Temporal Course of Stereoscopic Acuity within One Second of Pattern Exposure

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TEMPORAL COURSE OF STEREOSCOPIC ACUITY WHITHIN ONE SECOND OF PATTERN EXPOSURE

By

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Maruyama and Tsukahara (1968) hypothesize that the acuity for stereoscopic depth perception is expected to be highest immediately after the exposure of stereo pattern.

To exmaine the validity of the hypothesis, the present study was projected, and the temproal course of the acuity change in terms of visual disparity was measured by limiting the exposure duration of the pattern to whithin one second. The stereo patterns (S_1 and S_2) were exposed to their corresponding eyes in the following manner: First, the antecedent stimulus S_1 was presented to the right eye, then, after four points in delay time of 0, 200, 400, and 700 msec., S_2 was exposed to the left eye for 250 msec. As to each of these four points in delay time, the stereoscopic threshold in terms of angular disparity was determined by the method of constant stimuli, and the stereoscopic acuity (the reciprocal of the threshold) was plotted as a function of the delay time.

Based on the results of five *S*s, it was concluded that the hypothesis was confirmed, i.e., the stereoscopic acuity rises immediately after the onset of S_1, although the results were not so clear as had been expected.

A supplementary report which verify the validity of data from Maruyama and Tsukahara (1968) was attached.

Problem

Maruyama & Tsukahara (1968) exposed two test patterns (S_1 and S_2) successively to their corresponding eyes in order to produce stereoscopic depth perception and found that when the exposure duration of S_1 is less than approximately 375 msec. (maximal limiting delay time), stereoscopic depth perception is established in the fusional image of S_1 and S_2 even without the former's tail being overlapped with the head of the latter. This result agrees with that of Ogle (1963) except that in his study the maximal limiting delay time was 250 msec. Two more principal findings in the study by Maruyama & Tsukahara were: (1) When the duration of S_1 was less than approximately 375 msec., the critical delay time (defined as the limit to delay the presentation of S_2 after the onset of S_1) increased as the exposure duration of S_1 decreased. (2) When the duration of S_1 was extended over 375 msec., it was necessary to lap the tail of S_1 over the top of S_2 for approximately 30 msec. at least in order to establish stereoscopic depth perception.

Based on a set of postulates deduced from the results described above, they presented the following hypothesis; a certain psychophysical process contributing to

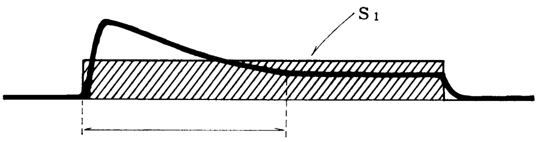


Fig. 1. Hypothesized temporal course of the "process for stereoscopic depth perception" over the period of exposure of S_1 and after it. Abscissa: time which elapsed after the onset of S_1. Ordinate: magnitude of excitation of the "process".

the establishment of stereoscopic depth perception ("process for stereoscopic depth perception") rises rapidly in its excitation magnitude immediately after the onset of S_1, begins to fall down gradually thereafter, and finally, after 375 msec. it stablizes itself at a certain level. Fig. 1 depicts the hypothesized temporal course of the change in the magnitude of the excitation of the process of stereoscopic depth perception. As shown, acuity for stereoscopic depth perception is expected to be highest immediately after the onset of S_1. The present study consequently aimed at testing the validity of the hypothesis by examining the acuity for stereoscopic depth perception.

Brightness of stimulus, visual disparity and others have been proposed as variables related to the establishment of stereoscopic acuity. The brightness of stimulus variable has been found by Maruyama (1967) to be an inadequate measure. Thus in this study visual disparity was selected as an index of stereoscopic acuity as was also done in the previously mentioned study by Ogle.

According to a preliminary study, even in the case of two patterns of the identical size of visual disparity, the longer the delay between S_1 and S_2 is, the smaller the magnitude of stereoscopic depth perception becomes. This observation strengthens the expectation that visual disparity would reflect stereoscopic acuity. Thus the present study had the specific objective of measuring the temporal course of the acuity change in visual disparity by limiting the exposure duration of the antecedent stimulus S_1 to within one second.

