ARMY RESEARCH LABORATORY

The Effects of Divided Attention on Peripheral Target Localization

Ann Marie Rohaly
Robert Karsh

ARL-TR-1334

APRIL 1997

19970606 125

Kodak™ and Wratten™ are trademarks of Kodak.

Titmus® II is a registered trademark of Titmus.

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5425

ARL-TR-1334

April 1997

The Effects of Divided Attention on Peripheral Target Localization

Ann Marie Rohaly
Robert Karsh
Human Research & Engineering Directorate

Abstract

Designers and users of helmet-mounted displays often assume that single-eye devices reduce operator workload relative to dual-eye devices by allowing two tasks to be performed simultaneously, one by each eye. In other words, the two eyes are assumed to constitute separate attentional channels. To test this assumption, we implemented a modified version of the useful field of view (UFOV) paradigm of Ball, Beard, Roenker, Miller, and Griggs (1988) to measure the effects of dichoptically divided attention on dual-task performance. Subjects localized a peripheral target within a semicircular region of 30° radius while simultaneously performing a foveal task. The degree of difficulty of the experiment was manipulated by varying the foveal task workload and the number of clutter (distractor) items in the periphery. The foveal and peripheral tasks were either presented to the same eye (monocular viewing) or different eyes (dichoptic viewing). Peripheral target localization performance was essentially perfect at all eccentricities for all the non-clutter conditions: monocular and dichoptic viewing, low and high foveal task workload. Introduction of peripheral clutter caused a significant deficit in localization performance that increased with increasing target eccentricity. Similar to the non-clutter conditions, there was no difference in performance between monocular and dichoptic viewing. Thus, we find no evidence to support the assumption that dividing attention between two eyes allows dual tasks to be performed more efficiently than when attention is divided within the same eye, implying that the two eyes do not constitute separate attentional channels.

ACKNOWLEDGMENT

The authors would like to express their appreciation to Ramakrishna Pillalamarri for the many hours he spent writing and debugging the software used to run the experiments. Without his help, the study would not have been possible.

CONTENTS

THE EFFECTS OF DIVIDED ATTENTION ON PERIPHERAL TARGET LOCALIZATION

INTRODUCTION

In recent years, the military has initiated multiple programs to develop helmet- or head-mounted display (HMD) technologies for field use. A common feature of many of these HMD concepts is their single-eye configuration. The reasons for proposing single-eye instead of dual-eye designs[1] are

- Reduced cost.
- Reduced weight.
- Increased field of view. (Designers assume that by preserving peripheral vision in the unaided eye, a single-eye HMD will decrease spatial disorientation and facilitate navigation.)
- Decreased workload. (Designers assume that a single-eye HMD will allow two tasks to be performed simultaneously by allocating one task to each eye.)

Apache (AH-64) helicopter pilots currently fly with a single-eye HMD that is part of the integrated helmet and display sighting system (IHADSS). This system presents the pilot's right eye with symbology and a forward-looking infrared (FLIR) image of the outside world transmitted from a sensor mounted on the nose of the helicopter. The pilot's left eye remains unaided and is free to scan cockpit instruments and the outside world. As such, IHADSS puts the pilot in a dichoptic viewing situation: his left and right eyes receive different visual images. During normal viewing, the left and right eyes receive images that are identical except for slight offsets in features that result from the different vantage points of the two eyes. These offsets, known as binocular disparity, are interpreted by the visual system as cues to stereoscopic depth. With IHADSS, however, the left and right eyes' images are completely different and cannot be fused into a single percept. The result is a phenomenon known as binocular rivalry (Hale & Piccione, 1990); the visual system oscillates and perception alternates between the left eye's image and the right eye's image. While the use of any single-eye HMD can cause binocular rivalry, prudent design decisions may be able to minimize its effects, owing to the large body of empirical research investigating the phenomenon (Blake, 1995).

---

[1] Throughout this report, the term "single-eye HMD" is used to refer to what is conventionally called a monocular HMD, and the term "dual-eye HMD" is used to refer to what is conventionally called a binocular HMD. These terms are introduced for clarity and to emphasize the distinction between various hardware configurations and experimental viewing conditions.

Relatively few studies have been conducted to investigate task performance under dichoptic viewing conditions, the situation presented by single-eye HMDs. The likely reason for this dearth of information is that dichoptic viewing represents a situation that does not occur under normal viewing conditions. Caldwell, Cornum, Stephens, and Rash (1990) tested Apache pilots experienced in using IHADSS and other pilots with no single-eye HMD experience in a dichoptic letter discrimination task. No difference in performance was found between the two groups. Likewise, Kimchi, Gopher, Rubin, and Raij (1993) found no difference in performance of a simple visual search task under dichoptic and binocular viewing conditions. In both studies, during dichoptic testing, part of the visual stimulus was presented to the left eye only and part to the right eye only. As a result, integration of information between the two eyes was required to perform a single task. This experimental paradigm does not faithfully represent the intended use of single-eye HMDs, namely, the simultaneous performance of competing tasks by the left and right eyes.

Gopher and co-workers (Gopher, Grumwald, Straucher, & Kimchi, 1990; Gopher, Kimchi, Seagull, Catz, & Trainin, 1992) investigated the effects of dichoptic viewing on dual-task performance. Subjects were required to "fly" through a curved tunnel while simultaneously performing a letter-detection task. The accuracy of letter detection was found to be significantly worse when the tracking symbols used to control the flight path of the simulated helicopter were presented to a different eye than were the letters. In addition, performance deteriorated as the retinal eccentricity of the letters increased from 0° (foveal presentation, superimposed on the flight path) to 8°. This finding is at least partly artifactual as the authors did not size-scale the letters to compensate for the lower acuity of the peripheral retina. Problematic as they are, however, these are the only systematic studies to date that have quantitatively assessed the effects of divided attention on dichoptic dual-task performance.

There is, however, additional anecdotal evidence to support the hypothesis that dividing attention between the left and right eyes degrades performance. Hale & Piccione (1990) conducted a survey of 52 AH–64 pilots to assess problems associated with the use of the IHADSS. Overall, the survey results indicated that the single-eye HMD increased workload. Specifically, 69% of the pilots reported that their visual attention was at times drawn to the display unintentionally, and 67% reported that focusing their attention on the unaided eye was extremely difficult. Approximately 40% reported that they could not simultaneously attend to the inputs from both eyes and that the HMD imagery interfered with their ability to monitor cockpit instruments with the unaided eye. In addition, Rash, Verona, and Crowley (1990) reviewed the accident investigation reports of all Class A, B, and C AH–64 accidents (damages exceeding $10,000 or injuries resulting in at least one lost workday) that occurred between 1985 and 1989. They found that 28 of the 37 accidents were attributed to use of the IHADSS. "Division of attention" was the most frequently cited accident factor, causing 9 of the 28 IHADSS-related accidents.

To summarize, although single-eye HMD systems are currently used in the aviation community, and various sectors of the military are planning to field single-eye HMDs for other purposes, little empirical research has been conducted to assess the perceptual and cognitive consequences of such technology. This paucity of knowledge exists despite the fact that perceptual and cognitive problems have been identified and documented (Hale & Piccione, 1990; Rash et al., 1990; National Research Council, 1995). In a recent human factors assessment of the proposed 21st Century Land Warrior (21 CLW) single-eye HMD, the National Research Council (1995) determined that unless more research is conducted in key areas, fielding such technology will be extremely risky. One of the critical areas recommended for further research was division of attention in a competing task environment under different levels of workload.

Ball and colleagues (Sekuler & Ball, 1986; Ball et al., 1988; Ball, Roenker, & Bruni, 1990) have developed an experimental paradigm to measure the effects of divided attention on dual-task performance. The paradigm was designed to quantify the "functional" or "useful" field of view (UFOV), defined as the portion of the visual field that can be attended to and from which information can be acquired during a single glimpse (i.e., without head or eye movements). As such, the UFOV represents the spatial extent of the pre-attentive mechanism of visual attention (Julesz, 1981; Ball et al., 1990). The function of pre-attentive processing is to alert and direct the attentive mechanism to areas of the visual field that require further scrutiny. It operates over a large spatial area within a short period of time and is not under voluntary control (Kröse & Julesz, 1989; Nakayama & Mackeben, 1989; Ball et al., 1990).

