AD-A208 077

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Naval Ocean Systems Center; 6b. OFFICE SYMBOL (if applicable): NOSC	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code): San Diego, California 92152-5000	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Naval Ocean Systems Center; 8b. OFFICE SYMBOL (if applicable): NOSC	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code): San Diego, California 92152-5000	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO.: In-house; PROJECT NO.; TASK NO.; AGENCY ACCESSION NO.

11. TITLE (include Security Classification)

OPERATOR PERFORMANCE AS A FUNCTION OF TYPE OF DISPLAY: CONVENTIONAL VERSUS PERSPECTIVE

12. PERSONAL AUTHOR(S)

S.V. Bemis, J.L. Leeds, and E.A. Winer

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Professional paper	FROM TO	March 1989	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	tactical display operators, communicating information, Reprints.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of this experiment was to evaluate operator performance on a perspective tactical display. The distinguishing feature of the perspective display is its visual representation of vertical as well as horizontal craft information. In contrast, current tactical display systems provide only two-dimensional views requiring numerical representation for altitude information. Subjects were required to perform two tasks: detect threats and select the closest interceptor for each detected threat. Errors and response time were recorded for each subject by the computer in a completely within-subjects experimental design. The experiment revealed a significant reduction in errors of detection and interceptors with use of a perspective display. Response time for selecting interceptors was greatly reduced. The discussion recommends relevant directions for future research.

Published in *The Human Factors Society*, 1988.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: [X] UNCLASSIFIED/UNLIMITED [ ] SAME AS RPT [ ] DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED
22a. NAME OF RESPONSIBLE PERSON: S.V. Bemis	22b. TELEPHONE (include Area Code): 619-553-3651; 22c. OFFICE SYMBOL: Code 441

DD FORM 1473, 84 JAN — 83 APR EDITION MAY BE USED UNTIL EXHAUSTED. ALL OTHER EDITIONS ARE OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

HUMAN FACTORS, 1988, 30(2), 163–169

Operator Performance as a Function of Type of Display: Conventional versus Perspective

SUZANNE V. BEMIS,[1] JEFFREY L. LEEDS, *and* ERNST A. WINER, *Naval Ocean Systems Center, San Diego, California*

The purpose of this experiment was to evaluate operator performance on a perspective tactical display. The distinguishing feature of the perspective display is its visual representation of vertical as well as horizontal craft information. In contrast, current tactical display systems provide only two-dimensional views requiring numerical representation for altitude information. Subjects were required to perform two tasks: detect threats and select the closest interceptor for each detected threat. Errors and response time were recorded for each subject by the computer in a completely within-subjects experimental design. The experiment revealed a significant reduction in errors of detection and interception with the use of a perspective display. Response time for selecting interceptors was greatly reduced. The discussion recommends relevant directions for future research.

INTRODUCTION

With the advent of more sophisticated computer hardware and increased computer display resolution, new options are available for communicating information to tactical display operators. In the present study a perspective display was investigated for naval tactical display systems. In contrast to conventional tactical displays, this perspective display depicts vertical as well as horizontal information for aircraft, surface vessels, and submarines.

The purpose of this research was to compare operator performance on a conventional tactical display with performance on the perspective display to determine the significance of vertical information in cases in which relative altitude differences between threats and interceptors may be important. In conventional tactical displays the operator "hooks" the symbol to obtain altitude information from data readouts. With a perspective display relative altitude information is quickly visible while more accurate information may still be obtained from data readouts.

Background

Conventional naval displays present information to the operator on the relative position, orientation, and movement of aircraft, ships, and other platforms. On the basis of this information the operator makes recommendations and takes actions involving the deployment of friendly assets. Use of a perspective display may enhance such operations by reducing the information-processing load for the operator and decreasing operator

[1] Requests for reprints should be sent to Suzanne V. Bemis, Naval Ocean Systems Center, Code 441, 271 Catalina Blvd., San Diego, CA 92152-5000.

reaction times. Uttal, Azzato, and Brogan (1982) indicate that another advantage of perspective displays may be higher margins of safety in critical control situations. Merritt (1982) suggests that previous research has not evaluated perspective displays in many applications because of the belief that perspective information may be irrelevant to a particular task.

Recently a study by Smith, Ellis, and Lee (1984) used data tags on a conventional display to provide altitude information to pilots in a simulated perceived threat and avoidance scenario. This study found that the majority of maneuvers made by pilots using conventional displays were in a horizontal rather than vertical fashion. However, Ellis and McGreevy (1983) suspected that this tendency to maneuver in a horizontal fashion could be a result of the type of display and encounter used. Specifically, the preference for horizontal avoidance maneuvers could be unique to a conventional display with only two dimensions portrayed. Accordingly, avoidance maneuvers could be modified by implementation of a perspective display for oncoming traffic. Pilots would then be able to maneuver more frequently in a vertical fashion.

