SOME CRUCIAL PROBLEMS IN TRAINING TANK GUNNERY SKILLS

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ABSTRACT

Instructional systems development presents many problems for tasks that can be accomplished a variety of ways, and particularly for tasks containing unobservable processes. While unobservable processes are often ignored in instructional systems development, the way in which they are performed can have significant impact on operational performance. Evaluation of a tank gunnery trainer emphasized that considering only observable measures of performance when training gunners to engage moving targets was insufficient. The operational performance in hitting a moving target depends critically on the amount of lead applied. The correct amount of lead, in turn, depends on the target speed. There are, however, several different (unobservable) cognitive strategies for determining lead based on target speed. The current research demonstrates that the cognitive strategy selected for training will have a marked impact on operational performance, and that selection of a strategy to be trained rests on an understanding of underlying psychological processes.

BACKGROUND

The U. S. Army Research Institute at Fort Knox recently evaluated a conduct of fire trainer (COFT) for tank gunnery. The COFT simulated the fire control system of an M60A1, the U. S. Army's main battle tank, and could present the trainee with targets moving at any one of three different speeds.

The behavioral elements of moving-target gunnery technique were analyzed to help determine how training with moving targets should be conducted on the COFT. The analysis revealed that correctly leading moving targets was a critical skill in moving target gunnery.

The M60A1 fire control system does not automatically correct for target motion, so the gunner must manually lead the target to compensate for the distance that the target travels during the round's time of flight. Although the distance traveled by the target along its path is a direct function of both the target speed and range from the firing tank, leads expressed in an angular measure (in mils) are nearly invariant with target range. Hence, for each speed one can specify a value of lead in mils that will be effective regardless of range.

In order to select a lead, the target speed must be known. Without mechanical aids, the gunner must immediately estimate the speed of the target, and know how to relate speed to an appropriate lead value. Both the perceptual skill of speed estimation, and the cognitive skill involved in relating speed to lead are examples of critical, but unobservable processes. In the discussion which follows, the term strategy will refer to a combination of perceptual and cognitive processes used to select a given lead.

Several kinds of lead strategies have been proposed for engaging moving targets. The first, and simplest strategy, requires gunners to apply a standard lead (a different value for each ammunition) to all moving targets, regardless of speed. Current Armor doctrine indorses this strategy in FM 17-12-2, and a standard lead is given for each type of ammunition. The obvious strengths of a standard lead strategy are simplicity in training, and speed of firing the first round against a moving target. However, one must consider that a single lead covers only one small part of the speed range expected from targets on the modern battlefield. The lead specified by Army doctrine is optimal only for targets moving at approximately 10-12 mph; vehicles on the modern battlefield will certainly move at much higher speeds than this.

The second, and slightly more complex kind of strategy, requires gunners to categorize target speed into one of a number of possible speed bands and apply a different lead for each speed band.

Although a categorization strategy places more demand on the gunner than a single lead strategy, it has the potential to cover a range of target speeds much more effectively.

The third, and most complex kind of lead strategy, involves calculation of the amount of lead needed based on the estimated speed of a moving target. Bessemer and Kraemer (1979) recommended such a speed magnitude estimation strategy. Specifically, they recommended that gunners determine a target's speed in miles per hour, divide this speed by ten miles per hour, and multiply the result by a constant; the value of the constant depends on the ballistic characteristics of the ammunition used. Performance with this strategy would depend, of course, on how accurately observers could judge target speed in miles per hour. If observers could accurately determine a target's speed within a few miles per hour and perform the mental computations necessary, this strategy would be the most accurate of the three.

Clearly, the three strategies all involve some kind of speed discrimination, but differ in the demands each places on the gunner's perceptual system. A single lead strategy demands only that gunners be able to discriminate moving from stationary targets, a categorization strategy involving a small number of categories demands only that gunners make a few discriminations among broad categories, and a speed estimation strategy demands that gunners be able to estimate target speed fairly accurately along a continuum. While the complexity of the discrimination increases going from a single lead to a speed estimation strategy, the potential payoff in terms of target hits also increases, provided that gunners can make the perceptual discriminations each kind of strategy demands.

