rather than rote, thereby enhancing learning and retention.

Presentation of Specific Vehicles and Their Cues

When soldiers are first exposed to a set of vehicles, they need to be presented with images that help them internalize the "thermal representations" of those vehicles. There are many ways to accomplish that goal. Critical to this instruction are the following visual displays for each vehicle:

- Comparison of thermal and visible (color) images
- Displays that allow a 360° view
- Displays showing changes in thermal signature with distance
- Videos of the vehicle moving at tactical speeds

The Proto-FLIR programs included an instruction module with all these displays, except for moving vehicles, as moving imagery for each vehicle did not exist. Side-by-side visible and thermal displays helped soldiers relate daylight to thermal images. These displays provided a connection from the "known" to the "unknown." Another technique used to accomplish the same purpose was "morphing." A visible image of the vehicle was shown, which then turned into a series of white-hot and black-hot thermal images, and then back to the original visible image.

Instructional features allowing soldiers to see the vehicle from all aspects help them understand how hot spots change as the vehicle's orientation changes. For example, the exhaust may be physically located on the flank and have a rectangular thermal signature from that aspect. This exhaust signature will not necessarily disappear when the vehicle is viewed from other

angles. It may also be visible from the front, but appear circular in shape from that view. In the Proto-FLIR programs three techniques were used to help soldiers obtain a 360° understanding of each vehicle. At the bottom of the Image Library screen and the display from another instructional module called Vehicle Basics were small images of all eight aspects of the vehicles (see Figure 3 of Image Library). In addition, in the Image Library, the soldier could click on a "toy top" icon and see the vehicle as it rotated in space (a video animation of the eight aspects). Lastly, there was an aspect matching exercise, where soldiers matched images to an icon depicting the vehicle's aspect (refer to Figure 11).

As with aspect, instructional features that allow the soldier to see how the vehicle's thermal signature changes with range is required. Because exhaust plume signatures are often unique to vehicles, display of movement is also desirable.

The instructional software should point out specific thermal features as the images are displayed. Conduct this instruction with near images. Cues common to most vehicles (engine, tread friction, and exhaust heat) and cues associated with vehicle classes (large, prominent turrets on tanks) should be pointed out for each vehicle. And finally, the features that give each vehicle its unique thermal signature must be stressed. This signature is impacted by the vehicle's shape, its hot spots, the arrangement of these hot spots, and the other temperature differences on the vehicle that are typically less distinct, yet integral to its signature.

Cues can be illustrated in several ways. One option is to present a screen displaying several key aspect angles and use labeled arrows to point to the cues associated with each aspect. Audio description of the cues could supplement this diagrammatic technique. This "multiple-cues" option presents problems, however, because the amount of information on the screen can be overwhelming and appear cluttered. An alternative is to display cues, one at a time, while each aspect is displayed. A sequence of "slides" can be arranged so that it cycles through the aspects, using an arrow to point out each hot spot. This presentation may take longer than the previous approach, yet the information will be more readily understood. If the signature changes dramatically with range, instruction on these "distant" cues should be added.

The instruction on cues should systematically point out how and why the vehicle's signature changes with aspect in order to give meaning to its signature. Figures 4 and 5, which show the eight aspects of the BTR-80 and the BMP-2 respectively, illustrate why this is necessary. In each instance you can observe what hot spots remain visible as the vehicle's angle changes as well as how the shapes of the hot spots change. For example, with the BTR-80 in Figure 4, as you progress from the right flank to the rear, the right rear external exhaust remains highly visible but goes from a cigar-shape to something more like a circle and is clearly a circle in the rear view. The wheels are separated in the flank view, appear more "run together" in the rear oblique, and are difficult to distinguish from tracks in the rear view. The two rear exhausts that were clearly evident in most views are barely visible from the front. Figure 5 shows the BMP-2, where the exhaust is to the front on the right flank and has an elongated appearance. It can be seen from the rear and the front, but only as a small circle of light. The left flank presents a much cooler signature, as the engine and exhaust are on the right flank. With the left flank, soldiers must rely on other features such as shape and the more subtle temperature differences on the BMP-2 to identify it.

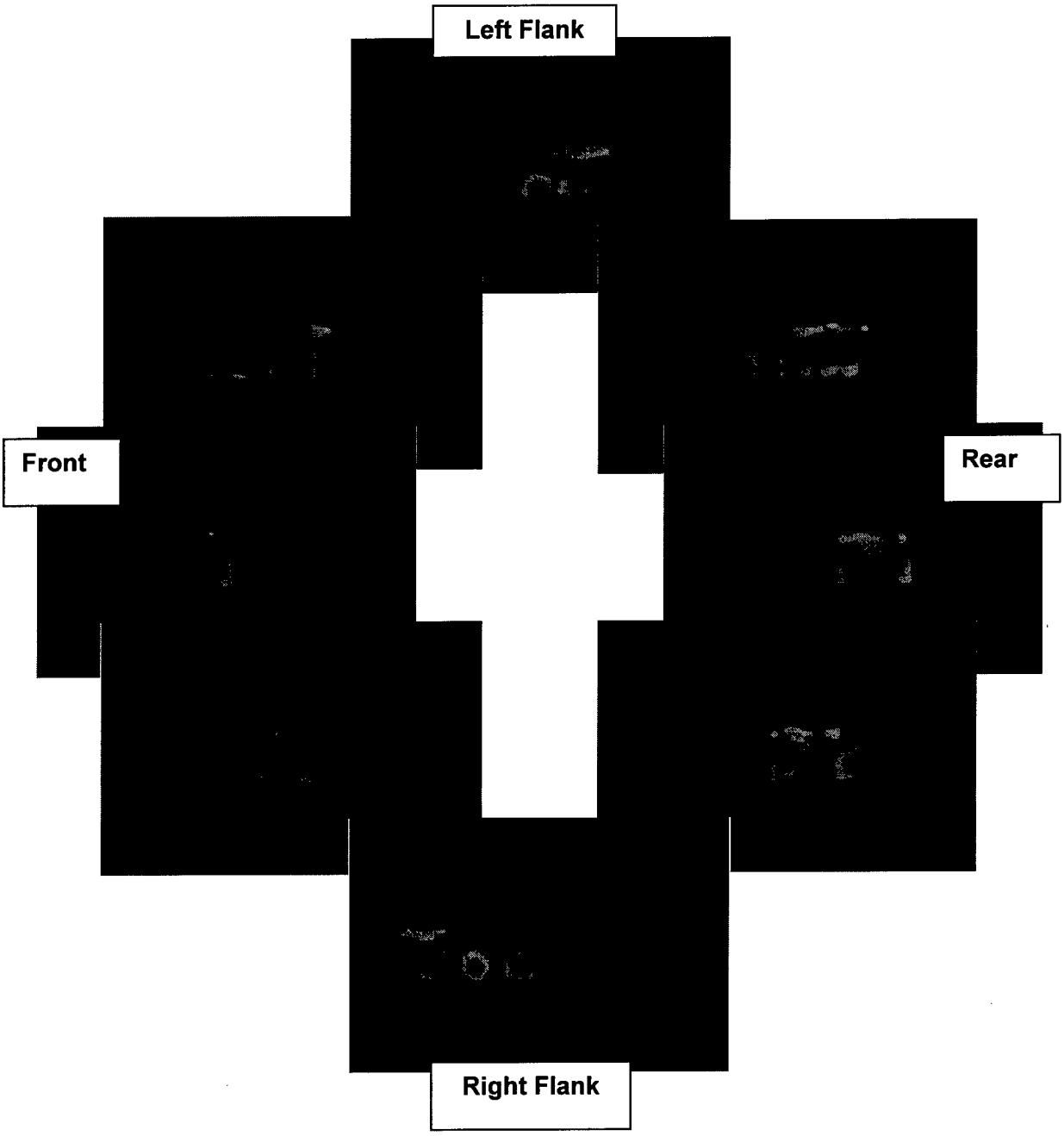


Figure 4. Eight aspects of the BTR-80 from the Proto-FLIR database.

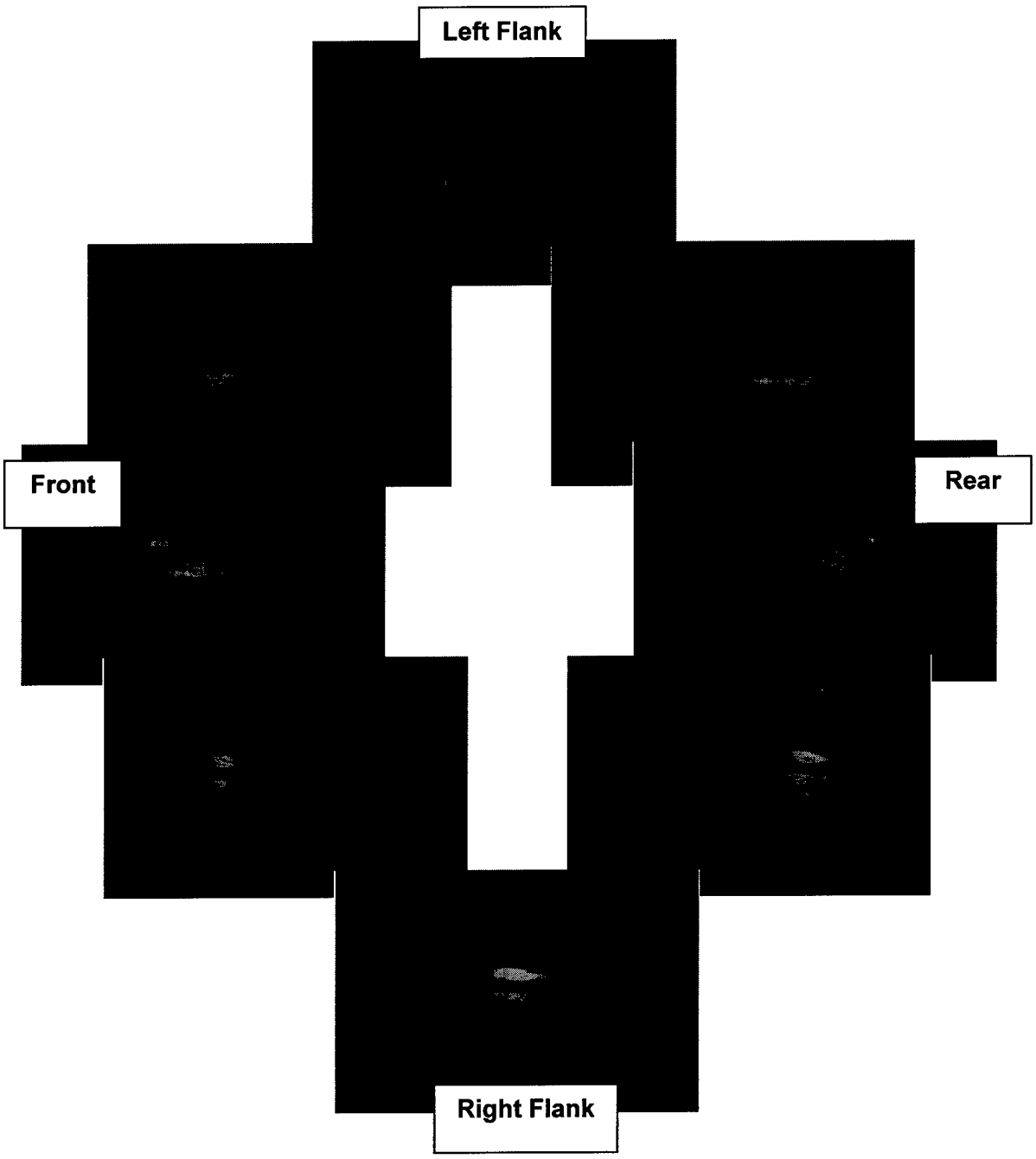


Figure 5. Eight aspects of the BMP-2 from the Proto-FLIR database.

After several vehicles have been presented, it may be advisable to check soldier's memory for key hot spots. If a touch-sensitive screen were available, it would be possible to have the soldier look at the visible daytime color display and then touch the areas of the vehicle that would appear hot. Performance feedback would follow. This feature would make the instruction interactive and keep motivation and interest high.

Although the most obvious hot spots are typically the engine, exhaust, and suspension, it is not simply these hot spots that create the thermal signature. For example, shape and whether the signature is the same on both flanks are also important cues. Figures 4 and 5 illustrate how both shape and hot spots contribute to the thermal signature.

So critical cues are not overlooked in the training software, the training developer should apply a strategy for analyzing an image. Without a strategy, soldiers are left to develop their own system by trial and error. Often these approaches do not make use of all the image and are subject, therefore, to greater chance of error. Soldiers will learn to identify vehicles more accurately if they are trained in how to identify a vehicle by applying strategies that break the image into components and also integrate these components. With thermal images, the whole is often more than the sum of its parts. So the integration process, which is dependent upon perception of the entire image, must not be ignored. As pointed out by Campbell (1990), it is the composite of these features that must be learned.

Within the aviation community, the WEFT strategy has been used since World War II (ADA, 1993; Campbell, 1990; Gibson, 1947) to train visual aircraft recognition. WEFT stands for wings, engine, fuselage, and tail. No commonly accepted strategy has been applied to combat vehicles, and none had been developed for thermal signatures per se. However, we (Dyer et al., 1997) developed a strategy which we labeled "S^4HEET." S^4HEET is an acronym referring to eight features to examine when studying thermal signatures of vehicles: size, shape, suspension, symmetry of the thermal signature, hull, engine, exhaust, and turret. Table 1 defines each dimension and provides examples.

One dimension in this table, typically not cited when training visible images, is the symmetry (non-symmetry) of a vehicle's thermal signature. The BTR-80 (see Figure 4) is a vehicle whose right and left flanks are symmetric, as are the right and left halves of the front and rear. On the other hand, the BMP-2 (see Figure 5) is asymmetric from both flanks and the rear and front views. The exhaust is on the right flank, not the left. The engine is on the right front and the exhaust is visible on the right. From the rear, the exhaust is visible on the right. Typically, it is the vehicle's hottest spots (engine and exhaust) that influence the thermal symmetry of the signature, although the location of major components such as the turret impact it as well.

The S^4HEET strategy can be applied to thermal signatures as seen during the day and night. Some features are visible both day and night; others less so. Typically the first priority is to describe features seen at night, as soldiers have other means of identifying vehicles during the day. Probably the best instructional strategy is to have soldiers master night thermal images, and then progress to day thermal images, which typically are more difficult (Dyer et al., 1997). Learning to discriminate vehicles with day thermal imagery is considered by most to be an

advanced skill. An instructional module on day thermal cues should be available once soldiers reach this phase in their training.

Table 1
S^4HEET Framework for Thermal Cues

Framework	Description	Examples
S: Size[a]	Size of vehicle relative to other vehicles in its class.	M60 is a large tank with a high profile. T72 is a small tank, with a flat silhouette.
S: Shape	Overall shape of the vehicle.	M113 is rectangular, often referred to as a toaster or a brick on tracks.
S: Suspension	Heat signature of tracks and wheels; nature of skirts, sprockets, etc.	M1 has hot suspension because of friction from heavy road wheels. The cut-out for the sprocket connects heat from the suspension with heat from the exhaust. Skirts are cooler at night than the suspension when tank is running. T72 has rubber/vinyl skirts that hide heat at night, but heat up during day.
S: Symmetry Of Thermal Signature	Whether both flanks present the same thermal signature; whether right and left sides of the front are mirror images of each other; and whether right and left sides of the rear are mirror images.	Both flanks of the M1 are basically symmetric, as are the rear and front. M2 flanks are not symmetric as the thermal signature from the engine and exhaust appears on the right only. Front is asymmetric because of engine location. Rear hull is symmetric, but turret and upper part of hull is asymmetric because of exhaust signature and TOW launcher.
H: Hull	Shape and thermal characteristics of the hull.	Flat top on T72 hull quite visible from the flanks.
E: Engine	Location of engine. Effect of type of engine on heat signature.	M1, T72, and M60 engines are centered in the rear. M2, BMP, and LAV engines are on front right. Turbine engine in the M1 presents a very hot signature.
E: Exhaust	Location of exhaust, size of exhaust outlet, and size and direction of exhaust plume.	M1 exhaust in the rear; exhaust directed downward and forms a plume. T72 exhaust is on the left side toward rear of hull; exhaust is directed downward.
T: Turret	Thermal characteristics of the turret; size and shape; location on vehicle.	M1 has needle nosed turret with angular sides. Storage boxes on sides present a cool signature. M60 turret is rounded and big. Large cupola on right is visible at close ranges.

[a] Size is best illustrated when there is a standard for comparison (such as a 6 ft. tall man) or when two or more vehicles are photographed simultaneously for comparison purposes.

Finally, an instructional module is needed on hard-to-discriminate vehicles. Some vehicles, at certain aspects and ranges, were confused with each other despite extensive prior training (Dyer et al., 1997). This training module could be used at different times during training. It could precede training on these images, be used for remedial training, or be a review. In this module, side-by-side comparisons of images would be displayed so the soldier can visually compare the vehicles. The instruction (audio, text, diagrams) to support this visual presentation would draw the soldier's attention to the critical differences in the thermal signatures, as these are the important teaching points that help soldiers distinguish similar vehicles (Birkmire, Karsh, Barnette, Pillalamarri, & Breitenbach, 1991). If for example, the T-72 and T-62 are confused, reiterating the fact that the exhaust is on the left flank of each does not help soldiers discriminate the two. Thus the discriminating features in this module would most

likely be different from the more general and absolute features presented during the initial instruction on each vehicle.

