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N79-15592

EFFECTS OF UNCERTAINTY ON MANUAL TRACKING PERFORMANCE

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SUMMARY

In this experimental study we investigated some transient phenomena and target acquisition modes associated with interrupted observations during ground-to-air AA tracking. Our subjects, using a two-axes control stick, tracked a computer-generated airplane image on a CRT display. The airplane image executed a low-level straight pass. At certain pseudo-random times during each 25-second run the screen was blanked for a period of one second (simulating a temporary loss of visual contact with the target due to clouds, fog or obstructions). When the target image reappeared the subjects reacquired it and continued tracking, attempting to minimize vector RMS error for the entire run (including the blanked period).

The results reveal an increase both in tracking error and in error variance during the blanked period, only when the target disappears while in the crossover region. Blanking at other times effected increased variance but had no effect on the mean error. Also, blanking before and after crossover had opposite effects: A blanking period just before crossover produced an increase lag while a blanking just after crossover resulted in a lead and thus made the error curve more symmetric.

INTRODUCTION

The problem of manual tracking performance with sampled observations has been studied before [e.g., Refs. 1, 2] from a "macroscopic" point of view. In these studies the overall control performance was investigated when the human was assumed to have access to periodic, frequent observations of the system outputs.

In the study reported here we intedded to concentrate on the microscopic aspects of the tracking behavior. We were not interested in the operator's performance as a whole; rather, we set out to examine the details of the tracking behavior during periods when observations of the system outputs were not available to the human. Understanding the operator's behavior during such essentially open-loop tracking is of interest as these situations occur quite frequently in practice. Examples of operators subjected to this type of manual tracking may be the driver of a high-speed automobile during the first few seconds after entering a dark tunnel; a radar operator attempting to track a target with the aid of noisy position

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data; or an anti-aircraft battery operating in an environment of electronic counter-measures, optical counter-measure or simple topographical and meteorelogical obstructions masking the target's image. Indeed, our experimental set-up simulated the situation of the latter, i.e., the AAA paradigm.

THE EXPERIMENT

Our experimental facility consisted of a PDP 11/20 computer, a CRT screen, and a two-axes control stick. The PDP 11/20 generated a delta-shaped airplane image used in the compensatory tracking, with the image displayed on the CRT screen (see Fig. 1).

Our subjects were instructed to manually track the delta-shaped image, both in elevation and in azimuth, as it passed across the CRT screen. Each target pass was a 25.6-seconds straight-and-level flyby. At predetermined times during the run the target disappeared from the screen for a period of one-second. This blanking simulated the temporary loss of visual contact with the target. Five experimental conditions were implemented.

Condition A: No blanking

Condition D: Blankings at -5 sec. and at +9 sec. (0. sec. = crossover)

Condition E: Blanking at -3 sec.

Condition F: Blanking at +1 sec.

Condition G: Blanking at +3 sec. and at +9 sec.

The purpose of two blanking periods (Conditions D and G) was twofold: In an attempt to prevent the subjects from relaxing their tracking effort after the first blank occured, the second blanking at +9 seconds was introduced. Also, this set of blanking periods enabled us to compare the transient tracking behavior of subjects during periods of good tracking (where the target angular velocity is small and the tracking error is also small) with the transient phenomena in the crossover region. Condition A - no blanking served as the control for the subjects' baseline tracking ability.

Six University of Connecitcut students, members of the University Air Force ROTC program, participated in thes experiment. They were trained extensively in this task by tracking a variety of flybys; however, they were not exposed to blankings until the formal experimentation commenced.

Each subject was presented with each of the five experimental conditions in randomized order and there were 7 replications, for a total of 35 runs per subject. The subjects were not informed as to the number of blanking periods in each run, nor were they told how many experimental conditions were to be presented. They were told, however, the total number of runs to be presented. The subjects were instructed to minimize their RMS tracking error for the entire run, including the blanked periods. Following each run, each subject was informed of his RMS error score and was encouraged to keep it as low as possible.

Tracking errors in azimuth and elevation, and the control inputs in these axes were sampled by the PDP-11/20 at a rate of 40 Hz. Each 25.6-second run thus yielded 1024 dacum points for each of these four dependent variables. The data were stored in real-time or secondary devices (discs and magtapes) for subsequent, off-line processing and analysis.

