Stimulus Wave Form and Beta Motion

STIMULUS WAVE FORM AND BETA MOTION

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A relationship between the stimulus wave form and the perception of beta motion was examined by changing the wave forms with the use of what may be called a method of "frequency modulation of glow train" which was devised on the basis of Talbot-Plateau's law.

Three wave forms of positive ramp sawtooth, negative ramp sawtooth, and triangle waves were employed. One of the three waves served as a first stimulus which was followed by a second stimulus chosen likewise, producing nine combinations of the stimulus pairs. For each wave form three stimulus exposure times of 60msec, 100msec, and 200msec were used. In a pair the exposure time of the first and second stimulus was identical. 27 pairs in total were presented to the *S*s. Peripheral vision was adopted as a mode of observation.

As a result it was revealed that values of the "actual stimulus onset asynchrony" showed a very systematic change. This regularity was interpreted to be due to the fact that the "effective onset asynchrony" of the paired stimuli, which was defined as the interval between the effective onsets of the two stimuli at a certain constant slice level of luminance, gave a constant value in spite of the difference in the wave forms. This, however, holds only when the stimulus exposure times are 60msec and 100msec, where the "effective stimulus onset asynchrony" was about 120msec. Under the condition of 200msec exposure time, the "effective stimulus onset asynchrony" gave a constant value of 140msec.

If onset and offset points are assumed to be at the point where the slice level is set, then the results of the 60msec and 100msec condition gave quite a good fit to the Kahneman s "onset-onset law", whereas those of the 200msec fit to what may be called the "offset-onset law".

PROBLEM

The beta motion has been traditionally studied with the stimuli which are rectangular in wave form.

The purpose of the present experiment lay in investigating the effects of wave forms other than rectangle on the beta motion. Namely, it is the primary purpose of this study to inquire into the mechanism of the beta motion by examining the parameter of stimulus wave form i.e. the stimulus intensity distribution with time.

Since the manipulation of stimulus wave forms means to alter the slope of the sitmulus onset and offset, the secondary aim of the study is to understand the role of the sensory on- and off-transient characteristics in the perception of beta motion.

Method

Apparatus

In order to obtain a given wave form, a method that may be called the "frequency modulation of glow train" was employed. The method was based on the following three considerations: (1) Talbot-Plateau's law, (2) frequency modulation, and (3) utilization of the glow modulator tube(R1131C). An objectively intermittent light will appear as a steady light if its rate of the periodic intermittency exceeds CFF. According to the Talbot-Plateau's law which states that the brightness of this fused light is equal to that of the steady light which has the same brightness as the time-averaged luminance of the intermittent light, the changes in the density of the glow pulses in a glow train which is fused sufficiently are sensed as the corresponding changes in brightness on the sensation. If a desired voltage wave form which can be formed by the function generator is fed into the voltage-frequency transformer, then a given pulse train can be frequency-modulated, obtaining the desired changes in the pulse train. This frequency-modulated pulse train triggers the glow modulator tube and thus the resulting temporal change in the brightness on the sensation is correctly identical to the input voltage wave form (Maruyama, 1973).

The block diagram of the apparatus is shown in Fig. 1, which was designed by the just described methods. The light stimulus generating system was composed of two identical units since two stimuli had to be displayed in the experiment of the beta motion. The temporal relationship of the stimuli was manipulated by a delayed pulse generator. The stimulus wave form was produced in the following way. A trigger pulse generator drove a wave form generator which produced a single voltage wave set in advance (a positive ramp swatooth is shown in the diagram). This wave rose from 0V up to +2V. By feeding this voltage into the VCF (voltage controlled frequency) circuit, a 200Hz rectangular wave was frequency-modulated in correspondence with the voltage change. The range of modulation was from 200Hz(0V) to 600Hz (+2V). This modulated rectangular wave triggered another pulse generator to get a modulated pulse train of which pulse duration was 0.2msec with the voltage of +50V. Thus obtained pulse train was amplified by a power amplifier up to +120V, which then was fed into a glow modulator tube (R1131C). In this way the frequency modulation of glow train was achieved. The frequency of thus obtained glow train exceeded so far beyond CFF that a brightness variation corresponded exactly to the voltage generated from the wave form generator according to the Talbot–Plateau's law. The changes in brightness could not begin from complete darkness but from a certain level of brightness i.e. the mean brightness of a 200Hz glow train because the 200Hz pulse train formed the base on which the frequency modulation was made.

