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Predicting Table VIII Tank Gunnery Performance From M-COFT Hit Rate and Demographic Variables

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July 1992

United States Army Research Institute for the Behavioral and Social Sciences

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13. ABSTRACT *(Maximum 200 words)*
This report describes research efforts to determine the ability to predict Table VIII performance from Conduct-of-Fire Trainer (COFT) proficiency and tank crew demographics and to develop cut scores for predicting Table VIII qualification. Tank commanders (TCs) and gunners in 24 Army National Guard M1 tank crews completed the COFT Test of Gunnery Proficiency (CTGP) before firing Table VIII during annual training. Hit Rate, based on 22 engagements from the CTGP, correlated positively with Table VIII scores. Gunner's age, TC vision, and crew years of military service also correlated with Table VIII. TC vision was positively related to Table VIII scores, whereas gunner's age was negatively related to both Table VIII scores and CTGP Hit Rate. The relationship between crew years of military service and Table VIII was curvilinear (crews with intermediate years of service outperformed those with either few or many years of service). When the three best predictor variables were combined in a multiple regression algorithm, they accounted for more than 60% of the variance in Table VIII scores. The results show that Table VIII performance can be predicted from a combination of COFT Hit Rate and other measures and support
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the viability of device-based training strategies for Army National Guard armor units. If the results are replicable, COFT cut scores can be constructed to serve as training guidelines. Crews trained to specified levels of COFT proficiency can be expected (with known levels of probability) to qualify on Table VIII.

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Training Simulation

FOREWORD

The Army National Guard (ARNG) is emphasizing the use of training devices to enhance home-station training of M1 tank gunnery. To this end, work is under way to develop a device-based tank gunnery training and evaluation strategy for ARNG use at the company level. This report describes the results of research performed to (a) determine the ability to predict live-fire Table VIII performance from M-COFT proficiency and tank crew demographic variables, and (b) develop an M-COFT test-based cut score for predicting Table VIII qualification.

The research was conducted by the Training Technology Field Activity, Gowen Field (TTFA-GF), whose mission is to improve the effectiveness and efficiency of Reserve Component (RC) training by using the latest in training technology. The research task supporting this mission, "Application of Technology to Meet RC Training Needs," is organized under the "Training for Combat Effectiveness" program area.

The National Guard Bureau (NGB) sponsored this research under a Memorandum of Understanding signed 12 June 1985 and establishing the TTFA-GF. Results have been presented to Chief, Organization and Training Division, Training Support and Management Branch, NGB; Chief, Training Division, Office of the Chief, Army Reserve; Director, Training Development and Analysis Directorate, Training and Doctrine Command; and Deputy Director, Training and Doctrine, U.S. Army Armor School.

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Technical Director

PREDICTING TABLE VIII TANK GUNNERY PERFORMANCE FROM M-COFT HIT RATE AND DEMOGRAPHIC VARIABLES

EXECUTIVE SUMMARY

Requirement:

The purposes of this research were to (1) test the relative effectiveness of a composite COFT achievement measure (Hit Rate based on the COFT Test of M1 Gunnery Proficiency [CTGP] versus more specific COFT measures as predictors of Table VIII performance; (2) investigate the incremental contribution of demographic variables to the Table VIII prediction equation; (3) examine the predictability of COFT achievement; (4) evaluate the impact of temporal proximity between the CTGP and Table VIII on the COFT-to-live-fire gunnery relationship; and (5) develop COFT cut scores, based on the derived Table VIII prediction model, for use in setting COFT training objectives.

Procedure:

M-COFT, Table VIII, and demographic data were obtained from tank commanders (TCs) and gunners of 24 M1 tank crews in four Army National Guard armor companies. All data except M-COFT and demographic measures were also collected from TCs and gunners of 12 additional crews from the same battalion to assess the impact of CTGP administration. Hoffman and Witmer's (1989) Hit Rate, based on the CTGP, provided the composite assessment of COFT gunnery skills. Table VIII scores were collected during annual training (AT) at the first operation of a new computer-automated firing range with electronic scoring. Tank crews were randomly assigned to one of three treatment conditions, determined by whether the CTGP was administered and the timing of its administration (either 1 month prior to AT or 1 day prior to AT). All tank crews subsequently fired Table VIII during AT.

Findings:

COFT Hit Rate, a composite measure of tank gunnery performance from the CTGP, correlated significantly with Table VIII scores. Hit Rate was superior to specific performance measures in predicting Table VIII performance. Generally, the greater the number of COFT exercises used to calculate Hit Rate, the stronger its correlation with Table VIII. Relationships between COFT Hit Rate and Table VIII were robust with either 1-day or 30-day intervals between COFT testing and Table VIII. The addition of

demographic variables (gunner's age, crew years of military service, and TC vision) significantly enhanced the Table VIII prediction equation.

Utilization of Findings:

These research findings are not suitable bases for revising training policies until they can be replicated in all essential details. However, the results demonstrate that Table VIII performance can be predicted from a combination of COFT Hit Rate and demographic variables. If the findings are replicable and the suggested model is valid, the COFT device can be used to identify tank crews with both the highest probability of qualifying on Table VIII, as well as those most urgently in need of remedial training. COFT cut scores can be developed to serve as gunnery simulation training objectives. Tank crews trained to specified levels of COFT proficiency can be expected (with known levels of probability) to qualify on Table VIII.

PREDICTING TABLE VIII TANK GUNNERY PERFORMANCE FROM M-COFT HIT RATE AND DEMOGRAPHIC VARIABLES

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Background

Total Force Policy requires that the Army's Reserve Component (RC) soldiers attain and maintain readiness standards comparable to those of their Active Component counterparts. Because of constraints on time, mission-essential equipment, and access to range/maneuver areas, the majority of RC training must be accomplished at home station (i.e., armory or reserve center), where it is difficult to provide the kind of realistic tank gunnery training necessary to ensure skill proficiency.

Tank Gunnery Simulation

To increase RC home-station training capability (especially for combat arms units) the National Guard Bureau is seeking to use technology in the form of simulators and training devices. To guide the use of this technology and thereby promote the successful RC transition from equipment-based to device-based training in the area of tank gunnery, Morrison, Campshure and Doyle (1991) developed a strategy to link device-based training with on-tank performance. Under this strategy, the purpose of device-based training is to prepare individuals, crews, and platoons to be trained on the tank combat tables, with these tables providing the intermediate and terminal performance objectives for gunnery training.

The strategy has three phases: 1) begin with basic device-based training at the armory, 2) proceed to intermediate device-based training at home station coupled with on-tank training at the Local Training Area (LTA), and 3) conclude with live-fire tank combat table evaluation at the Major Training Area (MTA).

M-COFT (Mobile Conduct-of-Fire Trainer)

The centerpiece device for this strategy is the M1 M-COFT (Mobile Conduct-of-Fire Trainer), a computer-based tank gunnery simulator. Tank commander (TC) and gunner teams are placed in simulated crew stations and presented with a full range of target engagement situations. The crew stations replicate interior features, dimensions, and lighting of the M1 tank, including weapons, sights/optics, and TC/gunner fire control systems. TC/gunner teams follow actual engagement procedures, striving to produce "kills" of the computer-generated target images. The M-COFT simulates all major TC/gunner M1 tank components across a variety of potential operating conditions (see Campshure, 1991, p. 12, 21-22). Functionally equivalent to its predecessor, the U-COFT (Unit Conduct-of-Fire Trainer; U.S. Army Armor Center, 1985), the M-COFT can be moved from site to site because it is mounted on an enclosed flatbed truck. The M-COFT's mobility reflects its intended purpose of fulfilling the unique training needs of armor units primarily in the Army National Guard (ARNG). These units often have company-sized elements that are geographically dispersed from the rest of the battalion.

Out of six devices included in the Morrison, Campshure and Doyle (1991) strategy, COFT was allocated over one third of recommended basic and intermediate training hours. According to Morrison, Campshure, and Doyle (1991), and Morrison, Drucker and Campshure (1991), COFT simulates more gunnery training requirements than any other simulation device, and is the only device that can support the training of some gunnery related tasks (e.g., simultaneous engagements and most degraded mode gunnery procedures).

Relationship Between M-COFT and Table VIII

Morrison (1991, p. 29) concluded that the M-COFT "simulates the most comprehensive segment of ... gunnery training requirements, and rightly deserves its prominent role in current armor gunnery training." If the COFT device simulates a broad spectrum of M1 components and condition parameters, it is not unrealistic to expect that proficiency on the COFT should correlate with M1 tank gunnery scores. If crews can be trained to M-COFT proficiency at home station, and this training transfers to subsequent live-fire tank combat evaluations, numerous advantages will result, including reduced training costs, more efficient allocation of training time, and reduced ammunition requirements. Theoretically, it should be possible to examine COFT scores and predict which crews will successfully qualify on Table VIII. Support for this notion, however, has been mixed at best. Morrison, et al. (1991) reviewed four investigations that reported either no significant correlations between COFT and live-fire gunnery performance (Butler, Reynolds, Kroh & Thorne, 1982; Kuma & McConville, 1982; Hughes, Butler, Sterling & Bergland, 1987) or a few low correlations on the speed, but not the accuracy, of performance (Black & Abel, 1987). One reason for this inconsistent relationship may be unreliable COFT and gunnery table scores. Graham (1986), however, reported robust COFT test-retest reliability coefficients, based on data samples of approximately 15 to 20 min at each administration. Six of his nine measures produced reliability coefficients of .70 or greater, and three of the six were in excess of .80. DuBois (1987) successfully replicated Graham's findings, although the obtained reliability coefficients were lower.

The clearest demonstration of a COFT-to-live-fire gunnery relationship suggests the importance of both methodological and analytic factors. Campshure and Drucker (1990) reported significant bivariate correlations between Table VIII total score and either crew Reticle Aim Level or TC Reticle Aim Level of the COFT training matrix. An even stronger relationship emerged when they analyzed the data with a multiple regression routine, a statistical technique that simultaneously examines the relationship between two or more predictor variables and a single outcome measure.

As Campshure and Drucker (1990) observed, a composite measure of COFT achievement (e.g., COFT matrix position, based on aggregated sessions) may provide a more reliable prediction of Table VIII performance than scores from a few COFT engagements. Both empirical and logical grounds suggest that composite measures are more stable than specific test performance scores. Table VIII performance represents a multi-faceted composite of many behaviors (including cognitive, motivational, and perceptual-motor functioning) as well as quality, extent and intensity of prior training. Because of the complexity of the criterion measure, only a composite sampling of COFT performance, encompassing a broad array of specific COFT behaviors, can reasonably be expected to predict Table VIII outcomes. Campshure and Drucker (1990) used composite measures on both sides of their prediction equation. Table VIII total score (the sum of 10 engagements, or "tasks") served as the live-fire composite measure, and COFT matrix position (a broad but admittedly undifferentiated aggregate) served as their primary composite predictor.

Analytic procedure also may play a role in efforts to predict Table VIII qualification. The COFT-to-live-fire relationship may be extremely difficult to demonstrate with bivariate correlations based on limited COFT performance from a few engagements. Other analytic approaches may be required, where the influence of multiple factors can be examined simultaneously. In addition to COFT matrix position, Campshure and Drucker (1990) used two other measures (time in crew and total number of exercises) to augment the power of their prediction equation. M1 tank operation depends critically upon high levels of coordination and communication efficiency among crew members. Campshure and Drucker (1990) reasoned that crew turbulence would jeopardize performance. They examined such variables as the total length of time a crew had served together, and total number of COFT exercises the TC and gunner had completed. Consistent with their hypothesis, the best prediction of Table VIII performance was obtained by combining time in crew with Crew Reticle Aim Level (a composite measure from the COFT matrix) in a multiple regression equation.

Thus, the only clear demonstration of a COFT-to-live fire relationship incorporated composite performance measures on both sides of the prediction equation with an analytic procedure that permitted simultaneous examination of multiple predictor variables. Much of the previous research into the COFT-to-live-fire relationship has been characterized by limited data samples on both the predictor and criterion sides of the prediction equation. That is, although numerous tank crews are usually observed, only a limited sample of data is collected from each crew, sometimes as little as one COFT exercise and a single live-five gunnery exercise. A typical procedure has involved calculation of bivariate correlations between a single COFT exercise and a single live-fire gunnery exercise (Butler, et al., 1982; Kuma & McConville, 1982), or discrete speed and/or accuracy measures and live-fire performance (Black & Abel, 1987; Hughes, et al., 1987).

Implications of Transitioning to M-COFT Training

Even if RC units accept the M-COFT as an effective tank gunnery simulator, little is known about how they can best use the device in order to facilitate subsequent Table VIII qualification. Despite the central importance of M-COFT devices in planned RC tank gunnery training, extant research provides little guidance for setting COFT proficiency objectives. How much COFT proficiency is necessary in order to confidently predict subsequent Table VIII qualification? The present research addresses these information deficits, with special attention to probing the basic COFT-to-live-fire gunnery relationship.