METHOD

The optical instrument for the exposure of stereo test patterns consisted of three systems: right, left and central. For the right and left optical systems a synoptiscope was employed. This is a type of stereoscope commonly used for ophthalmological examinations, and is constructed in such a way that stimulus patterns can be freely moved in finelly calibrated grades either vertically, horizontally or to the right or left direction and even in rotating fashion. The synoptiscope used in the present study was attached with 6 cm. square camera films with the stereo patterns on them. The stereo patterns thus set in the right and left optical systems of the synoptiscope were arranged so that they would be superimposed on the reference pattern of the central optical system by the beam splitters. As shown in Fig. 2., the stereo test pattern (S_1

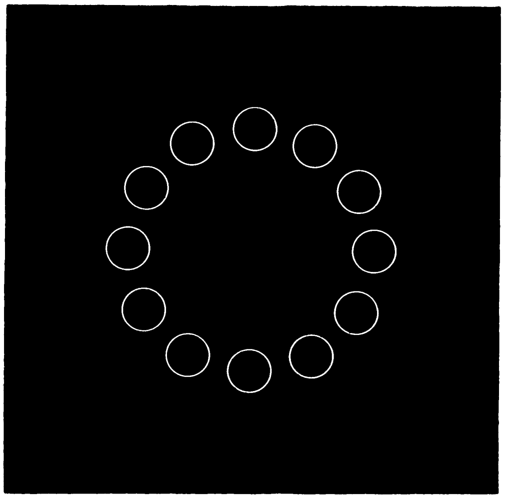


Fig. 2. A stereo test pattern employed for S_1 and S_2. A ring is consisted of 12 criclets.

was identical to S_2) was a ring consisting of 12 circlets. S_1 was presented to the right eye of the observer and S_2 to the left eye, while at the same time maintaining a certain constant visual disparity. The diameter of the ring subtended a visual angle of 6.3° at the observer.

The pattern set in the central optical system was, as illustrated in Fig. 3, a particular arrangement of 35 circlets which served as a reference in making a stereoscopic depth judgement. When the three patterns from the three optical systems, right, left and central, were superposed on each other, the configuration of stimuli

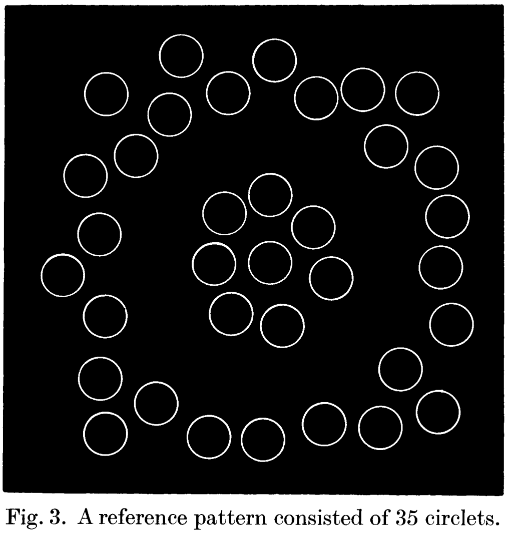


Fig. 3. A reference pattern consisted of 35 circlets. This was set in the central optical system and always exposed.

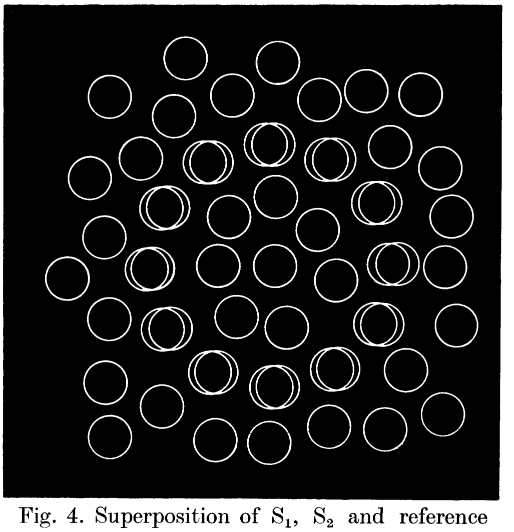


Fig. 4. Superposition of S_1, S_2 and reference pattern.

which resulted was as in Fig. 4. The task of the *S* was to judge whether the fusioned ring of S_1 and S_2 would appear either farther back of, or in front of, the reference pattern consisting of the 35 circlets.

