VISUAL CUE MANIPULATION IN A SIMULATED AIR-TO-SURFACE WEAPONS DELIVERY TASK

DR. RONALD G. HUGHES, MAJOR JAY PAULSEN, JR., REBECCA BROOKS, and 2LT WILLIAM JONES

Air Force Human Resources Laboratory
Flying Training Division
Williams Air Force Base, Arizona

ABSTRACT

Experienced pilots with no prior air-to-surface training practiced a 30 degree dive bombing task in the T-37 cockpit of the Advanced Simulator for Pilot Training (ASPT) located at the Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, Arizona. Use of a bomb impact predictor cue by one group of subjects produced no better performance than that of a second group which practiced without the cue. Abrupt removal of the cue, which during training was not made contingent upon performance, produced a significant disruption of performance on the bombing task, both in terms of accuracy and in terms of variability of performance. Best performance was obtained by a third group for which the gunsight itself was initially withheld in training. The results are discussed in terms of the need in future systems for more active control over the stimuli controlling flying performance as well as the need for research into strategies for making changes in the pilots environment contingent upon performance.

INTRODUCTION

A basic assumption of adaptive training is that a difficult task can be learned more efficiently if it is presented throughout training at a level of difficulty that is matched to the individual's current ability to perform the task. Traditional approaches have sought to control task difficulty through the manipulation of the response characteristics of the task, e.g., Gaines, (1967); Norman, Lowes, and Matheny, (1972).

In some instances, attempts have been made to modify the difficulty of a complex motor skill task by providing augmented feedback to the performer. Lintern (1977) and Lintern and Roscoe (1978), for example, showed that the use of an "off course" augmented cue could be used to enhance the landing training of naive students.

In the present study, an attempt was made to reduce the difficulty of an air-to-surface weapons delivery task in one case through the addition of a visual bomb impact predictor cue and in a second case through selective introduction of a dominant visual cue inherent in the task itself. In neither case, was the introduction or withdrawal of the cue contingent upon changes in student performance. The results of the study are discussed in terms of the need in future sytems for more active operator/instructor control over the visual environment of the learner as well as the need for research dealing with the adaptive use of augmented cuing.

METHOD

Subjects

Twenty-two T-37 Instructor Pilots (IP's) assigned to Williams AFB, Arizona served as subjects. No subject had previous experience with air-to-surface weapons delivery. Their flying experience both in terms of T-37 flying hours as well as overall military flying hours is given in Table 1.

TABLE 1

FLYING EXPERIENCE

Group	T-37 Hours X	T-37 Hours s.d.	Total Hours X	Total Hours s.d.
Standard	642.00	338.93	1580.32	1185.86
Predictor	701.67	297.21	1150.17	720.93
No Gunsight	922.00	168.88	1158.00	152.30
Overall	721.91	306.86	1367.02	919.50

Instructors for the bombing task were Instructor Pilots assigned to AFHRL's Flying Training Division at Williams AFB.

All were familiar with the air-to-surface task being taught. None were considered, however, as "TAC-qualified" instructors. Because of constraints on the use of instructors, no attempt was made to counterbalance instructors across conditions.

Apparatus

The Advanced Simulator for Pilot Training (ASPT) located at AFHRL/FT was used for training of the air-to-surface task. Technical references for this device are found in Gum, Albery, and Basinger (1975) and in Rust (1975). For the study, the g-seat was inflated but not otherwise operational. Neither was the motion platform in operation. The computer generated visual scene was presented via ASPT's seven 36-inch monochromatic cathode-ray tubes placed around the cockpit giving the pilot +110 degrees to -40 degrees vertical cuing and ± 150 degrees of horizontal cueing. Configuration of the visual scene for this study included a conventional gunnery range visual data base similar to that developed for project 2235 and that used by Gray and Fuller (1977) as well as a depressible bombing sight (A-37 Optical Sight Unit). The aerodynamic mathematical models driving the simulator were those of the T-37 aircraft.

