AMCCMS Code 5567.12.20300.01 Technical Memorandum 20-62

A TECHNIQUE OF INVESTIGATING TANK GUNNER TRACKING ERROR

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September 1962

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ABSTRACT

This study is a report of the ability of tank gunners to track continuously over a period of time, to evaluate the role of experience in reducing error, and to provide a basic measurement technique for future tracking studies. Experienced and novice gunners served as subjects, tracking a target tank through evasive maneuvers around a rectangular course, at various ranges. The results of the study indicate that the instrumentation and procedure designed for this study provide a satisfactory technique of measuring tracking error, that the subject's experience did not affect tracking performance in this problem, and that the measuring technique may be used to evaluate target evasive techniques as well as tracking error.

Technical support was provided by Tank Armaments Branch, Weapons Systems Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground, Md., for this study.

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A TECHNIQUE OF INVESTIGATING TANK GUNNER TRACKING ERROR

INTRODUCTION

The tracking ability of the tank gunner is one of the limiting parameters in the newer weapon systems that use line-of-sight control. For this type of system, meeting the basic accuracy requirement depends on the gunner's ability to track continuously and accurately over a period of time. Therefore, a study was conducted with the following objectives:

a. To develop a technique to measure the tracking error of a representative group of gunners, with a moving tank as target, at three ranges.

b. To determine, through the use of skilled and novice gunners, the role that experience plays in reducing tracking error.

c. To establish a base line for comparative studies.

APPARATUS

Two tanks were used -- one as target, one for measuring tracking (Figs. 1, 2).

SUBJECTS

Eighteen subjects were chosen as follows:

Nine Ft. Meade " novice gunners" from the 3rd Squadron, K Troop, 3rd Cavalry. These men had received training, qualified as gunners, and, with one exception, fired 40 or less rounds as gunners.

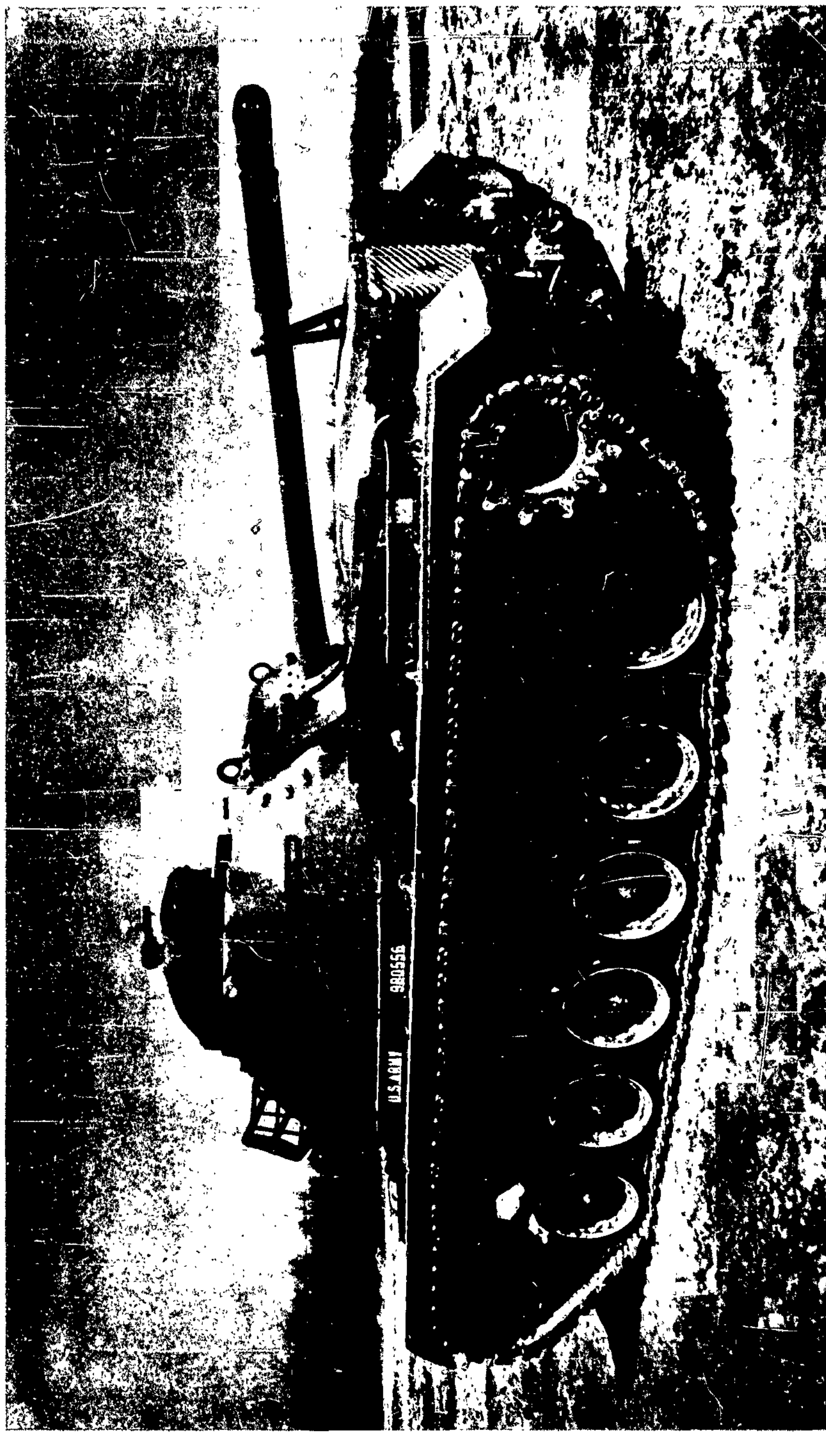

Fig. 1. TARGET TANK

Five Ft. Knox Armor Board master gunners who had fired from 150 to 900 rounds as gunners.

Four Aberdeen Proving Ground civilian gunners who had fired between 800 and 2000 rounds as gunners.

All subjects were given an Ortho-Rater vision test to assure normal visual acuity.

INSTRUMENTATION

Film records of each run were obtained with two 16-mm cameras that were mounted on the gun tube so that the line of sight of the cameras approximately paralleled the longitudinal axis of the gun tube.

The prime instrumentation was a Cine Special camera with a 63-mm Kodak Anastigmat lens, which was positioned $\frac{1}{4}$ inch from the eye lens of a T35 periscope. The lens was set at $-\frac{1}{2}$ diopter. This system was the equivalent of a 15.24-inch focal length lens. The adjustments of the T35 permitted superimposing the reticle on the target to facilitate data reduction.

Experimentation resulted in the following film and camera settings:

a. Tri-X reversal film (ASA 200), developed as negative.

b. G filter (factor of two).

c. Camera operating at 16 frames/second.

d. 1/100-second exposure time.

e. Light value of De Jur 18 (Weston 300).

f. Lens aperture f/19.

Secondary instrumentation consisted of a Cine Special camera with a Raptar "20" telephoto lens. A fiducial system was provided by making four notches in an oval mask, which was positioned behind

Fig. 2. TRACKING TANK

the lens and close to the focal plane. In this case, Plus-X reversal film (ASA 50) was used with 1/50-second exposure time and a lens aperture of f/13.

The mounting of the two recording cameras is shown in Figures 2 and 3.

To establish a reference point for data reduction purposes, an unlit #2 photoflood bulb, painted matte white, was located and securely fastened above the uppermost part of the tank, in the center of the turret ring. Its small size was chosen to avoid disturbing or influencing the gunners during tracking.

A scale factor, whereby image measurements could be converted to object size, was obtained by positioning two unlit #2 photoflood lamps, painted matte white, on the target tank during one of the gunner-camera calibrations. These lamps were 18 feet apart. Later, the lamps were replaced by 15 x 15-inch white cardboards having a 3-inch-wide black cross. These boards provided a better image when the camera was 1744 meters (the maximum range used) from the target tank.