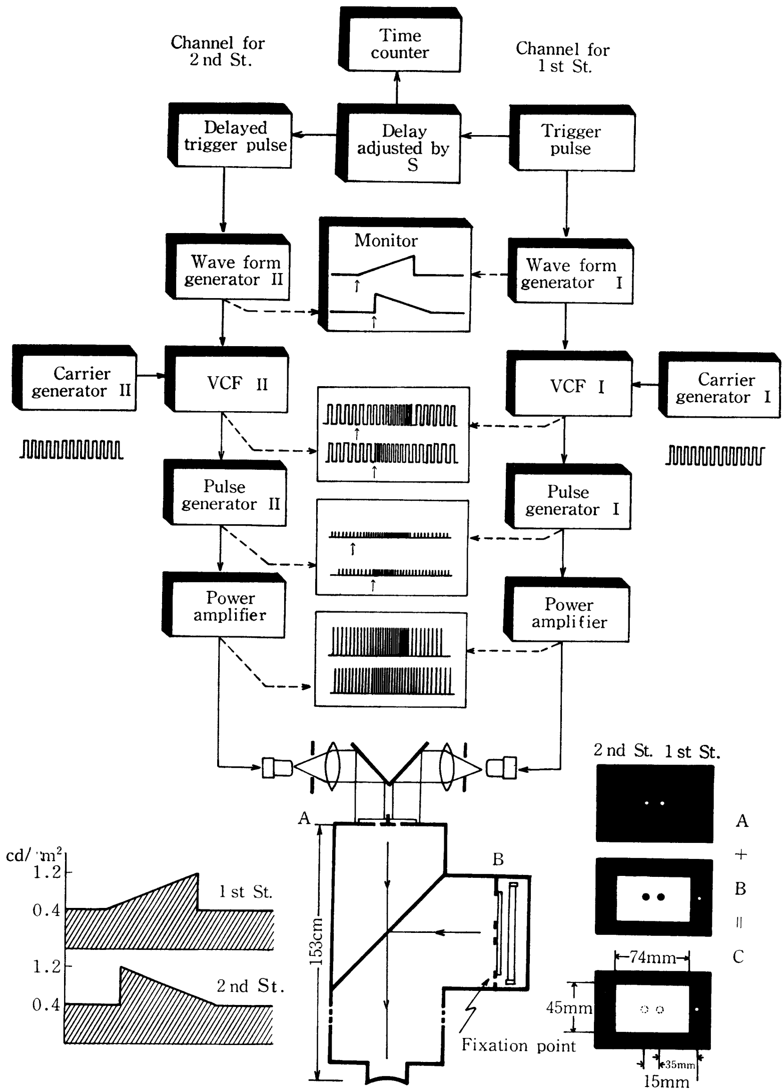


Fig. 1. Schematic arrangement of the apparatus with the stimulus display for the observation of beta motion.

The light fluxes radiated from the glow modulator tubes were projected on the frosted glasses attached on the back of a dark box after being made parallel through the lenses and turned by the flat mirrors. By attaching a sheet of black paper with two holes of 6mm, the stimulus display shown in Fig. 1(A) was obtained. A stimulus displaying a rectangular field shown in Fig. 1(B) which was 45mm by 74mm or 1.68° by 2.77° in terms of visual angle and had the same luminance as the base luminance of two stimuli (0.4cd/m^2) and a dark red light point shown in Fig.1(B) as well were imposed on the display of Fig. 1(A) through a half silvered mirror, thus resulting in the whole display drawn in Fig.1(C). The two dot lined circles shown in the central portion of the rectangular field of Fig.1(C) served as the stimuli for beta motion subtending the visual angle of 0.22° at the *S*'s eyes. The first stimulus appeared on the right side to the *S* and the second on the left being separated by 15mm between their centers. The *S*s observed the two stimuli at the distance of 153cm by means of peripheral vision fixing their lines of sight to the dark red point with both eyes. The distance between the fixation point and the right (first) stimulus was 35mm or 1.31° in terms of visual angle.

