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MOTION PREDICTION AS A FUNCTION OF TARGET SPEED AND DURATION OF PRESENTATION [1]

EARL L. WIENER

University of Miami

This study investigated the ability of Ss to predict the future position of a moving target after the target disappeared. Target speed, duration of target exposure, and S's mode of responding to the visible target were varied. The performance measure was the absolute deviation from the correct target position at the end of 9 sec, converted to error relative to target speed. Results show: (a) no significant differences resulting from mode of response (tracking vs. monitoring), order of presentation, duration of presentation, or speed-duration interaction; (b) significant learning effect from session to session ($p < .01$); and (c) an increase in relative error, in an inverse relation to target speed ($p < .01$). It is concluded that a human operator may be able to make motion predictions equally as well with minimal as with maximal exposure to target input; only target speed exerts an influence on prediction accuracy.

Prediction of the future position of a moving target is an essential task of the human operator in any system in which he monitors or controls a dynamic, continually-varying process. Prediction may be defined as an extrapolation to a future position from current information on the state of the system and probable changes in that state. The efficiency of a system is, to a large degree, dependent on the success with which an operator can anticipate its future state.

Prediction is especially important when input information or feedback loops are subject to degradation as, for instance, in the occurrence of functional breakdown of equipment. In such an emergency, if the operator is to continue functioning in the system, he must make prediction based on prebreakdown inputs. This is particularly true of radar displays, where even with the equipment functioning properly, the target under surveillance may temporarily disappear in scope clutter.

Several authors (Bowen & Woodhead, 1953, 1955; McGuire, 1956; Manglesdorf, 1955; Manglesdorf & Fitts, 1954a, 1954b; Schipper & Versace, 1956) have investigated man's ability to make predictions of future position on a static display. Generally these authors have reported that accuracy of prediction varies inversely with the distance to be extrapolated, but is unaffected by the length of the initiating target which represents speed.[2] Using a dynamic display, Gottsdanker (1952a, 1952b, 1955) demonstrated a phenomenon which he called "rate smoothing": the subjects (Ss) tended to underestimate accelerating targets and overestimate decelerating targets. Accuracy was very high on constant rate targets.

The present study investigated the effect of target speed, duration of exposure, and mode of response on prediction of future position of constant-rate targets following disappearance of the target.

METHOD

Apparatus

The apparatus was an adaptation of that used by Gottsdanker (1952a). A moving target was produced by driving a chart with a diagonal pencil line under a 2 mm. slit in an aluminum plate. The plate was

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[2] It is interesting that one of the first pilot selection devices involved motion prediction with a static display. Stratton, McComas, Coover, and Bagby (1920) report the use of such a device in selecting World War I aviators. The subject was required to estimate where one branch of a parabolic curve would intersect a horizontal line. This was thought to be an analog of the landing task. The correlation between scores of this test and flight instructors' ratings was .05

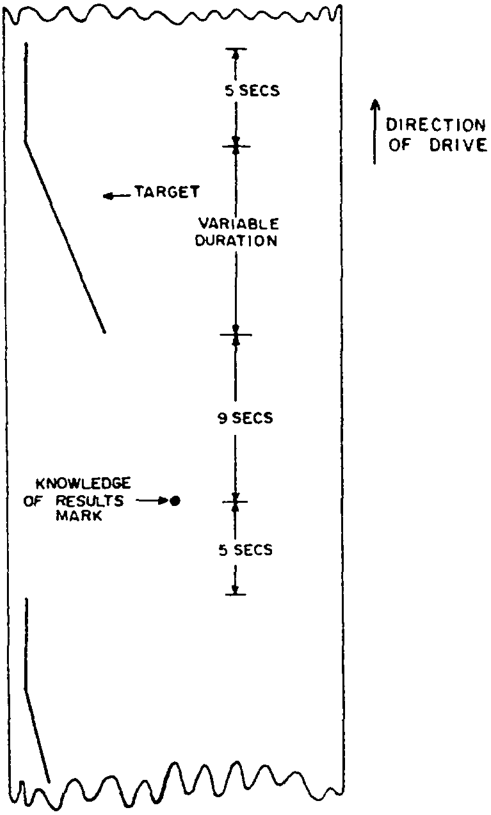

FIG. 1. A sample stimulus.

