

EFFECT OF SCENE CONTENT AND FIELD OF VIEW ON
WEAPONS DELIVERY TRAINING

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ABSTRACT

Two of the issues faced by designers of modern high-performance aircraft simulators are: (1) the level of visual scene realism required to adequately train complex tasks within the simulator; and (2) the field-of-view required for such training. The experiment discussed in this paper was designed to study both of these problems as they relate to the training of manual dive bombing in the F-16 aircraft. The experiment was performed in two separate simulators using the same visual image generators and data base. The first simulator was a Fiber Optic Helmet Mounted Display (FOHMD) System with a full 360 degree field of regard; the second used Wide Angle Collimated (WAC) Windows to provide a more restricted field-of-view (FOV). Subjects with no previous fighter aircraft experience were trained to perform 10°, 20°, and 30° dive bomb attacks on either a simulated bombing circle, a low detail airfield target scene, or a high detail simulation of the same scene. The transfer/test condition was a second different high detail airfield scene.

INTRODUCTION

The simulator can provide an ideal training ground for a wide variety of flight tasks. In years past, the tasks fell mostly in the realm of procedures training, cockpit layout familiarization, and basic contact/transition skills. As flight simulators become more complex and visual image generators more powerful, many new and previously unconsidered tasks can be trained in the simulator - complex skill and judgment tasks. For many such tasks the simulator may prove to be a better initial trainer than the actual aircraft, particularly those involving large amounts of initial approach and set-up time or high degrees of risk. An ideal candidate task for such training is precision ground attack - the actual aircraft can only carry a limited number of practice bombs and each pass requires considerable positioning time.

If such tasks are to be trained within the simulator, two questions are of prime importance: (1) how much detail must the visual scene contain; and (2) how large of a field-of-view does the pilot require to perform the task. More complex visual scenes require more powerful (and more expensive) image generators. Full FOV systems are much more complex than those with more limited fields of view (and approximately five times as expensive). Using the minimum effective capability is important for cost savings in both acquisition and maintenance.

BACKGROUND

Scene Content

Investigations of scene content variables and their effects on pilot performance are relatively few in number, and for the most part have

concentrated on approach and landing and low altitude flight. Buckland, Monroe, and Mehrer (1980) placed a checkerboard textural pattern of various size directly on a runway. Increased texture density produced greater control of the aircraft at touchdown, as indicated by slower vertical velocity, less displacement from centerline, and touchdown closer to the desired touchdown point. Kraft, Anderson, and Elsworth (1980) evaluated the effects of a complex visual scene, which included peripheral cues located adjacent to the runway. The complex scene resulted in less vertical deviation from the glideslope for straight in approach segments, and less lateral deviation from centerline at touchdown. Additional research performed by Westra (1981, 1982) suggests that performance is enhanced in the approach and landing segments of flight when additional cues are presented.^{13,14} It seems that further increases in scene complexity, particularly vertical object development along the approach and landing path, would result in further improvement to performance of this type of task.

Another task that has shown performance improvement with vertical development is low-level flight. Martin and Rinalducci (1983) used three terrain cue configurations—(1) all black inverted 35-foot high tetrahedrons, (2) inverted tetrahedrons of the same type with black bottoms and white tops, and (3) flat white triangles placed directly on the ground of the same density as conditions 1 and 3. The study showed that pilots performed better under conditions that had vertical development. Another low-level flight study of interest was performed by Buckland (1981) to examine the effect of vertical cues and checkerboard textural patterns on flight performance. The results showed less deviation from the ideal flight parameters for the conditions involving vertical objects or textural cues.

Some other interesting investigations into the effect of using the scene content variable in simulation studied its effect on performance for carrier landings and 30° bombing attacks.^{15,8} Westra manipulated the scene content on a simulated carrier representation by using a day carrier scene as a high detail condition and a night carrier scene for a low detail condition. He found no transfer advantage between those trained with the high detail scene or the low detail scene. These findings suggested that a low detail scene could be used to train naval pilots for carrier landings. Lintern employed the same approach to study 30 degree bombing attacks. He used a complex day scene, bombing range with vertical objects, for the high detail condition and a dusk scene, bombing range less many terrain features, for the low detail condition. The experiment found no significant difference in either condition, but methodological problems between the comparisons

were discussed that could have confounded the data.

The experiment discussed in this paper was concerned primarily with the addition of two and three dimensional cues of known size to an otherwise simple data base. All three of the training data bases involved utilized irregular hardware texture to represent fields and other ground cues. The low and high detailed training data bases included two dimensional objects representing airport runways and three dimensional cues representing associated structures. The high detail testing data base used essentially the same representation for two and three dimensional cues as the high detail training data base (See Figures 1-4).