How to Establish Vehicle Sets

General strategies. When the goal is to teach soldiers to master an entire list of vehicles, you must decide how best to present the material. One approach is to train on all the vehicles — whole-task training. Another approach is to divide the vehicles into sets or parts and train on these sets — part-task training (Proctor & Dutta, 1995), culminating with training on or assessment of all vehicles.

Whole-task training will work if the number of vehicles and the total number of images are limited. Whole-task training can also be beneficial and quite efficient for sustainment of acquired skills — for example, refresher training. During initial training, we (Dyer et al., 1997) found that when the total number of images in a training session was greater than about 40 (e.g., 5 vehicles with 8 aspects each), whole-task training created some problems. As the number of images/vehicles increased, some soldiers encountered more and more difficulty in discriminating them. Frustration and fatigue mounted when they had to repetitively cycle through a large number of images in order to achieve the training criterion. Once they realized they had exceeded the allowable number of errors, some soldiers tended to guess in order to "get through" the session, rather taking advantage of learning from the remaining images. The whole-task approach can be inefficient because unnecessary time is spent on "overlearning" vehicles that are already mastered. It is also likely that with substantial repetitions, soldiers will begin to memorize the imagery rather than learn each vehicle's distinguishing characteristics.

When the database of interest is large, some variation of part-task training is required (Salisbury, 1990). Research has shown that breaking down large learning tasks into smaller component parts facilitates learning. However, there are many part-task training schedules. The challenge to the training developer is to select those schedules that make vehicle-recognition training efficient and effective, and maintain soldier motivation.

What are known as fractionated part-task schedules (Proctor & Dutta, 1995) apply to vehicle recognition training. There are three main types of fractionated schedules: repetitive-part, pure-part, and progressive-part. Interestingly, the pure-part was used in most of the experiments conducted on visual vehicle recognition by the Army Research Institute (Smith et al., 1989; Warnick & Kubala, 1979; Warnick & Smith, 1989). It was also used by Gibson (1947) and his colleagues in WWII research on aircraft recognition, although they recognized that more research was needed on this issue. Whitmore et al. (1968) used a variation of the progressive-part schedule in their aircraft recognition research. Our experiments (Dyer et al., 1997) used pure-part schedules, and pilot work was conducted with repetitive-part schedules.

What are these schedules and how do they differ from each other? What are the perceived advantages and disadvantages of each? Unfortunately there is limited empirical data regarding which training schedule is most effective in the learning of vehicle recognition skills. In fact, one schedule may not be the best for all soldiers or for all stages of learning. Therefore the training program should include more than one schedule in order to maximize learning for

all. Multiple options are easily provided in a multi-media medium; less easily generated with other instructional techniques. The advantages and disadvantages cited below for each part-task schedule are based on prior research as well as our (Dyer et al., 1997) on-site observations of soldiers as they trained with the Proto-FLIR programs.

We illustrate each of these three schedules with vehicles, labeled A, B, C, D, etc. The assumption is that eight aspects of each vehicle are presented, generating many training trials within each vehicle set. Figure 6 is an example of a pure-part schedule. The pure-part schedule divides the entire pool of vehicles into distinct sets. Soldiers then train on each of these sets. The pure-part name comes from the fact that no vehicle in one subset is mixed with vehicles in another set. At the end of the part-task training, soldiers can train on all vehicles or be tested on all vehicles. In either case, the final set requires soldiers to discriminate vehicles that have not been presented together previously. In one series of vehicle recognition studies (Smith et al., 1989; Warnick & Kubala, 1979; Warnick & Smith, 1989), the typical procedure was to train soldiers on 25 vehicles. These 25 vehicles were divided into five sets, each set consisting of five different combat vehicles. After all five sets were presented, soldiers were administered a whole-task test of all vehicles.

Part-Task Vehicle Sets			**All Vehicles - Whole Task**
Set #1	**Set #2**	**Set #3**	**Set #4**
Vehicle A	Vehicle C	Vehicle E	Vehicle A
Vehicle B	Vehicle D	Vehicle F	Vehicle B
			Vehicle C
			Vehicle D
			Vehicle E
			Vehicle F

Figure 6. Illustration of pure-part training schedule.

What are some factors to consider in determining whether a pure-part schedule should be used? An asset to this approach is that it provides short periods of practice, which give better results than long concentrated periods of study. If the number of vehicles/images is relatively small, it is also an efficient means for training and review. It is also efficient for soldiers whose initial skill is high. They are not required to repeat vehicles with which they are highly familiar, as can be the case with a repetitive-part schedule.

With a pure-part schedule, it is important to select the vehicles in each set carefully. If the vehicles in a set are either too distinct or too similar, learning may be impaired. For example, it may be such that asking soldiers to distinguish a wheeled APC (i.e., LAV) from a tank (i.e., M1 Abrams) is so self-evident that using time to present this pair is inefficient and of little training value. Similarly, if highly similar vehicles are presented (i.e., pairing the T-72 and the T-72 with reactive armor), especially to soldiers with low-skill levels, time may be wasted because few will reach criterion. Using a pure-part schedule with this vehicle set might cause unnecessary frustration in some soldiers. An appropriate balance of difficulty, based on the skill level of the soldier and the training goals of the instructor, must be considered. It is suggested

that vehicle sets be ordered from low to high degrees of confusability (i.e., in increasing difficulty) so as to allow soldiers to build upon their successes.

With the pure-part schedule, unexpected confusions may occur when all vehicles are combined in the final set. Soldiers may learn to distinguish the vehicles presented in the prior sets, but become confused by the effects of interference when all vehicles are presented. We (Dyer et al., 1997) found this in our research, particularly when the thermal signature from a vehicle in one set was similar to that of a vehicle in another set.

Figure 7 illustrates the repetitive-part schedule. This schedule is incremental. A new vehicle is added to each new part-task set. Thus each time, training is repeated on the vehicles presented previously. Training culminates with all vehicles.

Part-Task Vehicle Sets				
Set #1	**Set #2**	**Set #3**	**Set #4**	**Set #5 - All vehicles**
Vehicle A	Vehicle A	Vehicle A	Vehicle A	Vehicle A
Vehicle B	Vehicle B	Vehicle B	Vehicle B	Vehicle B
	Vehicle C	Vehicle C	Vehicle C	Vehicle C
		Vehicle D	Vehicle D	Vehicle D
			Vehicle E	Vehicle E
				Vehicle F

Figure 7. Illustration of repetitive-part training schedule.

The intended merit of this approach is that it allows soldiers to learn one vehicle at a time. Unfortunately, there are several factors that interfere with this endeavor. For example, using this approach, it is possible that soldiers will not learn the newly presented vehicle in the same manner or depth as they did the original pair. When a third vehicle is first presented, they are is likely to say, "This is not the M1 or the T-72, so it must be the M2." They are therefore learning by exclusion rather than inclusion. Soldiers do not learn to associate specific vehicle characteristics with the label M2, but instead simply notice that the image presented does not match their template of the M1 or T-72 in the previous set. Another disadvantage is that soldiers can become over-trained on some vehicles and less-well trained on others. With the example in Figure 7, Vehicles A and B are presented repetitively, in all five sets, while Vehicle F is presented in only one set. If A and B are easily-learned vehicles or already known by most soldiers, this may be time wasted. In contrast, if soldiers are faced with many presentations of a difficult-to-learn vehicle, the chances that they may learn it are maximized. Importantly though, soldiers may become fatigued, bored, or frustrated with redundant and lengthy exercises. Pre-test information on each soldier could be used to tailor the sequence to his strengths and weaknesses (Merrill & Salisbury, 1984). But computer algorithms that accomplish this easily and appropriately are difficult to develop. The repetitive-part schedule can be very effective, but the instructor must consider carefully the vehicle sequence in designing training sessions.

The last schedule is the progressive-part schedule. It combines features of the pure-part and the repetitive-part schedules. It integrates training on sets of vehicles; a procedure that is lacking in pure-part, but in a manner that is not as repetitious as repetitive-part (see Figure 8).

Part-Task Vehicle Sets				All Vehicles
Set #1	**Set #2**	**Set #3**	**Set #4**	**Set #5**
Vehicle A	Vehicle C	Vehicle A	Vehicle E	Vehicle A
Vehicle B	Vehicle D	Vehicle B	Vehicle F	Vehicle B
		Vehicle C		Vehicle C
		Vehicle D		Vehicle D
				Vehicle E
				Vehicle F

Figure 8. Illustration of progressive-part training schedule. (Pairs of vehicles illustrate this schedule, but pairs are not required. The smallest sets could include more than two vehicles.)

In progressive-part training, vehicle sets are presented first in isolation and then in combination with previously presented sets. This schedule includes spaced practice of the vehicles presented previously, as opposed to continuous practice with repetitive-part and no spaced practice with pure-part. Like the pure-part and repetitive-part schedules, a final set of all vehicles is also presented. Many of the same factors impinging on the incremental, repetitive-part schedule (i.e., vehicle selection, fatigue, boredom and overlearning) are important considerations here as well. This schedule, however, has the strength of allowing soldiers to review and integrate their knowledge as they go. It is hypothesized that when compared to a pure-part schedule, the progressive-part schedule will yield higher final set scores due to the lower amounts of cross-set confusions. This approach may not be as well suited for soldiers with high initial skills in vehicle identification as this amount of repetition and review may not be necessary.

In summary, points made by Lintern (1989) are very relevant to the choice of part-task training schedules. Part-task schedules do lead to substantial and persistent enhancements in transfer of skill. However, in decomposing tasks and selecting training schedules, critical integration skills may not be trained; components that offer no substantive learning challenge may be selected for intensive training; and learned high levels of skill do not always develop resistance to interference from additional loads. The training developer should require that the vehicle identification software allow soldiers and instructors to access any part-task schedule, so training can be adapted easily to match the training objective and immediate need.

Selecting vehicles for the sets. Often, military instructors select vehicles for training by class or type. This is a logical and appropriate approach as soldiers operate weapon systems designed to be effective against certain types of vehicles. For example, some soldiers man anti-armor weapon systems, making tanks their priority. Some employ weapons effective against thin-skinned vehicles, making logistic vehicles and some personnel carriers the primary targets. Overall, vehicles within a class are more alike than vehicles in different classes. However, there will always be some vehicles in different classes that are easily confused because of similar

features. Figure 9 illustrates these concepts as do Figures A-1 through A-8. In Figure 9, the four circles represent four types or classes of vehicles: tanks, APCs, artillery and air defense, and logistic vehicles. The areas where the circles overlap represent vehicles from these classes with similar thermal signatures.

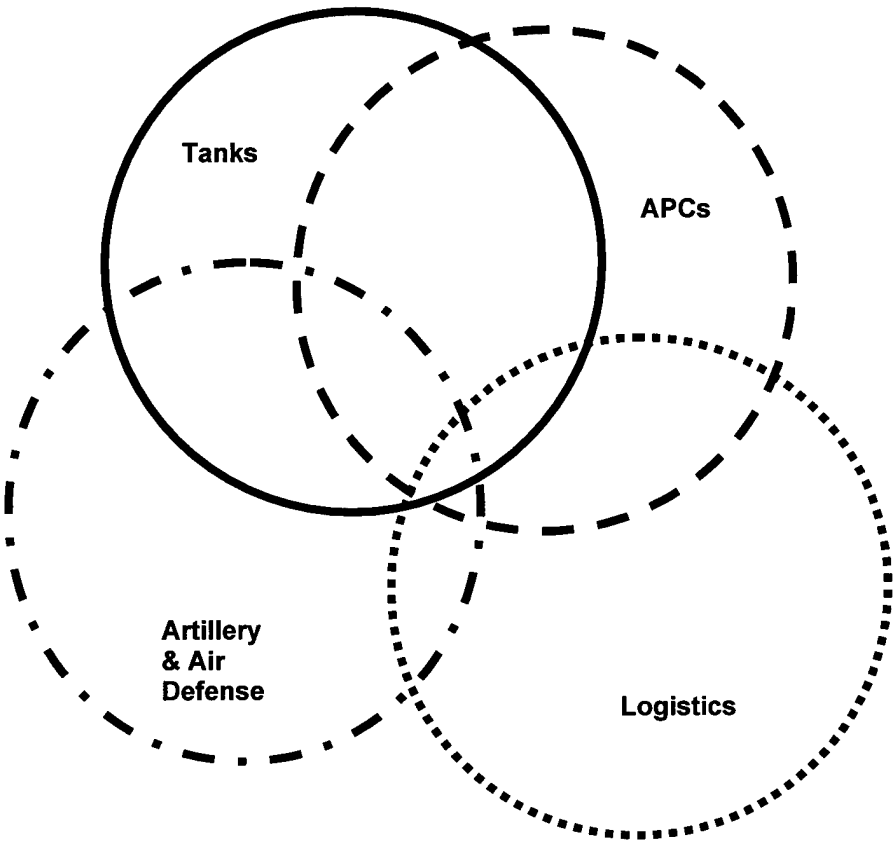


Figure 9. Graphic representation of potential overlap (degree of similarity) in the thermal signatures of vehicles from different classes.

Another factor that instructors consider is the vehicle's country of origin and the countries that possess the vehicle. Although it is not as easy to separate friendly vehicles from enemy vehicles as it once was, classifying vehicles as Soviet or US or NATO is still a useful distinction.

The training objective is to have soldiers identify a particular set of vehicles. However, training only on the vehicles in the target group is not sufficient, because other vehicles can be very similar to those in the target group. Training on these other vehicles is also required, as soldiers will not automatically discriminate the vehicles from the two pools (Dyer et al., 1997). Failure to attend to these potential confusions is likely to contribute to misidentification on the battlefield.

Therefore, the instructor and training developer must consider not only the vehicles of interest, but also the vehicles that could be confused with vehicles in this target group. An important training principle to remember is that the nature of the confusions among all vehicles in the database should influence the specific vehicle sets and the training sequence. If soldiers are to accurately and consistently discriminate two or more vehicles with similar thermal signatures, these vehicles must be presented in the same vehicle set. Training them in separate sets was not enough, despite extensive prior training (Dyer et al., 1997). Other investigators (Nesbit & Yamamoto, 1991) have also found that when using part-task training schedules, it is better to present similar items in each group so as to reduce the amount of interference when all items are regrouped in a posttest. These findings answer a question raised by Gibson (1947) in early research on aircraft recognition regarding whether discriminations could be best taught by presenting dissimilar aircraft together or by presenting similar, confusing aircraft together.

Although presenting similar vehicles together is necessary to reduce confusions, the trainer is still left with the burning question of how best to present and train the vehicles. Additionally, if only limited training time is available, then one must prioritize which vehicles are to be mastered.

Based on our experiments, research by Whitmore et al. (1968), and general guidance on computerized drill-and-practice (Merrill & Salisbury, 1984; Salisbury, 1990), a good approach is as follows:

❶ Select the vehicles of interest (e.g., by class, country of origin).

❷ Place the vehicles in sets on the basis of their similarity in thermal signature. Determine these vehicle sets from earlier training results or on the basis of experts' judgements. If soldiers are relatively inexperienced, do not put really hard-to-discriminate vehicles (e.g., T-72 and T-72 with reactive armor) together initially.

❸ Adhere to the other guidelines presented previously (i.e., use relatively small vehicle sets, train on close ranges first).

❹ Consider a progressive-part training schedule. Develop several training sets with vehicle overlap as a means of providing spaced practice. Embed spot tests to check on progress.

❺ Test soldiers on all vehicles of interest after completion of the initial training.

❻ If confusions still remain among some vehicles, create modified vehicle sets and training schedules that focus on the vehicles soldiers confused with each other. Eliminate from the sets vehicles that were not confused with each other. [Remember that with only two vehicles in a set, a soldier has a 50/50 chance of correct identification. A more challenging situation and better assessment of skill at this more advanced learning phase is to include three or more vehicles per set.]

❼ Conduct training on the modified vehicle sets and test again.

❽ Finally, select vehicles from outside the target group that are likely to be confused with vehicles in the target group. Create vehicle sets requiring soldiers to make the appropriate discriminations. For example, if the primary training is on tanks, but you know that soldiers typically confuse the M2 BFV and the ZSU with tanks, then create practical exercises that require soldiers to discriminate these "nontanks" from tanks.

❾ Assess performance.

❿ Plan for spaced review of the vehicles.

An example of how to create a part-task schedule tailored to specific confusions is presented. Suppose the training results show that the M1, T-72, T-62, T-55, and Leopard are confused with each other, as depicted in the confusion matrix in Table 2. The second column in the table indicates that the T-55 was identified correctly 65% of the time; but 25% of the time it was misidentified as a T-62, and 10% of the time as a T-72. Overall, the confusion matrix indicates that the Soviet T-series tanks were confused with each other, as were the M1 and the Leopard. In addition, the M1 and T-72 tended to be confused, and the Leopard with the T-62. These confusion patterns can be used very effectively to design a training sequence, because they tell us what needs further training and what does not.

