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VISUAL RESPONSES TO LUMINANCE INCREMENT AND DECREMENT OF TEMPORAL RAMP STIMULI WITH DIFFERENT RISE AND DECAY TIME

By

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Two indices of visual responses to luminance increment and decrement of the temporal ramp stimuli with different rise time and decay time were measured psychophysically: simple reaction time (SRTs) and visual masking functions. Results of SRT experiment showed that the difference in effects of rise time and decay time on SRTs lay in the way of increase in SRTs with the increase in rise and decay time; curvilinear vs. linear increase. Results of masking functions revealed that the peak amplitude and the peak latency of masking functions varied with the increase in rise and decay time although their variation associated with the increase in decay time was less systematic. Results of SRTs and those of masking functions to luminance change of temporal ramp stimuli with different rise and decay time correspond well when they are compared within each type of responses to increment and decrement in luminance, while correspondence between them is poor when they are compared between two types of responses.

Introduction

Visual response to the temporal ramp stimuli which differ in their rise or decay time has been investigated either in electrophysiological or in psychophysical experiments. Enroth-Cugel & Jones (1961) reported results of extracellularly recorded action potentials of ganglion cells to exponentially increasing stimuli from opened cat eyes and found that inhibition, as judged by reduction in discharge frequency, might depend upon the rate of increase in luminance. Bornschein (1962a) also recorded single unit responses from the two types of cat's retinal ganglion cells (on-center and off-center neurons) to light onset and offset with the variation of rise and decay time and found that the effect of temporal gradients of luminance was marked on the off-responses but less so on the on-responses of these cells. Moreover Bornschein (1961) studied ERG responses to the stimuli with different rise gradients in the souslik and reported that the amplitude of the souslik ERG was strongly influenced by the stimulus gradient whereas the peak latency of the b-wave showed less dependency. Similar results were obtained for the photopic x-wave of human ERG in his succeeding study (Bornschein, 1962b). Although results from single unit and those of ERG do not nessesarily correspond well, these electrophysiological studies clearly show that the temporal parameter of rise and decay time or temporal gradient influences the way of responses of the visual system.

Psychophysical evidence which was in good accord with the results of ERG response to ramps was offered by Matsumura (1976). He measured visual masking functions, which had been often regarded as indirect on- or off-responses of the visual system, to temporal ramp stimuli, and found that the peak magnitude and the peak latency of masking functions varied with the increase in rise or decay time, although their variation associated with the increase in decay time was less systematic.

From these electrophysiological and psychophysical facts it is expected that the factor of rise and decay time will influence the simple reaction time (SRT) to the onset and offset of temporal ramp stimuli, which has been traditionally used to assess the response latency to a stimulus. In fact auditory and cutaneous responses to ramp stimuli have been studied mainly by means of SRT to them and it has been reported that the prolongation of rise or decay time produces the increase in SRT to onset and offset of the stimuli (Grier, 1966a, 1966b; Sticht & Foulke, 1966; Warm & Foulke, 1970).

To date, however, SRT to these stimuli has not yet been examined in the visual research. Therefore it is the primary aim of the present study to examine the effect of rise and decay time of the ramp stimuli on the SRT to their increment(on) and decrement(off), and the secondary aim is to compare the SRT data with those of masking functions obtained with the same ramp stimuli as are employed in the SRT experiment. It is assumed that both reduction in the peak amplitude and delay in the peak latency of the masking functions induced by the variation of rise and decay time lead to increase in SRT.

SRTs and masking functions were measured in two separate experiments; SRTs in experiment I and masking functions in experiment II.

Experiment I

Visual SRTs to luminance increments and decrements of the temporal ramp stimuli were measured as a function of their rise time and decay time.

Method

Two male *S*s, a graduate and the present author, were employed. They had two or three practice sessions of SRT task in advance of the present experiment.

