pretation should be made, regardless of temporary effects such as those produced by a hurricane.

There is, however, no indication as to the absolute amount of sand available for littoral drift, nor for the absolute energy level. Examples of these "overload" shoals can be seen along areas of essentially zero energy, low energy, moderate energy, and high energy. In each case it is necessary only that the supply of sand along the beach exceed the amount which would normally be moved, in view of the wave energy level.

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Delayed Visual Feedback and Behavior

Abstract. By means of video-tape recording the visual presentation of a person's behavior, as he carries out some task, can be delayed in such a way that the individual sees what he is doing a short time after he has done it. The effects of this delay of visual feedback on a variety of simple visual-motor tasks are found to be both marked and deleterious, and in some respects similar to the effects of delayed auditory feedback on speech and motor tasks.

In the same way that the sound of a subject's voice can be stored momentarily on magnetic tape and played back during the course of speech (*1*), it is possible, through the use of newly developed video-tape recording and reproducing equipment, to store and play back the visual representation of a subject's performance field in such a way that the subject observes a televised display of his behavior shortly after the behavior has occurred. In this report we describe the results of some preliminary observations concerning the effects of such visual delay on a sample of visual-motor tasks.

The RCA laboratory magnetic tape video recording and reproducing system was used to produce delayed vision (*2*). The subject sat in front of a television monitor (21-in. screen) which received the output of a second playback unit. A delay of approximately 520 msec was provided. In order to prevent the subject from seeing the task area directly, a pair of special goggles was used. An RCA miniature television camera was located at eye level and next to the subject's head to minimize angular distortion of the televised performance field. Magnification of the performance field was approximately 1.5.

The subject carried out various tasks on the electronic handwriting analyzer, a device described by Smith and Bloom (*3*), which permits the measurement of both manipulative and travel components of writing or similar motions. The subject observed on the television screen a portion of the writing surface of this device, together with his hand with the pencil in it and a part of his forearm.

The nine different tasks listed in Table 1 were performed by two subjects under three conditions of observation; television-delay, television-no delay, normal (ordinary observation). Tasks, as well as sequences of words and syllables, were randomly assigned to each subject. Comparisons among the three conditions suffer from the lack of control for practice, in that the observations with delay were obtained 2 weeks prior to those obtained under the no-delay conditions, but in view of the magnitude and nature of the observed differences and the nature of the tasks themselves, not much significance is attached to the possible effects of practice from condition to condition. Instructions in all three cases were to perform the task as accurately and as rapidly as possibile (and as neatly as possible in the case of writing tasks).

The first thing to be said about the effect on behavior of delayed visual feedback as revealed in these observations is that performance becomes inordinately difficult and frustrating. It is nearly impossible to perform the simplest of tasks, such as placing a dot in the center of a circle, with any reasonable degree of accuracy. Any localizing movement, in fact, demands great effort, and little accuracy is obtained. What normally would be fast, smooth, placing motions become erratic and oscillatory movements which assume a characteristic jerkiness. Handwriting, even of very familiar material, becomes severely degraded and in some cases completely illegible. In Fig. 1 are reproduced some of the original records showing samples of star tracings, drawings of simple geometrical figures, maze tracings, and handwriting. Specimens from the records of the two no-delay conditions are given for purposes of comparison.

An error analysis of the writing material reveals that, in addition to the obvious degradation of legibility, particular kinds of errors occur. The most frequent kind of error in a total of 64 errors was letter duplication (40.6 percent), examples of which can be seen in Fig. 1, *D* and *E*. The predominance of this type of error parallels the findings of the Bergeijk and David study (*4*) and agrees with the results on articulatory errors found in delayed auditory feedback.
most frequent kind of error found in our observations was error of insertion —that is, the occurrence within a word of letters or part letters which did not belong there (26.6 percent). There were a few errors of omission (7.8 percent), one error of substitution, and a variety of miscellaneous errors (23.4 percent). The relatively frequent occurrence of errors of duplication and insertion might be considered "graphic stammering and stuttering," analogous to the articulatory effects in speech due to delayed auditory feedback.

Evaluation of the accuracy of performance of the nonwriting tasks shows more dramatically the effects of delayed vision. In the star- and maze-tracing tasks some of the records were so bad that they were literally unscorable. The star record in Fig. 1 is the best example of this extreme degree of degraded performance. There was, however, an obvious improvement in these two tasks over the few trials performed by each subject. An interesting question for future investigation is the degree of improvement obtainable in such tasks with extended practice.

In addition to the low quality and low accuracy of performance produced by the delayed visual feedback, very marked effects on temporal characteristics of performance were found. Table 1 summarizes the time data for the two

Table 1. Manipulation or contact time for the various visual-motor tasks for each subject under the three conditions of observation. All values are means in seconds. Data on two tasks under the television-delay condition were not obtained for subject B.