Table 2
Illustration of a Vehicle Confusion Matrix: Vehicle Presented by Vehicle Named (% Responses)

Name of Vehicle Given by Soldier	Vehicle Presented				
	T-55	T-62	T-72	M1	Leopard
T-55	**65%**	20%	10%		
T-62	25%	**70%**	5%		5%
T-72	10%	5%	**75%**	10%	
M1			10%	**75%**	20%
Leopard		5%		15%	**75%**

Note. Column percentages sum to 100%. Diagonal cells give % correct responses.

Figure 10 outlines one possible training schedule based on this confusion matrix. The sequence does not correspond directly to the part-task schedules discussed previously. But it does repeat some vehicles, a feature of both the repetitive-part and progressive-part training schedules. It focuses on vehicle sets containing the vehicles the soldiers confused in the test that followed training.

Vehicle Sets			
Set #1	Set #2	Set #3	Set #4
T55	T55	M1	M1
T62	T62	Leopard	Leopard
	T72		T62
			T72

Figure 10. Illustration of a training sequence that addresses the vehicle confusions depicted in Table 2.

Because of the high rate of confusion between the T-62 and the T-55, a vehicle set composed of only those two vehicles was created (see Set #1 in Figure 10). In the final set (#4), vehicles involved in some of the minor confusions were included in order to provide integrative training and a check on the effectiveness of the prior training. This sequence does not require soldiers to discriminate vehicles they found easy to distinguish from each other. Specifically, the T-55 was not included in a vehicle set with the M1 and the Leopard. With this schedule, soldiers devote their training time to the vehicles they confused. As these vehicles had been found

difficult to discriminate, the total number of vehicle sets was limited in order to reduce potential frustration and fatigue.

Many training options are available to the instructor at this stage of training depending on the nature of the confusions. You might want to train with the sequence depicted in Figure 10 at near ranges and then repeat it at far ranges. Or you might want to train with white-hot images and then black-hot images. Or you might want to train with night images and then day images. If the confusions were confined to front and rear views, then most images could be front and rear, with some other aspects included to provide diversity, interest, and spaced practice. A multitude of strategies can be used. But the primary training goal is to ensure that soldiers can discriminate the vehicles they found highly similar.

The same approach can be applied to train soldiers to discriminate vehicles in the original target set from other vehicles. Confusion matrix data like that in Table 2 can be extremely valuable in the original development of a training program. If we know which vehicles soldiers tend to confuse (that is, those vehicles that are hard to discriminate initially, remain difficult during training, and are hard to retain over time), we can design special training sequences to focus on them after the initial training on all vehicles. Or the training software could be "intelligent" with built-in algorithms that automatically generate new training sequences tailored to the confusions unique to each individual.

A final comment on creating vehicle sets with similar vehicles. Eventually soldiers should be able to discriminate vehicles with highly similar thermal signatures, particularly at the closer ranges. However, it may not be advisable to put the most difficult discriminations in initial training, as this can be frustrating. Phase-in these comparisons in the training sequence.

The images in Figures A-1 through A-8 show how the ease with which a vehicle is identified depends on other vehicles in the set. These figures compare the M2 BFV with three other APCs (LAV-25, Warrior, M113) and with three vehicles that are not APCs --- a tank (T-72), artillery vehicle (M109), and logistics vehicle (HEMTT). Each aspect is shown in order to illustrate how vehicle similarities and differences can change with aspect. Typically the M2 is more similar to the other APCs than to the three other vehicles. But from some aspects it can be easily confused with one or more of the other vehicles. If a vehicle set were composed of just the four APCs, it would be very difficult to master. On the other hand, a vehicle set with the M2, T-72, M109 and HEMTT would be easier to learn. If vehicle scores were obtained for each set, the M2 would appear to be a difficult vehicle using the APC set, yet an easy vehicle in the set with no APCs. Further, the difficulty of either set could be heightened simply by an increase in range or by eliminating the flank views. These displays reinforce the fact that vehicle recognition is not an absolute property of the vehicles, but is relative to the context in which they appear (Birkmire, et al., 1991). This principle must be kept in mind when designing vehicle sets for training and testing.

Training Exercise Formats and Strategies

To most soldiers, the vehicle identification task is intrinsically motivating. And if the training exercises are highly interactive, are progressively challenging, provide timely feedback,

and stress the perceptual nature of the task, soldiers will learn while also enjoying the training experience. Exercises that meet these criteria will be, by default, "game-like." Many exercise formats are possible, but in all cases it is important to keep the following in mind:

- **The skills to be trained**. More than one skill can be of concern: determining the vehicle's class, identifying the vehicle by name, determining vehicle angle or aspect, responding quickly as well as accurately, etc.

- **Perceptual learning**. Make maximum use of the image database in training exercises.

- **Integration of initial instruction with interactive practice**. Instruction on each vehicle's characteristics should be well integrated with the vehicle sets and part-task training schedule.

- **Advanced skill training**. Develop additional exercises to improve soldier skills with more challenging imagery; that is, imagery not included in the initial instruction and practice sessions.

- **Performance feedback**. Feedback that provides diagnostic information is invaluable. Good feedback will prevent learning plateaus, help soldiers transfer and retain skill, and make the learning process meaningful.

- **Individual differences**. At a minimum, computer-based instruction can easily adapt to differences in learning rates. More challenging, however, is to adapt to differences in response patterns both at the start of training and during training.

Integration of initial instruction and training exercises. Initial instruction on a set of vehicles must provide images of each vehicle and cues to help soldiers understand its thermal signature, followed by exercises that present images of vehicles and require soldiers to name the vehicles. Suggestions on the features to include in the initial instruction on each vehicle have been presented and are not repeated here. However, the sequence of this instruction must correspond to the structure of the vehicle sets. And the computer software must provide the flexibility to adapt to the part-task schedule selected. Examples of this concept follow.

If a repetitive-part schedule is selected as depicted in Figure 7, then instruction would be given on the two vehicles in the first set followed by training exercises on those two vehicles. Then the third vehicle would be presented, followed by training exercises on the three vehicles. This incremental type strategy would continue until all vehicles in the set are included.

If a pure-part schedule is selected (see Figure 6), a different instructional sequence would be adapted. Instruction would be given on the vehicles in the first set, followed by training exercises. Then instruction would be given on vehicles in the second set, followed by training exercises, and so on. A review of the discriminating features of the vehicles before practice on the final set of all vehicles could be an option.

If a progressive-part schedule is selected (see Figure 8), instruction would be given on the vehicles in the first set, followed by training exercises on that set. Then instruction would be given on the vehicles in the second set, followed by training exercises on Sets 2 and 3. Then instruction would be given on the new vehicles in the fourth set, following by the next two sets of exercises, and so on. Again, an instructional review of all vehicles could be optional.

The Proto-FLIR programs included another feature, which kept soldiers involved during the instructional phase. This was called aspect matching. After instruction on a vehicle, all eight aspects of that vehicle were randomly displayed on the screen (see Figure 11). Soldiers then had to drag and drop each image to the appropriate box at the bottom of the screen. Soldiers first worked with night, white-hot images, and then day, white-hot images.

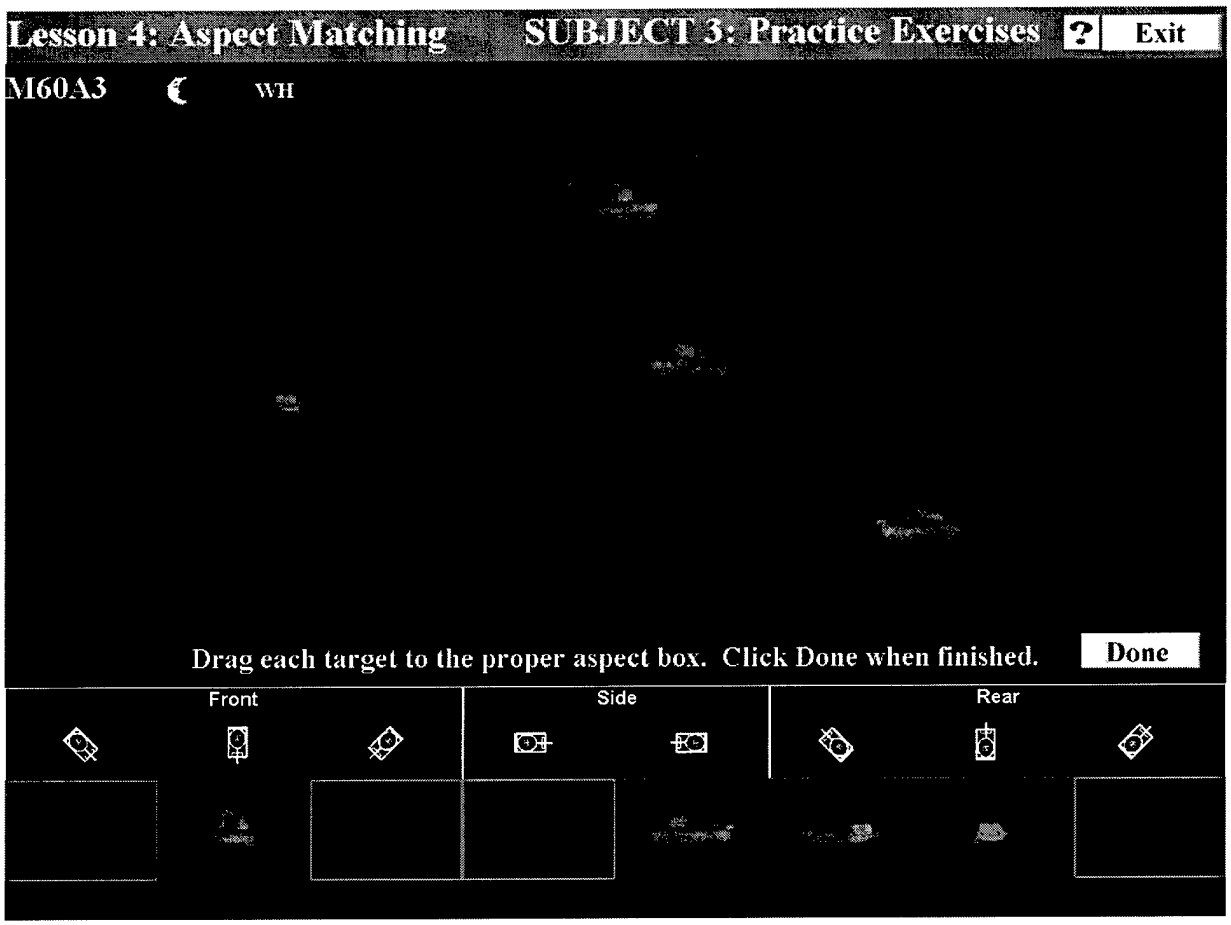


Figure 11. Aspect Matching exercise from the Proto-FLIR programs.

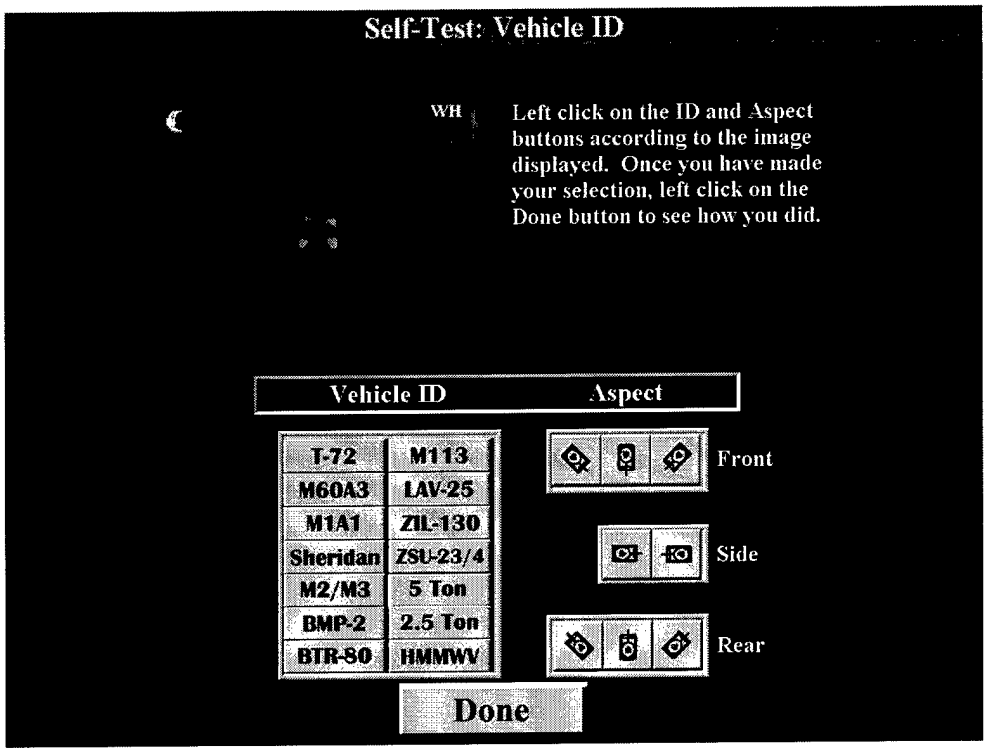
Type of imagery. During initial training exercises, we believe it is best to present night, white-hot images of all eight aspects at the near ranges. This imagery should be the foundation of training for the following reasons. First, all thermal sensors have white-hot polarity, but not all have reverse polarity with the capability of switching to black-hot. Second, the primary use of thermal sensors is at night, although these sensors add substantial target acquisition capability during the day as well. Third, near ranges make it easy for soldiers to relate the thermal cues presented to the image they see, and the vehicles will not be extraordinarily difficult for them to master, thus maintaining motivation and interest while simultaneously gaining skill. Fourth, training exercises incorporating all eight aspects help soldiers attain a 360° view of each vehicle, allowing soldiers and the instructor to determine which, if any, aspects need special attention.

Additional comments are made regarding range as it is a critical issue for the instructor. When should close-up images be used; when should distant views be used? We suggest that the more difficult long-distance imagery be introduced after the more fundamental concepts of heat signatures are mastered with vehicles displayed at closer ranges. During the practice sessions that follow, gradually increase the ranges presented. Presenting soldiers with imagery of increasing difficulty, rather than all the hard ones first, not only allows them to obtain a sense of success, but also enables them to build upon and integrate information already previously. We suggest that soldiers be trained on two adjacent ranges simultaneously. Because the differences between adjacent ranges are not substantial, training in this manner allows for efficient learning and integration of the material. It is also more interesting for the soldiers.

Exercises for initial training. The Proto-FLIR programs met the complex objectives of thermal vehicle signature recognition by using two distinct training exercises. One exercise stressed signature understanding while the other emphasized speed. Both required the soldier to be accurate and to achieve a pre-determined performance criterion. Each incorporated immediate knowledge of results feedback as well as evaluative feedback. As defined here, immediate feedback was information given to soldiers on the correctness of their response to each image displayed. In one exercise, feedback was simply a red or green light; in the other, feedback illustrated why the answer was wrong. After finishing an exercise, evaluative feedback summarized information on right and wrong answers. It, therefore, documented the soldier's progress in learning to discriminate among all vehicles in the training set.

The exercise format designed to facilitate signature understanding was called Vehicle ID (Veh ID). It was not timed and it allowed soldiers to change their answer before signifying they were done. The Veh ID exercise presented an image and required selection of the vehicle's name and aspect (see Figure 12). If soldiers correctly identified the vehicle and its aspect, they were given a text-based confirmation (the word "correct" was displayed in green). If soldiers responded with the incorrect vehicle or the incorrect aspect, an image corresponding to the incorrect answer was displayed next to the original image for purposes of comparison. Soldiers were encouraged to compare the two images, using this comparative display to understand differences in the heat signatures (see Figure 12).

The exercise format emphasizing speed was called Signature Challenge (SC). SC (see Figure 13) presented soldiers with an image and buttons with the names of the vehicles in the training set. Alongside the image, a timer counted down the seconds remaining to respond, and a



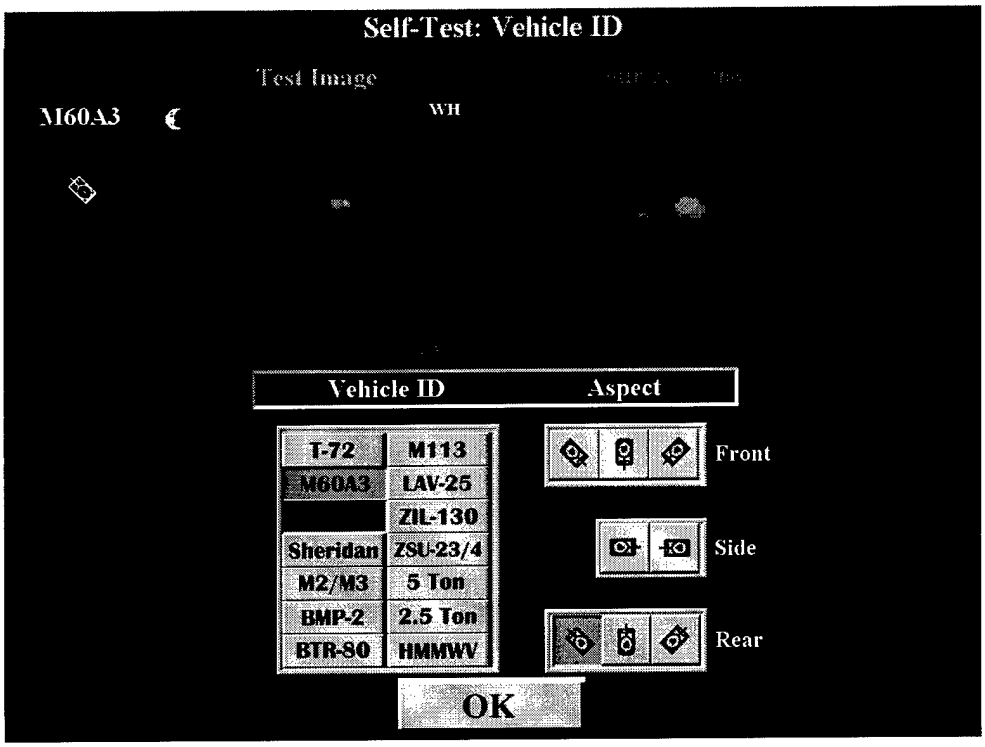


Figure 12. Vehicle Identification exercise displays of the response format and of the corrective visual feedback after responding (from Proto-FLIR programs).

