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An Experimental Evaluation of the Cueing Procedures Used With the Pilot's Line-of-Sight Reticle

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Three experiments were conducted to evaluate the cueing procedure for the copilot-gunner's (CPG) line-of-sight (LOS) symbol in the AH-64A pilot night vision system. The location of the CPG, or cued, LOS is indicated by dots positioned on imaginary axes extending from the arms (0^o, 90^o, 180^o, 270^o) of the pilot's LOS reticle. The procedure uses either one- or two-dot cues to indicate one of eight search areas for locating the CPG LOS. The cueing dots also flash when the pilot must boresight the integrated helmet and display sight subsystem (IHADSS). The three experiments used a selective visual attention paradigm. Experiment 1 evaluated the effects of the number of cueing elements and the presentation duration on the accurate perception of the cues. Experiment 2 compared the effectiveness of the one- and two-dot cues in locating a fixed target. Experiment 2 also evaluated the effects of presentation duration and practice on target identification accuracy. Experiment 3 evaluated the effect of the secondary meaning (boresight required) on the accuracy of target identification under the dot, (Continued)

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duration, and practice conditions. The results of the three experiments led to four recommendations for possible design options, training considerations, or further research: (1) redesign the Cued LOS procedure to create equally effective cues for all portions of the field of regard, (2) develop a different method for indicating an IHADSS boresight requirement, (3) provide extensive practice in using the cueing procedure, and (4) advise the pilots to ensure they are interpreting the cue accurately before beginning a search for the Cued LOS.

AN EXPERIMENTAL EVALUATION OF THE CUEING PROCEDURES USED WITH THE PILOT'S LINE-OF-SIGHT RETICLE

CONTENTS

LIST OF FIGURES

AN EXPERIMENTAL EVALUATION OF THE CUEING PROCEDURES USED WITH THE PILOT'S LINE-OF-SIGHT RETICLE

Introduction

The AH-64A attack helicopter is the first Army aircraft to employ the Pilot Night Vision System (PNVS). The PNVS is a display system that enables crew members to conduct attack missions at night and in adverse weather by providing an infrared image of the external visual scene. It presents a 30° x 40° field of view to the pilot's right eye via a 1 inch diameter cathode ray tube (CRT) mounted on the pilot's helmet. A set of 27 symbols, intended to provide the pilot with critical flight and targeting information, can be projected onto the field of view (see Appendix A for more information on the AH-64A systems).

To date, little research has been published that evaluates whether a PNVS-type symbology format enhances or degrades information transfer during mission tasks. Prior to the development of the PNVS in the late 1970s, Schmit (1977) found that there was little research to provide a basis for evaluating potential symbology formats. During the development of the PNVS symbology format, Buckler (1978a) arrived at a similar conclusion. He described the state of empirical research comparing different formats as sorely lacking. Furthermore, Buckler (1978b) reported that reconfigurable simulators were not readily available to test alternative symbology formats for the PNVS.

Nevertheless, the Department of Defense military standard for symbology formats, MIL-STD-1295A(AV), is patterned after the PNVS symbology set (Department of Defense, 1984). In the foreword of the document, the authors note that they expect changes to be made to the standard as new symbology is developed or as new data become available, thus acknowledging the need for research on symbology format design.

Historically, however, the development of symbology has been evolutionary rather than a process of systematic research (Shrager, 1977). A current example is the symbology format being developed for the Army's MH-60K and MH-47E special operations helicopters (International Business Machines [IBM], 1988). Different symbols are used to present some of the same basic flight information represented in the PNVS symbology format. No information is publicly available (i.e., the information was not documented or is considered proprietary) to explain how the new symbols were developed or how the new symbology format will affect crew performance.

Thus, the PNVS symbology format needs to be systematically evaluated. The Army Research Institute Aviation Research and Development Activity (ARIARDA) was tasked by the Army Aviation Systems Command (AVSCOM) to initiate research to meet these needs.

In response to the AVSCOM tasking, ARIARDA began a program of research on the PNVS symbology format using an approach derived from research in visual attention processes. Specifically, a selective attention approach was chosen because it provides a method of empirically comparing the demand of attending to different visual stimuli.

The cueing procedure for the PNVS Cued Line-of-Sight (LOS) symbol was chosen as the first aspect of the PNVS symbology format to investigate. Cueing is an important, but frequently underutilized, function in complex visual displays. Furthermore, the amount and complexity of information represented on future aircraft visual displays is likely to increase, making the cueing function even more important.

The remainder of this report is presented in six sections. The first section describes the specific cueing procedure for the PNVS Cued LOS symbol. The next section provides a brief review of research issues in visual attention pertinent to cueing selective visual attention. The next three sections present the results of three experiments conducted using the selective visual attention paradigm to evaluate the Cued LOS. The last section discusses the results of the experiments and presents recommendations regarding the Cued LOS and the selective visual attention paradigm.

Cueing Procedure for the PNVS Cued LOS Symbol

The PNVS has a dynamic and complex visual background created by infrared imagery. Flight and weapons information in symbolic form is overlaid on that imagery. This symbology, in conjunction with the imagery, is intended to provide the critical information required to perform flight and target acquisition tasks in adverse weather and night conditions.

The complete PNVS symbology set consists of the 27 alphanumeric, shape, size, and position coded symbols shown in Figure 1. Some of the symbols are adapted from traditional electromechanical instrument displays and are located in fixed positions on the display. Others, however, are unique, dynamic representations of spatial information that

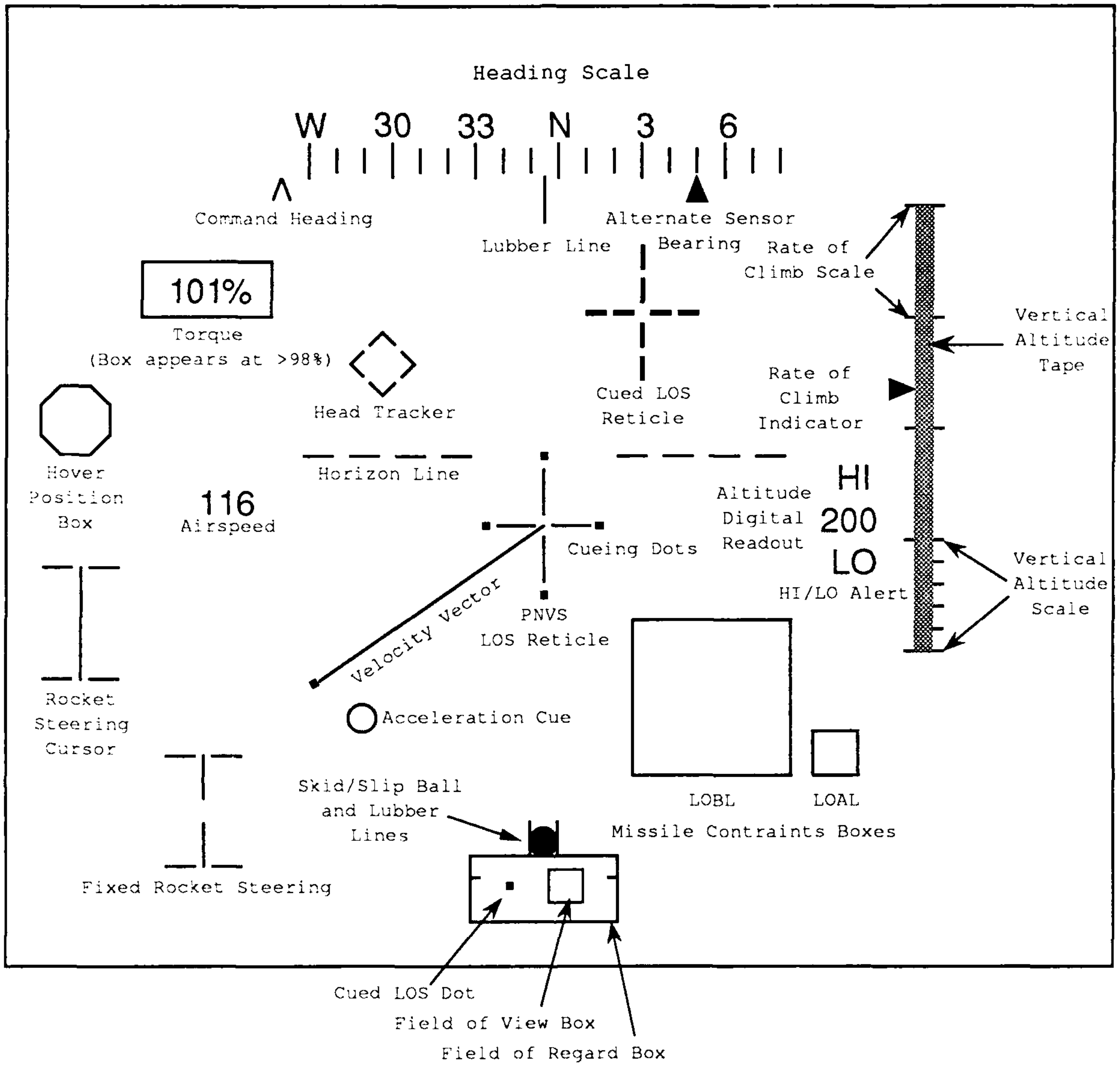


Figure 1. The PNVS symbology format shown without any background imagery.

move about the display and in or out of the viewing area as a result of changes in sensor or aircraft orientation.

Because of the possibility of display clutter, a cueing procedure was developed to help the pilot locate the Cued LOS symbol when it represents the copilot-gunner's (CPGs) line of sight. The section below describes the symbols and the cueing procedure for the Cued LOS.

Cued LOS Reticle Description

The Cued LOS reticle, depicted on the left side in Figure 2, is a cross-shaped reticle subtending a maximum of 3.75° visual angle. The symbol has two distinct meanings. If the pilot places his gun switch in the fixed position and activates the gun while the fire control computer is in either the safe or the armed condition, the Cued LOS indicates the computed impact point of rounds fired from the 30mm gun. However, if the pilot places his acquisition select switch in the CPG position, the symbol indicates the CPG's line of sight.

The cueing procedure for the Cued LOS uses four small dots, each created by a 4 x 4 matrix of pixels. Each side of the matrix subtends approximately 0.3° visual angle. The dots are positioned on imaginary axes extending from the arms of the symbol used to indicate the pilot's line of sight, designated here as the Pilot's LOS. The Pilot's LOS is the center of the 30° x 40° PNVS field of view presented to the pilot's right eye. As shown on the right side of Figure 2, the cueing dots are positioned 0.625° beyond each arm of the Pilot's LOS symbol. The maximum distance between two dots subtends 5° visual angle and the minimum distance between two dots subtends 3.5° visual angle.

