Structuralization of Early Vision for Perceptual Grouping in Apertures

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Abstract Aperture problem is an experiment for anlying the early motion processing in the visual pathway. Nishina argues that the perception depends on the display time and discuss the processing of visual computation tasks. However, the perception rate in the display time more than 550ms tends to decrease. In this paper, we measure various perceptual rates in the experiments for analaying the dependence of this phenomenon on the attention mechanism, and discuss the possibility of two types for structuralization in the early vision.

1. Introduction

Neurons in the human early stages of motion processing detect contour orientation and position of objects. This process is complicated by the fact that local velocity measurements can differ depedning on contour orientation and spatial position [1, 2]. Any receptive field can measure only the orientation of motion perpendicular to a contour of the object. Aperture problem [3–8] is a kind of experiments for analyzing the binding mechanism for motion processing in the early visual pathway(See Fig.1). A circle aperture in which a bar is moving in the background is first displayed at the center of computer CRT. The orientation of the bar would be the motion perpendicular to the contour's orientation, because there are no-terminators. While the bar is moving, two other circles at both sides of the center circle appear and two bars with terminators are also moving in the background, but the bar's direction is different from the center bar's direction. If subjects perceived three bars to be one bar, they would recognize that the bar's orientation in the center circle changed itself to be the orientation as same as at both sides of circles. Nishina et al. [4] discuss that this perception strongly depends on the display time, and argued that the processing of visual computation tasks under iterative is not as far as when processing other tasks.

We have already affirmed Nishina's claim and measured the perceptual rate in more detail experiments under changing various conditions, e.g., the bars' orientation, radius, distance between circles, display time and so on [7, 8]. However, we found that the perception rate in the display time more than 550ms tended to decrease. In order to discuss the decreasing more, in this paper, we assumed that the decreasing related to attention mechanism. We compared the perceptual rate added attention stimulus with no-attention. In our experiments with attention, the various stimulus signals are inserted at both circles. From these results, we here discuss that the decreasing would come from structuralization in the early vision process, and that the possibility of two types in the structuralization in the early vision process in which two kinds of motion processes would exist for responding the slow motion and the fast motion.

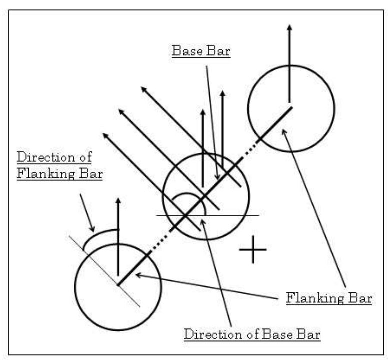

Fig. 1: Aperture Problem

2. Aperture Problems

Subjects are softly stabilized by a supported equipment in front of the computer CRT to keep the distance between the subject and the computer CRT 50cm. The vertical frequency of the computer CRT(FMV-DP9713) is 85.0Hz and the horizontal frequency is 68.7KHz.

Figure 1 shows a diagram for the aperture experiment. A bar in the center circle is called the base

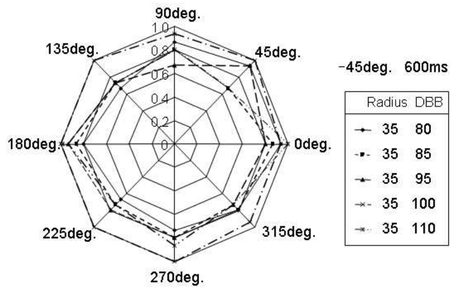

Fig. 2: Perceptual Rate of -45 Degreee

bar and two bars in both sides of circles are called the flanking bar. If subjects perceived three bars to be one bar, they would recognize that the bar's orientation in the center circle changed itself to be the orientation as same as at both sides of circles.

First of all, we measured the perceptual rate when changing the direction of the base bar and the flanking bar, which is calculated as the ratio of the number of subjects' recognition for changing orientation of the base bar among all trials. The perceptual rate is measured for five subjects in their twenties. The radius was kept at 35mm and each experiment was iterated in three trials. Other conditions are represented as follows:

- DT(ms) : 50, 100, 200, 400, 600, 800, 1000, 1200.
- DBC(mm) : 80, 85, 95, 100, 110.
- DBB(degree) : 0, 45, 90, 135, 180, 225, 270, 315.
- DFB(degree) : -45, 0, +45.

where, DT means the display time, DBC means the distance between circles, DBB means the direction of base bar, and DFB means the direction of flanking bar.

