Technical Report 590

A STUDY OF METHODS FOR ENGAGING MOVING TARGETS

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This research focused on two methods for engaging moving targets--tracking and trapping. Our interest was in determining the conditions under which either method would prove superior. It was hypothesized that a shooter's ability as well as the speed and range of the target may affect the outcome. All testing was accomplished on a M16A1 rifle marksmanship simulator which permitted the manipulation of the target's speed (velocity or duration) and range (apparent size). Following a 24-target pretest, the 24 subjects were evenly divided into high and low ability groups. All subjects then fired two

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additional 24-target sequences, being instructed to track and then trap targets or vice versa. Following testing, subjects were required to indicate their preference for either tracking or trapping. Neither method appears optimally suited for all individuals or for all targets. Trapping proved superior for low ability subjects and for the farthest (smallest) target moving at the slowest observed speed. Tracking proved superior for high ability subjects and for the closest (largest) target moving at the fastest observed speed. Subjects generally preferred to use the method producing better results.

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FOREWORD

The U.S. Army has devoted considerable effort to the development of its rifle marksmanship program. This program traditionally has focused only on the engagement of stationary targets. Attempts have been made to include training on moving targets, and for good reason. Moving targets are the type most frequently encountered on the battlefield and are more difficult to hit than stationary targets. Until recently, however, these attempts have been frustrated by a lack of suitable range facilities.

Now that the Army is testing range facilities that include moving targets, more attention is being given to the problems associated with training soldiers to shoot these targets. Considerable subject matter expertise already exists within the Army Marksmanship Unit's Running Target Branch. And, the Army Research Institute's Fort Benning Field Unit has mounted a research effort to facilitate the development of new and better training methods and materials. This research was carried out as part of that effort.

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A STUDY OF METHODS FOR ENGAGING MOVING TARGETS

BRIEF

Requirement:

This research focused on two methods for engaging moving targets--tracking and trapping. Tracking involves moving the muzzle of the weapon with the target. Trapping involves holding the muzzle slightly in front of the target and waiting for it to pass through the aiming point. Our objective was to determine the conditions under which either method would prove superior. Independent variables of main interest were shooting ability, target speed and range. It was hypothesized that low ability shooters perform better trapping, while high ability shooters perform better tracking. No specific hypotheses were advanced relating to the effect of target speed or range on tracking and trapping.

Procedure:

All testing was done on the Moving Target Rifle Marksmanship Trainer, a prototype marksmanship training device which simulates the live-fire conditions of the M16A1 rifle. The 24 subjects first completed a questionnaire designed to assess their previous marksmanship experience. They then zeroed the weapon and fired a pretest involving a sequence of 24, single-target presentations. Each target was seen at one of four simulated ranges--50, 100, 150, or 250 meters--moving from right to left at a simulated speed of either 1 or 3 meters per second. Subjects were divided into two groups of 12 based on a median split of their pretest scores. All subjects then were required to shoot two additional 24-target sequences. Half the subjects having high pretest scores were instructed to track all targets during the first sequence and to trap all targets in the second sequence. The other half received the opposite instructions. This also was true for subjects having low pretest scores. Performance data (hit or miss) and method data (track or trap) were recorded following each shot. Following testing, subjects were required to indicate their preference for either tracking or trapping.

Findings:

(a) Subjects performed better when targets were moving 1 meter per second than when they were moving 3 meters per second.

(b) High ability subjects performed better than low ability subjects, although this effect appeared more pronounced when targets were moving 3 meters per second than when they were moving 1 meter per second.

(c) Performance declined across all simulated ranges. This was true under both speeds, but less evident when targets were moving 3 meters per second. At this faster rate, performance at the closer ranges suffered disproportionately relative to performance at the longer ranges.

(d) Trapping proved the superior method for low ability subjects and for the 250-meter target, the farthest (smallest) target moving at the slowest observed speed. Tracking proved the superior method for high ability subjects and for the 50-meter target, the closest (largest) target moving at the fastest observed speed.