Figure 1. Standard Air Force Gateway Range



Figure 2. Low Detail Representation of Standard Air Force Runway (Cannon AFB NM)



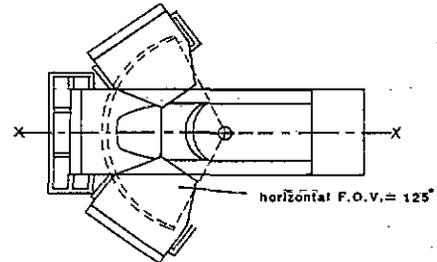
Figure 3. High Detail Representation of Standard Air Force Runway (Cannon AFB NM)



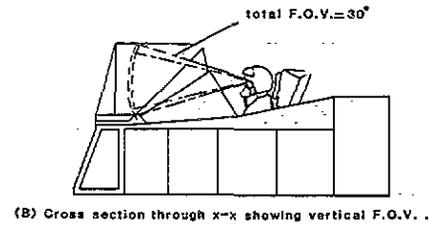
Figure 4. Test Condition; High Detail Representation of Standard Air Force Runway (China Lake NAS, CA)

Field-of-View.

The definition of FOV for this research effort will be the instantaneous field displayed by the system from the pilots eyepoint. For the current experiment and all subsequent mentioning of FOV dimensions will be in degrees with the pilots' eyepoint considered 0, 0 (See Figures 5-6).



(A) Plan view of display heads showing F.O.V. .



(B) Cross section through x-x showing vertical F.O.V. .

Figure 5: WAC window field of view size.

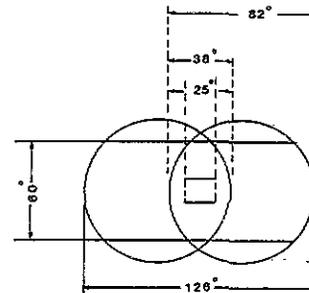


Figure 6: FOHMD instantaneous field of view size.

Many researchers have attempted to define FOV requirements. These early attempts focused almost exclusively on using the aircraft as the primary tool to provide data for FOV requirements.^{18,12} These techniques incorporated either pilot subjective data or video techniques, such as mounting a camera in the cockpit that followed the pilot's eye-track. More recently attempts have focused on using the simulator as the primary research tool.

The early investigations utilizing the simulator as a research tool concentrated on determining the FOV requirements for straight-in take-offs and landings using experienced pilots. The results of these findings are summarized by Collyer, Ricard, Anderson, Westra, and Perry (1980) as follows: safe and acceptable take-offs and landings could be performed in FOV configurations with dimensions of 10° horizontal by 10° vertical, 21.5° horizontal by 21.5° vertical, and 5.7° horizontal by 37° vertical. The most important findings of this series of studies were that the FOV configurations used were significantly smaller than those currently used in simulation. Other studies on take-offs and landings comparing performance across two FOV's concluded that no significant differences were noted between a 36° horizontal by 48° vertical limited FOV and a 300° horizontal by 150° vertical FOV for take-offs using experienced pilots.⁶ These results are consistent.

These early investigations led to research designed to investigate basic contact maneuvers. This strategy was investigated to provide further options for the training of Air Force pilots, since fuel and aircraft costs had risen considerably. Several studies were accomplished that explored basic contact maneuvers performed by undergraduate pilot students, such as aileron rolls, barrel rolls, and the 360° overhead (OVHD) landing pattern. In three subsequent studies, between 1977 and 1979, FOV was used as an independent variable in conjunction with various other environmental factors.^{6,9,11} These studies showed that the FOV requirements are extremely maneuver specific, but performance improved as the FOV increased. Several of the other variables investigated in these studies were significant across the various tasks and several did not affect performance in any manner.

The significant technological advances of the last decade in simulator design and display mediums began driving FOV research toward defining more complex tasks that could now be accomplished in the simulator (air-to-ground attacks, aerial refueling, carrier landings, and close air support). These studies examined the effect of various FOV configurations on experienced pilots for each of the above specified maneuvers.^{4,8,11} All of the above studies showed that a FOV smaller than those in the actual aircraft could be used to practice these tasks by experienced pilots. A general summary of the significant results was stated by Wiehorst and Vaccaro (1986) as follows: (a) flying tasks can be performed with a LFOV or area of interest in the simulator, and (b) the FOV requirement is very task.¹⁶ Although consistent research has been completed on the FOV requirement, there needs to be significant in-simulator transfer of training studies using inexperienced pilots with larger sample sizes than previous studies. The current experiment will investigate the effects of FOV on acquisition and in-simulator transfer.