The film was developed in Dektol developer, 1:1 for 4 minutes at 68° F.

The recording cameras, which were spring-operated, were fully wound before each run. At the conclusion of the test, each film run was checked to insure a nominal 16 frames per second. The camera was operated continuously from the time the target tank "moved out" until the tank returned to the start position. This action required approximately 1-½ minutes of operating time.

Camera Calibration Procedure

The gunner positioned his cross hairs on the center of mass or midpoint of the turret of the stationary target tank. After his aiming point had been verified, a calibration picture was made. Then the two markers -- the #2 photoflash bulbs and, later, the 15 x 15-inch white cardboard squares with black crosses -- were positioned 18 feet apart and another calibration picture was made. This procedure indicated a known distance and gave a scalar value for the conversion factor, used later in final data reduction.

Fig. 3. INSTRUMENTATION CAMERAS

Calibration pictures were taken at several times: (a) before and after the familiarization series, and (b) before and after each of the trial runs. This procedure verified that vibration had not loosened the camera during the runs, to prevent errors in film reading that would be caused by a loose camera.

TEST COURSE

The course (Fig. 4) was based on recommendations from the Automotive Division, Development and Proof Services, Aberdeen Proving Ground, Md. Familiarization trials, consisting of crossing runs in both directions on the first leg of the course, were conducted at 3 speeds -- 5 mph, 10 mph, and a high speed (HS) run, which was normally 15 mph. During familiarization, the tracking tank was positioned at two ranges -- 500 and 1744 meters for each gunner -- and canted at an angle between 4° and 5°.

For the familiarization runs, the driver proceeded across the course at the proper speed for the trial concerned, turned at the other side of the course, positioned his tank for the return run and waited for the next command.

After a subject's familiarization runs were completed, the trial runs began. There was one run for each of the three ranges. The target tank traversed the entire course at high speeds.

PROCEDURE

The procedure for the three trial runs was as follows: at the experimenter's order, the gunner offset his aim 20 mils to the rear of the target tank. Then the trial run began. The gunner's time-to-fire was measured.

The target tank accelerated to high speed (approximately 15 mph), which took about 50 meters. The tank maintained this speed across the course -- a distance of 105 meters further. Then it made a 90° left evasive turn toward the tracking tank on a 30-meter radius for

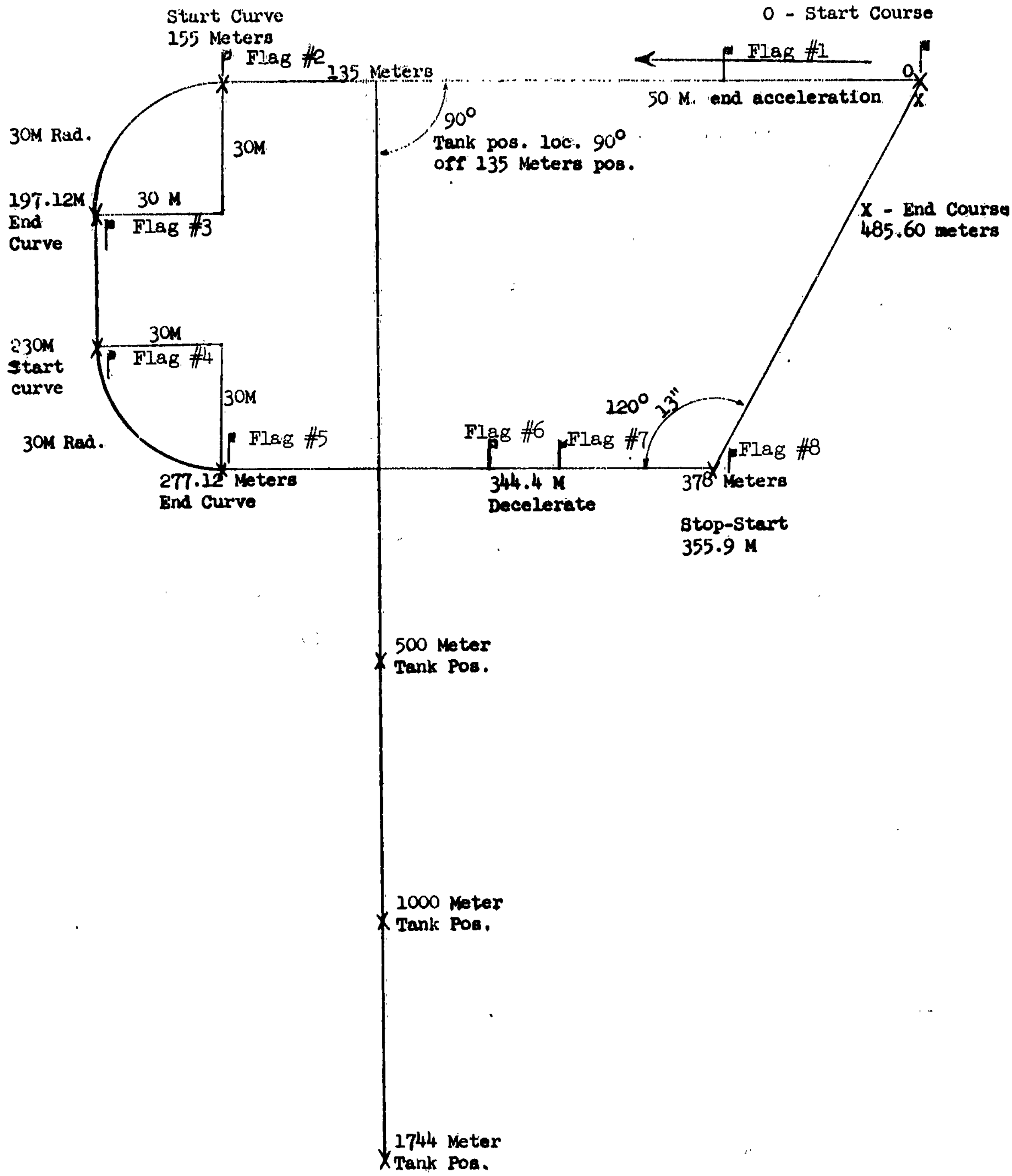

Fig. 4. TRACKING STUDY COURSE LAYOUT

approximately 33 meters, made another 90° left 30-meter radius turn, proceeded back across the course for 67 meters, then decelerated for 12 meters and came to a complete stop. It started again immediately, accelerated for 24 meters, pivot-turned 60° left, and continued for 107 meters to the starting point. The entire run -- 485.6 meters -- took somewhat less than 1-½ minutes in all. The target course and segment description are shown in Figure 4 and Table 1.

Run times for both familiarization and trial runs were recorded by two men who were halfway across the course at a point between the parallel runs of the standard course (Fig. 4).

EXPERIMENTAL DESIGN

The experimental design was as follows:

a. Familiarization Runs

(5, 10, 15 mph trials, with target crossing. Time-to-fire from a 20-mil traverse, 10-mil elevation standoff was recorded). These trials were run out 500 and 1744 meters.

b. Trial Runs

(1) The order of presentation of the ranges was counterbalanced.

(2) Flag markers were placed at the beginning of each discrete segment to facilitate data reduction.

(3) Times were recorded for each segment, to facilitate data reduction.

TABLE 1

Target Tank Action for Each Segment

Segment	Action of Target Tank	End of Segment
1	Straight line acceleration to high speed, constant velocity, perpendicular to tracker's line of sight, right to left.	Tank passes flag #1.
2	Constant velocity.	Tank passes flag #2.
3	90° evasive turn at constant speed toward tracker.	Tank passes flag #3.
4	Constant velocity.	Tank passes flag #4.
5	90° (to tracker's right) evasive turn at constant speed and constant velocity.	Tank passes flag #6.
6	Deceleration.	Tank passes near flag #7.
7	Full stop.	Tank begins to move.
8	Acceleration to high speed, constant speed and 60° left turn.	End of test run.