Figure 2 shows the perceptual rate in polar coordinates when DFB is -45 degree and DT is 600ms. The perceptual rate is larger according to outside of each axis of DBB. The smaller the distance between the circles is, the higher the perceptual rate is. When the base bar is either in the horizontal or in the vertical, the perceptual rate is relatively higher than other orientaions [9]. These results support Nishina's arguments [4].

Next, we measured the perceptual rate under changing DT, while DBC was not changed. Three subjects in their twenties performed experiments by iterating ten trials. At each trial, DBB was fixed at 135 degrees and DBC was kept at 95mm. Other conditions are represented as follows:

- DT(ms) : 100, 250, 400, 550, 700, 850, 1000, 1150.
- Radius(mm) : 30, 35, 40, 45.
- DFB(degree) : -45, 0.

Figure 3 shows the perceptual rate. The perceptual rate depends on the length of radius. The longer the display time is, the higher the perceptual rate is. However, the perceptual rate in the late display time more than 550ms slightly tends to decrease.

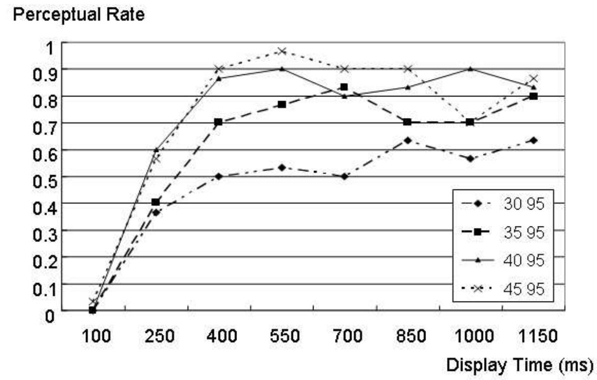

Fig. 3: Perceptual Rate for Changing Radius

Thirdly, we measured the perceptual rate when the gap ratio of the radius to DBC was kept at 0.37, in order to clarify the dependence of the perceptual rate to the combination of the radius and DBC. We measured the perceptual rates for three subjects in their twenties by iterating ten traials. Other conditions are represented as follows:

- DT(ms) : 100, 250, 400, 550, 700, 850, 1000, 1150.
- (Radius(mm), DBC(mm)) : (30, 81.4), (35, 95), (40, 108.6), (45, 122.1).
- DFB(degree) : -45, 0, +45.

The resultant perceptual rate is shown in Figure 4. The perceptual rates is overlapping each other, and it is obvious that the perceptual rate depends on the combination of the radius and DBC. We should notice that the perceptual rate in the display time from 550ms to 1150ms tends to decrease.

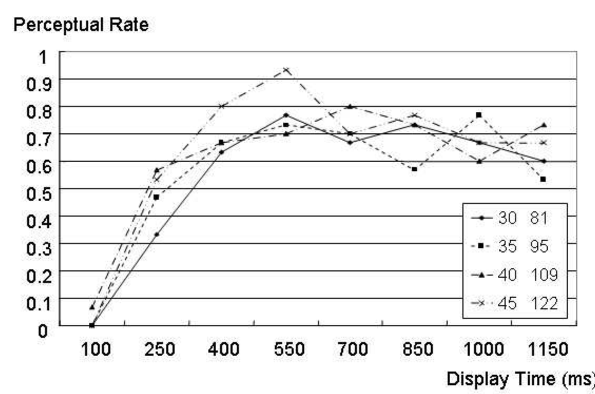

Fig. 4: Perceptual Rate Keeping Gap Ratio

From these results, we calculated the variance analysis using the F distribution value in order to confirm the dependence of the perceptual rate on DT. We assumed the following two hypotheses:

- Null Hypothesis: DT doesn't influence on the perceptual rate.
- Alternative Hypothesis: DT influences on the perceptual rate.

The results are shown in Table 1. The F value, 13.364, for DT is bigger than the critical value, 4.28, with the significance level at 1% of the free degree(7,14). Therefore, the null hypothesis was abandoned and the alternative hypothesis was adopted. As a result, the dependence of the perceptual rates on DT was confirmed at the significance level of 1%.

After the dependence of the perceptual rate on DT is confirmed, we calculated HSD values of Turkey and the trend values of the trend analysis to show the dependence of the decreasing of the perceptual rate in the late display time more than 550ms on DT. However, we didn't obtain the useful results. In stead of these calculation, we calculated the deviation of the perceptual rate of 700ms, 850ms, 1000ms and 1150ms from 550ms. The resultant deviations are shown in Table 2. Almost all of the deviations are minus. Especially, every deviation for DT in Figure 4 is minus. We also measured the perceptual rate under arranging display time by either ascending-order or descending-order, and another perceptual rate informing subjects the display time. However, the similar decreasing of perceptual rates in the late display time more than 550ms is measured as well as the previous experiments. From these results, we suppose that some regularity for decreasing the perceptual rate in the late display time would exists.