OBJECTIVE

The objective of this research was to determine the effect of scene content and field of view size on the skill acquisition of manual dive bombing tasks.

Subjects

Thirty-six current Air Force pilots with high performance, Fighter/Attack/Reconnaissance (FAR) aircraft ratings were used as subjects in this experiment. None of the subjects had any previous flight experience in the F-16 aircraft or previous dive bombing experience. All were currently flying the Northrop T-38 aircraft, a supersonic flight trainer.

Apparatus

This study was conducted in an F-16C flight simulator with two visual display systems. The first was a window type display using three wide angle Collimated (WAC) windows with an approximate field of view of 125° horizontally and 36° vertically. The second display was a Fiber Optic Helmet Mounted Display (FOHMD) which allowed an unrestricted field of view in all directions (cockpit, wings, nose were computer masked), and an instantaneous FOV of 126° horizontally and 60° vertically, with the only restricted visual area being that occupied by the simulated aircraft itself. Imagery in both cases was provided by a Singer-Link Digital Image Generation System (DIGS). Identical data bases were used under both of the display conditions. The cockpit itself was fully instrumented, with the Head-Up Display (HUD) targeting system set for the manual bombing mode. All necessary information to perform the dive bombing tasks (dive angle, airspeed, g-factor, altitude, flight path marker, targeting reticle, and compass heading) was presented to the subject in the HUD, thus lessening the distraction caused by having to perform complex cross checks with an unfamiliar cockpit layout.

Experimental Design

This study was a mixed design. Independent variables and their treatments were as follows:

1. Field-of-View:
 - (a) WAC Window (125° x 36°)
 - (b) FOHMD (360° field-of-regard)
2. Scene Content (Data Base):
 - (a) Low Detail Bombing Range
 - (b) Low Detail airfield
 - (c) High Detail airfield
3. Presentation Order:

(a)	10°	20°	30°
(b)	20°	30°	10°
(c)	30°	20°	10°
(d)	30°	10°	20°
(e)	20°	10°	30°
(f)	10°	30°	20°
4. Dive Angle:

(a)	10°
(b)	20°
(c)	30°

The training data bases on this study varied on the amount of visual information they presented to the pilot. The lowest level was a standard Air

Force gunnery range with minimal visual information, primarily a target circle with three down range distance markers at 600, 1250, and 2000 feet. The second data base was a two dimensional representation of Cannon AFB, NM including all runways, taxiways, parking aprons, etc. The third data base differed from the second only by the addition of three dimensional cues around the airfield (buildings, hangers, a control tower, etc). The target in both of the airfield conditions was located at the intersection of a taxiway and the main runway. (Refer to Figures 1-4.) Each subject performed attacks at dive angles of 10°, 20°, and 30°. The order of presentation of these angles was balanced across subjects, with each subject completing all passes at a given dive angle before proceeding to the next. Dive angles were investigated within subjects. Data bases, field-of-view, and dive angle presentation order were looked at across subjects.

Procedure

Each subject was given a one-half hour briefing on the nature of the experiment and on the techniques for performing a manual dive bomb attack in the F-16 aircraft. This briefing included information on both optimum delivery patterns and parameters, as well as correction factors for variations from optimum. During this briefing, the subject was also familiarized with the Heads-Up Display and instrumentation within the simulator cockpit. Following this, the subjects were put into the simulator and instructed to practice the material which they had just learned. A practice pass consisted of the simulated aircraft being placed on base leg of the bombing run 11,800 feet back from the target and 12,000 feet outboard from it, initialized at an altitude commensurate with the dive angle to be used in the attack (2500', 4000' or 7000'). Ideally, the subject was to maintain straight and level flight until reaching a point parallel to the target, then make a 90° turn toward the target, rolling out of the turn on the prescribed dive angle. During the dive, he was to accelerate to 450 knots, align the target reticle with the target, and release the bomb at the proper altitude (500', 1600' or 3000' depending on dive angle).