RESULTS

Raw data consisted of the mean and standard deviation (SD) of the azimuth and elevation tracking error over each segment for each subject*. Statistical analysis was based on the product of the SDs for azimuth and elevation, rather than on the mean values.**

Statistical design was a 2 x 3 x 8 (experience x range x segments) factorial analysis of variance in which, assuming that the 18 subjects were randomly selected from the population of all tank gunners, subject differences were controlled for all factors and interactions except for the main effect of experience (2).

Results were evaluated as either significant at or beyond .01 level or not significant as follows (Table 2):

a. There was no significant difference between the mean performance of the experienced vs. non-experienced trackers.

b. All interaction effects, except the range x segment effect were not significant.

c. There were differences, significant at the $P < .01$ level among the means of the segments (Table 3) and among the means of the ranges (Table 4).

The mean error of the subjects, averaged over experience and segments, was highest for range one (500 yards) and lowest for range three (1744 yards). But the difference in performance between range two (1000 yards) and range three was not significant.

*To obtain an estimate of error introduced into the data by the film reader, one run was reduced by two readers, three groups of 20 frames were chosen at random, and a standard deviation of the differences was determined. The results were as follows:

Group	Horizontal SD	Vertical SD
1	.05	.09
2	.05	.10
3	.07	.09

This indicates, in terms of SD, that the error introduced by the data-reduction process would be less than 0.1 mil for the majority of individual measurements. (But note that, if $\sigma = .10$, 5 percent of the differences will be greater than $\pm .20$, and so on.)

**See Appendices A and B.

TABLE 2

Summary of Analysis of Variance

	Source of Variation	Sum of Squares	d.f.	Mean Square	F
R	Range	5.9120	2	2.956	418.9*
S	Segments	2.0655	7	0.295	12.3*
E	Experience	.0475	1	0.048	0.4
RxE	Range x experience	.0079	2	0.004	0.6
RxS	Range x segments	1.7692	14	0.126	4.1*
ExS	Experience x segments	0.1155	7	0.017	0.6
RxExS	Range x experience x segments	0.1436	14	0.036	0.3
Error,	R, RxE	0.2258	32	0.007	--
	S, SxE	2.6921	112	0.024	--
	RxS, RxSxE	6.9826	224	0.031	--
	E, G	1.9438	16	.121	--
	TOTAL	21.9055	431		
	G Subjects	1.9913	17	.117	0.9

Where $SS_G = SS_E + SS$ error (E, G)

*Significant at or beyond the .01 level.

TABLE 3

Multiple Comparisons -- Segments

a. Mean Performance (in square mils)

Range Segment	1	2	3	4	5	6	7	8
500	.14	.24	.16	.32	.54	.41	.16	.52
Average 1000-1744	.13	.09	.0[illegible]	.10	.15	.13	.02	.14
Average 500-1000-1744	.13	.14	.22	.17	.28	.23	.07	.27

b. Theoretically-Significant Mean Differences (P = .05)

Range/Difference in Segment Rank	1	2	3	4	5	6	7
500	.17	.18	.18	.19	.19	.20	.20
Average 1000-1744	.04	.04	.05	.05	.05	.05	.05
Average 500-1000-1744	.06	.06	.06	.06	.07	.07	.07

c. Ranking of Segments and Significance of Rank* (P = .05)

Range/	Increasing Error							
500	1	7	2	4	6	3	8	5
Average 1000-1744	7	2	3	4	1	6	8	5
Average 500-1000-1744	7	1	2	4	3	6	8	5

*Any two segments not enclosed by the same bracket are significantly different.

TABLE 4

Multiple Comparisons -- Range

(Reference 1, pg. 136-140)

Ranges	Mean Difference
500 and 1000	.245*
1000 and 1744	.007
500 and 1744	.251*

*Significant at or beyond the .01 level.

Finding a significant interaction between range and segments complicates the interpretation of performance by segments. It was possible to rank the segment means (averaged over experience levels) for each range separately and for an average of the ranges. The rank order of the segments was different for each range, and for the average of all ranges, which indicates that the interaction of range and segments influenced the subjects' performance.

In evaluating the ranks of the segment means, it should be noted that not all the differences between means (for a given range) are statistically significant, e.g., for range one, segments 1, 2, 4, and 7 do not differ significantly from each other; neither do 2, 4, and 6, nor 3, 5, 6, and 8.

The Kendall coefficient of concordance, $\underline{W}$, provides an index of how consistently segments maintained their relative difficulties for each subject. The segments could easily be arranged into order of difficulty for each subject. Ordinary correlation techniques, such as rho, could have been used to find the relationship between these rank-orders for any two subjects; however, such a treatment would be tedious because of the many possible pairs that could be drawn from a pool of 18 subjects -- some 153, in all. Kendall's ($\underline{W}$) approximates the average of these 153 possible correlation coefficients (3). Table 5 gives the concordance coefficients which were obtained. Those for the three ranges are low, but significantly positive (.436, .339, and .442). The coefficient of concordance for all three ranges together was considerably larger (.630). These findings indicate that the segments do tend to have the same relative difficulties at the three ranges for all 18 subjects.

TABLE 5

Consistency of Segment Difficulties for the 18 Subjects, as Evaluated with Kendall Coefficients of Concordance (W)

Range	W
500 yards	.436
1000 yards	.339
1744 yards	.442
All	.630

Figure 5 shows the relationship between range and segment difficulty. If there were no interaction, the curves for the three ranges would be parallel.

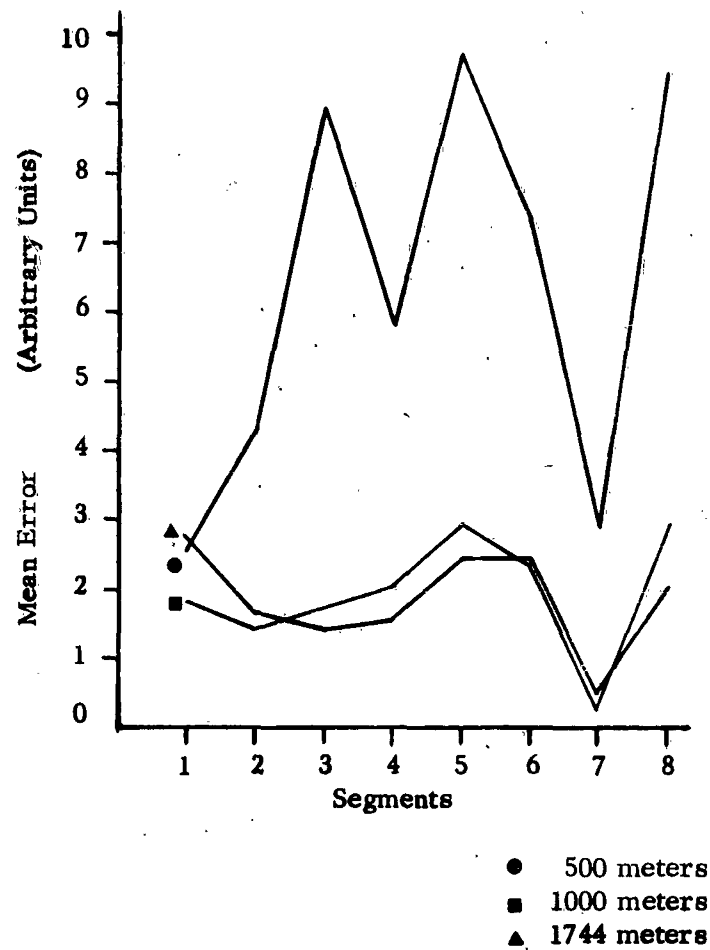

Fig. 5. TRACKING PERFORMANCE BY SEGMENTS

DISCUSSION

In tracking a target, the azimuth and elevation corrections that a subject applied to the tracking device were not independent. When a gunner followed the target up a slope, for instance, the tracking pattern was rarely a smooth curve, but, rather, a series of step-like horizontal and vertical adjustments. When the target tank executed evasive maneuvers in a horizontal plane (i.e., over level terrain), it became more difficult to make the necessary elevation adjustments. In short, the elevation and azimuth tracking problems -- which are distinct operations in theory -- are found to depend on each other in practice. In this study the product-moment correlation of azimuth and elevation error was 0.51, significantly substantiating the above contentions.