The dual-task UFOV paradigm of Ball and co-workers requires subjects to localize a target presented in the peripheral visual field while concurrently performing another task in the central visual field. Under these experimental conditions, the UFOV for binocular viewing in normal young adults is a circle, centered on the fovea, approximately 30° in radius (Ball et al., 1988, 1990; Seiple, Szlyk, Yang, & Holopigian, 1997). The size of the UFOV is influenced by many factors, including the presence of peripheral distractors (clutter) and the difficulty of the central task (Ball et al., 1988, 1990; Kröse & Julesz, 1989). Both of these factors increase the cognitive demand (workload) of one of the two tasks to be performed, forcing the subject to reallocate his or her attention between the tasks. A reduced ability to divide attention efficiently to successfully perform the competing tasks is reflected in a reduction in the measured UFOV, a phenomenon sometimes referred to as attentional narrowing or attentional tunneling.

The most important characteristic of the UFOV is that this simple laboratory measure has proven functional significance. Ball and colleagues (Ball, Owsley, Sloan, Roenker, & Bruni, 1993; C. Owsley, personal communication about unpublished data, 1996) have demonstrated that UFOV measures are predictive of driving and navigation performance, whereas traditional measures of visual function such as acuity and contrast sensitivity are not (Allen, 1970; Henderson & Burg, 1974; Council & Allen, 1974; Shinar, 1977). Therefore, by measuring the UFOV in a dichoptic viewing paradigm, insight can be gained into the level of performance to be expected of a soldier outfitted with a single-eye HMD system.

OBJECTIVES

The main objective of the present experiments was to test the hypothesis that dividing attention between the left and right eyes does not improve dual-task performance relative to the level of performance achieved when attention is divided within the visual field of one eye. This hypothesis was formulated on the basis of the following facts:

- The neuroanatomical circuitry and information-processing algorithms of the human visual system have evolved to integrate the inputs to the left and right eyes and not to treat the two eyes as separate information channels. Psychophysical studies of detection performance suggest that because of this integration, the visual system does not have "eye of origin" information (Cormack & Blake, 1980).

- If it were possible to perform two competing tasks more efficiently by allocating one task to each eye, this strategy would be adopted by individuals with congenital disorders that prevent the left and right eyes from working together (e.g., amblyopia) but it is not. Instead, such individuals suppress the input from one eye and view the world monocularly (Perry & Childers, 1972; D.H. Levi, personal communication, 1996).

- Some empirical and anecdotal evidence exists in the literature to support the hypothesis (see Introduction).

An ancillary objective was to determine whether ocular dominance affects performance under dichoptic viewing conditions. The results of this research were also intended to partly fill a critical data gap (National Research Council, 1995) relating to the feasibility of using single-eye HMDs in military operations.

PARTICIPANTS

Sixteen civilian subjects participated in this study. All participants were volunteers recruited from the employees of the U.S. Army Research Laboratory's Human Research and Engineering Directorate. To be included in the study, subjects were required to have normal or corrected-to-normal visual acuity (i.e., 20/20 or better in each eye), to have normal color and binocular vision, and to be younger than 40 years of age. These entrance criteria were necessary for the following reasons:

- Future single-eye HMD systems will primarily be used by infantry personnel. According to Army Regulation 611–201 (Department of the Army, 1994), infantry personnel awarded the 11B military occupation specialty (MOS) must have at least 20/20 vision (corrected or uncorrected) in one eye.

- Although AR 611–201 allows an 11B infantryman to have only 20/100 acuity in his fellow eye, at an acuity of 20/40, the individual would meet the clinical definition of anisometropic amblyopia (Levi, 1996), more commonly known as "lazy eye." As such, he would exhibit extreme dominance of the "good eye," suppressing all or most of the input to the "lazy eye," thereby rendering dichoptic dual-task performance impossible.

- Similarly, normal binocular vision was necessary to ensure that the input to one eye would not be suppressed.

- Normal color vision was needed to ensure proper isolation of the left and right eye's views through the use of red and green filters (see the following description of stimuli).

- An age limit of 40 years was imposed because the effects of normal aging on visual function accumulate at an increased rate beyond that age (Owsley, Knoblauch, & Katholi, 1992).

PROCEDURE AND METHODOLOGY

Vision Screening

Initial vision screening was conducted using a Titmus® II vision tester. Testing assessed acuity, color vision, and binocular vision. Ocular dominance was also assessed using the unconscious sighting method of Miles (1929, 1930). Subjects were asked to place the wide end of a truncated paper cone over both eyes and while keeping both eyes open, to fixate the experimenter's nose. The experimenter then recorded which of the subject's eyes was aligned with the opening at the narrow end of the cone, thereby identifying the subject's dominant eye.

Stimuli

All stimuli comprised a central component and a peripheral component and were displayed on a Mitsubishi (model XC-3730C) 37-inch, high resolution color cathode ray tube (CRT) monitor with a 1280 x 1024 pixel screen. For the dichoptic viewing conditions, the two stimulus components were presented to different eyes. Separation of the left and right eyes' views was achieved through the use of anaglyph stimuli. In an anaglyph, the left and right eyes' views are displayed in different colors, typically red and green. To separate the monocular views from the composite stimulus, subjects view the anaglyph through color filters. For the present study, separation of the left and right eyes' views was achieved through the use of filters whose absorption spectra are specifically tuned for this purpose (Kodak™ Wratten™ gelatin filters, red No. 26 and green No. 58). The filters were mounted in a pair of cardboard eyeglass frames, similar to those worn to view 3D movies.

The stimulus colors displayed on the monitor were calibrated with respect to the color filters using a Minolta luminance meter (model nt-1/3°), following the method of Mulligan (1986). This calibration ensured that the component of the stimulus intended for the left eye was not seen by the right eye and vice versa. A test grid consisting of four square regions was displayed on the monitor. The squares were red, produced by activating only the red gun; green, produced by activating only the green gun; yellow and brown. Initial values for the luminances of the red and green squares were determined by measuring their luminances through both filters, computing transmission factors for each filter and adjusting the luminances until equal contrasts were achieved.

Once these initial colors were set, a subjective matching procedure was used to determine the luminances of the yellow and brown squares. To set the luminance of the yellow square, it was initially displayed as black. While the subject viewed the yellow square through the red filter, red light was added until it matched the red square. Switching to the green filter, the square appeared dark. Green light was added until the yellow square matched the green square. Returning to the red filter, the amount of red light in the yellow square was adjusted to reestablish a match with the red square. Two iterations of this procedure were necessary to achieve a simultaneous match through both filters. The luminance of the brown square was then set in an analogous fashion by matching the appearance of the brown square to the red square when viewed through the green filter and to the green square viewed through the red filter.

The result of this calibration was a set of four colors having the property that when viewed through each color filter, they appeared as only two distinct gray levels. In other words, two of the four colors appeared as identical light patches and the other two colors appeared as identical dark patches. The appearance of each color as seen through each filter is summarized in Table 1. Three subjects performed the calibration. The resulting set of colors was the same for each subject.

Table 1

Appearance of the Four Stimulus Colors

Stimulus color	Appearance through Red filter	Appearance through Green filter
red	light	dark
green	dark	light
yellow	light	light
brown	dark	dark

A schematic representation of the test stimulus is shown in Figure 1. The central component appeared within the fixation circle and consisted of a Snellen "E" presented in one of four orientations: facing up, down, left, or right. The "E" was 1.2° wide by 1.2° high, which is substantially larger than characters used in normal reading material (G.S. Rubin, personal communication, 1996). The peripheral component consisted of the silhouette of a side view of a generic tank. It appeared randomly at one of 15 possible locations corresponding to three different retinal eccentricities (10°, 20°, 27°) along five different radial lines (two vertical, two oblique, one horizontal). The size of the tank was 4.9° wide by 2.1° high, similar to that used in previous studies (Ball et al., 1988, 1990). In addition, for some conditions, the tank was presented along with clutter items that appeared in the unused target locations. The clutter items were silhouettes of a generic tree, 4.3° wide by 2.3° high. Because the central and peripheral components stimulated non-overlapping retinal regions, binocular rivalry was not induced (Blake, O'Shea, & Mueller, 1992).

