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ONSET- AND OFFSET-SLOPES OF LIGHT STIMULUS AND THEIR EFFECTS ON THE BETA MOTION

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Thresholds for the appearance of the beta motion were obtained from 3*S*s when the onset- and the offset-slopes of the first stimulus and those of the second were varied independently with the use of the method of "frequency modulation of glow pulse train". Results showed that the two descriptive laws which had been obtained with the usual rectangular stimuli hold even when the slopes of the stimuli were varied, that is, the onset-onset law holds for the relatively short stimuli and the offset-onset law for the relatively long stimuli regardless of the steepness of their slopes. *S*s' introspections showed that the determination of the thresholds was difficult and the impressions of the optimal motion were different from the others when the slopes were very gentle. It was concluded that the variations in the slopes of the stimuli would not influence the occurence of the beta motion so long as the slopes were not too gentle.

Problem

In a usual experiment of vision the temporal factors of light stimuli are controlled by keeping their onset and offset as steep as possible. For this control several means have been devised, using such as the shutters at the focus of light beams, luminous bodies which have good onset- and offset-characteristics, and so forth. It appears, however, that the degree of steepness of the onset- and offset-slope may be an important parameter especially in the studies of the visual phenomena in which temporal factors play a part. This parameter, none the less, has been rather ignored and examined only in the field of the flicker vision (Luckiesh, 1914; Ives, 1922; de Lange, 1958; Maruyama, 1973 etc.) and in the other few studies (Clyners, *et al*. 1964; Somiya, 1967). Stimuli used in almost all experiments on visual perception have been those which have the rectangular light intensity distribution in time and therefore have the steepest onset- and offset-slopes.

It can be expected that the manipulation of this parameter has some connection with the sensory transient characteristics such as on- and off-responses. The visual system overshoots itself to the stimuli of which onset-slopes are very steep and also shows particular responses to the stimuli which turn off rapidly. Now when the stimuli increase or decrease their intensity gradually, how does the visual system respond to such stimuli ?

As a first step to attack this problem, our previous study examined the effects of stimulus wave form on the beta motion, using the stimuli which varied in intensity distribution with time: negative and positive ramp sawtooth waves and triangular waves (Maruyama & Matsumura, 1974). Contrary to their expectation they did not find any effect, in the context of the sensory on- and off-transient characteristics, of the stimulus wave forms of various onset- and offset-slopes on the thresholds for the appearance of the optimal motion. The results showed that the occurrence of the apparent motion was fundamentally governed by the following two descriptive laws even when the stimulus wave forms were varied, that is, the onset-onset law holds for the relatively short stimuli and the offset-onset law holds for the relatively long stimuli, which coincide with the conclusion obtained with the usual rectangular stimuli (Kahneman, 1967, 1970).

The purpose of the present study is to reexamine the effects of the onset- and offset-slopes of the stimuli on the perception of the beta motion, by changing them independently and in addition with the use of the considerably long lasting stimuli.

Method

Apparatus

The onset- and the offset-slopes of the stimuli were varied in the same manner as in the previous study, employing a method of "frequency modulation of glow train" (Maruyama & Matsumura, 1974). This method is based on the following three considerations: (1) to adopt the Talbot-Plateau's law which states that, when a periodical visual stimulus is repeated at a rate which is sufficiently high so that it will appear fused to an observer, it will match in brightness a steady light which has the same time-averaged luminance, (2) to be able to obtain desired variations in the mean luminance according to this law, if a train of glow pulses which is repeated at a considerably high rate (far above CFF) is frequency-modulated, and (3) to use the glow modulator tube (R1131C) as a glow pulse generator.

A single voltage wave form which has desired onset- and offset-slopes was generated from a function generator. This voltage change was transformed correctly into the change in the frequency of pulse train with the aid of VCF(Voltage Controlled Frequency) circuit. After amplified through an power amplifier, this frequency-modulated pulse train flowed into the glow modulator tube from which the frequency-modulated glow train was obtained. In the present study the input voltage wave forms varied from 0V to +2V in some conditions or from 0V to +4V in the other conditions and the frequency of glow train changed from 200Hz to 600Hz or from 200Hz to 1000Hz corresponding to the input voltage changes, respectively. As these frequencies were well beyond CFF, changes in brightness on the sensation were identical to the input voltage wave forms generated from the wave form generator. In these ranges of frequencies the mean luminance which was calculated according to the Talbot-Plateau's formula varied from 0.4cd/m^2 to 1.2cd/m^2 or from 0.4cd/m^2 to 2.0cd/m^2 and consequently stimuli always began to rise from the base luminance level of 0.4cd/m^2 which was the mean luminance of a 200Hz glow train.