Procedure

The examination was made on the following three wave forms : positive ramp sawtooth, negative ramp sawtooth and triangle waves. The stimulus exposure times at their base were 60msec, 100msec, and 200msec. For each of these three exposure times, nine pairs of wave forms were composed, resulting in 27 conditions in all, as shown in Fig.2. Peak luminance of the stimuli was remained constant 1.2cd/m^2 which was the mean luminance of the 600Hz glow train. Therefore three wave forms of equal exposure time were the same in their own total energy and different only in the temporal distribution of luminance.

The *S*s observed the two circular spots presented on the left side of their visual field while fixating their both eyes to the red fixation point. The right spot was the first stimulus, which was followed by the second stimulus on the left. This sequence of the stimuli was recurrently presented to the *S*s every 2.5sec. At each presentation the *S*s gradually turned a variable resistor at hand, thus changing the time interval between the stimuli until an optimal beta motion was observed. Each series was started from the simultaneous stage in which the time interval was gradually increased by a modified method of limits as mentioned above. Although the thresholds for optimal motion usually consist of the two series, one of which begins from the simultaneous stage and the other from the successive stage, in this experiment only the former was used because of the difficulty accompanied in the determination of the thresholds for the latter series. The time interval between the stimuli was altered by a delayed pulse generator which was manipulated by the *S*s

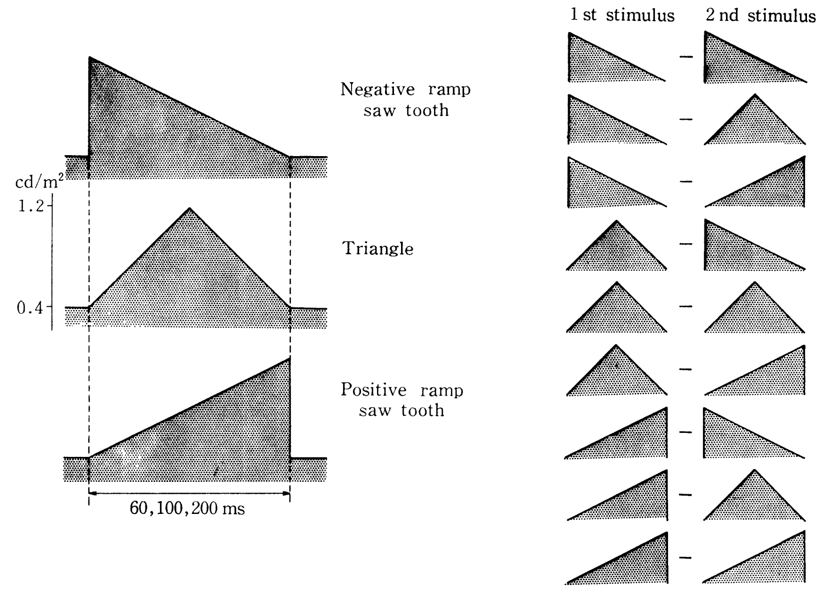


Fig. 2. Wave forms and their combinations employed in the experiment.

with a variable resistor. This interval was measured as an onset-to-onset interval (the "actual stimulus onset asynchrony")which was shown on a digital time counter. Manipulation of the resistor was rendered to the *S*s who were instructed to adjust it to their satisfaction till the impression of the beta motion was achieved.

10 trials for threshold determination were administered in a block to the *S*s for each pair of stimuli. A session consisted of nine blocks, namely, nine pairs of stimuli with the equal stimulus exposure time. Within a session the presentation of the stimulus pairs was made in quasi-random order. Including each 5 min rest between blocks it took about 2 hours to complete one session. Three of such sessions were given to each *S* in three consecutive days. Before beginning the experiment, the *S*s were trained well that they might establish a criterion of optimal motion. Furthermore one or two exercises were given before the start of each block to assure them of their subjective criteria.