Utilization:

These results would argue for a flexible approach toward training individuals to engage moving targets. That is, individuals should be informed about both methods and permitted to try them both. High ability shooters are likely to be biased initially toward tracking, while low ability shooters are likely to be biased toward trapping, biases that will result in superior performance for both groups.

This research also suggests that snipers, shooters of exceptionally high ability, would perform better trapping targets moving slowly at ranges beyond 250 meters. These shooters may be predisposed initially to track these targets, even though these targets are easier to hit trapping.

Overall, if one method were emphasized during training, it should be tracking. The reason this method is favored is because moving targets of primary concern tend to be closer, faster moving targets. This concern was reiterated in the planning of the Infantry Remoted Target System (IRETS) ranges which include moving targets at five ranges, all well inside 250 meters (i.e., 15, 35, 75, 125, and 185 meters).

A STUDY OF METHODS FOR ENGAGING MOVING TARGETS

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INTRODUCTION

This research focused on two methods for engaging moving targets--tracking and trapping. Tracking involves moving the muzzle of the rifle at a rate that more or less matches the rate of the target. The shooter then attempts to fire the moment the target is in proper relation to the sights, or a correct "sight picture" is obtained. Trapping involves holding the muzzle slightly in front of the target and firing the moment the target passes through the aiming point. While tracking involves continuous motor output and error nulling (e.g., Adams, 1961), trapping depends on anticipatory timing (e.g., Schmidt, 1968).

Our objective was to identify the conditions under which either method (tracking or trapping) would prove superior. Independent variables of main interest were shooting ability, target speed and range.

It was hypothesized that method interacts with shooting ability. Low ability shooters usually find it difficult maintaining muzzle control, and this problem is exacerbated by target motion. Trapping should be easier for these shooters because it entails little muzzle movement and can be accomplished with external body and weapon supports. In contrast, high ability shooters are likely to perform better tracking. The movement of the muzzle with the target should afford them more time to achieve the desired sight picture.

No specific hypotheses were advanced relating to the effect of target speed or range on tracking and trapping. Tracking accuracy is known to be inversely related to the velocity of the stimulus (e.g., Noble, Fitts, & Warren, 1955; Noble & Trumbo, 1967). Similarly, timing accuracy has been reported to depend on the duration of the stimulus (Alderson & Whiting, 1974; Shea, Krampitz, Tolson, Ashby, Howard, & Husak, 1981), which is related to (and frequently confounded with) its velocity (e.g., Wrisberg & Hardy, 1979). Both tracking and anticipatory timing also must depend on the size of the stimulus or target zone, since the size of the stimulus or target zone will affect the precision of the tracking or timing response required to achieve errorless performance (e.g., Poulton, 1969). However, no evidence was found to suggest that either method may hold an advantage against a particular class of stimuli, that is, stimuli representing a particular speed or size. This research varied targets' speed and range (apparent size) to test this possibility.

METHOD

Subjects

The subjects were 24, right-handed, right-eyed males (n = 17) and females (n = 7) employed at Fort Benning, Georgia. Nineteen were civilians, and five were military personnel. The median subject's age was 30 years, and the range was 28 (18 - 46) years. Twelve subjects were assigned to both High- (H) and Low- (L) ability groups, with approximately half the males and half the females being assigned to each group. Six of the subjects in Group H and one subject in Group L reported having experience shooting moving targets. All subjects were treated individually. Participation in this experiment was voluntary.

Apparatus

All testing was done using the Moving Target Rifle Marksmanship Trainer, a prototype marksmanship training device manufactured by Spartanics Ltd, Rolling Meadows, Illinois. This training device, which appears as Figure 1, includes three major subassemblies. These are the rifle, target assembly, and console.

