AM 68-22

A COMPARISON OF EFFECTS OF PERIPHERAL VISION CUES ON PILOT PERFORMANCE DURING INSTRUMENT FLIGHT IN DISSIMILAR AIRCRAFT SIMULATORS

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September 1968

Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Office of Aviation Medicine

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I. Introduction.

Two recent studies[1,2] on the use of peripheral vision cues for bank angle information, and their effect on pilot performance during simulated flight, utilized two different aircraft simulators; one represented a medium weight, straight wing aircraft, powered by two piston engines (Figure 1); the other, a "heavy" sweptwing transport with four jet engines (Figure 2). Data from these two studies were compared to determine if the differences in flight characteristics of the two aircraft produced significant differences in pilot performance—with and without peripheral vision cues.

II. Procedure.

As described in the previous studies, the peripheral vision cues were provided by two sets of colored lights located on the pilot's control wheel in each simulator (Figure 3). Turns (banks) to the left triggered illumination of a left-hand light; turns to the right illuminated a right-hand light.

Relationship of cue light illumination to bank angle was as follows:

Convair 340	Boeing 720	Cue Light Illumination
0° – 3°	0° – 1½°	None
3° – 10°	1½° – 10°	1 Flash/Sec. (Green)
10° – 18°	10° – 22°	2 Flashes/Sec. (Green)
18° – 22°	22° – 26°	Steady (Green)
22° – 90°	26° – 90°	4 Flashes/Sec. (Red)

The slight differences in bank angles used for the various illumination ranges were due, in part, to small differences in the roll stability and heading divergence characteristics of the two aircraft; these angular differences, however, did not affect the results of the study in any significant manner.

Subjects. Twenty pilot-subjects were used in the "720" study; thirty others participated in the "340" study; for purposes of this analysis, data for the "highest twenty" of the subjects in the 340 study (those with more than 200 hours flight time) were used to provide two groups with more equal flight time and experience. Flight hours and type of pilot license for each subject are shown in Table #1.

Instrument Display Modes. Three different instrument/cue light displays (modes) were used alternately in each of the two "aircraft"; they were:

Display Mode

"A" Complete instrument panel, including the attitude indicator (artificial horizon instrument) *without* peripheral vision cue lights (Figure 4).

"B" Complete instrument panel, including attitude indicator and, in addition, functioning peripheral vision cue lights.

"C" "Partial" instrument panel (*without attitude indicator*) with peripheral cue lights as the only source of bank angle information (Figure 5).

Flight Task. After a "flight" familiarization period of approximately 30 minutes, each subject performed six standard (right-hand) holding patterns at maneuvering speed while alternately using each of the three instrument/cue light display modes described above; in the last three

Convair 340		
Subject #	Flight Hours	Type License
11	250	C
12	300	P
13	350	C
14	400	C
15	550	C
16	900	C
17	1,200	P
18	1,400	C
19	1,500	C
20	2,500	C
21	4,600	ATR
22	4,000	C
23	7,000	ATR
24	7,400	ATR
25	7,900	ATR
26	8,000	ATR
27	9,000	ATR
28	9,000	ATR
29	8,950	ATR
30	12,500	C

Boeing 720		
Subject #	Flight Hours	Type Licence
1	8,000	ATR
2	7,000	ATR
3	18,400	ATR
4	9,000	ATR
5	6,800	C
6	12,800	ATR
7	11,000	C
8	8,000	ATR
9	7,200	C
10	12,000	ATR
11	7,000	ATR
12	8,000	ATR
13	12,000	ATR
14	5,700	C
15	8,200	ATR
16	5,600	ATR
17	19,500	ATR
18	15,000	ATR
19	9,500	ATR
20	6,000	C

TABLE #1. Subject flight hours and type of pilot license (ATR=Air Transport Rating; C=Commercial; P=Private).

patterns, each subject also performed an additional task of mentally calculating and writing answers to a series of mathematical problems on a sheet attached to a clip board resting across his lap. This mathematical task served to divert the subject's foveal vision, as well as his mental attention, away from the instrument panel.

III. Results.

Only data from the last three patterns (those in which both tasks were conducted simultaneously) were used for the present analysis. Each subject's performance was rated according to (1) the percentage of time he kept his aircraft at the proper bank angle, (2) the percentage of time his gaze was directed away from the instrument panel, and (3) the number of mathematical problems completed (adjusted to a common time period). The Student test (for two independent samples) was used for statistical analysis of the data.

Bank Angle Performance. A comparison of bank angle scores for the two aircraft (Table #2) shows that performance was significantly better in the Convair in Mode A (without peripheral vision cues) than in the Boeing. This suggests that when visual and mental attention is diverted periodically to other tasks, maintenance of desired bank angle in a sweptwing jet aircraft by use of a conventional instrument display may be more difficult than in a conventional straight wing aircraft. However, when peripheral vision cues were added (Modes B and C), there were no significant differences between the scores for the two aircraft; i.e., 66.0 vs. 62.7 in Mode B and 59.7 vs. 64.8 in Mode C.

