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An empirical approach to the timing limitations of the raster-scan CRT

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This paper describes an empirical investigation of brief stimulus durations produced by raster-scan CRT displays operating at a line frequency of 60 Hz. Timing accuracy of stimulus presentation was examined by empirical measurement of the number of refresh cycles (16.67 msec/cycle) occurring over a range of nominal time intervals (10, 20, 30, 40, 50, 60, and 70 msec). For our microcomputer system with multiple CRT terminals, the results suggest that the minimum nominal time interval used should be 20 msec to ensure a maximally reliable stimulus presentation and that successive nominal time intervals should be separated by at least 30 msec. The empirical timing check provided useful information for determining the microcomputer system's capabilities and limitations in experiments involving brief stimulus presentations.

The rapidly growing interest in the laboratory use of microcomputers as controlling and recording systems has been accompanied by the discovery of new and often unsuspected calibration and measurement problems. Discussions on some of the problems associated with the use of cathode-ray tube (CRT) video displays for tachistoscopic and reaction time research have been provided by Lincoln and Lane (1980), Reed (1979), and Sentis and Barowicz (1978).

Many microcomputers and video displays have the required millisecond precision for fine temporal control of brief stimulus presentations. Some of the relatively more expensive video displays (e.g., X-Y coordinate point plot with accompanying digital-to-analog converter) have the capability of presenting programmed arrangements of stimuli at very brief durations. The advantages and disadvantages of the point-plot system are addressed by Taylor, Klitzke, and Massaro (1978). The more common, less expensive raster-scan CRT display, however, does not have this same operational capacity.

An important area of concern for some users of microcomputer systems with the raster-scan CRT video display is the feasibility of using a CRT to present stimuli for brief exposure durations. A major problem with the use of most raster-scan CRTs in research involving relatively fine temporal control is that these video displays are altered or "refreshed" at a rate determined by the line frequency of the electrical current, generally 60 Hz (Ogdin, 1981). The theoretical minimum time unit for stimulus presentation on raster-scan CRTs is therefore 1/60 sec, or 16.67 msec. This refresh rate restricts stimulus presentations on raster-scan CRTs to multiples of 16.67 msec.

The purpose of this report is to describe an investigation and empirical resolution of the stimulus timing problem associated with raster-scan CRT displays when they are used for brief stimulus presentations. Our goal was to measure the reliability of our microcomputer system operating at brief stimulus presentation intervals. An empirical timing check was conducted in an attempt to determine the extent to which programmed stimulus presentation times (nominal values) deviated from actual stimulus presentation times (observed refresh cycles).

A DEC LSI-11 microcomputer (Andromeda Systems, Inc.) linked to four identical MIME-I (Micro-Term, Inc.) CRTs operating at 9,600 baud was designed to serve as a computer-based multiple-station tachistoscope. This system was used to present a series of tachistoscopic presentations of three-, four-, five-, and six-letter target words in a range of exposures as brief as could be reliably handled by the system. To allow for simultaneous operation of multiple CRT terminals in our experiments, all timing was controlled by the use of a 10-msec machine language software clock program. In addition, the software (written in FORTRAN IV) allowed the experimenter to enter desired nominal values for real-time presentation durations of the stimuli, consisting of the fixation point (+), target word, and pattern mask (a series of asterisks). For the empirical timing check, fixation and pattern mask presentations were eliminated from the stimulus presentation sequence of the experimental task program by a simple modification of the software.

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Timing accuracy of stimulus presentation was examined by empirical measurement of the number of refresh cycles occurring for each nominal time interval. The basic procedure used to observe the number of CRT refresh cycles consisted of mounting a phototransistor on the face of the video display screen. The background intensity of the CRT screen was reduced until only the stimulus presentation triggered the phototransistor. The output signal of the phototransistor was conditioned to a square wave and fed to an oscilloscope (Tektronix Model 465), which was adjusted to trigger on the first refresh pulse. Initially, an electronic counter was used to record the number of refresh cycles for each nominal time interval, but this device was later dropped from the recording system because of the ease of observing and manually recording the number of refresh cycles, clearly displayed as amplitude peaks on the oscilloscope.

In our first empirical timing check, 60 measurements were made for each nominal time value (10, 20, 30, 40, 50, 60, and 70 msec), in order to obtain a reasonably large sample for reliable comparisons. Data were collected from CRTs in single operation as well as in simultaneous operation.

Each set of 420 observations obtained from the CRT under the timing check conditions was subjected to separate analysis. Nearly identical results were obtained from each of the two CRTs operating simultaneously and the one operating independently. In general, data collected during the 10- and 20-msec nominal time intervals consisted of a large number of zeros (92% and 63%, respectively, for a CRT in single operation). The absence of refresh cycles during the 20-msec nominal stimulus presentation was probably attributable to time required for the execution of the program. Moreover, regression parameters revealed a strong linearity between nominal time intervals of 30 msec to 70 msec and real-time refresh cycles. For a CRT in single operation, these calculations produced a Pearson product-moment correlation coefficient of .91 with a slope of .062 and an intercept of −.84. (Multiplying the number of refresh cycles by 16.67 msec converts the slope and intercept to 1.03 and −14 msec, respectively.)