FIGURE 7: FINAL LEG PARAMETERS FOR DIVE BOMB TASKS

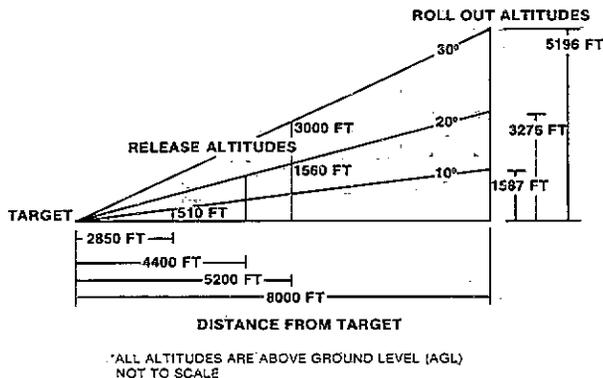
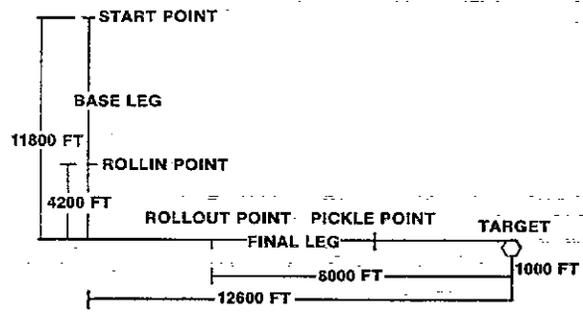


FIGURE 8: IDEAL FLIGHTPATH



NOT TO SCALE

Following each training passes, feedback was provided by the experimenter on how well the subject followed the commanded flight profile, bomb miss distance, the angle at which the bomb landed with respect to the target, deviation from ideal release parameters (dive angle, airspeed, and release altitude), and possible corrective actions which might have been implemented. Subjects continued flying training passes until reaching a predetermined criterion level of performance defined as three successive training passes resulting in bombs falling within 65 meters of the target. Once this level of proficiency was attained, the subject was transitioned to a test condition which consisted of a series of six simulated attacks on a second high-detail airfield (China Lake NAS, CA). In this condition subjects were provided with feedback only on their miss distance and miss angle. Each dive angle was both trained and tested before proceeding on to the next dive angle.

Data Analysis

Data from this research effort were initially examined using the SPSSX-MANOVA program resident on the AFHRL/OT VAX 11/780 computer system. In cases where the MANOVA indicated significant results, further examination of the univariate ANOVAs were performed and residuals were looked at using the RUMMAGE statistical package. With the MANOVA procedure, the Wilks F-statistic was used to determine whether a multivariate effect had reached significance. Only comparisons of a priori importance were investigated. These were: (1) comparison of both of the data bases exhibiting no vertical development (the bombing range and the low detail Cannon AFB data base); (2) comparison of the two Cannon data bases to determine the effect of adding the three dimensional cues; and (3) comparison of the bombing range and the high detail Cannon data base.

Data from the experiment were divided into three categories. The first set included the number of practice trails needed by the subject to reach the required minimum level of proficiency. The second set included data relating to the subject's approach profile during the series of test attacks. The final set was composed of the instantaneous parameters from the aircraft at the moment the bomb was released.

A. Training trials:

- (1) Total number of training passes across all dive angles.
- (2) Number of training passes required for 10° proficiency.
- (3) Number of training passes required for 20° proficiency.
- (4) Number of training passes required for 30° proficiency.

B. Approach to the target:

- (1) Mean and standard deviation of roll.
- (2) Mean and standard deviation of pitch error.
- (3) Mean and standard deviation of g's.
- (4) Mean and standard deviation of the horizontal deviation.
- (5) Mean and standard deviation of the altitude deviation.
- (6) Mean and standard deviation of airspeed.

C. Bomb release parameters:

- (1) Roll.
- (2) Pitch error.
- (3) g factor.
- (4) Horizontal deviation from ideal flight path.
- (5) Deviation from ideal bomb release altitude.
- (6) Airspeed.
- (7) Bomb miss distance from the target.

RESULTS

Comparison I: Bombing Range vs Low Detail Cannon

A. Trials Data: No significant effects were noted for any of the training trials metrics.

B. Approach Data: The FOV by dive angle and the data base by dive angle interactions were both significant ($F(24,58)=1.693$, $p=.050$, and $F(24,58)=1.889$, $p=.025$), as was the dive angle effect ($F(24,58)=32.804$, $p<.0005$). For the FOV by dive angle interaction, the univariate F tests showed the effect was in the mean altitude deviation and standard deviation of roll metrics ($F(2, 40)=3.866$, $p=.029$ and $F(2, 40)=3.415$, $p=.049$). Graphic representation of this data is presented in Figures 9 and 10. The data base by dive angle effect lay solely in the mean altitude deviation metric ($F(2,40)=4.354$, $p=.019$). This effect is shown in Figure 11. All metrics for the dive angle effect were significant with the exception of mean airspeed and the standard

deviation of the horizontal flight path deviation (see Table 1).