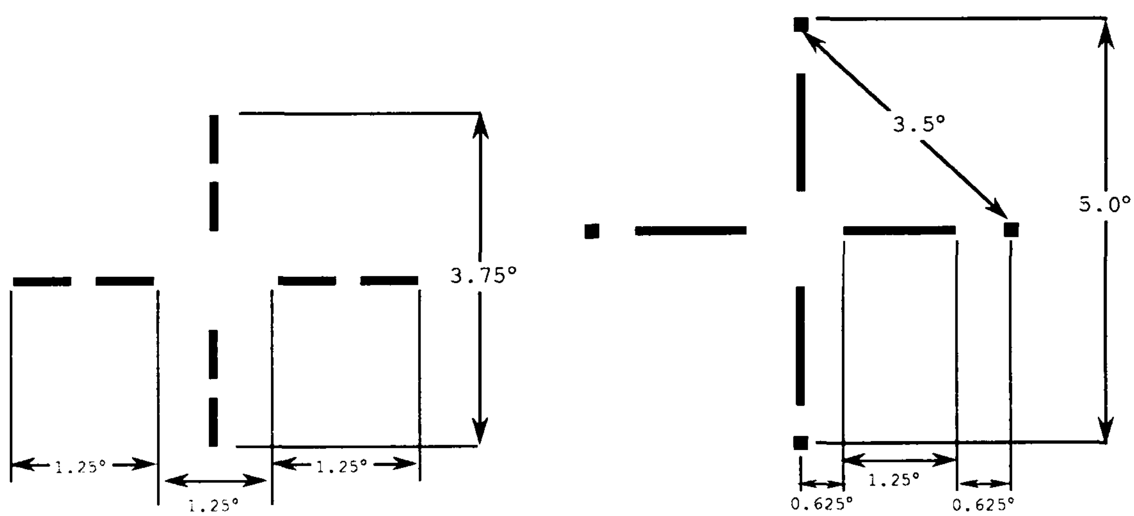


Figure 2. The Cued LOS reticle and the Pilot's LOS showing all four cueing dots.

The Cueing Procedure

The cueing dots are used to indicate the direction the pilot must move his line of sight to be coincident with the CPG's line of sight, indicated by the Cued LOS. The cueing procedure operates as if the total PNVS sensor field of regard (± 110° azimuth, +35° to -60° elevation) is quartered by imaginary axes extending from the arms of the Pilot's LOS (see Figure 3). For example, the presence of two dots, one on the 0° arm (top arm) and one on the 90° arm (right arm) as shown in Figure 3, indicates that the CPG's line of sight is in the upper right quadrant of the field of regard. One cueing dot on the 90° arm and one on the 180° arm would indicate that the Cued LOS is in the lower right quadrant, and so on around the reticle.

When the Cued LOS is within 4° of one of the quadrant borders, only the dot on that border is displayed. As shown in Figure 4, if the cueing procedure is initiated and the Cued LOS is located between 356° and 4°, relative to the 0° arm of the Pilot's LOS, only the dot on the 0° arm will be displayed.

The PNVS cueing procedure defines eight search areas (numbered 1 through 8 on Figure 4) within the PNVS sensor field of regard. These eight areas extend outward from the center of the PNVS LOS, but are unequal in size. Four narrow search areas, (1, 3, 5, and 7) are defined by the single-dot condition. The narrow search areas extend 4° to either side of each arm of the Pilot's LOS symbol. The remaining four search areas (2, 4, 6, and 8) are wider rectangular areas separated by the four narrow search areas.

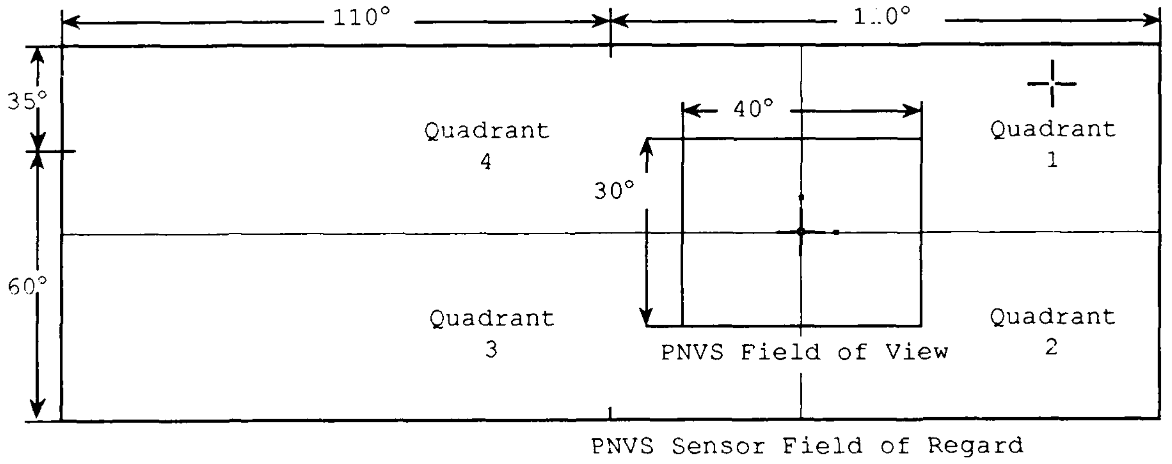


Figure 3. The PNVS sensor field of regard with quadrants created by extensions of the Pilot's LOS symbol axes.

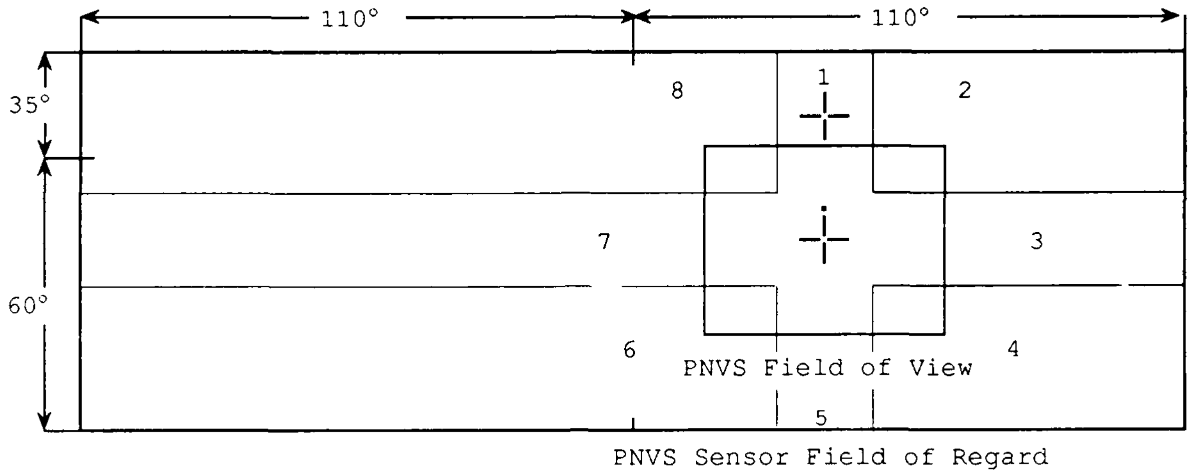


Figure 4. The PNVS field of regard with eight search areas formed by extending the Pilot's LOS axes.

Secondary Purpose of the Cueing Dots

The cueing dots also have a secondary purpose: they flash at a 1 Hz rate (750 ms on and 250 ms off) to indicate that the pilot must boresight the Integrated Helmet and Display Sight Subsystem (IHADSS). If the cueing procedure is active while a boresight is required, all four cueing dots are displayed but the dot or dots indicating the direction to the Cued LOS do not flash. For example, a condition of one constantly illuminated dot on the 90° arm and flashing dots on the 0°, 180°, and 270° arms conveys two types of information: first, the single dot indicates that the Cued LOS is near the border between the upper and lower right quadrants and, second, the three flashing dots indicate that an IHADSS boresight is required.

Perception of the CPG LOS Cues

As described above, when the Cued LOS is in a narrow search area, only the single dot on the appropriate arm of the Pilot's LOS is displayed. However, when the Cued LOS is in one of the wider search areas, two cueing dots are used to cue attention to the search area. In terms of search time, if the Cued LOS is located a constant distance from the cues, the number of dot locations the pilot must examine to obtain unambiguous search information is the limiting factor. No cues are available on the display to suggest which locations should be searched first.

If the pilot observes one cueing dot on the 90° arm and subsequently examines the 0° position but does not see a dot, he must still examine the 180° position for a possible cueing dot. Therefore, each dot has several possible interpretations. For example, a single dot on the 0° arm could be part of two pairs, one indicating the Cued LOS is in the upper left search area and one indicating that the Cued LOS is in the upper right search area. Alternatively, a dot on the 0° arm could be the solitary cue indicating the Cued LOS is in the narrow vertical search area defined by the 0° axis. However, the first cueing dot position that is examined may not be strictly a matter of chance. The pilot may be aware of the CPG's previous visual orientation or may rely on his own situational awareness to predict likely cue positions.

The secondary purpose of the cueing dots poses an additional limitation on the cueing procedure. If the procedure is used while a boresight is required, the particular cueing dot or dots that indicate the direction of the Cued LOS reticle do not flash. However, the other cueing dots flash to indicate that a boresight is required. Because the boresight required indication uses all four cueing dots, the number of alternative responses to any one dot is multiplied by a factor of two. That is, any dot can indicate a search area or a boresight requirement. Furthermore, the IHADSS boresight indication dots are displayed for 750 ms durations, enough time for several shifts in visual attention. If pilots extract information from the cueing dots through a series of rapid shifts in visual attention, a dot examined during the on phase of the flash cycle is likely to be misinterpreted as a search cue. As a result, the pilot could either search the wrong area or ignore an IHADSS boresight requirement indication.

Since the late 1970s, when the PNVS symbology format was developed, research in the area of visual attention has resulted in a number of findings that have implications for aircraft display designers. Furthermore, inexpensive personal computers and powerful graphics applications now provide a feasible alternative to reconfigurable simulators for the evaluation of candidate symbology formats. These tools can also be used to provide sophisticated training in the use of aircraft display symbology. The next section presents a brief review of issues from research in selective visual attention that are specific to cueing and that provide a basis from which to evaluate the cueing procedure for the Cued LOS.

