# Computer-controlled PCM System for Investigation of Dichotic Speech Perception[†]

Franklin S. Cooper and Ignatius G. Mattingly[*]
Haskins Laboratories

Investigations of dichotic perception of speech require tests in which different stimuli are presented to the two ears of a subject either simultaneously or with some selected relative delay. Ordinarily, stimuli from a small inventory are presented many times in random pairings and in random order. There is a short interval after the presentation of each pair, during which the subject writes his response on an answer form. The series of pairs in a test are usually divided into short groups, and after each group there is a longer interval. This format helps the subject keep his place on the answer form. Depending on the purpose of the experiment, the stimuli may be either synthetic speech or natural speech. Preparation of the audio tapes for such tests has been accomplished in the past by laborious and time-consuming dubbing and splicing, and it has been difficult to achieve accurate relative timing of paired stimuli.

This afternoon I would like to describe a system developed at Haskins Laboratories for making dichotic test tapes under computer control. With this system an experimenter can prepare tapes quickly and accurately. The system is used only for natural speech; we also have a system -- which I shall not describe today-- for making dichotic tapes with synthetic stimuli. (SLIDE)

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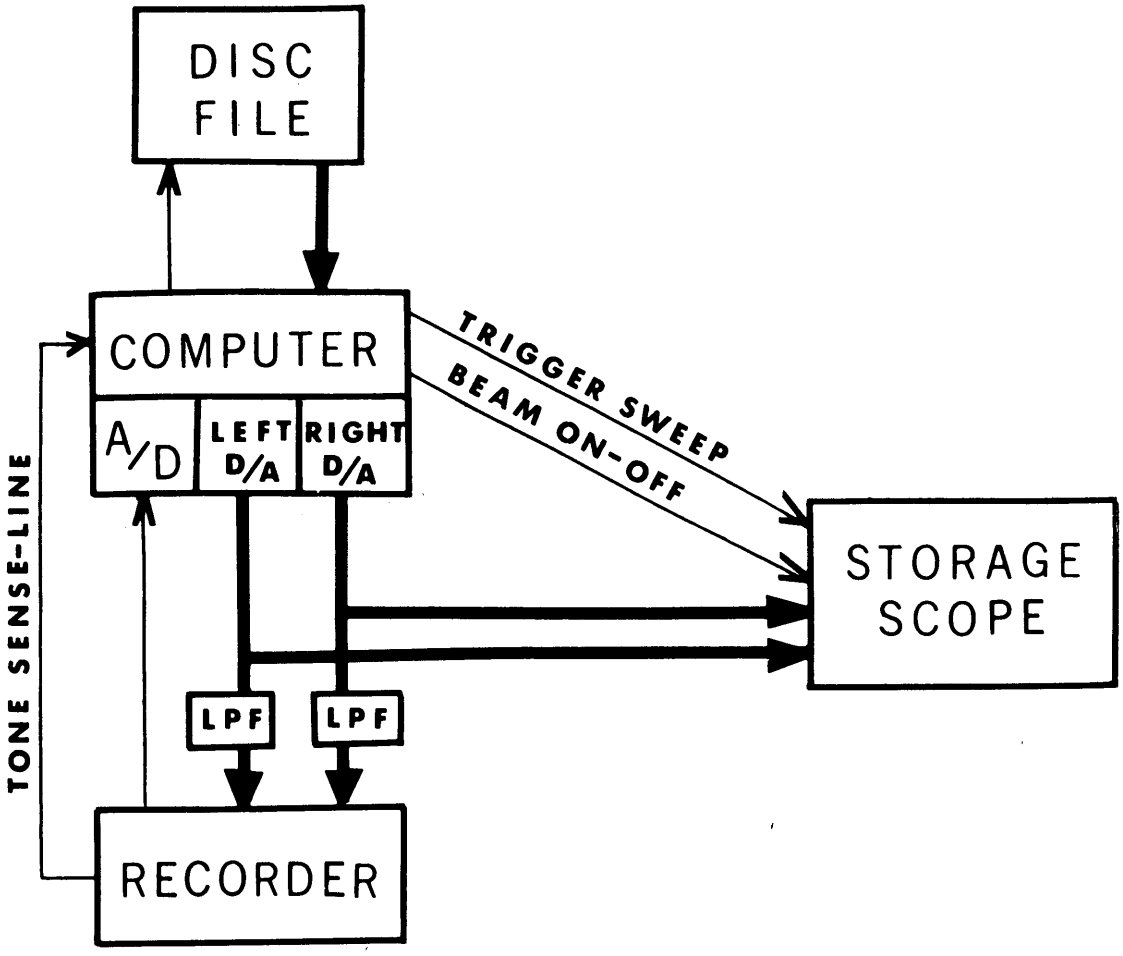
[*]Also, University of Connecticut.




