A Hypereffective Visual Signal for Night Driving Warning Device

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•THE ENHANCEMENT of retinal sensitivity described in this report was first observed in electroretinographic studies of frogs. However, in the interest of brevity, only human perception is discussed here.

There are many studies of flicker reported in literature, but they are almost all concerned with the upper frequency terminus of the visual perception; that is, they are concerned with a rate of iteration so fast that the iterative stimulus seems to be a steady light—that is, at the critical flicker frequency (1, 2, 3). The present study is also concerned with iterative stimulation, but at very slow frequencies, near 5 per second, instead of near 50 per second.

At very slow rates, the stimulus can be perceived as going on and off. If the stimulus is modified to be brighter and dimmer, instead of on and off, a brightness contrast can be found which is so low that the change in the stimulus cannot be seen. This is a visual threshold, and, of course, must be estimated by the usual psychometric procedure. However, at these slow rates, another and new variable can be introduced, the duty-cycle, or fraction of time within a single brighter-dimmer-brighter cycle in which the brightness occurs. This duty cycle is called "temporal contrast." Just as brightness contrast, $\Delta B/B$, varies from 0 to 100 percent, so temporal contrast, $\Delta T/T$, also varies from 0 to 100 percent. In presenting slow iterative stimuli, therefore, there are two contrast parameters—luminance and time. These two parameters can be independently superimposed on the rate of iteration or repetition.

The interaction of these two parameters of visual perception were measured, and the preliminary results of these measurements are presented. The stimulus apparatus consists of a glow-modulator tube, of a type originally developed for telephonic transmission of pictures (Sylvania, operated at 2,000 cps and less than 25 mA). The activating voltage of this tube permits independent control of frequency, duration, and brightness of the light pulses. The light was presented to the human subject in Maxwellian view as a featureless circle about 30° in diameter, through an effective 2-mm pupil. The tube was maintained at a constant background brightness of 8 ft-candles, and brighter flashes were then introduced in groups of five at controlled rates, as shown in Figure 1.

In the present experiment, these rates were 2½, 5, and 10 per second. The temporal contrast, or duty cycle, of these groups of flashes was varied between 5 and 20 percent. The brightness contrast was varied near the threshold between 1 and 5 percent. The subject sounded a buzzer if he saw the flashes after a warning ready signal. Brightness contrast thresholds were estimated at the 50 percent level of probability of seeing. Visual sensitivity, or stimulus effectiveness is shown as the ordinate, with varying temporal contrast on the abscissa. The data are presented logarithmically.

The lowest ordinate indicates the greatest effectiveness of the stimulation. In this series, and at this adaptation level, a brightness contrast threshold of just over 1 percent is found, with 10 percent temporal contrast, in this subject, when the stimulus is presented at a rate of 5 per second. The slower presentation rate of 2½ per second raises the threshold; that is, is less effective as a stimulus. The faster rate of 10 per

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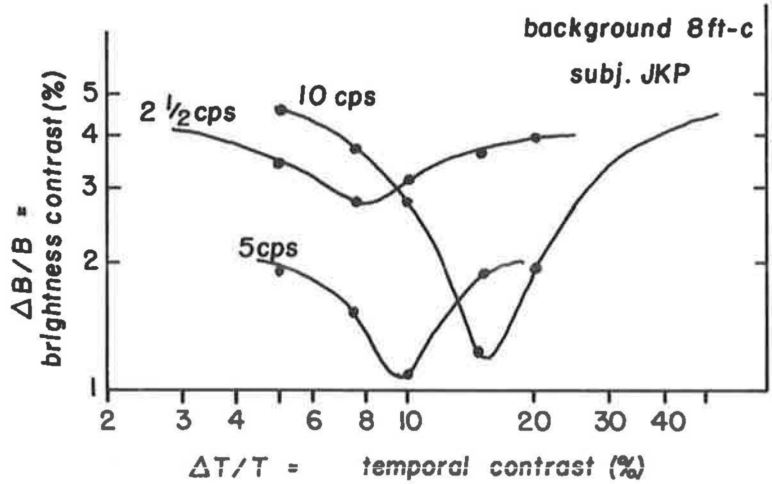

Figure 1. Relation between brightness contrast and temporal contrast (duty-cycle) at very slow flicker rates, showing sharp decrease in brightness contrast at threshold for specific temporal contrasts, at moderate brightness levels comparable to headlight road illumination.

