N-channel tachistoscopes[1]

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Two 10-channel tachistoscopes are described. In one the optical system is based upon fiber optic light guides; channel and interchannel time control is provided by Tektronix pulse and waveform generators. In the other the optical system uses 10 8-mm variable power projector lens systems. Timing control is obtained from an Iconix timebase generator and preset counters. Two methods of programming the equipment are described and some experimental applications are considered.

The two-channel Dodge type tachistoscope (T-scope) has over the years proven to be an extremely useful instrument in visual perceptual research. However, in recent years increased knowledge and the changing nature of experimental problems has rendered the two-channel T-scope practically obsolete. Study of the phenomenon of backward and forward visual masking has required a minimum of three channels with the result that three-channel T-scopes have now become standard. The masking research requires one channel for the adapting field and fixation point, a second channel for the test stimulus, and a third channel for the mask. But even here, the use of a single test and masking stimulus has been dictated more by the availability of equipment rather than by theoretical considerations. Recently Dember & Purcell (1967) and Robinson (1968) have studied masking situations in which two different masking stimuli are employed. In these studies three-channel Scientific Prototype T-scopes were used but the nature of the experimental manipulations and stimulus variables that could be employed were severely circumscribed by the limitations of only three available channels for stimulation.

A relatively new area of investigation concerns the problem of visual perceptual rate, a problem that, in part, has its antecedents in the masking studies. Little or nothing is known concerning the rate at which humans can have distinctly separate visual percepts. Investigations into this problem have been severely limited by the unavailability of suitable equipment. Ideally, studies on visual perceptual rate would require a T-scope with enough channels to exceed the immediate span of apprehension. There would be little experimental advantage in presenting four separate stimuli at a rate of, say, one every 10 msec over presenting the four simultaneously in a single exposure. If enough channels are available it should be possible to determine the rate at which stimuli can be presented without the S showing a decrease in performance as the number of successive stimuli is increased.

Mayzner, Tresselt, & Helfer (1967) have studied very fast sequential input rates by employing a PDP-7 digital computer coupled with a Type-340 CRT display. This equipment is more than adequate, providing essentially unlimited channels along with precise sequencing control, time control, and flexibility in programming. The major limitation is cost. Other limitations are the inadequacies of luminance control, the fineness of grain in the figure of the stimuli (the alpha-numeric characters are made up of points), and the ability to present white on black figures. What is needed is a multichannel tachistoscope whose cost is within the capabilities of even the smaller laboratories.

In any attempt to develop n-channel T-scopes the Dodge principle has to be abandoned. The principle is based upon the use of half-silvered mirrors or beam splitters which reflect as well as transmit light. In a two-channel T-scope a single beam splitter is employed which reflects the light from one channel and transmits the light from the other permitting the two fields to be superimposed. The Dodge principle can be successfully extended to three channels but beyond this number the equipment becomes very cumbersome and three stimulation fields become too widely separated to permit easy manipulation and interchange of stimuli by a single E.

Perhaps even more serious is the luminance loss as the number of beam splitters is increased. In a two-channel T-scope only one beam splitter is required. If a half-silvered mirror is employed that transmits and reflects 50% of the light falling upon it, the luminance of each field is reduced by slightly more than 50% (some light is lost by absorption). Light from a field having to pass through or reflect from two mirrors is reduced by slightly greater than 75%. In a three-channel T-scope such as the Scientific Prototype Model GB, at least one of the fields has to reflect from or pass through three beam splitters with a loss of light greater than 87½%.

In addition to the luminance loss as the number of channels is increased, there is a change in color associated with the respective fields. Half-silvered mirrors have the peculiarity of reflecting the short end of the spectrum and transmitting the long end. The differential transmission causes gross color mismatch between the T-scope fields. As Koletsky & Kolers (1959) point out, the most feasible method of matching colors is to arrange for the light from each field to reflect from and pass through the same number of mirrors. This arrangement unfortunately requires reduction of greater than 87½% of the luminance of each of the fields in a three-field T-scope. Obviously, the energy decrease involved in a T-scope with four or five channels would be excessive.