Two identical series of these electronic circuits, intermediated by a delayed pulse generator, were prepared for the observation of the beta motion: one was for the first stimulus and the other for the second.

The first and the second stimuli were both circular spots of 6mm in diameter, subtending the visual angle of 0.22° at the observer's eyes and they were transilluminated by the glow pulses through two separate frossed glasses. In the central portion of the rectangular background which was 45mm(1.68°) by 74mm(2.77°), the first stimulus appeared on the right side and the second on the left at a distance of 15mm between centers. The luminance of the background was matched with the baseline luminance of the stimuli(0.4cd/m^2). A dark red light point on the line of vision served as a fixation point, lying 35mm(1.31°) apart from the first stimulus to the right. The whole stimulus display which contained two stimuli, fixation point and the background was presented in a light proofed box. *S*s observed binocularly the sequence of the stimuli in peripheral vision at a distance of 153cm.

Procedure

Sawtooth waves were used to vary the slopes of the stimuli, which varied in the stimulus exposure times (the durations of the base), the peak luminance remaining constant(2.0cd/m^2). Changes in the onset-slopes were obtained with the use of the positive ramp sawtooth waves and those of the offset-slopes with the use of the negative ramp sawtooth waves. The stimulus exposure times were following five: 50msec, 100msec, 150msec, 200msec, and 300msec, and thus there were five positive and five negative ramp sawtooth waves, respectively. One of the stimulus pair was a sawtooth wave and the other was a rectangular wave which had the same duration as the exposure time of its sawtooth pair. The peak luminance of the rectangular stimuli was kept constant, being 1.2cd/m^2, and therefore two stimuli in a pair were equal in their own total energy.

The effects of the onset- and the offset-slope of the first stimuli and those of the second on the beta motion were examined in the following four independent sessions.

Session I: The onset-slope of the first stimulus. Five positive ramp sawtooth waves with different exposure times for the first stimuli and five rectangular waves with different durations for the second stimuli. Five pairs.

Session II: The offset-slope of the first stimulus. Five negative ramp sawtooth waves with different exposure times for the first stimuli and five rectangular waves with different durations for the second stimuli. Five pairs.

Session III: The onset-slope of the second stimulus. Five rectangular waves with different durations for the first stimuli and five positive ramp sawtooth waves with different exposure times for the second stimuli. Five pairs.

Session IV: The offset-slope of the second stimulus. Five rectangular waves with different durations for the first stimuli and five negative ramp sawtooth waves with different exposure times for the second stimuli. Five pairs.

Additional five pairs in which both first and second stimuli were rectangular waves of equal duration were examined for control in each session. Stimulus durations of these five pairs were corresponding to the five exposure times of the sawtooth waves.

Thresholds for the appearance of optimal motion were measured from the simultaneous stage. While a certain stimulus pair was presented repeatedly at an interval of 3.2sec, the *S*s varied the interval between onsets of the two stimuli by turning a knob of the variable resistor attached to the delayed pulse generator. The *S*s were instructed to begin to turn it from the stage of simultaneity where the two stimuli in a cycle appeared to be concurrent, then to make longer the interval gradually, and to stop adjusting when the good optimal motion began to be seen. The interval between the onset of the first stimulus and that of the second at this final point was measured by means of the digital time counter. This interval has been called the stimulus onset asynchrony and its abbreviation SOA will be used in the rest of the present article. The adjustment of the variable resistor was left entirely to the *S*s and the *S*s were allowed to adjust it to their satisfaction. Although it was possible to measure the thresholds for the optimal motion from the successive stage, they were not measured because it was found difficult to decide them in the preliminary experiment.