The size of the 35 circlets each held at 18′ of arc at the *S* was the same as a circlet for S_1 and S_2. The three patterns, S_1, S_2 and the reference pattern, were created by using regular camera films so that the parts making up the circlets would appear transparent. The pattern in Fig. 4 is nearly the same as that in Fig. 1 used by Maruyama & Tsukahara (1968), but it has been slightly modified so that the *S* could attend to the center of the pattern with greater ease. Maruyama & Tsukahara have already explained why this particular pattern was selected, but, here, it should be added that it was hoped that the use of a pattern of this complexity would greatly facilitate the detection of any possible malfunctioning of the experimental apparatus. The reference pattern was continuously presented by illumination from a white neon bulb. Exposure of S_1 and S_2 was controlled by a pair of glow modulator tubes (R1131 C) that were continuously illuminated by feeble light fluxes from the actuators so that the tubes could fire in dim darkness. Lest the patterns should be illuminated by beams from the actuators and come in sight before the tubes fire, several neutral dentisy filters were inserted between the films and the tubes. The glow modulator tubes were fired by direct current from a pair of pulse generators (Nihon Kohden, MSE-40). The timing conditions for exposure of each stereo pattern (duration of exposure and delay between two exposures) were constructed by setting the time sequence of the DC pulse. The setting was monitored by a 2-channel synchroscope. The visual disparity between S_1 and S_2 was ajdusted by finely calibrated, horizontal movement of the stimulus patterns. A schematic presentation of the entire experimental apparatus is given in Fig. 5.

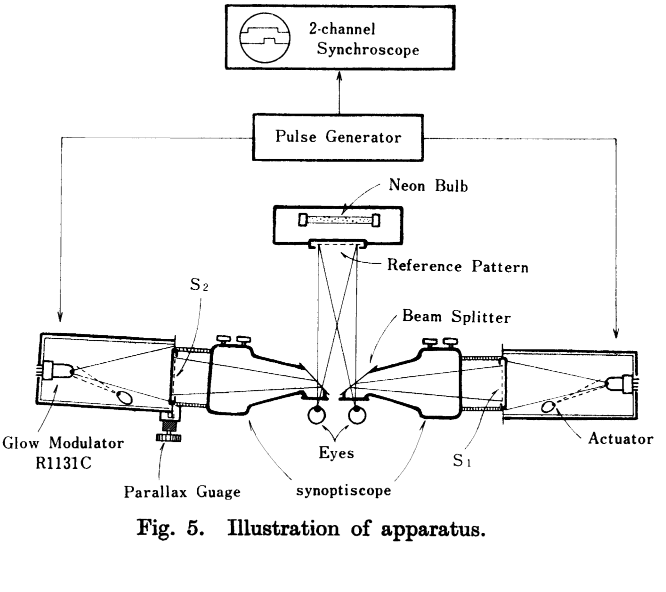


Fig. 5. Illustration of apparatus.

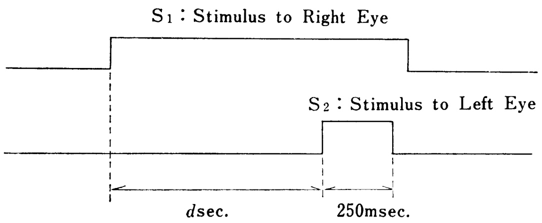


Fig. 6. Illustration of exposure mode of S_1 and S_2.