The predictor cue used in the present study consisted of a hexagonal-shaped spot of light, approximately 30 feet (9.114 meters) in diameter, which appeared from the air to move along the ground, giving a continuous indication to the pilot of where a bomb would impact if dropped at that point in time. The manner in which the cue was generated by the system and other details of its implementation are described by Cyrus, Templeton, and McHugh (in press). The cue was programmed so as to be available under command of the console instructor. In the present study, the cue was illuminated continuously. No provision was made by the system to systematically vary the intensity of the cue.

Procedure

Individuals in each of three separate groups (referred to hereafter as Standard Group, Predictor Group, and No-Gunsight Group) of T-37 Instructor Pilots (IPs) performed 15 repetitions of a 30 degree dive bomb task in the T-37 cockpit of the Advanced Simulator for Pilot Training (ASPT). Prior to entering the simulator, each subject completed a short paper and pencil pretraining exercise intended to familiarize the subject with the basic elements of the task. Once the subject entered the simulator, the subject was presented a recorded demonstration of a 30 degree dive bomb task. For the predictor group, the demonstration contained the predictor cue in addition to the gunsight. For the no gunsight group, the demonstration contained neither the gunsight nor the predictor cue. For the standard group, the demonstration contained the gunsight but not the predictor. The narrative content of the demonstration was provided by an instructor pilot seated in the T-37 cockpit beside the subject. Following presentation of the recorded demonstration, the instructor exited the cockpit and all further instruction was accomplished from the instructor/operator console. The only exception to this procedure was for the no gunsight group, where in order to familiarize the subject with the use of the gunsight, a second demonstration (this time with gunsight) was presented between trials 5 and 6.

All groups performed 15 trials without interruption. For the Standard Group, all 15 trials were performed with the gunsight, but not with the predictor cue present. For the predictor group, the predictor cue was continuously present during all 15 trials. For the No Gunsight group, the predictor cue was never available. For the first five trials, the gunsight was not available either. For the No Gunsight group, the gunsight was introduced on trial 6 and was present for all remaining trials.

Instructors seated at the console were given a planar view of the ground track and final leg segment of the maneuver as well as a graphic display of the bomb circle and impact point with indications of the following release parameters (airspeed, heading, altitude, dive angle, g-load). No restrictions or specific instructions were given to the instructor as to the manner in which this information should be used.

Following the 15th trial, subjects exited the simulator for a short break and final critique by the instructor prior to reentering the cockpit for the 10 final trials which were conducted in the absence of any instructor feedback. For the final 10 trials, subjects in all three groups performed under the same conditions (i.e., gunsight, no predictor cue, and no instructor feedback). Dependent measures collected consisted of circular error and release parameters.

RESULTS

The results of the present study will be presented in three sections. The first section will examine the relationship of various measures of flying experience to circular error measures of bombing performance. The second section will present differences between treatment groups in terms of measures of circular error. The third section will present differences between treatment groups in terms of release parameters.

Measures of Flying Experience and Bombing Performance

Prior to comparing treatment groups in terms of bombing performances, groups were compared for possible significant differences in flying experience. Neither of three different measures of performance were found to be significantly different. Groups did not differ in terms of total flying hours ($F(2,19)=0.5676$, $p > .05$); T-37 flying hours ($F(2,19)=3.30332$, $p > .05$); or the ratio of T-37 to total flying hours ($F(2,19)=1.35116$, $p > .05$). With one exception, none of the above measures of flying experience was found to be correlated significantly with bombing performance, when bombing performance was taken as the mean circular error over trials 20-25. The one exception was for the predictor group, where the ratio of T-37 to total flying time was found to be significantly correlated with circular error ($r=-.9165$, $df=4$, $p < .05$) for trials 20-25. Comparisons, however, between this measure of flying experience for subjects in the predictor group with performances over Blocks B1-B3 did not reveal the presence of a significant relationship. Thus, despite the wide range of flying experience represented across the three subject groups, the results indicate that the experience variable was not systematically related to performances in the present study.