The rifle is a nonrestorable M16A1 which is loaded and fired in the same way as the standard service rifle. Recoil is simulated by the operation of a recoil rod which attaches to the barrel of the rifle. The sound of the rifle is transmitted through a headset.

The target assembly houses a scaled 250-meter zeroing target and scaled 50-, 100-, 150-, and 250-meter "E-type" silhouette targets. Each "E-type" target was scaled to represent the 14-inch (35.56 cm) wide by 34-inch (86.36 cm) high head and torso of a man. These targets may be programmed to appear stationary or to move laterally, right-to-left or left-to-right, at simulated speeds of 1, 2, or 3 meters per second.

The console contains the control panel, a video display, and a printer.

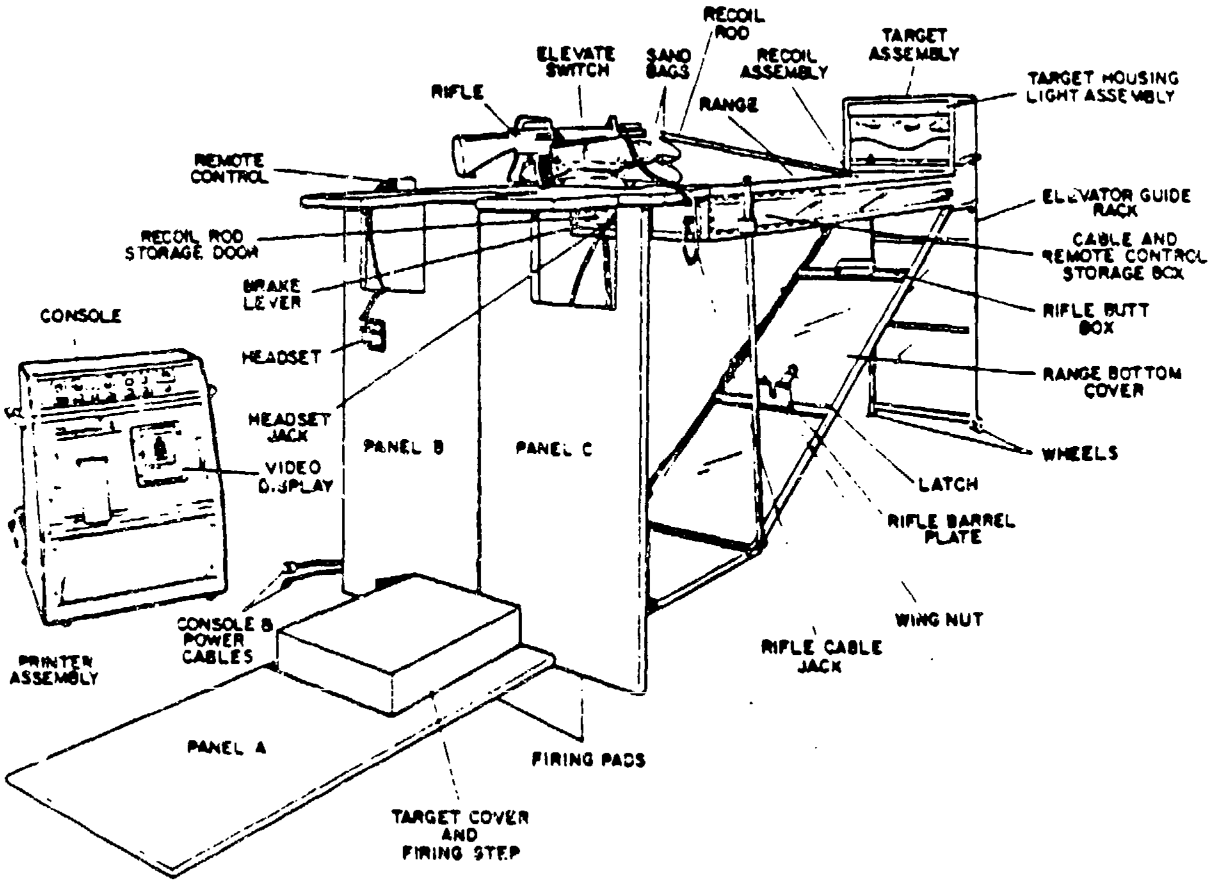

Figure 1. Moving Target Rifle Marksmanship Trainer

The control panel has the dials and pushbuttons which energize and operate the various features of the device. The video display shows the shooter's aiming point which appears as a dot, or ball of light, and the location of hits and misses up to 32 shots. A unique aspect of the video display is the replay feature. When activated, a replay shows the movement of the rifle (aiming point) 1 second prior to firing. It makes it easy to diagnose shooting problems (e.g., trigger jerk, unsteadiness) or to identify a shooter's method of target engagement (e.g., tracking; trapping). A voice synthesizer operates in conjunction with the video display to provide the shooter information about shot location. Misses and off-center hits are indicated by separate tones (miss: low tone; hit: high tone) and a voiced direction (e.g., "high-left"); center hits are signaled only by a high tone. The printer is available to provide printouts of shooters' performance.

Design and Procedure

On entering the test roc , each subject filled out a questionnaire designed to assess his or her marksmanship experience, particularly experience engaging moving targets. This questionnaire also permitted the collection of some demographic data on our sample (e.g., age, sex). After completing this questionnaire, the subject was told to assume a comfortable foxhole firing position and was provided a sandbag to enable him or her to support the nonfiring hand and rifle. The experimenter then presented the scaled, 250-meter zeroing target and had the subject fire as many three-round shot groups as necessary to zero the weapon. No subject required more than six shot groups to zero. The headset was not used, primarily, to facilitate better communication between the experimenter and the subject.