The major problem in designing an n-channel instrument is primarily an optical one. Developments in modern electronics offer several alternative ways of providing precise control over timing and sequencing for the on-off relations of the different channels. In the past three years we have constructed two 10-channel T-scopes. The first of these was designed to study visual perceptual rate under very rapid sequential input conditions. We wished to present up to 10 capital letters to S at rates that varied from a couple of milliseconds per letter to 3 or 4 sec between successive stimuli. The S's task was one of visual search in which he was required to determine whether a given target letter had occurred in the sequence of letters presented. In addition to having precise control over rate we wished to be able to present the successive letters on essentially equally sensitive but different foveal locations. This consideration required presenting the letters in a circular arrangement around a central fixation point. Control of luminance over a moderate range was essential as was rapid change of stimuli and sequencing between trials.

These experimental requirements were met in the following way. For light sources we used 10 Sylvania F4T5/CWX fluorescent lamps. These lamps have a much better spectral energy distribution than do mercury argon lamps and are considerably less expensive. When a subcritical 100-V dc is maintained on the lamps and they are fired with 300-V dc, not only is performance exceedingly reliable but they are capable of emitting square pulses of light with rise and decay times in the microsecond range. The lamps were individually mounted in light-proof boxes attached to the surface of a sheet-metal drum and equally spaced around the circumference (see Fig. 1). From each light-proof box a flexible fiber optic light guide (American Optical Co.), 1/8 in. inner diam and 12 in. long, extended to a machined fitting where each was coupled to ¼-in. diam Lucite rods 6 in. long. These latter served as diffusers for the light. Each Lucite rod was wrapped in

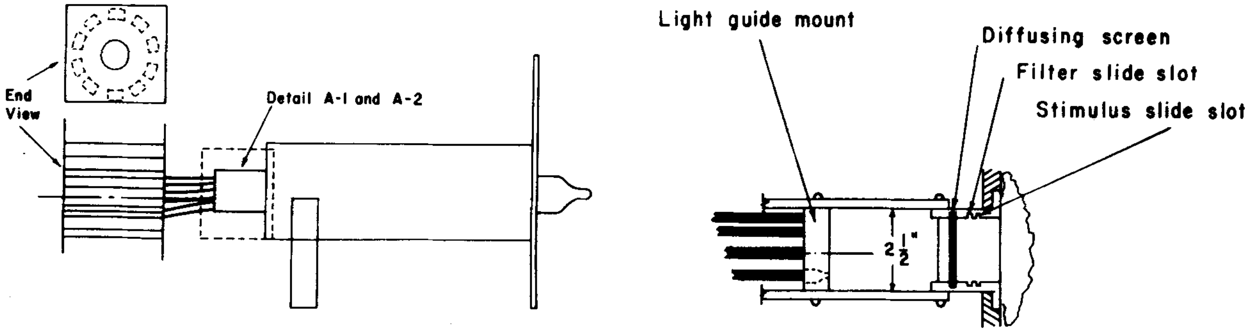

Fig. 1. Viewing tunnel and light sources for 10-channel T-scope. The two detailed drawings show the means by which the light via the fiber optics is brought into the machined fittings for presentation to the S.

aluminum foil except for the two end surfaces. The ends of the rods extended through the machined fitting and formed a circular pattern of 1 in. diam with the center of each light guide spaced approximately 5/16 in. from the centers of the adjacent guides. A separate light source projected at the center of the circular arrangement and was used to provide a fixation point. The machined fitting provided for 35-mm slides to be placed immediately in front of the projecting ends of the 10 Lucite rods and the fixation light source. Additional space in the fitting provided for neutral density filters mounted as 35-mm slides.

The machined fitting was mounted at the end of a visual tunnel 18 in. square and 30 in. long. At the other end of the visual tunnel was a headrest and viewing hood; the distance from the S's eye to the front surface of the 10 light guides was 38 in.

The diameter of the circular arrangement of the light guides and the machined fitting was chosen so as to accommodate 35-mm slides. Our primary interest was to be able to present alpha-numeric characters at high sequential rates and with this design up to 10 different characters could be placed on a single 35-mm slide, each one positioned to correspond to the location of one of the 10 light guides. As viewed by S, firing one of the 10 lamps illuminated the character located at the end of the associated light guide from that lamp.