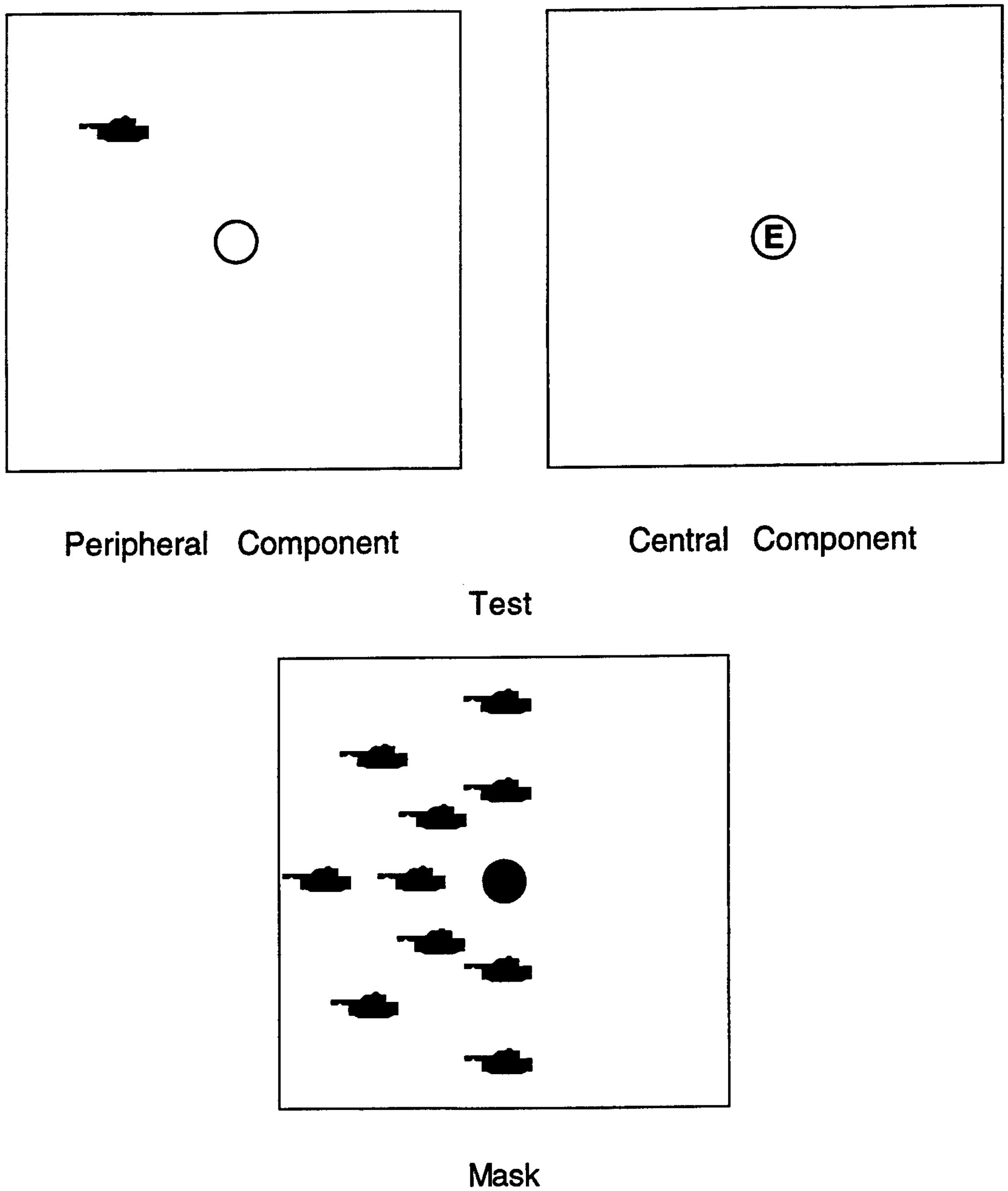

Figure 1. Schematic representation of test and mask stimuli. (In the actual experiment, three retinal eccentricities were tested, corresponding to a total of 15 possible target locations as opposed to the 10 locations depicted in the figure.)

For the dichoptic viewing conditions, the central component of the stimulus ("E") was displayed in green and was viewed by one eye through the red filter (see Figure 2). As a result of the calibration procedure described previously, this component appeared black through the red filter and was invisible through the green filter by blending into the background (see Table 1).

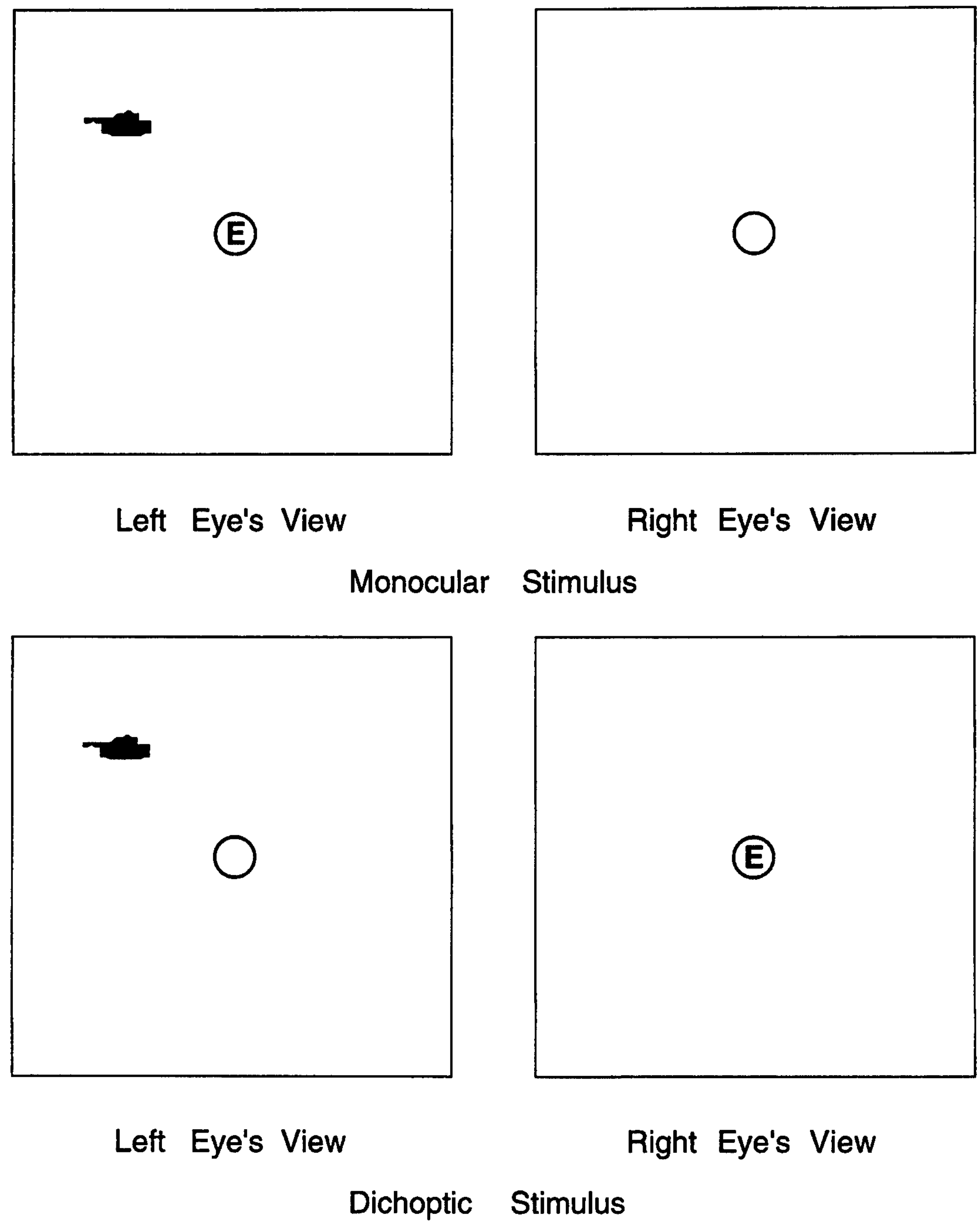

Figure 2. Schematic representation of test stimuli used for the two different viewing conditions presented in the experiments. (The top half of the figure depicts the stimulus configuration used in the monocular viewing conditions. In this case, both the central and peripheral components of the stimulus are presented to one eye only. The other eye sees only the background and the fixation circle. In the dichoptic viewing conditions, shown in bottom half of the figure, the central and peripheral components of the stimulus are presented to different eyes.)