The *S*s were three undergraduates (two males and one female) and both the present writers, all of whom have experienced some experiments in perception.

Results

The optimal motion could be observed with every pair of wave forms examined this time. Impressions of the motion did not differ essentially among the pairs. There were, however, several reports that the optimal motion was obtained relatively easily in the conditions of 100msec and 200msec pairs.

The mean thresholds (the "actual stimulus onset asynchronies") for appearance of the optimal motion obtained from 5 *S*s are shown in Table 1-A. In this table those means and *SD*s which had the same stimulus wave forms as the first stimuli were grouped together for each exposure time. The results of analysis of variance are attached as well. Table 1-B contains rearranged results in Table 1-A in which those pairs are grouped together for each exposure time; they have the same wave forms as the second stimuli. Statistical results are shown together as in the former table. Fig. 3 illustrates the results contained in Table 1-A with the actual wave forms. Distances between these stimulus pairs signify the time interval in which optimal motion began to be seen.

It can be seen from these tables and figures that the "actual stimulus onset asynchronies" shows a systematic variation in accordance with that in wave forms for any of the exposure times. That is, if, for instance, the first stimuli had the wave form of negative ramp sawtooth, then the variation in the wave forms of the second stimuli from negative ramp sawtooth over triangle wave to positive ramp sawtooth made the start of the second stimuli earlier, thus shortening the "actual stimulus onset asynchronies" between the stimuli (See Fig. 3 and Table. 1-A). On

Table 1-A. Mean results (the "actual stimulus onset asynchronies") of 5 *S*s for 27 pairs of wave forms under 3 stimulus exposure times, together with the results of analysis of variance among three pairs in which the first stimuli are of the same wave form and exposure time.

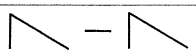
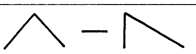
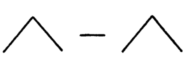
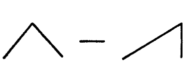
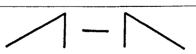
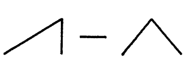
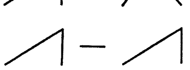
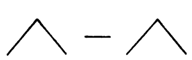
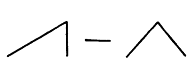
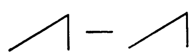
Stimulus exposure time	60msec			100msec			200msec		
Stimulus pair	$\overline{X}$	*SD*	Anal. of var.	$\overline{X}$	*SD*	Anal. of var.	$\overline{X}$	*SD*	Anal. of var.
	msec 116	msec 21.6		msec 119	msec 31.9		msec 138	msec 12.2	
	112	25.3	n. s.	107	33.0	$p<.01$	110	11.7	$p<.01$
	99	24.4		86	38.0		83	19.0	
	126	35.7		138	27.9		174	5.7	
	115	24.4	n. s.	123	36.4	$p<.05$	137	16.7	$p<.01$
	113	29.9		111	34.0		110	9.6	
	138	22.2		156	32.2		208	12.7	
	125	27.4	n. s.	136	32.6	$p<.01$	169	10.9	$p<.01$
	119	32.1		117	25.5		145	18.4	

Table 1-B. Rearranged results of Table 1-A, together with the results of the analysis of variance among three pairs in which the second stimuli are of the same wave form and exposure time.

Stimulus exposure time	60msec			100msec			200msec		
Stimulus pair	$\overline{X}$	*SD*	Anal. of var.	$\overline{X}$	*SD*	Anal. of var.	$\overline{X}$	*SD*	Anal. of var.
	msec 116	msec 21.6		msec 119	msec 31.9		msec 138	msec 12.2	
	126	35.7	$p<.05$	138	27.9	$p<.05$	174	5.7	$p<.01$
	138	22.2		156	32.2		208	12.7	
	112	25.3		107	33.0		110	11.7	
	115	24.4	n. s.	123	36.4	n. s.	137	16.7	$p<.01$
	125	27.4		136	32.6		169	10.9	
	99	24.4		86	38.0		83	19.0	
	113	29.9	$p<.05$	111	34.0	$p<.05$	110	9.6	$p<.01$
	119	32.1		117	25.5		145	18.4	

the other hand, if the second stimuli were the same in the wave form, say triangle, then the variation in the first stimuli from negative ramp over triangle to positive ramp brought about the reversed results, namely the second stimuli began to start later, elongating the "actual onset asynchronies" (See Table 1-B). As the exposure time of the stimuli became longer from 60msec to 200msec, these systematic shifts of the beginning of the second stimuli could be seen more clearly.