To facilitate the construction of stimuli a photographic layout was constructed with positions indicated on the layout that corresponded to the center of each of the 10 light guides. Scaling was such that when the letter stimuli were placed in the indicated positions on the layout and the camera was mounted in its rigid position, the appropriate location and reduction in letter size on the photograph was obtained. The fixation cross was provided within the center of the layout so that each slide contained its own fixation stimulus.

As the apparatus was constructed the stimuli could either be lighted figures against a black ground or the reverse; we have used both types. For illuminated figures against the black ground a Polaroid 210 camera has been used along with 146-L negative high contrast film. This film permits the presentation of a transilluminated stimulus having a contrast of better then 98% with the surrounding ground. For presenting black figures against a lighted field, Para-tipe letters and characters mounted directly on 35-mm glass slides provide good definition in which the S sees the black figure centered in a ¼-in. diam lighted field.

The "on" time of each of the 10 fields and the delay between successive fields was accomplished with 10 Tektronix Model 162 waveform generators and nine Tektronix Model 161 pulse generators. The waveform generators were used for the "on" time of each of the 10 lamps while the pulse generators timed the interstimulus intervals. Switching of the lamps was controlled by Sylvania 2N3585 transistors which were biased to the conducting state by the gate biases from their associated waveform generators. The voltage which fires the lamps is 300 V dc taken from a constant voltage power supply. The first waveform generator is keyed by an external switch or trigger. For the duration set on the dial the signal generator holds its gate circuit closed and then emits a negative going sawtooth pulse at the end of the duration. The sawtooth triggers the adjacent pulse generator which in turn emits a brief gating pulse at the end of the time period set on the dial. This gate triggers the next waveform generator and so on successively through the n-pulse and waveform generators.

We have employed two different methods to program the fields presented to S on a given trial and the order in which the fields occur. The first of these is a scrambler box inserted in the circuit between the output of each waveform generator and the 10 lamps. This scrambler consists of a base in which are mounted 10 copper bars each connected to one of the field timers. The top of the scrambler is similarly constructed except that the 10 copper bars are at right angles to those in the base and are connected directly to the light source through the transistorized switches. The top and bottom halves are connected with a hinge so that the scrambler can be opened and a 10 by 10 matrix pegboard of dielectric material inserted between the upper and lower 10 bars. By placing metal pins in the appropriate holes in the pegboard a circuit is completed between the upper and lower halves. Appropriate placing of the pins determines the fields to be presented during a trial as well as the order of their occurrence. In order to insure reliability of contact the pins in the pegboard need to be springloaded. Pegboards composing the different orders of stimulus presentation can be constructed prior to the experiment and quickly inserted and removed between trials.

A second method of programming utilizes a bank of 50 12-pole single throw switches. Mounted in five rows of 10 each these switches permit prewiring of up to 50 different sequential orders prior to an experiment. By having a panel light associated with each switch the E can quickly determine which switch is in operation or which sequential presentation is scheduled for a given trial.

Luminance of each of the 10 ¼-in. diam fields is slightly in excess of 30 mL, after diffusion through the 6 in. of Lucite rod. Somewhat higher luminances can be obtained if the ferrules of the fiber optic light guides are mounted directly in the machined fitting without passing through the Lucite. This, of course, would result in a smaller diameter field unless larger light guides are used. Luminance reduction is obtained by providing in the machined fitting for up to five neutral density filters mounted as 35-mm slides.

In our work the limitation on the upper range of luminance values is relatively unimportant. Identification accuracy of alpha-numeric characters in practiced Ss with dark pre- and postexposure fields is generally in the 90% region with

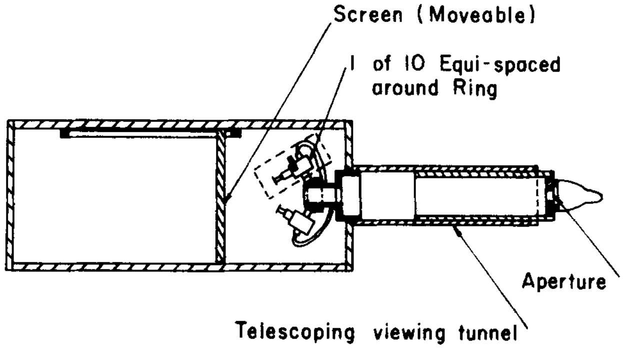

Fig. 2. Viewing tunnel and lens mounting system for 10-channel T-scope.

exposure durations as short as 2 msec and 1 mL luminance. Increase in the upper range of luminance would depend upon finding suitable lamps since only approximately 10% of the luminance is lost per foot in the fiber optic light guides.

