NASA Technical Memorandum 81171

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June 1981

NASA
National Aeronautics and
Space Administration
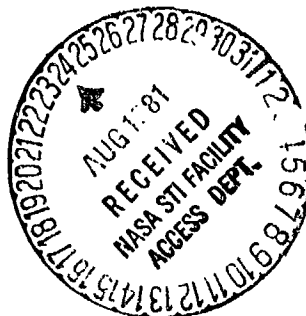
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EFFECT OF DISPLAY UPDATE INTERVAL, UPDATE TYPE, AND BACKGROUND ON

PERCEPTION OF AIRCRAFT SEPARATION ON A COCKPIT DISPLAY

OF TRAFFIC INFORMATION

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SUMMARY

The concept of a cockpit display of traffic information (CDTI) includes the integration of air traffic, navigation, and other pertinent information in a single electronic display in the cockpit. The present study was conducted as part of a research project designed to develop clear and concise display symbology for use in later full-mission simulator evaluations of the CDTI concept. This experiment required test subjects to monitor a CDTI and to make perceptual judgments about the future position of an intruder aircraft in relationship to their own aircraft. Experimental variables used in the study included the update interval motion of the aircraft, the update type, that is, whether the two aircraft were updated at the same update interval or not, the background (grid pattern or no background), and encounter type (straight or curved). Results indicated that only the type of encounter affected performance.

INTRODUCTION

Projected estimates of air traffic indicate a marked increase that is expected to create a demand for improved air traffic control services to maintain or improve present levels of safety. The concept of a cockpit display of traffic information (CDTI) is being considered to determine whether such a display could have a beneficial role in the air traffic system. A CDTI shows the pilot the position of another aircraft, in relation to the pilot's own aircraft (herein referred to as "ownship") on a moving map display. This display also indicates the pilots own position and direction of travel with respect to ground-referenced area-navigation routes and terrain features. Objects on the display move down the display at a rate proportional to aircraft movement over the ground.

Prior experiments in this project were directed toward developing a clear and easy to use display symbology CDTI (refs. 1, 2). These studies dealt with some basic factors affecting pilot perception of motion and traffic separation. Pilots made judgments while monitoring a dynamic CDTI display. Errors in judgment were recorded to determine how accurately pilots could predict the future separation between their own aircraft and an intruder aircraft. The

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main concern of this paper is how various ways of updating information on the CDTI may affect the pilot's ability to use that information. Ownship translation, rotation, and updating can be continuously updated if the information comes from an on-board area-navigation system. Continuously updated information is necessary if the display is to be used for guidance and control of the ownship. The ownship and intruder can only be updated once every 4 sec, if all the information is transmitted to the aircraft from ground radar. Discrete updating may cause fewer perceptual errors. When updating is not continuous the symbols seem to "jump." These jumps may be useful in estimating relative motion.

Three types of updating of the two aircraft symbols were investigated in this study. With one type, the rotation would update 10 times/sec, with the ownship and intruder updating and translating once every 4 sec. This updating type was used in the previous experiments; it allows the relative motion to be estimated when both positions update together. With the heading of the ownship continuously updating, the display can be used for heading control. In the second type of updating, the rotation and translation are the same, with both the ownship and intruder updating once every 4, 2, 1, or 0.1 sec. This is perhaps perceptually the cleanest type of updating, with the ownship and intruder always updating simultaneously. This would be the kind of information provided by data link from the ground. In the third type of updating, the ownship rotation and translation updates once every 0.1 sec, and the intruder's position updates once every 4, 2, or 1 sec. In this case, the ownship position and heading are assumed to be available from an on-board area navigation unit and therefore continuously available. This should result in the best control of the ownship. This type could cause a perceptual illusion. The continuous relative motion may not be perceived with the large discrete update of just the intruder.

Background information (route, terrain features, etc.) provides a frame of reference that allows the pilot to separate intruder movement relative to the ground from movement relative to the ownship. In previous studies navigation routes were displayed for reference; in this study there was a rectilinear grid background or no background at all.