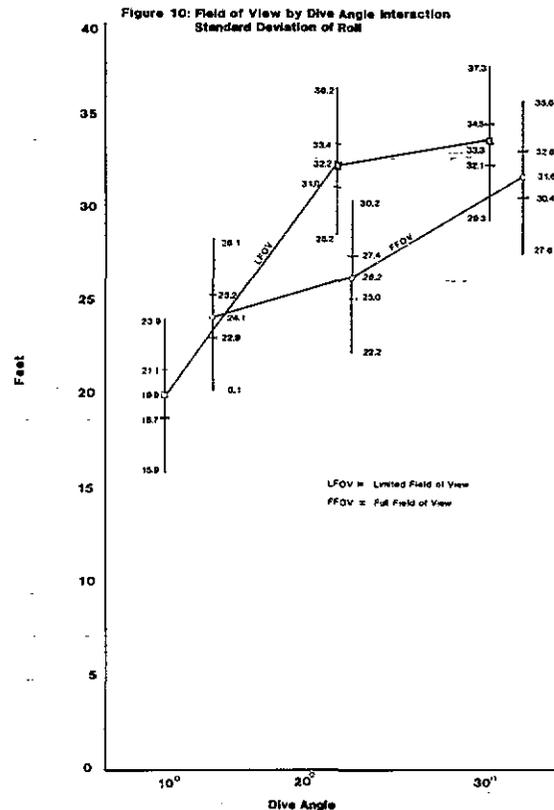
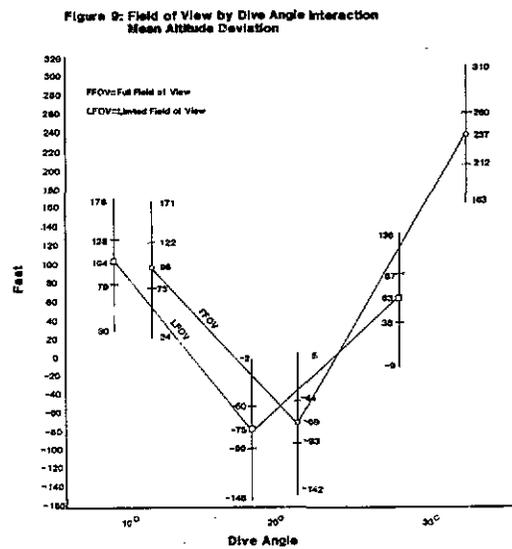
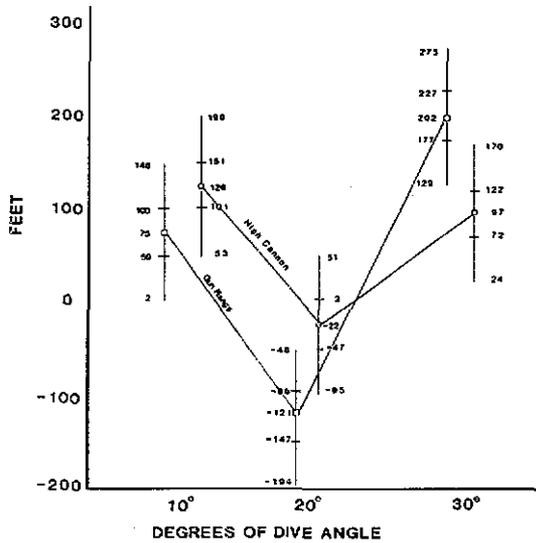


Figure 11: Data base by Dive Angle Interaction, Mean Altitude Deviation



deviation metric ($F(1,20)=6.382, p=.020$ and ($F(1,20)=9.649, p=.006$). Pilots with limited fields of view exhibited an average of 3° of right roll and were almost 420 feet to the left of the ideal ground track at bomb release, while those with full fields of view averaged 2° of left roll and were only 110 feet off track, also to the left. This is summarized in Table 2. The significant metrics for the data base effects were roll ($F(1,20)=7.249, p=.014$), pitch ($F(1,20)=7.753, p=.011$), and horizontal deviation ($F(1,20)=6.536, p=.019$). Pilots trained on the bombing range averaged 2° of left roll, were pitched 1.7° shallower than optimum, and were 144 feet off to the left at bomb release. Pilots trained on the low detail Cannon AFB data base averaged 3° of right roll, $.35^\circ$ of pitch error, and 390 feet of ground tract deviation at this point (see Table 3). For the dive angle effect, all metrics other than roll were significant. Results for this effect are summarized in Table 4.