Table 1: Influence of Display Time to Perceptural Rate

Elements	Square Sum	Free Deg.	Ave. Sq. Val.	F Val.	Sig. Val.
DT	1.27	7	0.181	13.36	4.28
Individual	0.87	2	0.434	32.00	6.51
Deviation	0.19	14	0.014		
Total	2.33	28			

Table 2: Deviation of Perceptual Rate between 550-1150ms

		Dispaly Time			
		700	850	1000	1150
Fig.3	30mm	-0.033	+0.1	+0.033	+0.1
	35mm	+0.067	-0.067	-0.067	+0.033
	40mm	-0.1	-0.067	0.0	-0.067
	45mm	-0.067	-0.067	-0.267	-0.1
	Ave.	-0.033	-0.025	-0.075	-0.009
Fig.4		-0.063	-0.083	-0.106	-0.149

3. Dependence of Perceptual Rate on Attention

In this paper, we supposed that the decreasing of perceptual rate in more than 550ms would depend on an attention mechanism. In order to clarify our assumption, various attention stimuluses were inserted in the experiments. If subjects overfocus the center circle, the binding between the base bar and the flanking bar doesn't easily occur. On the other hand, if the attention stimulus is inserted to the surround area of both sides of circles, the perceptual rate in the late display time would be going up since subjects' focusing is distributed in the surround area. The perceptual rate is measured for three subjects in their twenties by iterating ten trials:

(1) The flanking circle has the bold arc.
(2) The arc of flanking circle is flashing.
(3) The red flashing points are inserted out of flanking circles.
(4) The color of flanking bar is changed to to be red.

At each trial, DBB was kept set at 135 degrees, the radius was kept at 35mm and DBC was kept at 95mm. Other conditions are represented as follows:

- DT(ms) : 100, 250, 400, 550, 700, 850, 1000, 1150.
- DFB(degree) : -45, 0, +45.

The resultant perceptual rate is shown in Figure 5. The correlation coefficient between the perceptual rate after inserted attention stimulus and without attention is shown in Table 3. The perceptual rate is also decreasing in the late display time more than 550ms. The conformity of the perceptual rate between adding attention and no-attention is relatively high. From these results, our assumpiton on attention isn't necessarily corrected.

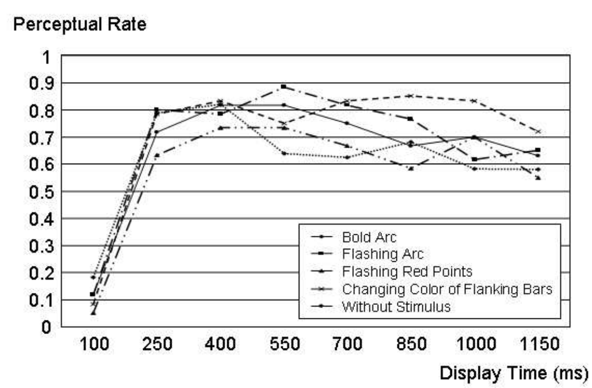

Fig. 5: Perceptual Rate Added Attention

In order to discuss the decreasing of percetual rate more, Figure 6 shows the average values of perceptual rates drawn by lines and the standard deviation of perceptual rates drawn by dotted lines in the case

Table 3: Correlation Coefficient

	Without Attention	Bold Arc	Flashing Arc	Flashing Points
Bold Arc	0.41	–	–	–
Flashing Arc	0.65	0.12	–	–
Flashing Points	0.71	0.51	0.26	–
Red Bar	0.48	0.74	0.33	0.59

of inserting flashing red points outside of surround circles. The maximal perceptual rate and minimal perceptual rate are simultaneously represented by vertical bars. The standard deviation of the perceptual rate in the early display time until 550ms are gradually increasing. However, the standard deviations in the late display time more than 550ms are incoherent. Especially, the average perceptual rate at 700ms is slighly smaller than at 550ms, but the standard deviation is extremely small. At 850ms, the deviation between the maximal perceptual rate and the minimal perceptual rate is larger than others. Figure 7 shows the average perceptual rate and the standard deviation in the case of flashing arc. The similar structuralization in the late display time more than 550ms is seen.

In order to clarify the discussion, the following γ_t is introduced at each display time t.

$$\gamma_t = \frac{SD_t}{|PR_t - 0.5|}$$

where, SD means the standard deviation of perceptual rates at t display time and PR_t is perceptual rate.