The pretest involved a sequence of 24, single-target presentations, the subject firing one shot with each presentation. Each target was seen at one of four simulated ranges--50, 100, 150, or 250 meters--moving right to left at a simulated speed of either 1 or 3 meters per second. Targets simulating the same range and speed were presented in the same 3-trial block. Blocks always were presented in the same random order.

Prior to each 3-trial block, subjects were shown an example of the targets to be seen. Subjects also were shown how to lead the targets. For example, prior to the first block (50-meter target moving 1 meter per second), the experimenter showed the subject a drawing depicting the back corner of the front sight post against the center of the target. Prior to the next block (150-meter target moving 3 meters per second), the experimenter showed the subject a drawing depicting a gap between the target and the front sight post equal to about one-half the width of the front sight post, and so on. Subjects were not instructed how to engage moving targets or told anything relating to tracking or trapping.

Using the replay control, the experimenter recorded the method employed by the subject in engaging each target (track, trap, unknown) and whether the shot resulted in a hit or a miss. The voice synthesizer provided the subject shot location information following each shot.

On establishing the subjects' median pretest performance, the experimenter divided the sample into two groups of 12. All subjects then were required to shoot two additional sequences of 24, single-target presentations. Ranges and target speeds were identical to the pretest; only the arrangement of 3-trial blocks changed randomly across sequences. Six subjects in Group H were assigned randomly to the Track/Trap (K/P) condition; the other six were assigned to the Trap/Track (P/K) condition. Similarly, six subjects in Group L were assigned randomly to the K/P condition; the other six were assigned to the P/K condition. Subjects in the K/P condition were instructed to track all targets during the first sequence and to trap all the targets in the second sequence. Subjects in the P/K condition received the opposite instructions. Instructions to track or to trap targets were given immediately before each of the latter sequences. Instructions included definitions of the terms tracking and trapping but did not cue the subject as to how either method could best be accomplished. Otherwise, the procedures used during these sequences were identical to those used during the pretest.

On completing the experiment, each subject filled out a second questionnaire. This questionnaire required subjects to indicate their preference for either tracking or trapping and to outline the reasoning behind their preferences.