	LIMITED FOV	FULL FOV
ROLL	-3.1 deg	1.9 deg
HORIZONTAL FLIGHT PATH ERROR	419 ft	109 ft

Table 2: Effect of Field of View on Release parameters

	BOMBING RANGE	LOW DETAIL CANNON
ROLL	2.0 deg	-3.3 deg
PITCH ERROR	1.7 deg	.3 deg
HORIZONTAL FLIGHT PATH ERROR	136 ft	392 ft

Table 3: Effect of Database on Release Parameters

	10°	20°	30°
MEAN ROLL	-7.3 deg	-8.6 deg	-12.0 deg
MEAN PITCH ROLL	.9 deg	6.5 deg	7.8 deg
MEAN G	1.30 G	1.69 G	1.98 G
MEAN HORIZONTAL FLIGHT PATH ERROR	426 ft	361 ft	612 ft
MEAN GLIDE SLOPE ERROR	101 ft	-71 ft	150 ft
STD DEV ROLL	22.0 deg	29.2 deg	32.4
STD DEV PITCH	3.2 deg	8.0 deg	11.4 deg
STD DEV G	1.10 G	1.81 G	2.30
STD DEV ALTITUDE ERROR	128 ft	234 ft	364 ft
STD DEV AIRSPEED	17 kt	17 kt	24 kt

Table 1: Effect of Dive Angle on Approach

	10°	20°	30°
SPEED	450 kts	456 kts	471 kts
PITCH ERROR	-1.0 deg	2.5 deg	1.5 deg
G	.86 G	1.16 G	1.10 G
HORIZONTAL FLIGHT PATH ERROR	-180 ft	220 ft	405 ft
RELEASE ALTITUDE ERROR	-4 ft	224 ft	321 ft
MISS DISTANCE	46 m	65 m	66 m

Table 4: Effect of Dive Angle on Release Parameters

C. Release Data: Analysis of the release data showed significant effects for FOV ($F(7,14)=3.265, p=.028$), data base ($F(7,14)=4.904, p=.006$), and dive angle ($F(14,68)=10.270, p<.0005$). For the FOV effect, the univariate F tests showed the effect was in the roll metric and the horizontal flight path

Comparison II: Low Detail vs High Detail Cannon AFB

A. Trials Data: No significant effects were noted for any of the training trials metrics.

B. Approach Data: Significant effects were found for FOV ($F(12,9)=9.950$, $p=.001$), data base ($F(12,9)=3.388$, $p=.038$), and dive angle ($F(24,60)=18.755$, $p<.0005$). For the FOV effect, the univariate F tests showed the effect was concentrated in the mean roll and mean horizontal deviation from the flight path ($F(1,20)=12.717$, $p=.002$ and $F(1,20)=32.722$, $p<.0005$). For the roll metric, pilots with a limited FOV averaged 1.5° of right roll, while those with full FOV averaged only 6°. For the horizontal deviation metric, limited fields produced an average of 925 feet of error off the ideal path, while full fields resulted in just over 40 feet of deviation (see Table 5). For the data base effect, significance was found on the G metric ($F(1,20)=4.670$, $p=.043$), mean horizontal path deviation ($F(1,20)=10.789$, $p=.038$). For the G metric, it was found that high detail trainees averaged 1.81G, while those trained with low detail averaged 1.55G. On the flight path metric, those trained on the higher detail condition were an average of 230 feet off track, while those trained on low detail were almost 740 feet off. Standard deviation of airspeed for high detail pilots was 22.5 knots, and 18.5 knots for low detail pilots. This is summarized in Table 6. All metrics for the dive angle effect were significant with the exception of mean roll, mean airspeed, and horizontal flight path deviation (See Table 7). Performance decreased as five angle increased.