The resultant values are shown in Table 4 and 5 for Figure 6 and 7, respectively. The variance value is also represented by VAR. In Table 4, γ at 850ms and 1150ms are relatively higher than others, especially at 250ms where the perceptual rate is as same as at 850ms and 1150ms. In Table 5, the standard deviations from 850ms to 1150ms are larger than others.

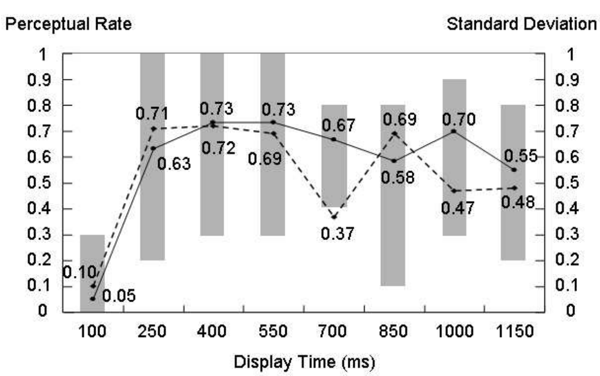

Fig. 6: Flashing Red Points

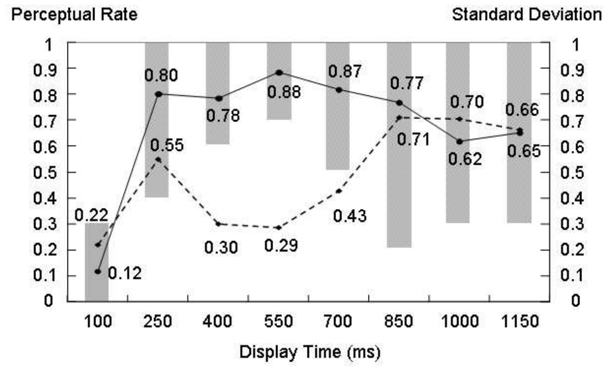

Fig. 7: Flashing Arc

Table 4: Result of Flashing Stimulus

	Display Time							
	100	250	400	550	700	850	1000	1150
PR	0.05	0.63	0.73	0.73	0.67	0.58	0.70	0.55
max	0.3	1.0	1.0	1.0	0.8	0.8	0.9	0.8
min	0.0	0.2	0.3	0.3	0.4	0.1	0.3	0.2
VAR	0.01	0.50	0.52	0.48	0.13	0.48	0.22	0.23
SD	0.10	0.71	0.72	0.69	0.37	0.69	0.47	0.48
γ_t	0.22	5.46	3.27	3.00	2.18	8.63	2.35	9.60

4. Discussion

In this paper, we first measured various peceptual rates for changing orientations, radius and the distance between circles. Next, we confirmed that the perceptual rates with the same gap ratio are overlapping. However, we found that the perceptual rate in the late display time more than 550ms tended to decrease relatively. We supposed that the decreasing of perceptual rate would come from the attention mechanism. By the assumptions, we measured the perceptual rates in several experiments in which attention stimuli are inserted to the surround area. However, as a result, the perceptual rate in the late display time more than 550ms is also decreasing. Therefore, we concluded the decreasing of perceptual rate doesn't relate to attention mechanism.

On the other hand, we defined γ values and γ from 850ms to 1150ms are relatively higher than others. C.C.Pack [5] argues that MT neurons of macaque brain initially respond primarily to the component of motion perpendicular to a contour's orientation, but over a period of approximately 60ms the responses gradually shift to encode the true stimulus direction, regardless of orientation. S.J.Cropper [10] argues that a different pathway exists in the visual cortex for detecting the extreme short stimulus signal. From these arguments,

Table 5: Result of Flashing Arc

	Display Time							
	100	250	400	550	700	850	1000	1150
PR	0.12	0.80	0.78	0.88	0.82	0.77	0.62	0.65
max	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
min	0.0	0.4	0.6	0.7	0.5	0.2	0.3	0.3
VAR	0.05	0.30	0.09	0.08	0.18	0.50	0.49	0.44
SD	0.22	0.55	0.30	0.29	0.43	0.71	0.70	0.66
γ_t	0.57	1.83	1.06	0.74	1.35	2.66	6.03	4.41

some switching mechanism in the visual pathway exists for depending on the speed of stimulus. We can't exactly relate the experiment results we discussed in this paper to the switching mechanism, but we are interesting in two types of structuralization for the perceptual rate divided at 550ms of the display time.

5. Conclusions

In this paper, we measured various perceptual rates in apertures. However, we couldn't conclude the fruitful verification as to the decreasing of perceptual rate. We should discuss it more from the viewpoint of physiology experiments, e.g., using the EEG and fMRI.

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