Ellis and McGreevy (1983) compared pilots' avoidance maneuvers when using a perspective cockpit traffic display with their avoidance maneuvers on a conventional plan-view display. These avoidance maneuvers included turns toward the intruding aircraft or away from the intruding aircraft while the altitude remained approximately the same. Aircraft on the conventional and perspective displays were represented by schematic airplane-like symbols. Vertical lines on the perspective display extended from the symbol to a grid on which horizontal separation was represented. Tic marks on the vertical lines in the perspective display divided present or future positions of aircraft into intervals of 1000 feet (304.8 m). The number of vertical maneuvers pilots made with the perspective display increased twofold over the vertical maneuvers made with the conventional display. The relative differences between the two displays suggest that use of the perspective display results in avoidance maneuvers that achieve greater separation between aircraft.

The current experiment was designed to test performance accuracy of subjects who must detect a threat and select the closest interceptor. Subjects were required to perform both tasks (detect a threat and select the closest interceptor for each threat) in order to compare performance in two display conditions: the conventional display and the perspective display.

The fundamental difference between the two displays was the manner in which altitude information was presented to the operator. In the conventional display condition subjects were required to press a key on the keyboard to enter the detect mode, followed by "hooking" the symbol to obtain altitude information. In the perspective display condition vertical separation was more readily presented on the screen. However, the subject still had the option of hooking the symbol to obtain an exact numerical representation of the altitude. This numerical value was presented in the top right corner of the display.

Variables and Hypotheses

The within-subjects independent variable was display condition (conventional and perspective). The dependent measures were (1) latent time to detect possible threats, (2) response time for selection of interceptors, (3) number of incorrect selections (false alarms), and (4) number of omissions for both threats and interceptors.

Based on previous research (Ellis and McGreevy, 1983; Merritt, 1982; Uttal, Azzato, and Brogan, 1982), it was hypothesized that subjects would select the correct interceptor for detected threats quicker and more accurately with the perspective display than with the conventional tactical display. It was expected that no significant differences would be found in search and detection between the conventional display and the perspective display.

METHOD

Subjects

The subjects were 21 male staff operational personnel from surrounding naval facilities who qualified for this experiment by passing a visual acuity test with a corrected vision of 20/20. Subjects had a mean of 9.4 years of naval experience and a mean age of 29.7 years (range 24–36).

Equipment

The Genisco Model 6210 high-resolution graphic display terminal with a Microvax II as a host via DMA (Direct Memory Access) were used for both the conventional and perspective display conditions. The display was 14 inches wide × 11 inches high (35.6 cm × 27.9 cm) with a resolution of 1392 × 1024 pixels. Symbol width on the conventional 2-D display was 4.8 mm and symbol height was 3.0 mm. Symbol size varied on the perspective display from 4.4 mm wide and 2.7 mm high for distant symbols to 5.1 mm wide and 3.2 mm high for the closest symbols. The display represented a circular area with a 24-mile (38.7-km) radius. Ownship was positioned in the center of the area. Figures 1 and 2 show samples of the two displays.

A digitizer pad and pen were used to "hook" symbols on the display. Subjects used three keys on the Genisco keyboard to select the desired mode (pick, detect, or intercept). In addition to written instructions, the experimental task was demonstrated with an 8-mm videocassette recorder on a 19-inch Sony color monitor. A standard visual acuity chart (Form 2C) was used to test vision.

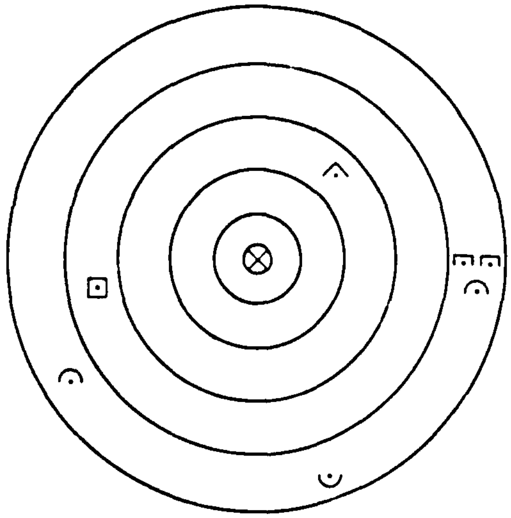

Figure 1. *Conventional display.*

Scenario

A large sea was the location for the 30-minute scenario. Only 30 symbols were presented on the display at any one time. When a craft left the 24-mile area portrayed on the display, another craft appeared. Fifteen threats were interspersed throughout the 30-minute scenario. A threat was defined as any hostile aircraft that appeared on the display or any unknown aircraft that left an air corridor. In all scenarios the tactical symbology represented ownship (aircraft carrier), 15 friendly aircraft, 12 unknown aircraft, and 8 hostile aircraft.