Cueing Visual Attention

The capability of attending to a particular object in the visual field is termed selective visual attention. In many types of selective visual attention paradigms, subjects perform fundamental visual tasks similar to those required of pilots using aircraft visual displays (e.g., Lyon, 1987; Williams, 1982). Such experiments have revealed that a number of factors affect attentional performance on visual tasks. For example, Eriksen and Hoffman (1972) demonstrated that efficient encoding of information from visual displays can be detrimentally affected by the number, nature, or proximity of noise elements. Pilots using aircraft visual displays with several symbols in close proximity, a condition described as display clutter, have reported similar encoding detriments (e.g., Egan & Goodson, 1978).

Response to Cues

A number of researchers (e.g., Bashinski & Bacharach, 1980; Klein, 1979; Posner, Snyder, & Davidson, 1980) have demonstrated that selective visual attention can be shifted, rapidly and accurately, in response to cues. They have also shown that the processing of stimuli is more effective at cued locations than at uncued locations. That is, the gathering of information at a particular spatial location can be made more efficient by cueing visual attention to that location. Furthermore, it is possible to cue shifts in visual attention that occur so quickly that the fixation of the eye is not changed. For example, Lyon (1987) found that visual attention can be shifted from one location to another in less than 68 ms. He suggested that such rapid attention shifts may be a measurable component of skilled performance in vision dependent tasks.

The basic nature of visual attention shifts is a matter of continued debate. Shulman, Remington, and McLean (1979) described shifts in visual attention as an analog movement of attention across space. Consequently, they predicted increases in the latency of attention shifts with increases in the distance between cues and the targets. To describe their findings, they used the metaphor of a spotlight that follows the movement of actors across a stage. Remington and Pierce (1984), however, presented evidence that contradicted an analog movement of attention shifts. In their experiments, latency for visual attention shifts was independent of the distance between the cue and the target. They used a similar metaphor, however, to describe the basic nature of visual attention shifts. Remington and Pierce described visual attention as a spotlight, but a spotlight that was turned off at one place and turned on at another.

Whatever the exact nature of visual attention shifts, the process is extremely fast. Assuming analog movement, Tsal (1983) estimated that attention was shifted across the visual field at about 8 ms per degree of visual angle traversed. Because Tsal's estimate was based on the time required for attention shifts to have a measurable effect on performance, actual shifts may occur even faster. Similarly, Lyon (1987) noted that some experimenters reported attention shift effects in as little as 50 ms after the presentation of a cue. Other experimenters, however, have reported that several hundred milliseconds were required before attention shift effects were measurable.

The research above provides fundamental support for the use of cueing in aircraft display symbology. Under laboratory conditions, individuals can respond to cues on a visual display by shifting visual attention very rapidly and accurately. Furthermore, cueing a shift in attention increases the efficiency of processing information at the cued location. However, research in visual attention has shown that some display conditions are more conducive to effective cueing than others. Conditions such as the size of the attentional search area, the number of stimulus elements to be evaluated, the type of stimulus features that define the cue, the location of the cue, and the effect of practice pose important constraints on the effectiveness of cueing functions and are discussed below.

Search Area

There are conflicting results in the visual attention literature concerning the size of the search area in which attention can be focused. Mackworth (1965) was one of the first researchers to describe the visual field as a dynamic system. That is, when the amount of information contained in an area exceeds some limit, the functional field of view contracts to prevent overloading the visual system. Williams (1982) confirmed Mackworth's observation that the functional field of view decreases in size in response to increased processing demands. Furthermore, Williams described the functional field of view as sensitive to manipulations of task demand as well as the quantity of information. In his experiment, low task demand, (a physical matching task) resulted in a maximum functional field of view of about 4° in diameter. Under high to moderate levels of task demand (a category matching task), he found that the functional field of view decreased to 1° or 2° in diameter.

Eriksen and Hoffman (1972) found that an area subtending approximately 1° of visual angle constituted the minimum functional field of view for subjects in their experiment. They found that stimuli presented within this area were processed more or less automatically. However, subsequent research conducted by LaBerge (1983) suggested that the minimum functional field of view could be as small as 0.3°. Later research by Eriksen and Yeh (1985) also suggested that attention could be focused on an area smaller than 1°.

Eriksen and Yeh (1985) found that the area of attention in the visual field varied as a function of time and task demand. They defined task demand as the amount of information that must be extracted to reach a decision. Task demand determines the concentration of attentional resources required. Therefore, task demand also determines the level of processing that will occur. They suggested that when task demand is low, the level of processing will be diffuse and parallel. When task demand is high, it will be focused and serial. Eriksen and Yeh concluded that the attentional area automatically contracts, concentrating attentional resources until the necessary information can be extracted.

The size of the attentional area is an important consideration in evaluating the cueing procedure for the Cued LOS. For maximum efficiency, the information required to resolve the ambiguity of a cue should be processed as quickly as possible, a condition fostered by the use of a single attentional field. The PNVS symbology format is intended to be used in an environment with task demands far exceeding those of a category matching task under laboratory conditions. It is likely that the pilot's field of visual attention will be at a minimum rather than a maximum. However, the area containing all four cueing dot positions is 5° in diameter, larger than the maximum area found in Williams' (1982) experiment. Under the assumption that multiple shifts in attention are required to search that area, the two cueing conditions may have different attentional requirements. A single cueing dot is no larger than the minimum area reported by LaBerge (1983), but cues formed by two dots subtend an area 3.5° in diameter, larger than the area reported by Williams in his high demand condition.

Number of Stimuli

In most types of visual detection tasks, performance generally decreases as the number of stimuli increases. Even a minor increase in stimuli, such as an increase from a one- to a two-dot cue, may result in an increase in latency (Glass, Holyoak, & Santa, 1979). Similar results are found in selective visual attention research. Research by Jonides (1983), and Posner, Nissen, and Ogden (1978) suggests that, in many cases, attentional resources cannot be concentrated on multiple stimuli at the same time if the stimuli are physically separated. That is, unless the stimuli to be examined are contiguous, the attentional field contracts to concentrate on each element individually, thus resulting in an increase in latency.

Sagi and Julesz (1986) concluded that the search for spatially separated stimuli in the attentional field was a serial process. Similarly, research by Eriksen and Yeh (1985) suggests that faster, parallel processing of separate stimuli occurs only when task demand is low, resulting in a large attentional field and distributed processing capacity. As discussed previously, the PNVS environment can be expected to impose a considerable task demand, resulting in a small attentional field. As a consequence, simply attending to cues formed by two dots may require multiple attention shifts, thus resulting in an increase in latency for the two-dot condition.

Conjunctions of Features

Treisman and Gelade (1980) proposed that attention shifts act to integrate the features of visual stimuli. They considered features to be values on any separable coding dimension such as shape or color that is used to define a visual stimulus. Conjunctions of features, such as shape and color, can also be used to define a stimulus. They concluded that the demand of attending to features was less than that required to attend to conjunctions of features. Thus, a search for stimuli defined by conjunctions of features required a serial process. In the two-dot condition, the cueing procedure for the Cued LOS uses both numerosity and position dimensions to define the cues, suggesting that the two-dot condition, at least, might require a serial search. Furthermore, Bergen and Julesz (1983) report that detecting differences in the position dimension alone may require serial processing.

Location

Several researchers (Brand & Klein, 1987; Jonides, 1980; Lyon, 1987) have noted that the physical location of the cue is a critical factor in the efficiency of the cueing process. Typically, results suggest that cues located in the subject's periphery are more effective at cueing attention shifts than centrally located cues. Lyon noted that experiments demonstrating rapid attention shifts at shorter durations generally employed a cue located in the subject's visual periphery. Furthermore, Jonides found that cues in the periphery are relatively unaffected by factors that usually increase processing demands. Jonides and Brand and Klein have suggested that the attentional mechanisms used in response to central and peripheral cues may be different.

The PNVS field of view is projected by a small CRT mounted on the pilot's helmet and positioned to present the infrared and symbolic imagery to the pilot's right eye. Although the pilot's eye movements are somewhat independent of his head position, the Pilot's LOS symbol does represent the pilot's line of sight if he is looking directly ahead. Thus the cueing procedure for the Cued LOS uses cues located near the center of the field of view, suggesting that they would be less effective than cues located in the periphery. However, because task demand is high in the aircraft environment, specific research on the field of view would be required to define an area that could be considered the periphery of the pilot's visual field.

Practice

Automatic processing, usually developed through practice, may partially compensate for symbology that inherently imposes a high task demand or that is presented in a high task demand environment. According to Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977), there are at least two methods of mentally processing incoming visual stimuli. The first method, controlled processing, is characterized by a slow search that requires focused attention to identify the stimulus. However, after practice, a second method, automatic processing, may become possible. Automatic processing is characterized by a rapid search through the stimulus array from which the stimulus seems to "jump out" without the searcher's focused attention.

Fisk and Schneider (1981) found that the process of target recognition in a vigilance task could become greatly improved by automatic processing achieved through practice.

Similarly, Christ and Corso (1983) found that practice overcame the initial disadvantages of the multiple coding dimensions they employed. With practice, it is possible that the processing for the Cued LOS cueing procedure could become automatic, partially counteracting deficiencies inherent in the symbology or related to the task. However, Shiffrin and Schneider (1977) proposed that automatic processing of visual stimuli was likely to occur only under conditions in which targets never become distractors. They called this condition consistent mapping. Flach (1986) found that automaticity, under consistent mapping conditions, relied on two processing changes. The first change occurred when the individual could respond to the target or targets as if to a single class of stimuli, increasing the efficiency of the memory comparison process. The second change occurred when the individual could filter out the distractor elements, increasing the speed of visual searches. The cues in the PNVS cueing procedure are not consistently mapped. A single dot is sometimes a valid cue, but at other times it is part of a two-dot cue; if an IHADSS boresight is required, there are two or three flashing dots that are distractors.

Research by Durso, Cooke, Breen, and Schvaneveldt (1987), however, suggests that a perfectly consistent mapping of a stimulus to a response may not be a necessary precondition for reduction in visual search times, at least after extensive practice. Their subjects participated in 3,348 to 6,480 trials using a variable mapping paradigm in which targets were sometimes distractors. The magnitude of the reduction in search time was dependent on the number of elements in the display and represented a small gain in processing efficiency relative to other types of tasks with the same amount of practice. Therefore, even if the cueing procedure could become automatic, it is likely to require extensive amounts of practice for a relatively small gain in efficiency.

Evaluation Rationale

The efficiency of an aircraft display system is a result of the amount of time required to locate and comprehend the information being displayed. The time required is determined by factors such as the complexity of the display, practice in using the display, and the location, number, and choice of symbols. Even small variations in the structure of a symbol may affect its utility. For example, Detro and Bateman (1983) found that small changes in the length of a tracking line significantly affected pilots' accuracy while performing a simulated weapons release task.