The objective of this experiment was to see if there were significant differences in performance on a perceptual task of aircraft separation with different update intervals, update types, and backgrounds.

METHOD

Display Hardware

The CDTI was displayed on a 18- by 18-cm CRT located directly below the altitude indicator in a fixed-base cockpit simulator. The center of the display was located 25° (0.44 rad) below the horizontal and 0.87 m from the pilot's eye-reference point. The display symbols were generated by a general

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purpose, stroke-writing computer graphic system. The green phosphor on the CRT left no noticeable afterglow.

Display Symbology

Figure 1 shows display formats used in this experiment. A chevron symbol for the ownship and a circular symbol for the intruder aircraft remained constant throughout the experiment. These symbols were preferred by the most pilots in Hart's study of pilot opinion on various types of CDTI symbols (ref. 3). The top point of this symbol indicated the actual location of the ownship. The intruder was displayed by a circular symbol, with the present location at the center of the circle. Neither symbol included predictors on or history of previous motion. All subjects received practice trials with the symbology. The width of the terrain displayed on the CRT was 10 n. mi. With this map scale, which seems reasonable for terminal-area operations, 1 n. mi. on the ground equals 1.2 cm on the display. No sensor noise or tracker lag was simulated for these tests.
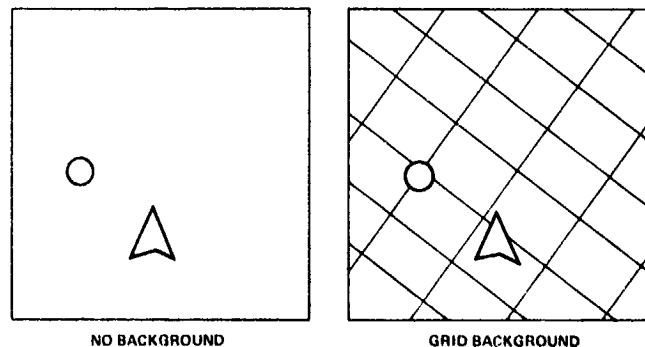

NO BACKGROUND   GRID BACKGROUND

Figure 1.- Display format used in experiment.

Figure 2 shows the eight parameters that were used to specify an encounter between the ownship and an intruder. The encounter variables included viewing time, miss distance, and type of encounter. The viewing time for the experiment was 16 sec. The encounter began at 44 sec and ended at 28 sec before the point of closest encounter. In all the encounters the miss distance was 3000 ft. There were no encounters that would result in a collision. For each display condition, the subjects monitored 24 encounter situations. In 12 of these encounters, the intruder would ultimately pass in front of the ownship. Figure 3 depicts those 12 encounters and the parameters as they would appear if they were displayed with ground-referenced predictor and history. The remaining 12 encounters differed in that the intruder would pass behind the ownship. In 12 encounters both aircraft were going straight, and in the remaining 12 one or both aircraft were turning. During the experiment, the order of presentation was randomized by the computer. In addition, whether the subject saw the encounter or its mirror image was also randomized by the computer.
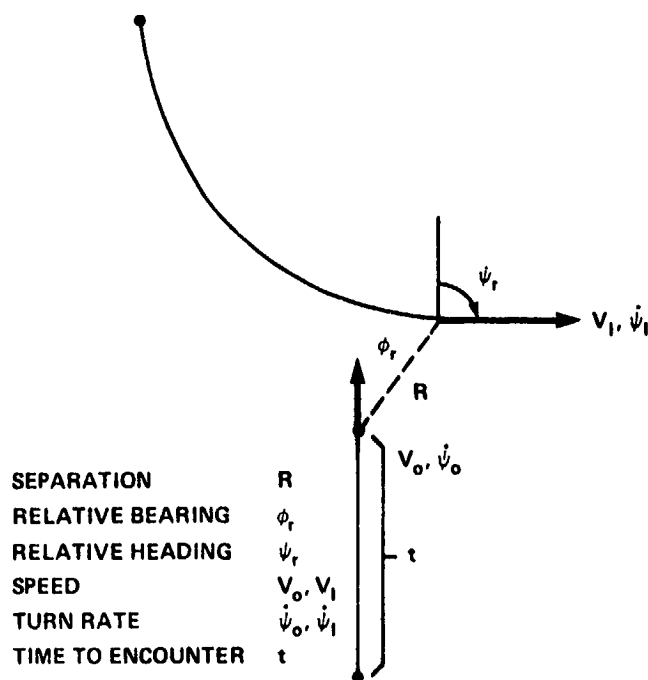
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SEPARATION R
RELATIVE BEARING ϕ_r
RELATIVE HEADING ψ_r
SPEED V_o, V_I
TURN RATE $\dot{\psi}_o, \dot{\psi}_I$
TIME TO ENCOUNTER t