The light signals to be responded consisted of the following two sets of temporal ramp stimuli. One was the increment stimuli which rose linearly from a certain adaptation luminance level (600nit) to a constant top luminance level (1,000nit) with different rise time and receded to the prevailing adaptation level after a second, and the other was the decrement stimuli which went down linearly from the same adaptation level as the increments (600nit) to a constant bottom luminance level (200nit) with different decay time and receded in a similar way to the increments (Fig. 1). *S*s responded to the luminance increment in the former set and to the luminance decrement

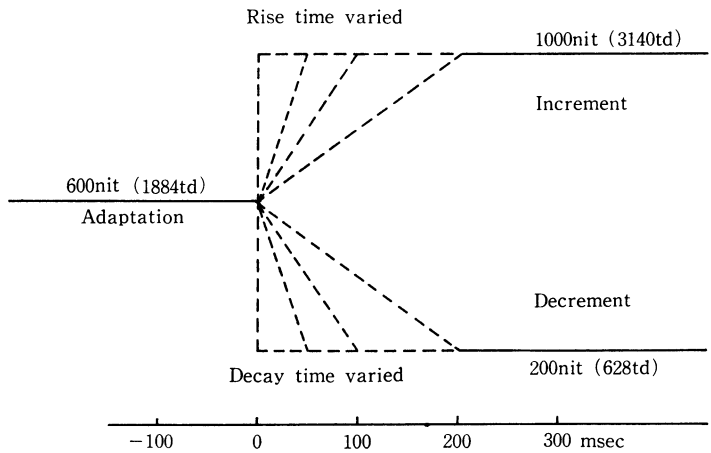

Fig. 1. Two sets of temporal ramp stimuli used in the present study.

in the latter. Rise time of the increment stimuli and decay time of the decrement stimuli were set in four steps, respectively; 0, 50, 100, and 200 msec. The linear increment and decrement in luminance were obtained with the use of "the method of frequency-modulation of glow train" mentioned in detail in the preceeding paper (Matsumura, 1976), and modulation-frequency range between 200 Hz and 1,000 Hz was employed in order to obtain the variation of luminance between 200 nit and 1,000 nit at the eye. These stimuli were presented to the *S*'s left eye through one channel of the dual beam Maxwellian view system. An artificial pupil of 2 mm diameter was employed. Spatial configulation of the stimuli was a disk which subtended a visual angle of 6.73°.

Following a sign of "Be ready" by *E*, *S*s fixated the center of the disk which could always be seen, and pressed a telegraph key at hand. After one of three foreperiods (1.5, 2.0, and 2.5 sec) the luminance of the disk was increased or decreased, and *S*s were instructed to release the key quickly when they detected brightness change of the disk; in increment conditions, as soon as they found the disk become brighter than the prevailing brightness, and in decrement conditions, as soon as they found the disk become darker than the prevailing brightness. Information on whether the disk became brighter or darker was given to *S*s in advance of ready signals. SRTs were measured by means of Digitimer (TKK Co. Ltd.) which began counting at the beginning of increment or decrement in luminance and stopped at the time of the *S*'s reactions, and which, in turn, was connected with a digital printer (TKK Co. Ltd.) that printed measured SRTs automatically.

Each *S* participated in four experimental sessions. A session contained four blocks of each 50 trials. In each block, *S* made 25 consecutive reactions to luminance increment of a given rise time and the other 25 reactions to luminance decrement of decay time of equal length to paired rise time. In each session, four blocks of paired rise and decay time were given to each *S*. Presentation orders of blocks and of increment-decrement were counterbalanced across sessions. In advance of each session, *S*s had more than 50 practice trials.

Results and Discussion

Mean SRTs were obtained for each *S* under 8 experimental conditions. In computing these values, the data from the first 5 among 25 trials under each condition were considered as practice and eliminated. Thus, *S*'s mean SRT for each treatment was based upon 80 reactions.

As results of two *S*s were nearly the same, averaged SRTs were plotted in Fig. 2 as a function of rise and decay time, with reactions to increment and decrement as a parameter. Fig. 2 showed that SRTs to luminance increment increased curvilinearly with the prolongation of rise time whereas SRTs to luminance decrement increased linearly with the increase of decay time, and that SRTs were faster to luminance decrement than to increment under the rise and decay time conditions of 50 msec and 100 msec while under the extreme conditions of 0 msec and 200 msec SRTs to increment and decrement were nearly the same. Hence the total increase in the latency of reactions to luminance increments and decrements when the rise and decay time increased from 0 msec to 200 msec, was identical and was only about 35 msec.