The experiments described in the next three sections were designed to evaluate the effects of display complexity, presentation duration, practice, and secondary meaning of the symbol on the accuracy of interpreting and using the cueing procedure for the Cued LOS. A more detailed rationale for each experiment is presented at the beginning of each section.

Experiment 1: Evaluation of the Cueing Conditions

Rationale

Experiment 1 was conducted to evaluate the effects of the number of stimulus elements and the presentation duration on the accurate perception of the cueing procedure. Three cueing conditions (no cueing dots, one cueing dot, and two cueing dots) were used. The visual stimuli were presented at a very low level of task demand relative to the operational PNVS environment. On each trial, the subject's task was simply to indicate which of the four cueing dot positions, if any, contained dots. Because the number of elements that define the cue partly determine its attentional demand, the accuracy of identifying a cue should decrease with an increase in the number of dots. In Experiment 1, the cues were randomly presented at four durations: 67, 83, 100, and 133 ms. The presentation duration manipulation was designed to determine the minimum presentation time required for subjects to obtain an asymptotic accuracy level for each stimulus condition.

Method

Subjects

Six volunteers at the U.S. Army Aviation Center, Fort Rucker, Alabama, served as the subjects for this experiment. The subjects were male warrant officer candidates or second lieutenants with normal vision between the ages of 22 and 28 years. The subjects were awaiting entry to the Initial Entry Rotary Wing (IERW) qualification course and had no experience with the PNVS display format. The subjects participated in the experiment during normal duty hours.

Apparatus

A Mitsubishi AUM1371A Diamond Scan monitor was used to present all visual stimuli. The monitor has a noninterlaced

60 Hz frame rate and produces green and blue with P-22 phosphors that decay to 10% of their initial radiant energy in 0.1 ms. All stimuli and instructions were presented in green in the foreground. The background was also presented in green at 50% of the brightness of the foreground. Contrast and brightness controls on the monitor were placed at 50% of their maximum value.

A Zenith Z-386 computer was used to control the monitor. A computer program, written in a combination of the QuickBASIC 4.0 programming language and assembly language, employed the monitor's vertical retrace interrupt cycle as a timing device. One complete vertical retrace interrupt cycle requires approximately 16.667 ms. Therefore all display durations noted in this experiment are multiples of the 16.667-ms interrupt cycle. A mouse was used by the subjects as their response device.

An adjustable chin rest was positioned to maintain the subject's head approximately 11 inches (27.94 cm) from the monitor. At that distance, the area containing the Pilot's LOS and the cueing dots subtended approximately 5° visual angle, which is comparable to the visual angle subtended in the PNVS symbology format. The IHADSS only presents PNVS symbology and infrared imagery to the pilot's right eye. Therefore, a small piece of cardboard was affixed to the chin rest to block the subjects' view of the monitor with their left eye.

<u>Stimuli</u>

With the exception of a square 4-pixel fixation point presented in the center of the Pilot's LOS symbol, stimuli for this experiment simulated symbols currently used in the PNVS symbology set. The Pilot's LOS symbol subtended 3.75° visual angle and was presented in the center of the subject's field of view. The cueing dots were 16-pixel squares subtending approximately 0.3° visual angle on each side. They appeared in locations 2.5° from the center of the Pilot's LOS symbol and 0.625° beyond the arms.

<u>Procedure</u>

<u>Procedure demonstration</u>. After an explanation of the experiment, the experimenters demonstrated the three cueing conditions and the screen sequence. Following the demonstration, subjects were allowed to work through the screen sequence with the cueing conditions presented at durations of

3 seconds. Each of the three conditions was presented four times. Any subject incorrectly identifying the conditions received additional demonstrations and then worked through the screen sequence again. Subjects were reminded that optimal performance on the task required keeping their right eye focused on the fixation point in the center of the Pilot's LOS reticle.

Experimental procedure. Each trial consisted of the sequence of five steps shown in Figure 5. In step 1, the computer presented a screen containing the prompt: READY?; when the subject was prepared for the trial, he pressed any button on the mouse. In step 2, after a 16-ms pause, the Pilot's LOS appeared with a fixation point presented in the center. The fixation point was presented for a randomly chosen duration of either 150 or 200 ms.

In step 3, the fixation point was extinguished, signaling the simultaneous onset of a cueing dot condition. There were three possible cueing conditions: no cueing dot, one cueing dot, or two cueing dots. In the one- and two-dot conditions, the position of the dots was randomly determined, with each position being presented an equal number of times. Each cueing condition was presented for one of four possible durations: 67, 83, 100, or 133 ms. The condition and duration for each trial were selected on a random basis.

In step 4, cueing dots appeared in all four positions and the subject was required to reconstruct the cueing dot condition that had been presented on that trial. The subjects responded by using the mouse to move the cursor to any position that they believed contained a cueing dot during the trial. Then they pressed any button on the mouse to change the color of the cueing dot to blue. A second press on the mouse in the same position would return the dot to green. The correct response to a condition with no dots was to move the cursor to the center of the Pilot's LOS and press any button on the mouse. After indicating the cueing condition, the subject moved the cursor to an area marked OK and pressed any button on the mouse.

In step 5, the word YES or NO appeared in the center of the screen to provide the subject with feedback on the accuracy of his response. After a 1-second pause, the feedback screen was replaced by the screen shown in step 1 and the subject could begin the next trial.

Screen Sequence for Experiment 1

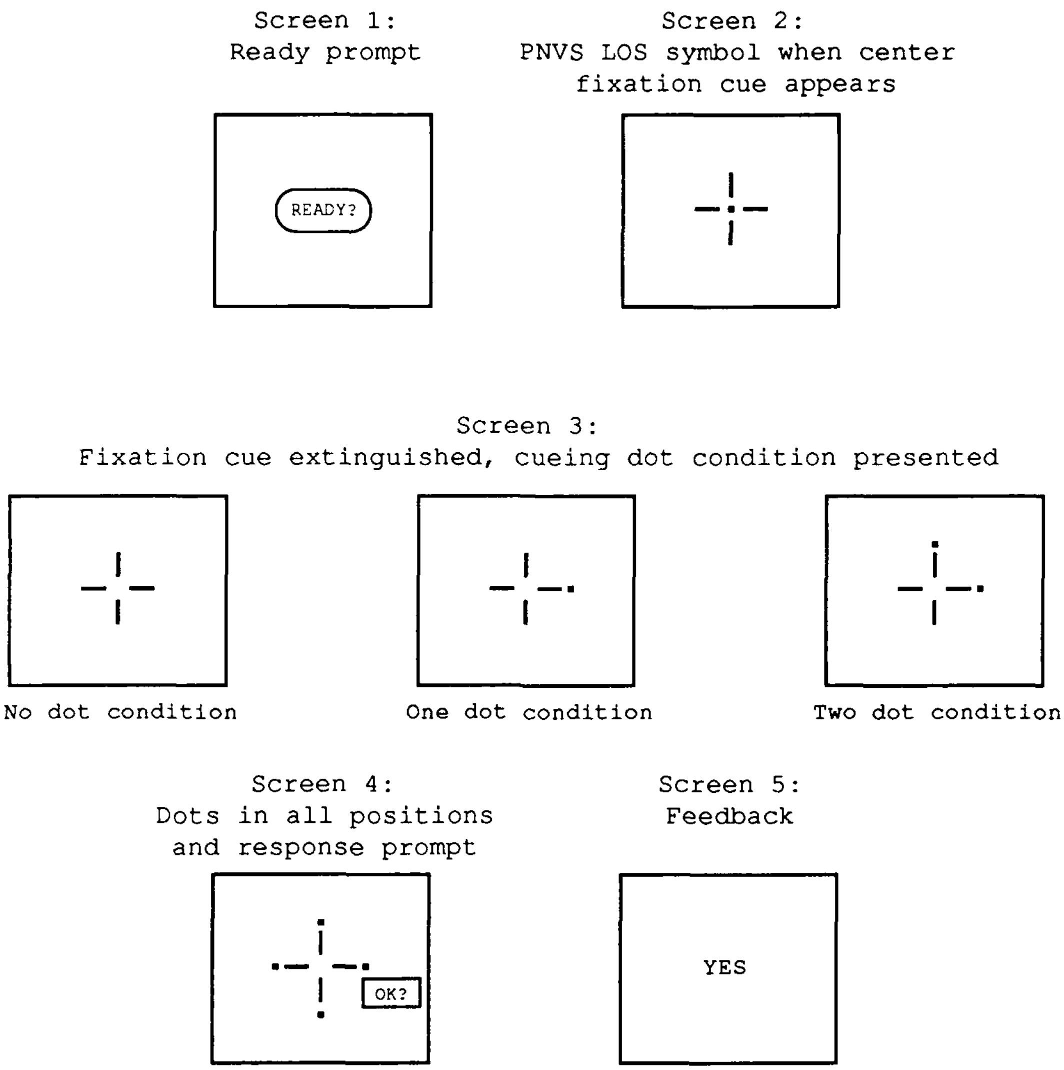


Figure 5. Five-step screen sequence for Experiment 1.

Stimulus blocks. To accustom the subjects to the procedure, an initial block of 60 trials was presented at a constant duration of 150 ms. Data from the first block of trials were not included in analyses of the experiment. Following the initial block, five blocks of 120 trials were presented. Each block was followed by a 5-minute rest period. The condition and duration for each trial were selected on a block-random basis. Thus, at the end of the fifth block of trials, each subject had received a total of

600 experimental trials; 50 trials were presented under each of the three conditions at each of the four durations.

Dependent measure. The dependent measure in Experiments 1 - 3 was the percentage of correct responses across trials under each cueing condition and presentation duration.