The peripheral component was displayed in red and was viewed by the other eye through the green filter. Again, this component appeared black through the green filter and was invisible through the red filter by blending into the background color. For the monocular viewing conditions, both stimulus components were displayed in red and were viewed by one eye through the green filter (see Figure 2). The other eye simply saw a uniform field (the background) through the red filter. For both viewing conditions, the background was yellow and was visible to both eyes. In addition, to ensure that both eyes were fixated on the same depth plane, a brown fixation circle was also present that was visible to both eyes.

Procedure

Subjects wore cardboard eyeglasses containing the color filters and were seated 18 inches from the monitor with their heads positioned in a chin and forehead rest. At this viewing distance, the monitor screen subtended 60° (height) by 80° (width). As the monitor resolution was set to 1024 by 768 pixels, each pixel subtended 4.7 arc min.

All experiments were automated and under the control of an IBM PC-compatible computer. Dual-task performance was measured using a modification of the UFOV paradigm developed by Ball and colleagues (Sekuler & Ball, 1986; Ball et al., 1988, 1990). The specific stimuli and tasks for the present study were chosen to be representative of a typical scenario in which a single-eye HMD would be used; reading text or symbology on the HMD while simultaneously acquiring targets in the outside environment with the unaided eye (National Research Council, 1995). Subjects were asked to perform one of two central tasks simultaneously with a peripheral target localization task. A central character-detection task constituted a low cognitive workload condition, and a central character-recognition task constituted a high cognitive workload condition. To ensure that all subjects were using the same decision criterion, they were told that the central task was to be considered the primary task and the peripheral task was to be considered the secondary task.

To familiarize the subject with the experimental procedure and to remove the effects of stimulus uncertainty, before beginning formal data collection, the subject was presented with at least two blocks of practice trials. Each block contained five trials presented monocularly (i.e., both tasks to the same eye; see Figure 2). The first block was always the high central task workload, low peripheral clutter condition, and the second block was always the low central task workload, high clutter condition. After the second block of practice trials, the subject was asked if he or she was confident that he or she understood the task. If the subject responded "yes," formal data collection began. If the subject responded "no," a third block of practice trials was presented consisting of the low central task workload, low peripheral clutter condition. If, after completing the third block, the subject was still not comfortable with the task, he or she was given a final block of practice trials consisting of the high central task workload, high peripheral clutter condition.

In each experimental trial, the subject was presented with a fixation circle for 2.0 seconds, followed by a test stimulus presented for 187 msec. This exposure duration was too brief for the subject to shift his or her fixation between the central and peripheral components of the stimulus and was too brief to cause binocular rivalry (Anderson, Bechtoldt, & Dunlap, 1978; Arditi, 1986; Wolfe, 1982). A 750-msec mask followed the test stimulus to prevent the subject from using afterimages to do the tasks. The mask (see Figure 1) was created by filling the fixation circle and illuminating all 15 peripheral target locations simultaneously (Kröse & Julesz, 1989). Following the mask, the subject was prompted to respond to the central task. For the character-detection (low workload) task, the subject indicated whether the "E" was present or absent while for the character-recognition (high workload) task, the subject indicated the orientation of the "E". In both cases, the possible responses were displayed on the monitor and the subject indicated his or her response by positioning a cursor over the desired response and clicking the mouse button. If the response was incorrect, an auditory tone was presented to alert the subject to pay more attention to the center of the display. In addition, the trial was discarded and presented again later in the block of trials, under the assumption that the subject was not properly fixating on the center of the screen (Ball et al., 1988, 1990). Once the central task response was recorded, a pattern of five arrows was displayed, indicating the possible responses for the peripheral target localization task. The subject indicated the radial direction of the tank by again positioning a cursor over the appropriate arrow and clicking the mouse button. Each subject completed one block of trials for each experimental condition (see Experimental Design). In each block, the target tank was presented twice at each of the 15 possible target locations (three eccentricities along five meridians) for a total of 30 trials.

As stated in the description of the stimuli, two different viewing conditions, dichoptic and monocular, were tested (see Figure 2). Although the stimuli displayed on the monitor differed in these two cases, their appearance to the subject as seen through the color filters was identical. Therefore, to prevent any bias that may affect performance, the subject was not informed that viewing condition was manipulated during the course of the experiment. This manipulation was necessary, however, in order to quantify the effects of dividing attention dichoptically. Monocular viewing was chosen to be the comparison condition (baseline level of performance) because, just as with dichoptic viewing, the information necessary to perform each task was available to one eye only. Therefore, the only difference between the two viewing conditions was the manner in which attention was divided.[2]

Experimental Design

The two experiments conducted were repeated measures designs with subjects as a random factor. In the first experiment, the independent variables were

- Central task workload — two levels (low [character detection], high [character recognition]).
- Peripheral clutter — two levels (low [no clutter], high [clutter at all unused target locations, i.e., 14 items]).
- Retinal eccentricity — three levels (10°, 20°, 27°).
- Viewing condition — two levels (dichoptic, monocular).

In the second experiment, the independent variables were

- Peripheral clutter — two levels (moderate [two clutter items], high [clutter at all unused target locations, i.e., 14 items]).
- Retinal eccentricity — three levels (10°, 20°, 27°).
- Viewing condition — two levels (dichoptic, monocular).

For both experiments, the dependent variable was the number (percentage) of incorrect responses (errors) on the peripheral target localization task.

As all three stimulus eccentricities for the peripheral target localization task were tested in each block of trials, there were a total of eight experimental conditions in Experiment 1 and four conditions in Experiment 2, representing the factorial combination of the remaining independent variables. In both experiments, the conditions were counterbalanced across subjects using a Latin square design. The presentation of individual trials within each block (representing one condition) was randomized separately for each subject.

---

[2]The other possible comparison condition would be binocular viewing. In a binocular viewing situation, however, the information necessary to perform each task would be available to both eyes. Therefore, binocular viewing confounds the manner in which attention is divided with the number of eyes performing each task.

RESULTS AND DISCUSSION

To facilitate comparison of the results of these experiments with those of previously published studies, the data were analyzed in the same manner as those of Ball et al. (1988). The percent error scores obtained for each subject in each experimental condition were transformed for statistical purposes according to the following formula:

$$\sin^{-1}\sqrt{\%errors} \tag{1}$$

Under this arc sine transformation, a value of 1.11 corresponds to chance performance (80% errors), a value of 0.79 corresponds to 50% errors, and a value of 0.0 corresponds to perfect performance (0% errors). These transformed error scores were analyzed in repeated measures analyses of variance (ANOVAs) as described next.

Experiment 1

In this experiment, the peripheral component of the stimulus (tank or tank and trees) was always displayed on the left side of the monitor screen and was always viewed by the left eye (see Figure 2). For the monocular viewing conditions, the central component of the stimulus ("E") was also viewed by the left eye. For the dichoptic viewing conditions, the central component was viewed by the right eye.

Peripheral target localization performance (as defined by Equation [1]) was analyzed in a 2 (central task workload) × 2 (peripheral clutter) × 3 (retinal eccentricity) × 2 (viewing condition) repeated measures ANOVA. The primary focus of this analysis was on the effect of viewing condition. As can be seen from Figure 3, target localization performance under dichoptic viewing was not significantly different from performance under monocular viewing ($F < 1.0$). These data support the hypothesis that dividing attention through dichoptic viewing does not improve dual-task performance. Central task workload (circles versus squares) also had no effect on performance ($F \cong 1.0$), in agreement with previous research (Ball et al., 1988). The presence of clutter (open symbols versus filled symbols), however, caused a significant deficit in localization performance ($F = 375$; df $= 1, 15$; $p < 0.001$). No significant interactions of any order were found.