flush-mounted in the top of a plywood box which held the drive mechanism, an Esterline-Angus Model 38-D chart drive. The targets were drawn on blank Esterline-Angus chart paper. The target appeared as a dot moving from left to right through the slit

Stimuli

Four durations of exposure (2, 4, 8, and 16 seconds) and four speeds (.5, 1, 2 and 4mm/sec) were combined forming 16 unique combinations of stimulus lines. The various speeds were produced by varying the slope of the target line and the durations by the length of the line.

Each target appeared in the extreme left of the slit remaining stationary for 5 seconds before beginning its left-to-right travel Nine seconds after the disappearance of the target a red dot appeared on the extension of the target line. This indicated the end of a trial and provided knowledge of results at the terminal point. Five seconds later a new target appeared at the left. A complete set of the 16 speed-duration stimuli comprise a "replication" of the experiment. The order of presentation of the 16 stimuli was determined by means of a random number table for each replication. A sample of the stimulus tape is shown in Figure 1.

Subjects

The *Ss* were 10 male undergraduates at the Ohio State University. They were chosen from a list of students who had contacted the laboratory seeking employment and were paid one dollar per session None had previous experience in tracking, motion prediction, or radar.

Procedure

Under the tracking condition, *S* traced the visible target in the slit with a pencil and continued tracing its predicted position until the trial ended. Under the monitoring condition, *S* simply watched the target with the pencil in his hand and then began tracing its predicted position after it disappeared. From the time that the target disappeared, the two conditions were identical.

The 10 *Ss* were randomly assigned to two groups. Group A began with the tracking condition and Group B with the monitoring condition. Each *S* participated in the experiment for 5 days, the first being devoted to instructions and two practice replications under the initial response condition On the second and third days *S* ran 3 replications each day under his initial response condition. On the remaining 2 days he ran 3 replications per day under the opposite condition. No practice was given for the

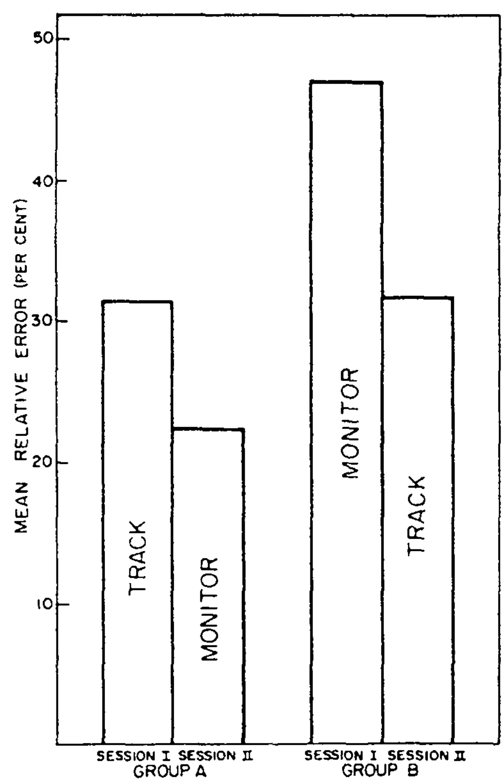

FIG. 2. Mean relative error by sessions and groups.

TABLE 1

LATIN SQUARE ANALYSIS

Source	df	MS	F
Conditions	1	79	2 32
Groups (order)	1	671	1 60
Sessions	1	616	18.1**
Subjects/Groups	8	420	12 4**
Error	8	34	
Total	19		

** $p < .01$.

transfer condition. An entire replication took about 8 minutes After each replication *S* received a 5-minute rest period.