	LIMITED FOV	FULL FOV
MEAN ROLL	-15.5 deg	-6.0 deg
MEAN HORIZONTAL FLIGHT PATH ERROR	925 ft	41 ft

Table 5: Effect of Field of View on Release Parameters

	LOW DETAIL CANNON	HIGH DETAIL CANNON
G FACTOR	1.55 G	1.81 G
STD DEV AIRSPEED	19 kt	23 kt
MEAN HORIZONTAL FLIGHT PATH ERROR	737 ft	230 ft

Table 6: Effect of Database on Release Parameters

	10°	20°	30°
MEAN PITCH ERROR	1.0 deg	6.5 deg	7.3 deg
MEAN G	1.36 G	1.72 G	1.96 G
MEAN HORIZONTAL FLIGHT PATH ERROR	472 ft	326 ft	652 ft
MEAN GLIDE SLOPE ERROR	89 ft	-61 ft	107 ft
STD DEV ROLL	23.2 deg	30.6 deg	35.0 deg
STD DEV PITCH	3.6 deg	8.0 deg	11.0 deg
STD DEV G	1.14 G	1.87 G	2.31 G
STD DEV ALTITUDE ERROR	153 ft	283 ft	385 ft
STD DEV AIRSPEED	18 kt	20 kt	24 kt

Table 7: Effect of Dive Angle on Approach

C. Release Data: Examination of the instantaneous release point data, showed significant effects for FOV ($F(7,14)=5.156$, $p=.004$), data base ($F(7,14)=2.976$, $p=.039$), and dive angle ($F(14,68)=10.596$, $p<.0005$). For the FOV effect, significance was found for the horizontal flight path deviation metric only ($F(1,20)=27.266$, $p<.0005$), with full fields producing 45 feet of error at release versus 490 feet for the limited field. For the data base effect, the airspeed and horizontal deviation metrics are significant ($F(1,20)=5.035$, $p=.036$ and $F(1,20)=8.722$, $p=.008$). The low detail pilots averaged being 8 knots fast at release and were about 393 feet wide to the left of optimum. High detail pilots were approximately 17 knots fast, but only 140 feet wide. All of the dive angle metrics except roll were significant (See Table 8).

	10°	20°	30°
SPEED	451 kts	463 kts	473 kts
PITCH ERROR	0.7 deg	2.4 deg	1.4 deg
G	.91 G	1.21 G	1.11 G
HORIZONTAL FLIGHT PATH ERROR	-176 ft	-205 ft	-414 ft
RELEASE ALTITUDE ERROR	13 ft	261 ft	491 ft
MISS DISTANCE	50 m	84 m	70 m

Table 8: Effect of Dive Angle on Release Parameters

Comparison III: Bombing Range vs High Detail Cannon AFB

A. Trials Data: Again, none of the training trials data showed significant results.

B. Approach Data: The only significant treatment effect found was for dive angle ($F(24,60)=21.498$, $p=.0005$), with all metrics other than mean roll, mean airspeed, and the standard deviation of horizontal flight path deviation reaching significance (See Table 9). Results in general followed the previously observed pattern of better performance at shallower dive angles.

	10°	20°	30°
MEAN PITCH ERROR	1.3 deg	7.0 deg	7.7 deg
MEAN G	1.43 G	1.87 G	2.06 G
MEAN HORIZONTAL FLIGHT PAT ERROR	219 ft	80 ft	329 ft
MEAN GLIDE SLOPE ERROR	64 ft	-110 ft	160 ft
STD DEV ROLL	22.9 deg	31.3 deg	33.3 deg
STD DEV PITCH	3.9 deg	8.7 deg	12.0 deg
STD DEV G	1.21 G	1.84 G	2.35 G
STD DEV ALTITUDE ERROR	137 ft	256 ft	373 ft
STD DEV AIRSPEED	18 kt	21 kt	25 kt

Table 9: Effect of Dive Angle on Approach

C. Release Data: The FOV by data base interaction and dive angle effects were both found to be significant in this condition ($F(7,14)=3.167$, $p=.031$ and $F(14,68)=7.506$, $p<.0005$). For the FOV by data base interaction, significance was

concentrated in the roll and miss distance metrics ($F(1,20)=15.898, p=.001$ and $F(1,20)=5.365, p=.031$). These interactions are shown in Figures 12 and 13. For the dive angle effect, all of the metrics other than roll and miss distance were significant. These results are summarized in Table 10.