The systematic deviation between nominal times and actual presentation durations reflected in the −14-msec intercept is probably attributable to a combination of hardware and software characteristics. In any case, it is likely to vary from system to system, and probably also from program to program. This 14-msec discrepancy between nominal and real-time presentation values was substantially eliminated by changing the software. All computer processing activities were stopped during the critical time interval for each stimulus presentation (i.e., stimulus onset, duration, and offset). Typically, these activities included calculating results and writing them on the disk, as well as presenting other experimental stimuli in the form of questions and confidence ratings. Upon completion of the stimulus (target) presentation period, all computer activities resumed their normal operational mode.

The empirical timing check procedures were then repeated with 80 measurements taken from each of the nominal time values (10 msec to 70 msec). These data were collected from a CRT in single operation and subjected to statistical analysis. The means, recorded ranges, and frequencies of observed refresh cycles as a function of nominal time intervals for our second empirical timing check are shown in Figure 1.

The overall results of the empirical timing check can be summarized in three major statements. First, data collected during the 10-msec period indicate that approximately one-third (35%) of the stimulus presentations involved no actual presentation; hence, stimulus durations less than approximately 20 msec are unreliable for our system. Accordingly, the minimum nominal time interval of 20 msec is recommended for use in this kind of application as the lower range value for stimulus presentation duration.

The poor temporal resolution reported above severely limits the use of raster-scan CRTs as tachistoscopic devices because of the typical need for briefer exposures of target stimuli. The same timing application applies when one is attempting to control for other temporal events, such as length of the interstimulus interval. The seriousness of these restrictions will, of course, depend upon the individual needs of the researcher and the problem under investigation.

Second, the overlap in the ranges of refresh cycles for successive timing intervals evident in Figure 1 may present additional problems for the tachistoscopic use of CRTs. In order to ensure maximally reliable presentation durations for experiments, nominal time intervals must be unique in terms of refresh cycles. In Figure 1, it seems that nominal time intervals must be separated

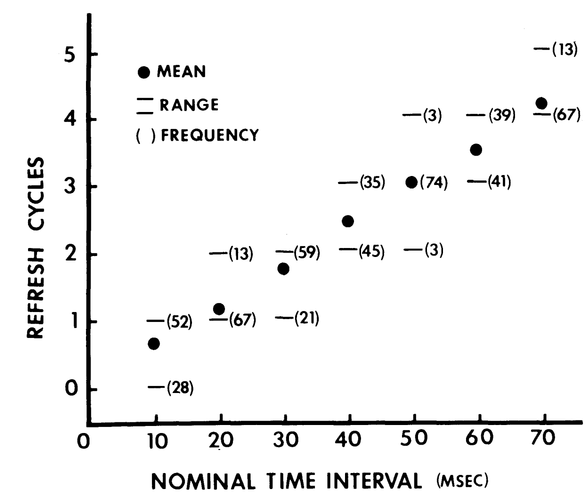

Figure 1. Means, recorded ranges, and frequencies of refresh cycles as a function of nominal time intervals. Empirical frequencies of refresh cycles are indicated in parentheses.

by more than 30 msec in order to be completely distinguished.

Nevertheless, the data also indicate that a very substantial degree of separation of timing intervals, and one that might well be satisfactory for many experimental purposes, can be achieved by nominal temporal steps of 30 msec. There was a minimal amount of overlap between nominal intervals of 20 and 50 msec, as indicated by the actual frequencies of two refresh cycles shown in Figure 1. Thus the probability of a duplication of two refresh cycles was computed to be less than 1% (.006). No overlap at all was found between 30 and 60 msec, or between 40 and 70 msec.

With temporal steps less than 30 msec, the proportion of overlap of refresh cycles between nominal time intervals will, of course, increase, the amount of the increase varying with the particular nominal settings used. Use of a smaller step would permit a more effective implementation of certain experimental designs. Some researchers might consider this amount of imprecision a fair price to pay for the greater experimental maneuverability afforded by the smaller temporal step.

Third, the data collected indicate that within these timing limitations, raster-scan CRTs can be useful for certain applications because of the linear relationship demonstrated between nominal and real stimulus presentation times. Calculations of regression parameters for all the data collected in our second timing check produced a Pearson product-moment correlation coefficient of .94 with a slope of .059 and an intercept of .027 in refresh cycle units, or .98 and .45 msec, respectively. Excluding the 10-msec nominal time interval data in the regression analysis only slightly attenuates the correlation ($r = .92$) and yields an identical slope of .059 (or .98 msec) and a slightly lower intercept of −.01 (or −.17 msec).

The empirical findings of the timing check of raster-scan CRTs linked to our microcomputer provide useful information on the system's performance during brief stimulus presentations. With this type of knowledge about a system's capabilities, the experimenter can make decisions about the efficacy of the experimental apparatus used to investigate a particular research question. For example, our methodological experimentation of the timing limitations of the raster-scan CRT has led to the investigation of other suitable methods for reducing or degrading the stimulus presentation on our apparatus. Methods used in this search were designed to manipulate the stimulus (target) energy relationship, with careful consideration given to the problems associated with the use of a visual mask (Eriksen, 1980). Stimulus degradation procedures included a programmable target stimulus presentation that was reduced to exactly half of the other stimulus intensity levels used in our experimental task and the systematic varying of the CRT screen intensity as a means of controlling the subject's recognition performance. Such stimulus degradation enlarges the functional range within which accurately timed brief stimuli can be used.

Awareness by researchers of these timing limitations should facilitate the more prudent use of raster-scan CRTs as video display devices in psychological research involving brief stimulus presentations.

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