For the purposes of data reduction, error was recorded as horizontal and vertical deviations of the tracker's periscope reticle from the reference target fixed to the target tank. The mean of these deviations for each segment provides no useful information about the quality of tracking performance, for this quantity represents a fixed bias which can be corrected through instrument or subject adjustment. The scatter of the tracking performance, given by the variance of these deviations, is the measure that was considered most meaningful for analysis.

The statistic used in the analysis was the product of the SDs of the azimuth and elevation deviations. It indicates the area of a hypothetical error rectangle within which a fixed percentage of tracking time for each segment was spent. The units of this statistic are square mils, which can be converted to square inches at the various ranges.

The subjects were divided into two groups, according to previous experience as gunners -- masters and novices. The novice gunners had been trained and qualified as tank gunners and represented the normal user tank gunner in experience. They generally had fired 40 or less rounds in training. The master gunners had many years of experience as gunners and represented the experienced experimental and proof test gunners. They had fired from 150 to 2000 rounds. Under the conditions of this experiment, there was no significant difference between the average performance of the masters and that of the novices. The practice trials given before the experiment began may have trained both groups to the same level of performance, although the available data do not prove that they necessarily did. If not, then one can only infer that the groups did not differ in tracking ability when the study began. Or both could have been true -- practice trials may have tended to equate the groups, at least roughly, and experience may not have differentiated them.

A multiple-range statistical test (1) was used to compare segment means. Not all of the differences between segment performance differ significantly; thus the segments can be arranged into groups with statistically equivalent performance, which presumably would have the same tracking difficulty. For the 500-yard range, there were two such groups: segments 7, 1, 2, 4 and segments 6, 3, 8, 5.

In summary, the target tank's maneuvers in these segments were as follows:

a. Segments 7, 1, 2, 4:

7 -- Tank stopped (a motionless target is the easiest to hit!).

1 and 2 -- Constant velocity from right to left.

4 -- Constant velocity toward tracker.

b. Segments 6, 3, 8, 5:

6 -- Deceleration left to right.

3 and 5 -- Evasive turn.

8 -- Acceleration left to right, and left evasive turn.

None of the members of a group are statistically differentiable from the other members of the same group (i.e., the rankings 7, 1, 2, 4, -- or 1, 4, 2, 7 -- or 7, 2, 4, 1, etc. -- would be equally probable, on the basis of chance, if the study were repeated),but the groups themselves can be ranked reliably. This statistical order of segments agrees with intuitive estimates of difficulty: accelerations and turns seem more difficult to track than constant-velocity movement, etc.

The segments could have been grouped, as above, for each range, but the results would be confusing because of chance variations from one range to another. Since over-all performance for the 1000- and 1744-yard ranges did not differ significantly, the segment grouping was obtained for the average of these two ranges.

Table 3 shows how the difference in performance by segment decreases at greater ranges.

To track successfully at the closer ranges, a gunner must change his tracking rate more than he would have to at 1000 or 1744 meters.

The only segment which led to performance that was significantly different from all the other segments was segment 7, in which the target stopped. This finding may suggest a maneuver to avoid when executing evasive action against distant gunners.

Using the significance information from the multiple ranking of the segment means, it is possible to make an over-all appraisal of tracking performance for statistically-determined groups of segments.

Since the comparison of experienced and inexperienced trackers showed no significant difference in performance, it is not surprising that there were no significant interaction effects between range or segments and experience levels.

SUMMARY OF RESULTS

1. A satisfactory technique for measuring gunner-induced tracking error under simulated field conditions has been demonstrated.

2. There was no significant difference between mean performance of the master and novice gunners.

3. For the main effects, both the means of the ranges and the means of the segments differed significantly.

4. The interaction between ranges and segments was statistically significant with $p > .01$.

5. For the 500-meter range, the average of the 1000- and 1744-meter ranges, and for the average of all three, statistically-equivalent segment means were obtained, as a basis for grouping the segments into two or three sets of equivalent difficulty. Then the groups were ranked by the relative difficulty of each group.

6. The combined azimuth and elevation error, represented by an <u>area of tracking deviations</u>, falls within 8100 sq. in. ($7\frac{1}{2}' \times 7\frac{1}{2}'$) more than 99 percent of the time for all groups of segments at all ranges, except for the group of segments with the poorest scores in the third range (57 percent).

REFERENCES

1. Edwards, A. L. Experimental Design in Psychological Research, New York: Holt, 1960, pp. 136-140.

2. Lindguist, E. F. Design and Analysis of Experiments in Psychology and Education, Boston: Houghton Miffin, 1956, pp. 292-297.

3. Siegel, S. Nonparametric Statistics for the Behavioral Sciences, New York: McGraw-Hill, 1956, pp. 229-239.

APPENDIX A

GUNNER INDUCED TRACKING ERROR

Development and Proof Services

Analytical Laboratory Report 61-AL-118

16 October 1961

Analytical Laboratory Report 61-AL-118
16 October 1961

Title: Gunner Induced Tracking Error

OMS No.: 5510.11.26700

Prepared For: Human Engineering Laboratory

INTRODUCTION

A study was conducted to investigate the ability of tank gunners to track a moving target. Provision was made in the test so that it would also be possible to appraise the effect of training on the performance of the gunners. For this purpose, two groups of gunners were used in the study, one group, identified as "Experienced", consisted of 10 master gunners, and the other group, identified as "Inexperienced", made up of 9 men who had received gunnery training at either Ft. Meade or Ft. Knox.

This report presents measurements of "tracking error", or deviation from the intended point of aim, for all 19 of the gunners attempting to track a target tank traveling over a perscribed course in which it performed a number of typical maneuvers, at ranges of 500, 1000 and 1744 meters. The following sections of the report contain discussions of the test procedure, instrumentation used to acquire data, reduction procedures and estimated errors attributed to film reading, and other related aspects of this test. The gunners' ability to track and the effect of training on this ability are not analyzed in this report.

INSTRUMENTATION

Film records of each run were obtained from two 16-mm cameras that were mounted on the gun tube such that the line of sight of the cameras approximately paralleled the longitudinal axis of the gun tube. One camera with a 3-inch lens was used in conjunction with an M35 gunner's periscope, so that the resultant focal length of the combined system was approximately 15 inches. The other camera was equipped with a 20-inch lens and a fiducial mask.

A reference target for film reading purposes was mounted on the target tank directly above the center of the turret ring. The reference point was a light bulb, not lit but painted yellow to provide contrast with the background. The purpose of this reference point was to minimize the errors of data reduction. Figure 1 illustrates the relationship between the reference target and the point of aim, as determined from calibration records.

TEST PROCEDURE

The gunners' tank was positioned with approximately 5 degrees cant at the selected distance, either 500, 1000 or 1744 meters from the course. Prior to starting of each run, the gunner was instructed to lay his sight on the center of the turret ring of the target tank. A calibration record was then made to provide a reference for determination of lay deviation during the test run.

Figure 1 illustrates the position of the reference target, gunner's sight, and the reticle in the M35 gunner's periscope during a typical calibration photograph.