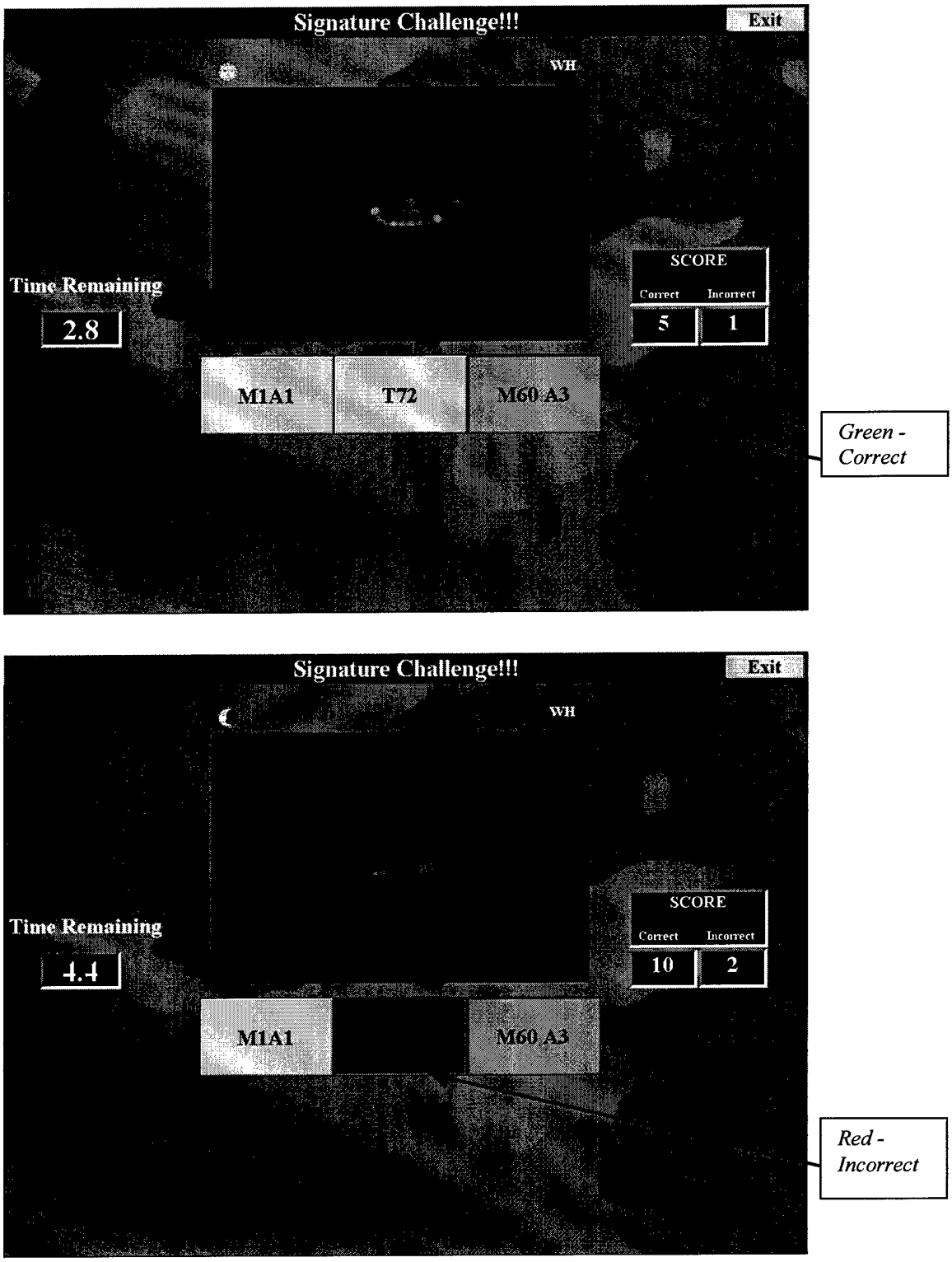


Figure 13. Signature Challenge exercise displays with feedback for correct and incorrect responses (from Proto-FLIR programs).

a tally appeared to the right indicating the number of images presented and the number correctly identified. The goal of the exercise was to respond with the correct answer as quickly as possible, although the time of exposure was controlled by the instructor. Soldiers could not change their response. If the correct name was selected, the button with the vehicle name changed to green. If the incorrect response was selected, the correct button turned green and the incorrectly selected button turned red. A warning beep and a text message indicating an error also accompanied wrong answers.

These two training exercise formats, Veh ID and SC, were extremely effective. They were challenging, maintained soldier interest, and provided the desired skill. The images and the sequence of vehicles could be controlled by the instructor, providing tremendous training flexibility. Based on our research (Dyer et al., 1997), we feel that the Veh ID format should be used in initial training of soldiers who have limited experience with thermal imagery. As a rule of thumb, if soldiers score below 70% on a pretest, they will benefit greatly from the visual corrective feedback in Veh ID. Having soldiers determine the aspect of the vehicle also led to closer scrutiny during the learning process. The SC format sometimes led soldiers to focus on responding quickly, rather than accurately. If soldiers score high on a pretest, SC may be the more appropriate exercise for initial training. Although, soldiers took more time in Veh ID, as it was not timed, this increased time occurred mostly for soldiers with limited initial skill. Those who already knew many vehicles responded quickly, resulting in times similar to those in SC.

An optional feature in these two exercises was audio cues when errors were made. The audio cues pertained only to thermal features of the correct vehicle. Although helpful in some circumstances, often this audio feature interfered with the perceptual learning process. This interference was most noticeable during Veh ID when the audio cues did not address the cues that discriminated the vehicles, either because the cues were not visible from the aspect presented or the features cited were in fact the same for both vehicles. For example, soldiers often confused the T-62 as a T-72. But an audio cue that stated that the T-62 has its exhaust on the left flank does not help discriminate the T-62 from the T-72, because the T-72 also has its exhaust on the left flank. Presenting this as a discriminating cue, therefore, did not help soldiers who confused these two vehicles. The intent of the audio cues was to provide a form of tutoring during the learning process. But when audio cues distract from the perceptual learning process and do not provide the cues that differentiate the similar-appearing vehicles, this approach is not recommended. Alternative approaches would be to allow soldiers to review the instructional module, use the library of images for self-study, or both.

Another exercise format that involved vehicle matching did not work well and was dropped from the program. This format required the soldier to determine which of four images was the same vehicle as the vehicle in the center of the screen (see Figure A-9). Feedback was provided on the correctness of the soldier's selection. The problem with this exercise format was that soldiers only had to match vehicles, not name them. Frequently, they matched correctly on the basis of the vehicle's shape and other thermal characteristics, without knowing the vehicle's name. Thus soldiers did not develop skill in naming vehicles with this training exercise.

Although not used in our research, some writers in the area of computer-based instruction (Clariana, 1990) suggest the use of the answer-until-correct approach. In this approach, soldiers

are presented with a stimulus (i.e., FLIR image of a combat vehicle), they must then select the correct response among a pool of vehicle names. When an error is made, they are given the message, "No, Try Again." Presumably soldiers will use this feedback to reduce the number of vehicle confusions and increase the level of accuracy. Unfortunately, for those soldiers who are having difficulty, the answer-until-correct method tends to be frustrating. Additionally, unless soldiers are using the additional information for learning as opposed to a "guess-until-correct" game, this approach will be an inefficient use of training time and will not enhance learning or retention.

Two other key features are important in the design of any exercise format: a criterion should be established that soldiers must reach before progressing to the next vehicle set, and images within a set should be presented randomly to prevent soldiers from learning the image sequence. Both features are easily implemented in a computer-based program. We also learned that if soldiers had to repeat an exercise four times or more they needed help. The additional repetitions were of no or limited benefit. At that point in the training, they needed to go back and study the vehicles being confused. So it is a good idea to implement a "three strikes, assistance needed" rule in the software.

Another factor to keep in mind in designing and implementing vehicle recognition training is that soldiers should not necessarily complete all training in a single setting. Spaced practice and spaced reviews will enhance learning and retention over massed practice. As such, with a multi-media system, the software needs to keep track of each soldier's progress. When returning to training, soldiers can then begin where they left off rather than starting the training over again.

Exercises for advanced training. The Veh ID and SC exercise formats are also excellent tools for sharpening soldier's vehicle recognition skills. Advanced training requires a change in the difficulty of the vehicle sets, rather than the exercise format. After completing the initial exercises with near, white-hot night images, more challenging imagery sets should be given. Greater difficulty can be implemented by including imagery at farther ranges, day thermal images, highly confusing vehicles, shorter times to respond in SC, etc. In addition, exercises with moving vehicles, partially exposed vehicles, etc. could be included at this point. The software should allow a variety of ways of establishing vehicle sets to match advanced training and sustainment needs.

Training feedback to the soldier and the instructor. Retention of vehicle recognition skills can be improved by increasing the meaningfulness of this task. The goal of training should not be to simply "burn" the information into soldiers' memories, but rather to provide them with strategies with which to think about and analyze the instructional material so they can apply these principles when novel stimuli are encountered. Providing feedback is one way to create meaningfulness.

Feedback has long been acknowledged as an important factor in the facilitation of learning, especially if this feedback is immediate. Because there are many forms of feedback, one must decide which form is the best suited for providing soldiers information about their performance on particular tasks. For example, knowledge of results typically provides simple

information on the correctness or incorrectness of a response (right/wrong; correct/incorrect). This type of feedback is critical to any skill.

However, given the perceptual nature of the vehicle recognition task, feedback that provides some knowledge of performance and directs the soldiers to specific, individually tailored information regarding their perceptual confusions is also recommended. This form of feedback directs attention to the critical aspects of performance that must be modified. In our experiments, soldiers obtained knowledge of performance feedback in the Veh ID exercises. This approach provided corrective visual feedback, allowing soldiers to compare and contrast images of the two vehicles they confused (refer to Figure 12). Soldiers began to understand why they incorrectly identified the vehicle. This form of corrective feedback has been found to be superior to the simple correct/incorrect feedback approach in many types of instructional material (Kim & Phillips, 1991; Proctor & Dutta, 1995). Comparative, visual feedback, tailored to each soldier's errors, typically cannot be given in a classroom setting. Yet, creating computer software with this capability is easily accomplished.

The results of our experiments reflect the complex nature of providing feedback. In particular, soldiers who had difficulty in mastering vehicles had better, more steady performance gains in the Veh ID exercise than SC. In addition, soldiers exposed to Veh ID exercises scored higher on tests of transfer than those who trained on SC. Based on these findings, it appears that soldiers exposed to Veh ID training were engaging, to a greater extent, in what is called the high road to transfer, or the intentional, mindful abstraction of material from one context and application of it to new, oftentimes more complex, contexts (Salomon & Perkins, 1989). These findings could reflect the differences in the nature of the feedback, the untimed nature of the exercises, or both. However, we believe that the visual corrective feedback played an important role in this enhanced performance, based on the time soldiers spent examining the images when mistakes were made.

Trial-by-trial feedback during training, whatever its form, should be supplemented with summary feedback at the completion of a vehicle set. Typically, the percentage correct (with X of Y correct) will be provided. But this information does not indicate strengths and weaknesses. Soldiers must rely on their own internal understanding of the material in order to adjust their performance. Therefore, soldiers who have a better understanding of the material to begin with will benefit more from this approach. Those who are confused about their mistakes and the material to be learned will continue to flounder.

We recommend presenting three other types of summary feedback on each individual: percent (%) correct responses for each vehicle; a matrix showing which aspects resulted in each vehicle being identified incorrectly; and the number of sessions to achieve the criterion for each vehicle set. When these summaries should be provided is shown in Table 3. This information should be available to soldiers and instructors in both hard-copy and electronic-copy form.

Figure 14 illustrates the matrix feedback provided at the end of each vehicle set in the Proto-FLIR programs. When an error was made for a specific aspect, the name of the vehicle confused with the displayed vehicle was presented in the cell. The hypothetical data in Figure 14 are on six vehicles: 2 tanks - the M1 and the T-72; 2 tracked APCs - the M2 and the BMP-2; 2

Table 3
Recommended Summary Feedback on Each Soldier

Type of Feedback	Timing of Feedback		
	After each vehicle set (regardless of whether criterion was achieved)	After achieving criterion on a vehicle set	After tests
Total % correct and # correct (X of Y correct)	X	NA	X
% Correct for each vehicle presented	X	NA	X
Matrix displaying vehicle errors by aspect	X	NA	X
# Sessions to achieve criterion	NA	X	NA

wheeled APCs - the LAV-25 and the BTR-80. When the M2 BFV was shown, it was never incorrectly identified. The two tanks (M1 and T-72) were confused when the right flank and right oblique views were shown. These aspects do not show the exhaust of the T-72, a key identifying feature, which is on the left flank. The LAV-25 was misidentified as the M2 from two rear views. From certain angles these APCs look very similar, particularly when wheels cannot be distinguished from tracks. Finally, there was some confusion among the other Soviet vehicles.

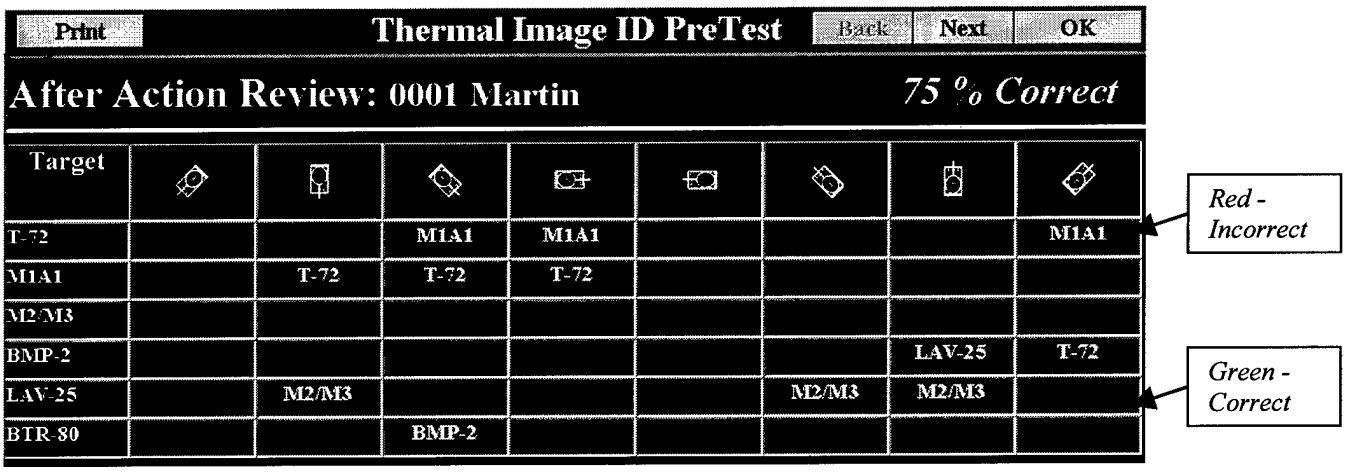


Figure 14. Feedback matrix: Vehicles by aspects (from the Proto-FLIR programs). [Solid cells were green, indicating a correct response. Cells with vehicle names were red; vehicle name is the soldier's incorrect response.]

Clearly, this feedback format allows both the instructor and soldier to determine which aspects are creating problems, as well as which vehicles are the most difficult. A training feature integrated in this feedback matrix was that the soldier could access the Image Library by clicking any of the cells that indicated an erroneous response, allowing a visual comparison of the two vehicles that were confused. As stressed here, this type of feedback reinforces the perceptual nature of the task being trained and makes effective use of the image database. This particular matrix is easily generated by computer software, but would be extremely difficult and time-consuming if done by hand, thereby again, highlighting the advantage of computer-based training for this particular skill.

These types of feedback can also be tallied for a group of soldiers to provide the instructor a picture of overall strengths and weaknesses within a class during training and on tests. The summary vehicle data informs the instructor which vehicles are difficult for the class and which are easy. The matrix format illustrated in Figure 14 could be modified to provide a picture of overall strengths and weaknesses by vehicle-aspect combinations. To do this, the cells of the matrix would contain the percentage of soldiers who misidentified the vehicle when each aspect was presented. The percentage of soldiers requiring different numbers of training sessions to reach criterion on each vehicle set also provides useful feedback for the instructor. When most soldiers reach criterion the first time, the vehicle set is easy. But when the average is 2.5 to 3 sessions or greater, then the vehicle set is difficult.