Since speed discrimination plays a fundamental part in all three lead strategies, the empirical research addressed observers' ability to judge the speed of targets in the COFT being evaluated. Because of the minimal demands of a single lead strategy, the experimenters did not collect empirical data on how well observers could discriminate stationary from moving targets, but concentrated on the speed discriminations demanded by the other two strategies.

METHOD

Subjects. Twenty-eight (28) trainees (25 gunners and 3 drivers) in the One Station Unit Training (OSUT) course at Ft Knox served as observers. Observers were assigned to two groups of 14 each. One group consisted of 13 gunners and one driver; the other consisted of 12 gunners and two drivers. Group assignment was counter-balanced based on the order in which observers came to the experiment. On the first day the first observer was assigned to Group A, and second to Group B, etc., and on the second day the first observer was assigned to Group B, and the second to Group A, etc.

Apparatus. A computer-controlled prototype conduct of fire trainer developed by Chrysler Defense Engineering was used to display moving targets. Figure 1 provides an artist's representation of the simulator's visual display. As Figure 1 shows, the COFT presented trainees with visual displays of a rectangular target that could move left to right or right to left. Observers viewed displays through an eyepiece like that of the primary sight of an M60A1 tank. The experimenter timed the duration of the visual displays with a hand-held stopwatch.

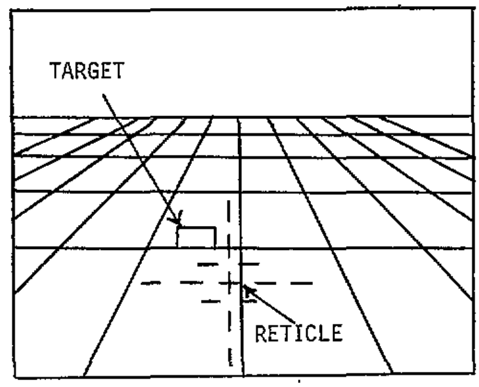

FIGURE 1. ARTIST'S REPRESENTATION OF COFT DISPLAY

Procedure. Each observer was tested individually. Observers sat in front of the simulator's gunner controls and adjusted the sight's focus while viewing the simulator's display of a stationary head-on target at a range of 1500 meters.

The experimenter told each observer that he would see some displays of moving, tank-sized targets and that his task was to judge each target's speed. Each of the two experimental groups received different specific instructions about judging target speed. The experimenter informed the first group (the Categorization group) that the targets would move across their field of view at either a slow, medium, or fast speed at various distances from them, and that they were simply to say on each trial whether the speed of the target was slow, medium, or fast. The second group (the Magnitude Estimation group) was told that the targets would move across the screen at different speeds and at different distances from them, and that on each trial they were to report to the nearest 5 mph how fast the target was moving.

At the beginning of each trial, the experimenter instructed the observers in both groups to look away from the eyepiece, and not to look into it until the experimenter said "go." The experimenter initiated the display and adjusted the reticle crosshairs so the horizontal line of the crosshairs was even with the bottom of the target, and the vertical line of the crosshairs was centered horizontally on the grid. When the target moved to the center of the grid, the experimenter said "go" and began timing the display, as the observer looked into the sight. After approximately five seconds, the display went off and the observer reported the target speed according to the instructions for his group. The experimenter recorded the observer's response and initiated the next trial. Because the target moved at different speeds, and therefore took different times to reach the center of the grid, the inter-trial interval was varied independently of the target speed. This prevented differences in inter-trial interval from serving as a cue to target speed.

Each observer judged target speed in four blocks of 18 trials each. Each block of 18 trials consisted of targets at one of three different ranges (1000, 1500, or 2500 meters), moving at one of three different simulated speeds (10, 15, or 25 miles per hour), and moving one of two different directions (left or right). Each possible combination of these variables occurred only once in a random sequence during each block.

During the first two blocks of 18 trials, observers received no information about the target range. During the second two blocks, the experimenter told observers the target's range before each trial to determine whether range information produced a sharp improvement in speed judgments.

RESULTS AND DISCUSSION

Speed Judgments. Speed judgments of the Magnitude Estimation group showed large inter-observer variability, and remained variable over all four blocks of trials. Figure 2 shows the speed judgment data of this group separated for trials on which observers received no range information, and trials on which observers did receive range information. The dotted diagonals in these figures indicate perfect performance. Before observers received range information, they underestimated target speed on the average. Average performance came closer to actual target speed after observers received range information, however, the extreme inter-observer variability in both cases discourages much discussion based on average performance. The large amount of variability in speed judgments agrees with that found in previous research (see Haglund and Torre, 1978).