Figure 2.- Eight parameters used to specify an encounter.

Independent Variables

For the experiment, the update intervals of the ownship and intruder were varied. The different update intervals were: once every 4, 2, 1, and 0.1 sec. Three update types were used: (1) rotation was 0.1 sec (continuous) with the ownship and intruder updating and translating every 4 sec; (2) rotation and translation were the same for both the ownship and intruder with the rotation and translation updating either every 4, 2, 1, or 0.1 sec; and (3) rotation and translation continuously while the intruder was different (every 4, 2, or 0.1 sec). The display had two background conditions: a grid or no background.

Task

The subject's task was to monitor the CDTI display and to predict whether the intruder aircraft would pass in front of or in back of the ownship. Each trial was started by the subject pushing a button. After 4 sec, the intruder appeared on the CDTI with a position, velocity, track angle, and turn rate calculated so that the intruder would be either directly in front of or in back of the ownship in 44 sec. After viewing the encounter for 16 sec, the CDTI blanked and was replaced by a message asking whether the intruder would pass in front of or in back of the ownship. The subject pushed a hand-held instrument to make his choice of four possibilities: positive in front, guess in front, guess in back, or positive in back. The words "IN FRONT" or "IN BACK" then appeared indicating the correct response. Although data were

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1

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

3

$\psi_r = -45°$
$V_l = 200$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

5

$\psi_r = -135°$
$V_l = 200$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

7

$\psi_r = -90°$
$V_l = 133$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

9

$\psi_r = -90°$
$V_l = 300$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

11

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = -1.50°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

13

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = -1.50°/\text{sec}$

15

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = +1.50°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

17

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = +1.50°/\text{sec}$

19

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = -1.50°/\text{sec}$
$\dot{\psi}_l = -1.50°/\text{sec}$

21

$\psi_r = -90°$
$V_l = 167$ knots
$\dot{\psi}_0 = 0°/\text{sec}$
$\dot{\psi}_l = 0°/\text{sec}$