Five trials for one stimulus pair were administered in a block. If there were large variations in the values, further two trials were added and in this case the longest and the shortest SOAs were omitted in the processing of the results. Each session consisted of 10 blocks: 5 blocks for sawtooth-rectangle pairs and 5 blocks for rectangle-rectangle pairs. 10 blocks in a session were administered to the *S*s in a quasirandom order. Before the measurement in each block two training trials for the forthcoming stimulus pair were inserted that the *S*s might confirm the criterion for the good motion which had been established in the preexperimental training. It took about 2 hours to terminate one session including each five minutes' rest given between blocks.

An undergraduate and two present writers served as *S*s. They all participated in the previous study (Maruyama & Matsumura, 1974) and were regarded as the well trained subjects in the present study. Only one of three partipated in all sessions. One of the rest served as *S* in session I, II, and III, and the other only in session II. Numbers of *S*s in each session were, therefore, as follows: I; 2*S*s, II; 3*S*s, III; 2*S*s, and IV; 1*S*.

Results

Mean results of the thresholds for the appearance of the optimal motion obtained in Session I, II, III, and IV were illustrated with the actual wave forms in Fig. 1, Fig. 2, Fig. 3, and Fig. 4, respectively. In the figures solid lines represent the first stimuli and broken lines the second. Thick lines denote the experimental pairs (sawtooth–rectangle pairs) and thin lines the control pairs (rectangle–rectangle pairs). Each figure shows that the good motion begins to be seen when the first and the second stimulus are exposed in these temporal sequences shown in the figure.

Control results of the rectangular pairs obtained in the different sessions showed some difference in the mean values of SOAs. The direction of change in the thresholds with the increase of the stimulus durations was, however, virtually identical in every session. When the durations of the stimulus were less than 100 msec(50 msec and 100msec), the optimal motions were obtained at constant SOA (120–130msec). When the stimulus durations were prolonged more than 150msec, the SOA for the optimal motion increased with the increase of the durations, and in these cases the optimal motions began to be seen at or near ISI (interstimulus interval)=0, where the offset of the first stimulus coincided with the onset of the second.

When the onset-slopes of the first stimuli were changed, the "actual SOA", defined as the interval between two actual onsets of the first and the second stimulus at the baseline luminance level, increased regularly, as seen in Fig. 1 (pairs of thick lines). When the term "effective SOA" was introduced which could be defined as the interval between the two effective onsets of the first and the second stimulus at a certain constant luminance level, however, this "effective SOA" at the nearly constant luminance level lying between 0.6cd/m^{2}and 0.8cd/m^2 was nearly constant and was 120–130msec as to the three steeper pairs (exposure time: 50msec, 100msec, and 150msec), as represented by the arrows in the figure. In two conditions of the