RESULTS

During the pretest, a hit was counted when a shot landed within the target, regardless of method used. During the next two sequences, a hit was counted only when a shot landed within the target and the subject used the instructed method.

Hit data were submitted to a 2 X 2 X 2 X 2 X 4 mixed factorial analysis of variance in which Ability (2) and Condition (2) were between-subjects variables and Speed (2), Method (2), and Range (4) were within-subject variables. Cell scores for this analysis were the mean numbers of hits out of the three possible within each block.

Subjects generally performed better when targets were moving 1 meter per second ($M = 2.28$; $SD = .66$) than when they were moving 3 meters per second ($M = 1.56$; $SD = .84$), $F(1, 20) = 103.99$, $p < .05$. The overall performance of subjects in Group H ($M = 2.14$; $SD = .70$) also was better than that of subjects in Group L ($M = 1.70$; $SD = .80$), $F(1, 20) = 8.16$, $p < .05$, although a significant Speed X Ability interaction, $F(1, 20) = 8.19$, $p < .05$, revealed that the effect of ability was more pronounced when targets were moving 3 meters per second than when they were moving 1 meter per second.

Performance declined across all simulated ranges, $F(3, 60) = 39.47$, $p < .05$. This was true under both speeds, but less evident when targets were moving 3 meters per second. At this faster rate, performance at the closer ranges suffered disproportionately relative to performance at the longer ranges. This effect was indicated by a marginal Speed X Range interaction, $F(3, 60) = 2.56$, $.05 < p < .10$. The means and standard deviations for targets moving 1 meter per second at 50, 100, 150, and 250 meters were as follows: $M = 2.83$, $SD = .32$; $M = 2.58$, $SD = .62$; $M = 2.08$, $SD = .87$; $M = 1.63$, $SD = .82$. The means and standard deviations for targets moving 3 meters per second at the same respective ranges were as follows: $M = 1.79$, $SD = .88$; $M = 1.83$, $SD = .87$; $M = 1.56$, $SD = .77$; $M = 1.04$, $SD = .86$.

The main effect of Method failed to achieve significance, $F(1, 20) < 1$, $p > .05$. However, Method interacted with Speed, indicating that targets moving 3 meters per second were easier to hit tracking, while targets moving 1 meter per second were easier to hit trapping, $F(1, 20) = 7.84$, $p < .05$. On closer inspection, this effect was found localized at the 50- and 250-meter ranges and was indicated by a significant Speed X Range X Method interaction $F(3, 60) = 2.87$, $p < .05$. This interaction is shown in Figure 2. When the 250-meter target was moving 1 meter per second, subjects showed a clear advantage trapping, $F(3, 60) = 9.99$, $p < .05$. In contrast, when the 50-meter target was moving 3 meters per second, subjects showed a similar advantage tracking, $F(3, 60) = 3.92$, $p < .05$.

Interestingly, the pretest data showed that most subjects were not predisposed initially to trap the 250-meter target when it appeared moving 1 meter per second. Subjects in Group L trapped this target on 33.3% of the trials, whereas subjects in Group H trapped it on only 22.2% of the trials. Also, when the 50-meter target appeared moving 3 meters per second, subjects in Group H tracked it on 83.3% of the trials, but subjects in Group L tracked it on only 47.2% of the trials. Apparently, subjects did not recognize that a more efficient method existed or chose to ignore it having once adopted a particular method.