The responses were scored by extending the target line to the terminal point, and measuring to the closest millimeter the absolute distance from the terminal point to *S*'s terminal estimate. The mean of each *S*'s six scores under each speed-duration-condition combination was computed and formed the basis for the analysis Thus each data point was the mean of six independent observations by each *S*.

RESULTS

The mean of each *S*'s six measurements in terms of absolute error was converted to relative error by dividing each mean by the distance traveled in the 9 seconds that *S* was making his predictions. For example, an absolute error of 9 mm. for a 4 mm/sec target was equal to 9 mm/36 mm or a 25% relative error.

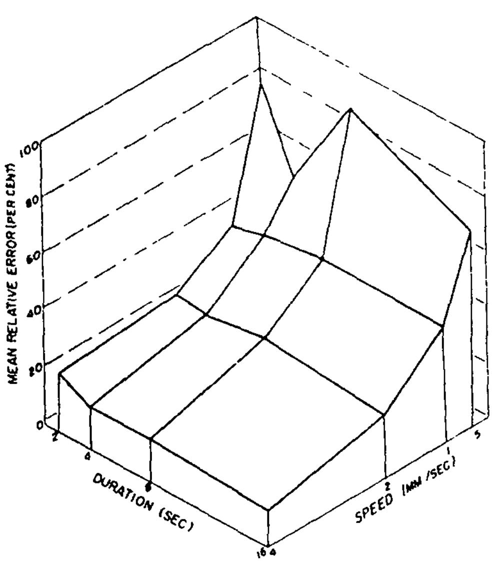

FIG. 3. Mean relative error as a function of duration and speed· Session I

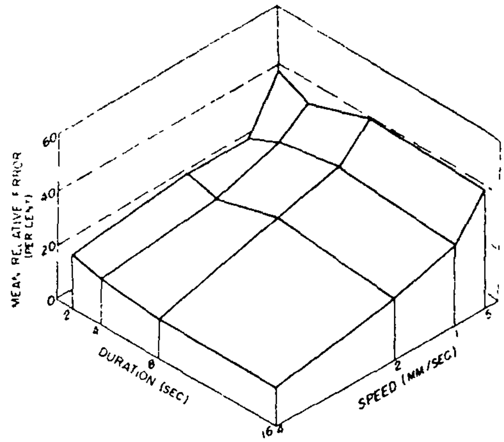

FIG 4. Mean relative error as a function of duration and speed: Session II.

The mean relative error by groups and sessions (averaged across all 16 stimulus presentations) is shown in Figure 2. The data are analyzed by a 2 × 2 Latin square design as outlined by Grant (1948). The results of this analysis are shown in Table 1. These results indicate *no difference between response conditions* or order of presentation (groups), but only a significant learning effect from Session I to Session II and individual differences within groups.

TABLE 2

ANALYSIS OF VARIANCE FOR SESSION I (First 6 trials)

Source	df	MS	F
Groups (G)	1	9,630	
Subjects/Groups	3	5,082	
Speeds (S)	3	26,911	14 6***
S × G	3	2,377	1.29
Error	24	1,846	
Durations (D)	3	807	1.77
D × G	3	1,547	3.19*
Error	24	485	
S × D	9	519	1.03
S × D × G	9	860	1.71
Error	72	502	
Total	159		

* $p < .05$.
*** $p < .001$.