Differences in Circular Error Scores

The results of primary concern deal with the differences between treatment groups in terms of mean circular error. As can be seen in Figure 1, all groups show a significant decrease in circular error scores over the first 15 trials. Mean circular error and standard deviation in circular error by blocks of trials are given in Table 2.

TABLE 2

MEAN CIRCULAR ERROR (FEET)

Group		Blocks of Five Trials 1-5	6-10	11- 15	16-20	21-25
Stand (N=11)	X*	314.74	227.14	205.22	144.80	192.76
	s.d.*	251.99	177.12	129.22	96.25	111.63
Pred (N=6)	X*	405.13	237.87	212.60	316.67	170.13
	s.d.*	247.49	167.42	164.22	172.05	138.63
No Gun sight (N=5)	X*	456.76	152.28	126.60	170.40	167.20
	s.d.*	282.86	122.67	83.95	89.68	76.85

Not only was an improvement in accuracy noted over the first three blocks of trials, but also a decrease in the variability of the bombing performances. The difference, however, between circular error scores for the predictor and standard groups was not found to be statistically significant ($F(1,15)=0.363$, $p=.5619$). Neither was the difference between the standard group and the no-gunsight group statistically significant ($F(1,14)=.004$, $p=.9469$). The failure to find a difference between the standard and no-gunsight groups is probably accounted for by the poor first block performance of the group performing the task without the gunsight. When a comparison is performed between the standard and no-gunsight groups for blocks 2 and 3 (i.e., trials 6-15), the difference approaches statistical significance ($F(1,14)=2.528$, $p=.1274$).

Discontinuation of instructor feedback produced no significant effect upon the performances of the no-gunsight and standard groups. It must be remembered that the no-gunsight group and the standard group were practicing under identical conditions for trials 6-15. As is seen, however, in Figure 1, abrupt removal of the predictor cue produced an approximate 50 percent decrease in accuracy. This decrease in accuracy was quickly overcome, however, so that by the last block of five trials, little if any difference can be noted between the three groups. The effect of removing the predictor cue is instructive, inasmuch as the absence of any difference between the standard and predictor groups during the first 15 trials gives little evidence that the cue was even being utilized. The marked disruption, however, following its removal gives evidence to the contrary.