Results

A 3 x 4 repeated-measures analysis of variance (ANOVA) indicated a significant condition by duration interaction, F (6, 30) = 9.66, $p < .01$. The interaction effect is shown in Figure 6; the vertical bars show the standard error for each mean. Newman-Keuls analyses ($\alpha = .01$) indicated no significant difference between accuracy in the no-dot condition at any of the four durations. The average percentage correct in the no-dot condition was approximately 97%. The subjects were significantly more accurate in identifying the no-dot condition than the one- or two-dot conditions, except at the 133-ms duration. The subjects were significantly more accurate in the one-dot condition than the two-dot condition only at the shortest presentation duration, 67 ms. Accuracy

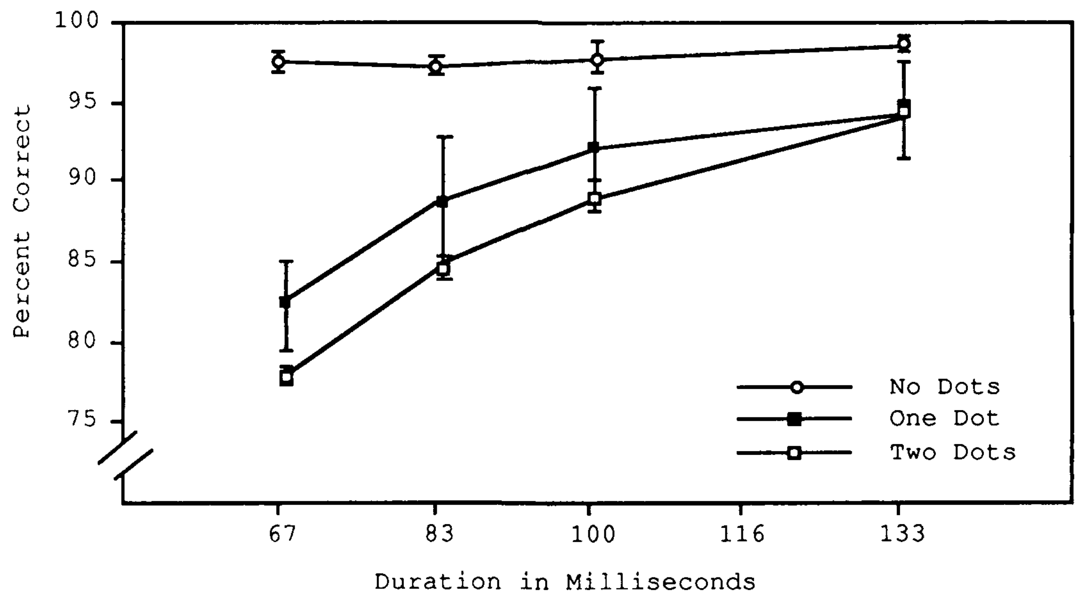


Figure 6. Identification accuracy across presentation durations in Experiment 1.

did improve for the one- and two-dot conditions as the presentation duration increased up to 133 ms. The average maximum percentage correct in the one- and two-dot conditions was approximately 94%.

Discussion

The results of this experiment indicate that minor increases in the complexity of the stimulus, or cue, can reduce the accuracy of simply perceiving the cue during very short presentation durations. Although accuracy in the no-dot condition was not affected by changes in the presentation duration, overall accuracy in both the one- and the two-dot conditions increased as the presentation duration increased up to 133 ms.

The response to the no-dot condition was similar to Williams' (1982) physical matching task, a very low demand task. That is, subjects had little difficulty in determining that either no dots or some dots were present on the display. However, when some dots were present, subjects had difficulty in determining the actual number of dots at very rapid presentation rates. At 133 ms, however, there was no difference between the three conditions and the accuracy of identification had reached asymptote for this level of task demand.

Experiment 2: Evaluation of the Cued LOS Procedure

Rationale

Experiment 2 was conducted to compare the effectiveness of the one- and two-dot cueing conditions at a moderate level of task demand. In this experiment, subjects were required to use the one- and two-dot condition cues to locate targets (PNVS LOS reticles with one arm missing) presented at a known distance and azimuth. Once the targets were located, target identification was considered a constant, because all targets were randomly selected from a set of four highly similar targets.

In Experiment 1, accuracy in identifying both the one- and the two-dot conditions increased as the amount of time permitted to examine the cue increased. At 133 ms, there was no significant difference between the conditions in identification accuracy. Therefore, a duration of 133 ms was selected as the minimum duration in Experiment 2 for evaluating whether the cues could be used to locate the target. It was anticipated that overall accuracy would increase as the presentation durations increased and that accuracy under both conditions would improve with practice.

Method

Subjects

Ten male warrant officer candidates or second lieutenants with normal vision between the ages of 22 and 28 years participated in Experiment 2. The subjects were awaiting entry to the IERW qualification course, but had no experience with the PNVS display format. The subjects participated during normal duty hours.

Apparatus

The same monitor and computer used in Experiment 1 were used in Experiment 2. Subjects were positioned in the same manner as described in Experiment 1. A similar computer program, also written in a combination of the QuickBASIC 4.0 programming language and assembly language, was used to control the presentation of stimuli. Actual display durations used in Experiment 2 were multiples of the 16.667-ms interrupt cycle.

Stimuli

In addition to the Pilot's LOS and the cueing dots that were described in Experiment 1, four different target stimuli were used in Experiment 2. The four targets were variations of the Cued LOS, subtending 3.75° visual angle along their longest dimension. Each target variation lacked a different arm of the Cued LOS symbol.

On every trial, one target stimulus and seven nontarget stimuli were presented at 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° around the fixation point. These stimuli were presented so that the distance between their centers and the center of the Pilot's LOS subtended 10° visual angle. On each trial, the target stimulus was the only example of that particular variation, but the seven nontarget stimuli were randomly chosen examples of the other three variations.

Procedure

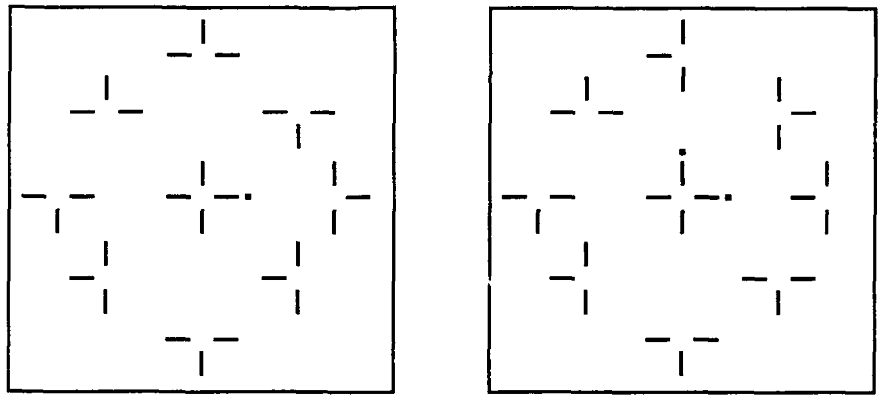
Cueing procedure demonstration. After an explanation of the experiment, the researchers demonstrated the cueing conditions using a Cued LOS symbol as the target stimulus. Both the one-dot and the two-dot cues were demonstrated at durations of 3 seconds. The subjects were asked to indicate the search area where the stimulus should appear. The demonstrations were repeated for any subject who failed to predict the correct search areas. The researchers reminded the subjects that optimal performance on the task required focusing their eye on the fixation point in the center of the Pilot's LOS reticle and using the cueing procedure.

Experimental procedure. Each trial consisted of five steps. Steps 1, 2, and 5 were the same as described in Experiment 1. Figure 7 shows steps 3 and 4 for Experiment 2. In step 3, the fixation point was extinguished, signaling the simultaneous onset of either a one- or a two-dot cue. The target and the seven nontarget stimuli also appeared as the fixation point was extinguished. The cueing condition and, therefore, the search area occupied by the target was selected at random. All areas were selected an equal number of times.

In step 4, Cued LOS symbols appeared in all eight stimuli locations and the cueing dots were extinguished. Subjects were then required to identify which of the targets had been presented by altering the Pilot's LOS to match the target. Subjects used the mouse to move the cursor into position over the arm of the Pilot's LOS that corresponded to the arm missing from the target. The subject eliminated the arm on the Pilot's LOS symbol by pressing any button on the mouse. To change a response, a second press on any button on the mouse in the same position would replace the arm.

Stimulus presentations. The subjects were presented 12 blocks of 128 trials each. Each block of trials was followed by a 5-minute rest period. All trials in the first two blocks were presented at a duration of 267 ms. These blocks were intended to familiarize the subjects with the procedure and to provide practice in identifying the four target stimuli. Data from the first two blocks were not included in analyses of the experiment. In the remaining ten blocks, trials were presented at randomly selected durations of 133, 167, 200, 233, or 267 ms. Of the 1,280 experimental trials, 128 were presented under each condition at each duration.

Step 3:



One dot cueing Two dot cueing

Step 4:

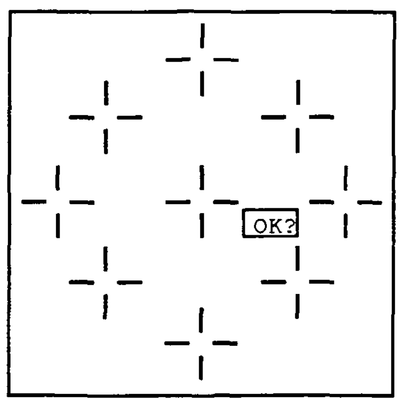


Figure 7. Steps 3 and 4 in the screen sequence for Experiment 2.

Results

A two-way repeated measures ANOVA (2 x 5) of the percentage of correct responses indicated a significant interaction between cueing condition and duration, F (4, 36) = 3.95, $p < .01$. At every duration other than 267 ms, Newman-Keuls analyses ($\alpha = .01$) indicated that accuracy in the one-dot cueing condition was significantly higher than in the two-dot condition (see Figure 8). In the one-dot condition, accuracy increased significantly as the duration increased from 133 to 200 ms; there was no further increase in accuracy at 233 and 267 ms. In the two-dot condition,

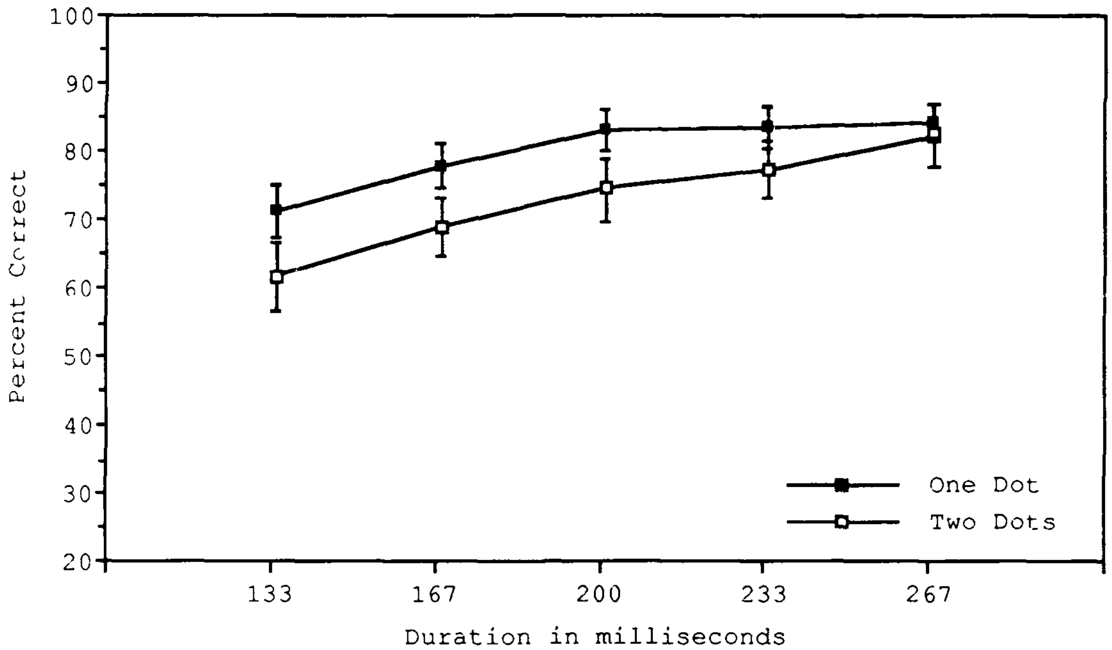


Figure 8. Identification accuracy across presentation durations in Experiment 2.

there were significant increases in accuracy as the duration increased, except between 200 ms and 233 ms. At 267 ms, the percentage of correct responses for both conditions was approximately 83%.