In order to measure the temporal change of stereoscopic acuity when the exposure duration of S_1 was within one second, the method as illustrated in Fig. 6 was employed. First, the antecedent stimulus S_1 was exposed to the right eye of the observer who had been instructed to fixate his sighting line to the central circlet on the reference pattern. After a delay of d second (delay time), S_2 was presented to the left eye for 250 msec. Four delay times, i.e., 0, 200, 400, and 700 msec. were selected, for each of which stereoscopic acuity was obtained and compared with each other.

As in Ogle's study, the method of constant stimuli was used to measure stereoscopic acuity. Initially S_1 and S_2 were adjusted so that they could be seen to be located on the same plain as the reference pattern. Then, with the reference pattern as the central point, a series of five steps of angular disparity were determined. Each one of which was adjusted to fit the acuity of the *S*. The test patterns of the five steps of visual disparity were presented 20 times in random order for each of these steps. Following each exposure, the *S* was asked to state whether he had perceived the momentarily seen ring either farther away (response category "far") or nearer than ("near") or equal in depth ("equal") to the reference pattern. In case the judgement of the *S* was a doubtful one, the trial was repeated once again.

The *S*s were five male graduate students in the Department of Psychology at Tohoku University. The trial order of the four *d* values was counterbalanced for each of the five *S*s. The *S* was tested with two *d* values a day. Thus the completion of the entire experiment for one *S* covered two days.

Results

The percentage of the trials in which the *S* reported "far" was calculated for each of the five visual disparity values. Here, judgements belonging to "equal" were divided into either "far" or "near" category in equal proportion. For each of the four *d* values for the five *S*s, a psychometric function was obtained by relating the five degrees of angular disparity to their corresponding percentage values. Fig. 7 illustrates an example of a psychometirc function thus obtained. For each function, standard deviation (σ) was obtained and this was defined as measure of threshold of stereoscopic depth perception. On the graph σ is the difference in angular disparities for which stereoscopic depth was perceived at about the 84% or about the 16% and the 50% level. Finally, the reciprocal of σ-disparity was calculated, which in turn was

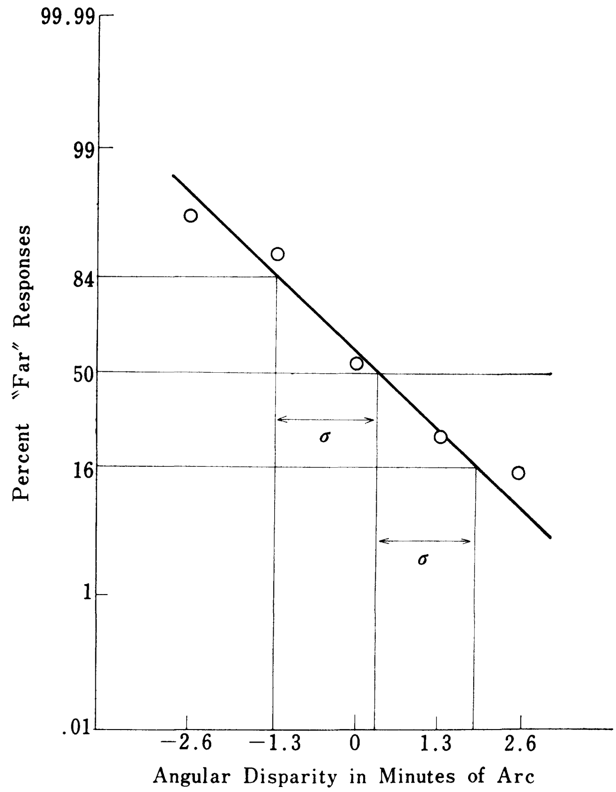


Fig. 7. An example of obtaining the psychometric function.

defined a stereoscopic acuity. Since σ-disparity is expressed in terms of seconds of arc, $60/\sigma$ is the value of acuity. The procedure thus followed is nearly the same as that of Ogle. Fig. 8 shows the values of stereoscopic acuity for each of the four *d* values. In Fig. 8 are described the individual results for each of the five *S*s and also the mean of the five *S*s. The latter is not the mean of $60/\sigma$ of the five *S*s but the reciprocal of the mean of σ for the five *S*s. Fig. 8 thus indicates the temporal course of stereoscopic acutiy during the exposure period of S_1. Our hypothesis would be considered supported if the pattern of the results from each *S* would assume the same pattern as described in Fig. 1. On the mean, the pattern of a temporal course similar to that in Fig. 1 can be discerned but the only significant difference by *t*-test was found between 0 msec. and 400 msec. (5% level)

Discussion and Conclusion

The results were not as clear as originally expected.