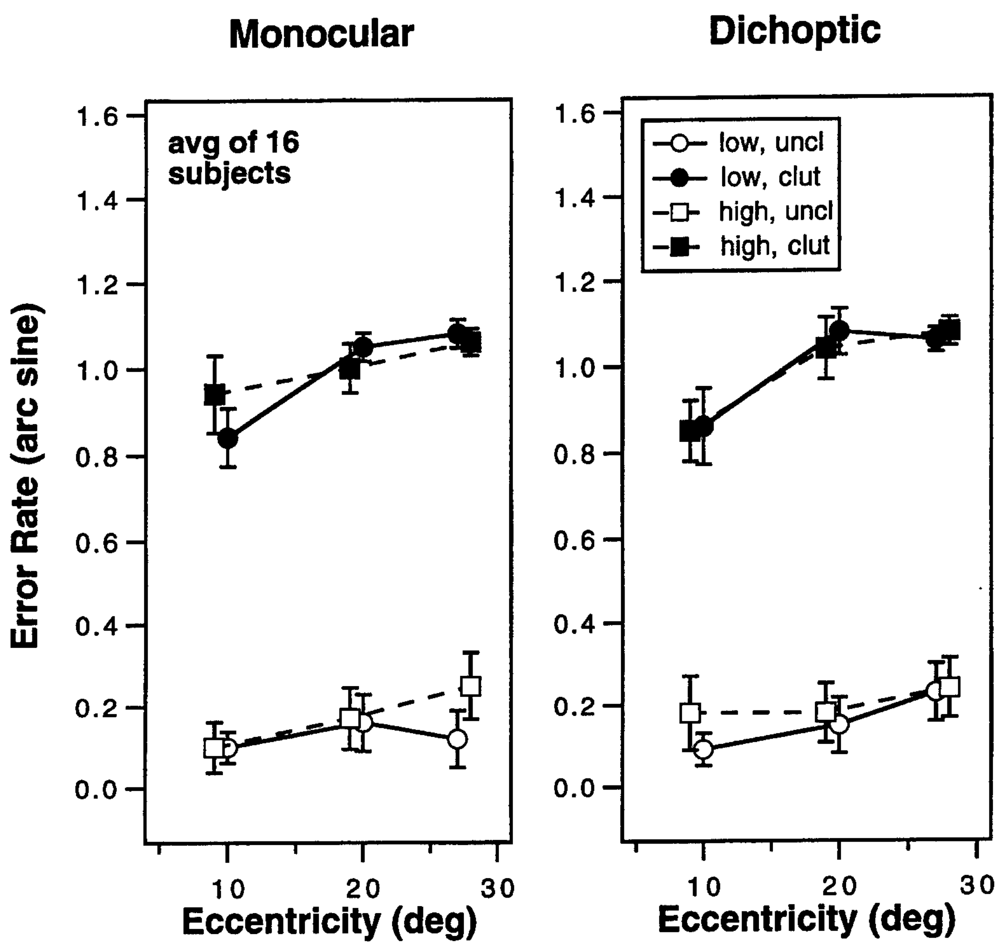

Figure 3. The effects of central task workload, clutter and eccentricity on peripheral target localization performance. (Data points represent the mean performance of 16 subjects and error bars represent ±1 standard error of the mean [SEM]. Data obtained in the low central task workload conditions are plotted as circles while data obtained in the high central task workload conditions are plotted as squares. Target localization performance is expressed as an error rate defined by Equation [1].)

Since the UFOV is defined as the area surrounding the fovea that can be attended to and from which information can be acquired during a single glimpse, it is of interest to know how performance varies as a function of retinal eccentricity (i.e., distance from the fovea). Overall, eccentricity had a significant effect on performance ($F = 11.90$; df = 2, 30; $p < 0.001$). The number of target localization errors increased as eccentricity increased from 10° to 20° ($F = 14.79$; df = 1, 15; $p < 0.003$) and then remained constant as eccentricity increased from 20°

to 27° ($F = 2.99$; df = 1, 15; $p > 0.1$). At 20° and 27°, the error rate was not significantly different from chance ($t < 1.0$): the level of performance to be expected from pure guessing.

Ball et al. (1990) have quantified the size of the UFOV by defining it as the eccentricity at which subjects can correctly localize the peripheral target 50% of the time. In terms of the arc sine transformation of Equation (1), the size of the UFOV corresponds to the eccentricity at which the error rate is 0.79. Examination of Figure 3 indicates that when there was no peripheral clutter (open symbols), target localization performance was essentially perfect at all eccentricities. Therefore, in an uncluttered scene, the UFOV is larger than 27°. In the clutter conditions (filled symbols), however, target localization performance was not significantly different from 50% correct at the smallest eccentricity tested ($t < 1.0$). Therefore, when clutter is present, the UFOV shrinks to 10° or less.

Experiment 2

In Experiment 1, the peripheral component of the stimulus (tank or tank and trees) was always displayed on the left side of the monitor screen and was always viewed by the left eye. If ocular dominance affects task performance, however, different results might have been obtained for some subjects in the dichoptic viewing conditions if the peripheral component of the stimulus had been viewed by the right eye. Therefore, to control for this possibility, the same 16 subjects were run in another experiment in which the peripheral task was always presented to the right eye. Because the results of Experiment 1 demonstrated that central task workload does not affect performance, only one central task was used in this experiment, the character-recognition task. In addition, to further explore the effect of clutter on peripheral target localization performance, a moderate clutter level was tested in which the tank was presented with two clutter items.

The effect of ocular dominance on target localization performance is illustrated in Figure 4. The data plotted in the figure were obtained in the high central task workload, full clutter (i.e., 14 clutter items) conditions of Experiments 1 and 2.[3] For each subject, the data from each experiment were classified as corresponding to either the dominant or non-dominant eye, based on the results of the ocular dominance screening test. The data of Figure 4 were then subjected to a 2 (viewing condition) × 2 (ocular dominance) × 3 (retinal eccentricity) repeated measures ANOVA. As in Experiment 1, performance was the same under monocular and dichoptic viewing ($F < 1.0$) and deteriorated with increasing eccentricity ($F = 9.51$; df = 2, 30;

[3]Before the data from the two experiments were combined, a repeated measures ANOVA was run to eliminate the possibility that overall performance in Experiment 2 was better than performance in Experiment 1 because of a practice or learning effect. The results of the two experiments were not found to differ significantly ($F = 3.90$; df = 1, 14; $p > 0.06$).

$p < 0.002$). In addition, performance in the dominant eye was no different than performance in the non-dominant eye ($F = 1.57$; df = 1, 15; $p > 0.2$).

The effect of clutter can be seen in Figure 5. The no-clutter and 14 clutter items data were obtained in Experiment 1 (see Figure 1, open and filled squares, respectively) while the two clutter items data were obtained in Experiment 2. These data were subjected to a 2 (viewing condition) × 3 (clutter) × 3 (retinal eccentricity) repeated measures ANOVA. Once again, viewing condition did not affect performance ($F < 1.0$) while performance deteriorated with increasing eccentricity ($F = 14.32$; df = 2, 30; $p < 0.001$). As in Experiment 1, the presence of clutter caused a significant deficit in performance ($F = 91.34$; df = 2, 30; $p < 0.001$). The number of target localization errors increased dramatically with the addition of only two clutter items ($F = 209$; df = 1, 15; $p < 0.001$) and increased at a slower rate with the addition of further clutter items ($F = 15.44$; df = 1, 15; $p < 0.002$).