Experimental Design

The experimental design was a one-way within-subjects design. Each subject was

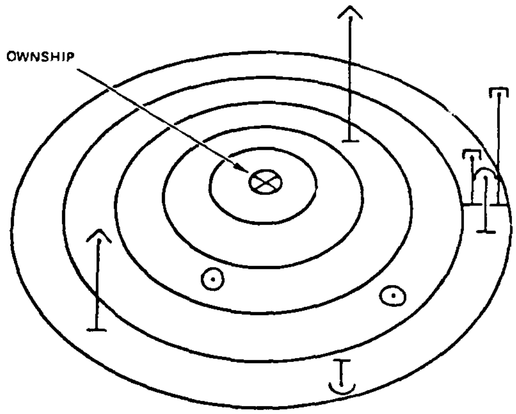

Figure 2. *Perspective display.*

tested in both the conventional and perspective display conditions. For this experiment the perspective display was fixed at a 41-deg viewing angle, whereas the conventional display showed the traditional PPI (Plan Position Indicator) overhead view with ownship centered on the display. Shape coding denoted the category of the symbol (surface, subsurface, or air) and the identity of the craft (friendly, hostile, or unknown).

The same two scenarios were used for all subjects in both display conditions. The scenarios differed in only one respect: each scenario had a different sequence of threats to which the subjects were instructed to respond.

Procedure

Subjects were tested in a partitioned area in a computer laboratory. Normal staff operations continued in the laboratory surrounding the testing area; however, the testing area was covered with an opaque tarpaulin so that illumination resembled the darkened room in the Combat Information Center (CIC). Consequently, noise and illumination replicated normal CIC operating conditions.

Each subject was first administered the visual acuity test. After confirming 20/20 (corrected) vision, the subject was given written instructions about the task. The first task required subjects to search the display and detect any threats. Each of the 15 threats appeared on the display one at a time. The second task consisted of choosing the closest interceptor (the friendly aircraft that was nearest the detected threat both horizontally and vertically). Instructions described the three modes of operation: pick, detect, and intercept. The pick mode was used to gain only a numerical value for the altitude of any hooked symbol on the display. The altitude was then presented in the top right corner of the display. The detect mode was used to target a threat for interception. The third mode, intercept, was used to select an appropriate interceptor. The subjects used three keys on the Genisco keyboard to select the desired mode. In all three of these modes peripheral equipment was used. The subjects were instructed on the use of the peripheral digitizer pad and pen. The digitizer pad and pen controlled a crosshair (cursor) on the screen. It was with the crosshair that the desired craft was pinpointed for altitude information, targeting, or interception, depending on which mode the subject was operating. Subjects were instructed to work as quickly and accurately as possible.

After reading the instructions, the subject watched an eight-minute video to become acquainted with the equipment. Then the subject was presented with a practice scenario consisting of four threats and lasting a total of five minutes. When the practice scenario was successfully completed, the subject was tested on the first thirty-minute scenario. A five-minute break was given to each subject after the first scenario and before commencing the second scenario. After completion of the second scenario, the subjects were given a questionnaire asking information about preference for display condition, age, years in service, and relevant experience. The subjects were then debriefed and thanked for their participation.

Data Collection

Detection latency for each threat and response time for each interception were recorded automatically. Mean latency and mean response time for each subject were computed. Errors—including omissions, false detections, and false interceptions—were recorded for all events.

RESULTS

Analyses of variance (ANOVAs) were performed to discover any significant differences between the perspective display and the conventional display for the number of errors and reaction time. All within-subjects analyses for the perspective and conventional display conditions included subjects with data in both experimental conditions. The ANOVAs showed that significantly fewer errors were made using the perspective display. Figure 3 displays the mean errors for each task.

An analysis of total errors for the task of detecting threats showed that significantly fewer total errors (false detections and omissions) were made in the perspective display condition, $F(1,19) = 5.84, p < 0.05$. False detections refer to symbols that were incorrectly selected as a threat. Omissions are threats that were not detected. The largest advantage found for the perspective display was the substantial reduction of errors for the task of selecting interceptors, $F(1,19) = 66.32, p < 0.01$. This finding was consistent for both false interceptions and omissions. False interceptions refer to symbols that were incorrectly selected as the closest interceptor. If the subject failed to select an interceptor, an error of omission was made.

The results of the analysis showed that response time for interceptor selection was shorter for the perspective display, $F(1,19) = 58.94, p < 0.01$, than for the conventional display (see Figure 3). However, no significant differences in response time were found between the two display conditions for threat detection.