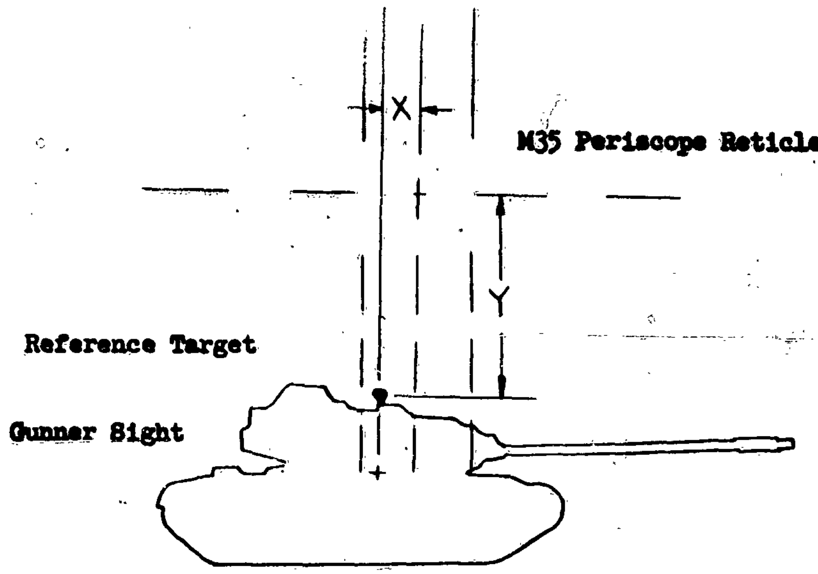

Figure 1. Calibration Schematic

The course followed by the target vehicle is shown in Figure 2. The table following Figure 2 presents the tracking condition during each segment of the run.

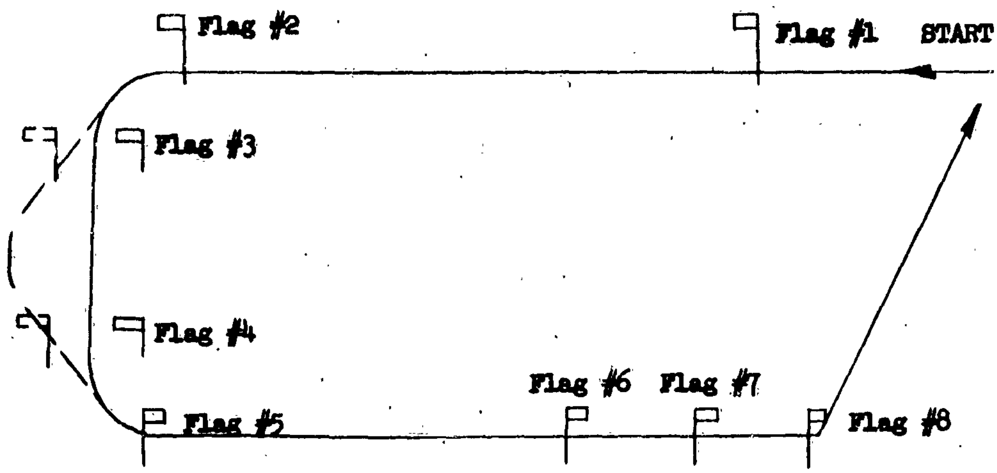

Figure 2. Target Course and Tracking Condition

Segment	Target Tank Attitude	End of Segment
0	Acceleration	Gunner acquires target
1	Acceleration	Tank passes Flag #1
2	Constant Velocity	Tank passes Flag #2
3	Evasive Turn	Tank passes Flag #3
4	Constant Velocity	Tank passes Flag #4
5	Evasive Turn and Constant Velocity	Tank passes Flag #6
6	Deceleration	Tank stops near Flag #7
7	Stopped	Tank begins to move
8	Constant Velocity	End of test run

The solid line indicates the course followed by the target tank for the earlier runs. After the track became deeply rutted, the tank had difficulty making the two 90° turns, and changed to the course shown by the broken line.

Based on records obtained during preliminary tests, it had been determined that a fixed point should be provided on the tank for use during reading of the film records. The reference which was actually used during the test runs was a small target, previously discussed under Instrumentation, placed on top of the turret (see Figure 1). The calibration record provided a means of relating the gunners' point of aim to the position of the reference target, so that film readings made from the dynamic test records could be translated to the gunners' point of aim. The reticle in the M35 gunners' periscope, which also appeared on the film records, was used to relate the above two points.

After calibration and before starting each run, the gunner laid the gun approximately 20 mils off his point of aim, to the rear of the target tank.

The "X" and "Y" dimensions shown in Figure 1 are the position of the reference target with respect to the center of the periscope reticle of the M35 gunner periscope. The procedure followed in making film readings provided changes in X and Y values from the initial offset, i.e., the calibration values were subtracted from the values obtained by reading each film frame, and the difference presented as the gunners' "error". Negative values for the horizontal readings (X) indicate the reticle was toward the starting pole side, or end, of the calibration "point-of-aim" on the tank. Values for the vertical deflection are shown positive when the reticle was above the calibration value.

The identification code for each test run was composed in the following manner, using the code number 2001110 as an example:

20 01 1 1 0

20	Day of month (April 1961) of test run
01	Gunners identification number
1	Indicates master (No. 1) or graduate (No. 0) gunner
1	Range of test run - 1 denotes 500 m 2 denotes 1000 m, and 3 denotes 1744 m
0	Indicates segment number during each run

For any one run, only the last digit should change as the target tank proceeds from one segment to the next.

RESULTS

Inclosure 1 consists of a table of segment starting times, made up from the field data sheets, which show stop watch times for the course segments.

Data obtained from the reduction of film records are presented in Inclosure IV as follows:

1. Tables of adjusted values which accompany frame-by-frame data are contained in Table II of Inclosure 2.

2. Statistical summaries of vertical and horizontal tracking error by course segment are contained in Tables I and II of Inclosure 3.

3. Frame-by-frame horizontal and vertical deviations:
   a. IBM cards
   b. Listing from IBM cards
   c. Plots of error vs time by segment of the course.

DISCUSSION OF RESULTS

Two methods were used to determine the end of the zero segment. When a blank frame appeared during the acceleration phase, this indicated the gunner had "fired" his weapon believing that he was on target. This condition appeared on five test runs, (2505110, 2508020, 2711120, 2514030, and 2415120). However, in the absence of this frame, the zero segment was considered ended at the time when the gunner caught up to the tank and was laid to the same point on the tank as during calibration. To determine the ends of the other segments, the stop watch readings in the field, taken by an observer as the tank passed the various flags, were correlated to the film speed of the camera. Zero frame number (zero time) was located for all test runs by working back from the time segment number 1 ended, as noted by the field observer. The number of frames that had elapsed between the start of the test run and the end of segment number 1 were obtained from the framing rate of the camera (0.065 seconds/frame), and the zero time frame identified.

A number of obvious outliers were found in the data. On the charts of deflection error vs time, Inclosure 4, an outlier appears as an erratic datum point in an otherwise smooth record. (See Figure 3)

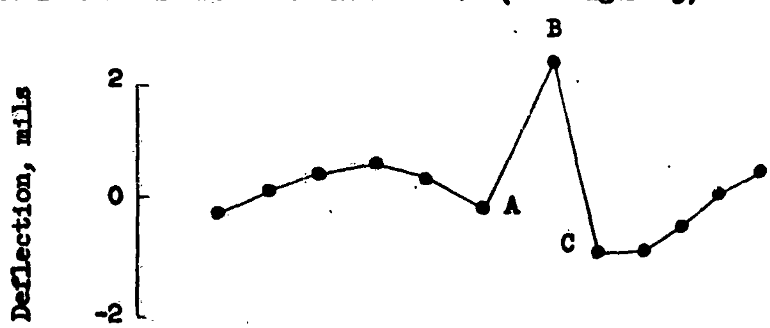

Figure 3. Illustration of Outliers on Charts, Inclosure 4

It is believed that these outliers resulted from difficulties in reading film records, such as poor resolution, heat shimmers, dust, etc. Though these were relatively few in number (representing less than 1 in 200 frames), it was worthwhile to provide adjusted readings for these outliers, such as "B" above, by linear interpolation between points "A" and "C". These adjusted values are presented in the tables of adjusted values in Inclosure 2.