The effect of Method also interacted with Ability, $F(1, 20) = 9.10$, $p < .05$. As shown in Figure 3, subjects in Group H showed an advantage tracking over trapping, $F(1, 20) = 6.32$, $p < .05$, whereas subjects in Group L showed an advantage trapping over tracking, $F(1, 20) = 2.97$, $.05 < p < .10$. This

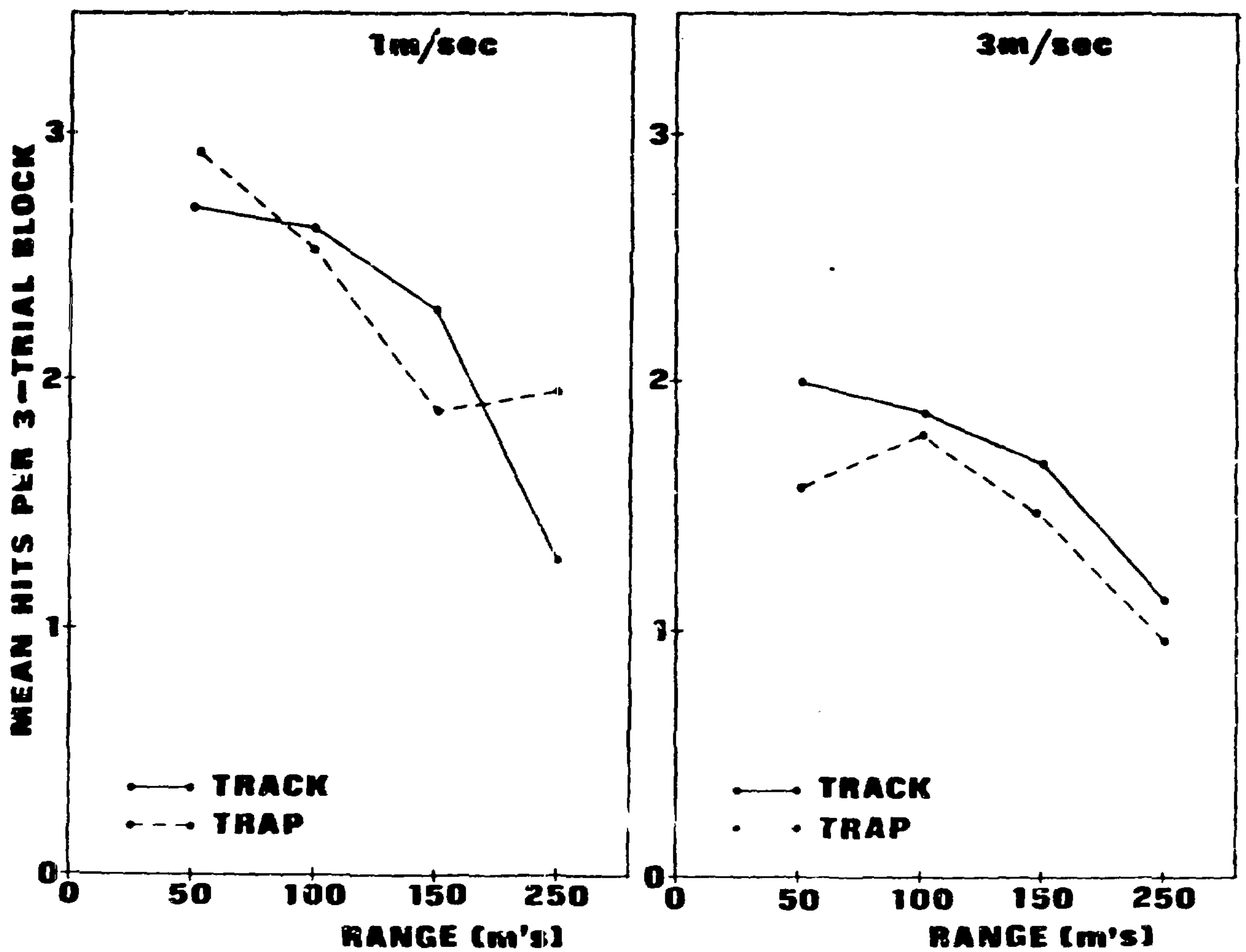

Figure 2. *Speed X Range X Method Interaction*