A post hoc ANOVA was also performed to ensure that no learning effect was present for the display or scenario conditions. No learning or order effect was present. Regression analyses were performed to determine any correlation between (1) response time and errors for the combined tasks of detecting threats and selecting interceptors for both display conditions (perspective and conventional) and (2) response time and errors for each task (detect only and intercept only) for both display conditions. No significance was found.

DISCUSSION

The results of this experiment clearly show the utility of the perspective display in reducing errors of all types and in decreasing reaction time to send interceptors. It was expected that subjects would have slower response times for selecting interceptors in the conventional display because subjects needed to use the "pick" key to determine the precise altitude of possible interceptors.

The perspective display significantly reduced errors in interceptor selections. This finding was expected given the graphic representation of the interceptors' altitude in relation to the hostile or unknown craft. However, the perspective display significantly reduced detection errors as well, which was not expected. Because the perspective display has tic marks attached to each air symbol, it was initially thought that these additional tic marks might cause a sensory overload in subjects. This possibility was disproved, however, as subjects' detection errors were reduced significantly in the perspective display condition when compared with the conventional display condition. The

MEAN ERRORS

CONDITION	DETECT	INTERCEPT
CONVENTIONAL DISPLAY	2.78 *(0.08)	8.0 *(1.76)
PERSPECTIVE DISPLAY	1.83 *(0.08)	4.83 *(1.34)

MEAN RESPONSE TIME IN SECONDS

	DETECT	INTERCEPT
CONVENTIONAL DISPLAY	45.65 *(9.67)	84.10 *(8.79)
PERSPECTIVE DISPLAY	41.06 *(9.26)	54.93 *(9.59)

* STANDARD DEVIATION

Figure 3. *Mean errors and reaction times.*

perspective display reduced all types of errors and clearly could help Navy Tactical Data System (NTDS) operators do their job better.

A survey with a comment section was given to each subject at the conclusion of the test period. Many subjects commented that the graphically depicted vertical separation in the perspective display condition was an excellent feature that could expedite interceptor selection for operation specialists in the fleet. Nineteen subjects preferred the perspective display. The remaining three subjects preferred the conventional display because they were familiar with it.

Display density and complexity were not studied in this experiment. Future research is necessary to determine the effects of overlapping symbols and data tags in order to effectively evaluate the usefulness of the perspective display for the Combat Information Center. Among the factors that still need to be investigated before this display can be implemented are the usefulness of color coding in this particular display, display density and complexity, and the effect of the rotated field of view on operator performance.

The use of a perspective display for other applications was also investigated. It has been suggested that one possible application for the perspective display might be the Mine Warfare Planning System (T. Hass, personal communication, December 1984). Mine areas are commonly viewed as a cylinder when in reality they are usually a series of spheres or a single hemisphere centered on the bottom, and future research could investigate the use of perspective displays as an alternative to present mapping methods. Several subjects also mentioned the potential use of this display for air traffic control as well as for air intercept control in the Combat Information Center.

SUMMARY AND CONCLUSIONS

This experiment revealed a significant reduction in errors of detection and interception with the use of the perspective display. As expected, response time for selecting interceptors was greatly reduced in the perspective display condition. No difference existed in response time for threat detection between the two display conditions. The regression analyses showed that no correlation existed between (1) response time and errors for the combined tasks of detecting threats and selecting interceptors for both display conditions (perspective and conventional) and (2) response time and errors for each task (detect only and intercept only) for both display conditions.

The results of this experiment show that the perspective display has the potential to reduce errors and response time for air intercept controllers in the Combat Information Center. Before this type of display can actually be implemented in the fleet, however, it is essential that display density and complexity be studied on the perspective display.

ACKNOWLEDGMENTS

The authors would like to thank Anthony Louie, Information Processing and Display Technology Branch, Code 443, Navoceansyscen, for developing the perspective display and computer programs.

REFERENCES

Ellis, S. R., and McGreevy, M. W. (1983). Influence of a perspective cockpit traffic display format on pilot avoidance maneuvers. In *Proceedings of the Human Factors Society 27th Annual Meeting* (pp. 762–766). Santa Monica, CA: Human Factors Society.

Merritt, J. O. (1982). Issues in the evaluation of 3-D display applications. In D. J. Getty (Ed.), *Three-dimensional displays: Perceptual research and applications to military systems* (pp. 419–427). Washington, DC: National Academy of Sciences.

Smith, J. D., Ellis, S. R., and Lee, E. (1984). Perceived threat and avoidance maneuvers in response to cockpit traffic displays. *Human Factors, 26*, 33–48.

Uttal, W. R., Azzato, M., and Brogan, J. (1982). Dot and line detection in stereoscopic space. In D. J. Getty (Ed.), *Three-dimensional displays: Perceptual research and applications to military systems* (pp. 456–465). Washington, DC: National Academy of Sciences.