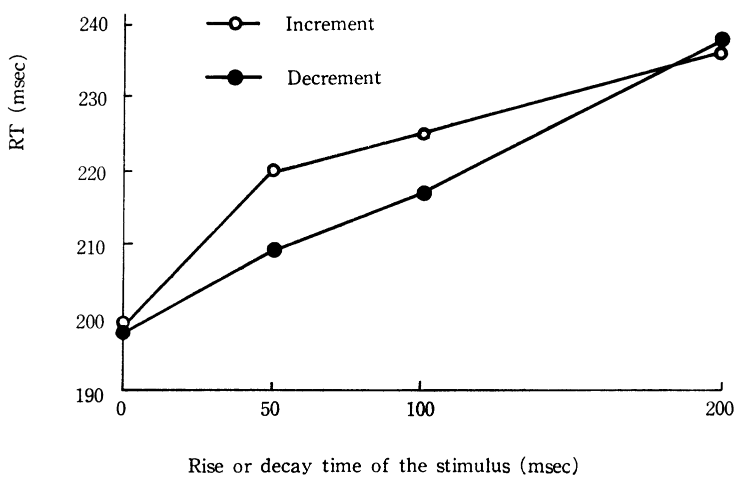

Fig. 2. Averaged SRTs of 2 *S*s as a function of rise and decay time, with reactions to increment and decrement as a parameter.

No comparable data are available in the visual research field which examined the effect of rise and decay time on SRTs to luminance increment and decrement, but the present result that SRTs to increments and decrements were identical under rise and decay time condition of 0 msec, is consistent with the result of Vicars & Lit (1975) who obtained RT responses to stepwise incremental and decremental target luminance changes at various photopic background levels and showed that RTs to luminance changes in both directions were about 200 msec at the similar luminance level to that employed in the present study.

Difference in effects of rise time and decay time on SRTs was found in the way of increase in SRTs with the increase in rise and decay time; curvilinear vs. linear. Similar results are found in the auditory RT experiment by Warm & Foulke (1970), but the results are just opposite in RTs to the onset and offset of electrocutaneous stimuli (Sticht & Foulke, 1966). Direct electrical stimulation employed in the latest experiment, however, is the peculiar method of stimulus presentation, and thus, this study and ours are not to be mentioned in the same breath. Similarity of the results in the visual and auditory RT experiments implies that sensory generality exists in the effects of rise and decay time on the response latency to temporal ramp stimuli.

The results of RTs under long rise and decay time conditions of 200 msec or more are different between two modalities; there is no difference in visual RTs to onset and offset as shown in the present study, while there is a remarkable difference in auditory RTs (Warm & Foulke, 1970). This may be attributable to the differences in the range of intensity change, presence or absence of prevailing adaptation, and sensory modalities employed in two experiments.

Experiment II

Masking functions to the temporal ramp stimuli with various rise and decay time were measured. When increment threshold for detecting the small test flash superimposed on the larger field (masking stimulus) whose luminance varies between two levels is measured before, at and after the change in luminance of the latter field, a complex threshold curve is obtained. This increment threshold curve is called masking function (Kahneman, 1968), which is obtained here by following the same procedure. This experiment is a replication of previous one (Matsumura, 1976) with a few modifications of experimental conditions.

Method

*S*s were the same as employed in experiment I. They had normal or normal corrected vision and were well experienced in the masking experiments.

Masking stimuli were the temporal ramp stimuli quite identical to those employed in SRT experiment as light signals (Fig. 1). Increment and decrement stimuli used as masking stimuli were called increment MS and decrement MS in the present paper.

Test flash, which was abbreviated to TF, was a circular spot subtending a visual angle of 1.72°, and superimposed on the center of MS field(disk) through another channel of the dual beam Maxwellian view system. A glow modulator tube was used as a light source of TF. TF duration was 2 msec.