The problem of the present experiment lies in the original assumption that the four temporal sets of the paired presentation of S_1 and S_2 would not be qualitatively different from one another. In other words, it was assumed that the strength of the

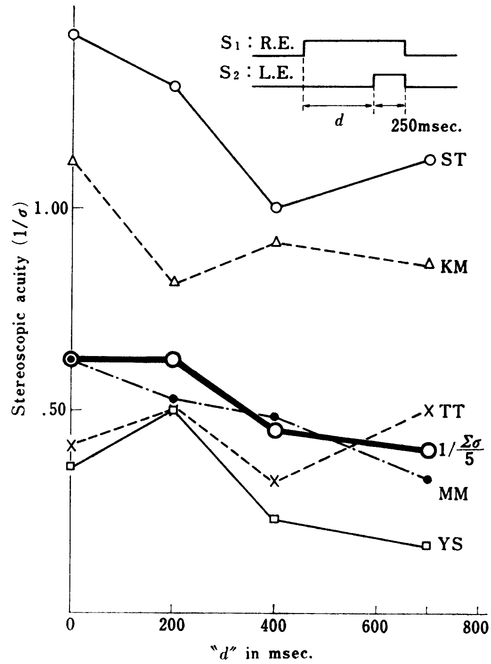


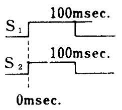
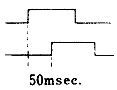
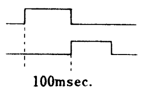
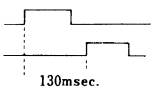
Fig. 8. Results of experiments.

expected effect would be such that it would not be compound by the differential effects of the four temporal sets. The results did not confirm this expectation. Reports of the *S*s show that four different temporal conditions differed in the relative easiness with which they could respond to the stimulus conditions. *S*s reported unanimously that when *d* was 0 msec., the judgement was hardest to make, and as the value of *d* increased, it became progressively easier. Difficulty of making a judgement does not necessarily indicates the low acuity, but if this can be tentatively assumed to be a valid interpretation, then we could conclude that at 0 msec. stereoscopic acuity increases in spite of the difficulty in making a judgement. However, no definitive data are available to give a full support for such a conclusion. Thus the experimental procedure employed in the present study did not confirm fully the validity of the hypothesis presented in Fig. 1. However, as is evidence in the results, we could still conclude that stereoscopic acuity rises immediately after the onset of the stereo pattern exposure.

Supplementary Report

Maruyama & Tsukahara (1968) carried out their study without knowlegde of the results by Ogle (1963). In spite of some difference in the details of the procedures followed, the results from the two studies were in essential agreement. The major difference between them consisted in the procedure taken to obtain the critical delay

Table 1. Results of YS.

Sets of Exposure Timing	Trial Order	σ-angular Disparity	60/σ
	2	174″	.34
	1	270″	.22
	3	330″	.18
	4	552″	.11

time (from the termination of S_1 to the onset of S_2) past which stereoscopic depth can not be established. Maruyama and Tsukahara obtained it directly by keeping constant the value of visual disparity, whereas Ogle first measured stereoscopic acuity, which is the reciprocal of the threshold in angular diparity, for several different values of delay time and then obtained the critical delay time.

The present report was designed to test the varidity of the results from Maruyama & Tsukahara in such a manner that its experimental procedure was identical to that of Ogle. One subject YS was employed. Exposure duration of S_1 and S_2 was 100 msec. each. As shown in Table 1, the temporal relations of the exposure timings of the two patterns were of four kinds: 0, 50, 100, and 130 msec. in the delay interval from the onset of S_1 to that of S_2, i.e., –100, –50, 0, and 30 msec. in the delay interval from the termination of S_1 to the onset of S_2. In the same procedure as already mentioned in this paper, the method of constant stimuli was applied for each one of these four delay intervals, and the obtained results in σ-angular disparity and stereoscopic acuity are shown in Table 1.