Purpose

The research (1) tested the relative effectiveness of a composite COFT achievement measure (the COFT Test of M1 Gunnery Proficiency [CTGP]; Hoffman & Witmer, 1989) versus more specific COFT measures as predictors of Table VIII performance, (2) investigated the incremental contribution of demographic variables to the Table VIII prediction equation, (3) examined the predictability of COFT achievement, (4) evaluated the impact of temporal proximity between the CTGP and Table VIII, and (5) developed M-COFT cut-scores, based on the derived Table VIII prediction model, for use in setting COFT proficiency objectives.

Specific Questions to be Answered

1. To what extent can a composite measure of COFT proficiency predict Table VIII performance?

2. What is the relative effectiveness of a composite measure compared to specific performance benchmarks in predicting Table VIII performance?

3. To what extent are COFT predictions of Table VIII stable, or is better prediction possible with a shorter time interval between COFT and Table VIII?

4. To what extent does the addition of demographic variables improve the Table VIII prediction equation?

5. To what extent is cut-score development possible, so that crews with the highest probability of qualifying on Table VIII can be identified, as well as those most urgently in need of remedial attention?

6. To what extent does collection of COFT proficiency measures, per se, improve subsequent Table VIII performance?

Method

Participants

M-COFT, Table VIII, and demographic data were obtained from TCs and gunners of 24 M1 tank crews in four Army National Guard armor companies. All data except M-COFT and demographic measures also were collected from TCs and gunners of 12 additional crews from the same battalion in order to assess the impact of CTGP administration per se.

The COFT Test of Gunnery Proficiency (CTGP)

Matrix position, the only previous COFT measure to convincingly demonstrate a relationship with Table VIII scores, was not suitable for the present research. Although matrix position provides a composite measure of COFT achievement, it is a gross metric that is largely unsuitable for differentiation into analyzable subcomponents. Also, all TCs and gunners in the present research had approximately the same matrix position. All TCs and gunners were experienced tankers (with a wide range of experience levels), but because the COFT arrived at their armories only days before the research began, each crew had received only two hours prior familiarization with the COFT device.

Hoffman and Witmer's (1989) CTGP provided an alternative composite assessment of COFT gunnery skills. The CTGP consists of four COFT matrix exercises (duration of administration approximately one hour) selected to correspond to conditions that occur in Table VIII. The exercises cover: target arrays, ranges, firing tank movement, target movement, Nuclear, Biological and Chemical (NBC), crew configuration (four- or three-man), day/night, and number of targets per engagement. The selected COFT exercises do not replicate Table VIII tasks exactly, but they represent all Table VIII conditions in somewhat different sequences and combinations. Figure 1 lists exercises included in the CTGP, with major Table VIII conditions represented. Hoffman and Witmer (1989) provide extended discussion on the rationale for selecting COFT exercises and the overlap among conditions represented in Table VIII, the CTGP, and the known domain of M1 gunnery conditions.

EXERCISE	CONDITIONS REPRESENTED
34611	STATIONARY FIRING TANK MULTIPLE MOVING AND STATIONARY TARGETS DAYLIGHT WITH UNLIMITED VISIBILITY SIMULTANEOUS ENGAGEMENT MODIFIED TO INCLUDE NBC CONDITIONS MODIFIED TO COVER THREE-MAN CREW ENGAGEMENT
34633	MOVING FIRING TANK MULTIPLE MOVING AND STATIONARY TARGETS TANK, HELICOPTER, TROOP AND ARMORED PERSONNEL CARRIER TARGETS BATTLEFIELD CONDITIONS FRIENDLY M1 TANK IN ONE ENGAGEMENT FIRING FROM OTHER VEHICLES DEPICTED IN THE SCENE VISIBILITY REDUCED BY FOG
34622	NIGHT GUNNERY STATIONARY FIRING TANK MULTIPLE, MOVING AND STATIONARY TARGETS TANKS, APC, AND HELICOPTER TARGETS MODIFIED TO INCLUDE NBC CONDITIONS MODIFIED TO COVER THREE-MAN CREW ENGAGEMENT
31563	STATIONARY AND MOVING TARGETS GUNNER'S AUXILIARY SIGHT (GAS) FIRING FROM SHORT HALT

Figure 1. Conditions represented in CTGP exercises (Exercise 1 = 34611; Exercise 2 = 34633; Exercise 3 =34622; Exercise 4 = 31563).

Standardized Administration. A standardized set of CTGP administration procedures (Hoffman and Witmer, 1989) was followed closely, including verbatim reading of instructions at the beginning of each exercise. The test procedures emphasized testing requirements, rather than usual COFT training needs. For example, no feedback or coaching was provided during testing, and switch setting instructions were given only at the start of each exercise.

Instructor/Operator (I/O) Training. To ensure consistency of CTGP administration, I/Os were limited to two master gunners. (Two were required in order to avoid fatigue from consecutive testing sessions.) Both I/Os were provided an overview of research objectives through briefings that highlighted differences between CTGP testing and normal COFT training. Briefings also emphasized the critical importance of withholding feedback. I/Os practiced the test administration scenario prior to the first actual session, and observed each other's performance during early sessions to ensure that they were implementing a standardized set of administration procedures. At least one principal researcher was present during test administrations in case questions or problems arose.

Hit Rate. The CTGP produces a composite measure of gunnery proficiency -- a "test-wide" COFT performance measure that is weighted for the number of targets in each of 22 contributing engagements. This composite measure of gunnery proficiency is called Hit Rate, which Hoffman and Witmer (1989) define as:

$$\underset{\text{(hits/time)}}{\text{Hit Rate}} = \underset{\text{(hits/rounds)}}{\text{Hit Proportion}} \times \underset{\text{(rounds/time)}}{\text{Fire Rate}}$$

"Hit rate, adjusted for hits on friendly targets, is the recommended metric for assessment of overall crew proficiency. Hit rate is calculated for each engagement from information on COFT printouts on rounds fired, hits, and time. Overall hit rate is calculated from the weighted averages for firing rate and hit probability, where engagement firing rates and hit probabilities are weighted by the number of targets in the engagement." (Hoffman and Witmer, 1989; p 28)

Although the scoring procedure for Hit Rate is computationally complex and laborious, it does capture in a single metric the essential elements of gunnery success: rounds fired, time expended, accuracy of fire, and completeness (were all threat targets hit?). (For details on the Hit Rate scoring procedure, refer to Hoffman and Witmer, 1989.) In addition to the overall Hit Rate which is based on a weighted combination of all exercises, similar scores can be calculated for individual exercises. Additionally, standard COFT computer printouts provide numerous subsidiary measures, all of which can be compared and contrasted with the predictive utility of the various Hit Rate measures.

Table VIII

Table VIII scores were collected during Annual Training (AT) at the first operation of a new, computer-automated firing range where all hit/miss decisions were determined electronically. It was the first time the range was used. Each crew fired six day engagements and four night engagements, selected from among fourteen engagements described in FM 17-12-1 (Department of the Army, 1988).

Scoring. Crews received raw scores of from 0 to 100 on each engagement, based on engagement speed, accuracy of fire, and threat capability. Penalty points (crew cuts) were deducted from each engagement raw score based on observed procedural errors. Scores were summed (after deduction of penalty points) for the six day engagements, producing a total day score. Similarly, scores were summed for the four night engagements, producing a total night score. Day score and night score were summed to produce a total Table VIII score for each crew. Crews must obtain a minimum score of 700 out of a possible 1,000 in order to qualify on Table VIII.

Design and Procedure

Tank crews were randomly assigned to one of three treatment conditions, as shown in Figure 2. The CTGP was administered either one month prior to AT (Group 1), one day prior to AT (Group 2), or not at all (Group 3). All tank crews subsequently fired Table VIII during AT.

GROUP	N OF CREWS	TIMING OF CTGP	TABLE VIII?
1	10	ONE MONTH BEFORE AT	YES
2	14	.... ONE DAY BEFORE AT	YES
3	12	NO COFT TEST OF GUNNERY PROFICIENCY	YES

Figure 2. Treatment design.

Questionnaires. During Table VIII debriefing, information was collected on age, rank, length of military service, and years in current tanker MOS (see Appendix A). Following AT, additional data were collected from crews in Groups 1 and 2 on TC and gunner amount of tank operations experience, and on vision (see Appendix B). Appendix B data were collected as part of subsequent COFT training sessions or via mailed questionnaires. Efforts to recontact three TCs and three gunners were unsuccessful.

Only intact crews were retained for data analysis. Intact crews were defined as those having no TC or gunner changes between CTGP administration and completion of Table VIII. Differential attrition from Group 1 occurred because of TC/gunner changes in the 30 day interval between administration of the CTGP and Table VIII.

Results

Relationship Between COFT Hit Rate and Table VIII Scores

Table VIII scores. The mean Table VIII score was 356, with a standard deviation of 184. Only one of 24 crews qualified (with a score of 703). As indicated in Table 1, scores were distributed widely about the mean, ranging from 59 to 703.

Debriefing comments indicated that the predominant reason for low scores was the inability to acquire targets in time to fire a round. Forty-four percent of engagements, for example, ended with a zero score, and no round was fired in the vast majority of these engagements. The percentage of zero scores was 49 for night engagements and 41 for day engagements. The most common explanation for a day engagement with zero score was that a target was eventually identified, but too late to permit a round to be fired. Among night engagements with a zero score, however, targets were never identified in a majority (54.3%) of cases.

Table 1

Distribution of Table VIII Total Scores

Score	Frequency	Percentage	Cumulative Percentage
59	1	4.2	4.2
77	1	4.2	8.3
136	1	4.2	12.5
138	1	4.2	16.7
164	1	4.2	20.8
198	1	4.2	25.0
227	1	4.2	29.2
274	1	4.2	33.3
284	1	4.2	37.5
291	1	4.2	41.7
322	1	4.2	45.8
335	1	4.2	50.0
357	1	4.2	54.2
364	1	4.2	58.3
373	1	4.2	62.5
418	1	4.2	66.7
433	1	4.2	70.8
487	1	4.2	75.0
499	1	4.2	79.2
501	1	4.2	83.3
609	1	4.2	87.5
624	1	4.2	91.7
671	1	4.2	95.8
703	1	4.2	100.0

Note. N = 24
Mean = 356
SD = 184

Contrary to previous research (Campshure and Drucker, 1990; Hoffman, 1989), night and day scores were positively correlated, $r(24) = .56$, $p = .005$. Another index of internal consistency was calculated by summing scores for odd-numbered and even-numbered engagements for each crew. (Each sum comprised three day engagement scores and two night engagement scores.) The correlation between odd/even sums was significant: $r(24) = .43$, $p = .038$

COFT Measures. Hit Rate is the composite index of COFT proficiency. Hit Rate scores, as shown in Figure 3, were normally distributed about a mean of .018, with a standard deviation of .007. In addition to Hit Rate, the COFT provides four types of measures, assessing a crew's ability to: a) correctly identify targets and prepare for engagement, b) fire at correctly identified targets, c) hit the targets, and d) manage the tank's fire control systems. The left column in Table 2 lists specific measures in these four areas, followed by coefficients of correlation between each listed COFT score and Table VIII total score. The first four data columns show correlations between scores from individual COFT exercises and Table VIII. The last column reports correlations between data combined from all four exercises and Table VIII scores.