23

$\psi_r = -90°$
$V_l = 200$ knots
$\dot{\psi}_0 = +1.50°/\text{sec}$
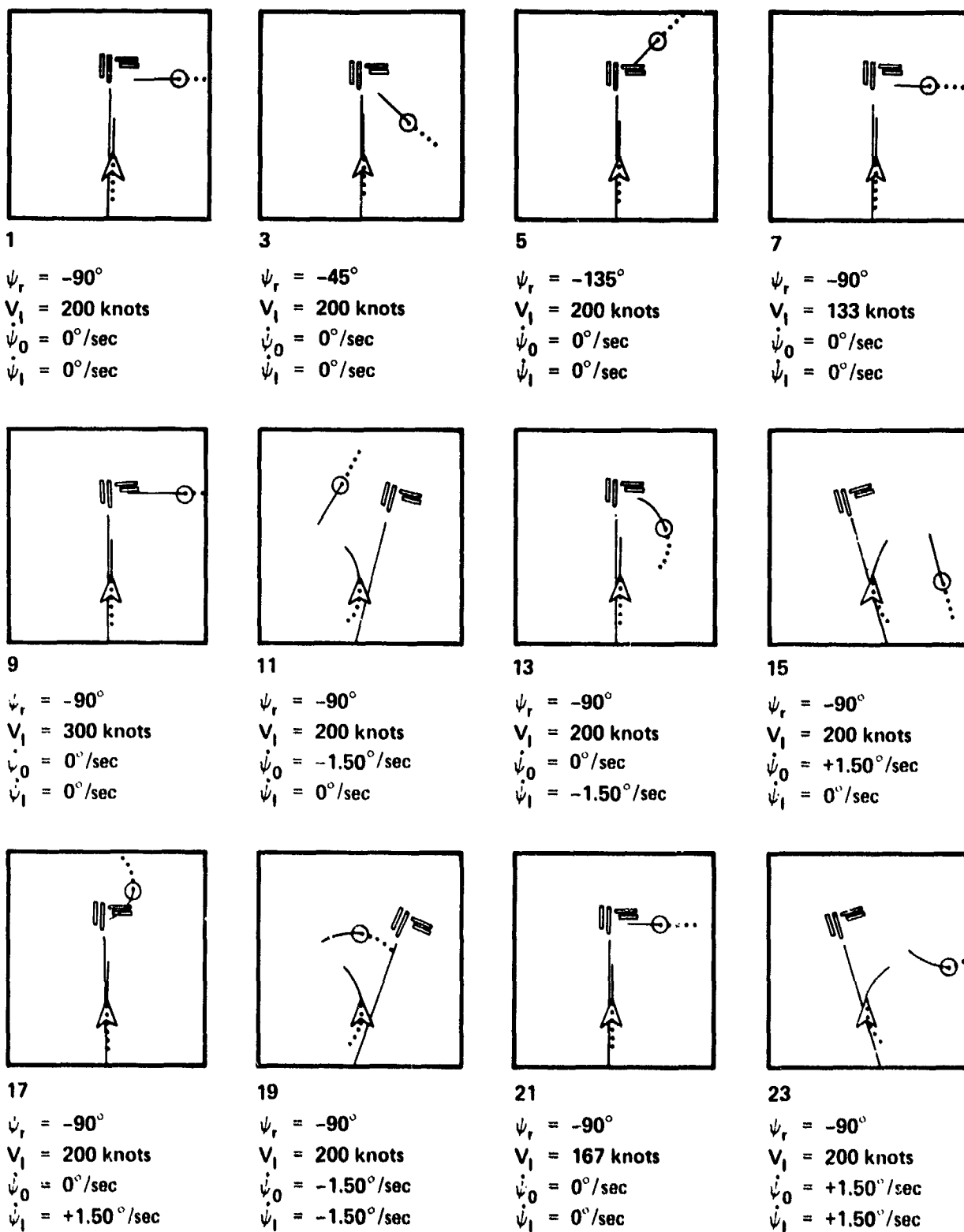$\dot{\psi}_l = +1.50°/\text{sec}$

Figure 3.- Twelve encounters used in experiment shown with curved ground-referenced predictors and history (predictors and history were not used in this study).

collected for all four choices, the data were collapsed over "positive" and "guess." It was felt that subjects were developing response patterns and were not really able to respond to the four choices.

Subjects

Four students served as paid subjects for this experiment. Because the experiment involved a perceptual task that required no flight experience, it was not felt necessary to use pilots as subjects. One of the subjects had participated in an earlier experiment in which CDTI symbology was used.

Experimental Design

The experiment was run with the subjects participating two at a time over a 2-day test period; the testing days were consecutive. Each subject viewed the CDTI on a separate CRT. The response of one subject was unknown to the other. Subjects used the same simulator seats throughout the experiment.

Oral instructions were given. Approximately 30 min were spent describing the task and training the subjects on the interpretation of the different display symbology.