Figure 9 represents the percentage of correct responses to the targets across blocks of 256 trials. A two-way repeated measures ANOVA indicated a significant difference between cueing conditions, F (1, 9) = 8.58, $p < .05$, with accuracy in the one-dot condition consistently higher than in the two-dot condition. There was also a significant effect across blocks of trials, F (4, 36) = 6.65, $p < .01$. Newman-Keuls analyses ($\alpha = .01$) indicated that accuracy increased significantly between 256 trials and 768 trials. There were no significant changes in accuracy between 768 and 1,280 trials. The interaction between conditions and trials was not significant.

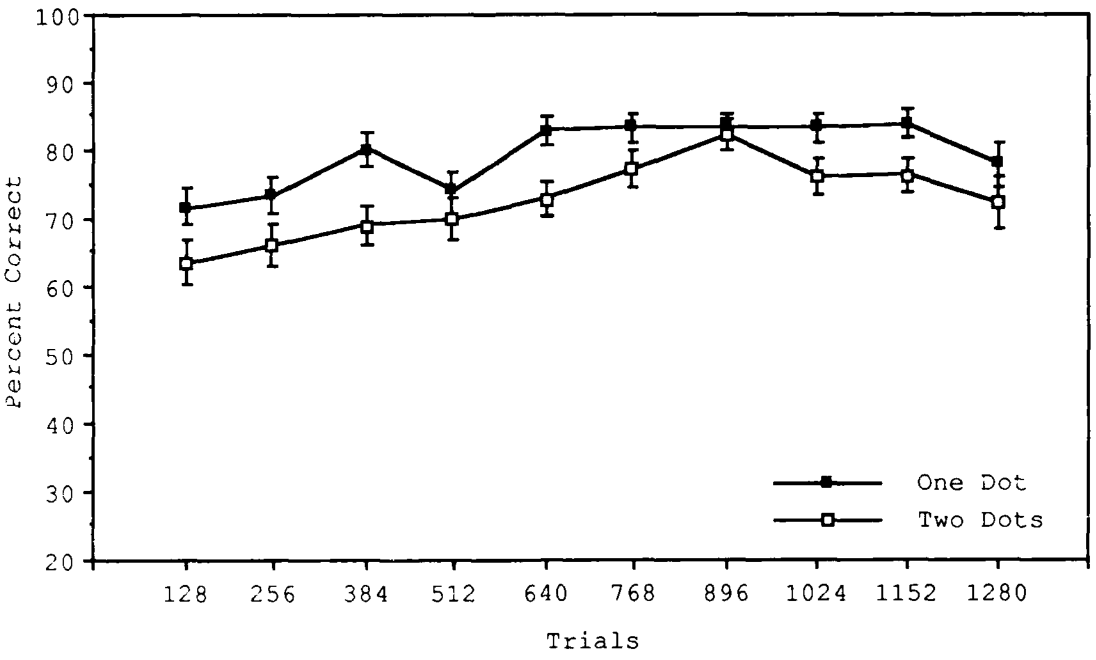


Figure 9. Identification accuracy across trials in Experiment 2.

Discussion

In Experiment 1, accuracy in the no-, one-, and two-dot conditions did not differ significantly at 133 ms. Therefore, at the minimum duration used in Experiment 2, 133 ms, subjects should have had ample time to perceive either the one- or two-dot cueing condition accurately. At the 133-ms duration in Experiment 1, mean accuracy for both the one- and the two-dot conditions was 94.5% (SD = 6.77). In Experiment 2, the mean accuracy was much lower for both conditions at 133 ms: 71% (SD = 11.75) for the one-dot condition and 61% (SD = 15.27) for the two-dot condition. The decrease in accuracy must be attributed to lack of time to shift attention from the cue to the target.

Furthermore, accuracy in Experiment 2 in the one-dot condition was significantly greater than accuracy in the two-dot condition at every duration except 267 ms. This result indicates that the one-dot cue is more effective than the two-dot cue in locating the target at presentation durations between 133 and 233 ms.

There are two possible explanations for this effect. First, in the PNVS, the search area indicated by the two-dot cue is much larger than the search area indicated by the one-dot cue. In the experimental condition, however, the targets in the two-dot condition are in a fixed location in the search area and are the same distance from the fixation point as the one-dot targets. The second explanation is that, in the one-dot condition, the dot is on the same azimuth as the target and the arm of the Pilot's LOS associated with the dot is also directly in line with the target. The combination of the one cueing dot and the LOS arm may produce a more effective cue than the two-dot cue. The practical implication of this finding is that the PNVS cueing procedure should be modified to improve the effectiveness of the two-dot cue. The modifications could include changes in the search area for the cues or adding secondary arms to the reticle.

The analysis of performance across trials indicated that performance under both the one- and the two-dot conditions gradually improved with practice during the first 768 trials. Additional practice did not significantly improve subject performance in this task. The asymptotic performance levels are near 80%, but this accuracy level is across all presentation durations.

Experiment 3: Evaluation of the Boresight Indication

Rationale

The secondary purpose of the cueing dots in the PNVS symbology is to signal an IHADSS boresight requirement. Flashing dots in cueing positions not used by a one- or two-dot cue indicate a boresight requirement. Experiment 3 was designed to determine if the boresight indication reduced the effectiveness of the one- and two-dot cueing procedures.

Nine of the subjects who participated in Experiment 2 also participated in Experiment 3. Each subject, therefore, had at least 1,280 trials of experience in identifying targets cued by the one- and two-dot conditions. Experiment 3, therefore, was also designed to determine if identification accuracy can be improved by practice beyond 1,280 trials.

Method

Subjects

The 10 subjects from Experiment 2 were scheduled to participate in Experiment 3. However, 1 subject entered the IERW qualification course and was unable to participate. The remaining 9 subjects had 1,280 trials of experience performing the target identification task at the beginning of Experiment 3. The subjects participated in Experiment 3 during normal duty hours.

Apparatus and Stimuli

The apparatus and stimuli described in Experiment 2 were also used in Experiment 3.

Boresight Simulation

In the PNVS symbology set, the four cueing dots are displayed for 750 ms out of each second when they are used as an IHADSS boresight indication. During a 750-ms period, however, several attention shifts can occur. To examine the effect of the cueing dots' secondary function, a 66.667-ms cycle was used to simulate the boresight-required function. This cycle was selected to present two flashes during the minimum presentation duration (133 ms). The cycle consisted of a 50-ms on phase and a 16.667-ms off phase, which is proportional to the 750-ms on, 250-ms off cycles in the PNVS. At the initiation of each boresight-simulation trial, the flash cycle began with the 50-ms on phase.

Procedure

Boresight required indication demonstration. The same procedure used to demonstrate the two cueing conditions in Experiment 2 was used to demonstrate the secondary purpose of the cueing dots. During the demonstrations, all cueing conditions were presented at durations of 3 seconds. The demonstrations were repeated for any subject who failed to predict the correct search areas. Subjects were reminded that optimal performance for the task required keeping their eye focused on the fixation point in the center of the Pilot's LOS reticle and using the cueing procedure.

Experimental procedure. The same procedure described in Experiment 2 was used in Experiment 3, except in step 3. In step 3, flashing dots were randomly presented on half the trials in the positions not used as cues to the target stimulus.

Results

A three-way repeated measures ANOVA (2 x 2 x 5) was conducted to determine the effects of cueing condition, presentation duration, and secondary symbol function on the percentage of correct responses to the target stimulus. Figure 10 presents a graph of the results. The first two effects were similar to the results of Experiment 2, except that there was no interaction. Subjects were significantly less accurate under the two-dot condition than under the one-dot condition, F (1, 8), = 10.09, $p < .05$, and there was a significant increase in accuracy as the duration increased, F (4, 32), = 24.95, $p < .01$. Newman-Keuls analyses ($\alpha = .01$) indicated significant increases in overall accuracy between the 133- and 167-ms durations and between the 167- and 200-ms durations; there was no further increase in accuracy at the

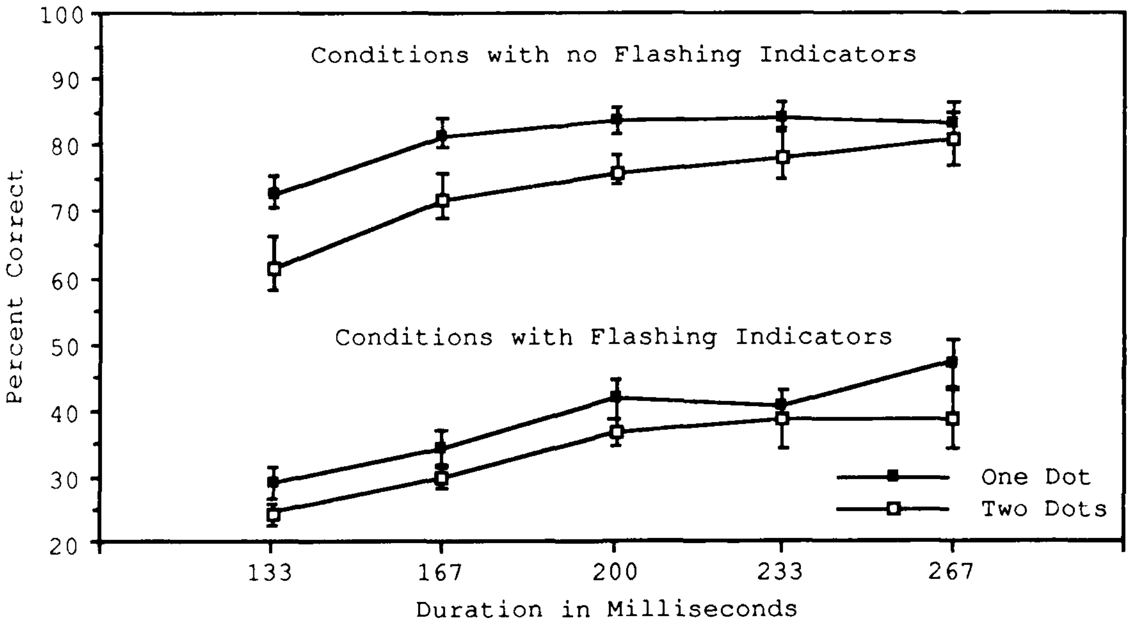


Figure 10. Identification accuracy across presentation durations in Experiment 3.