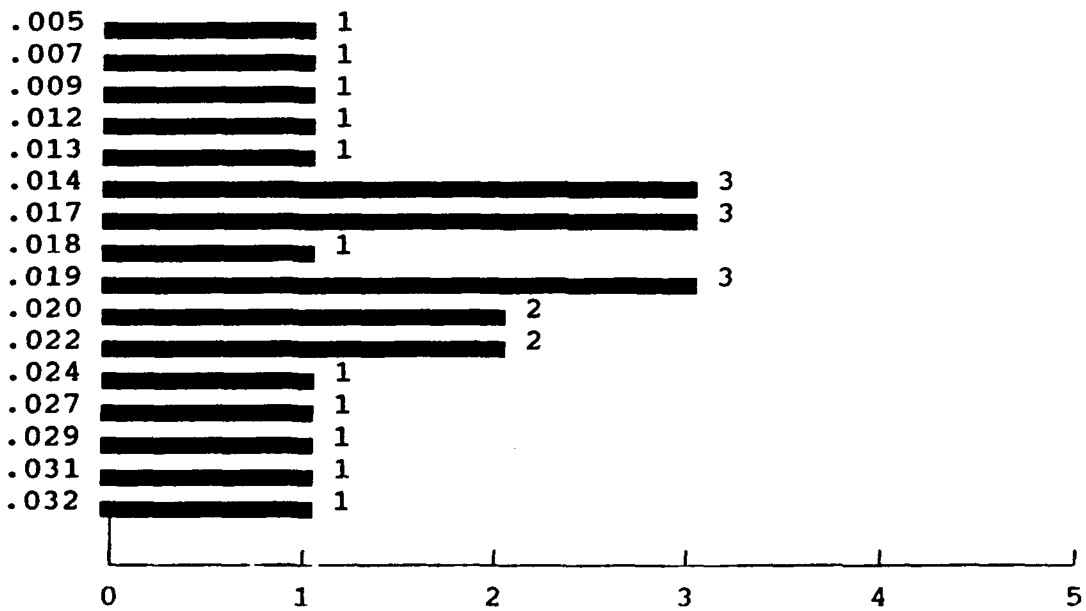

Figure 3. Distribution of COFT Hit Rate scores (N = 24; Mean = .018; Median = .019; Standard Deviation = .007)

Predictive utility of individual exercises versus composite measures. As seen in the first four data columns of Table 2, eight percent of COFT measures from individual exercises correlated significantly with Table VIII total score, and no coefficient exceeded $r = .46$. The fifth data column, however, shows that when these same COFT measures were calculated on the basis of data combined from all four exercises, 33% of the correlations were significant. Significant correlations in column five of Table 2 range from $r = .45$ to .65. The highest coefficient in the table is between composite COFT Hit Rate and Table VIII, $r(24) = .65$, $p < .01$. Hit Rate, accounting for 42 % of Table VIII total score variance, is listed in the "Accuracy of Fire" category. Along with its constituent elements (Fire Rate and Hit Proportion), its correlations with Table VIII are highlighted in Table 2.

Although composite Fire Rate and composite Hit Rate produced robust correlations with Table VIII total score ($r[24] = .64$, $p < .01$ and $r[24] = .65$, $p < .01$, respectively), this was not the case when these measures were based on data from individual exercises. Only Fire Rate based on Exercise 3 and Hit Rate based on Exercise 1 correlated significantly with Table VIII total score. Thus, even COFT Hit Rate did not reliably correlate with Table VIII when based on single exercises.

Of the eight significant composite correlations, five measures are relatively easy to obtain and/or calculate. Proportion of targets fired upon ($r = .57$, $p < .01$) is obtained by dividing the number of targets fired upon by the total number of available targets. The measure of did not fire at a target ($r = -.53$, $p < .01$) is automatically recorded (as one of several error scores) on COFT printouts. However, these two simple-to-calculate indices measure the same thing, from different approaches, as indicated by their robust intercorrelation of $r = -.94$, $p < .01$. These two variables also correlate highly with the other easy-to-calculate measures. The average (absolute) intercorrelation between the five "easy-to-obtain" measures that correlate significantly with Table VIII scores is $r = .71$ (based on $n(n-1)/2$ possible intercorrelations). Moreover, these five easy-to-obtain measures also correlate highly with composite COFT Hit Rate, with an average coefficient of $r = .67$. Thus, any combination of simple-to-obtain COFT variables adds little to a prediction equation beyond what any one measure in isolation contributes, and all are highly related to composite Hit Rate. Because composite Hit Rate is more highly correlated with Table VIII scores than any other COFT measure, it emerges as the superior predictor of live-fire gunnery performance. Figure 4 plots COFT Hit Rate with Table VIII total score.

Predictive utility of two and three exercise combinations. Composite Hit Rate is a calculationally complex measure that

Table 2

Correlations Between COFT Measures and Table VIII Total Score

Category/Variable	Exer 1 (34611)	Exer 2 (34633)	Exer 3 (34622)	Exer 4 (31563)	1+2+3+4 (Composite)
A: Target Identification	1	2	3	4	5
Proportion of Targets Identified	.46*	-.17	.26	.26	.31
Average Time to ID First Target	-.02	-.26	.07	-.21	-.20
Target Acquisition Grade	na	.24	.20	.26	.37
Fired at Non Target (Error I)	-.19	-.06	.05	.24	.05
B: Fire Rate					
Hoffman & Witmer (1989) Fire Rate	**.28**	**.09**	**.43***	**.32**	**.64****
Proportion of Targets Fired Upon	.39	.37	.45*	.29	.57**
Gross Fire Rate (Rnds/# of Targets)	.37	.26	.41*	.25	.45*
Average Opening Time	-.10	-.29	.19	-.23	-.20
Did Not Fire at a Target (Error 2I)	-.45*	-.27	-.38	-.30	-.53**
Lasing Error (Error L)	.14	-.22	.41	na	.27
Magnification Error (Error M)	-.22	na	na	na	-.22
Ammo Switch Error (Error R)	-.25	.00	na	.05	-.09
Wrong Weapon or Wrong Ammo (Error A)	.09	.09	na	.21	.28
Failure to Engage Most Dangerous Target First (Error C)	.36	-.11	-.09	na	-.01

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Table 2 (Continued)

Correlations Between COFT Measures and Table VIII Total Score

Category/Variable	Exer 1 (34611)	Exer 2 (34633)	Exer 3 (34622)	Exer 4 (31563)	1+2+3+4 (Composite)
C: Accuracy of Fire					
Hoffman & Witmer Hit Proportion	**.33**	**.16**	**.05**	**.16**	**.49****
Hoffman & Witmer Hit Rate	**.42***	**.21**	**.27**	**.20**	**.65****
Gross Kill Rate (# Kills/# Targets)	.27	.43*	.29	.19	.46**
Average Time to First Kill	.09	-.04	.20	.07	.03
Proportion of First Round Kills (# First Round Kills/# Targets)	.22	.42*	.21	.10	.44*
Average Time to First Round Kill	.09	.09	.31	.07	.11
Average Miss Distance	-.12	-.15	.36	.16	.02
Reticle Aim Grade	na	na	na	.20	.20
D: Systems Management					
Exposed too Long in Hull Defilade (Error D)	-.12	na	-.13	.36	-.18
Systems Management Grade	.05	na	-.24	na	-.13

<u>Note</u>. N = 24 crews
Correlations are between listed variables and Table VIII total score.
Two-tailed tests.
* $p < .05$
** $p < .01$

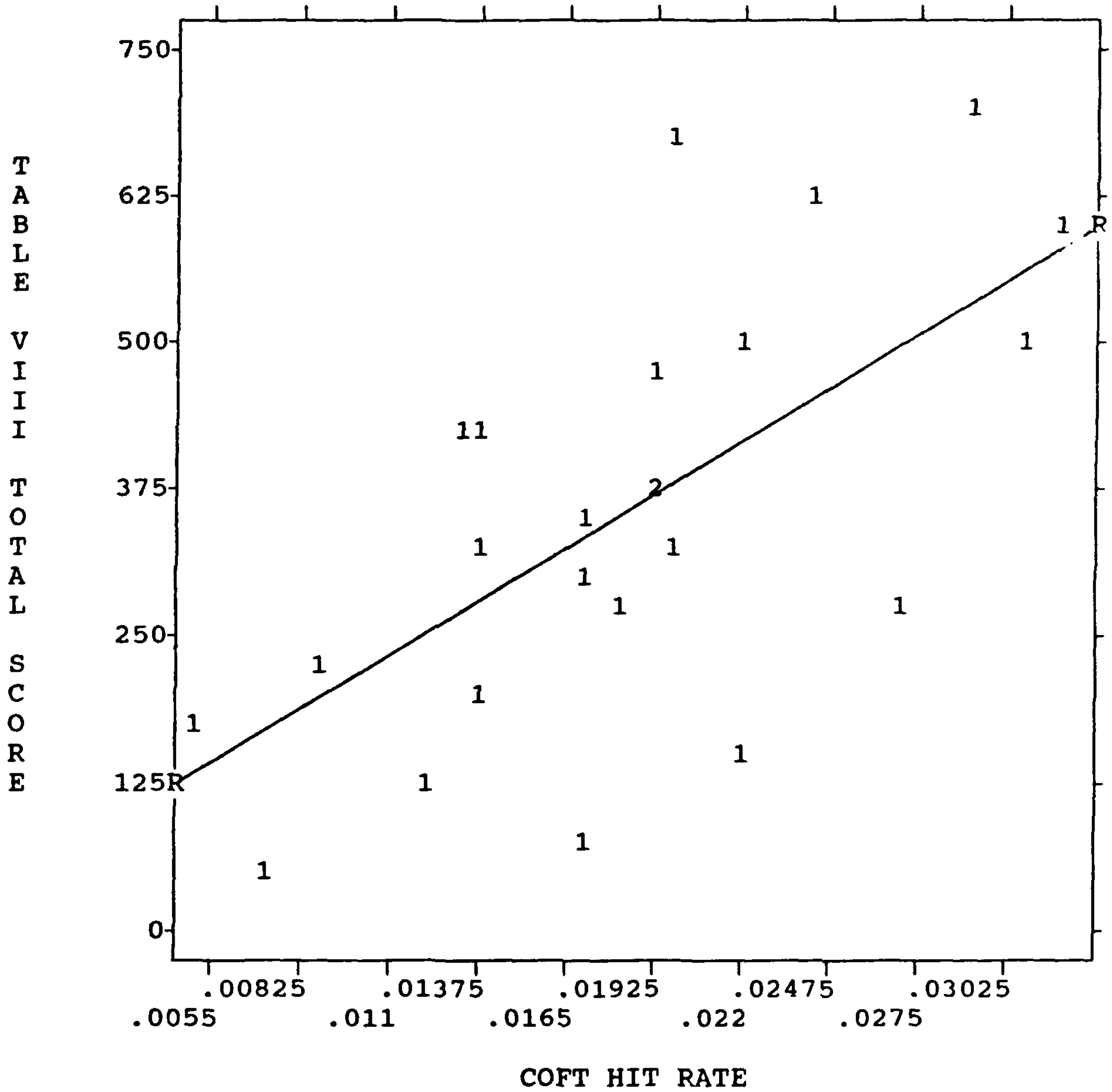

Figure 4. Plot of COFT Hit Rate with Table VIII total score (N = 24; $\underline{r}$ = .65; $\underline{p}$ = .0006). The "Rs" printed on the vertical axes indicate the points of intercept for the best-fit linear regression line.

takes into consideration number of rounds fired, time expended to fire the rounds, accuracy of the rounds, and whether or not all targets were hit. Because the Hit Rate measure is laborious to calculate, it is desirable to base its calculation on as few exercises as possible. Four exercises produce a robust correlation with Table VIII ($\underline{r}$ = .65). Basing the Hit Rate measure on single exercises, however, seriously compromises the strength of observed relationships. In order to determine the predictive utility of Hit Rate when based on more than one -- but fewer than four -- exercises, correlations were calculated between Table VIII scores and Hit Rate measures based on all possible combinations of two and three exercises. Table 3 summarizes the results.

Table 3

Correlations Between Table VIII Total Score and CTGP Fire Rate, Hit Proportion, and Hit Rate Based on Single Exercises and Combinations of Two, Three, and Four Exercises

Exercise(s)	Fire Rate	Hit Pro.	Hit Rate
1	.28	.33	.42*
2	.09	.16	.21
3	.43*	.05	.27
4	.32	.16	.20
1+2	.38	.35	.39
1+3	.49*	.32	.54**
1+4	.47*	.34	.43*
2+3	.31	.18	.28
2+4	.17	.24	.23
3+4	.36	.24	.33
1+2+3	.48*	.33	.47*
2+3+4	.31	.26	.31
1+3+4	.50*	.37	.51*
1+2+4	.36	.35	.38
All Four	.64**	.49**	.65**

Note. N = 24 crews
* $p < .05$
** $p < .01$
1 = 34611
2 = 34633
3 = 34622
4 = 31563

The average correlation between Hit Rate and Table VIII based on one, two, three and four exercise combinations was .28, .37, .42, and .65, respectively. For the Hit Rate index, the best single exercise was 34611 (Number 1). The best combination of two exercises was 34611 and 34622 (Number 1 and Number 3), with r = .54, p < .01, which is superior to any combination of three exercises. However, in terms of the ability to account for variance in Table VIII scores, all four exercises combined are approximately 45% more successful than the best two ($.65^2/.54^2 = 1.45$).

Inter-exercise correlations among COFT measures. To determine if the same COFT variables from different exercises correlated with one another, correlations were calculated for all possible exercise pair-wise combinations. The results are presented in Table 4. Only three variables (Opening Time, Gross Kill Rate, Exposed Too Long in Hull Defilade) produced significant correlations on as many as two of the six possible pair-wise combinations of exercises. The last column in Table 4 presents algebraic averages for the six possible pairings of the four exercises. Only 17% of the intercorrelations in the last column were greater than .20, and none was as great as .30.