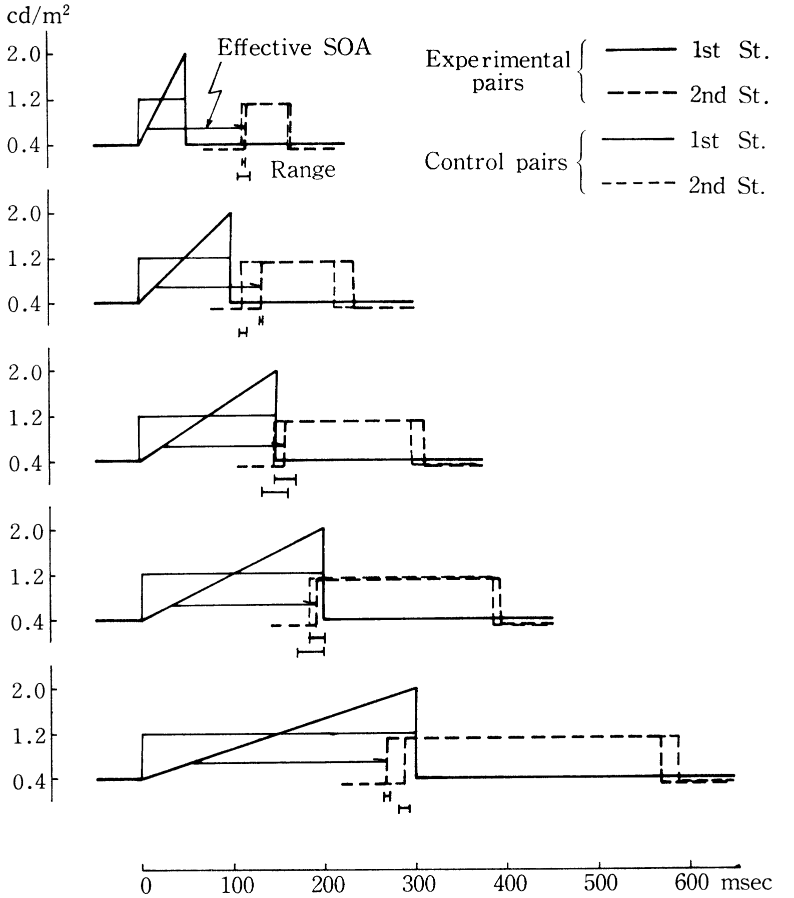

Fig. 1. Schematic representation of temporal sequences of the stimuli for the beginning of optimal motion when the onset-slopes of the first stimulus are varied, together with results of control rectangular pairs. Mean results of 2 *S*s. Arrows in the right direction denote the "effective SOA" at a constant luminance level.

gentler slopes (exposure time : 200msec and 300msec) the "effective SOAs" at the same level as in the steeper ones were prolonged and the optimal motions were obtained at or near ISI=0.

Results of Session II were shown in Fig. 2 where the offset-slopes of the first stimulus were varied. In the three conditions of the steeper slopes the "actual SOA" for the optimal motion which was identical to the "effective SOA" here was constant regardless of their offset-slopes and was, here again, 120–130msec. In the other two conditions where the stimulus exposure times were longer than 200msec, the SOAs were lengthened. Considering the "effective ISI" which could be defined as the

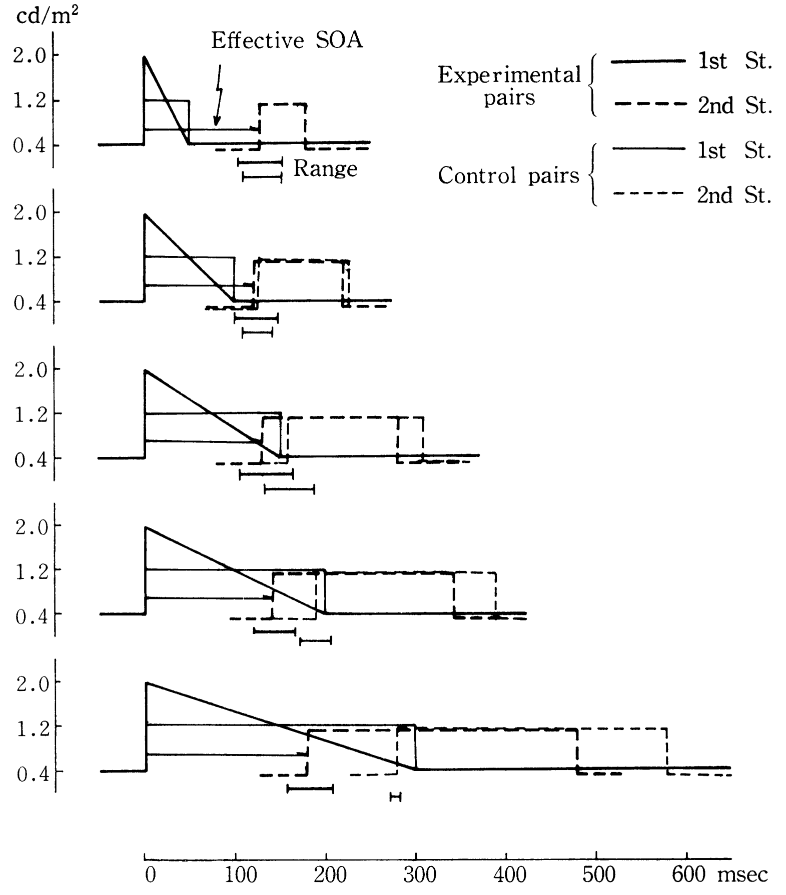

Fig. 2. Schematic representation of temporal sequences of the stimuli for the beginning of optimal motion when the offset-slopes of the first stimulus are varied, together with results of control rectangular pairs. Mean results of 3 *S*s. Arrows in the right direction denote the "effective SOA".

interval between the effective offset of the first stimulus and the effective onset of the second at a certain luminance level, this "effective ISI" for these two conditions was nearly constant and was of the negative value at the same luminance level as that in Fig 1, where the constant "effective SOA" was obtained for the steeper onset-slopes of the first stimulus.