As reflected in the *SD*s in the table, individual difference was considerably large, and this was especially the case for the exposure time of 60msec.

From the systematic variations in the "actual stimulus onset asynchronies" mentioned above it can be seen that the following laws are involved in the results.

Fig.4 shows the results when the exposure times were 60msec and 100msec, which indicated that these two conditions had the same onset-to-onset interval of about 120msec regardless of the difference in the slopes of offset. Under these conditions of exposure time it could be seen that every pair besides the ones just mentioned required this interval for the appearance of beta motion if the interval was assumed to be the time while the stimuli exceed a certain constant slice level of the luminanec (See Fig.5 in which the interval is shown by the arrows). In

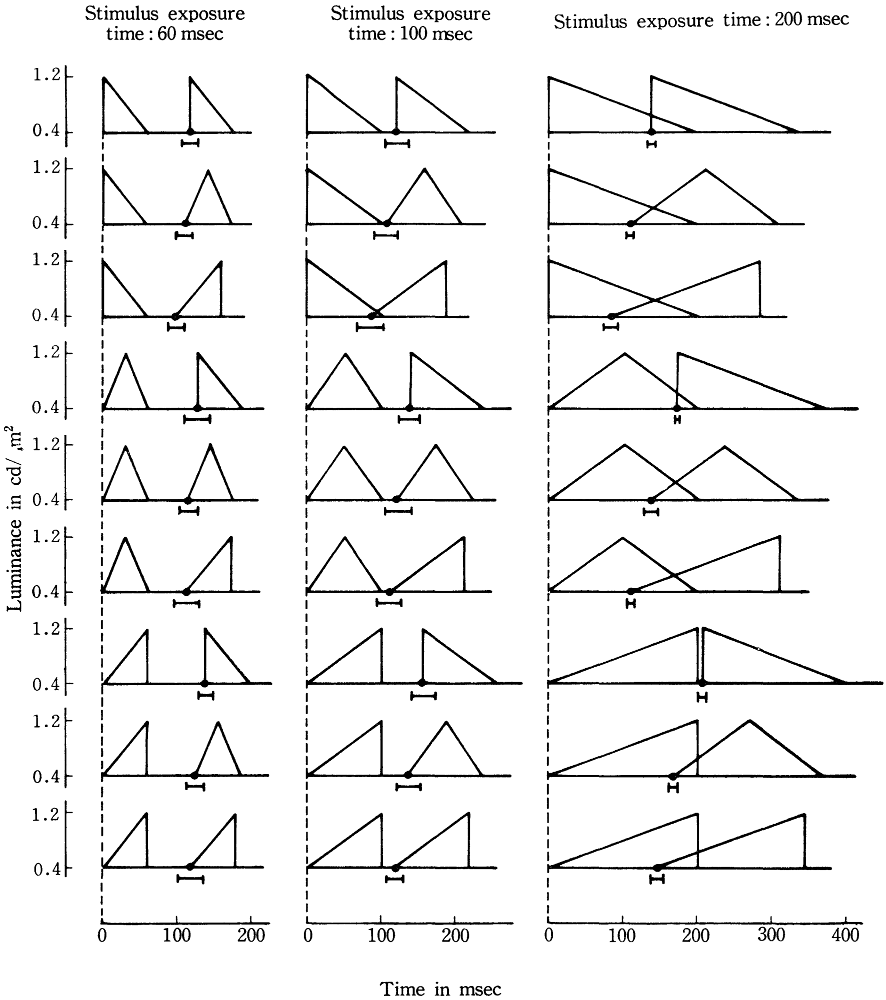


Fig. 3. Schematic representation of the results in Table 1-A, with the actual wave forms and *SD*s.