Part (single exercises) - whole (four exercises combined) correlations. Table 5 reports correlations between COFT measures based on single exercises and their composite counterparts based on all four exercises (part-whole correlations), for the eight variables having a significant relationship with Table VIII (see Table 2). Although their inter-exercise correlations were negligible (refer to Table 4), part-whole coefficients are robust, averaging r = .51

Timing of CTGP Administration and Its Relationship with Table VIII.

Table 6 compares correlations between COFT composite measures and Table VIII total score for crews tested 30 days before AT versus those tested one day before AT. Only the eight composite measures (based on all four exercises) with an overall significant correlation with Table VIII (refer to Table 2) are compared. Coefficients of correlation with Table VIII are higher for a majority of measures when based on a single day's interval between COFT and Table VIII, but the small number of crews in each group make interpretation of differences in magnitude risky. Moreover, correlations between composite Hit Rate (the most omnibus COFT measure) and Table VIII total score are virtually identical for 1 day and 30 day intervals.

Table 4

COFT Inter-exercise Correlations

Category/Measure	Exercise Combinations						
	1x2	1x3	1x4	2x3	2x4	3x4	Algebraic Avg
Target Identification							
Proportion of Targets Identified	.36	.39*	.07	.22	.34	-.03	.24
Average Time to ID First Target	-.07	-.05	.17	-.09	.44*	.31	.13
Target Acquisition Grade	nc	nc	nc	.21	.17	.14	.17
Fired at Non Target (Error I)	-.18	.16	.24	.07	.17	.43*	.15
B: Fire Rate							
Hoffman & Witmer (1989) Fire Rate	**-.02**	**.32**	**-.08**	**-.11**	**-.22**	**.36**	**.04**
Proportion of Targets Fired Upon	.30	.04	.04	.27	.25	.35	.21
Gross Fire Rate (Rnds/# of Targets)	-.20	.29	.03	.04	.37*	.32	.14
Average Opening Time	.45*	.20	-.21	.11	.46*	-.19	.14
Did Not Fire at a Target (Error 2I)	.24	-.07	.11	.24	.29	.35	.19
Lasing Error (Error L)	-.13	.50*	nc	-.08	nc	nc	.10
Magnification Error (Error M)	nc	nc	nc	nc	nc	nc	nc
Ammo Switch Error (Error R)	-.05	nc	-.07	nc	.90**	nc	.26
Wrong Weapon or Wrong Ammo (Error A)	-.05	nc	-.21	nc	.08	nc	-.06
Failure to Engage Most Dangerous Target First (Error C)	-.07	-.34	nc	-.07	nc	nc	-.17

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Table 4 (Continued)

Category/Measure	Exercise Combinations						
	1x2	1x3	1x4	2x3	2x4	3x4	Algebraic Avg
C: Accuracy of Fire							
Hoffman & Witmer Hit Proportion	**.09**	**-.10**	**.36***	**.08**	**.24**	**-.18**	**.08**
Hoffman & Witmer Hit Rate	**.18**	**-.03**	**.16**	**-.04**	**.54****	**.10**	**.14**
Gross Kill Rate (# Kills/# Targets)	.28	-.21	.43*	.20	.43*	.04	.20
Average Time to First Kill	-.08	-.08	-.22	.11	-.04	.31	.00
Proportion of First Round Kills (# First Round Kills/# Targets)	-.06	-.11	.32	.02	.13	-.02	.03
Average Time to First Round Kill	-.03	-.03	-.06	.53**	.09	.18	.11
Average Miss Distance	-.17	-.11	.02	-.15	.33	-.03	-.02
Reticle Aim Grade	nc	nc	nc	nc	nc	nc	nc
D: Systems Management							
Exposed too Long in Hull Defilade (Error D)	nc	.38*	.37*	nc	nc	-.04	.24
Systems Management Grade	nc	.00	nc	nc	nc	nc	.00

Note. N = 24 crews
Two-tailed tests.
* p <.05
** p <.01
nc = Not calculable (due to zero variance on one or both variables).

Table 5

COFT Part- to- Whole (Single Exercise- to- Composite) Intercorrelations

Category/Measure	Exercise # with Composite Ex1	Ex2	Ex3	Ex4
<u>B: Fire Rate</u>				
Hoffman & Witmer (1989) Fire Rate	**.16**	**.03**	**.58****	**.51****
Proportion of Targets Fired Upon	.44*	.63**	.69**	.69**
Gross Fire Rate (Rnds/# of Targets)	.33	.44*	.49*	.82**
Did <u>Not</u> Fire at a Target (Error 2I)	.50**	.66**	.70**	.55**
<u>C: Accuracy of Fire</u>				
Hoffman & Witmer Hit Proportion	**.41***	**.52****	**.24**	**.45***
Hoffman & Witmer Hit Rate	**.50****	**.56****	**.37**	**.62****
Gross Kill Rate (# Kills/# Targets)	.49*	.76**	.48*	.77**
Proportion of First Round Kills (# First Round Kills/# Targets)	.37	.53**	.45*	.70**

<u>Note</u>. N = 24 crews
Two-tailed tests.
* p <.05
** p <.01

<u>The Relationship Between Demographic Variables and Table VIII Scores</u>.

Table 7 lists variables that correlated significantly with Table VIII scores. Figure 5 graphically depicts the significant negative relationship between gunner's age and Table VIII total score. Although the depicted negative correlation in Figure 5 is modest in magnitude ($r[24] = -.44$), the plot shows that the six crews with highest Table VIII scores had gunners under 25 years of age (mean age = 23). Moreover, no crew with a gunner over age 30 shot higher than 418 (mean Table VIII total score = 356; standard deviation = 184). The highest Table VIII score (703) was fired by a crew with a 22 year-old gunner. The lowest Table VIII score (59) was fired by a crew with a 45 year-old gunner.

Table 6

Correlations Between COFT Composite Measures and Table VIII Total Score For Two Time Intervals

Variable	30 Days (N = 10)	One Day (N = 14)
Fire Rate	.61	.74**
Hit Proportion	.46	.53
Hit Rate	.67*	.64*
Proportion of Targets Fired Upon	.58	.49
Gross Fire Rate	.25	.42
Did Not Fire at Tgt	-.54	-.53
Gross Kill Rate	.51	.57*
Proportion of First Round Kills	.47	.60*
Mean (Absolute) Correlation	.51	.57

Note. *$p<.05$
**$p<.01$

Table 7

Correlations Between Demographic Variables and Table VIII Total Score

Variable	r	p	N
Gunner's Age	-.44	.032	24
TC Vision[1]	-.49	.025	21
Crew Years of Military Service[2] (Quadratic Component)[3]	-.54	.006	24

Note. All probability levels are based on two-tailed tests.
[1]Perfect Vision = 1; Corrected Vision = 2.
[2][(TC years + Gunner years)/2].
[3]The quadratic component was tested with squared z-scores.

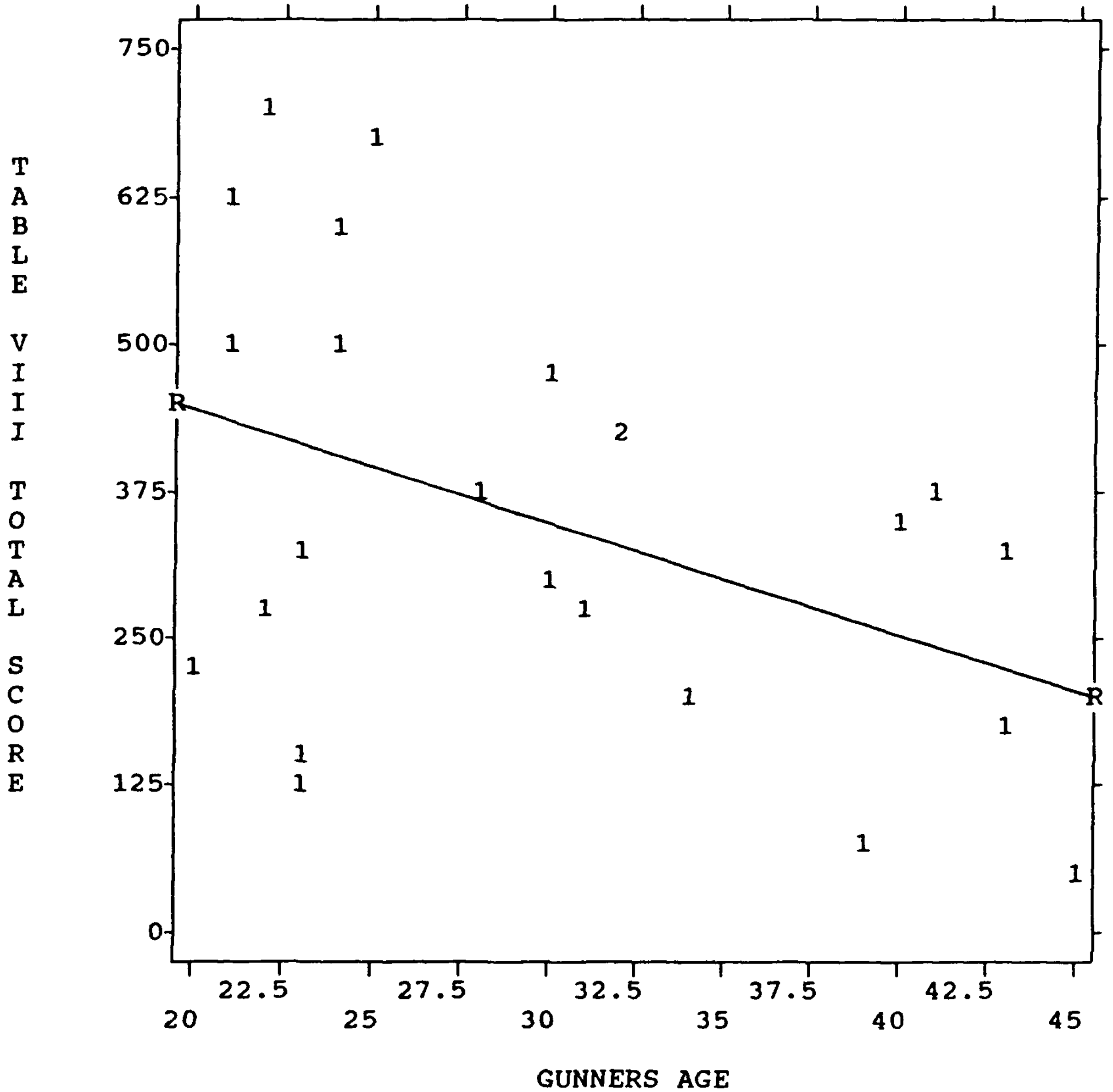

Figure 5. Plot of gunner's age with Table VIII total score ($N = 24$; $r = -.44$; $p = .032$).

The association between gunner's age and Table VIII scores is further illustrated in Table 8, where *Table VIII scores for* crews with the twelve youngest (mean age = 23) and twelve oldest (mean age = 37) gunners are compared. Day score (the sum of six day engagements) differed significantly for the two groups, $F(1, 22) = 6.25$, $p < .05$, and total score (the sum of day and night engagement scores) approached significance, $F(1, 22) = 3.44$, $p = .077$.

Table 8

Association Between Gunner's Age and Table VIII Scores

Gunner's Age	Mean Table VIII Day Score	Mean Table VIII Night Score	Mean Table VIII Total Score
Youngest (N=12)	275	148	422
Oldest (N=12)	158	132	290

The unexpected negative relationship between gunner's age and Table VIII scores prompted close examination of all demographic data via scatter plots in order to judge if the data contained nonlinear relationships. One distinct curvilinear relationship was uncovered, between Table VIII total score and crew years of military service (defined as the sum of TC and gunner years of service divided by two). Graphically depicted in Figure 6, the linear coefficient of correlation was nonsignificant, $r = -.31$. However, the two variables seem to be related curvilinearly (in the shape of an inverted "V"). When the crew years of military service variable was transformed (by substituting squared z scores for raw data values), the resulting correlation with Table VIII total score was significant ($r[24] = -.54$, $p <$ 01), revealing a strong quadratic trend. Crews with either relatively few or many years of military service obtained low Table VIII scores, compared to crews with intermediate years of service. A plot of Table VIII total score with the transformed variable (squared z-scores) is presented in Figure 7.