Luminance increment thresholds of TF were measured at various temporal points before, at and after the beginning of the increment or decrement in MS luminance. In order to identify the precise peak value and peak latency of the masking function, temporal points of TF were chosen in 10 msec step from a rather narrow range of −10 msec∼+60 msec in which 0 msec was defined as the temporal point when MS began to change its luminance. While *S* was watching a given phase-locked sequence of MS and TF which was repeated once every 5 seconds, he adjusted TF luminance from the level on which he could see it clearly to its disappearance by means of a circular neutral density wedge.

Each *S* participated in four experimental sessions; two sessions for increment masking and the other two sessions for decrement masking. Each session was divided into four blocks. In each block, TF thresholds at all temporal positions were measured for a certain rise time or decay time condition. In addition to these thresholds, TF thresholds against adaptation level of luminance(600 nit) without MS were measured before and after each block to get resting levels. In each session, four blocks of rise time or decay time conditions were given to each *S*. Presentation orders of blocks and TF positions were counterbalanced across sessions.

Results and Discussion

Similar results were obtained from two *S*s and the averaged masking functions were presented in Fig. 3 and Fig. 4. R at the left bottom in each figure denotes the resting level.

Fig. 3 represents masking functions to increment MS with rise time as a parameter. This figure showed that the peak amplitude from the resting level decreased proportionately as the rise time of the increment MS became longer, and that the temporal position of the peak was at the moment of increment under the rise time condition of 0 msec, whereas it was around 20 msec after the beginning of increment in MS luminance under the other three rise time conditions.

Masking functions to decrement MS were shown in Fig. 4 with decay time as a parameter. This revealed that the peak amplitude of the function did not show proportionate decrease to the length of decay time and the greatest amplitude was obtained under the decay time condition of 50 msec, and that the temporal position of the peak was, as in the increment masking, at the moment of decrement in MS luminance under the decay time condition of 0 msec, whereas it was delayed by about 20 msec under the other conditions of decay time.

Peak amplitude of the masking functions from resting levels and the temporal position of the peak were plotted as a function of rise or decay time in Fig. 5. Peak amplitude was larger in masking by increment MS than in that by decrement MS at any rise or decay time. Results of peak latency as a function of rise or decay time, however, coincided well between two kinds of masking.

Results of the present experiment were similar for the most part to those of the previous one (Matsumura, 1976), but several differences were made perhaps due to

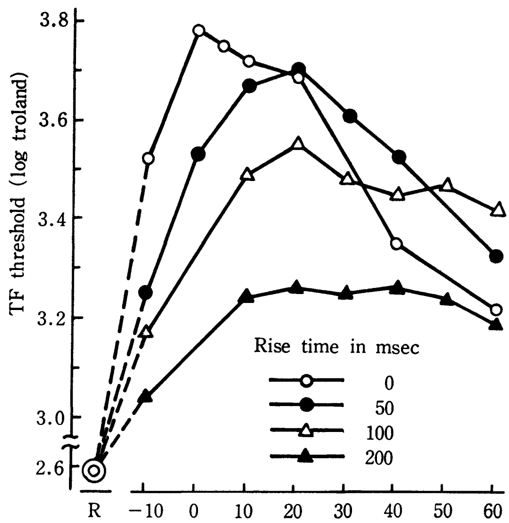

Fig. 3. Averaged masking functions to increment MS, with rise time as a parameter.

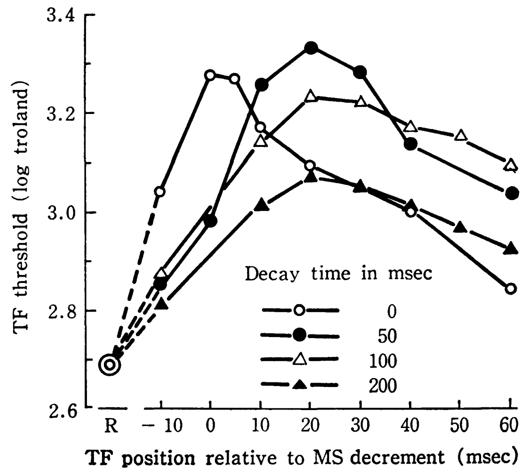

Fig. 4. Averaged masking functions to decrement MS, with decay time as a parameter.