DICHOTIC PCM SYSTEM

SLIDE 1

The hardware part of the system consists of a Honeywell DDP-224 computer, connected with a CDC disc file, an analog-to-digital converter and two digital-to-analog converters, a storage oscilloscope, and a tape recorder.

In preparation for using the system, the experimenter records his inventory of stimuli on one track of an audio tape, and a 10 kHz tone on the other track. A stimulus can be as long as one second. The tape is then cut up into segments, each of which contains a single stimulus plus a reasonable margin. The cuts need not be especially accurate or consistent, since the stimuli are edited later, anyway. A second tape is prepared consisting of these segments interspersed with leader. Thus the position of a stimulus on this tape is demarcated roughly by the presence of the 10 kHz tone on the other track.

A stimulus, with some preceding and following silence, is now digitized by the analog-to-digital converter under program control and the PCM samples read into computer memory. Read-in is initiated by the onset of the 10 kHz tone, which sets a sense-line connected to the computer. The PCM sampling rate is 8 kHz, and two 10-bit samples are stored in each computer word. A little less than two seconds' worth of PCM samples can be stored in the buffer area, which uses almost all of the available memory except for what is occupied by the program itself.

To facilitate editing, the stored data is converted back to audio, on command from the console, by one of the digital-to-analog converters. Since the trigger sweep and the beam on-off functions of the storage scope are under computer control, the analog wave-form can be displayed on the scope at the same time. Manual scope controls can be used to vary the time and amplitude scales of the display. Also, the audio-playback can be slowed to half-speed if desired.

The experimenter now edits the stimulus. He may first wish to adjust the level of the stimulus so that all pairs will be matched as to level. An option of the program permits him to try the effect of adding or subtracting up to 8 db in 1 db increments, without altering the stored samples: the absolute value of each

PCM sample is multiplied by an appropriate constant before conversion. Once he finds a satisfactory level the PCM samples in the buffer itself can be changed permanently.

By setting values in index registers on the computer console, the experimenter delimits one second or less from the two seconds' worth of PCM samples in the buffer. Display and playback now begin and end at the buffer positions which the experimenter has selected. Usually he will choose to delimit all the stimuli in his inventory with respect to some common reference point: for example, the onset of voicing or the peak syllable amplitude. Since two stimuli can be displayed in parallel on the storage scope, this can easily be managed. One stimulus is delimited and its wave-form then kept on display as a model for editing other stimuli.

When the level of the stimulus has been adjusted and its beginning and ending suitably delimited, the edited PCM samples for the utterance are stored on one cylinder of the disc file. Using the same procedures, the experimenter edits other stimuli until his inventory of different items is complete.

The experimenter can now compile the test. A test order is required: the experimenter must specify the number of stimulus pairs in the entire test and the number per group; and the delay after each stimulus-pair and after a group of pairs. For each pair, he must specify the disc file locations for the right-ear and left-ear stimuli, which of the two -- if either -- is to be delayed with respect to the other, and the length of this delay.

The test order is read into memory and the test is compiled. Each stimulus-pair is prepared in its turn. During the inter-stimulus interval the PCM samples for the two stimuli which form the next pair are retrieved from the disc file. The original two-second buffer area is now divided into two one-second buffers, one for the right-ear stimulus and one for the left-ear stimulus. Depending on which of the two stimuli is delayed, and the amount of the delay, each PCM sample in one buffer is paired with a sample from the other buffer or with a dummy silence sample. Time is kept by a computer clock, according to the test-order specifi-

cation, and at the end of the interstimulus interval, the series of paired samples is transmitted to the two digital-to-analog converters. After low-pass filtering, the outputs of the two converters are recorded on the two tracks of an audio tape. As soon as each pair of stimuli has been converted, the next pair is retrieved from the disc file and the output procedure repeated. After the output of a group of stimulus pairs, the specified inter-group delay will elapse before output is resumed. Output will then continue in this way until each group in the entire test order has been prepared.

So far several experimenters have used the system successfully for preparing dichotic test tapes. They are studying such interesting dichotic phenomena as phonemic fusion: the tendency of two different consonants, presented one at each ear, to be perceived as a cluster; the right-ear effect: the tendency for the consonant presented to the right ear to be reported more frequently by a subject than the competing consonant at the left ear; and the lag effect: the tendency for a stimulus at one ear to be reported more frequently, if delayed forty or fifty milliseconds with respect to the stimulus at the other ear. As exploration of these effects continues, we expect to elaborate the system to simplify some of the operations and to increase the range of possible experiments.