To probe the non-linear relationship between Table VIII total score and crew years of military service, crews were divided into quartiles based on years of military service ([TC + gunner]/2). Table 9 presents quartile means for crew years of military service and corresponding scores on Table VIII. The highest mean Table VIII scores were obtained by crews in the second and third quartiles, suggesting that about 10 years of military service is optimal for TCs and gunners. The data are potentially misleading, however, because crew years of military

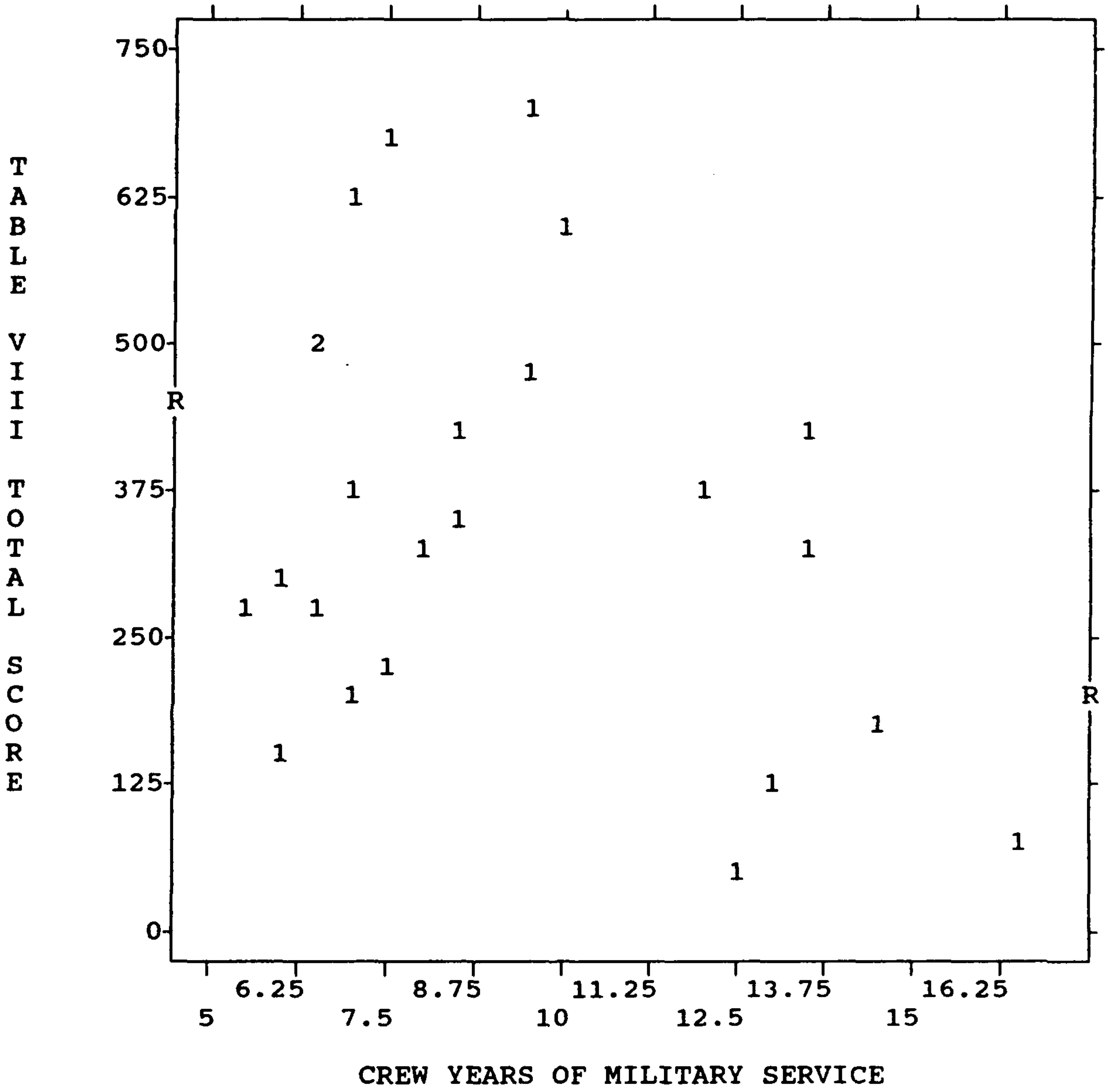

Figure 6. Plot of "crew years of military service" with Table VIII total score (N = 24; r = -.31; ns).

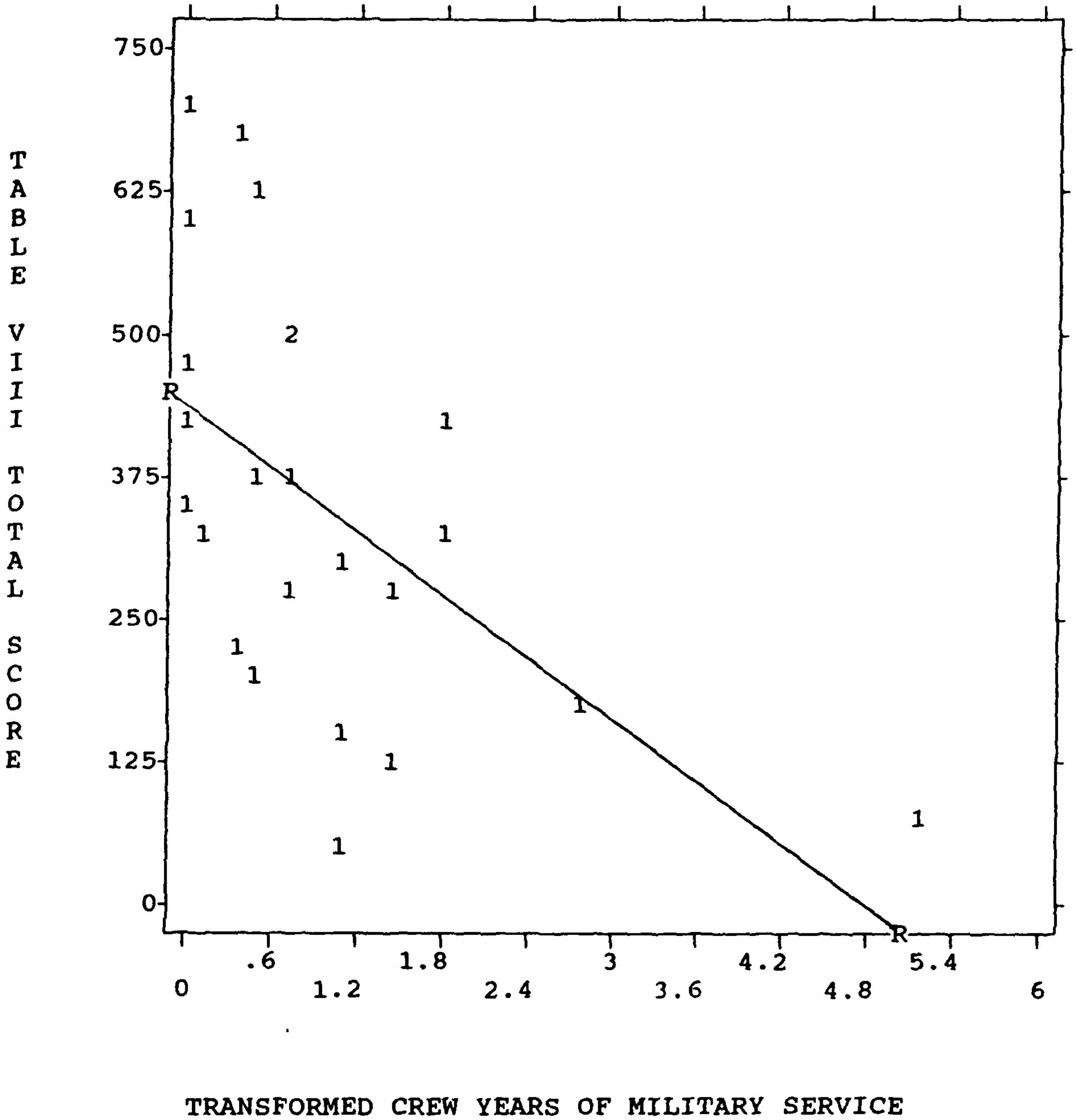

Figure 7. Plot of transformed "crew years of military service" with Table VIII total score (N = 24; r = -.54; p = .0063). The transformation consisted of squaring z-scores.

Table 9

Crew Years of Military Service Mean Quartile Scores and Corresponding Mean Table VIII Total Score

Quartile	Crew Years of Military Service	Table VIII Score Total	Day	Night
1 (N = 6)	6.2	331.2	212.2	119.0
2 (N = 6)	7.3	401.0	262.8	138.2
3 (N = 6)	9.7	491.2	273.3	217.8
4 (N = 6)	13.4	200.7	115.8	84.8
$F(3, 20)$		3.52	2.23	4.19
p		<.05	ns	<.05

service is an average of TC and gunner service records. Table 9 provides no insight regarding which combinations of TC and gunner years of service were associated with relatively high Table VIII scores. That is, crew years of military service = 10 could be obtained from a gunner and TC, each with 10 years of service -- or from a gunner with 5 years and a TC with 15 years of service Other combinations of TC and gunner age are possible, and they are not necessarily equally efficacious.

Table 10 probes the issue by partitioning crews into quartiles based on Table VIII total score and examining corresponding TC and gunner demographic variables. Neither TC age nor TC years of military service differed across Table VIII quartile groups. Mean TC age and TC years of military service were virtually identical in the top and bottom quartiles. Gunner's age, however, differed significantly across Table VIII quartiles, and a corresponding but nonsignificant trend emerged on the gunner's years of military service variable. Gunners in the lowest quartile of Table VIII scores were almost twelve years older, on average, than gunners in the top quartile, and they had over twice the years of military service. TCs in the top quartile crews, however, were no different in age or years of service than TCs in other quartiles. Two TCs in the top quartile were over age 40. One TC in this quartile was 48 years of age.

TCs rated their own vision as either perfect (N = 8; defined as at least 20/20 vision without glasses or contact lenses), corrected (N = 12), or imperfect but not corrected (N = 1). Perfect vision was coded = 1. The other two vision categories were combined and coded = 2. TC vision correlated negatively

Table 10

TC and Gunner Mean Age and Years of Military Service Corresponding to Table VIII Total Score Quartiles

Quartile	Mean Table VIII Total Score	Tank Commander		Gunner	
		Age	Years of Service	Age	Years of Service
1 (N = 6)	128.7	36.3	11.8	34.5	11.3
2 (N = 6)	288.8	31.5	9.3	28.2	6.3
3 (N = 6)	405.3	34.2	11.5	33.8	8.2
4 (N = 6)	601.2	36.2	11.2	22.8	4.5
$F(3,20)$		<1	<1	3.62	2.11
p		-	-	<.05	ns

Table 11

TC Vision and Table VIII Scores

TC Vision	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Total Day
Perfect	56.5	18.0	54.6	47.6	55.5	54.4	286.6
Corrected	30.8	4.3	42.4	26.9	33.1	44.5	182.0
$F(1, 19)$	1.61	2.87	< 1	1.21	1.24	< 1	3.64
p	-	-	-	-	-	-	.0715

TC Vision	Night 1	Night 2	Night 3	Night 4	Total Night	Total Total
Perfect	44.3	23.8	44.3	75.3	188.8	475.8
Corrected	10.5	19.8	22.9	53.5	106.6	288.6
$F(1, 19)$	7.54	< 1	2.30	1.07	5.81	5.94
p	<.05	-	-	-	<.05	<.05

($r[21] = -.49$, $p < .05$) with Table VIII total score. (Perfect TC vision was associated with higher Table VIII scores and corrected TC vision was associated with lower Table VIII scores.)

To determine if the influence of TC vision was more pronounced on some types of engagements, one-way ANOVAS were conducted in order to compare TC perfect vision crews (N = 8) with TC corrected vision crews (N = 13). Table 11 summarizes these comparisons. The two TC vision groups differed significantly on Table VIII total score and on total night score (the sum of four night engagements), but not on total day score (the sum of six day engagements).

Table VIII Prediction Model

Four variables correlated significantly with Table VIII (COFT Hit Rate, gunner's age, TC vision, and crew years of military service [squared z-scores]). These four variables were entered into a multiple regression algorithm to determine if jointly they could successfully model Table VIII performance. (Missing vision data on three TCs were estimated using the mean substitution technique.) The resulting prediction equation was highly significant, producing a Multiple R = .79 and $R^2 = .62$ ($F[4, 19] = 7.88$, $p = .0006$. The same variables also were entered into a stepwise routine to determine the order in which they would enter the prediction equation. The stepwise procedure selected three of the four variables. Table 12 lists the predictors in order of their entry into the prediction equation. The final Multiple R in Table 12 is as large as the one based on all four predictors, indicating that the three-predictor combination is a parsimonious model. (The excluded variable, gunner's age, was highly correlated with COFT Hit Rate. Once Hit Rate entered the equation, little unique variance remained in the gunner's age variable.)