233- or 267-ms durations. Finally, the subjects were significantly less accurate in the presence of flashing dots, F (1, 8), = 321.47, $p < .01$. As seen in Figure 10, accuracy decreased by approximately 40% under both cueing conditions and at all presentation durations when the boresight requirement was simulated. There were no significant interactions.

A second 2 x 2 x 5 repeated-measures ANOVA indicated that practice across blocks of trials did not improve the accuracy of target identifications under either cueing condition. That is, the asymptotic performance levels attained in Experiment 2 were maintained during Experiment 3. In addition, there was no improvement in performance across trials when the boresight requirement was active (see Figure 11).

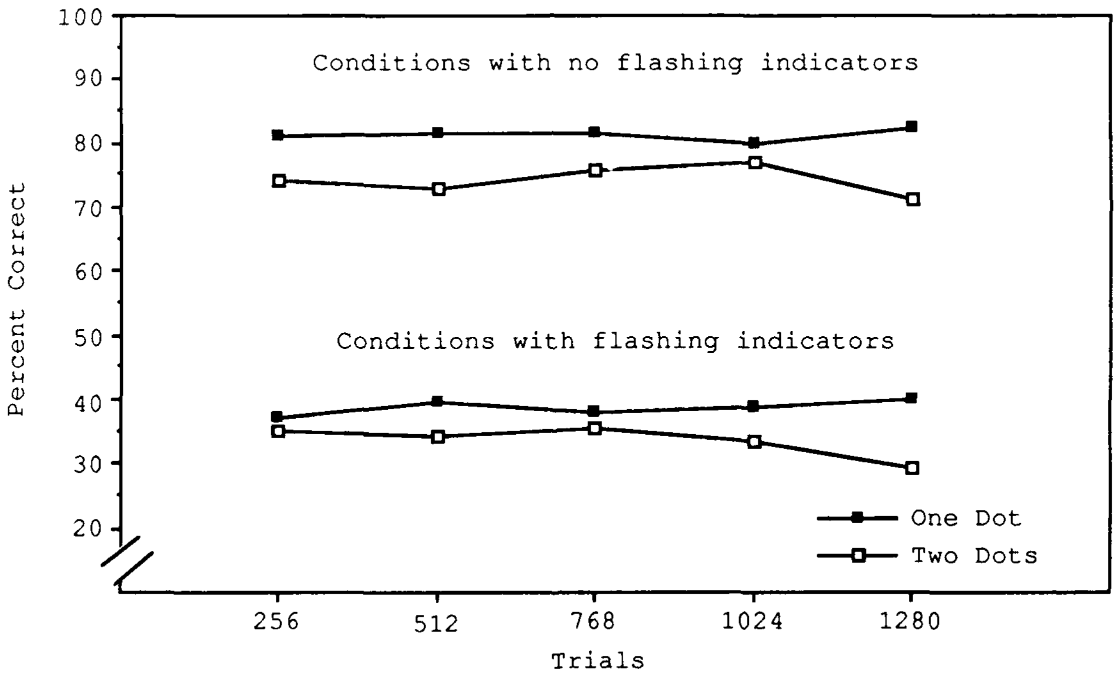


Figure 11. Identification accuracy across trials in Experiment 3.

Discussion

The additional task demand of interpreting the cues in the presence of flashing dots clearly impaired subjects' performance in both the one- and two-dot conditions. At the longest duration, 267 ms, accuracy was less than 50% for either cueing condition in the presence of flashing dots. At the shortest duration, 133 ms, performance in the two-dot condition deteriorated to a level no better than chance. As expected, overall accuracy increased as the time available for interpreting the cue and locating and identifying the target increased. At the 267-ms duration, accuracy in both cueing conditions was greater than 80%.

The results of the second analysis, examining accuracy across trials, did not indicate any significant improvements in performance over the course of the experiment. Subjects began with at least 1,280 trials of experience in identifying targets in response to the one- and two-dot cues. Practice on an additional 640 trials without flashing dots, did not result in any increase in accuracy. On the 640 trials with flashing dots, the absence of improvement indicates that the reduced accuracy caused by the boresight requirement function cannot be ameliorated by practice. That is, the subjects were not able to disregard the flashing dots despite the fact that they were already well practiced at identifying the cues.

General Discussion

There are major differences between the conditions presented in these experiments and the conditions that are present in operating the PNVS. Obviously, using the Cued LOS is only one of many tasks that the pilot is performing; in the laboratory, it is the only task being performed and there are no other stressors placed on the subject except for the speed stress imposed by the presentation durations. Perhaps most importantly, the pilot will not be searching for a stationary target at a known distance and azimuth presented against an uncluttered visual background. Nevertheless, the results of the three experiments lead to four conclusions regarding the effectiveness of the cueing procedure for the Cued LOS. The conclusions and recommendations for design options or training modifications are discussed in the following paragraphs. Finally, the usefulness of the visual attention paradigm for evaluating symbology is discussed.

Cued LOS Cueing Differences

The three experiments discussed in this report indicate that the one-dot cueing condition is consistently superior to the two-dot condition. In Experiment 1, perception of the one-dot cue was significantly better than the two-dot cue at the fastest presentation duration. Trials in Experiments 2 and 3 were presented at or above the minimum duration required for the accurate perception of either cue. However, Experiment 2 demonstrated that subjects required less time to use the one-dot cue than the two-dot cue. And, in Experiment 3, accuracy was consistently higher in the one-dot condition than in the two-dot condition, even under the simulated boresight requirement condition.

An obvious difference between the two cueing conditions is the search area each cue indicates. The one-dot cue indicates a narrow, rectangular search area, while the two-dot cue indicates a majority of the quadrant (see Figure 4). In the PNVS symbology, the simple difference in search areas between the one- and two-dot cues should make the one-dot cue more effective. However, in Experiment 1 there was no search area; subjects only had to perceive the cue. In addition, the difference in cueing effectiveness occurred only in the fastest duration. In Experiments 2 and 3, the targets were located in a fixed position in each search area and the targets were equidistant from the fixation point. Although the respective search areas may cause differential cueing effectiveness in the PNVS, the search areas do not explain the difference in cueing effectiveness in these three experiments.

An alternative explanation is that the cue formed in the one-dot condition is functionally superior to the two-dot cue. That is, one dot presented just beyond an arm of the Pilot's LOS, on the axis from the fixation point to the target, may be a better cue than two dots positioned beyond arms oriented at 45° to the target. This explanation could be tested by rotating the Pilot's LOS by 45° so that the arms of the reticle are oriented toward the 45°, 135°, 225°, and 315° target locations, or by using a reticle with eight arms and eight one-dot cues.

At least two design options should be considered to address these problems. The first option would be to redistribute the search areas associated with the one- and two-dot cues. The second option would be to design equally effective cues for all portions of the field of regard.

Presentation Duration

The three experiments also demonstrated that accuracy in perceiving the cues and in locating and identifying the cued targets increased as the presentation duration increased, up to approximately 233 ms. At this duration, the accuracy of target identification was approximately 80%. Fortunately, in operating the PNVS, the cues are presented continuously. However, a crucial factor is the pilot's need to locate the Cued LOS symbol as quickly as possible. In the PNVS, the target is not in a fixed position and the search area is cluttered. To avoid misinterpretation, pilots should be advised to ensure they have interpreted the cue accurately before instituting a search for the CPG line of sight.

Secondary Function Effect

In Experiment 3, the subjects' ability to respond to the familiar cues created by either cueing condition was significantly degraded by the presence of the simulated IHADSS boresight requirement. In the presence of flashing dots at the 133-ms duration, accuracy in response to the two-dot condition was no better than chance. The maximum accuracy level when the boresight required cue was active was approximately 50% (see Figure 10). Furthermore, the display cycle for the boresight requirement in this experiment (66.667 ms) was much shorter than the cycle used in the PNVS (1 s). Theoretically, the shorter cycle should produce fewer miscues than the longer cycle because the on-phase is less likely to be interpreted as a Cued LOS cue. Finally, the present results do not indicate that the flashing dots are an effective cue for a boresight requirement; they only indicate that the boresight requirement cue interferes with the effectiveness of the Cued LOS cues. Further research should be conducted to determine the effectiveness of the secondary cue or to develop a different method of indicating an IHADSS boresight requirement.

Practice Effects

Experiments 2 and 3 demonstrated that accuracy in target identification improved with practice, but it reached asymptote at less than 100%. In Experiment 2, the subjects' accuracy improved significantly during the first 768 trials, but did not improve between 768 and 1,280 trials. An additional 640 trials without distractors in Experiment 3 did not result in any significant improvement in performance. Furthermore, Experiment 3 demonstrated that practice did not improve performance when the simulated IHADSS boresight requirement was active. Although performance never improved to perfect levels, the results of these experiments indicate that extensive practice is required to use the cueing procedures with the maximum obtainable effectiveness.

Usefulness of the Selective Visual Attention Paradigm

As a first attempt at empirically evaluating the PNVS symbology format, the visual attention paradigm was successful. The ability of the paradigm to identify factors that influence the effectiveness of the Cued LOS cues indicates that it is an appropriate method for evaluating at least some aspects of existing and proposed display symbology formats. For example, the approach could be used to evaluate different positions and types of cues to determine a better cue for the Cued LOS symbol. The approach could also be used to evaluate different types of target symbols and to evaluate both target symbols and cues in the presence of distractions, such as infrared background imagery or display clutter. Furthermore, the paradigm could be used to create a map of areas in the PNVS format where the other symbols interfere with target acquisition or the interpretation of information from the background imagery. Symbols could then be relocated or systematically substituted to arrive at a better display format. By comparing candidate symbols proposed as substitutes with the existing symbols' established accuracy rates, the paradigm could provide an empirical evaluation of the discriminability of new symbols.