Fig. 3 shows the results obtained in Session III where the onset-slope of the second stimulus was a variable. As the slopes were varied from the steep one to the gentle one, the "actual SOA" varied irregularly at a glance. The "effective SOA" was examined here again in the same manner as before. Hence it was known that the "effective SOA" of the five pairs with different slopes coincided with the SOAs

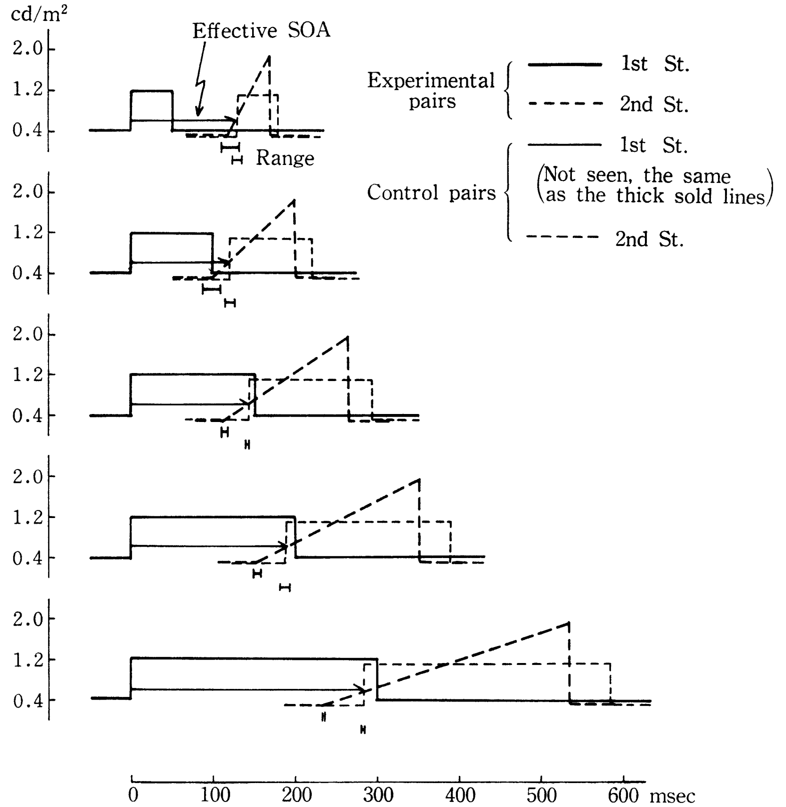

Fig. 3. Schematic representation of temporal sequences of the stimuli for the beginning of optimal motion when the onset-slopes of the second stimulus are varied, together with results of control rectangular pairs. Mean results of 2 *S*s. Arrows in the right direction denote the "effective SOA".

of the corresponding control rectangular pairs, as representted by the allows in the figure.

When the offset-slopes of the second stimulus were manipulated (Fig. 4), the SOAs for the appearance of the optimal motion were in good accord with the results of the control pairs.

On account of the long lasting sawtooth stimulus (exposure time : 300msec), which was the gentlest of all, all *S*s complained of the difficulty in the determination of the thresholds or reported the extraneousness of the motion impression in comparison with the other sawtooth stimuli. This was especially marked in Session II where the offset-slope of the first stimulus was varied.