RESULTS AND DISCUSSION

Some results of this experiment are presented in Figures 2-6. Each figure is the summary azimuth data of the (6 subjects x 7 replications =) 42 runs per experimental condition. (In the interest of brevity, elevation data, which are completely analogous, were omitted here.) Figures 2a and 2b are the mean and standard deviation, respectively, of the angular tracking error under the baseline condition, Condition A (no blanking). Figure 2a exhibits the asymmetry (large lag just before crossover and smaller lead immediately after) characteristic of this tracking task [3]. Also, the tracking errors are quite small in the so-called "areas of good tracking" outside the crossover region.

Comparison of Figure 3 (standard deviation, Condition D) with Figure 2b reveals the two blanking periods which manifest themselves as spikes in Fig. 3. As expected, a blanking period just before crossover produces an increased lag (Fig. 5), while a blanking period just after crossover effects a lead and thus makes the error curve more symmetric (Fig. 6a).

These deviations from the baseline error curve were tested using a point-by-point t-test and were found to be significant, under Condition E and F, at the $P < 0.01$ level. During periods of good tracking, however, blanking had no effect on the tracking error mean. This was true not only with respect to the blanking period at +9 seconds but also with respect to the blankings at -5 seconds and at +3 seconds.

CONCLUSIONS

Increasing the operator's uncertainty of the target's position for short periods increases the lagging tendency before crossover and the leading tendency - when the instance of uncertainty occurs after crossover. Uncertainty on the operator's part of the target's motion always results in increased error variance; the error mean, however, is sensitive to uncertainty only when the tracking task is difficult. In periods of good tracking (and hence, small tracking error) uncertainty has little effect on the error mean.

REFERENCES

1. Senders, J.W., Ward, J.L., and Carbonell: Human Visual Sampling Processes. NASA CR-1258, 1969.

2. Senders, J.W. et al.: An Investigation of the Visual Sampling Behavior of Human Observers. NASA CR-434, 1966.

3. Kleinman, D.L. and Ephrath, A.R.: Effects of Target Motion and Image on AAA Tracking. Decision and Control Conference, New Orleans, La., Dec. 1977.