Two other types of summaries should be provided to the instructor. The instructor needs a summary of soldier scores, and a vehicle confusion matrix (refer to Table 2). The vehicle confusion matrix then allows the instructor to design additional training exercises on the difficult vehicles.

When programs provide global evaluative feedback only (i.e., % correct), analogous to the grades given to students by teachers, the software developer has failed to distinguish between training and testing or assessment. The training value of global feedback is greatly limited by its separation in time from the incorrect response and by the paucity of information it typically conveys. Soldiers should be allowed to learn from mistakes as well as correct responses. Details on aspects missed and vehicle confusions benefit the soldier and the instructor. Without the types of feedback just described, soldiers are unable to get remedial help when needed, and learning plateaus occur.

Assessment: "When Do Soldiers Really Know Vehicles?"

Types of Assessments

Testing can be incorporated in a training program in several ways. Pretests, embedded tests, and posttests can all be given. Embedded testing allows for continuous evaluation of progress with a skill whereas pre and/or post-testing allow for a less interruptive evaluation. Since tests are intended to evaluate performance, not necessarily to enhance it, they are differentiated from training exercises by the absence of corrective feedback on each test item.

Pretests. Why give a pretest? There are two primary reasons for pretests in training: to individualize instruction, and to provide the soldier and instructor an index of progress made. The content of the pretest can change depending on its purpose.

If the intent is to individualize instruction, and to make instruction more efficient and more motivating by having soldiers enter the program at the appropriate learning difficulty or by tailoring the images presented to specific weaknesses, then a series of pretests may be necessary. If soldiers have advanced skills, they should not have to repeat training on the basics. But it may take several pretests to determine their skill level. For example, pretests can be made increasingly difficult by changing the range to the vehicles. If soldier A can easily identify vehicles at the close ranges but not at far, then training should start at the far distances. On the other hand, if soldier B cannot identify vehicles at the close ranges, then training should start with these close ranges. The same rationale can be applied to determining whether soldiers are skilled with reverse polarity (black-hot) images or with day thermal images as opposed to the more typical night thermal images.

Using pretests in this manner can also assist in sustainment or refresher training. If pretests show that soldiers have retained some but not all skills, then the efficient sustainment or refresher training strategy is to have them regain skills they have lost and to acquire new ones, not to repeat training on what is well known. Pretests can help trainers achieve these goals.

In tailoring instruction, we (Dyer et al., 1997) found that soldiers who scored low on the pretest would benefit more from initial training with a Veh ID format than with a SC format. The Veh ID format did not pressure them to respond, and it also provided visual corrective, comparative feedback. This feedback helped soldiers resolve their unique confusions and problems. A low score could be considered below 60 or 70%. On the other hand, those who scored well on a pretest, above 70%, would benefit from either exercise format.

The other primary use of pretests is to determine what has been achieved from a specific block of instruction. In this case, the instructor will typically generate identical pretests and posttests. These tests will sample the imagery from the training vehicle sets, and they may also include some transfer imagery if that is a training objective. Thus soldiers will take a pretest, receive instruction and training, and then take a posttest. The difference between the pretest and posttest scores provides an index of the effectiveness of the training. The instructor will know who learned the most from the pretest to the posttest, who achieved the highest scores on the posttest, and who need additional training. Assuming results are also available on each vehicle, the instructor will know which vehicles created the most problems, and whether there is a need to revise the training approach.

The software should be developed so the instructor can easily develop pretests to meet these two training requirements. The burden on the instructor to individualize instruction can be further reduced if "intelligent" software algorithms are available to direct the soldier to the appropriate vehicle sets and training exercise formats without instructor intervention.

Embedded Tests and Posttests. Embedded tests provide interim and quick assessments of training progress. It is not necessary, and often not desirable, to wait until the end of a long

block of training to check performance with a formal posttest. Embedded tests or spot tests should be easy to develop and easy to access. Many options are available for embedded tests. For example, they could assess just the vehicles being trained, or assess transfer as well. The test format could be the same as that in training (e.g., train and test with SC) or different (e.g., train non-timed with a Veh ID format and spot check speed of response with a SC format). The polarity of the imagery could change, from white-hot in training to black-hot or a mix of white-hot and black-hot in the embedded test. Such options are easily generated with a computer-based training program.

Posttests are typically viewed as being equivalent to a "final examination" or end-of-course qualification. From this perspective, they need to be comprehensive and balanced in difficulty, containing a spectrum of image difficulty. With vehicle identification, some imagery should be new imagery, as the ultimate goal is to prepare for combat. When that is the case, test results should provide separate scores for the "trained" imagery and the transfer imagery.

Performance Standards and Conditions

The military has established a doctrinal system to assure that training material has been mastered. Performance standards are set for training objectives and tests. A soldier may be allowed more than one attempt to reach this standard, depending on the context. This philosophy is efficient and assures that minimal standards are achieved by all. With many domains, it is often difficult to determine what the training standard should be. With vehicle identification, many conditions must be considered as they directly affect the difficulty level of the assessment. In the discussion that follows, the word "criterion" refers to percent correct (of the vehicle images presented).

For example, if the requirement is for mastery of eight combat vehicles and soldiers are presented with eight aspects of each vehicle in a repetitive fashion (64 images per trial), you must decide what constitutes mastery. You must carefully consider the criterion level. For example, if the criterion is 90%, then the soldier must obtain 58 correct out of a total of 64 images to pass. This criterion allows a total of six errors. Six errors may not appear excessive. But if we consider the possibility that the soldier has made all six errors on one of the eight vehicles, then this seemingly negligible margin of error becomes very consequential. This indicates that although the soldier knows seven vehicles very well, he nevertheless has an inadequate understanding of the eighth vehicle. This lack of understanding could be crucial on the battlefield. Scrutinizing these findings further, we conclude that he missed 12.5% of the eight vehicles to be learned and mastered 87.5% of them, a slightly different outcome than the desired 90% criterion. Therefore, using a fixed-criterion regardless of the number of images and other characteristics of the vehicle set can lead instructors to erroneous conclusions. As indicated in the example, reaching the fixed-criterion does not necessarily ensure training goals have been met.

Setting a high criterion does much to ensure that vehicles are actually mastered, but this does not come without potential cost. Inevitably many soldiers will need greater amounts of training time when passing standards are extremely difficult (i.e., above 90%). In fact, without remediation, learning plateaus are common. When soldiers are fixated in training just below the

cut-score, they are often forced to continuously repeat exercises, particularly if they have limited feedback on their errors.

To complicate this issue further, there are factors related to the imagery that can influence the overall difficulty of either a practical exercise or a test of vehicle recognition skill. Factors such as range and aspect angle can be varied in order to create a very difficult or very easy test. If the test is constructed using all close-up imagery of the flanks of vehicles, it will be relatively easy and most soldiers. Even those with very little skill will be able to reach a very high criterion in a reasonable amount of training time. Conversely, because identifying a vehicle from the front or rear is very difficult, especially at range, a test composed of this type of imagery will require much greater skill as well as training time. Range and aspect angle are only a few factors related to imagery that can ameliorate or exacerbate learning difficulty. Others are presented in Table 4.

Table 4
Factors Influencing the Difficulty of Vehicle Identification Exercises and Tests

Factor	**Example of an Easy Test**	**Example of a Hard Test**
Imagery		
Range to vehicle (vehicle size)	Close-up	Far - sized to be beyond maximum effective range of weapon system
Aspect of vehicle	Flanks	Front and rear
Time of day thermal imagery was collected	Night thermal	Day thermal
Exposure of vehicle	Fully exposed	Defilade positions
Similarity of thermal signatures	Quite distinct (e.g., M113, HMMWV, T72, LAV-25, ZSU)	Very similar (e.g., T72, T72 w reactive armor, T62, T55)
Soldier experience with vehicle imagery in set	Train for the Test: Same vehicles and same imagery as in training	Test for Transfer: Same vehicles, but images differ from those in training with no overlap
Test Format		
Response format	Multiple-choice with choices limited to the vehicles in the set.	Fill-in-the-blank *or* Multiple-choice format with vehicles not in the set also listed.
Time of vehicle exposure	Vehicle remains in view until soldier makes selection	Limited (5 sec or less) and then vehicle disappears
Ability to change identification response	Soldier can change response before proceeding to next display	Soldier cannot change response
Criterion: % correct	80%	95% and above

How the test or exercise is formatted also has an impact. The test will be difficult if soldiers are given a very limited time to respond (5 seconds or less); if they are given a surplus of vehicle names from which to choose the response; and if they are unable to change the response after answering. On the other hand, the test will be easy if it is not timed, soldiers can choose from a pool of items limited to those displayed in the vehicle set, and they are able to alter the response before proceeding. A trainer has the option of varying any or all of these factors. This flexibility is commendable, but becomes problematic for the trainer who is attempting to evaluate a soldier's progress and level of achievement. To summarize, achieving 80% correct on a test with very far day thermal imagery of fronts and rears of vehicles presented in a timed fashion might indicate an exceptional skill level on the part of the soldier, whereas obtaining 90% on a test of "easy" imagery presented in an "easy" test format might be the normative response for most soldiers.

Computerized training allows us to tailor training to both situational requirements as well as the learning needs of individual soldiers. When designing training objectives, trainers of vehicle identification must be aware of the many factors impacting the difficulty of both practical exercises and tests. Although the ease of enacting a doctrinal standard performance criterion is attractive, failure to take training and test difficulty issues into consideration not only results in inefficient use of training time, but also fails to take advantage of the training potential that is engendered in computerized versions of vehicle identification training. As illustrated, you can make tests hard or easy for almost any soldier. In the end, you want fair, yet rigorous tests.

Instructor Controls: "Reducing the Instructor's Load"

Typically, multi-media programs allow an instructor to tailor the lessons the soldier will encounter, to select the vehicles in the training, and to manage a database of soldier files. With vehicle recognition training, one of the primary concerns of those responsible for training is that they have some control over which vehicles are trained. Instructors mention the increased functionality of a program that they can adapt to vehicle training recognition in general as well as to special mission requirements. It is equally important, as instructors transition from traditional means of instruction to more automated systems, that they have control over what lessons are presented. Traditional means of training allows for some instructor discretion as to the emphasis and order of lessons within a curriculum. The analogous automated capability would allow instructors to manipulate the design of an automated course to fit the needs of their soldiers.

Another component typically included in many computer-based programs is automated record keeping. The goal of this component is to ease the load on the instructor by reducing time expended in grading and keeping track of individual progress. These two tasks are essential to any successful computer-training package. The goal should be to provide easy to use, confidential records of training progress and tests. The instructor should be able to tell at a glance which soldiers are falling behind, which are excelling, and which have passed a given test. The instructor should be able to print these records, and the records should be password protected. In addition, an audit trail of the vehicle sets used in training, with all the identifying characteristics of the imagery within each set, should be provided.

In designing these components, software developers must be mindful of the hardware system on which the instruction will be used. For example, if the computers will be networked, the program should automatically consolidate soldier progress data and test scores in a single, centrally located database. However, it is more likely that soldiers will use the program on separate computers in several locations. In some circumstances soldiers will share a computer. This creates a logistical problem in terms of consolidating the data for the instructor's use. One solution to the problem created by individual differences in learning rates and the scatter of the training data is to issue each soldier a disk. The disk would contain a lesson configuration plan to control the lessons each soldier received, a "bookmark" to hold the soldier's place between training sessions, and a database file reflecting progress and test scores. Such a system would allow soldiers to share computers and to proceed at a pace reflecting their individual learning speed without impeding the progress of others. It also helps instructors manage lessons with minimal time commitments.

The ideal computer program is easy to use under a variety of training situations. In the least complicated situation, with novice learners and/or with novice instructors, a "default" basic instructional and training system should be included. Running this version should be as simple as punching the "default" button. When, however, soldiers and instructors become more skilled and more familiar with the program, the program must be sufficiently flexible to adapt to their needs. Throughout this report we have stressed the need for such flexibility. However, creating different training routes and paths should be easy for the user. If not, alternative training sequences will not be used, even though they are essential to advanced, individualized, and challenging training.

How to create different training paths should be explained by way of a training guide or an instructor's book, available in hard copy as well as through menu selection on the computer. Typically, guides describe the "mechanics of training." Guides on "the mechanics" explain what each button does, how to create files, how to save files, and so on. But not all guides explain the "art of training." The art of training is critical when software programs have tremendous flexibility. Guides with this additional information not only convey lessons learned and help instructors understand the program's structure, but they also convey how these lessons can be applied with the software to meet training needs. Information on what techniques make learning more effective, efficient, and enhance retention is included. Instructors are cautioned about what typically does not work and why. The guides also explain why certain training modules have been developed; their advantages and their limitations. They describe creative approaches to developing instruction and practice exercises. In other words, guides that go beyond the mechanics of running a program do not leave the user "in the dark" with regard to how to execute it astutely and creatively.

Group Instruction: "Flexiblity for the Classroom"

Throughout this report, we have stressed the importance of a modular program, which provides the flexibility to tailor and enhance training for the target audience. An unstated assumption is that the training will be done independently by the individual soldier sitting at a personal computer. However, the reality is that often classroom or group instruction, training,

and testing are required. Resource constraints, in terms of computers, time, or both, mean that the program must be adaptable to group settings.

Overhead projection systems can show computer images to a large groups. And at first glance one might think that no software modifications are needed for classroom applications. However, we found in classroom try-outs that additional features must be considered. It is desirable to have a single-display capability where, except for tool bars, the entire screen is filled with an image of a vehicle. The instructor needs to be able to access any image at any time to illustrate teaching points and respond to questions. Up to this point, we have recommended random presentation of the images in the exercises and tests. But if a test must be administered to a group as a whole, it is desirable to have a pre-determined, fixed sequence of images to facilitate scoring of the tests. Otherwise, an expert must also take the test whenever it is given in order to determine the vehicle sequence and identify each vehicle.

Additional Modules

Vehicle recognition and identification are the final phase of the target acquisition process. First, vehicles must be detected. This critical phase, search and detection, was also addressed in the Proto-FLIR programs, but to a limited extent due to resource constraints. Consequently, we do not provide guidance in this report on how to best train search and detection skills. However, some of the basic considerations applicable to recognizing vehicles apply to search and detection as well: a large imagery database (different scenes or terrain, day and night, partially- and fully-exposed vehicles), instruction on appropriate search techniques, and exercises that vary in difficulty, to mention a few. Search exercises could be included both before and after vehicle recognition training, focusing on search and detection initially and adding the recognition requirement at the end.

Training on manipulating sight controls to optimize the image for target detection and then adjust the controls for vehicle recognition should also be included. The brightness, contrast, polarity, and focus controls are all critical in this process. As with search, the Proto-FLIR programs had limited training on these controls, but a module was included. Later versions enabled soldiers to change polarity during the vehicle recognition exercises themselves, as gunners would with their tactical systems. Some gunners prefer black-hot to white-hot; others prefer white-hot. Interestingly, the two polarities do provide slightly different visual information; one is simply not the complement of the other. So there are advantages for a training program with this capability.

Training on setting the brightness and contrast controls is critical. You can totally saturate the image by turning up the contrast and brightness, eliminating temperature differences and seeing only the vehicle's shape. Or you can eliminate all but the hottest hot spots by using a high contrast and lower brightness. The difference in images produced by these control changes is illustrated in Figure A-10. The Proto-FLIR programs incorporated guidelines on using these controls for vehicle detection and identification (Palmer et al., 1982), and included demonstrations of these effects with the thermal imagery in the database.

Summary and Conclusions

There are many ways to train soldiers to discriminate between vehicle classes and to identify particular vehicles, ranging from the most systematic to the most haphazard. A systematic approach not only makes sense to the soldier, but also has an increased probability of obtaining the most training effectiveness for the time invested. A steady progression from general to specific and from easy to difficult is the most sensible and supported strategy. Such a system works by implementing successive discrimination training. Soldiers are first trained to discriminate between classes of vehicles at close ranges and work through a program of instruction that gradually leads to fine discriminations between individual vehicles at range and under other tactical conditions. Along the way they are trained to differentiate vehicles with a propensity to be confused, and are given a systematic strategy for identification applicable to the thermal signature of any vehicle.

Another consideration in developing a vehicle recognition program is the combat requirement. The ultimate goal of thermal signature training is to have soldiers detect vehicles beyond the maximum effective range of their weapon system, and identify them as quickly as possible once detection is made. Soldiers who possess these skills will maximize the effectiveness of their weapon system and prevent fratricide. So the training challenge is great. However, not all battlefield conditions can be replicated in a training package, nor is a training package the only means of training this skill. Nonetheless, the need to prepare soldiers for combat was the driving force behind the recommendations in this report.

> ***Images***. *The imagery is critical. It is the subject matter. Its impact should not be underestimated. The imagery in the program affects the quality of the entire program. Poor or inappropriate imagery will result in inadequate training.*

The images in the program determine what is said about vehicle cues, what soldiers remember visually, and the level of skill to be obtained. Factors to consider when obtaining imagery for training thermal signatures include:

- ✓ **The vehicles.** Are the vehicles appropriate for the target audiences? Is there a good sampling of different classes of vehicles? Is there a good mixture of vehicles – some that look alike and hard to discriminate, and some that look very different and easy to discriminate?
- ✓ **Image fidelity.** High fidelity is important, given the dynamics of thermal imagery. In addition, the task is inherently a perceptual one.
- ✓ **Night and day imagery.** Thermal sensors can be the primary sensors during night and day. Include both day and night images as they are not the same. Training with one does not guarantee success with the other.
- ✓ **Polarity.** Include both white-hot and black-hot images. Replicate the polarities possible with the tactical sensors.
- ✓ **Aspect and range.** Vehicle aspect and range dimensions must be varied as they have significant effects on the ease with which vehicles are identified. Vehicles should be scaled by their size at each range so size is also used as an identifying cue.