Table 12

Table VIII Stepwise Multiple Regression Predictors

Variable	Multiple R	R^2	F	df	p
COFT Hit Rate	.65	.42	15.84	(1, 22)	.0006
Crew Years of Mil Ser[1]	.74	.55	13.02	(2, 21)	.0002
TC Vision	.79	.62	10.72	(3, 20)	.0002

Y = 347.5 + 12,600(HitRate) - 55.3(Crew Years of Military Service) - 105.0(TC Vision)

Note. [1]Quadradic component, obtained by squaring z-scores.

The strength of the multiple relationship can be seen by regressing predicted scores (based upon three significant predictor variables) upon actual Table VIII scores and plotting the results (see Figure 8). The correlation between actual and predicted scores ($\underline{r}$[24] = .79) is the same as the Multiple $\underline{R}$ between the three predictor variables and Table VIII total score.

COFT Cut-Scores for Establishing Training Guidelines

Using the multiple regression prediction equation:

$$Y = B_0 + B_1(X_1) + B_2(X_2) + B_3(X_3)$$

where Y is the predicted Table VIII score, B_0 is the intercept (or theoretical Table VIII performance with COFT and crew measures of zero), and B_1 through B_3 are the empirically determined regression coefficients for the three predictor variables, we can arbitrarily set crew variables (at obtained mean levels), set Y = the minimum Table VIII qualifying score, and algebraically solve for the single unknown: the COFT Hit Rate necessary in order to predict a mean Table VIII score of 700.

Using the stepwise multiple regression equation based on 24 crews (with Multiple R = .79 and R^2 of .62), we have:

$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(\text{CwYrsMSv}) - 105(\text{TC Vision})$$

Setting the crew variables at their means, we have:

$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(0.96) - 105(1.6)$$
$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 53.1 - 168$$
$$700 = 12{,}600(\text{Hit Rate}) + 126.4$$
$$573.6 = 12{,}600(\text{Hit Rate})$$

Solving for the only remaining unknown (Hit Rate) we have:

$$12{,}600(x) = 573.6$$
$$x = .046$$

Therefore, the model predicts that a new sample of tank crews (with average crew experience and TC vision capabilities) trained to a COFT proficiency as indicated by Hit Rate scores of .046, will shoot a mean Table VIII score of 700. Extreme levels on either TC vision or crew years of military service would change the required COFT Hit Rate. To see how this works, we can set TC vision and crew years of military service variables at extreme levels and calculate COFT Hit Rate required for relatively handicapped crews (that is, crews with corrected TC vision and either few or many years of military service) and relatively advantaged crews (that is, crews with perfect TC vision and crew years of military service squared z-scores = 0).

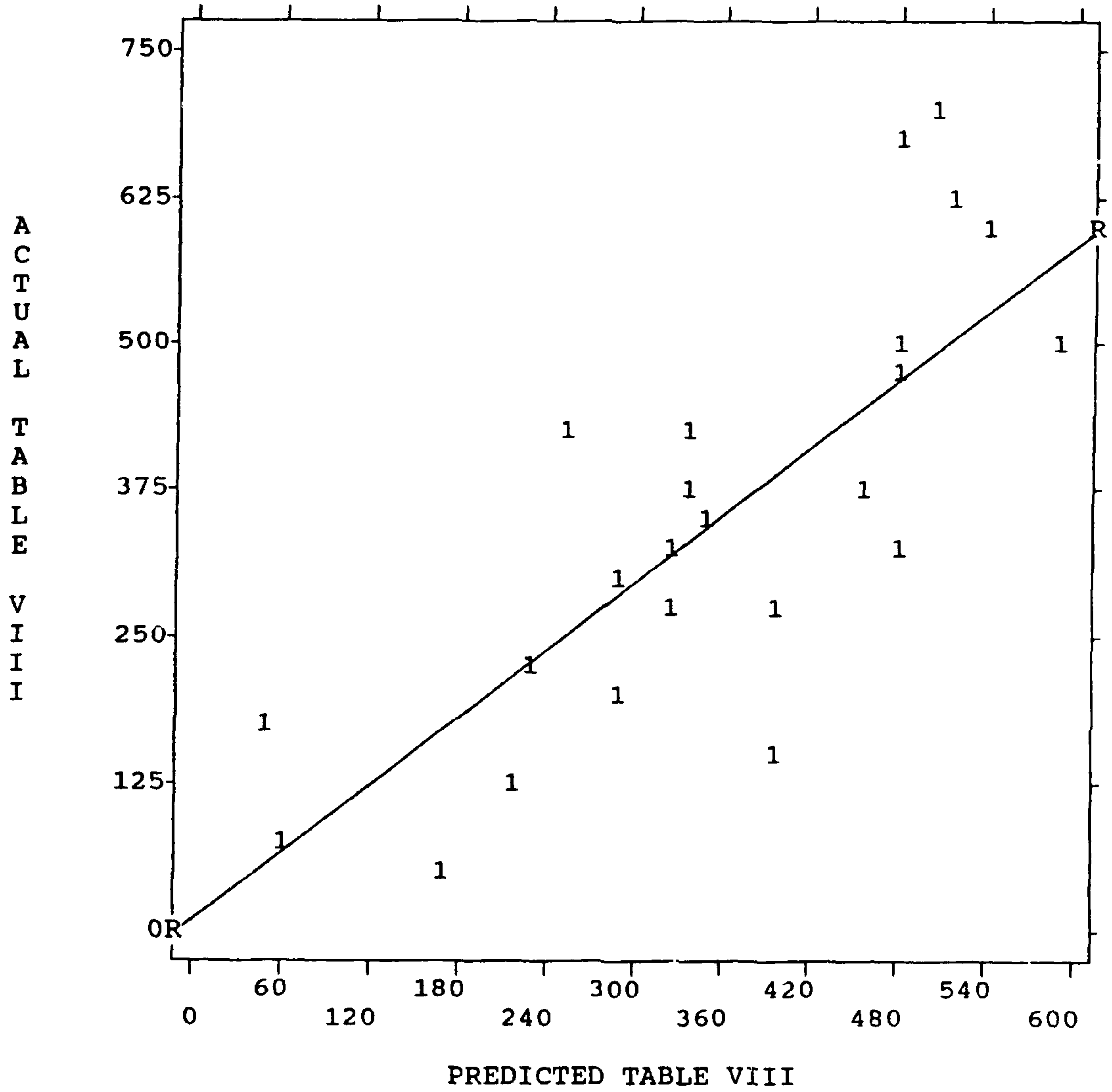

Figure 8. Plot of predicted and actual Table VIII scores (N = 24; r = .79; p < .000). Predicted total score = 347.5 + [12,600 x COFT Hit Rate] + [-55.3 x crew years of military service] + [-105 x TC vision]. Crew years of military service = [(TC years + gunner years)/2]. TC vision: 1 = perfect vision without correction; 2 = corrected vision or impaired and uncorrected.

Because TC vision was coded dichotomously (1 = 20/20 vision without corrective lenses; 2 = corrected vision), values of 1 on this variable (perfect vision) will be substituted for the advantaged crew and values of 2 (corrected vision) will be used for the relatively handicapped crew. The remaining predictor, the quadratic form of crew years of military service, had a mean of 0.96 and standard deviation of 1.13. Values of 0.0 and 2.09 will be used for advantaged and disadvantaged crews, respectively. Table 13 presents extreme TC vision and crew years of military service values that will be plugged into the Table VIII prediction equation.

Table 13

Mean and Extreme Values of Table VIII Auxiliary Predictor Variables

Variable	Mean	SD	Extreme Values Advantaged Crew	Extreme Values Disadvantaged Crew
[1]CwYrsMSv	9.27	3.17	na	na
CwYrsMSv z-score	0.00	1.00	na	na
$(\text{CwYrsMSv z-score})^2$	0.96	1.13	0.00	2.09
TC Vision	1.60	0.50	1.00	2.00

Note. CwYrsMSv = Crew years of military service

First, the relatively advantaged crew, which will have a lower required COFT Hit Rate:

$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(\text{CwYrsMSv}) - 105(\text{TC Vision})$$

Re-setting crew years of military service at 0.00 and TC vision = 1, we have:

$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(0.00) - 105(1)$$
$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 105$$
$$700 = 12{,}600(\text{Hit Rate}) + 242.5$$
$$457.5 = 12{,}600(\text{Hit Rate})$$

Solving for the only remaining unknown (Hit Rate) we have:

$$12{,}600(x) = 457.5$$
$$x = .036$$

In a similar fashion, we can estimate the necessary COFT Hit Rate for a relatively disadvantaged crew. The required COFT Hit

Rate will be higher for this crew because it has an extreme (either high or low) number of years of military service and is led by a TC with corrected vision:

$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(\text{CwYrsMSv}) - 105(\text{TC Vision})$$

Re-setting crew years of military service at +1 standard deviation and TC vision = 2, we have:

$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(2.09) - 105(2)$$
$$700 = 347.5 + 12{,}600(\text{Hit Rate}) - 115.6 - 210$$
$$700 = 12{,}600(\text{Hit Rate}) + 21.9$$
$$678.1 = 12{,}600(\text{Hit Rate})$$

Solving for the only remaining unknown (Hit Rate) we have:

$$12{,}600(x) = 678.1$$
$$x = .054$$

Depending upon crew characteristics, the level of COFT Hit Rate necessary to predict a mean Table VIII score of 700 ranges from .036 to .054. With average TC vision and crew years of military service, the required COFT Hit Rate is .046, in order to predict a mean Table VIII score of 700. Of the 24 crews tested on COFT in the present research, none scored as high as .046. The highest score was .032. The crew with the highest Table VIII score (703) had a COFT Hit Rate of .029.

The calculations above are concerned with predicting a mean outcome score of 700 for a new sample of tank crews. However, a mean Table VIII score of 700 will produce only 50% qualification. (Half the crews will score above the predicted mean of 700 and half will score below the mean.) A more pertinent issue is: what COFT Hit Rate is necessary in order to predict, with 95 percent confidence, that crews will qualify on Table VIII? This is an extremely tricky issue for several reasons. To paraphrase Hays (1963):

[Be sure to note the interesting fact that the regression equation found for a sample is not equally good ... over all the different values of the predictor variable. The prediction is at its best when the predicted score is the same as the mean predicted score, since the confidence interval is smallest at this point. However, as predicted values grow increasingly deviant from the mean predicted score (in either direction) the confidence intervals grow wider. For the more extreme values of the predicted score, we can have little confidence that the actual mean obtained for a sample of individuals (each showing the same predicted score) will be anywhere near what we have predicted.]

Based on data from the present research, a predicted mean score of 700 is definitely in the region of extremity, and warrants a cautionary approach. Moreover, predicting the level of COFT Hit Rate that will ensure a minimum Table VIII score of 700 takes us beyond the range of data values upon which the prediction model was constructed. Statistical extrapolation beyond the range of observed values is always risky. That the relationship between predictor and criterion variables will remain essentially unchanged outside the bounds of observed data values is an unsubstantiated assumption. For these and other reasons, the following analyses must be considered as speculative.

Another problem concerns the exact nature of the prediction, which is that a specified mean score will be obtained by a new sample of tank crews, given that all predictor variables fall within specified ranges. The prediction is not for any specific tank crew. An additional source of variance is introduced if we wish to pinpoint scores of individual crews. Individual crew performance on Table VIII can be predicted (and in fact the prediction will be the same as that for the sample), but the confidence interval around that prediction will enlarge substantially.

Nevertheless, given these caveats, the necessary level of COFT Hit Rate can be estimated that will predict with 95% confidence a minimum Table VIII score of 700. We can regress predicted Table VIII scores (which become the independent, or predictor variable) upon actual Table VIII scores (the dependent, or criterion variable). The squared correlation is the same as the multiple R^2 obtained in the stepwise algorithm with three predictor variables. The procedure also yields a single sample standard error of estimate. With this estimate, we can construct a confidence interval around the predicted mean criterion score of 700.

The 95% confidence interval is from 556 to 844 (see Hays [1963], p. 522). If we wish to ensure that 95% of crews shoot at least 700 on the next Table VIII exercise, and we assume that confidence intervals outside the bounds of observed values will be similar to those on the fringe of observed values, and we arbitrarily set crew measures at mean levels, we can calculate the COFT Hit Rate necessary to predict a <u>minimum</u> score of 700 on the Table VIII exercise, as follows:

$$844 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(\text{CwYrsMSv}) - 105(\text{TC Vision})$$

Setting crew years of military service and TC vision at their obtained mean values, we have:

$$844 = 347.5 + 12{,}600(\text{Hit Rate}) - 55.3(0.96) - 105(1.6)$$
$$844 = 347.5 + 12{,}600(\text{Hit Rate}) - 53.1 - 168$$
$$844 = 12{,}600(\text{Hit Rate}) + 126.4$$
$$717.6 = 12{,}600(\text{Hit Rate})$$

Solving for the only remaining unknown (Hit Rate) we have:

$$12{,}600(x) = 717.6$$
$$x = .057$$

Thus, average crews need approximately the same COFT Hit Rate (.057) to predict a minimum Table VIII score of 700 as disadvantaged crews (those having TCs with corrected vision and crew years of military service squared z-scores = 2.09) need in order to predict a mean Table VIII score of 700. An advantaged crew (perfect TC vision and crew years of military service squared z-score = 0.00) would require a COFT Hit Rate of .048 in order to predict a minimum Table VIII score of 700. Table 14 summarizes the previous calculations.