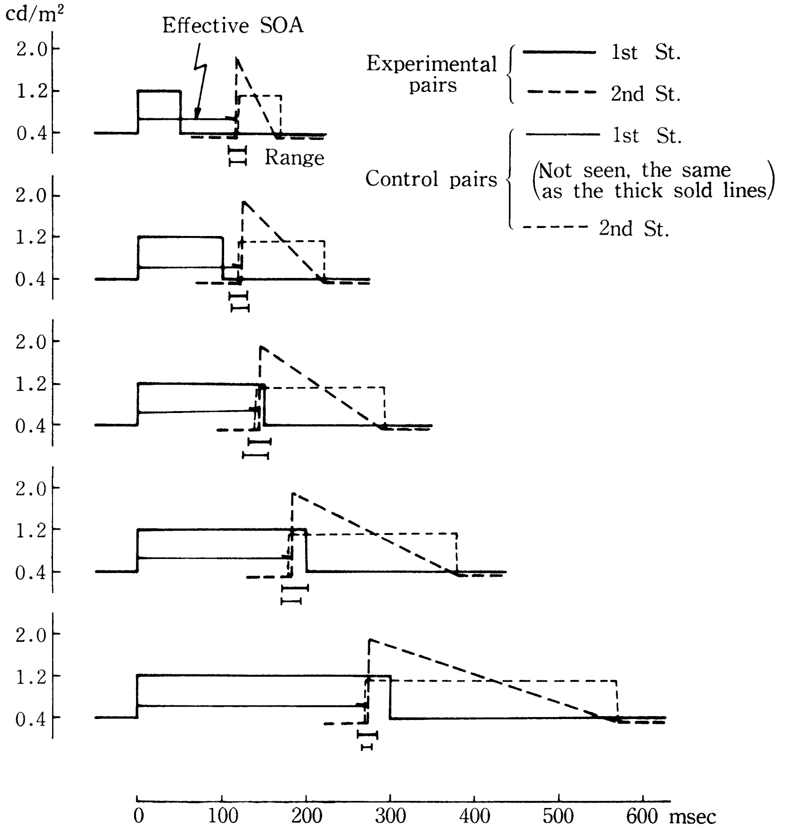

Fig. 4. Schematic representation of temporal sequences of the stimuli for the beginning of optimal motion when the offset-slopes of the second stimulus are varied, together with results of control rectangular pairs. Results of 1 *S*. Arrows in the right direction denote the "effective SOA".

Discussion and Conclusion

As to the rectangular pairs, the results obtained in the present studey are essentially the same as those in the conventional studies (Korte, 1915; Sgro, 1963; Kahneman, 1970). With the shorter stimuli the beta motion can be obtained at a constant SOA, suggesting that the onset-onset law maintained by Kahneman or the Korte's fourth law holds under these conditions. With the longer stimuli these laws break down and the beta motion can be seen at or near ISI (or pause)=0. When the duration is prolonged furthermore, the motion is seen with a constant negative value of ISI. Under these conditions the offset-onset law holds as the beta motion is determined by the temporal relationship between the offset of the first stimulus and the onset of the second. Both the onset-onset law and the offset-onset law fit the present data well.

Even when the slopes of the stimulus were varied by utilizing the sawtooth waves, the same rules as in the rectangular stimuli appear to hold if the terms of the "effective SOA" and the "effective ISI" are introduced at a certain constant luminance level. Results could be summarized as Fig. 5 where the new term the "effective stimulus duration" is introduced. It refers to the duration from the effective onset to the effective offset of a stimulus at a certain constant luminance level. In the case of the rectangular pair the "actual SOA", the "actual ISI", and the "actual stimulus duration" are, by definition, identical to the "effective SOA", the "effective ISI", and the "effective stimulus duration", respectively. When the "effective stimulus duration" is shorter than a critical value which is about 125msec under the present stimulus condition, the optimal motion can be seen with a constant value of the