- ✓ **Tactical images.** Moving vehicles, partially exposed vehicles, vehicles firing, degraded images, etc. are necessary for advanced skill training.
- ✓ **Test images**. Plan for a database sufficient large so that some of the test images can be reserved for testing transfer of skill.
- ✓ **Climate**. Because the thermal signature can vary with the temperature characteristics of the surrounding environment, imagery taken in different climates is important.
- ✓ **Color photographs**. Include color photographs of vehicles to allow thermal and visible comparisons of each vehicle.
- ✓ **Special imagery for instruction**. Special imagery is needed to illustrate FLIR concepts (e.g., diurnal cycles, temperature properties of natural and man-made objects).

To have an adequate database, these dimensions must be combined (e.g., all aspects shown at all ranges both day and night). Thus a large database will result when even a relatively small number of these dimensions are combined. However, most personal computers can handle databases of this size.

Library. *Plan for a library of all images, accessible at any time in training. Make it a "one-stop reference."*

A library of images can be used by instructors and soldiers to meet a variety of training needs: initial instruction, self-study, remedial training, refresher training, and as a basic reference. The library should be so structured that the user can select any vehicle and any image of that vehicle directly from the library screen's menu. Since one key to learning to name vehicles correctly is to be able to discriminate them, the library should enable the user to compare and contrast images. Figure 3 illustrates what was done in the Proto-FLIR programs. In addition, to make the library a complete reference, text information on distinguishing thermal features, the components that produce the vehicle's unique thermal signature (e.g., location of engine and exhaust), and other vehicle characteristics should be included.

FLIR technology instruction*. Include a module explaining forward looking infrared.*

The better soldiers understand the nature of FLIR and the parameters that affect what is seen through a thermal sight, the more adept they become at interpreting thermal signatures. This knowledge will also facilitate transfer from night to day images, to new tactical images, to interpreting objects in the terrain, and to detecting targets.

General training approach*. Present instruction and practice on the thermal features characteristic of classes of vehicles before training and instruction on naming individual vehicles. Then progress to individual vehicles within classes, then training on vehicles likely to be confused across classes, and finally training and testing on all vehicles.*

As the universe of combat vehicles is extremely large, training procedures must divide this pool into smaller groups. Initial training on classes of vehicles does this, as vehicles within

different classes often have common or similar thermal features. Thus the soldier works from gross discriminations to finer discriminations, and the final identification task is simplified. A breakdown by vehicle class is also an important tactical distinction, in that the priority for engaging a vehicle often depends on its type and the gunner's assigned weapon.

This approach corresponds to the strategy that soldiers often apply. We observed, as have others, that when soldiers identify vehicles, they often use characteristics of the image that are not there as much as those that are. For example, when looking at an image which shows no sign of a turret, they eliminate all tanks and artillery from the list of names they might assign the vehicle. Thus, they have made a "class discrimination," and have increased their likelihood of correct identification. After learning to distinguish classes of vehicles, training can progress to discriminations between the individual members of each vehicle class (tanks, APCs, artillery, logistics). Next, the training shifts focus to differentiating vehicles from different classes that are easily confused. Finally, all vehicles are trained together with emphasis on the most confusing vehicle sets.

> ***Instruction on vehicles***. *First, develop a procedure for determining the critical features of a thermal image. Then illustrate and describe these to soldiers in a systematic way. Use the imagery database heavily to illustrate how the vehicle appears under different conditions. Words aid in the learning process by pointing out hot spots, but often do not describe the entire image well. Start with ranges that clearly show the heat profile of the vehicle and progress to far ranges. Show how the thermal signature changes with aspect. Go from the known to the unknown by comparing daytime photographs with thermal images of the same vehicle. Special instruction on the features that distinguish very similar vehicles may be needed.*

Fundamental to the way images and cues are presented is a strategy for examining the image content. An effective instructional strategy leads the soldier to attend to the most important and distinguishing characteristics of a vehicle image in a methodical way. The S^4HEET system we developed is this sort of strategy. Not only does such a strategy influence what is said about vehicles and when it is said, soldiers should also learn to apply it.

Use the large database to show soldiers how the thermal signature changes with aspect, range, movement, time of day, etc. Tailor instruction (text, audio, graphics) to these variations. For example, if the signature of the engine or exhaust changes with range, aspect, or both, that change should be both described and illustrated. However, remember that words are often inadequate in characterizing the whole image and the subtle temperature differences that contribute significantly to the vehicle's unique thermal signature. The whole, in the case of vehicle identification, is more than the sum of its parts. Additionally, more than one way of presenting cues also is a means of adapting to individual differences and preferences.

It is at this point in the training that the relationship between the heat profile of the vehicle and its thermal signature is clarified. Soldiers must know where the engine and exhaust are located; how the shapes of these components affect the image. Explain how the metal and

other materials in the vehicle affect its thermal signature. By knowing the visual, the thermal cues make sense to the soldier.

Do not rush the initial instruction on individual vehicles. Being systematic, pointing out one critical feature at a time, and providing for repetition are necessary. But do allow flexibility for soldiers to go at their own pace.

> ***Vehicle sets and part-task training strategies.*** *For training, the vehicle pool must be divided into sets. Do not assume that if soldiers can identify a vehicle in one set, that they can also automatically identify it when it is placed in a different set. The more similar the vehicles in the set, the harder the identification task. Extensive practice is required to achieve a high level of skill.*
>
> *Instructors will require experience in learning how to create the appropriate vehicle sets and part-task training schedules to maximize learning and retention. When possible, construct the vehicle sets based on the skill and knowledge of the individual soldier.*

Instruction on vehicle characteristics is not sufficient for acquiring vehicle identification skills. Soldiers must be given extensive practice in discriminating one vehicle from another. Part-task training must be conducted, as soldiers cannot learn all vehicles in a single session. In addition, sequences for training the vehicles within each set and for training all the vehicles of interest must be established. The options for creating and sequencing sets are many and are easily implemented with a computer-based program. Some procedures are more effective than others. Here are a few tips on vehicle sets and part-task training schedules.

- ✓ **# of images in set**. Limit the number of images in a vehicle set to no more than 48. Long sets lead to frustration, fatigue, and guessing.
- ✓ **The difficulty of a vehicle set is affected primarily by the similarity of the thermal signatures, range to the vehicle, and vehicle aspect**. Sets with vehicles that are quite distinct are easy to learn; sets with vehicles with very similar thermal signatures can be extremely difficult. Far ranges are more difficult than near. Front and rear aspects are harder than flanks.
- ✓ **Tailor the training to the soldier's skill level**. Do not give very difficult sets to soldiers with limited initial skills.
- ✓ **Spaced practice**. A part-task training schedule that provides some form of spaced practice on vehicles presented previously will lead to fewer confusions when all vehicles are presented than a sequence with no integration of vehicles during practice.
- ✓ **Multiple sets and sequences must be established to accomplish the training objectives**. Use vehicle sets and sequences creatively to progress from easy to more difficult sets and to examine soldiers' abilities to transfer skills.

- ✓ **Use limited training time wisely**. Avoid vehicle sets and sequences that overtrain vehicles that are easily discriminated and undertrain vehicles that are easily confused.
- ✓ **Do not assume that training by class will prevent cross-class confusions and interference; it will not**. Vehicles from different classes can be confused with each other when their thermal signatures are similar. [To ensure Tanks A and B are discriminated from APCs C and D, vehicle sets must be created that force soldiers to distinguish these four vehicles.]
- ✓ **Tailor later instruction**. Use early training results to establish vehicle sets and training schedules that directly address the confusions made in early training.
- ✓ **Check for retention**. Even well-learned vehicles can be forgotten over time. Provide for additional practice as indicated by test results.
- ✓ **Remember that the ability to identify vehicles is not necessarily an absolute property of the vehicles, but is relative to the context in which the vehicles appear**.

Exercise formats and feedback. *Soldiers will learn and enjoy training if the training exercise format is (1) highly interactive, (2) progressively challenging, (3) provides timely feedback, and (4) focuses on the perceptual nature of the task. Use more than one format for variety and to meet different training needs. Make sure the format actually trains the skill of interest (e.g., to name vehicles, to determine aspect).*

Establish criteria for progressing to the next vehicle set. Soldiers cannot learn without feedback. Provide immediate, trial-by-trial feedback during an exercise and immediate summary feedback upon completing a vehicle set. Incorporate visual corrective feedback when the intent is signature understanding. Incorporate time standards when the intent is quick responses. Detailed summary feedback at the end of vehicles sets is critical for both the soldier and the instructor.

Exercise formats that are not timed, require the soldier to identify both the vehicle and its aspect, and provide corrective, visual feedback are most beneficial when the intent is to understand the vehicle's signature. Once baseline skills are established, a timed format can be used to further challenge soldiers. With either exercise format, however, when soldiers have difficulty reaching criterion in three attempts, they should receive some form of remedial training.

Frequently, the emphasis in developing training exercises with computers is to make them "game-like." However, this focus can be misguided, as games do not guarantee that the desired learning will take place. Game-like formats can be used, but a careful analysis is needed to determine which skills are actually trained. Are soldiers being trained simply to answer quickly, hoping answers will be right by chance? Is the game setting forcing them to memorize images in order to beat their buddy? As we found, if you adhere to the four criteria stated above

in developing exercise formats, the result will be a format that is inherently interesting and "game-like" as well.

Feedback provides meaningfulness to vehicle recognition training. Without it, soldiers will flounder. Soldiers learn from errors as well as from correct responses. The instructor learns from errors made by the entire class. As detailed in this report, different forms of feedback are needed to provide the appropriate information at the appropriate time. Summary feedback should incorporate general statements of percent correct as well as more detailed information on which vehicles are confused and which aspects or ranges are creating the confusions. Instructors also need feedback to make decisions on the effectiveness of the training, whether the vehicle sets are appropriate, and whether additional or remedial training is needed. All feedback reports can be easily generated and maintained with a computer, and should be easily accessible to both the soldier and the instructor.

***Assessment**. Pretests, embedded tests, and posttests are needed. The standards or criteria for "passing" are affected by the nature of the imagery and the test format. Tests can be made easy or hard. The goal should be to make fair, yet rigorous tests.*

Pretests can be used to diagnose the skill of soldiers and to tailor instruction to their initial level of skill. They can also be used in conjunction with posttests to assess training progress. Embedded tests are necessary to check on progress during training, instead of waiting until the end of many training sessions. Both embedded tests and posttests can be, and should be, used to test transfer of skill.

As with training, the imagery (vehicle similarity, range, vehicle exposure, etc.) affects the difficulty of the test. The test format (response time, opportunity to change answers, pass criterion) also affects test difficulty.

***Instructor controls**. Use the computer's capabilities to assist the instructor as well as the soldier. The instructor should be able to tailor the lessons the soldier will encounter, to select vehicles for training, to establish training sequences, and to manage a database of soldier files. A default training approach should be provided for new instructors. The training guide should explain the "mechanics" of using the computer as well as provide guidance on the "art of training" with the software.*

***Program flexibility**. Finally, incorporate flexibility and options into all modules so they meet the varying requirements of soldiers and instructors, in individualized training settings and in the classroom.*

This report has highlighted some of the dilemmas that must be attended to when creating a combat vehicle recognition training package, and has given direction to individuals interested in creating a package that offers benefits over and above that which can be taught in traditional ways. To put the proverbial trainer in the box, a program must maintain the interactive nature of

a traditional training environment while using the computer to help instructors manage groups of soldiers as well as help a soldier to learn independently of an instructor. It must provide immediate and individually-tailored feedback; employ appropriate exercise formats, adapt to individual differences in skill and rate of learning; and provide practical, realistic training that truly prepares soldiers to identify vehicles in battle situations. It is also important to strike an even balance between speed and accuracy. Although emphasizing speed in training ensures soldiers learn to react quickly in combat, if accuracy is not equivalently emphasized, many of those rapid reactions can result in misjudgments and fatal errors.

To become proficient in thermal combat vehicle identification is to learn a way to think about vehicles and their respective heat signatures. Proficiency is not simply a regurgitation of nomenclature in response to fixed imagery. The instruction and training must balance the use of images and words to facilitate soldiers' understanding of the vehicle's thermal signature. Because thermal imagery is dynamic and battle situations contain factors that cannot be totally anticipated in any training package, the soldier must leave training with a comprehensive and systematic way in which to think about vehicles' heat signatures.

The extent to which these goals can be achieved is not limited by the multi-media training medium. Rather it depends on our knowledge of how individuals best learn the thermal signatures of vehicles and our ability to apply these lessons learned to the instructional software. Therein lies the art of training.

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APPENDIX A

ADDITIONAL TRAINING MODULES AND IMAGES FROM THE PROTO-FLIR PROGRAMS

Figures A-1 through A-8 compare the M2 Bradley Fighting Vehicle (BFV) to three other APCs (LAV-25, Warrior, and M113) and to three vehicles that are not APCs --- a tank (T-72), artillery vehicle (M109), and logistics vehicle (HEMTT). Each figure displays these seven vehicles from a different aspect angle to show the similarities and differences in the thermal signatures as a function of target class and aspect angle. Similarities among the APCs are evident as well as differences among the four vehicle classes. But in addition, a careful examination of the vehicles will show potential for cross-class confusions. For instance, these displays illustrate that from the front and rear, it is often very difficult to discriminate tracks from wheels - both appear hot.

Each of the APCs has its engine toward the right front and its exhaust relatively high on the right flank toward the front. This creates very similar signatures from most aspects for these four APCs. The LAV-25's distinct exhaust system helps to distinguish it from the other APCs when much of its right flank is observable. In some cases the turret on the M2 helps distinguish it from the M113. The two APCs with the most similar signatures from all aspects are the Warrior and the M2.

From some views, the other vehicles could be confused with the M2. The front and rear of the M109 appear similar; but when the gun and external ammunition stowage are visible, it is more distinct. The HEMTT is usually distinguishable from the M2. But if a soldier was not taught the differences in the locations of the engine and exhaust systems of these two vehicles, they could be easily confused from the front view. Distinguishing features of the T-72, the exhaust toward the rear of the left flank and the rear engine, are evidence from several aspects, helping to separate it from the M2.

Overall, the displays indicate that the M2 would be relatively easy to identify if it were in a vehicle set with no APCs, but much harder to identify when merged with the other APCs.