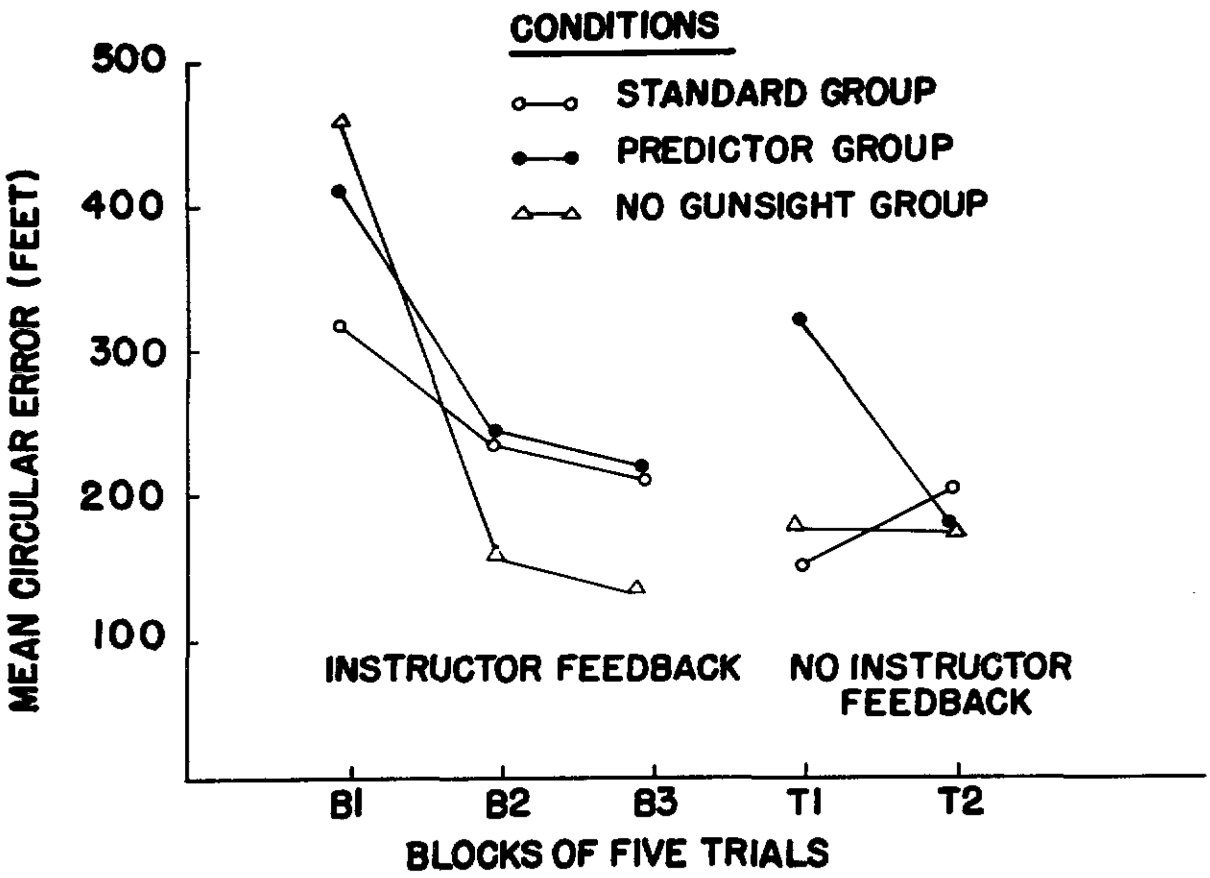

Figure 1

Circular Error Across Trials As A Function Of Instructional Conditions

Differences Between Groups in Terms of Release Parameters

Means and standard deviations for each of the five release parameters are given in Table 3.

Standard and predictor cue groups were found to differ significantly ($F(1,15)=4.619$, $p=.0461$) in dive angle variability over trials 1-15. While circular error scores were not found to differ significantly over these blocks of

TABLE 3
RELEASE PARAMETERS
MEANS

RELEASE PARAMETERS		BLOCKS OF FIVE TRIALS 1-5	6-10	11-15	16-20	21-25
HEADING (350 degrees)	S	349.37	349.84	349.70	346.14	248.90
	P	347.03	348.60	347.23	348.23	333.07
	NS	349.92	348.92	349.12	350.68	410.00
ALTITUDE (3000' AGL)	S	3012.95	2909.58	2840.92	2910.65	2886.32
	P	2992.37	2969.99	2965.83	2965.07	2984.70
	NS	2965.48	2839.64	2932.43	2965.43	3012.99
G LOAD (0.09)	S	1.10	1.18	1.12	1.11	1.20
	P	1.32	1.23	1.28	1.28	0.90
	NS	1.08	1.20	1.18	1.30	1.21
AIRSPEED (300 KIAS)	S	308.59	308.71	309.94	309.25	308.64
	P	308.80	306.40	304.87	307.60	303.90
	NS	309.96	312.48	310.24	311.36	307.64
DIVE ANGLE (30 degrees)	S	28.00	29.16	29.70	30.11	29.56
	P	28.83	29.00	27.33	28.00	28.03
	NS	30.12	29.24	29.52	29.12	27.84