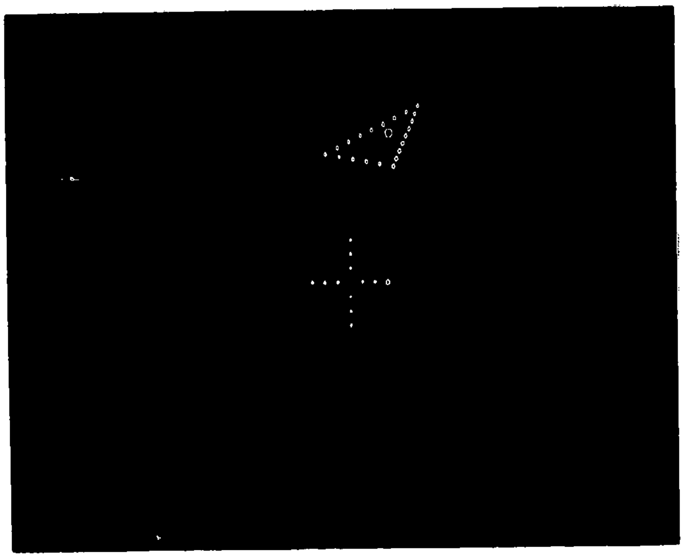

FIG. 1: CRT DISPLAY

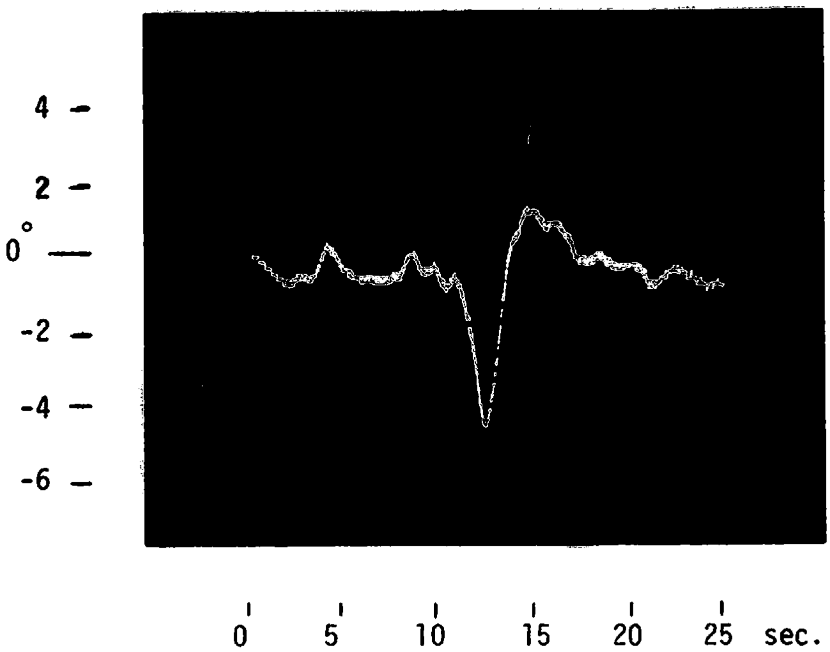

FIG. 2a: Azimuth Error Mean, No Blanking

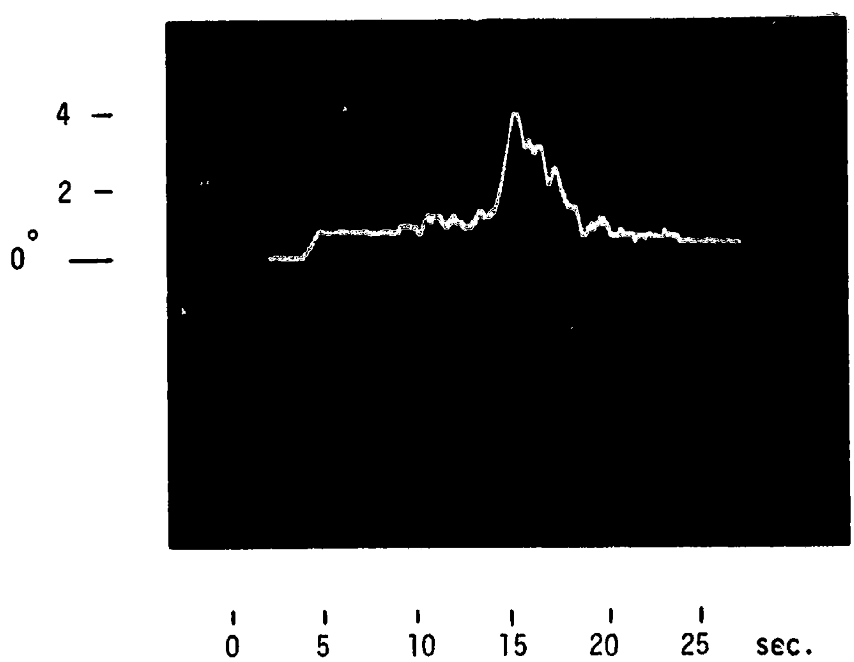

FIG. 2b: Azimuth Error S.D., No Blanking

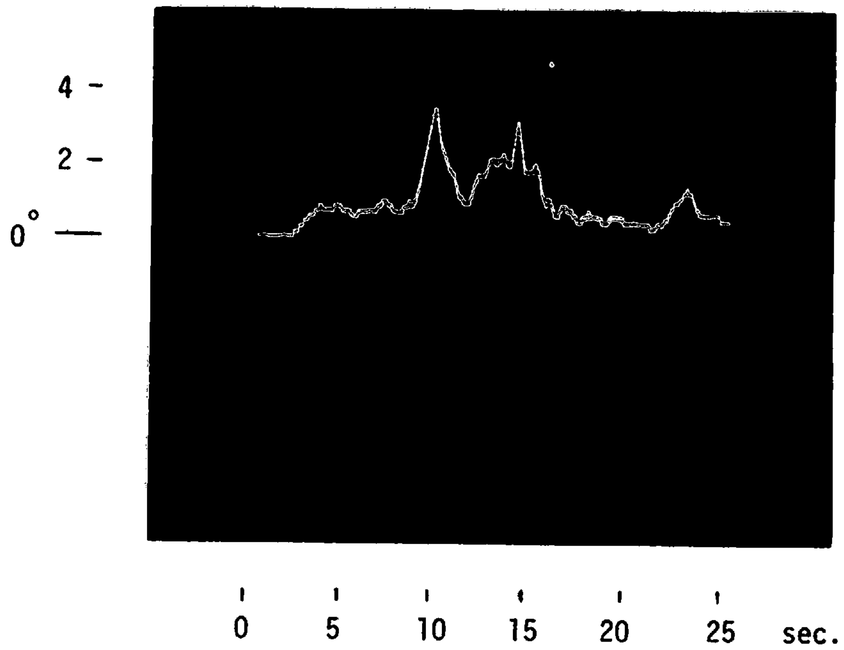