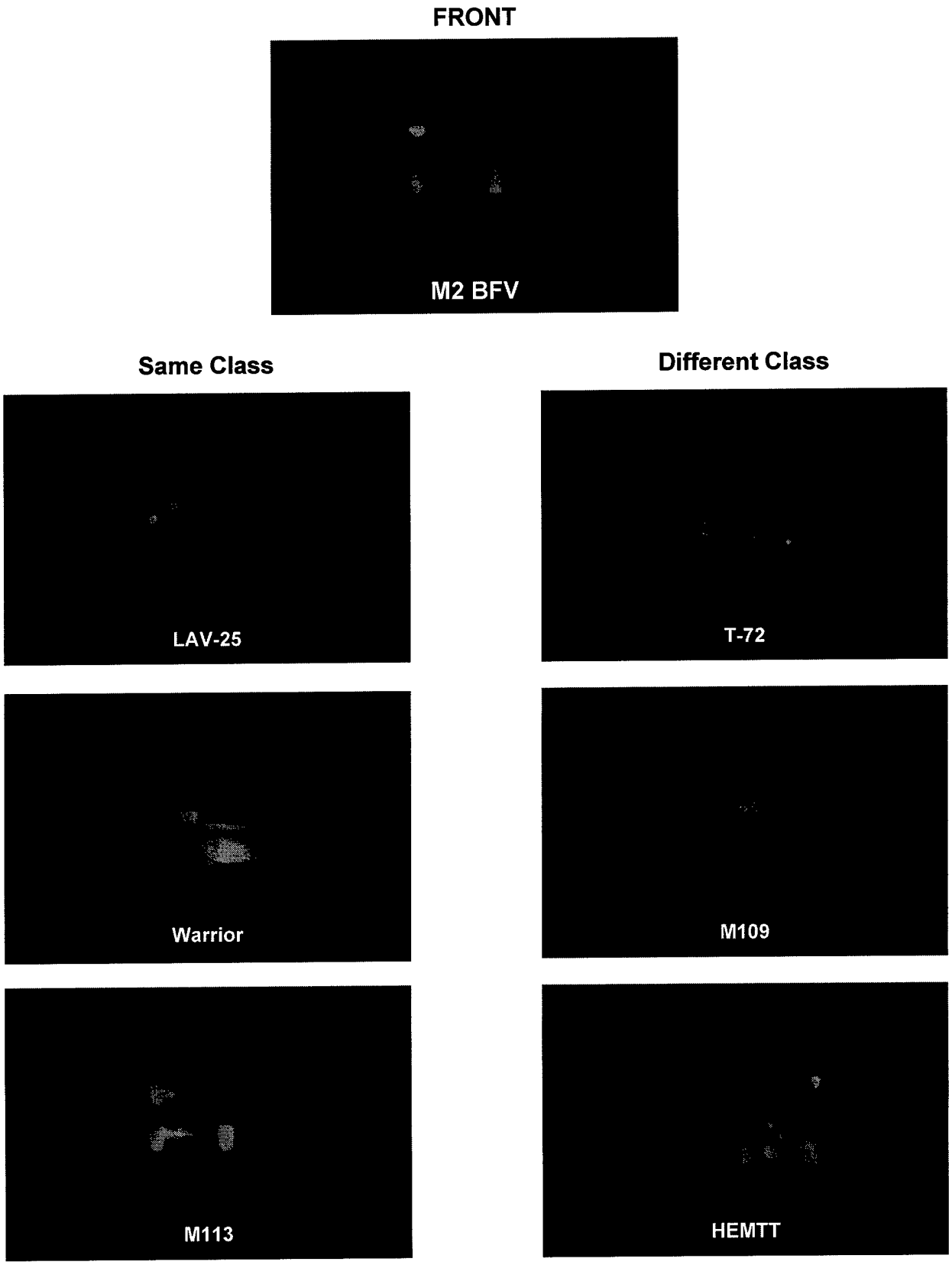


Figure A-1. Front: M2 compared to other APCs and vehicles from other classes

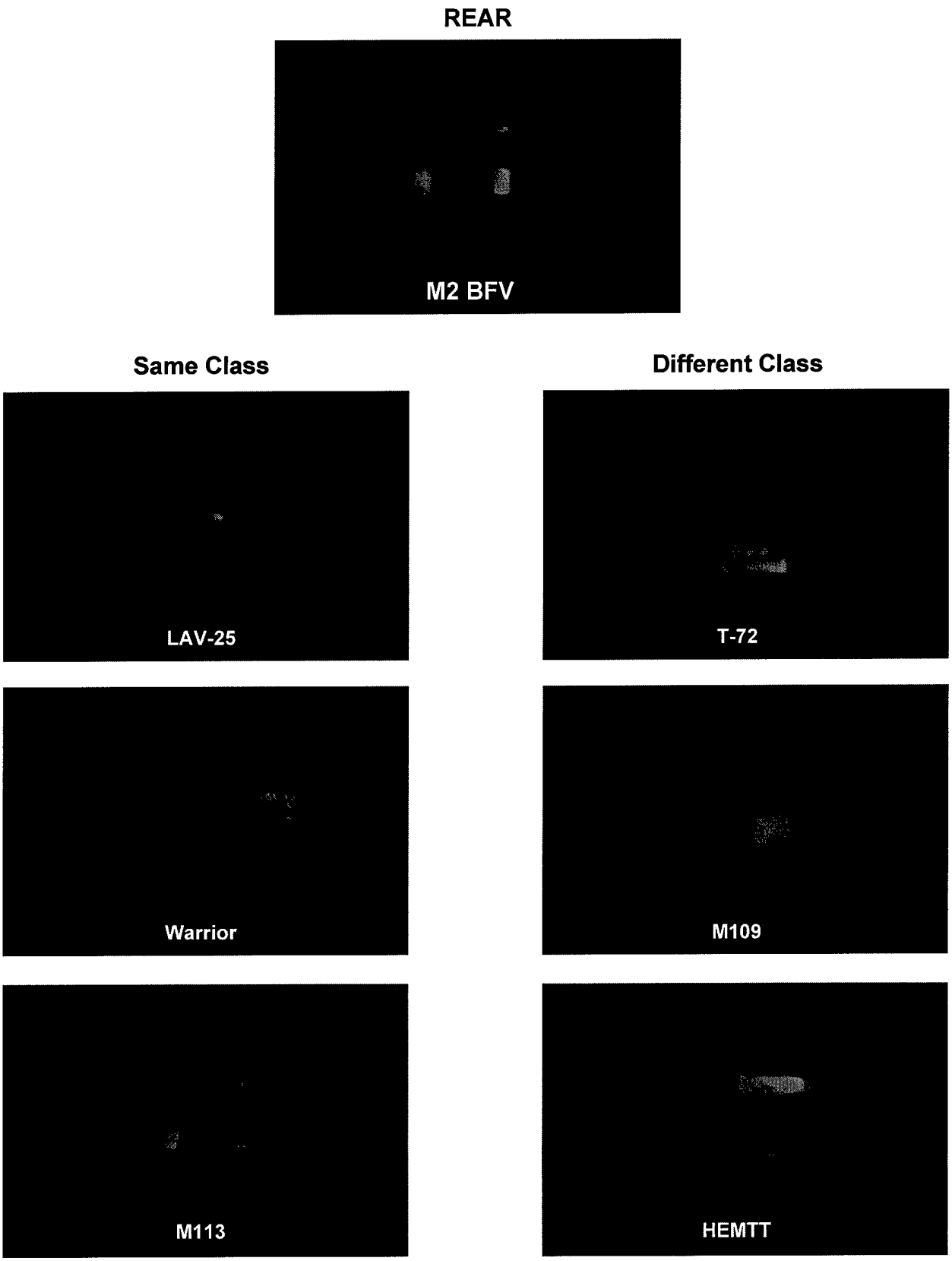


Figure A-2. Rear: M2 compared to other APCs and vehicles from other classes.

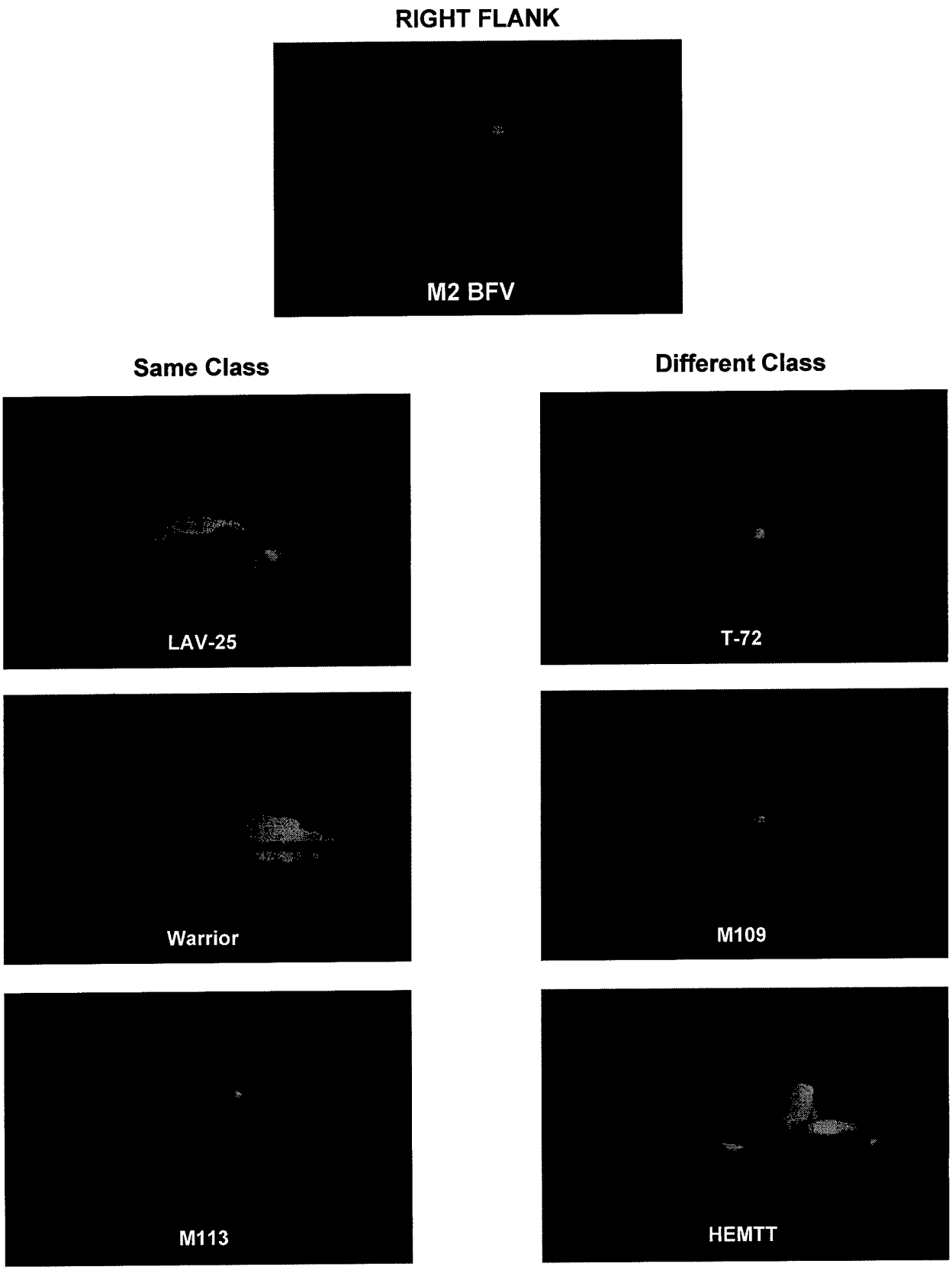


Figure A-3. Right flank: M2 compared to other APCs and vehicles from other classes.

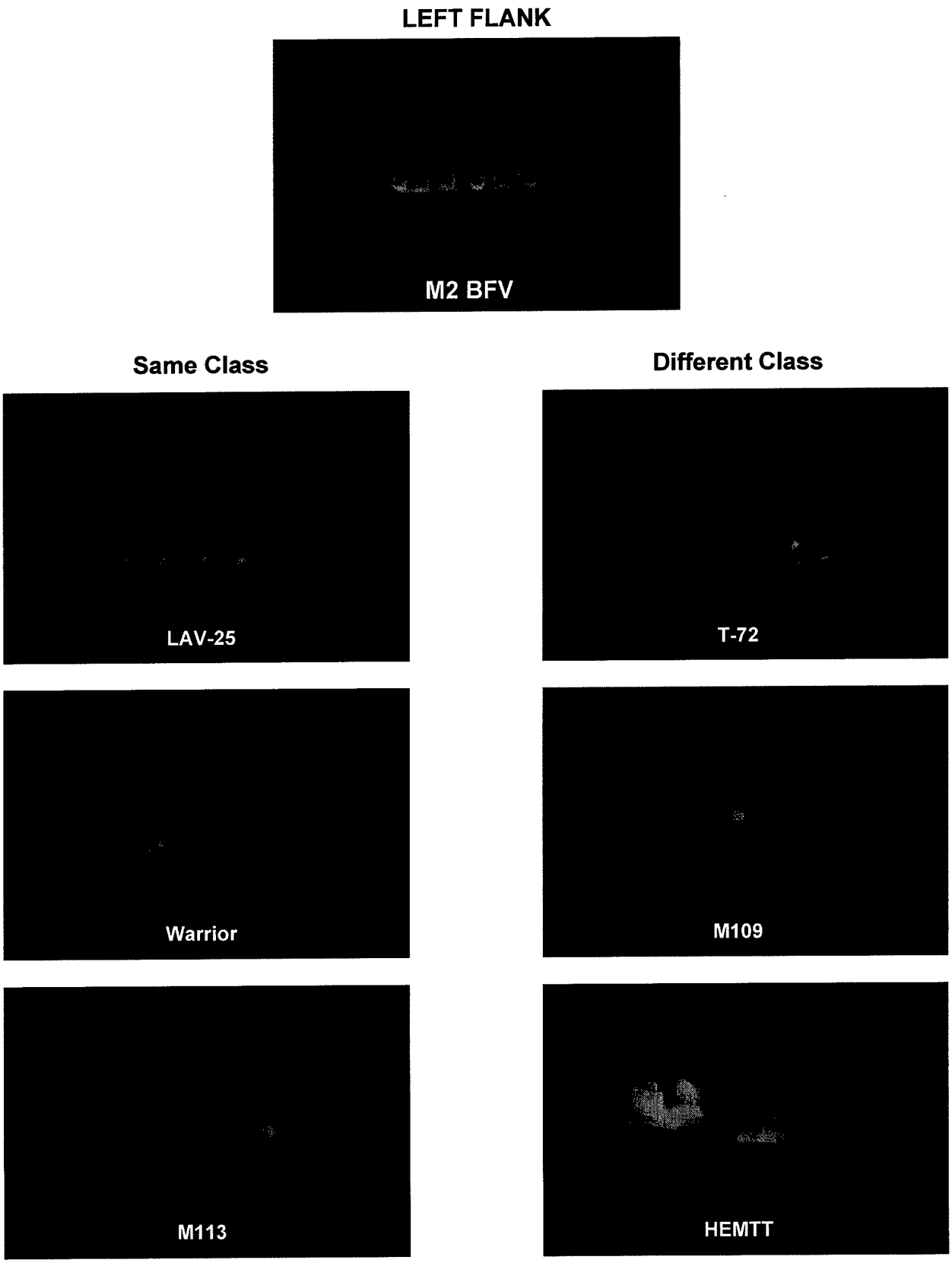


Figure A-4. Left flank: M2 compared to other APCs and vehicles from other classes.

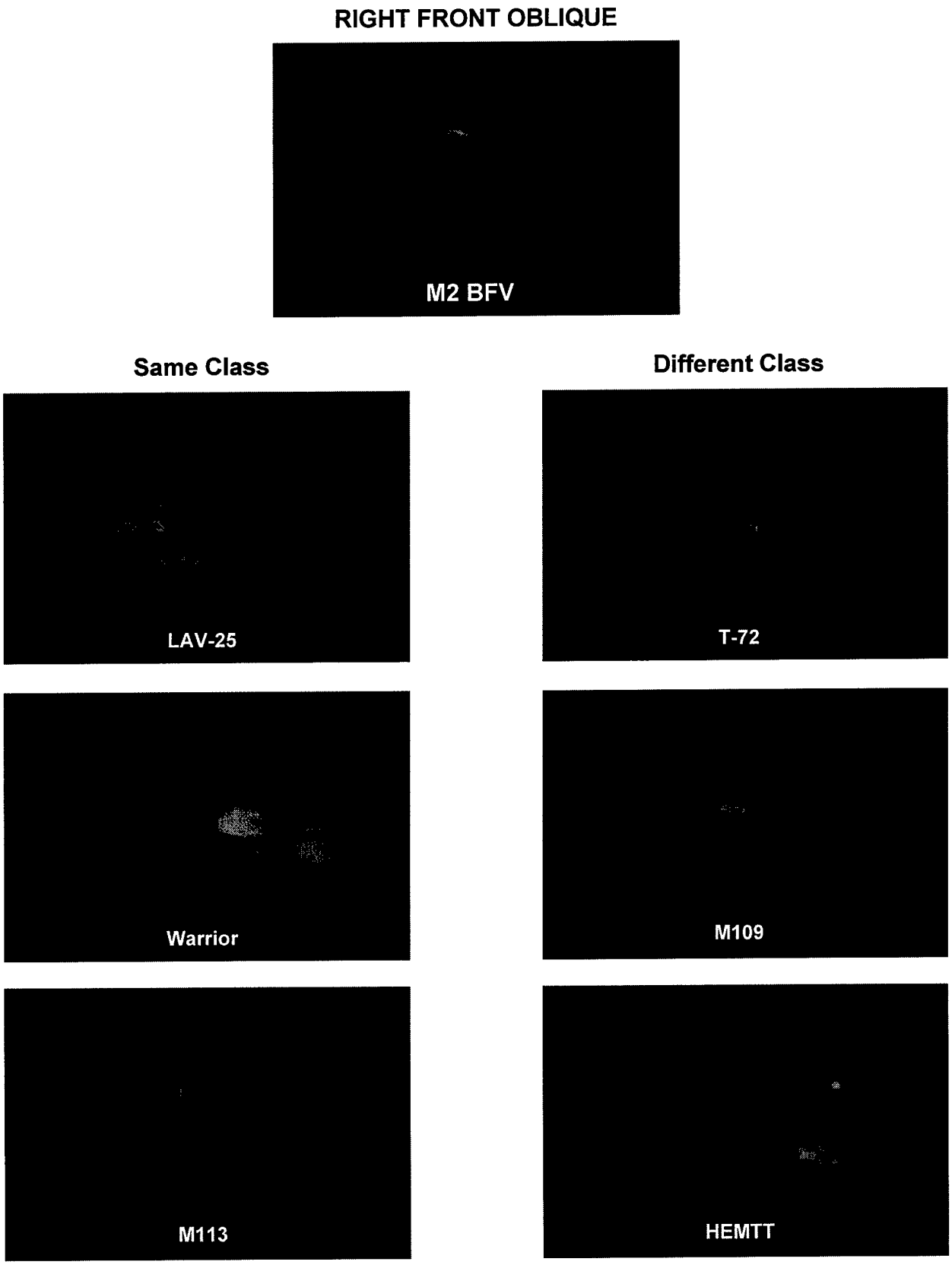


Figure A-5. Right front oblique: M2 compared to other APCs and vehicles from other classes.