The results in Table 1 were converted to Fig. 9 in accordance with the procedure followed by Ogle. An inspection of Fig. 9 gives the critical delay time of approximately 90 msec., which is considerably close to 92 msec. for KM and 67 msec. for TS obtained in the study by Maruyama & Tsukahara which employed the same values of the pairing sets of S_1 and S_2 but a different procedure. (In the Ogle's study, the results of four *S*s showed 44, 30, 56, and 43 msec., respectively.)

Since this supplementary report involves only one subject, nothing altogether can be claimed, but it again demonstrates a validity of the results by Maruyama & Tsukahara.

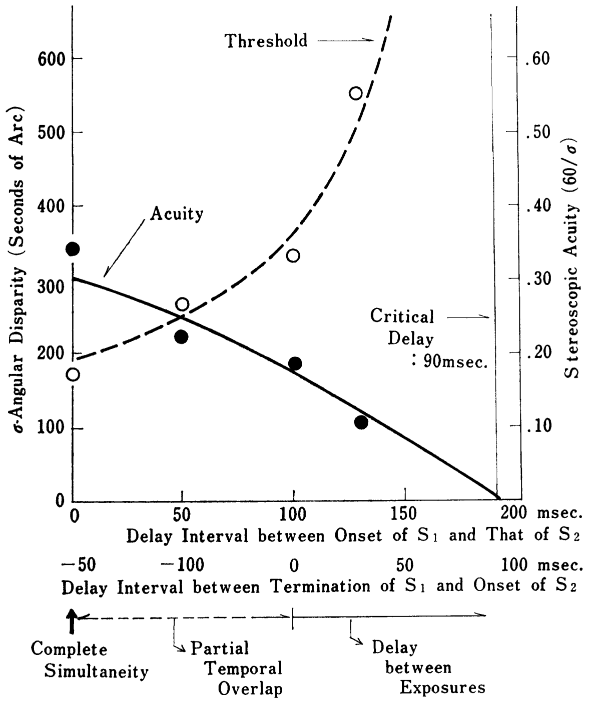


Fig. 9. Graphic illustration of the YS's data, showing loss of stereoscopic depth perceptien at a critical delay time.

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Zusammenfassung

Maruyama und Tsukahara (1968) formulieren die Hypothese, das die Schärfe der stereoskopsiche Tiefenwahrnehmung gerade nach der Aussetzung des stereoskopischen Reizes am höchsten ist. Um diese Hypothese zu prüfen, wurde die vorliegende Arbeit durchgeführt. Während der Aussetzung von einer Sekunde, wurde der zeitliche Gang des Schärfewechsels in der binokularen Parallaxe gemessen.

Die stereoskopischen Reize (S_1 und S_2) werden gegen die ihnen entsprechenden Augen ausgesetzt wie folgt : erstens wurde der vorhergehende Reiz S_1 gegen das rechte Auge vorgelegt, dann wurde je nach dem Auschub von 0, 200, 400, oder 700 msec. S_2 gegen das linke Auge während 250 msec. ausgesetzt. Über jede von vier Aufschubszeiten, wurde die stereoskopische Schwelle in der binokularen Parallaxe durch die Konstanzmethode entschieden, und als eine Funktion von den Ausschubszeiten wurde die stereoskopische Schärfe (der reziproke Wert der Schwelle) aufgewiesen.

Auf Grund der Ergebnisse von fünf *Vpn.*, folgte es, dass die Hypothese bestätigt werden

konnte, d.h., die stereoskopische Schärfe gerade nach dem Angriff des S_1 erhöht wird, obgleich es nicht so klar war, wie erwartet.

Die noch weiteren Ergebnisse wurden mit den Daten von Maruyama und Tsukahara (1968) verglichen.

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