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APPENDIX A

THE AH-64A SENSOR SYSTEMS AND SYMBOLOGY SETS[1]

The AH-64A attack helicopter is a two-crewmember aircraft designed to fly nap-of-the-earth missions to detect, engage, and destroy enemy armor during day or night and under all weather conditions. To provide this capability, the AH-64A is equipped with several complex flight and weapons delivery systems. The successful operation of these systems requires that the pilot and copilot/gunner (CPG) be able to identify and interpret both visual imagery and symbolic information presented on visual displays.

The AH-64A visual display systems that provide information to the pilot and the CPG are the Pilot Night Vision System (PNVS) and the Target Acquisition and Detection System (TADS). The PNVS provides forward-looking infrared (FLIR) imagery that enables the pilot to fly the aircraft at night and during degraded visibility conditions. The TADS is used by the CPG for target search, detection, recognition, and designation. The TADS uses information from three sensors: the FLIR system, the day television viewing system, and the direct view optics system. These three sensors provide the CPG with visual information to detect and engage targets at standoff ranges during day or night operations and in adverse weather conditions. The Fire Control Symbol Generator superimposes flight and weapons symbology on the imagery displayed by the PNVS and the TADS.

The visual imagery and symbology from the PNVS and the TADS can be presented to the pilot on a 4.0" by 5.0" panel-mounted display or to the CPG on a 2.25" by 3.25" panel-mounted display. In addition, the imagery and symbology can be presented to either crewmember through the Helmet Mounted Display (HMD) which consists of a 1-inch diameter CRT attached to the helmet. The HMD is a monocular display that enables the crewmember to cross-check flight and weapons information superimposed on infrared sensor imagery while directing attention outside the cockpit. All the displays provide the crewmember with a 30° (vertical) by 40° (horizontal) field of view.

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[1] Adapted from Ruffner, J. W., Coker, G. W., and Weeter, R. D. (1989, May), "Development of the AH-64A Display Symbology Training Module" (Research Note ASI690-322-89). Fort Rucker, AL: Anacapa Sciences, Inc.

PNVS Symbology

The PNVS symbology (flight symbology set) consists of the 27 alphanumeric and shape coded symbols shown in Figure A-1. The symbols are designed to help the crewmember fly the aircraft. Not all the symbols shown in Figure A-1 will appear on the displays at the same time. Many of the computer generated symbols are adaptations of traditional electromechanical instruments and are located in fixed positions on the displays (e.g., Heading Scale, Vertical Altitude Scale). Some, however, are unique dynamic representations of spatial information that move about the displays and in or out of the viewing areas as a result of sensor orientation or changes in aircraft position (e.g., Cued Line of Sight [LOS] Reticle, Hover Position Box).

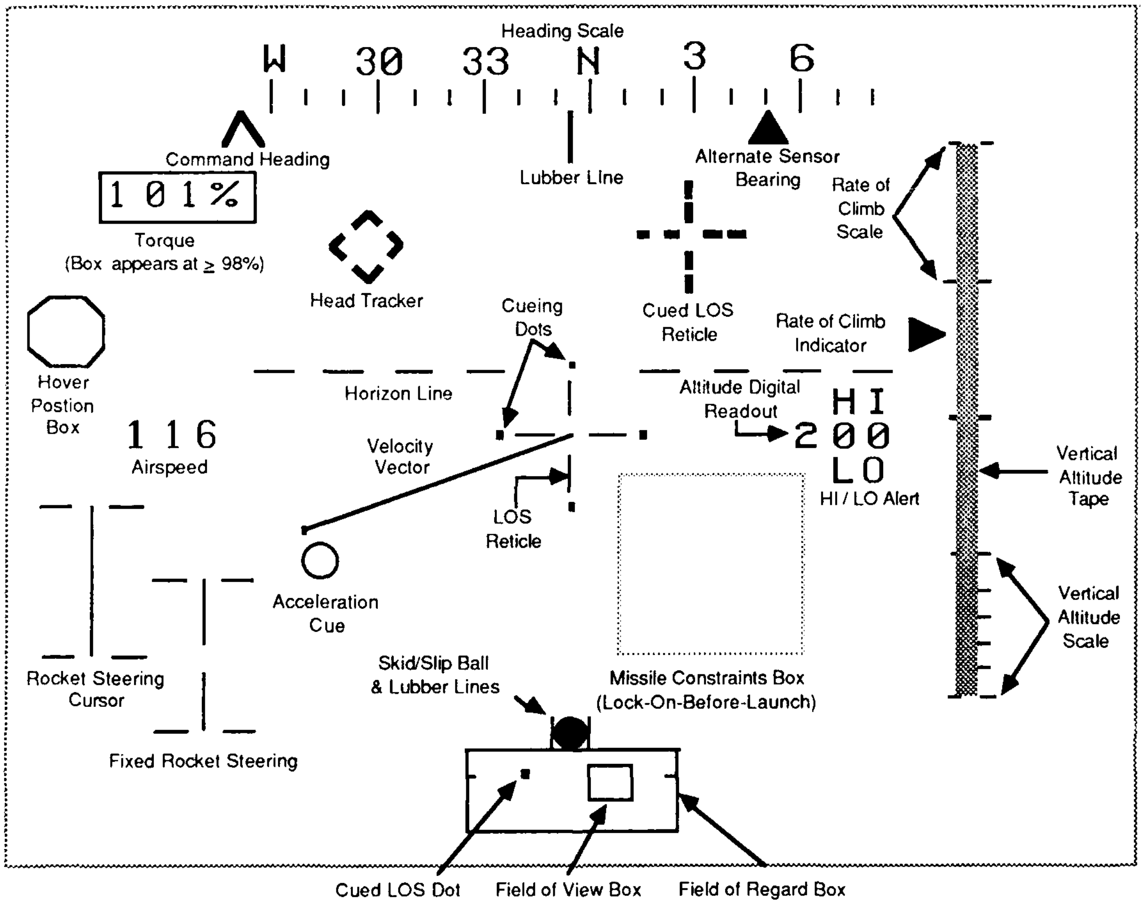

Figure A-1. The AH-64A flight symbology set (PNVS symbology) shown without background imagery.

To reduce clutter and to make the symbolic information more task specific, there are four operating modes that present subsets of the 27 symbols. Symbols representing aircraft heading, airspeed, altitude, engine torque, and certain other basic flight information are provided constantly during all four modes. The hover mode adds a velocity vector and an acceleration cue to aid the pilot in maintaining a hover. Selection of the transition mode adds a horizon line to the hover mode subset and is used when changing from a hover to cruise flight. Once cruise flight has been established, selection of the cruise mode removes the velocity vector and acceleration cue, adding only the horizon line to the basic symbology set. To aid the pilot in returning to a chosen location or remaining over the location with a specific heading, a bob-up mode adds the velocity vector, acceleration cue, command heading, and hover position symbols to the basic flight information.

TADS Symbology

The TADS symbology (weapons symbology set) consists of the 17 alphanumeric and shape coded symbols shown in Figure A-2. Fourteen symbols (e.g., airspeed, radar altitude, heading scale, missile constraints box) are common to both the flight and weapons symbolology sets. The TADS symbols are designed to assist the crewmember during the operation of the weapons systems. There is only one operating mode for the TADS symbology, but not all the symbols shown in Figure A-2 will appear on the displays at the same time. The number of symbols displayed at any given time depends on the nature of the weapons tasks (e.g., rocket or missile engagement).

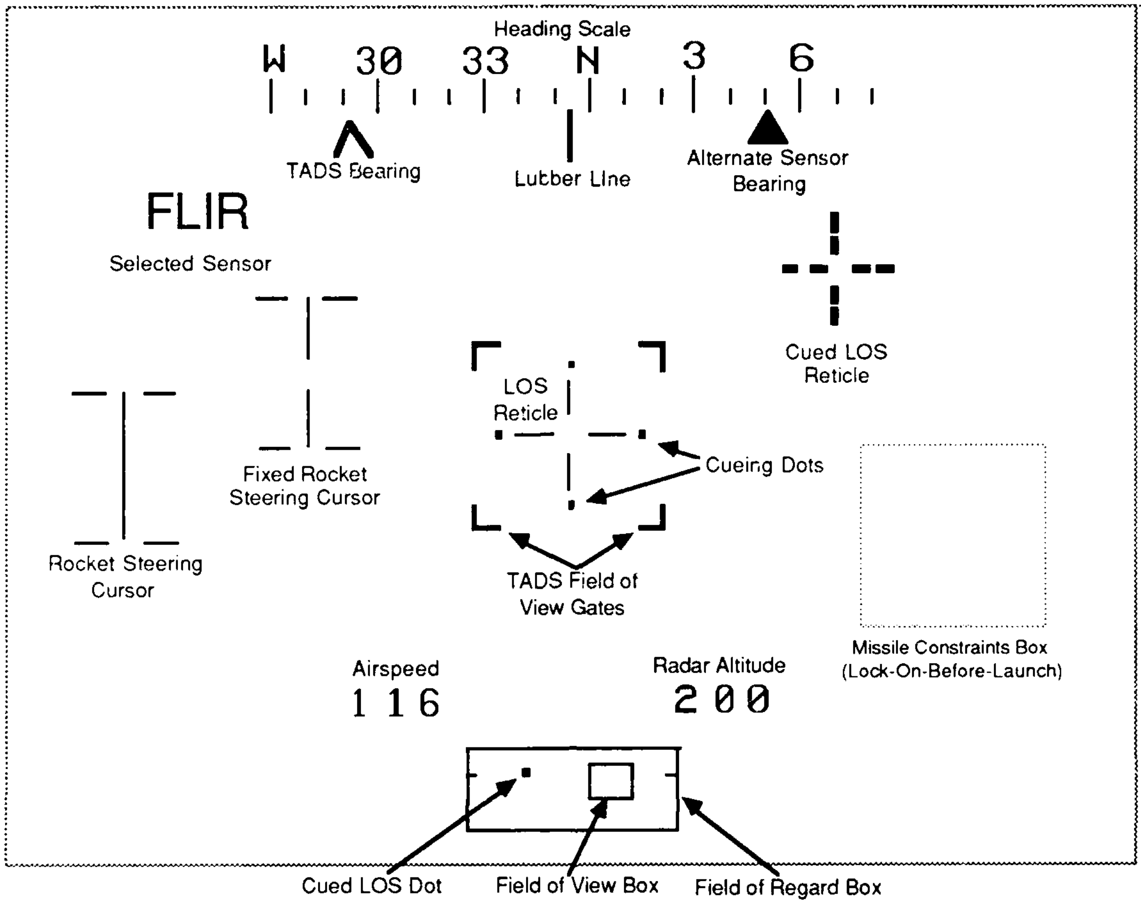

Figure A-2. The AH-64A weapons symbology set (TADS symbology) shown without background imagery.