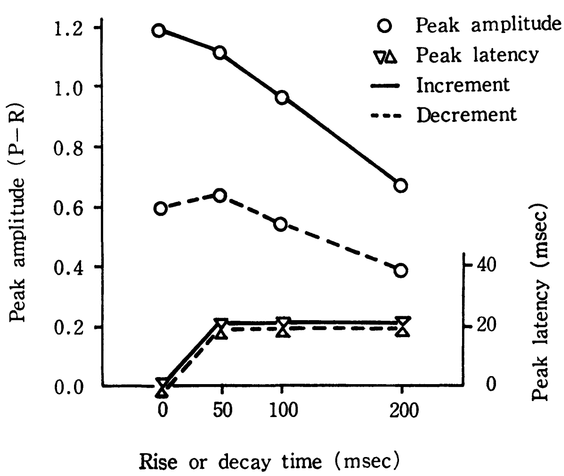

Fig. 5. Peak amplitude and peak latency of masking functions as a function of rise and decay time.

modifications of experimental conditions. First, absolute peak values of functions in any rise and decay time conditions were smaller in the present results than in the previous ones. This may be due to reduction in the range of changes in MS luminance; luminance increment and decrement of 400 nit in the present experiment and those of 800 nit in the previous experiment. Second, differences in peak amplitude from resting levels between two types of masking functions to luminance increments and decrements were also smaller in the present experiment than in the previous one. This may be ascribed to both reduction in the range of changes in MS luminance mentioned above and differences in the prevailing adaptation levels, which were identical both in increment and decrement MS in the present study but different in the previous one.

General Discussion

The primary aim of the present study was to examine the effects of rise and decay time of the ramp stimuli on the SRT to their increment and decrement in luminance. On this point we discussed in detail in the result and discussion section of experiment I, and thus, it is mainly concerned here to compare the SRT data with those of masking functions obtained with the same ramp stimuli.

SRTs to luminance increments increased curvilinearly with the increase in rise time and the larget increase in SRTs (approximately 20 msec) appeared between 0 msec and 50 msec conditions of rise time. This result corresponds well to the fact that the difference in the peak latencies of the two masking functions to luminance increments under the rise time conditions of 0 msec and 50 msec was about 20 msec with less reduction in the peak amplitude. Also gradual increase in SRTs with the increase in rise time of more than 50 msec may be related to the linear decrease in peak amplitude of masking functions without the change in peak latency under the same conditions of rise time.

As for the responses to the decrement in luminance, on the other hand, SRTs increased linearly as the decay time became longer. This result may be related to the fact that the peak amplitude of the masking functions to luminance decrements was greater under decay time condition of 50 msec than under 0 msec condition although the peak latency was, as in masking by increments, delayed by about 20 msec under the same conditions of decay time. In short, increase in SRT associated with the delay in masking peak may be partly compensated by the decrease in SRT associated with the greater peak amplitude of masking response at the decay time of 50 msec.

Although the correspondence between two indices of visual responses is remarkable when they were compared within each type of responses to luminance increment and decrement, there appears an important discrepancy when they are compared between responses to increments and decrements. That is, there is no difference between SRTS to increments and those to decrements under 0 msec and 200 msec conditions of rise and decay time, whereas under the same conditions, the peak amplitude of the masking functions was always larger in masking by increments than in that by decrements. Besides, SRTs were faster to luminance decrement than to increment under the rise and decay time conditions of 50 msec and 100 msec, although the peak amplitude was smaller in masking by decrement.

These discrepancies may arise partly from the incomplete nature of the masking function as a response index of the visual system. It has been generally said that the masking effect by light offset (decrement) is smaller than that caused by light onset (increment) (Baker, 1963). It is desired, therefore, to be examined with more adequete response indices.

In conclusion, results of SRTs and those of masking functions to luminance change of temporal ramp stimuli with different rise and decay time correspond well, when they are compared within each type of responses to increment and decrement in luminance, while correspondence between them is poor when they are compared between two types of responses.

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