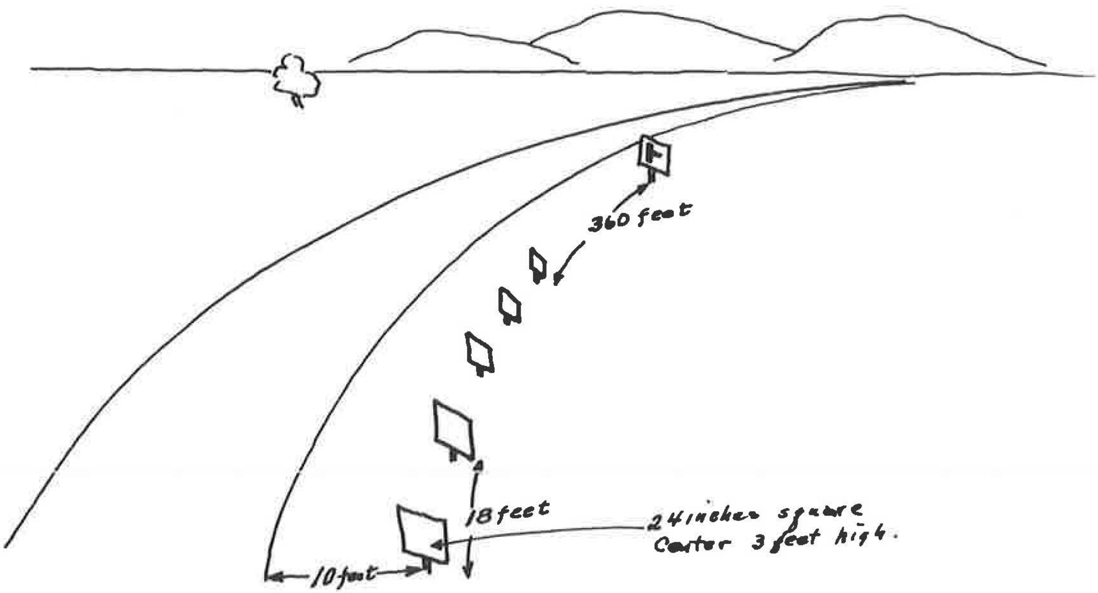

Figure 2. Presentation of hypereffective stimuli by directive retroreflective panels (rather than diffusely retroreflective panels), or by specularly reflective mirrors (dimensions shown approximated for speed of about 60 mph).

second is also less effective. There does exist, therefore, a combination of brightness and temporal contrasts, and rate of stimulus, which is a hypereffective visual stimulus.

Observation establishes a new and rather unusual fact. The rate and duration of a flashing stimulus can be modified or chosen to create a visual stimulus far in excess of the effectiveness that would usually be expected. This phenomenon is admittedly greatly unexplored. A whole new family of contrast thresholds has been uncovered. However, immediate application of this enhanced effectiveness is quite possible and practical.
A visual warning device that presents groups of short light flashes above the background

ered the preceding criteria if he has contemplated using simulation as a methodology for pursuing his research.

If an interest in the functional properties of the driver and the system in which he operates is assumed, a course that demands a concise and rigorous definition of the properties of the man-machine system is followed. In driving, one is confronted with a dynamic system characterized by complex equations. Man is a creature whose output is stochastic. Therefore, modeling the system becomes a tremendous challenge if an attempt is made to define the system in its entirety.

The dilemma may be resolved if the researcher is willing not to study the system in its entirety. A programatic approach that permits exploration of certain aspects of the driving situation and their interactions, and that requires that all assumptions be made explicit is known as part-task simulation.

Given the inherent complexity of the driving task, the alternate path (i.e., full-scale simulation) faces two difficult problems. First, by increasing the number of variables both explicitly defined by the research and implicitly involved by the nature of the driving field, the number of observations that must be made increases exponentially. Likewise, the variety and number of experimental controls required to obtain reliable data must be increased. Second, the human has a tremendous facility for adaptation. He selects, masks, and filters information in such a manner that it is difficult to obtain reliable data in highly complex and unstructured (unprogramed) experiments.

Therefore, the dilemma is that to oversimplify the research is to lose the reality of the driving task, whereas oversimulating makes theoretical research extremely difficult, if not impossible, because of its complexity. A choice has to be made and the one made here is the former. That is, to start from the existing body of theory on how the human operates under limited and sometimes ideal conditions and eventually to synthesize driving. Part-task simulation is performed piece by piece as the research dictates in order ultimately to approach the psychological and physiological reality of the highway. From this viewpoint, research on driver behavior is performed which hopefully leads to an understanding of the underlying behavioral processes that define driving.

METHODS

As suggested previously, the starting point of any snythesis of driving should be fairly close to the laboratory, and not too far from a single variant operation. There are several branches which such a research program may take. Figure 1 shows a representation of the type of research plan that dictates the steps to which specific inquiries should be subjected. The initial requirement is a logical analysis of the driving task out of which several alternative paths of research may evolve. The procedure generally involves several steps:

1. Selecting an operation or set of operations that appear to be involved in driving. Braking, steering, and sign legibility are examples.

2. Devising or using an existing model of operational performance based on rational analysis and empirical laboratory studies. Braking, for example, has been hypothesized to be in response to a discernible rate of closure, dependent on detection of the acceleration of the angle subtended at the eye by a leading vehicular form. It has also been hypothesized that the margin of closure is dependent on a risk-taking criterion employed by the driver. Such models lead to explicit and testable hypotheses. Theoretical studies along these dimensions have been conducted in laboratory settings.

3. Performing a study that includes system dynamics like those found in current automobiles. These dynamics should reside on a continuum, one end of which is predictable from laboratory studies.

4. Answering questions on whether the anchor ends of the continua are supported, whether, in the specific studies conducted, the outcomes match those already found in the areas where empirical research has already been conducted, and whether the vehicle dynamics react in the expected manner.

5. Taking the research effort to the field to validate the models in controlled tests. Inconsistencies and unexpected results must be fed back to earlier stages of the theory-building. Other permutations than the one detailed may issue from the logical analysis of the driving subtasks explored.