The reference target was difficult to observe during the early test runs because of dust clouds raised by the tank as it moved along the course. This was particularly true after the vehicle passed flag number 2 and turned toward the gunner. For these runs, in the portions where no measurements were possible for two or more consecutive frames, the gunners' tracking errors were plotted with zero values in order to keep the continuity of the traces.

To obtain an estimate of error introduced into the data by the film reader, one run (2616020) was reduced by two readers. Three groups of 20 frames were chosen at random and a standard deviation of the differences was determined.

The results are presented as follows:

Group	Horizontal, mils	Vertical, mils
1	0.05	0.09
2	0.05	0.10
3	0.07	0.09

This indicates, in terms of standard deviation, that the error introduced by the data reduction process would be much less than 0.1 mil for an individual measurement.

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Chart 1. Starting Time for Each Segment of the Gunner Induced Tracking Error for the Shillelagh Weapon System

Gunner	Range	Code No.	Segment 0	1	2	3	4	5	6	7	8	END
1	500	2001110	0.0	5.9	8.7	24.2	30.2	35.2	49.4	51.9	54.4	76.7
	1000	2001120	0.3	2.7	9.6	24.4	31.6	36.2	49.4	51.8	54.2	74.8
	1744	2001130	0.6	3.0	9.2	24.7	29.8	35.0	53.1	58.0	62.8	82.7
2	500	2702010	2.3	8.5	9.1	26.1	33.2	39.1	54.1	56.6	59.0	75.6
	1000	2702020	1.8	5.1	9.2	24.7	32.4	40.1	50.3	57.6	65.9	75.3
	1744	2702030	a	0.1	9.1	24.6	34.3	39.4	54.9	57.3	61.9	79.7
3	500	2003110	1.2	3.2	9.9	24.5	30.1	36.6	49.2	51.7	55.3	74.1
	1000	2103120	1.0	3.5	8.6	24.1	29.1	34.2	51.0	53.4	58.5	78.9
	1744	2103130	3.8	5.1	9.0	26.1	30.7	35.0	53.1	57.5	61.9	83.6
4	500	2704010	0.0	8.3	9.1	24.5	34.2	40.2	52.4	54.9	57.3	74.1
	1000	2704020	0.0	5.1	9.2	24.7	32.4	45.3	58.1	60.6	63.1	83.1
	1744	2704030	0.7	5.9	10.3	25.7	33.4	40.4	55.9	58.5	61.0	85.4
5	500	2105110	1.4	7.9	9.1	24.3	30.8	35.9	49.9	52.4	56.6	77.4
	1000	2205120	2.2	6.5	9.0	25.1	31.2	36.2	51.6	56.0	58.5	77.2
	1744	2205130	2.0	4.4	8.2	23.5	31.2	35.9	48.8	51.2	56.0	73.9
6	500	2206010	3.3	5.6	9.1	24.2	29.9	35.0	49.3	51.8	56.4	75.2
	1000	2206020	0.3	2.7	7.7	24.3	29.4	34.5	49.9	52.4	57.5	74.4
	1744	2206030	0.4	2.6	7.7	25.5	30.6	35.2	48.1	53.1	58.0	77.9
7	500	2207110	0.0	3.8	9.1	26.8	36.2	38.6	46.3	56.6	60.3	80.9
	1000	2207120	0.5	3.8	8.8	26.9	32.0	39.7	57.7	60.2	62.7	83.0
	1744	2207130	2.0	4.4	10.7	28.7	36.4	41.5	59.6	63.7	66.2	86.0
8	500	2208010	1.0	3.3	9.0	25.5	33.1	38.0	53.1	54.4	58.2	78.5
	1000	2608020	3.0	6.4	11.2	29.3	36.9	42.0	57.3	59.8	62.3	82.6
	1744	2608030	3.5	6.0	10.1	25.5	35.8	42.1	54.9	57.3	59.8	78.5
9	500	2209110	0.7	4.9	9.0	26.6	33.0	44.6	57.6	60.1	62.7	82.4
	1000	2309120	0.6	2.9	7.9	22.2	29.9	35.0	47.6	49.9	52.4	70.2
	1744	2209130	2.5	4.2	9.1	27.2	34.1	39.1	56.8	59.3	61.8	81.0

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Gunner	Range	Code No.	Segment 0	1	2	3	4	5	6	7	8	END
10	500	2310010	1.4	3.9	9.0	23.3	31.0	34.9	50.4	52.9	56.8	72.6
	1000	2310020	1.3	3.0	8.8	23.8	28.9	33.9	51.2	53.7	56.2	74.0
	1744	2310030	1.4	6.5	9.0	24.2	31.2	35.1	53.2	57.6	60.1	78.0
11	500	2311110	3.4	4.2	9.0	23.3	34.9	40.1	50.4	52.9	55.5	74.9
	1000	2711120	0.0	1.2	8.2	24.3	30.2	37.2	52.0	54.2	56.3	73.0
	1744	2711130	0.1	3.3	9.1	25.9	33.2	45.5	59.4	61.4	63.2	70.7
12	500	2312010	0.6	3.2	8.1	23.1	29.6	34.7	50.3	52.8	56.6	74.8
	1000	2312020	0.9	3.4	8.2	22.2	29.9	34.2	47.1	49.5	53.4	69.3
	1744	2312030	0.5	1.6	8.2	23.7	30.2	35.1	53.1	55.5	59.9	79.2
13	500	2513110	0.0	8.6	9.9	25.4	28.0	37.0	51.2	53.8	56.3	72.6
	1000	2513120	a	0.0	8.2	24.4	30.2	36.2	52.7	54.5	57.0	77.5
	1744	2513130	a	0.4	9.1	24.6	31.2	36.2	51.6	54.1	59.2	78.4
14	500	2514010	0.1	1.7	10.1	26.7	33.1	38.2	55.1	57.6	60.1	80.5
	1000	2514020	1.2	3.5	9.9	27.5	35.0	40.1	55.9	58.4	61.7	80.9
	1744	2414030	0.8	7.3	9.0	25.9	32.3	36.2	53.0	55.5	58.1	77.0
15	500	2515110	0.1	2.5	9.0	24.3	31.1	36.1	50.8	53.4	55.9	74.0
	1000	2415120	0.1	2.9	7.8	23.3	31.1	34.9	49.2	51.7	54.2	74.7
	1744	2515130	0.5	3.9	9.0	24.8	31.1	37.1	51.8	54.7	57.9	77.5
16	500	2716010	0.0	3.9	9.0	27.0	35.0	41.1	55.3	61.6	67.9	75.6
	1000	2616020	2.1	3.9	10.1	26.9	34.7	43.0	55.9	59.8	61.8	82.4
	1744	2616030	0.1	0.5	10.1	29.5	36.0	42.4	60.1	62.6	66.3	85.0
17	500	2617110	0.5	2.0	10.1	27.7	36.1	42.1	56.1	59.1	64.1	78.7
	1000	2617120	0.3	2.8	10.1	30.1	36.1	42.1	60.1	63.1	67.1	84.8
	1744	2617130	0.4	5.1	10.1	29.1	35.0	40.1	58.1	61.1	66.1	76.6
18	500	2718010	0.1	5.8	8.1	26.1	32.1	37.1	51.6	53.7	58.9	71.3
	1000	2618020	1.6	6.7	11.1	28.7	36.1	42.1	60.3	63.3	68.7	82.8
	1744	2618030	a	3.3	10.1	28.1	36.1	42.1	57.2	59.4	65.3	80.8

Incl 1

Gunner	Range	Code No.	Segment 0	1	2	3	4	5	6	7	8	END
19	500	2619110	0.0	0.7	7.8	24.2	31.9	37.1	51.1	54.0	57.5	71.8
	[b]1000	2619120	2.0	3.5	11.1	26.8	36.1	42.1	56.4	57.5	59.9	75.6
	[c]1744	2719130	4.4	5.4	10.1	20.4	24.3	26.8	37.1	39.7	40.9	54.3

[a]Camera was not operating during the zero segment.
[b]Starting time of each segment was determined from the film record by assuming the constant framing rate (.065 sec/frame) that was used throughout the complete test.
[c]Starting time of each segment was determined by correlating the stop watch time with the frame number on the film. For this one run, the camera apparently operated at a slower framing rate (.098 sec/frame).