Table 14

COFT Hit Rate Needed in Order to Predict Mean and Minimum Table VIII scores of 700

Crew Characteristics	COFT Hit Rate Needed to Predict Mean 700	COFT Hit Rate Needed to Predict Minimum 700
TC Perfect Vision + CwYrsMSv squared z-score = 0.00	.036	.048
TC Average Vision + + CwYrsMSv squared z-score = 0.96	.046	.057
TC Corrected Vision + CwYrsMSv squared z-score = 2.09	.054	.065

Note. CwYrsMSv = Crew Years of Military Service.

Figure 9 illustrates the interplay among the predictor variables of COFT Hit Rate, TC vision, and crew years of military service squared z-score by depicting the level of COFT Hit Rate needed in order to predict a minimum Table VIII score of 700 for crews with TC perfect vision and for crews with TC corrected vision as a function of crew years of military service. Because the relationship between Table VIII and crew years of military service is curvilinear, lower COFT Hit Rates are required for crews with intermediate years of military service (i.e., crews with a squared z-score = 0.00 on this variable). As crew years of military service become extreme (in either direction), the level of required COFT Hit Rate increases.

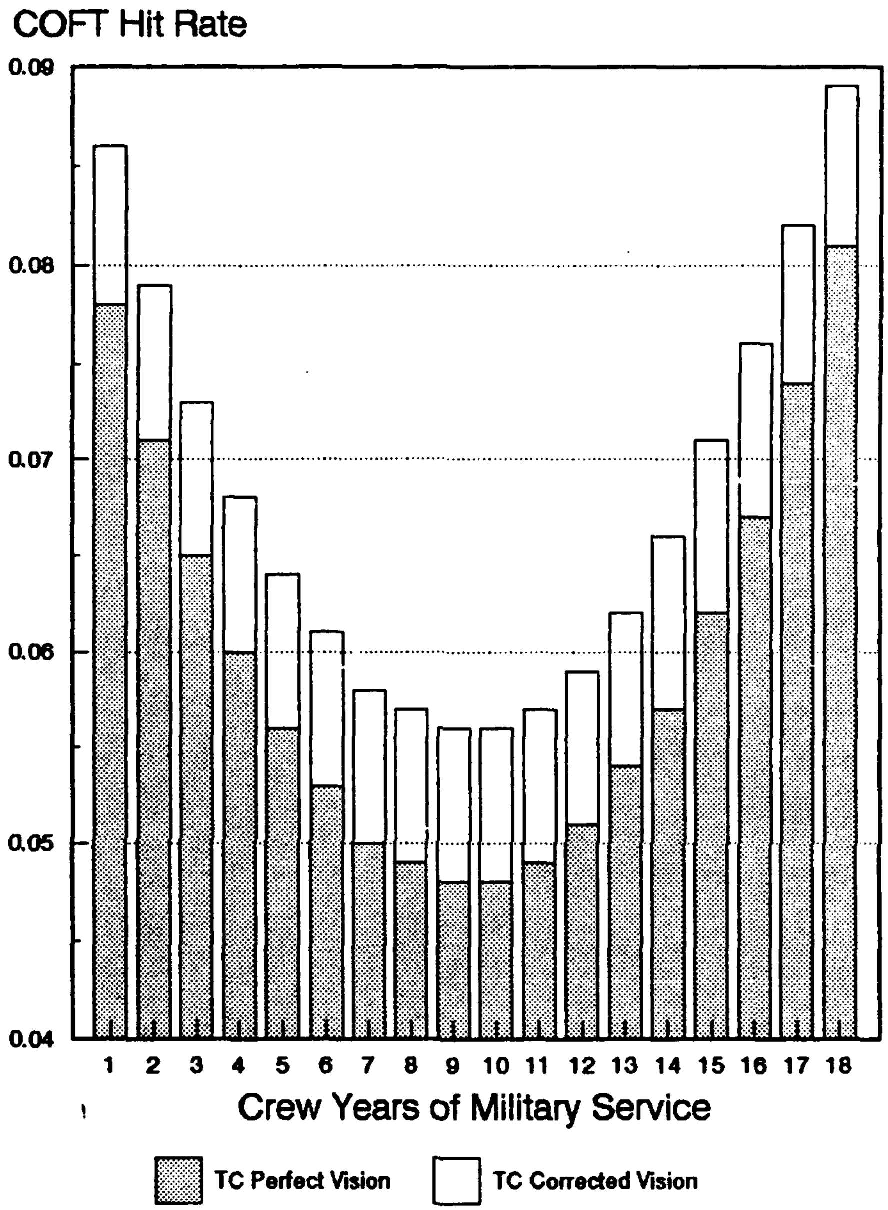

Figure 9. COFT proficiency required to predict minimum Table VIII score of 700 for crews with various "years of military service" and two levels of "TC vision."

Predicting COFT Hit Rate

Seven variables, listed in Table 15, correlated significantly with COFT Hit Rate. Four of the seven variables, all related to age or years of military service, correlated negatively with Hit Rate. As with Table VIII scores, younger gunners received higher scores on the CTGP than older gunners. Three variables correlated positively with COFT Hit Rate: gunner main gun engagement experience (from both offensive and defensive positions) and TC experience with emergency mode degraded gunnery. These seven variables were entered into a multiple regression algorithm to determine their joint ability to model COFT Hit Rate. (Missing data on three of the variables were estimated using the mean substitution technique.) The resulting prediction equation was highly significant, producing a Multiple $R = .85$ and $R^2 = .72$ ($F[7, 16] = 5.91$, $p = .0016$. The same variables also were entered into a stepwise routine to determine if all seven were needed in order to model COFT Hit Rate, and to observe the order in which they entered the prediction equation. The stepwise procedure selected three of the seven variables. Table 16 lists the predictors in order of their entry into the prediction equation. This combination of three variables accounted for almost two-thirds of the variance in COFT Hit Rate scores. The strength of the multiple relationship can be seen by regressing predicted scores upon actual Hit Rate scores and plotting the results (see Figure 10).

COFT Impact on Table VIII Scores

Timing of the CTGP. Table VIII scores for crews that were administered the CTGP 30 days before AT (N = 10) did not differ from those taking the test 1 day prior to AT (N = 14). F ratios for Table VIII total score, total day score, and total night score were all < 1.

Presence versus absence of the CTGP. Twelve crews shot Table VIII without benefit of prior CTGP testing (No COFT crews). When Table VIII scores for these crews were compared with scores for the 24 crews that were administered the CTGP (COFT crews), an ANOVA indicated that night scores differed significantly, $F(1, 34) = 8.74$, $p < .01$. *COFT* and *No COFT* crews differed significantly on two of the four individual night engagements. Means and F ratios for night engagements are presented in Table 17.

Other ANOVAS comparing COFT and No COFT crews revealed significant differences on both TC and Gunner variables. COFT TCs were significantly older (34.5 years versus 29.0 years; $F[1, 34] = 6.48$, $p < .05$), had more years of active army background (2.4 years versus 0.2 years; $F[1, 34] = 5.69$, $p < .05$), and had served fewer years in the RC (6.0 years versus 9.3 years; $F(1, 34) = 4.58$, $p < .05$). None of these TC variables, however, correlated with Table VIII night scores. Gunners in the two

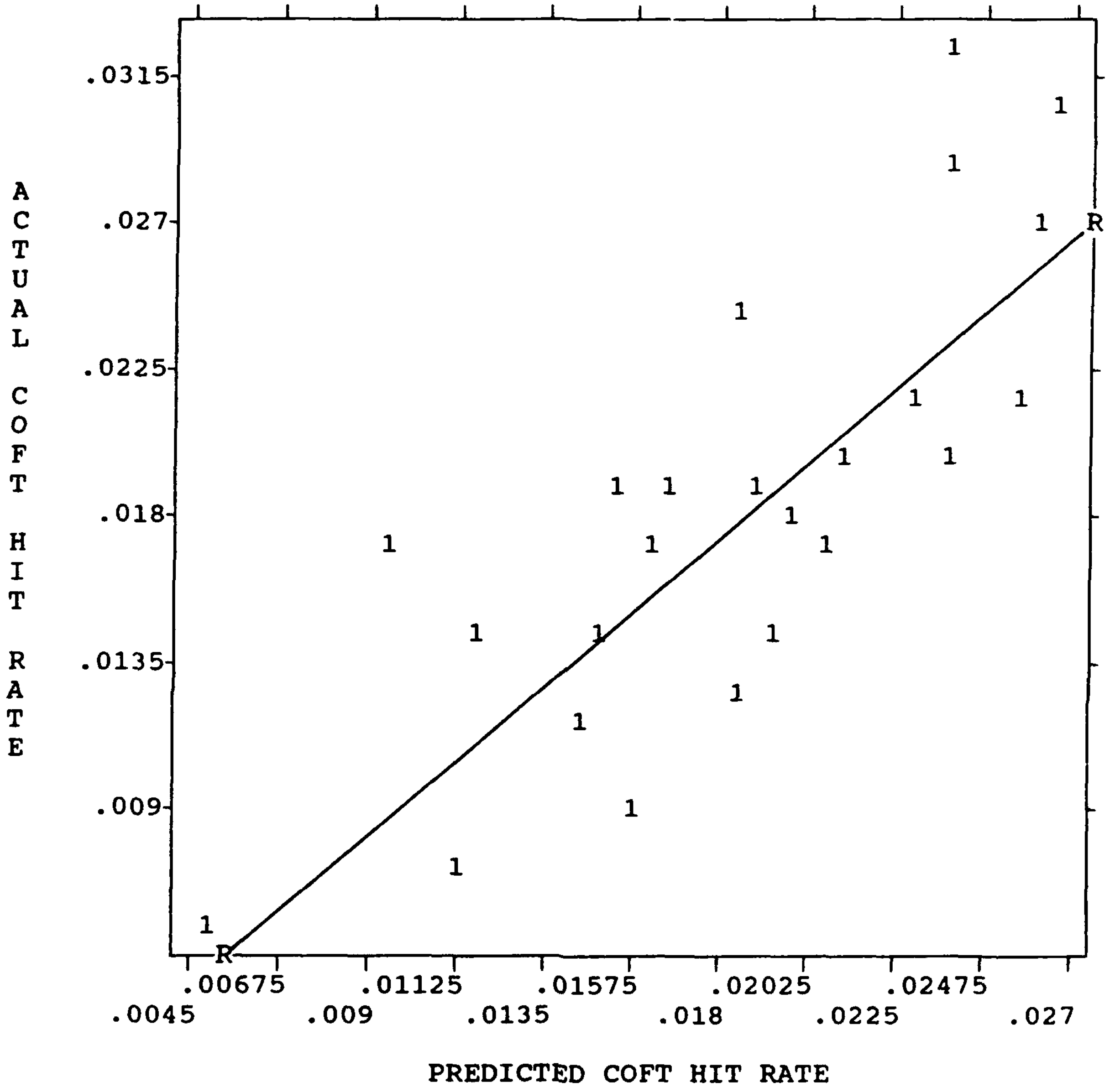

Figure 10. Plot of predicted and actual COFT Hit Rate scores (N = 24; r = .80; p < .0000). Predicted COFT Hit Rate = .024514 + [-.000443 x gunner's age] + [-.001676 x "crew years of service in the Active Army] + [.002311 x "gunner's main gun engagement experience"]. "Crew years of service in the Active Army = [(TC years + gunner years)/2]. "Gunner's main gun engagement experience" was measured on a 5-point self-rating scale.

Table 15

Correlations Be[illegible]en Demographic Variable and COFT Hit Rate

Variable	*r*	*p*	N
Gunners Age	-.60	.002	24
Gunners Years of Military Service	-.56	.005	24
Gunners Main Gun Engagement Experience (Offensive Position)[1]	.53	.013	21
Gunners Main Gun Engagement Experience (Defensive Position)[1]	.52	.015	21
Crew Years of Military Service[2]	-.46	.024	24
Crew Years in Active Army[2]	-.44	.033	24
TC Experience with Emergency Mode Degraded Gunnery[1]	-.43	.050	21

Note. All probability levels are based on two-tailed tests.
[1]5-Point scale (self-rated).
[2]([TC years + gunner years]/2).