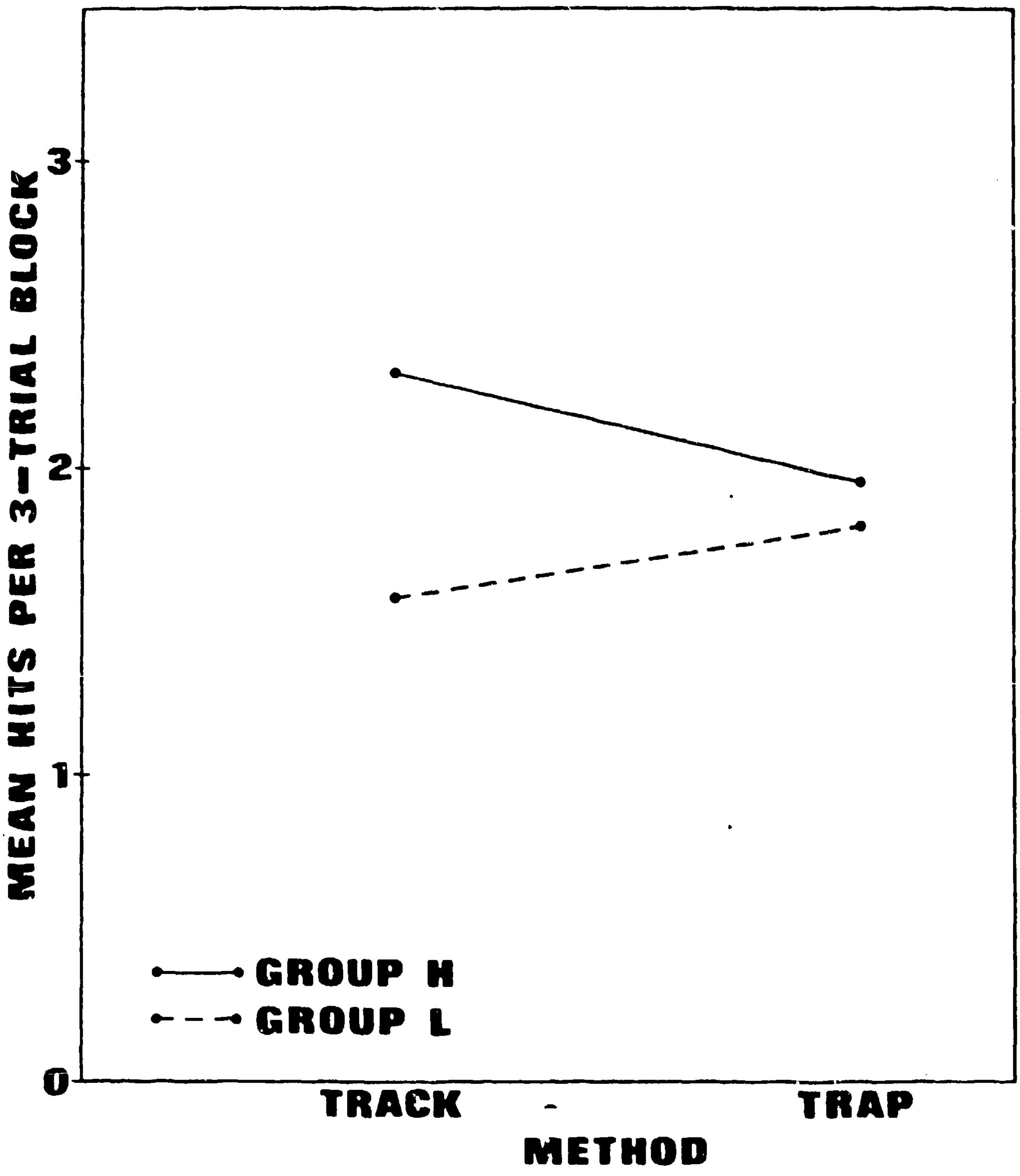

Figure 3. Ability X Method Interaction

observation is consistent with at least three other observations made during the course of this experiment:

(a) During the pretest, subjects in Group H showed a strong preference for tracking, tracking 80% of the targets presented. This effect was not apparent among subjects in Group L, who tracked 49% of these targets.