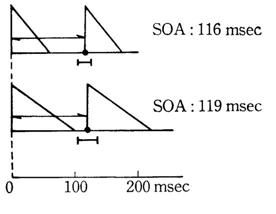


Fig. 4. Rearanged results from Fig. 3. for two stimulus pairs are identical in the wave form, negative ramp sawtooth, but differ in the slope of their offset.

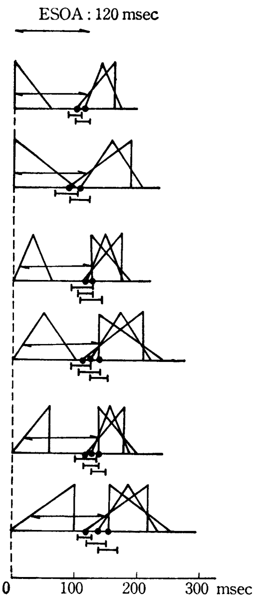


Fig. 5. Rearranged representation of results under two exposure time conditions of 60msec and 100msec, showing that the "effective stimulus onset asynchronies" take a constant value of about 120msec (shown by the arrows).

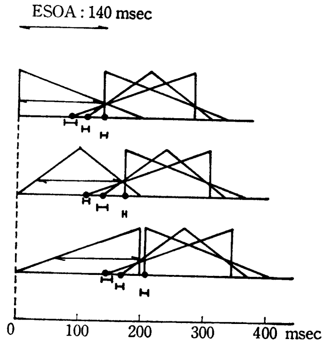


Fig. 6. Rearranged represention of results under a 200msec condition, showing that the "effective stimulus onset asynchronies" take a constant value of about 140msec (shown by the arrows).

short, if the exposure time was for 100msec or less, the "effective stimulus onset asynchrony", which could be defined as the interval between two effective onsets of the first and second stimuli at a certain constant luminance level, took a constant value of about 120msec which determined the appearance of the optimal motion irrespective of the differences in the exposure times and in the wave forms.

When the exposure time was 200msec, nine stimulus pairs had almost the same "effective stimulus onset asynchrony" determined at the same slice level as in the above mentioned conditions, though it was about 140msec, thus becoming longer (Fig. 6).

Discussion and Conclusion

In the conventional studies where rectangular stimuli have been used, the Korte's fourth law has been considered to hold under the condition of short duration. Recently Kahneman (1967) reformulated the same phenomenon maintaining an "onset-onset law". According to this law optimal motion appears when the sum of the duration of the first stimulus and the pause between two stimuli is constant, in other words, when the interval between the onset of the first stimulus and that of the second is constant if the stimuli have the duration of 100msec to 120msec or less. The results reporting here that the optimal motion was obtained when the "effective stimulus onset asynchrony" was about 120msec with 18 stimulus pairs that had the exposure times of 60msec and 100msec, are considered to be an evidence supporting this "onset-onset law" if the intervals were determined at a certain slice level, as were in the present study.

When the exposure time was 200msec, the "effective stimulus onset asynchrony" became longer showing thet the "onset-onset law" did not hold here. According to Kahneman & Wolman (1970), when the stimulus duration of rectangular wave exceeded 120msec, the optimal motion was most often observed under the conditions that the second stimulus began just after the offset of the first. This might be called the "offset-onset law". It can be concluded that the "offset-onset law" applies to our results of 200msec condition if the onset and offset are determined at a constant slice level of luminance.

Kahneman (1967) explained both the onset-onset law for the stimuli of short duration and the offset-onset law for those of long duration by assuming the response overlap at a certain level of visual processing. Whether this explanation is valid or not, it seems to be confirmed by the manipulation of stimulus wave forms that these laws apply to the beta motion.

From these results and discussion it would be concluded that the effects of wave forms that might be considered in the context of the sensory on- and off-effects as was expected in the problem are not reflected in the perception of beta motion. This circumstance was shown also in the fact that there was no difference in impressions of motion as far as the wave forms adopted in the present experiment is concerned.

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