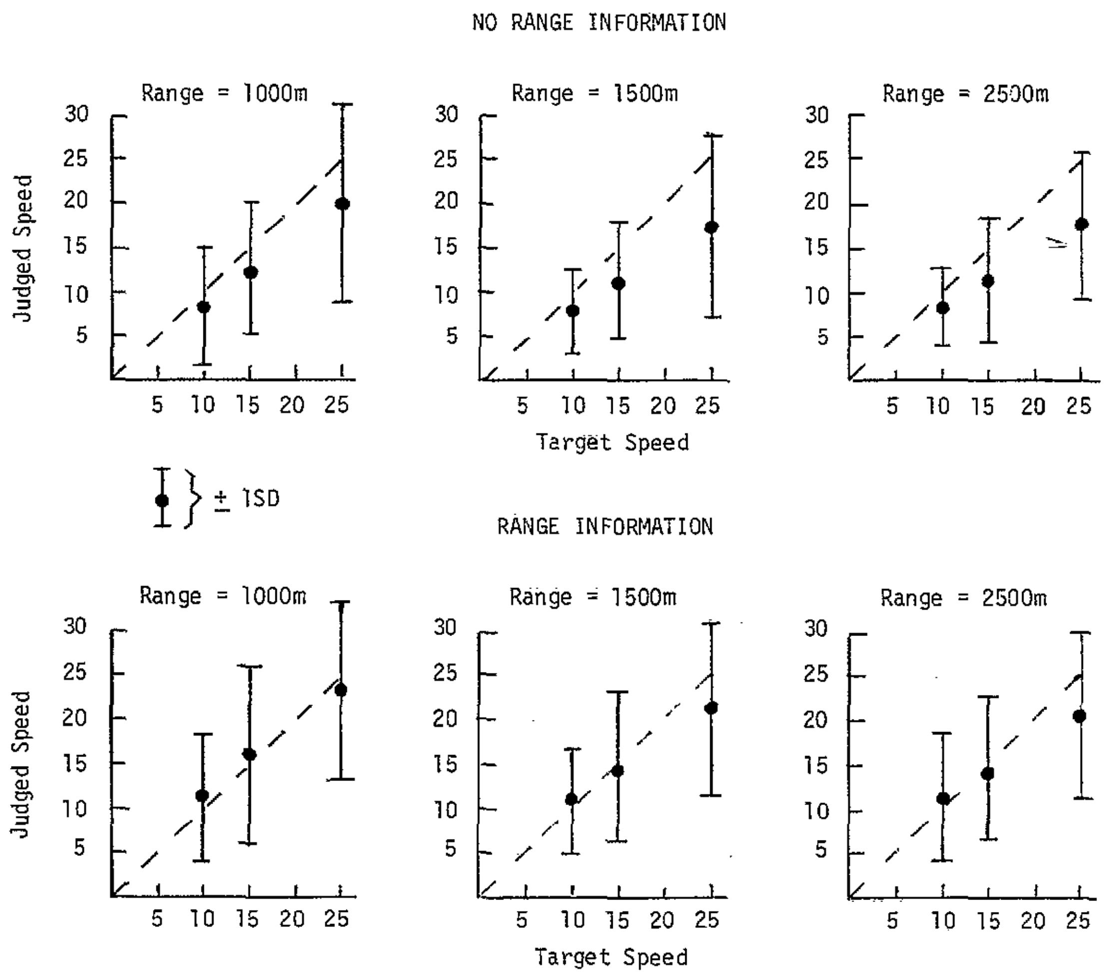

FIGURE 2. SPEED JUDGMENT DATA FOR SPEED MAGNITUDE ESTIMATION GROUP

Observers in the Categorization group identified target speed as either fast, medium, or slow quite well. Observers correctly categorized 76.3% of the target speeds before receiving range information, and correctly categorized 81.2% of the target speeds after receiving range information.

One cannot directly compare performance of the two groups, since the responses required from the two were qualitatively different. However, one can compare the performance of the two groups indirectly by using their speed judgments as input parameters to a model of tank gunnery. Inputting speed judgment parameters allows calculation of predicted hit probabilities and allows one to estimate the operational impact of different kinds of lead strategies.