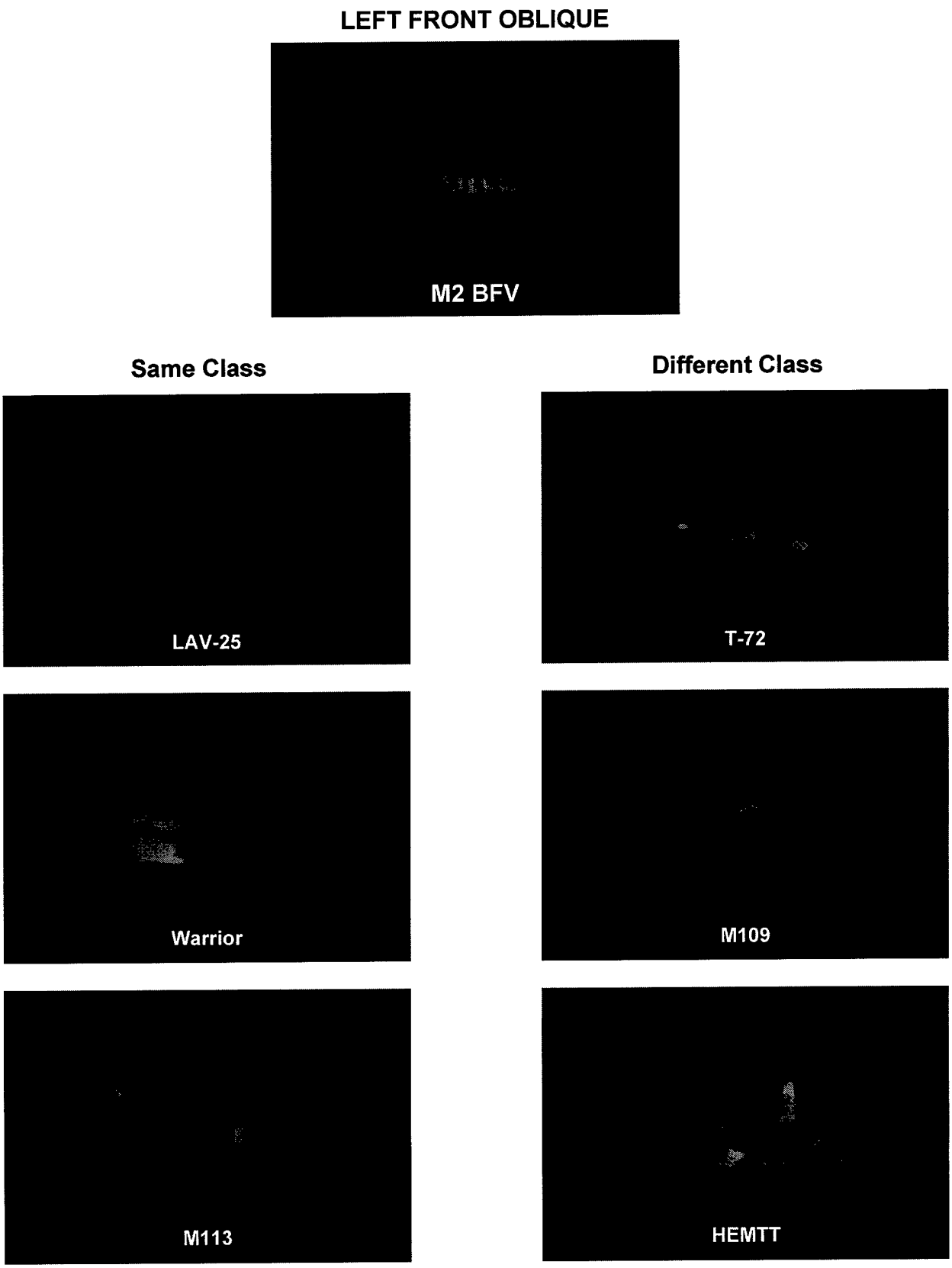


Figure A-6. Left front oblique: M2 compared to other APCs and vehicles from other classes.

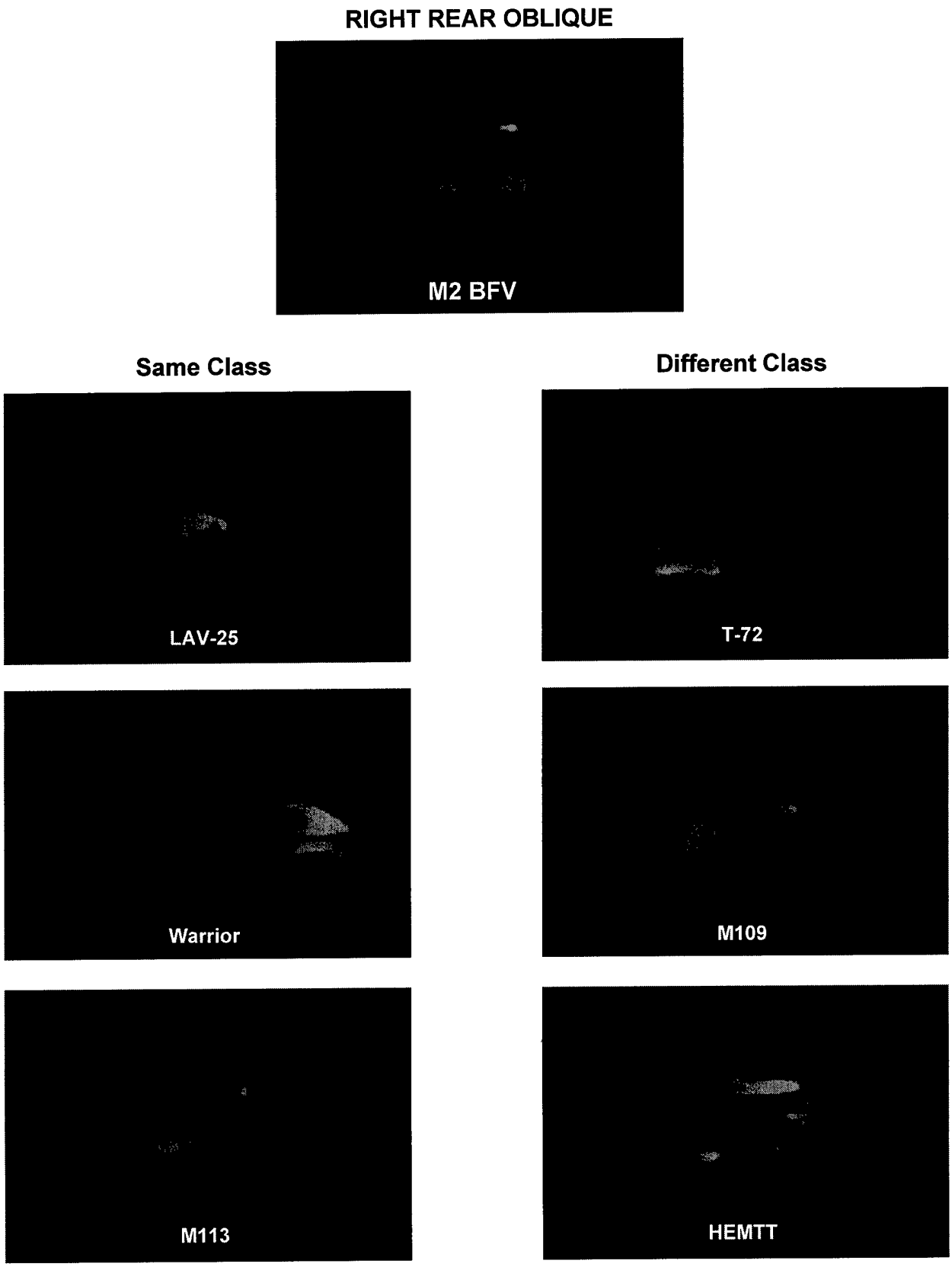


Figure A-7. Right rear oblique: M2 compared to other APCs and vehicles from other classes.

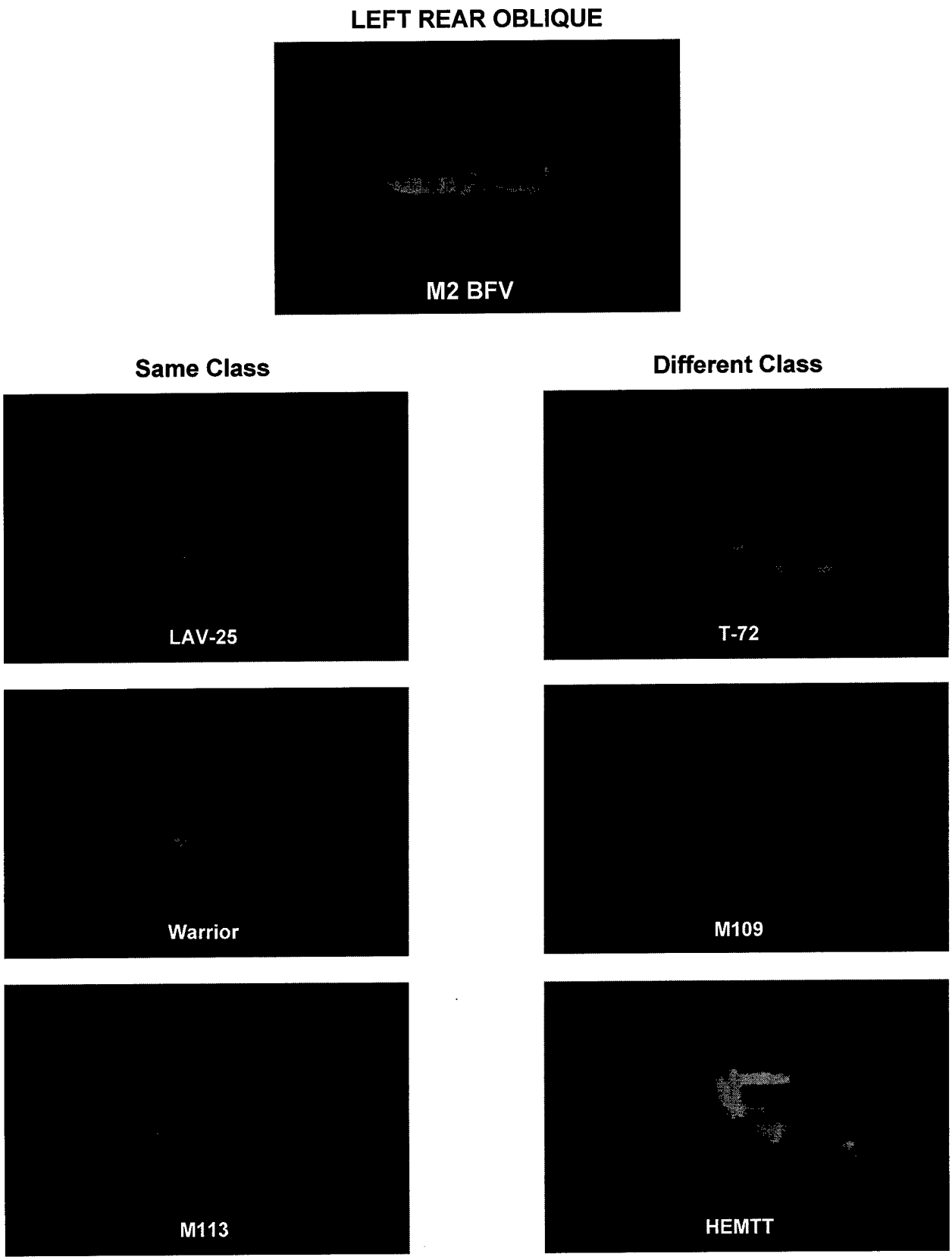


Figure A-8. Left rear oblique: M2 compared to other APCs and vehicles from other classes.

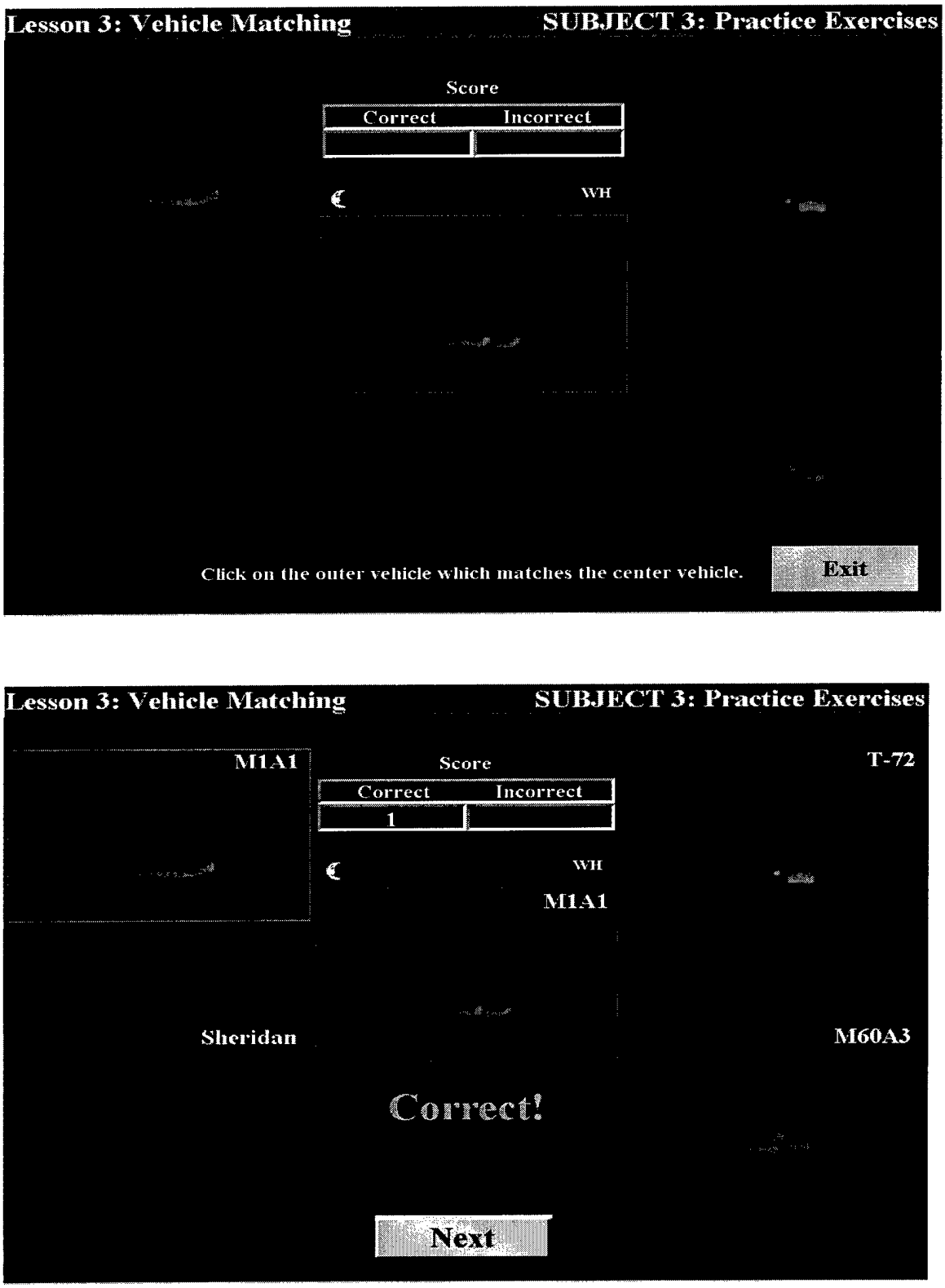
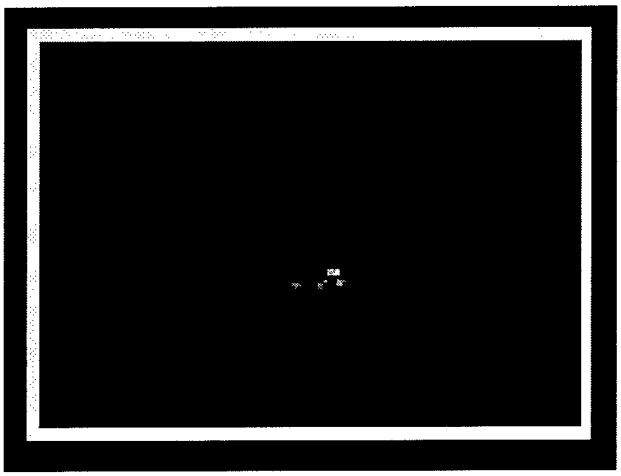


Figure A-9. Vehicle Matching exercise from the Proto-FLIR programs.

Scan & Detect:

Increase contrast and lower brightness to find hot spots.



Identify:

Adjust brightness and contrast to define shape and hot spot cues.

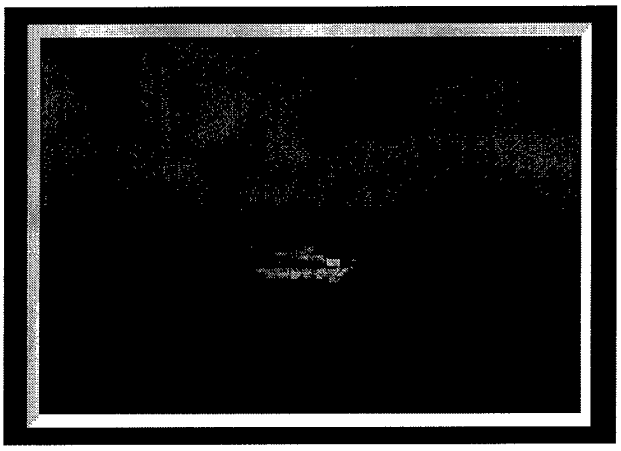


Figure A-10. Illustration of the effect of brightness and contrast control settings on the thermal signature of the T-72 (from Thermal Basics module of the Proto-FLIR programs.)