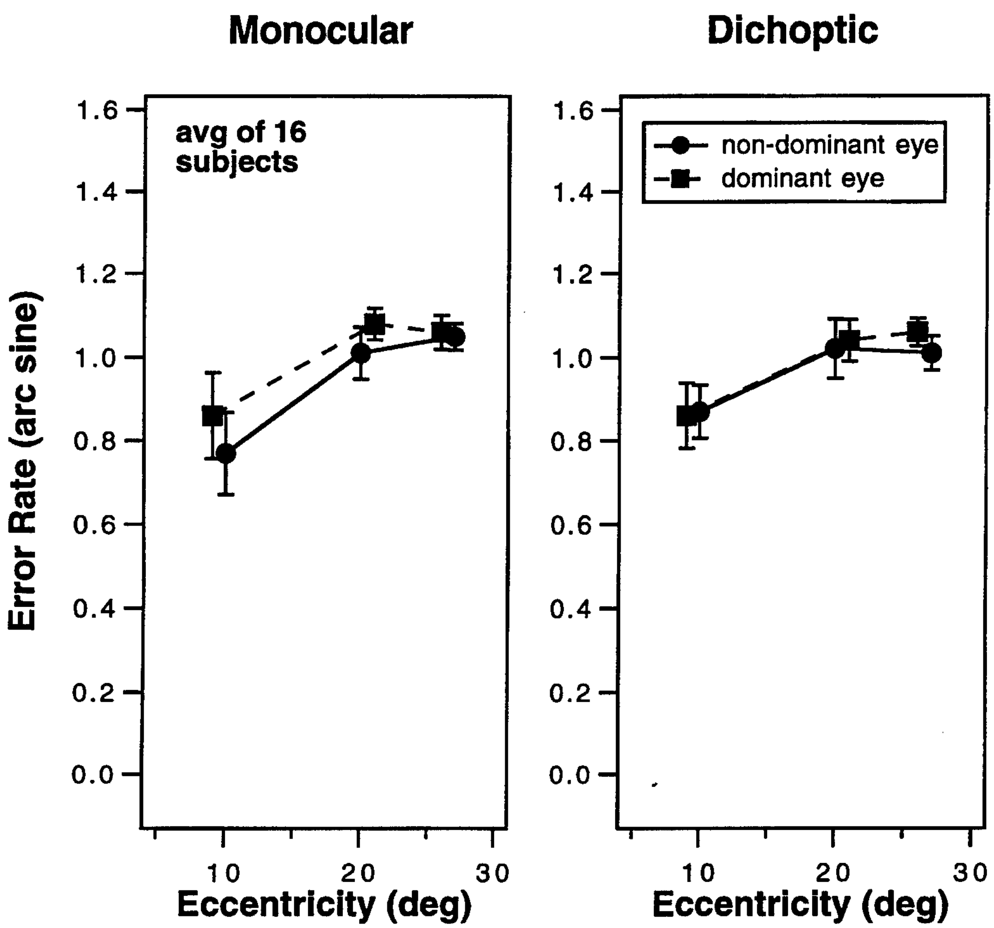

Figure 4. The effect of ocular dominance on peripheral target localization performance.

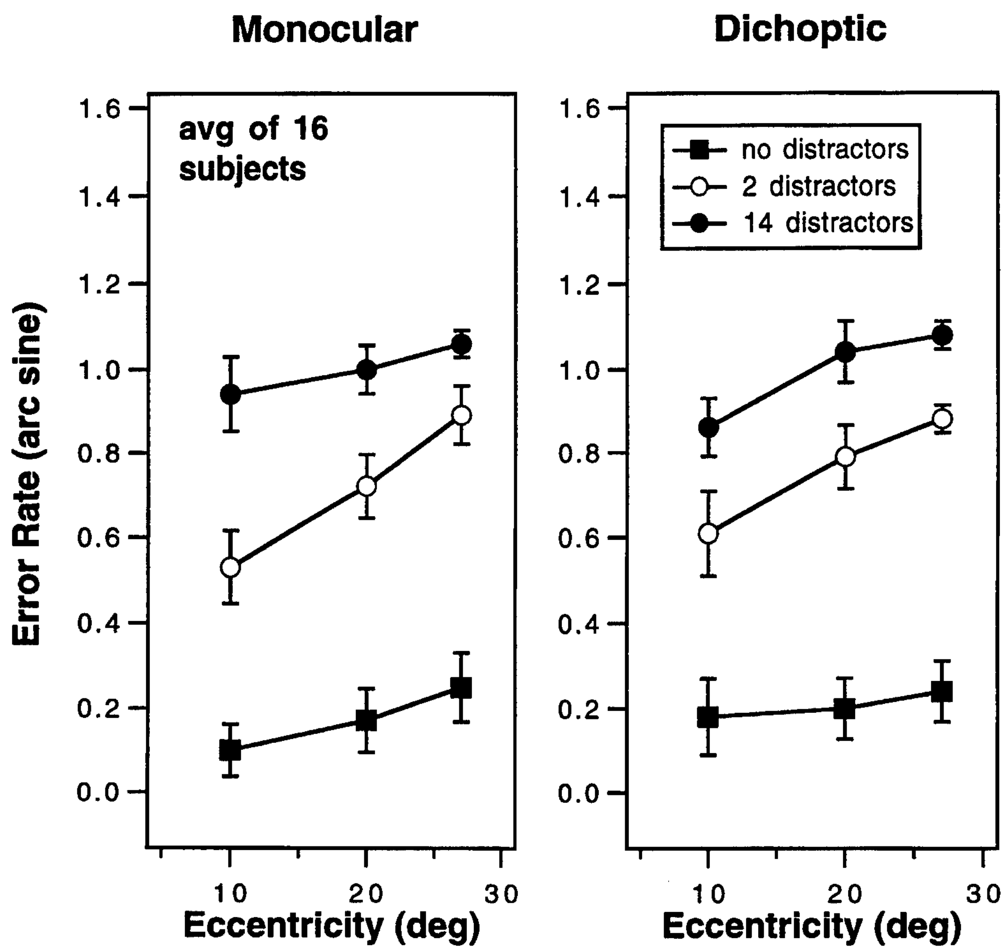

Figure 5. The effect of clutter on peripheral target localization performance.

CONCLUSIONS

The results of the present study support the hypothesis that dividing attention between the left and right eyes does not improve dual-task performance relative to the level of performance achieved when attention is divided within the visual field of one eye. Specifically, we find that peripheral target localization performance is the same under dichoptic and monocular viewing conditions. This result implies that the two eyes do not constitute separate attentional channels. If the eyes truly functioned as independent channels, we would expect to find an improvement in performance under dichoptic viewing because each eye is only responsible for processing one task as opposed to monocular viewing in which one eye must process two tasks simultaneously (see Figure 2).

The data also demonstrate that central task workload and ocular dominance do not affect peripheral target localization performance. The presence of clutter, however, causes significant deficits in performance and reduces the size of the UFOV from approximately 30° (Ball et al., 1990; Seiple et al., 1997) to 10° or less. This estimate of the size of the UFOV was calculated using Ball et al.'s definition, which only requires that subjects successfully localize the peripheral target 50% of the time. This definition is obviously inappropriate for military applications. Missing 50% of the targets is an unacceptable level of performance in a battlefield environment. Adopting a more stringent performance criterion, however, would further reduce the estimated size of the UFOV, indicating severe attentional narrowing (tunneling) in cluttered scenes.

Designers and proponents of monocular HMD systems often assume that these devices will enhance soldier performance by increasing field of view and reducing workload. We find no evidence to support either of these assumptions. As stated before, in a dual competing task situation, having each eye perform a separate task does not improve peripheral target localization performance relative to the level of performance achieved when a single eye performs both tasks. In addition, in both cases, the visual area that is available for target acquisition at any given moment is less than 10° in cluttered scenes. Therefore, while having only one ocular in an HMD will increase the physical field of view of the unaided eye, it will not increase its functional or useful field of view. In other words, although a single-eye HMD does not occlude the peripheral vision of the unaided eye, the present experiments indicate that this peripheral vision cannot be used to successfully perform tasks.

Furthermore, because these experiments were intentionally designed to avoid inducing binocular rivalry, the data can be considered an upper limit on the level of performance to be expected from a soldier outfitted with a single-eye HMD. Any real-world application of such a device will have the aided and unaided eyes receiving information from overlapping retinal regions, thereby inducing binocular rivalry (National Research Council, 1995). The detrimental effects of binocular rivalry on task performance with a single-eye HMD have been documented through the use of a subjective questionnaire (Hale & Piccione, 1990). Further research in a controlled laboratory environment is needed to quantitatively assess performance deficits attributable to binocular rivalry.

REFERENCES

Allen, M.J. (1970). Vision and highway safety. Radnor, PA: Chilton.

Anderson, J.D., Bechtoldt, H.P., & Dunlap, G.L. (1978). Binocular integration in rivalry. Bulletin of the Psychonomic Society, 11, 399–402.