Speed Judgment Data Applied to a Model of Tank Gunnery in the Simulator. Predicted hit probabilities for the simulator firing Armor Piercing Discarding Sabot (APDS) were *calculated for different hypothetical lead* strategies. It must be emphasized that the calculated hit probabilities are only for the device and would be much lower overall in any field tests of lead strategies; error factors such as zeroing, wind, weather conditions, etc., were ignored in predicting simulator hit probabilities. The predicted hit probabilities were also derived under the assumption that gunners would accurately adhere to each lead strategy.

Hit probabilities were calculated for (1) a single 2.5 mil lead strategy suggested by current Army doctrine, (2) a speed categorization strategy involving three speed categories, and (3) a speed magnitude estimation strategy, using parameters from the speed magnitude estimation group and assuming that gunners were only required to estimate target speed to the nearest five miles per hour. Hit probabilities for the speed categorization strategy were calculated from the empirical speed categorization data and assumed leads of 2.5, 5, and 7.5 mils for the three categories. To avoid any misunderstanding, it should be made clear that the leads used for the three categories are not the optimal leads for speeds of 10, 15, and *25 miles per hour; optimal leads for these* three speeds are approximately 2.5, 3.75, and 6.25 mils. The three leads selected for use in the model were selected because they are easily specifiable points on the M60A1 reticle and operationally would lead to smaller tracking errors than intermediate points. Because of the selection of these particular leads, the model was slightly conservative on predicting hits on targets classified as medium and fast speeds. Further details of the model and parameter estimation from the empirical data are presented elsewhere (Kottas and Bessemer, 1979).

Figure 3 shows the calculated hit probabilities for the three lead strategies as a function of target speed, combined over the three ranges at which speed estimation parameters were collected. Expressing speed judgment performance in terms of hit probabilities makes it clear that a categorization strategy would be the most effective for training gunners using the COFT that was evaluated.

The reason for the difference in performance between the two groups probably reflects the combined operation of two different phenomena. First, the difference almost certainly reflects the operation of an uncertainty effect. Recall that the Categorization group could make one of only three responses--slow, medium, or fast. The Magnitude Estimation group, on the other hand, could make any one of 11 different responses between 0 and 50 mph inclusive. The group estimating target speed in miles per hour was more uncertain about the stimulus that would occur (and hence which response they should make) and tended to use *a broad range of the responses available.* It was as if they tried to make finer discriminations of target speed than their cognitive or perceptual system allowed, and therefore their responses were highly variable. Limiting the number of allowable responses to three (for the Categorization group) avoided the large variability by restricting the fineness with which observers tried to make the speed discriminations.

A second, and related reason for the difference between the two groups may reflect the perceptual system's facility in processing relative information and inaccuracy in processing absolute information (see Gogel, 1977; Kottas, 1978). A major problem in making absolute judgments seems to be one of calibrating responses correctly, provided that the cues for ordering stimuli are available.

A similar approach can be applied to other gunnery problems, such as adjustment of fire. The primary technique for adjustment of fire is known as Burst-on-Target (BOT). BOT requires a gunner to observe the tracer's path or the burst produced when a round misses the target, and to change his aim point so the next round hits the target. *Clearly, this task has a large perceptual* component.

FM 17-12 specifies that in performing BOT the gunner relays on target after firing, notices the point of the sight reticle where the tracer or burst appears as the round passes by the target or impacts near it, and moves this point of the reticle to the center of mass of the target. Such a behavioral detailing of the BOT fire adjustment task fails to reveal the critical unobservable processes