(b) During testing, when asked to track, subjects in Group H complied on all trials; subjects in Group L failed to comply on 8.7% of the trials. When asked to trap, subjects in Group H failed to comply on 3.1% of the trials, but subjects in Group L failed to comply on only 1.4% of these trials.

(c) Following testing, when asked to select their preferred method for engaging moving targets, 83% of the subjects in Group H chose tracking, while 75% of the subjects in Group L chose trapping. Half the subjects in Group H indicated that they preferred tracking because this method gave them more time to adjust their aim. In contrast, most subjects ($n = 7$) in Group L indicated that they preferred trapping because this method made it easier for them to maintain a balanced or stable position.

The effect of Condition (KP versus PK) did not achieve significance, $F(1, 20) = 1.00$, $p > .05$, but this variable did interact with several other variables. When trapping, KP subjects generally performed worse at 150 and 250 meters than subjects in the PK condition, $F(3, 60) = 2.41$, $.05 < p < .10$. Subjects in the KP condition also performed worse at the faster target speeds than subjects in the PK condition, $F(1, 20) = 5.86$, $p < .05$. Furthermore, the higher-order interaction of Condition with Method, Ability, and Speed indicated that this effect was most dramatic when Group H subjects were instructed to trap and Group L subjects were instructed to track $F(1,20) = 12.41$, $p > .05$. This suggests that subjects in the KP condition were not as proficient as subjects in the PK condition, having more difficulty hitting targets presented at longer ranges, faster speeds, and when using a method other than their preferred method. Some evidence for this proposition comes from the pretest data. When these data (untied pairs, $n = 8$) were analyzed using a sign test, a difference in the performance of the two conditions was apparent, $z = 2.65$, $p < .05$. Given the above, and lacking a general theory, it seems most reasonable to attribute the effects of Condition to sampling error.

DISCUSSION

This research focused on two methods for engaging moving targets--tracking and trapping. It was hypothesized that low ability shooters perform better trapping, while high ability shooters perform better tracking. No specific hypotheses were advanced relating to the effect of target speed or range on tracking and trapping.

In fact, subjects in Group L shot better trapping, and subjects in Group H shot better tracking. Both groups also were biased in favor of using the method that yielded more favorable results. These biases appeared during the pretest in Group H, but more dramatically for both groups in response to the postexperimental questionnaire. As hypothesized, subjects in Group L indicated they preferred trapping because this method made it easier for them to maintain balance or stability when engaging targets; subjects in Group H indicated they preferred tracking because tracking afforded them more time to adjust their aim.

At 1 meter per second, only the 250-meter target, the farthest (smallest) target moving at the slowest observed speed, was significantly easier to hit trapping. At 3 meters per second, subjects tended to hit more targets tracking, but this effect was most apparent for the 50-meter target, the closest (largest) target moving at the fastest observed speed. These results suggest that trapping (anticipatory timing) is superior under conditions that require fine motor control (smallest target), given sufficient time is available to prepare a controlled response (slowest target). The increased control that subjects experienced trapping may be attributed to a decreased demand for movement coupled with an increased opportunity for using external body and weapon supports. In contrast, tracking appears superior under conditions that demand relatively less motor control (largest target) or that force the performer to respond under time pressure (fastest targets). Under these conditions, tracking appears to have the advantage because it affords subjects greater freedom of movement. While this freedom of movement comes at the expense of added control, it extends the time that is available to engage a target.

Overall, these results would argue for a flexible approach toward training individuals to engage moving targets. Tracking may be more effective than trapping or vice versa, depending on subjects' shooting abilities and targets' speeds and ranges.

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