RESULTS

Table 1 shows the percent error made for each update interval, update type, and background. The data were averaged over subjects. The results show little difference between the different experimental conditions.

TABLE 1.- PERCENT ERROR ACROSS SUBJECTS FOR
STRAIGHT AND CURVED ENCOUNTERS[a]

	Encounter							
	Straight				Curved			
	Update intervals/sec							
Update type	0.1	1	2	4	0.1	1	2	4
With grid								
Update same	40	22	32	34	42	38	42	40
Update different		40	34	38		42	30	38
Rotation continuous				18				34
Without grid								
Update same	36	16	12	16	34	32	30	40
Update different		40	30	46		38	42	42
Rotation continuous				18				34

[a]Each cell represents 96 trials.

An ANOVA on the error rate was calculated, and the only significant difference was between straight and curved encounters ($F(1,2) = 15.90$, $p < 0.025$). Table 2 shows the results of the ANOVA.

TABLE 2.- ANOVA FOR BACKGROUND (A), UPDATE CONDITION (B), AND TYPE OF ENCOUNTER (C)

Source	SS	df	MS	F
A (background)	4.13	1	4.13	6.35^a
B (update condition)	46.05	7	6.58	1.81^b
C (encounter type)	21.94	1	21.94	15.90^c
S (subjects)	2.46	3	.82	
AXS	1.96	3	.65	
BXS	76.23	21	3.63	
CXS	4.15	3	1.38	
AXB	20.69	7	2.96	1.44^b
AXC	.64	1	.64	<1
BXC	20.38	7	2.91	1.95^b
AXBXS	42.97	21	2.05	
AXCXS	7.09	3	2.36	
BXCXS	31.28	21	1.49	
AXBXC	8.91	7	1.27	
AXBXCXS	56.11	21	2.67	

^{a}p < 0.10
^{b}p < 0.25
^{c}p < 0.025

Multiple comparisons were conducted comparing the different update intervals, update types, and backgrounds; none of the comparisons indicated a significant difference. Table 3 shows the results of the comparisons.

TABLE 3.- PLANNED COMPARISONS FOR UPDATE INTERVALS (A), UPDATE TYPE (B), AND BACKGROUND (C)

Source	SS	df	MS	F
A at B_1/C_1	12.75	3	4.25	<1
A at B_2/C_1	10.5	2	5.25	<1
A at B_1/C_2	21.0	3	7.0	1.33
A at B_2/C_2	8.17	2	4.09	<1
B at A_4/C_1	18.5	2	9.25	2.18^a
B at A_4/C_2	35.17	2	17.59	2.22^a

^{a}p < 0.25

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In addition, subjective information was collected from the subjects in the form of a questionnaire at the end of the experiment. The results indicated that generally the subjects preferred a background grid over no background. The update intervals most preferred was the condition in which the update intervals were the same for both ownship and intruder. There was no consensus on update types.

DISCUSSION

As indicated in the analysis of the data, the different update intervals, update types, and background conditions did not significantly effect the ability of the subjects to accurately judge separation. A significant difference was found between straight and curved encounters. This finding supports previous studies (refs. 1, 2) in which it was found that fewer errors were made with straight encounters.

It is known that subjects exhibit a wide range of individual differences in perceptual, motivational, judgmental, and learning abilities. Statistical results from this experiment indicate that a large portion of the total variance may be accounted for by individual differences. The fact that the statistical analysis showed no difference in performance while subjective results from the questionnaire show a marked difference in preferences indicates that this study is also marked by individual differences. The results seem to indicate that variables such as update intervals and background do not significantly change performance although personal preference can be a factor.

CONCLUSIONS

This experiment is one more in a series of experiments designed to evaluate CDTI symbology in a dynamic but controlled environment. Two general observations are based on the study results: (1) the different update intervals, update types, and background did not effect perceptual judgment; and (2) prediction is more difficult with encounters in which one or both aircraft are turning.

REFERENCES

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