Figure 12: Field of View by Data base Interaction, Roll Metric

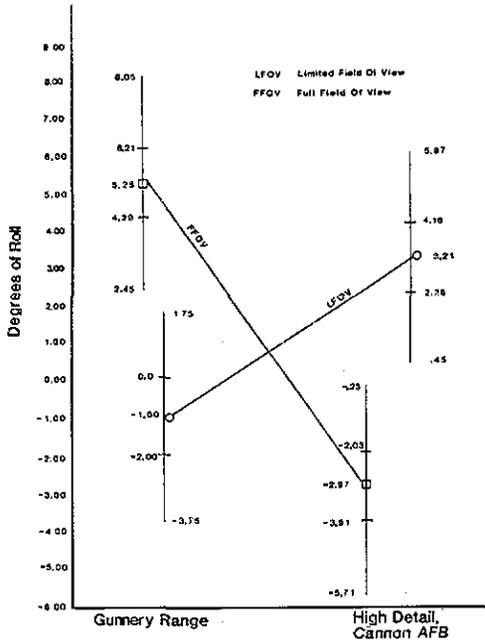
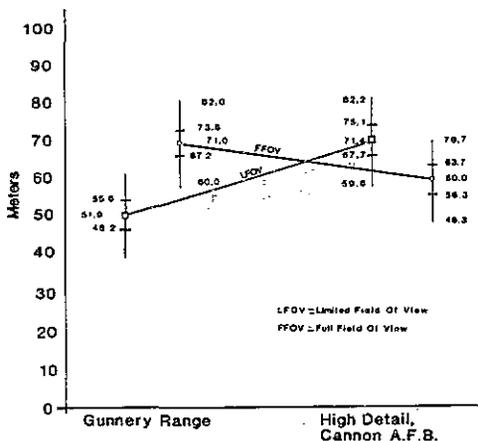


Figure 13 : Field of View by Data base Interaction, Bomb Miss Distance



	10°	20°	30°
SPEED	453 kts	463 kts	474 kts
PITCH ERROR	0.0 deg	3.4 deg	1.7 deg
G	.85 G	1.18 G	1.10 G
HORIZONTAL FLIGHT PATH ERROR	107 ft	62 ft	246 ft
RELEASE ALTITUDE ERROR	-1 ft	287 ft	395 ft
MISS DISTANCE	54 m	65 m	71 m

Table 10: Effect of Dive Angle on Release Parameters

DISCUSSION

This study was conducted to determine the effect of scene content and field-of-view on weapons delivery training. Neither scene content or FOV variables had a significant impact on the number of trials to reach proficiency. The approach data results revealed significant effects and interactions on a number of variables. There was a significant main effect associated with the task factor (10°, 20°, and 30° dive angle tasks) for approach and release data. In general performance was better with shallower dive angles. This can be attributed to the fact that the steeper dive angles are generally considered more difficult because release distances and altitudes are displaced further from the target.

Other significant main effects were noted for FOV and scene content in the approach and release data for - (1) the high versus low detail Cannon AFB comparison and (2) the release data in the bombing range versus low detail Cannon AFB. For FOV, this was reflected in a 10% larger horizontal deviation in the limited FOV condition. We believe that this is due to the difficulty associated with finding the proper roll-out cues, which are not visible at the turn point in the limited FOV condition. For scene content, the high detail airfield (with vertical development) was associated with a 70% decrease in horizontal deviations. The presence of buildings provided more precise cues for judging roll-out and run-in lines. The high detail airfield was also associated with higher g's at pull-out. We believe this effect may be due to the pilots' ability to better detect ground proximity with the addition of vertical development.

The main interaction effects for the approach data were FOV by dive angle and data base by dive angle in the bombing range versus low detail Cannon AFB comparison. The FOV by dive angle effect was concentrated in altitude deviation and roll. These effects are not easily interpreted. This effect did not appear in any of other comparisons and this is the only comparison involving scenes with no vertical development. It is possible that some other difference between the scenes manifest themselves in the absence of vertical cues. The data base by dive angle interaction was due to differences in altitude deviation, but the pattern, although consistent, allows no readily interpretable explanations (refer to Figures 9, 10, and 11).

The other main interaction effect was FOV by dive angle in the release data for the bombing

range versus high detail Cannon AFB comparison. The effect was due to the roll and bomb miss distance variables. Full FOV was associated with significantly more roll deviation for the gunnery range and less for the high detail airfield. We believe this is caused by pilots maneuvering more in an attempt to locate cues in the bombing range. The presence of vertical development in the high detail scene gave the pilot the appropriate cues and degrees of roll deviations decreased.

Even though there were no strong and consistent effects in bomb scores, the overall performance of subjects was better in training conditions that incorporated familiar objects (taxiways, aprons, and runway width) and vertical development. This is seen in the better adherence to the desired flight profile in the test condition for those trained in those conditions. There was also better performance for the full FOV display. This leads us to believe that tasks requiring close adherence to a command flight profile should use full FOV displays and incorporate vertically developed cues. Further testing is planned to validate this recommendation on additional air-to-ground maneuvers for scene content. Other follow-on investigations will include training in air-to-air and formation flight in limited FOV displays and testing in full FOV displays. This will help determine the transfer of training between the various FOV configurations.

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