TABLE 3

ANALYSIS OF VARIANCE FOR SESSION II (Second 6 trials)

Source	df	MS	F
Groups	1	2,320	
Subjects/Groups	3	2,169	
Speeds	3	4,749	8 27***
S × G	3	1,526	2 66
Error	24	574	
Durations	3	101	
D × G	3	61	
Error	24	104	
S × D	9	82	
S × D × G	9	98	
Error	72	160	
Total	159		

*** $p < .001$

Since the sessions dimension was the only main variable demonstrating statistical significance, the two sessions were analyzed separately for speed and duration effects These analyses of variance took the form of a Lindquist Type VI design (Lindquist, 1953) with four speeds, four durations, and two response conditions. Each *S* performed under all of the 16 speed-duration combinations, but was nested in one of the response (tracking-monitoring) conditions These results are displayed as three-dimensional plots in Figures 3 and 4. These plots indicate the marked effect of the speed variable and the lack of influence of duration of presentation. This is borne out in the analysis of variance presented in Tables 2 and 3. In both analyses, the speed variable was highly significant while the duration variable and the speed-duration interaction were not. Again response conditions failed to produce significant differences.

DISCUSSION

This study demonstrated the marked effect of target speed upon motion prediction accuracy with constant-rate targets. Previous investigations utilized static displays and failed to produce differences attributable to target speed. But on a static display speed of the initiating target is represented only by analogy, by varying the length of the trace line, or number of blips It is highly questionable whether the subjects perceive this as speed at all, whereas with a dynamic display the subjects are exposed to a true sample of target motion.

An interesting result from this study is the lack of influence of duration of target presentation. It is surprising that the operator is

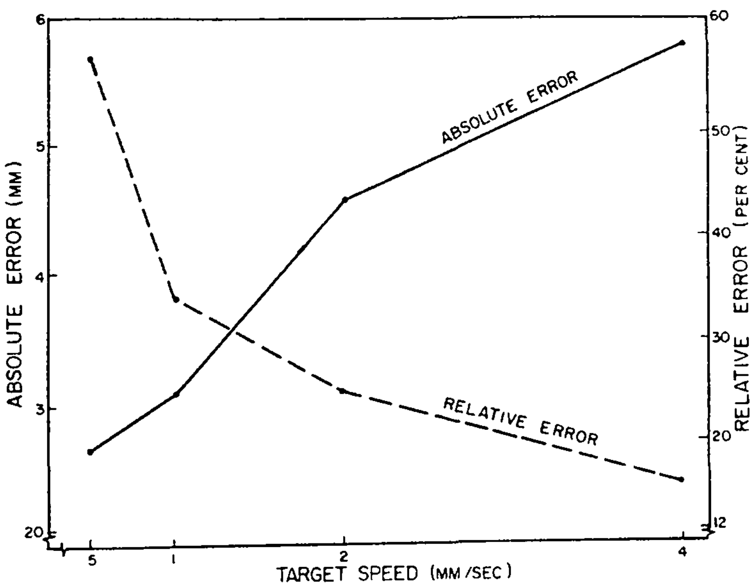

FIG. 5. Absolute error and relative error as a function of target speed.

able to make his prediction as accurately from a 2-second sample of target motion as from a 16-second sample. This result tends to support the view of Bowen and Woodhead (1953), who state: "As long as an observer has a minimum of information, he does not or cannot utilize any further information about the trace line" (p. 2). This has certain implications to system design where the operator or display mechanism must time-share. The results of this study would indicate that only a minimal amount of exposure of the target under control is necessary for accurate motion-prediction of constant rate targets.

The failure of the tracking-monitoring comparison to produce differences or transfer effects indicates that it makes little difference whether *S* receives his target information input actively or passively. Figure 2 indicates a trend toward a marked transfer effect from tracking to monitoring, which might have implications for training for a task where tracking is not possible. However, this effect failed to achieve statistical significance.

One brief remark on the performance measure employed in this study is advisable. The raw absolute error data were transformed to relative error, as it appeared to be more meaningful to express error in terms of the speed (and therefore distance traveled in the prediction interval). If the performance measure had been absolute error uncorrected for target speed, the opposite relationship of error to speed would have resulted as shown in Figure 5. This would imply that in application of these results to radar-like displays, the future position of high-speed targets would be most inaccurately predicted.

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