Chart 2. Table of Adjusted Values

Gunner	Code No.	Frame No.	Time	Deflection, mil Hor	Vert
1	2001111	98	6.371	0.7084	-0.2376
	2001111	130	8.452	0.6479	-
	2001120	-	-	-	-
	2101132	172	11.18	-	0.0540
	2101132	324	20.935	-0.4255	-
	2101132	328	21.196	-0.3606	-
	2101133	416	27.047	0.5831	-
	2101134	478	31.078	-	0.0044
	2101134	494	32.119	-	-0.1619
2	2702010	-	-	-	-
	2702023	442	28.738	-	0.0583
	2702024	582	37.840	-	0.5852
	2702025	618	40.181	-0.4492	-0.0583
	2702026	774	50.324	-	0.3282
	2702028	934	60.727	-0.4902	-0.4514
	2702028	1068	69.440	-	0.2699
	2702028	1088	70.740	-	0.1079
	2702032	220	14.30	0.0496	-0.0344
3	2003112	273	19.310	0.7321	-0.4319
	2003115	731	47.139	-0.2764	-
	2103120	40	2.600	-3.7907	-0.2807
	2103121	68	4.421	-	-0.1252
	2103121	92	5.981	-	-0.5896
	2103122	364	28.738	0.2246	-0.1684
	2103125	644	41.872	0.2742	-
	2103131	114	7.412	-0.1382	-0.3498
	2103133	416	27.047	-0.3650	-
	2103138	1050	68.270	-0.2656	-
	2103138	1176	76.462	0.2807	0.0755

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Chart 2. Table of Adjusted Values
(Continued)

Gunner	Code No.	Frame No.	Time	Deflection, mil Hor	Deflection, mil Vert
4	2704013	418	27.177	-1.0324	-0.8488
	2704015	658	42.782	-	-0.8596
	2704015	660	42.912	-	-0.8423
	2704020	-	-	-	-
	2704030	-	-	-	-
5	2105110	-	-	-	-
	2205120	-	-	-	-
	2205130	-	-	-	-
6	2206010	56	3.641	-8.5254	-
	2206011	124	8.062	3.4322	-
	2206013	394	25.617	-	0.1468
	2206020	-	-	-	-
	2206032	426	27.568	-	0.0302
7	2207118	1046	68.010	-2.6934	-0.8272
	2207123	482	31.338	-	-0.0771
	2207128	984	63.979	-	0.0734
	2207130	-	-	-	-
8	2208010	-	-	-	-
	2608021	98	6.371	0.1360	-
	2608021	100	6.501	-	-0.4341
	2608025	838	54.485	0.4708	0.4644

Incl 2

Chart 2. Table of Adjusted Values
(Continued)

Gunner	Code No.	Frame No.	Time	Deflection, mil Hor	Vert
8	2608032	330	21.456	-	0.2678
		332	21.586	-	0.3326
		334	21.716	-	0.3758
		336	21.846	-	0.4234
		338	21.976	-	0.3715
		340	22.106	-	0.2938
		342	22.236	-	0.2419
		344	22.366	-	0.1166
		346	22.496	-	0.0518
		348	22.626	-	-0.0090
		350	22.756	-	-0.0994
		352	22.886	-	-0.1426
		354	23.016	-	-0.1642
9	2209110	-	-	-	-
	2309121	46	2.990	0.3887	-
	2309122	152	9.882	0.3693	-
	2309123	346	22.496	0.2483	-
	2309123	362	23.536	-	-0.4297
	2309123	422	27.437	-1.1468	-0.2548
	2309123	434	28.218	-	-0.0697
	2309128	1066	69.310	-	0.2418
	2209130	-	--	-	-
10	2310010	-	-	-	-
	2310020	-	-	-	-
	2310038	1194	77.632	0.8700	0.2625
	2310038	1200	78.023	-0.6500	0.3250
11	2711110	12	0.780	5.0000	0.6900
	2711112	218	14.173	0.9634	-0.2765
	2711124	466	30.298	-0.8510	-0.0173
	2711124	532	34.590	-0.5250	-0.0325
	2711130	-	-	-	-

Chart 2. Table of Adjusted Values
(Continued)

Gunner	Code No.	Frame No.	Time	Deflection, mil Hor	Vert
12	2312010	29	1.885	3.5661	-0.0604
	2312013	397	25.812	2.0218	-
	2312013	398	25.877	2.2724	-
	2312013	399	25.942	2.5230	-
	2312020	-	-	-	-
	2312032	286	18.595	0.0367	0.2829
	2312032	356	23.146	-0.3434	-
13	2513112	233	15.149	0.3555	0.1830
	2513120	-	-	-	-
	2513132	226	14.694	0.1512	0.1555
	2513132	228	14.820	0.1814	0.1123
	2513132	230	14.950	0.2800	0.0475
	2513132	232	15.080	0.3888	0.1166
	2513132	234	15.210	0.4234	0.0950
	2513132	236	15.340	0.3197	0.0950
	2513132	238	15.470	0.3067	0.1555
	2513132	240	15.600	0.2290	0.2592
	2513132	242	15.730	0.1382	0.2246
	2513132	244	15.860	0.0994	0.3283
	2513132	246	15.990	0.0648	0.3154
	2513132	248	16.120	0.1685	0.1987
	2513132	250	16.250	0.2074	0.1728
	2513132	252	16.380	0.2808	0.1426
	2513132	254	16.510	0.2894	0.0518
	2513132	256	16.640	0.2765	0.0388
	2513132	258	16.770	0.1858	0.0259
14	2414010	-	-	-	-
	2414021	67	4.356	0.3450	0.1250
	2414023	423	27.503	-	0.1900
	2414024	579	37.645	-	0.5500
	2414028	963	62.613	-	0.2800
	2414030	-	-	-	-

Incl 2

Chart 2. Table of Adjusted Values
(Continued)

Gunner	Code No.	Frame No.	Time	Deflection, mil Hor	Vert
15	2515112	393	25.552	0.2160	0.3088
	2515115	555	36.085	-	-0.1144
	2515120	-	-	-	-
	2515132	199	12.938	-	0.3002
	2515133	421	27.372	-	0.1814
	2515135	710	46.163	-	0.0518
	2515138	1170	76.072	-	-0.1404
16	2716010	-	-	-	-
	2716020	-	-	-	-
	2716031	87	5.656	2.1200	0.3100
17	2617117	968	62.938	-	0.0380
	2617128	1293	84.075	-	-
	2617130	-	-	-	-
18	2618010	-	-	-	-
	2618020	-	-	-	-
	2618030	-	-	-	-
19	2619111	71	4.616	-0.1426	-0.4168
	2619123	442	28.738	-	-0.2894
	2619123	465	30.234	-0.9525	-0.5096
	2619124	561	36.476	-	-0.4038
	2619124	570	37.061	-	-0.3498
	2619125	746	48.504	-	-0.4989
	2619125	749	48.699	-0.4968	-
	2619130	-	-	-	-