FIG. 3: Azimuth Error S.D., Blankings @ -5 & +9 sec

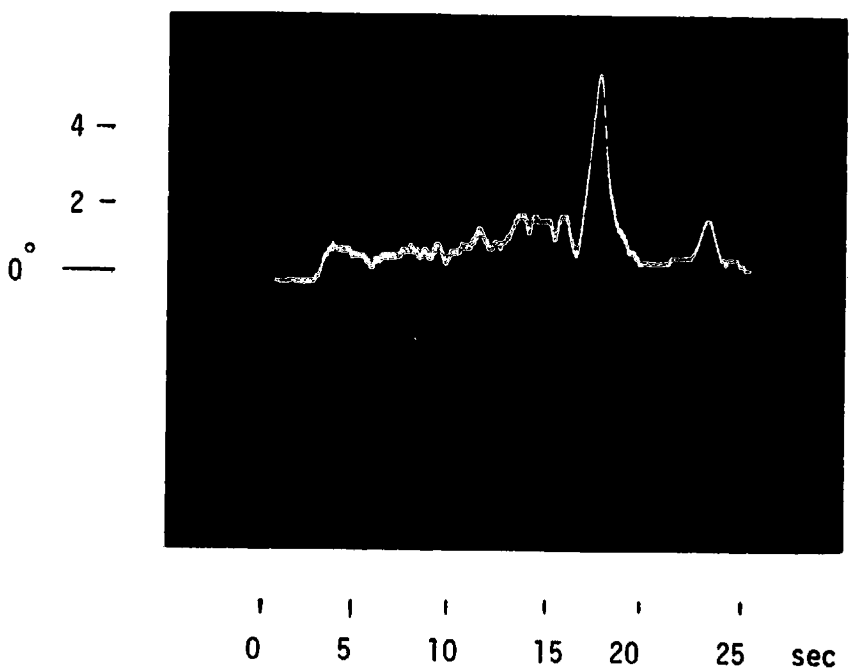

FIG. 4: Azimuth Error S.D., Blankings @ +3 & +9 sec.

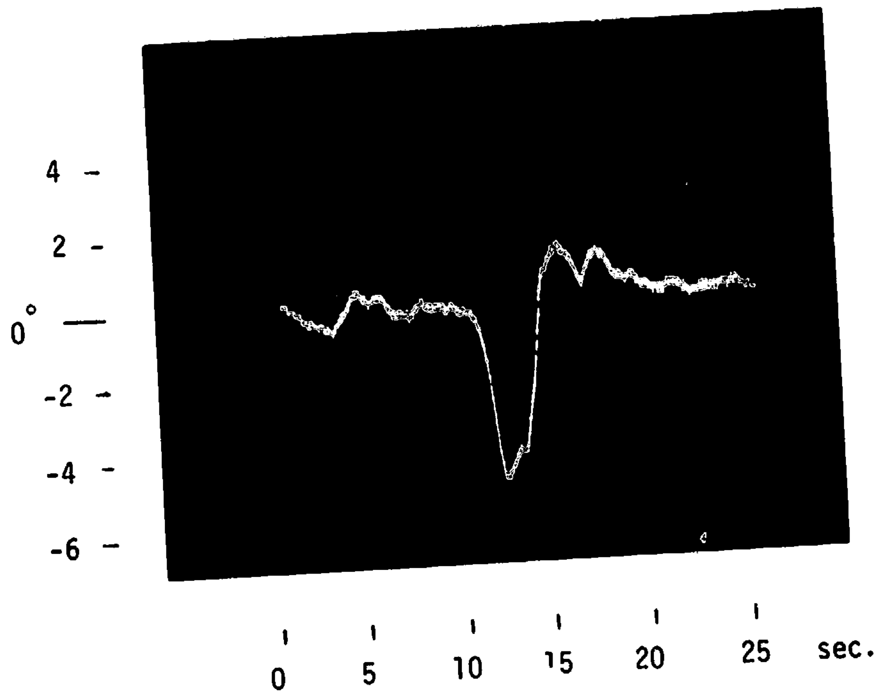

FIG. 5: Azimuth Error Mean, Blanking @ -3 sec.