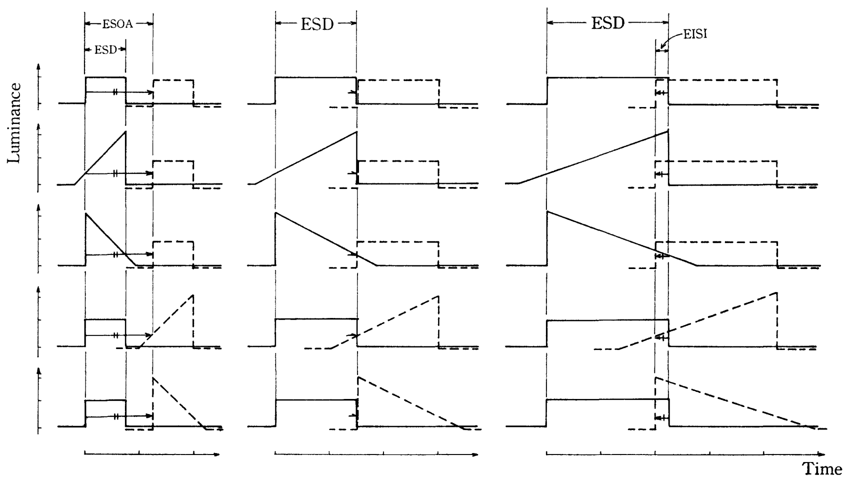

Fig. 5. Onset-onset law for short lasting stimuli and offset-onset law for long lasting stimuli. Left column (A) ; ESOA (effective stimulus onset asynchrony) is constant when ESD (effective stimulus duration) is shorter than a critical value, Middle column (B) ; EISI (effective interstimulus interval) is about zero when ESD is in intermediate range. Right column (C): EISI is constant with negative value when ESD is far longer than the critical value. Solid lines denote the first stimulus and broken lines the second.

"effective SOA" (See Fig. 5-A). When the "effective duration" is far longer than this critical value, the optimal motion appears with a constant negative value of the "effective ISI", as seen in Fig. 5-C. In the intermediate range of the "effective stimulus duration" the motion can be obtained at or near "effective ISI" $=0$ (Fig.

5–B). Hence the onset–onset law for the shorter stimulus and the offset–onset law for the longer stimulus appear to hold for the perception of the beta motion at a certain constant level of luminance regardless of the steepness of the onset slope and of the offset slope, supporting the conclusion obtained in the previous study(Maruyama & Matsumura, 1974).

From these results and the discussion, it seems that the variation in the onset- and offset-slopes of the stimuli does not influence the beta motion so far as the thresholds for its appearance are measured. What is essential here seems to be the effective onset and the effective offset at a certain luminance level and their time relationships.

*S*s' introspections, however, tell some effects of the variation in the slope on the perception of the beta motion. This is the case only as for the stimuli which have the very gentle slopes and therefore it would be difficult to find such effects as sensory on- and off-effects mentioned in the problem in the results obtained.

References

Clyners, M., Kohn, M., & Lifshitz, K. **1964** Dynamics and spatial behavior of light evoked potentials, their modification under hypnosis, and on-line correlation in relation to rhythmic components. *Ann. N.Y. Acad. Sci.*, **112**, 468–509.

de Lange, H. **1958** Research into the dynamic nature of the human fovea-cortex systems with intermittent and modulated light. II. Phase shift in brightness and delay in color perception. *J. opt. Soc. Amer.*, **48**, 784–789.

Kahnemen, D. **1967** An onset-onset law for one case of apparent motion and metacontrast. *Percep. & Psychophys.*, **2**, 577–584.

Kahneman, D. & Wolman, R.E˙ **1970** Stroboscopic motion: Effects of duration and interval. *Percep. & Psychophys.*, **8**, 161–164.

Korte, A. **1915** Kinematoskopische Untersuchungen. *Zeitsch. Psychol.*, **72**, 193–296.

Luckiesh, M. **1914** On the growth and decay of color sensations in flicker photometry. *Physiol. Rev.*, **4**, 1–11.

Maruyama, K. **1973** Stimulus wave forms formed by the method of "frequency modulation of glow train" and their behavior in the flicker vision at the low frequency region. *JPA Proceedings* 37*th Annual Convention*, Pp. 16–17. (in Japanese)

Maruyama, K. & Matsumura, M. **1974** Stimulus waveform and beta motion. *Tohoku Psychol. Folia*, **33**, 134–143

Sgro, F.J. **1963** Beta-motion thresholds. *J. exp. Psychol.*, **66**, 281–285.

Somiya, T. **1967** Measurements of on- and off-responses in the human fovea by means of psychophysical technique–An explanation for some contradictions between sensitivities measured in terms of light threshold and of CFF–. *Jap. J. Psychol.*, **38**, 1–13. (in Japanese with English abstract)

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