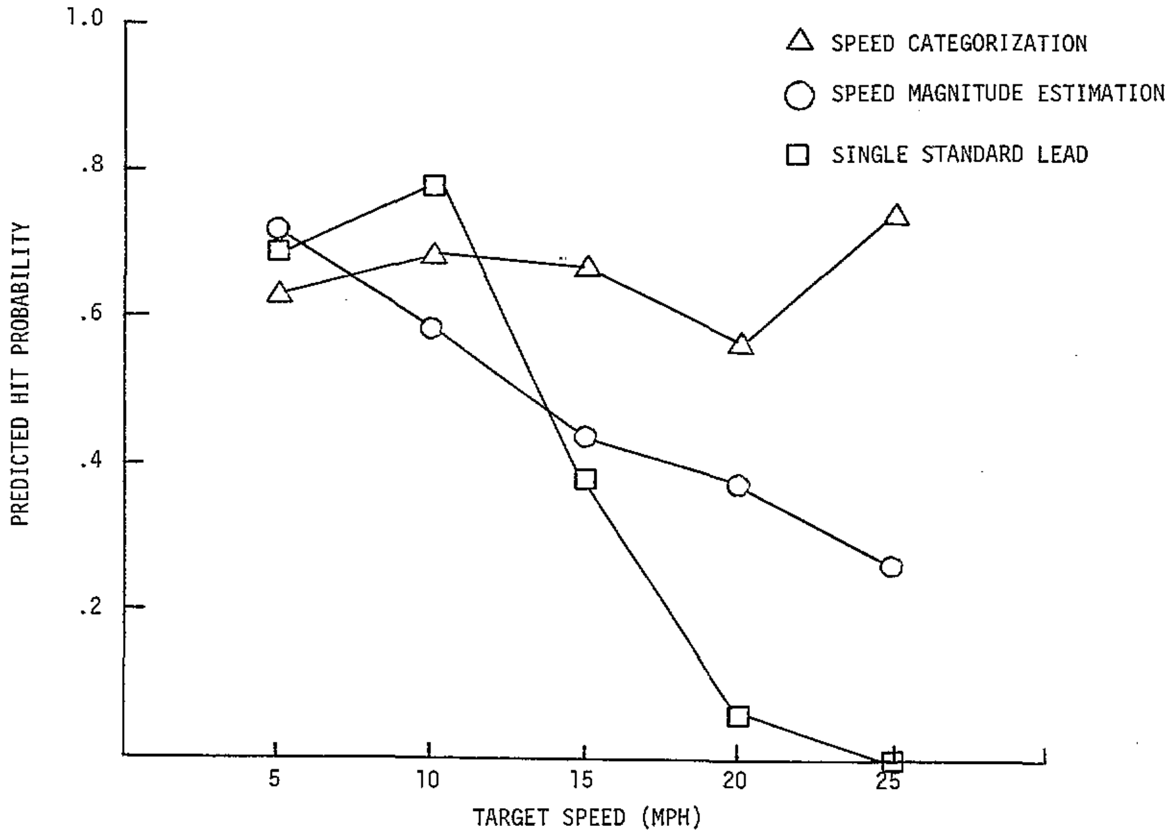

FIGURE 3. PREDICTED HIT PROBABILITIES OVER A RANGE OF TARGET SPEEDS

that might enable the gunner to perform these steps. Three different alternative procedures could be used: (1) a gunner could determine the distance and angle of the burst from the target and move the sight reticle a corresponding distance at a 180° angle from the burst, (2) a gunner could determine the distance of the burst or tracer from the target separately for the horizontal and vertical axes of the reticle, and move the reticle a corresponding distance along each axis, and opposite to the direction of deviation, or (3) a gunner could mentally place an aiming cross on the reticle at the point where the burst struck and simply move that imaginary aiming cross until it is centered on the target. The three strategies obviously have different cognitive and perceptual demands. The first strategy involves distance and angle estimation, the second involves distance estimation along two orthogonal axes, and the third involves the ability to fixate a point in the visual field and maintain that fixation relative to the reticle as it moves. An empirical investigation could assess the error involved in each of these processes for a sample of gunners, and the impact of these errors could be expressed operationally in terms of expected lay error or some other measure.

The kind of investigation described above does not directly address the problem of transfer of training. While it may increase the likelihood of transfer, it is not a substitute for a direct demonstration of the actual impact of the training approach on operational performance. Additional field research will be required to validate the training and transfer effectiveness of a lead strategy or a BOT strategy for tank gunnery. However, if a careful analysis such as the one described above is used in developing an instructional system for a simulator, one can be more confident of conducting a test of transfer that uses the fullest potential of the device.

The above research has implications for the design of training devices. The front-end analysis done in development of training devices typically stops with observable behaviors. The effectiveness of training could be markedly increased if devices are designed to train specific underlying skills rather than merely to simulate a task.

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