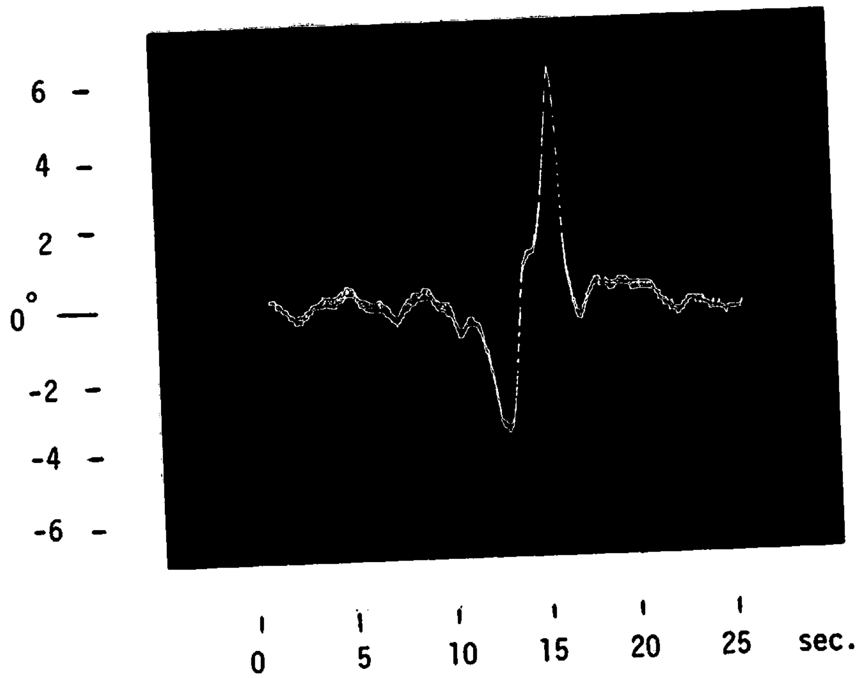

FIG. 6a: Azimuth Error Mean, Blanking @ +1 sec.

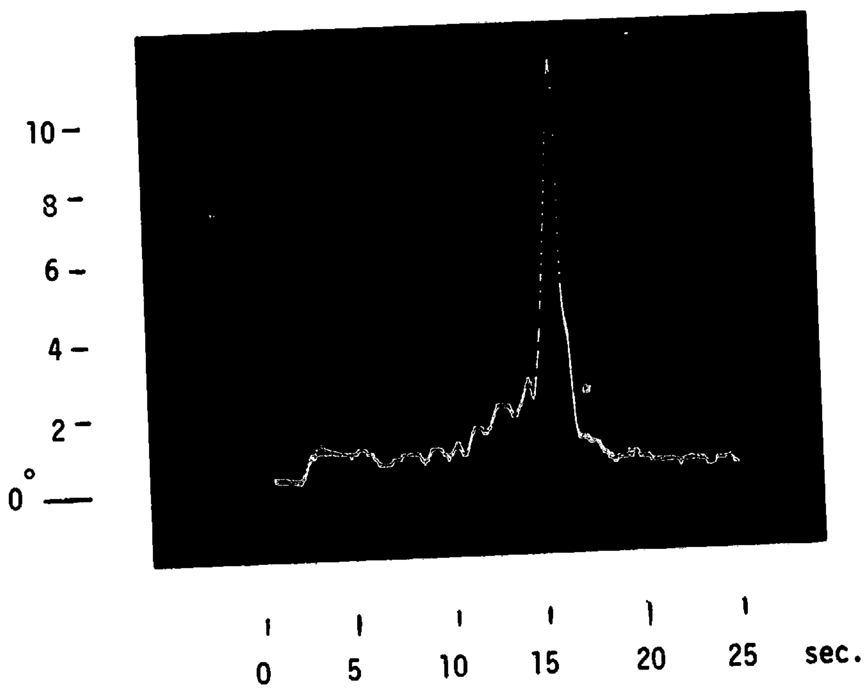

FIG. 6b: Azimuth Error S.D., Blanking @ +1 sec.

SESSION B: HUMAN OPERATOR MODELS: IDENTIFICATION AND CONJECTURE

Chairman: S. Baron