Arditi, A. (1986). Binocular vision. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), Handbook of perception and human performance, Volume 1 (pp. 23-1–23-36). New York: Wiley.

Ball, K.K., Beard, B.L., Roenker, D.L., Miller, R.L., & Griggs, D.S. (1988). Age and visual search: Expanding the useful field of view. Journal of the Optical Society of America A, 5, 2210–2219.

Ball, K., Owsley, C., Sloan, M.E., Roenker, D.L., & Bruni, J.R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. Investigative Ophthalmology and Visual Science, 34, 3110–3123.

Ball, K.K., Roenker, D.L., & Bruni, J.R. (1990). Developmental changes in attention and visual search throughout adulthood. In J.T. Enns (Ed.), Advances in psychology, Volume 69 (pp. 489–508). North Holland: Elsevier Science Publishers.

Blake, R. (1995). Visual suppression of one eye's view with dichoptic stimulation. In J. Morreale (Ed.), Society for Information Display International Symposium Digest of Technical Papers, Volume 26 (pp. 285–288). Santa Ana, CA: Society for Information Display.

Blake, R., O'Shea, R.P., & Mueller. T.J. (1992). Spatial zones of binocular rivalry in central and peripheral vision. Visual Neuroscience, 8, 469–478.

Caldwell, J.L., Cornum, R.L.S., Stephens, R.L., & Rash, C.E. (1990). Visual processing: Implications for helmet mounted displays. Proceedings of SPIE – The International Society for Optical Engineering, 1290, 165–172.

Cormack, R.H., & Blake, R. (1980). Do the two eyes constitute separate visual channels? Science, 207, 1100–1102.

Council, F.M., & Allen, J.A. (1974). A study of the visual fields of North Carolina drivers and their relationship to accidents. Chapel Hill, NC: University of Carolina Highway Safety Research Center.

Department of the Army (1994). Enlisted career management fields and military occupation specialty (Army Regulation 611–201). Washington, DC: Author.

Gopher, D., Grunwald, A., Straucher, Z., & Kimchi, R. (1990). Tracking and letter classification under dichoptic and binocular viewing conditions. Proceedings of the Human Factors Society 34th Annual Meeting, 1557–1561.

Gopher, D., Kimchi, R., Seagull, F.J., Catz, I., & Trainin, O. (1992). Flying with dichoptic displays: The interplay between display characteristics and attention control. Proceedings of the Human Factors Society 36h Annual Meeting, 1469–1473.

Hale, S., & Piccione, D. (1990). Pilot performance assessment of the AH-64A helmet display unit (Technical Note 1-90). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Henderson, R.L., & Burg, A. (1974). Vision and audition in driving (Technical Report TM(L)–5297/000/00). Washington, DC: Department of Transportation.

Julesz, B. (1981). Textons, the elements of texture perception and their interactions. Nature, 290, 91–97.

Kimchi, R., Gopher, D., Rubin, Y., & Raij, D. (1993). Performance under dichoptic versus binocular viewing conditions: Effects of attention and task requirements. Human Factors, 35, 35–55.

Kröse, B.J.A., & Julesz, B. (1989). The control and speed of shifts of attention. Vision Research, 29, 1607–1619.

Miles, W.R. (1929). Ocular dominance demonstrated by unconscious sighting. Journal of Experimental Psychology, 12, 113–126.

Miles, W.R. (1930). Ocular dominance in human adults. Journal of General Psychology, 3, 412–420.

Mulligan, J.B. (1986). Optimizing stereo separation in color television anaglyphs. Perception, 15, 27–36.

Nakayama, K., & Mackeben, M. (1989). Sustained and transient components of focal visual attention. Vision Research, 29, 1631–1647.

National Research Council (1995). Human factors in the design of tactical display systems for the individual soldier (Phase One Report). Washington, DC: National Academy Press.

Owsley, C., Knoblauch, K., & Katholi, C. (1992). When does visual aging begin? Investigative Ophthalmology and Visual Science (Supplement), 33, 1414.

Perry, N.W., Jr., & Childers, D.G. (1972). Monocular contribution to binocular vision in normals and amblyopes. In G.B. Arden (Ed.), The visual system: Neurophysiology, biophysics, and their clinical applications (pp. 213–222). New York: Plenum Press.

Rash, C.E., Verona, R.W., & Crowley, J.S. (1990). Human factors and safety considerations of night vision systems flight using thermal imaging systems. Proceedings of SPIE – The International Society for Optical Engineering, 1290, 142–164.

Seiple, W., Szlyk, J.P., Yang, S., & Holopigian, K. (1997). Age-related functional field losses are not eccentricity dependent. Vision Research, 36, 1859–1866.

Sekuler, R., & Ball, K. (1986). Visual localization: Age and practice. Journal of the Optical Society of America A, 3, 864–867.

Shinar, D. (1977). Driver visual limitations: Diagnosis and treatment (Department of Transportation contract DOT–HS–5–1275). Bloomington, IN: Indiana University Institute for Research in Public Safety.

Wolfe, J.M. (1982). When rivalry fails: The false fusion phenomenon and the temporal course of suppression. Perception, 11, A17.

NO. OF COPIES	ORGANIZATION
2	ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CS AL TA RECORDS MANAGEMENT 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CI LL TECHNICAL LIBRARY 2800 POWDER MILL RD ADELPHI MD 207830-1197
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CS AL TP TECH PUBLISHING BRANCH 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTORATE FOR MANPRINT ATTN DAPE MR DEPUTY CHIEF OF STAFF PERSONNEL 300 ARMY PENTAGON WASHINGTON DC 20310-0300
1	OUSD(A)/DDDR&E(R&A)/E&LS PENTAGON ROOM 3D129 WASHINGTON DC 20301-3080
1	CODE 1142PS OFFICE OF NAVAL RESEARCH 800 N QUINCY STREET ARLINGTON VA 22217-5000
1	WALTER REED ARMY INST OF RSCH ATTN SGRD UWI C (COL REDMOND) WASHINGTON DC 20307-5100
1	COMMANDER US ARMY RESEARCH INSTITUTE ATTN PERI ZT (DR E M JOHNSON) 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-5600

NO. OF COPIES	ORGANIZATION
1	DEPUTY COMMANDING GENERAL ATTN EXS (Q) MARINE CORPS RD&A COMMAND QUANTICO VA 22134
1	HEADQUARTERS USATRADOC ATTN ATCD SP FORT MONROE VA 23651
1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCAM 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-0001
1	USA BIOMEDICAL R&D LABORATORY ATTN LIBRARY FORT DETRICK BUILDING 568 FREDERICK MD 21702-5010
1	COMMANDER USA AEROMEDICAL RESEARCH LAB ATTN LIBRARY FORT RUCKER AL 36362-5292
1	US ARMY SAFETY CENTER ATTN CSSC SE FORT RUCKER AL 36362
1	CHIEF ARMY RESEARCH INSTITUTE AVIATION R&D ACTIVITY ATTN PERI IR FORT RUCKER AL 36362-5354
1	AAMRL/HE WRIGHT PATTERSON AFB OH 45433-6573
1	US ARMY NATICK RD&E CENTER ATTN STRNC YBA NATICK MA 01760-5020
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN BEHAVIORAL SCI DIV SSD NATICK MA 01760-5020
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN TECH LIBRARY (STRNC MIL) NATICK MA 01760-5040

NO. OF COPIES	ORGANIZATION
1	USAF ARMSTRONG LAB/CFTO ATTN DR F WESLEY BAUMGARDNER SUSTAINED OPERATIONS BRANCH BROOKS AFB TX 78235-5000
1	USA TRADOC ANALYSIS COMMAND ATTN ATRC WSR (D ANGUIANO) WHITE SANDS MISSILE RANGE NM 88002-5502
1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA RS/D REES WARREN MI 48090
1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA TSL (TECH LIBRARY) WARREN MI 48397-5000
1	GOVT PUBLICATIONS LIBRARY 409 WILSON M UNIVERSITY OF MINNESOTA MINNEAPOLIS MN 55455
1	LIBRARY ESSEX CORPORATION SUITE 510 1430 SPRING HILL ROAD MCLEAN VA 22102-3000
1	DIRECTOR US ARMY AEROFLIGHT DYNAMICS DIR ATTN SAVRT AF D (A W KERR) AMES RESEARCH CENTER (MS 215-1) MOFFETT FIELD CA 94035-1099
1	PEO ARMORED SYS MODERNIZATION US ARMY TANK-AUTOMOTIVE CMD ATTN SFAE ASM S WARREN MI 48397-5000
1	PEO COMMUNICATIONS ATTN SFAE CM RE FT MONMOUTH NJ 07703-5000
1	PEO AIR DEFENSE ATTN SFAE AD S US ARMY MISSILE COMMAND REDSTONE ARSENAL AL 35898-5750

NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCDE AQ 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333
1	COMMANDANT US ARMY ARMOR SCHOOL ATTN ATSB CDS (MR LIPSCOMB) FT KNOX KY 40121-5215
1	COMMANDER US ARMY AVIATION CENTER ATTN ATZQ CDM S (MR MCCRACKEN) FT RUCKER AL 36362-5163
1	DIRECTOR US ARMY AEROFLIGHT DYNAMICS DIR MAIL STOP 239-9 NASA AMES RESEARCH CENTER MOFFETT FIELD CA 94035-1000
1	COMMANDER U.S. ARMY NATL TRAINING CENTER AMC FAST SCIENCE ADVISER ATTN AMXLA SA FORT IRWIN CA 92310
1	HQ US SPECIAL OPERATIONS CMD AMC FAST SCIENCE ADVISER ATTN SOSD MACDILL AIR FORCE BASE TAMPA FL 33608-0442
1	DR SEHCHANG HAH DEPT OF BEHAVIORAL SCIENCES & LEADERSHIP BUILDING 601 ROOM 281 US MILITARY ACADEMY WEST POINT NEW YORK 10996-1784
1	USARL HRED FIELD ELEMENT USAADASCH ATTN ATSA CD ATTN AMSRL HR ME (K REYNOLDS) 5800 CARTER ROAD FORT BLISS TX 79916-3802
1	ARL HRED ATCOM FIELD ELEMENT ATTN AMSRL HR MI (A MANCE) 4300 GOODFELLOW BLVD BLDG 105 1ST FLOOR POST A-7 ST LOUIS MO 63120-1798

NO. OF COPIES	ORGANIZATION
1	ARL HRED AVNC FIELD ELEMENT ATTN AMSRL HR MJ (R ARMSTRONG) PO BOX 620716 BUILDING 514 FT RUCKER AL 36362-0716
1	ARL HRED CECOM FIELD ELEMENT ATTN AMSRL HR ML (J MARTIN) MYERS CENTER ROOM 3C214 FT MONMOUTH NJ 07703-5630
1	ARL HRED ATTN AMSRL HR MQ (M R FLETCHER) USASSCOM NRDEC BLDG 3 RM 140 NATICK MA 01760-5015
1	ARL HRED TACOM FIELD ELEMENT ATTN AMSRL HR MU (M SINGAPORE) BUILDING 200A 2ND FLOOR WARREN MI 48397-5000
1	ARL HRED USAIC FIELD ELEMENT ATTN AMSRL HR MW (E REDDEN) BUILDING 4 ROOM 349 FT BENNING GA 31905-5400
1	ARL HRED USASOC FIELD ELEMENT ATTN AMSRL HR MN (F MALKIN) BUILDING D3206 ROOM 503 FORT BRAGG NC 28307-5000
1	CECOM SP & TERRESTRIAL COMMCTN DIV ATTN AMSEL RD ST MC M H SOICHER FT MONMOUTH NJ 07703-5203
1	PRIN DPTY FOR TECHLGY HDQTRS US ARMY MATL CMND ATTN AMCDCG T M FISETTE 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	PRIN DPTY FOR ACQUISTN HDQTRS US ARMY MATL CMND ATTN AMCDCG A D ADAMS 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	DPTY CG FOR RDE HDQTRS US ARMY MATL CMND ATTN AMCRD BG BEAUCHAMP 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001

NO. OF COPIES	ORGANIZATION
1	ASST DPTY CG FOR RDE HDQTRS US ARMY MATL CMND ATTN AMCRD COL S MANESS 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	DPTY ASSIST SCY FOR RSRCH & TECHL SARD-TT F MILTON RM 3E479 THE PENTAGON WASHINGTON DC 20310-0103
1	DPTY ASSIST SCY FOR RSRCH & TECHL SARD-TT D CHAIT THE PENTAGON WASHINGTON DC 20310-0103
1	DPTY ASSIST SCY FOR RSRCH & TECHL SARD-TT K KOMINOS THE PENTAGON WASHINGTON DC 20310-0103
1	DPTY ASSIST SCY FOR RSRCH & TECHL SARD-TT B REISMAN THE PENTAGON WASHINGTON DC 20310-0103
1	DPTY ASSIST SCY FOR RSRCH & TECHL SARD-TT T KILLION THE PENTAGON WASHINGTON DC 20310-0103
1	ODCSOPS D SCHMIDT WASHINGTON DC 20310-1001
1	OSD OUSD(A&T)/ODDDR&E(R) J LUPO THE PENTAGON WASHINGTON DC 20301-7100
1	ARL ELECTROMAG GROUP CAMPUS MAIL CODE F0250 A TUCKER UNIVERSITY OF TEXAS AUSTIN TX 78712
1	DUSD SPACE 1E765 J G MCNEFF 3900 DEFENSE PENTAGON WASHINGTON DC 20301-3900
1	USAASA MOAS-AI W PARRON 9325 GUNSTON RD STE N319 FT BELVOIR VA 22060-5582

NO. OF COPIES	ORGANIZATION
1	CECOM PM GPS COL S YOUNG FT MONMOUTH NJ 07703
1	GPS JOINT PROG OFC DIR COL J CLAY 2435 VELA WAY STE 1613 LOS ANGELES AFB CA 90245-5500
1	ELECTRONIC SYSTEMS DIV DIR CECOM RDEC J NIEMELA FT MONMOUTH NJ 07703
3	DARPA L STOTTS J PENNELLA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
1	SPECIAL ASST TO THE WING CMNDR 50SW/CCX CAPT P H BERNSTEIN 300 O'MALLEY AVE STE 20 FALCON AFB CO 80912-3020
1	USAF SMC/CED DMA/JPO M ISON 2435 VELA WAY STE 1613 LOS ANGELES AFB CA 90245-5500
	ABERDEEN PROVING GROUND
2	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CI LP (TECH LIB) BLDG 305 APG AA
1	LIBRARY ARL BLDG 459 APG-AA

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1997	Final

4. TITLE AND SUBTITLE

The Effects of Divided Attention on Peripheral Target Localization

5. FUNDING NUMBERS

AMS Code 611102
PR: 1L161102B74A
PE: 6.11.02

6. AUTHOR(S)

Rohaly, A. M.; Karsh, R.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARL-TR-1334

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Designers and users of helmet-mounted displays often assume that single-eye devices reduce operator workload relative to dual-eye devices by allowing two tasks to be performed simultaneously, one by each eye. In other words, the two eyes are assumed to constitute separate attentional channels. To test this assumption, we implemented a modified version of the useful field of view (UFOV) paradigm of Ball, Beard, Roenker, Miller, and Griggs (1988) to measure the effects of dichoptically divided attention on dual-task performance. Subjects localized a peripheral target within a semicircular region of 30° radius while simultaneously performing a foveal task. The degree of difficulty of the experiment was manipulated by varying the foveal task workload and the number of clutter (distractor) items in the periphery. The foveal and peripheral tasks were either presented to the same eye (monocular viewing) or different eyes (dichoptic viewing). Peripheral target localization performance was essentially perfect at all eccentricities for all the non-clutter conditions: monocular and dichoptic viewing, low and high foveal task workload. Introduction of peripheral clutter caused a significant deficit in localization performance that increased with increasing target eccentricity. Similar to the non-clutter conditions, there was no difference in performance between monocular and dichoptic viewing. Thus, we find no evidence to support the assumption that dividing attention between two eyes allows dual tasks to be performed more efficiently than when attention is divided within the same eye, implying that the two eyes do not constitute separate attentional channels.

14. SUBJECT TERMS

helmet-mounted displays
vision
visual attention

15. NUMBER OF PAGES

35

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102