Table 16

COFT Hit Rate Stepwise Multiple Regression Predictors

Variable	Multiple R	R^2	*F*	df	*p*
Gunner's Age	.60	.36	12.41	(1, 22)	.0019
Crew Years in Active Army[1]	.74	.55	12.87	(2, 21)	.0002
Gunner's Main Gun Eng Exper (Offensive Position)[2]	.80	.64	11.90	(3, 20)	.0001

Y = .024514 - .000443299(Gunner's Age) - .001676(Crew Years in Active Army) + .002311(Gunner's Main Gun Engagement Experience)

[1][(TC years + gunners years)/2].
[2]5-point scale (self-rated).

Table 17

Mean Table VIII Night Engagement Scores for "COFT Crews" and "No COFT Crews"

Group		Night Engagement # 1	2	3	4	Total
COFT Crews	(N=24)	24.5	18.6	29.9	66.5	139.5
No COFT Crews	(N=12)	8.6	21.3	9.3	24.2	63.4
	ANOVA *F*	2.0	< 1	4.5	7.5	8.7
	p	ns	ns	<.05	<.01	<.01

groups had similar mean ages (29.8 years for COFT versus 29.3 for No COFT), but COFT crews had fewer years of active army experience (0.3 years versus 2.7 years), $F(1, 34) = 9.14$, $p < .01$. Gunner's years in the active army correlated significantly with Table VIII night score, $r(36) = -.34$, $p < .05$.

Discussion

Because the COFT device simulates a broad spectrum of M1 tank components and engagement condition parameters (Campshure, 1991), it is not unrealistic to expect that crew performance on the COFT should correlate with Table VIII scores. Yet this has been difficult to document. Even in instances where positive correlations have been reported, they were weak (e.g., Campshure and Drucker, 1990).

This investigation provided insight into conditions under which the relationship between COFT proficiency and Table VIII scores can be demonstrated. The relationship was convincingly demonstrated in the present research only when two conditions were met: 1) COFT proficiency was indexed by the Hit Rate metric, and 2) Hit Rate was based upon a broad sample of COFT engagement conditions (the CTGP: a total of four carefully selected and emendated exercises selected to represent Table VIII conditions, requiring slightly over 1 hour, administered according to a standardized set of instructions; Hoffman and Witmer, 1989).

Reference to Table 2 in the results section will reinforce the conclusion that COFT-to-Table VIII correlations depend critically upon which COFT scores are collected. If the present investigation had depended on any single COFT exercise, conclusions would have differed. If only Exercise No. 4 (31563) had been collected, the conclusion would have been that COFT performance and Table VIII scores are unrelated. Consistent with most past research, individual COFT measures showed little relationship with live-fire gunnery performance. Although difficult to administer and laborious to score, the Hoffman and Witmer (1989) CTGP (or some reasonably equivalent selection of exercises administered under rigorously standardized instructions) is highly recommended in future COFT research.

Other conditions may have influenced the robust correlation between COFT and Table VIII. On the criterion side of the prediction equation, dispersion of Table VIII scores may hold part of the key. Truncation of range is a well known suppressor of statistical relationships, and some Table VIII data reported in previous research may have embodied this characteristic. For example, Hoffman (1989) reported that 95.5% of the crews at Grafenwoehr passed Table VIII (and hence their scores were truncated between 700 and 1,000). Part of the robust COFT-to-live fire relationship that occurred in the present research may be attributable to the large amount of dispersion in Table VIII scores, which had a range of 644 and a standard deviation of 184. It is interesting to note that the only previous research to demonstrate a convincing COFT-to-Table VIII relationship (Campshure & Drucker, 1990) also reported robust Table VIII score dispersion (Range = 688; standard deviation = 153).

Table VIII scores in the present research were also similar to Campshure and Drucker (1990) in that both mean scores were under 700 (613 in Campshure & Drucker; 356 in the present research), with approximately equal dispersion above and below the mean. Although both means were depressed, relative to the expected qualifying score of 700, they differed by over 250 points. It is not known why scores were so depressed in the present research, but during debriefing sessions crews often blamed the range, especially the new computer-mediated features. It is possible that the new electronic scoring system influenced both mean level and internal consistency of the scores. (Both day/night and odd/even indexes of internal consistency were statistically significant.) By removing human judgment error, the electronic scoring system may not have left much, but what it did leave may have been highly reliable. Nevertheless, the current findings are suspect because they are based on atypically low Table VIII scores. Future research should probe the impact of electronic scoring systems on Table VIII data.

Future research also should explore which combinations of COFT exercises most reliably predict subsequent Table VIII performance. Although Hit Rate scores from four exercises in the present research predicted Table VIII performance, the vast majority of predictive utility came from only two of the exercises. It is possible that a better combination of four exercises might be selected. In any event, care should be taken to avoid the pitfall of over-reliance on any single exercise. Because of the complexity of Table VIII performance, COFT prediction measures must encompass a broad array of specific simulation behaviors. Specific measures of COFT performance from one exercise do not reliably correlate with the same measures taken from other exercises. The individual measures, however, do correlate reliably with a composite measure based on several exercises. For these reasons, it seems prudent to base future investigations of the COFT-to-live-fire relationship on the broadest possible sample of COFT exercises. Future research might probe the effect of expanding the sample base from four exercises to six, or even eight.

Stability of the COFT-to-live fire gunnery relationship is another topic worthy of future research. In the current research, the relationship was almost as robust when the two measures were separated by 30 days as when they were separated by 1 day. Nothing is known, however, about intervals greater than 30 days.

Although COFT Hit Rate was the best predictor of Table VIII scores, the prediction equation was enhanced significantly by addition of three other variables. Given the predominant importance of optical devices in modern tank gunnery, it was not surprising to discover that TC vision plays some role in performance outcomes. The magnitude of its influence, however, (especially on night engagement scores) was surprising. The importance of these results, if they are replicable, is hard to overemphasize, especially because the measurement of visual acuity in the present research was rudimentary. If measured more precisely, this variable could have been even more important. The topic is deserving of further research.

Gunner's age was inversely related to Table VIII scores, and even more strongly related (also inversely) to COFT Hit Rate. The influence of gunner's age was also seen in the non-linear impact of crew years of military service. The best crew combinations consisted of young gunners and highly experienced TCs with perfect vision. If both TC and gunner were young and inexperienced, Table VIII scores suffered. Otherwise, TC age and years of experience made little difference. Tank commanders in some of the best crews were over age 40. An older gunner, however, was the "kiss of death," regardless of the TC's vision or other capabilities. Although this conclusion is unavoidable, given the strength of the observed relationships, it was not expected and it is not readily explicable. While it seems reasonable that faster reaction time and better vision would be associated with youth, it seems equally tenable that advantages of experience and possibly superior judgment in ambiguous circumstances would favor age. This is another area which deserves closer scrutiny.

The strong multiple correlation between the combination of COFT Hit Rate, TC vision, and crew years of military service permitted development of cut scores, or specific COFT Hit Rate objectives. If the prediction model proves to be valid, COFT scores can be used to predict the probability of Table VIII qualification. Perhaps of even greater practical importance, the model will permit identification of crews most in need of intensive remedial practice prior to Table VIII. A reliable prediction model between simulator scores and Table VIII scores will smooth the transition to device-based training strategies. Based on the present research, it seems that such a model is possible. The present research, however, must be replicated in all essential details, with different tank crews, before that model can be offered for practical use. This is especially important because of the low observed Table VIII scores. The model should be viewed as demonstrative in nature. It demonstrates how COFT Hit Rate and demographic variables can be used to facilitate transition to a device-based training regimen. It is imperative, however, that the model be validated with additional data before it is used as the basis for any policy decisions.

The CTGP was constructed specifically for diagnostic purposes. The test is not intended as a training device. Hence it was not surprising that Table VIII scores for crews receiving the test differed little from comparison crews in the same battalion that did not take the test. The differences that emerged were on night engagements. It will be recalled that the CTGP contains one exercise of night engagements. Hence, it may be possible that the CTGP, per se, enhances a crew's ability to deal with night tank gunnery engagements. The effect, however, was weak, and COFT versus NO COFT crews also differed on one gunner variable (number of years in the Active Army) that was significantly correlated with Table VIII night scores.

In conclusion, there does seem to be a robust COFT-to-Table VIII relationship, at least when COFT proficiency is assessed with a composite measure like Hit Rate from the CTGP (Hoffman and Witmer, 1989) and Table VIII scores embody a large degree of dispersion. Other demographic variables enhance the Table VIII prediction equation. The combination of predictor variables can be used to construct COFT cut scores, or training objectives. Once these objectives are met, a crew will have a specifiable probability of qualification on Table VIII. More research is needed to pinpoint conditions under which these predictive relationships can and cannot be replicated.

Recommendations

Recommendations based on the conduct and results of this research are to:

1. Conduct variations on the present research to establish conditions under which the results generalize, with close attention to Table VIII score distributions and range conditions.

2. Develop a normative data base on Table VIII scores, to include basic reliability coefficients (test-retest and internal consistency).

2. Employ Hoffman and Witmer's (1989) Hit Rate, based upon the unabridged CTGP (or some reasonably equivalent selection of exercises), as the composite index of COFT proficiency. Regardless of the particular sample of COFT exercises, rigorously standardize the conditions of administration.

3. Consider expanding the sample of exercises beyond the four recommended for the CTGP, in order to explore which combinations of exercises most reliably predict subsequent Table VIII scores.

4. Probe the relationship between gunner's age and Table VIII scores.

5. Clarify the role of TC vision in tank gunnery performance.

6. Examine the differential effect of COFT practice on Table VIII day and night scores.

The results of this research, although promising, are not suitable bases for revising training policy. The present research must be replicated in all essential details before policy implications can be derived, for the following reasons:

1. The prediction model was based on a small (N = 24) number of tank crews with atypically depressed (mean = 356) Table VIII scores.

2. Table VIII data were collected on a computer-mediated firing range with an electronic scoring system. The innovative range may have affected Table VIII scores in unknown ways.

3. Cut-scores discussed in the results depended upon extrapolation well beyond the observed range of data values.

4. Tank crews trained to higher performance levels on the COFT may (or may not) subsequently improve on Table VIII. That they should do so is a reasonable assumption, to the extent that

COFT simulates a broad spectrum of the domain of tank gunnery engagement behaviors (Campshure, 1991). It is, nevertheless, an empirical issue that in the best of circumstances subtly confounds the concept of correlation with that of causation, and in adverse circumstances may invite spurious "teaching to the test."

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Appendix A

Debriefing Questionnaire

1. Name ____________________

2. SSN ____________________

3. Rank ____________________

4. Unit Duty Assignment ____________________

5. Age __________

6a. How many years have you spent in military service? _____

6b. How many of your military years were in the Army Active Component? _____ (Round to the nearest year)

6c. How many of your years in the Army Active Component were in a tank related MOS or specialty area? _____ (e.g., 19 Series MOS - Round to the nearest year)

6d. How many of your military years were in the Army Reserve Component? _____ (Round to the nearest year)

6e. How many of your years in the Army Reserve Component were in a tank related MOS or specialty area? _____ (e.g., 19 Series MOS - Round to the nearest year)

Appendix B

Follow-up Questionnaire

1. Name ______________________________

2. Rank ______________________________ 3. Age ____

4. Do you have 20/20 vision without glasses or contact lenses?
   ___ Yes
   ___ No

   If no, do you wear glasses or contact lenses?
   ___ Yes
   ___ No

Throughout your military career, how much experience have you had with each of the following Armor crew-level activities? Rate your amount of experience on the tasks listed at the bottom of the page by circling a number from 1 to 5 that best tells how many times you have performed each task. Use the following scale:

1	2	3	4	5
Never	During 1 to 3 training events	During 4 to 6 training events	During 7 to 9 training events	During 10 or more training events

NOTE: A "training event" may be a Tank Gunnery Table, a Tactical Table, a GUARDFIST TRAINING session, an M-COFT training session, or some other gunnery exercise in which you practiced the task.

5. Perform prepare-to-fire checks	1	2	3	4	5
6. Acquire targets:					
Search during day with closed hatch	1	2	3	4	5
Search at night	1	2	3	4	5
Detect/locate/identify/targets	1	2	3	4	5
Evaluate situation	1	2	3	4	5
7. Engage single target with main gun					
Offensive precision gunnery	1	2	3	4	5
Defensive precision gunnery	1	2	3	4	5
8. Engage single target with coax	1	2	3	4	5
9. Adjust fire using re-engage technique	1	2	3	4	5

10. Engage multiple targets with main gun	1	2	3	4	5
11. Engage target: emergency degraded mode	1	2	3	4	5
12. Engage targets from gunner's position	1	2	3	4	5
13. Acquire targets: Evaluate situation	1	2	3	4	5

920810