Display Mode	Convair 340	Boeing 720
	(Mean %)	(Mean %)
A	53.3	42.9
B	66.0	62.7
C	59.7	64.8

TABLE 2. Scores for mean time (%) at desired bank angle.

Visual Attention Time. The data were also examined to find if there was any significant difference between the amount of visual time the subjects devoted to the mathematical problem solving task in the two aircraft.

Display Mode	Convair 340	Boeing 720
	(Mean %)	(Mean %)
A	49.7	46.9
B	65.7	62.2
C	64.9	61.5

TABLE 3. Scores for mean time (%) devoted to problem solving task.

There were no significant differences found between aircraft in the percentage of mean time devoted to looking at the mathematical task sheet rather than at the instrument panel (Table #3).

However, when the scores for an individual aircraft type are examined relative to the absence (Mode A) or availability (Modes B and C) of peripheral vision cues, significant differences (P=<.01) are found. In the Convair, for example, "eye-time-on-mathematical-task" increased an average of 31.3% when peripheral cues were made available. In the Boeing the increase was almost the same—31.8%.

Problem Solving Task. Examination of the number of math problems completed (corrected to a common time period) shows a striking similarity for both aircraft, in relation to each display mode utilized (Table #4).

In Mode A (no cue lights) the scores were 27.7 for the Convair and 27.0 for the Boeing. When peripheral vision cues were available, the averages for Modes B and C combined were 33.6 and 34.4 for the Convair and Boeing, respectively. These averages, when compared to the scores in Mode A show an increase in task performance of approximately 21.4% in the Convair and 27.4% in the Boeing.

Display Mode	Convair 340		Boeing 720	
	Mean		Mean	
A	27.7		27.0	
B	33.9	36.6	36.3	34.4
C	33.3		32.4	

TABLE 4. Mean scores for mathematical problems completed (corrected to normalized base).

IV. Summary.

The use of peripheral vision cues as a part of the flight instrument display in simulators of two dissimilar types of aircraft resulted in similar, as well as improved, pilot performance; bank angle control, number of mathematical problems completed, and eye fixation time were about the same in simulators representing a large, jet-engined, sweptwing airliner and a medium-sized, piston-engined, straight wing aircraft.

REFERENCES

1. HASBROOK, A. H., and YOUNG, P. E., 1968: Pilot response to peripheral vision cues during instrument flying tasks. *OAM Report* No. 68–11, Oklahoma City, Oklahoma.
2. HASBROOK, A. H., and YOUNG, P. E., 1968: Peripheral vision cues: their effect on pilot performance during instrument landing approaches and recoveries from unusual attitudes. *OAM Report* No. 68–12, Oklahoma City, Oklahoma.