STANDARD DEVIATIONS

RELEASE PARAMETERS		BLOCKS OF FIVE TRIALS 1-5	6-10	11-15	16-20	21-25
HEADING	S	3.17	2.78	2.39	6.45	2.45
	P	2.55	3.12	4.66	2.58	2.25
	NS	3.84	1.91	1.64	2.02	1.54
ALTITUDE	S	311.63	264.28	204.79	149.11	161.02
	P	283.30	392.65	283.94	168.88	186.86
	NS	206.56	151.77	131.28	131.17	136.81
G LOAD	S	0.50	0.48	0.31	0.16	0.31
	P	0.41	0.35	0.42	0.42	0.28
	NS	0.39	0.33	0.29	0.22	0.33
AIRSPEED	S	10.05	7.47	4.77	6.84	4.72
	P	7.76	8 93	9.27	4.48	5.30
	NS	6.34	4.59	4.76	4.76	3.24
DIVE ANGLE	S	3.27	2.78	2.21	2.50	2.21
	P	4.85	3.23	3.38	2.54	2.11
	NS	3.11	2.10	1.80	1.39	1.86

trials, the predictor group showed as much as 53 percent more variability in dive angle (block 3) than the standard group. Comparisons between the standard and predictor groups for trials 16-25 when the predictor cue was removed and all subjects performed in the absence of any instructor feedback showed a tendency for mean dive angle to be shallower for the predictor group than for the standard group. This difference, however, was not statistically significant ($F(1,15)=2.887$, $p=.1068$). In attempting to isolate from measures of release parameters the basis for the disruption in accuracy caused by removal of the predictor cue, groups were compared over block B3 and block T1. The only difference, in terms of release parameters, that was identified was a significantly greater variability in g-loading for the predictor group as compared to the standard group ($F(1,15)=4.932$, $p=.0402$). While g-loading was approximately 35 percent more variable for the predictor group on block B3, removal of the predictor cue on block T1 caused the variability in g-load for the predictor group to increase to approximately three times that of the standard group.

While differences between the standard group and the no gunsight group were marked in terms of circular error, differences in terms of release parameters were more subtle. In fact, only one comparison between the two groups for trials 1-5 revealed a difference that even approached statistical significance. This was in the case of altitude variation upon release where there was a trend ($F(1,14)=2.834$, $p=.1164$) toward greater variation in altitude in the standard group as compared to the no gunsight group.

DISCUSSION

Comparisons of performances in the present study with those reported by Gray and Fuller (1977) reveal an approximate 30 foot difference in mean circular error for subjects performing the 30 degree task under similar conditions. In light of the variability associated with individual performances in the present study, a 30 foot difference would be considered to have occurred by chance. It must be remembered too that the Gray and Fuller (1977) study was conducted to demonstrate the limits to which this type of task could be taught in the simulator and in so doing employed experienced instructors within the context of a developed syllabus. The present study employed the air-to-surface task because of its convenience as a benchmark task against which alternative instructional treatments could be evaluated. Therefore, the level of performance attained was secondary to the sensitivity of the task to any main effects in terms of instructional treatment conditions.

These data are instructive too for several reasons. First, from the standpoint of flying training simulation, these data demonstrate that active control over cues inherent in the visual environment of the student (in this case, the gun sight itself) may lead to better performance than the augmentation of that environment with cues intended to "aid" the student in performing a difficult task. In the present study, control over stimuli in the student's visual environment proved to be more effective than attempts to alter the difficulty of a complex tracking task through augmented visual feedback.

Secondly, the present data clearly showed that the abrupt removal of an augmented visual cue (i.e., the predictor cue) can produce a significant decrease in accuracy and an accompanying increase in variability when no provision exists for gradually fading out that cue. The results of the present study clearly point out the need in future systems for more active control over the stimuli present in the training environment. . . not only their presence or absence, but also their discriminability (e.g., intensity, etc.). It is clear too that before such active control can be incorporated into adaptive approaches e.g., Williges and Williges, (1977), research must address how such changes are most effectively made contingent upon student performance.