We chose a circular arrangement of the 10 channels because the experimental work required the presentation of the different stimuli on essentially equally sensitive foveal areas. However, the flexibility of the fiber-optic light guides permits the stimulus field arrangement in any desired pattern. The only limitation, and this is a serious one, is that all 10 channels cannot be superimposed one on top of another. That is, they cannot be arranged so as to stimulate the same retinal locus. This limitation precludes the use of this equipment for visual masking experiments where the test and the masking stimulus are typically presented either on the same retinal locus or the masking stimulus circumscribes the locus upon which the test form has been presented.

Our experimentation has not required fields for light adapting, interstimulus interval, or postexposure, but provision for this type of stimulation can be easily arranged by insertion of a beam splitter in the visual tunnel and the construction of an adapting field on one side of the tunnel. This results in an arrangement similar to the two-channel Dodge type T-scope. The 10 channels are viewed through, and the adapting field is reflected off, the beam splitter. By the addition of the requisite number of timers the lighted adapting field can be made to turn off when any one of the 10 channels is being presented or can even be arranged to provide a lighted interstimulus interval.

While this equipment is quite well suited to our experimentation on perceptual rate, the inability to superimpose the 10 separate fields to stimulate the same retinal locus constitutes a serious restriction for certain types of experimentation. There are, also, other minor disadvantages. The Tektronix waveform and pulse generators do not have a continuous time setting but are calibrated in arbitrary discrete steps. In addition, it is impossible to obtain overlap of the 10 fields in time with the Tektronix timing equipment. Our second attempt at a 10-channel T-scope was oriented toward a solution of these problems.

An improvement in the timing equipment and control is readily obtained by employing the newly available Iconix Model 6255 timebase generator and two Model 6010 preset counters which contain 10 counter and pulse emitting circuits each. The timebase generator incorporates a readout display on the front panel and is specified accurate to ±0.001%. An external trigger starts the timebase generator which feeds into the preset counters. Each preset counter circuit emits a one-shot pulse when the time count reaches the specified number preset on the counter. The timebase generator automatically stops and resets after the highest preset number is reached. Ten flip-flop circuits are used to control the Sylvania 2N3585 transistor switches which switch on B+ to the lamps. The pulse from preset counter No. 1 puts flip-flop Circuit 1 into State B; preset counter No. 2 returns Circuit 1 to State A. The preset counters operate the 10 flip-flops in this pairwise fashion with counters No. 3 and No. 4 controlling circuit No. 2, etc.

In the elapsed time mode, each preset counter emits a pulse when the count reaches the set number independently of all the other preset counters. In the sequential mode the first counter emits its pulse as above, but the second counter begins the count from the time of the pulse of counter No. 1 and so on sequentially for Counter 3, 4, . . . n.

This timing equipment can be used with the above described optical system and has many obvious points of superiority over the Tektronix waveform and pulse generators. For a 10-channel T-scope with independent field timing and independent control of interfield intervals, the cost of the Iconix and the Tektronix equipment is comparable considering that the Tektronix instruments also require three associated power supplies.

An improvement in the optical system is somewhat more difficult to obtain. In order to meet the prime requirement that all 10 fields be capable of superimposition, a projection principle was decided upon. The optical system and viewing arrangement are shown in Fig. 2. Essentially, it consists of 10 variable power lens systems originally designed for 8-mm projectors. The 10 lens systems are mounted equally spaced in a circular arrangement on a machined base and brought to a common focus on a beaded screen 6 in. from the face of the objective lenses. Light sources are again from Sylvania F4T5/CWX fluorescent bulbs. Each is housed in a lightproof tube which is made integral with a housing with the lens system and a film holder.

Figure 3 shows a detailed drawing of the lamp housings and lens system along with the circular film holder designed to take circular pieces of film containing the stimuli. The 10 lamp housings and associated projection systems are mounted in a circular arrangement around a viewing tunnel. The forward end of the tunnel has a removable truncated cone whose small diameter opening is adjacent to the beaded screen. The S's line of sight is down this viewing tunnel to the beaded screen upon which the stimuli are projected. The tunnel serves to shield out any stray light that leaks from the film holders in the projection systems. Each lamp housing is individually adjustable in two dimensions so as to enable changes in the position of focus on the beaded screen. At a distance of 6 in.