Table I. Azimuth Tracking Errors for Experienced and Inexperienced Gunners at Several Ranges

			Range, meters											
			500				1000				1744			
			Tracking Bias, mil			Mean of Range of Individual Tracking Errors	Tracking Bias, mil			Mean of Range of Individual Tracking Errors	Tracking Bias, mil			Mean of Range of Individual Tracking Errors
Tracking Segment	Type Gunner	No. of Gunners	Average Bias for All Gunners	Largest Observed Average Bias	Smallest Observed Average Bias		Average Bias for All Gunners	Largest Observed Average Bias	Smallest Observed Average Bias		Average Bias for All Gunners	Largest Observed Average Bias	Smallest Observed Average Bias	
0	Exp	10	-3.307	-1.102	-5.641	12.920	-3.143	-.592	-6.289	10.270	-2.960	-.233	-6.468	12.558
	Inexp	9	-4.221	-.710	-6.405	13.907	-4.051	-2.133	-6.566	12.446	-2.955	-.701	-6.892	9.789
1	Exp	10	.070	.658	-.279	1.398	.237	.607	.274	1.187	-.133	.376	-.664	1.154
	Inexp	9	.564	3.371	-.843	1.642	.103	.865	-.623	1.348	.095	1.218	-2.815	2.425
			a(.214	1.058	-.843)									
2	Exp	10	.484	.866	-.158	2.385	.251	1.067	-.098	1.288	-.187	.391	-.819	1.303
	Inexp	9	.887	2.744	-.194	2.830	.132	1.112	-.685	1.766	.241	.572	.032	1.508
3	Exp	10	-.444	1.128	-2.079	2.960	-.243	.362	-.867	1.532	-.214	.221	-.905	1.157
	Inexp	9	.128	3.009	-1.855	2.601	-.074	.601	-.599	1.517	.015	.307	-.212	1.518
			a(-.231	1.752	-1.855)									
4	Exp	10	-.786	.025	-2.164	2.937	-.292	.805	-.901	1.637	-.245	.171	-.552	1.021
	Inexp	9	.489	2.144	-.442	2.585	-.331	.962	-1.808	2.080	.100	.246	-.411	1.883
5	Exp	10	-.262	.271	-1.561	3.902	-.031	.876	-.701	2.066	-.140	.196	-1.020	1.775
	Inexp	9	.528	3.627	-.730	4.067	-.136	1.511	-1.577	2.176	.171	.852	-.409	1.770
			a(.141	1.660	-.730)									
6	Exp	10	-1.718	-.475	-3.136	3.319	-.604	.237	-1.155	1.434	-.455	.061	-1.043	1.156
	Inexp	9	-1.703	-.172	-3.207	3.931	-.850	.297	-2.961	2.016	-.465	.613	-1.987	1.636
7	Exp	10	-1.382	1.844	-5.572	2.132	-.851	-.598	-1.303	.776	-.893	-.062	-2.884	.822
	Inexp	9	-1.703	2.582	-5.107	2.895	-.868	-.316	-1.868	.706	-.635	1.194	-3.105	.701
8	Exp	10	-.502	1.596	-2.015	3.690	-.164	.436	-.789	1.957	.017	1.649	-1.124	2.969
														a(1.519)
	Inexp	9	-.306	1.500	-1.810	3.891	-.272	.883	-1.898	3.396	-.104	.455	-.800	2.926
										a(2.630)				a(2.100)

[a] One extreme value omitted.

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Anal Lab, Engr Labs, TRPS
Sep 61 GTS

Table II. Elevation Tracking Errors for Ex- -rienced and Inexperienced Gunners at Several Ranges

			Range, meters											
			500				1000				1744			
			Tracking Bias, mil			Mean of Range of Individual Tracking Errors	Tracking Bias, mil			Mean of Range of Individual Tracking Errors	Tracking Bias, mil			Mean of Range of Individual Tracking Errors
Tracking Segment	Type Gunner	No. of Gunners	Average Bias for All Gunners	Largest Observed Average Bias	Smallest Observed Average Bias		Average Bias for All Gunners	Largest Observed Average Bias	Smallest Observed Average Bias		Average Bias for All Gunners	Largest Observed Average Bias	Smallest Observed Average Bias	
0	Exp	10	-.290	.082	-.631	1.103	-.275	.288	-.908	.801	.461	.872	-.226	1.325
														a(.975)
	Inexp	9	-.138	2.569	-1.274	1.685	-.429	-.023	-.902	1.017	.514	1.199	-.301	.795
			a(-.477	.422	-1.274)									
1	Exp	10	-.079	.342	-.280	1.137	-.078	.138	-.257	1.074	.143	.356	-.233	.928
	Inexp	9	.131	1.934	-.866	.859	-.239	.160	-.909	.865	.266	.843	-.198	.997
			a(-.094	.922	-.866)									
2	Exp	10	-.020	.142	-.182	1.540	.017	.196	-.144	.976	.170	.522	-.091	1.119
	Inexp	9	.090	1.934	-.934	2.011	-.177	.303	-.878	1.052	.119	.454	-.125	1.347
			a(-.140	.576	-.934)									a(1.130)
3	Exp	10	-.324	.498	-.926	1.785	-.085	.185	-.431	.853	.029	.419	-.393	.708
	Inexp	9	-.055	1.639	-.701	2.004	-.246	.321	-.929	.898	.061	.310	-.242	.905
4	Exp	10	-.394	.066	-1.008	1.236	-.034	.510	-.266	.814	.043	1.581	-.652	.564
						a(1.070)					a(-.128	.438	-.652)	
	Inexp	9	.040	1.476	-.648	1.691	-.182	.377	-.772	.749	-.231	.016	-.420	.802
						a(1.467)								
5	Exp	10	-.077	.474	-.649	2.444	.065	.307	-.250	1.397	-.166	.129	-.601	1.228
	Inexp	9	.209	1.818	-.186	3.224	.088	.825	-1.032	1.386	-.217	.043	-.421	1.224
							a(.228	.826	-.117)					
6	Exp	10	-.694	.782	-1.889	1.532	-.257	.137	-.515	.747	.067	.577	-.270	1.004
	Inexp	9	-.555	1.437	-1.833	1.224	-.217	.224	-1.487	.722	-.115	.184	-.619	.791
7	Exp	10	-.508	.254	-1.918	.706	-.018	.261	-.247	.316	.260	1.125	.003	-.527
											a(.152	.448	.003)	
	Inexp	9	-.128	1.595	-1.494	.570	-.315	.237	-1.107	.328	.033	.425	-.442	.284
8	Exp	10	-.199	.125	-.565	1.768	.084	.447	-.156	1.334	.034	.305	-.165	1.111
										a(1.148)				
	Inexp	9	-.063	.906	-.451	2.482	-.030	.375	-.847	1.549	-.093	.321	-.314	.950

[a]One extreme value omitted.

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APPENDIX B

HORIZONTAL AND VERTICAL ERRORS IN MILS

BY GUNNER AND SEGMENT

(Published Separately)

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Technical Memorandum 20-62 Unclassified
AMCCMS Code 5567.12.20300.01

This study is a report of the ability of tank gunners to track continuously over a period of time, to evaluate the role of experience in reducing error, and to provide a basic measurement technique for future tracking studies. Experienced and novice gunners served as subjects, tracking a target tank through evasive maneuvers around a rectangular course, at various ranges. The results of the study indicate that the instrumentation and procedure designed for this study provide a satisfactory technique of measuring tracking error, that the subject's experience did not affect tracking performance in this problem, and that the measuring technique may be used to evaluate target evasive techniques as well as tracking error.

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