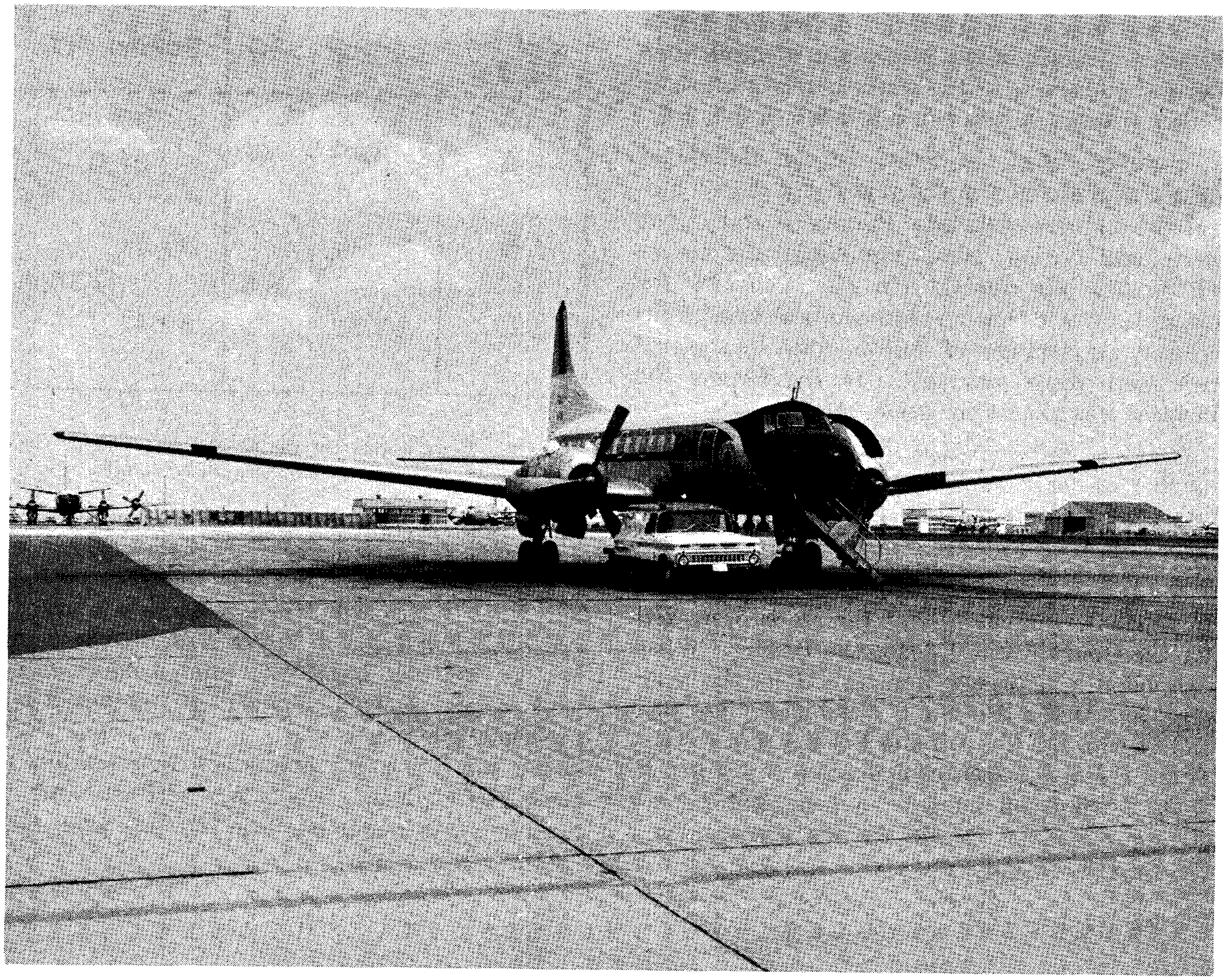

FIGURE 1. Convair 340/440; a medium weight, straight wing transport aircraft powered by two piston engines.

FIGURE 2. Boeing 720; a modern, "heavy" weight, sweptwing transport with four jet engines.

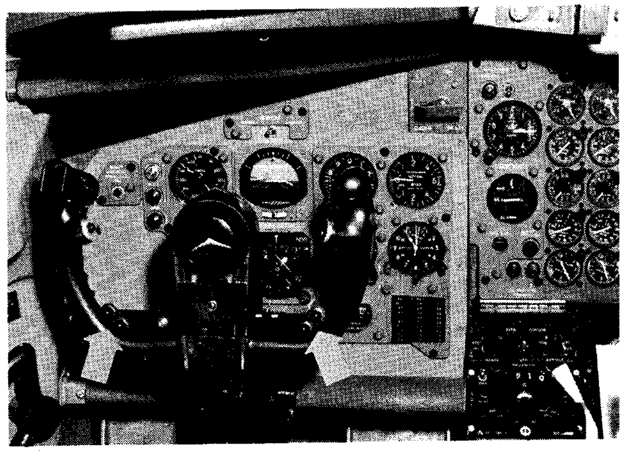

FIGURE 3. Peripheral vision cues relating to aircraft bank angle were provided by two sets of small colored lights attached to pilot's control wheel (arrows). Upper bulbs were red, lower ones green.

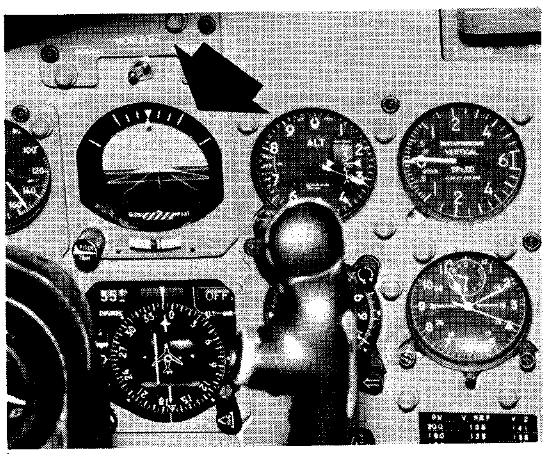

FIGURE 4. In conventional instrument display, attitude indicator (arrow) provides pitch and bank angle information.

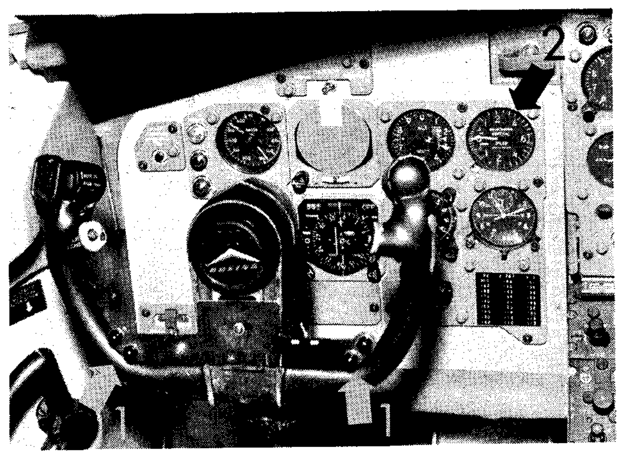

FIGURE 5. With attitude indicator covered, bank angle information was provided by cue lights (arrow #1); pitch information was derived from vertical speed instrument (arrow #2).