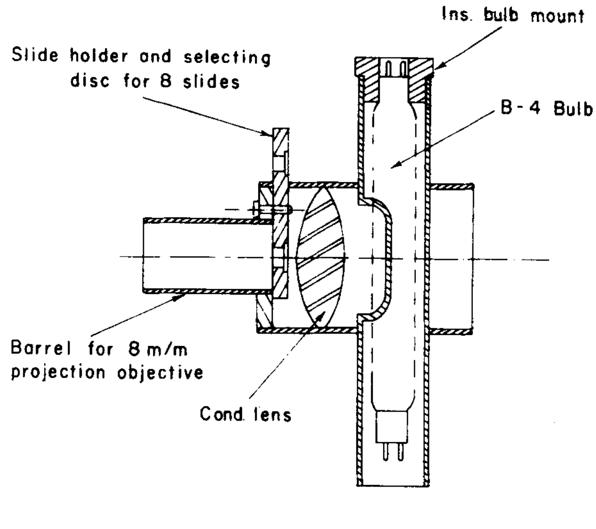

Fig. 3. Detailed drawing of one of the 10 projection systems in the 10-channel T-scope illustrating lamp housing, condensing lens, stimulus film holder, and variable power projecting lens system.

from the objective lenses of the projectors all 10 fields are superimposed. If a circular or other arrangement of the 10 fields is desired, the beaded screen can be moved further away from the lenses and the removable truncated cone portion of the viewing tunnel can be replaced with a longer section having a different shape. Each lens system contains an integral zoomar lens which allows independent size variation for each field. By adjusting the lens and the distance of the screen the size of the stimuli can be varied from less than 30 min of visual angle to more than 5 deg of angle.

The film holder associated with each projection system provides for eight different stimuli mounted on a circular wheel. The holder takes a circular piece of film containing the stimuli and the locations are counterbored to accept the film. Positive stops in the form of detents indicate when the film is properly aligned with the axis of the projection system.

To superimpose two or more fields of the T-scope requires that the projection system be on an angle which results in some distortion of the stimuli and a luminance gradient across the field. The distortion of the stimuli can be compensated for by using a layout table for photography that has built-in reverse distortion to compensate for the location and angle of the projector for the specific stimulus. The layout table we have used when all 10 fields are to be superimposed is conical in shape; the slope of the surface is the reverse of the angle of inclination of the projectors to the principal axis of the optical line of sight of the S. Thus, when projected, the image appears distortion-free to the S.

The luminance gradient obtained across the projected field is a little more difficult to deal with. It cannot be completely eliminated if all 10 fields are to be employed but for many purposes it is of trivial importance. A homogeneously illuminated field can be obtained by using the T-scope as only a five-channel system. Under this arrangement fields are operated in pairs so that when stimuli are presented they occur in the projection systems that are diametrically opposite each other. Thus, each projector compensates for the angular distortion imposed by the other and cancels it out.

Programming the fields to be presented in a trial and the order in which they occur is accomplished either by the scrambler box described above, or by the 10-pole single throw switches that are prewired for the different sequences of presentation. By changing the point of focus of the individual lamp housing projector systems, and the distance of the screen from the objective lenses, one can vary from a display in which all 10 fields are superimposed to one in which all fields occur in a circular arrangement around a common fixation point. Elliptical arrangements can also be obtained by appropriate adjustment of the lamp housing projector systems and the use of an appropriately shaped end to the viewing tunnel.

Total cost for either of the two T-scopes described above is under $4,000. The electronic timing equipment can be obtained for less than $3,000, fiber optic light guides 1 ft in length are approximately $20 each, and the integral zoomar lenses can be obtained for under $10 each from Edmund Scientific. One major item of equipment is the power supply to operate the Sylvania lamps. These lamps draw 80 mA and if all fields are to be operated simultaneously a regulated power supply of 3-A capacity is required. The power supply we have employed was constructed in the Psychology Department electronics shop for a total cost of less than $500.

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NOTE

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