Subject	Time (sec)		
	TV delay	TV no-delay	Normal
Writing letters of alphabet			
A	2.0	0.6	0.6
B	1.2	0.7	0.5
Star-tracing			
A	86.2	13.8	5.9
B	49.6	16.0	6.3
Drawing 3 geometric figures			
A	6.1	3.5	3.5
B	5.0	6.4	4.7
Writing 4-letter nonsense syllables			
A	4.8	4.1	2.0
B	6.4	2.4	1.9
Writing 4-letter words			
A	4.3	1.7	1.5
B		2.6	1.6
Maze-tracing			
A	102.8	18.0	7.2
B	107.6	23.9	7.6
Writing Bergeijk-David words			
A	5.9	2.5	2.2
B	5.5	3.1	2.4
Writing 3-letter nonsense syllables			
A	5.1	1.7	1.4
B		2.2	1.6
Placing dots in 6 circles			
A	27.8	2.8	2.5
B	12.7	4.0	1.7

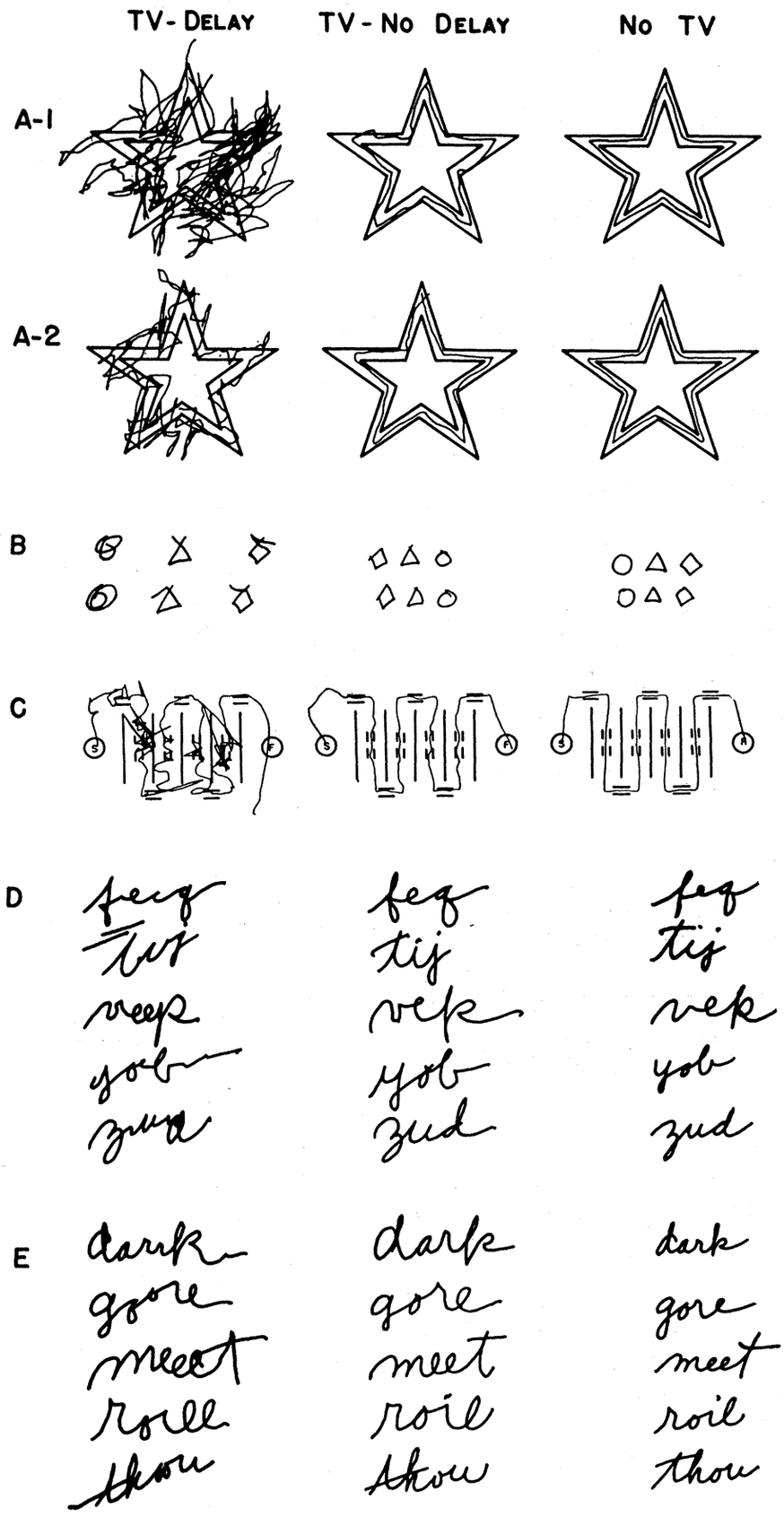

Fig. 1. Sample records for some of the tasks performed under delayed visual feedback.

subjects on all tasks for the three different conditions. The measures in this table represent the contact or manipulative time (the actual time the subject had the metal pencil touching the writing surface) expressed as means. As the table shows, some tasks required a tenfold or greater increase in time for completion, in comparison to the normal or television no-delay condition. Although not shown in the table, the separate measures of travel time (time the metal pencil was off the writing surface during the execution of writing movements, dotting circles, and so forth) provide similar results—namely, consistent and marked increases in time for the delayed condition in comparison to the other two.

These results clearly emphasize the critical importance of the temporal aspects of visual feedback in the control and regulation of human performance. They are, in addition, in general agreement with the results of an unpublished study on simulated delayed visual feedback (*5*), with the results of the investigation of delayed handwriting by Bergeijk and David (*4*), and with studies on the effect of delayed auditory feedback on speech, tapping, and other motor performances (*1*, *6*). Delayed auditory or visual feedback seriously degrades performance, introduces characteristic redundant motions, increases performance time by marked amounts, and imposes upon the subject very difficult and frustrating conditions.

We believe that the technical achievement of video-tape recording places in the hands of investigators a very significant technique for the future study of human perception and motion.

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References and Notes

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