A third point concerns the poor perfomance obtained from subjects using the predictor cue. While the disruption in performance upon removal of the cue was expected, the failure of the predictor group to initially outperform the standard group was totally unexpected. While subjects were instructed to treat the cue as an "aid" that after 15 trials would be removed, the evidence is clear from the disruption that occurred on Block T1 that the cue was being used during practice on Blocks B1-B3. It, thus, does not appear to be the case that the instructions biased subjects in the direction of not using the cue. It may be that although such a cue may serve to facilitate the performance of the naive student, its use with experienced pilots such as those in the present study served to increase rather than decrease the difficulty of the air-to-surface task.

The results, however, do not preclude the potentially effective application of such predictor cues with pilots of lesser experience. For example, a visual cue similar to that used in the present study but instead depicting the "aimpoint" of the aircraft (i.e., the point at which the aircraft would hit the ground given its present configuration) might prove to be effective not only in the bombing task but in acquisition of the landing task as well. Research is continuing at the Air Force Human Resources Laboratory's Flying Training Division into different and more effective means of manipulating the visual environment of the pilot.

REFERENCES

Cyrus, M., and Templeton, T., & McHugh, James W. Jr. Development of a bomb-impact predictor cue. Williams AFB Arizona: Flying Training Division, Air Force Human Resources Laboratory, 1978 (in press).

Gaines, B.R. Automated feedback trainers for perceptual-motor skills. Cambridge England: University of Cambridge, Final Report, Ministry of Defense Contract, September, 1967.

Gray, T.H., and Fuller, R.R. Effects of simulator training and platform motion on air-to-surface weapons delivery training. AFHRL-TR-77-29, Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, July 1977.

Gum, D.R., Albery, W.R., and Basinger, J.D. Advanced Simulation in Undergraduate Pilot Training: An Overview. AFHRL TR-75-59 (I), Wright Patterson Air Force Base, Ohio: Advanced Syst ems Division, Air Force Human Resources Laboratory, December, 1975.

Lintern, G. Acquisition of landing skill with the aid of supplementary visual cues. Savoy, Illinois: University of Illinois at Urbana-Champaigne, Aviation Research Laboratory, Technical Report ARL-77-AFOSR-77-5, January 1977.

Lintern, G., and Roscoe, S. Transfer of landing skill after training with supplementary visual cues. Paper presented at the sixth annual Psychology in the Department of Defense Symposium, USAF Academy, Colorado, April, 1978.

Norman, D.A., Lowes, A.L., and Matheny, W.G. Adaptive training of manual control: I. Comparison of three adaptive variables and two logic schemes. Orlando, Florida: Naval Training Equipment Center, Technical Report NAVTRAEQUIPCEN 69-C-0156-1, January 1972.

Rust, S.K. Flight simulator fidelity assurance. Proceedings of the Eighth NTEC/Industry Conference, November, 1975.

Williges, R.C., and Williges, B.H. Critical variables in adaptive motor skills training. Human Factors, vol. 20, April 1978, 201-213.

ABOUT THE AUTHORS

DR. RONALD G. HUGHES is a Research Psychologist for Air Force Human Resources Laboratory. Prior to coming to AFHRL, Dr. Hughes worked as a research psychologist for the U.S. Army Research Institute for the Behavioral and Social Sciences. Dr. Hughes holds a Ph.D. in experimental psychology from the University of North Carolina.

MAJOR JAY G. PAULSEN, JR. is an Instructor Pilot at Air Force Human Resources Laboratory with over 4,000 hours of instructor time. He flew 271 sorties over Vietnam using a variety of air-to-ground tactics.

MS REBECCA BROOKS is a Research Psychologist at Air Force Human Resources Laboratory. Before that she worked for the Federal Aviation Agency in the Aviation Psychology Laboratory in Oklahoma City, Oklahoma. Ms Brooks holds a Master's degree from Arizona State University in educational psychology and in counseling.

LIEUTENANT WILLIAM JONES is assigned to Air Force Human Resources Laboratory as a Behavioral Scientist. He is an Air Force ROTC graduate of the University of Alabama with Bachelor's and Master's degrees in psychology.