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Perceptual Grouping to Motion Direction and Speed in Apertures

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Abstract. In order to be raise the accuracy of the TAM network (Topographic Attentive Mapping network) structure, which is analogous to visual system, we need discuss how to provide it a simultaneous description of the receptive field. Aperture experiments are used for observing the mechanism of visual system. Nishina et al. claim that perceptual grouping strongly depends on the length of display time and argue that the processing of visual computation tasks, as in aperture experiment under iterative processing, is not as far as when processing other tasks. This paper supports Nishina's claim and describes experiments under a wider variety of conditions. Most of the results of our experiments support Nishina's claims, however, we encountered a potential new finding: we found some regularity in the decrease of the perceptual rate at more delayed speeds of the lines' motion.

1 Introduction

Advances in many neural networks, which simulate the human visual system, are being used now in the practical fields, e.g., pattern recognition, data analysis, and image processing. However, almost all of these models lack a fundamental structure parallel to that of the biological mechanism of the human visual system due to the goals of effectiveness and usefulness. However, neural networks based on visual system have been and are still being developed[1], e.g., BCS and FCS[2], Neocognitron[3], ARTMAP[4], and TAM[5], [6]. These neural networks, not only upgrade performance compare but also incorporate analogies of biological visual mechanisms to the neural network structure. For example, in the human visual system, the visual signal input from retina pulses through the lateral geniculate nucleus(LGN) and reaches visual cortical cells. In the TAM network (Topographic Attentive Mapping network), we have proposed that feature nodes encode orientation preference in the receptive fields as the visual input. The combination of center/surround processes is represented in the model within the feature layer. In order to be raise the accuracy of the TAM network structure, which is analogous to visual system, we need discuss how to provide it a simultaneous description of the receptive field.

Aperture experiments are used for observing the mechanism of visual system including the receptive field[7], [8], [9], [10], [11], [12], [13]. A circle aperture in which a moving line passes inside the circle is first displayed at the center of computer CRT. Before the line reaches the terminal position, two more circles with a moving line inside each of them appear at two sides of the center circle. The two new lines also move but in a different direction from that of the first line. If the subject identifies three lines as three parts of one line, the center line will be perceived as moving in the same direction as the other lines on each side. This phenomenon is a kind of perceptual grouping. Nishina et al.[7] claim that the perceptual grouping strongly depends on the length of display time and argue that the processing of visual computation tasks, as in aperture experiment under iterative processing, is not as far as when processing other tasks. This paper affirms Nishina's claim and describes more detail experiments under a wider variety of conditions, e.g., changing the lines' direction, radius, distance between circles, and the length of the display time. Most of the result of the experiments support Nishina and we confirmed our results using F distribution analysis. However, perceptual grouping at slower delayed display speeds decreased, against our expectation. We also discuss these unexpected results from our experiments.

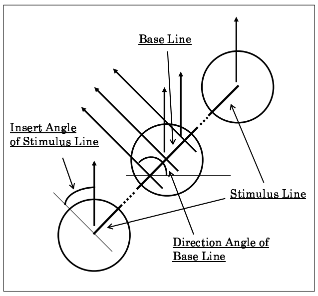
2 Aperture Experiments

In an aperture experiment the subject is stabilized by 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 of a stimulus in the aperture experiment. One circle aperture is first displayed at the center of CRT and a straight line is moving inside, which is called here the base line. The base line appears from one side of the circle and moves to the opposite. Before the base line reaches the terminal position, two more circles with a moving line inside, appear at two sides of the first circle. The lines inside the two circles are called the stimulus lines. If the subject identifies the three lines as three parts of a single line, the center line will be perceived as moving in the same direction as the other lines on each side. The phenomenon is a kind of perceptual grouping.

Perceptual grouping strongly depends on the positions of three lines, the direction of motion of the lines, the radius of the circles, the distance of circles to each other and the speed of the lines. We support Nishina et al.'s[7] argument. We also report a new finding that there is a point where the perceptual grouping decreases at the more slower speed. We measured the perceptual grouping through the following three experiments.

- An experiments in which the direction of the base line and the stimulus line are varied.
- An experiments in which the display time was varied, keeping the radius, or the distance between the circles, the same.



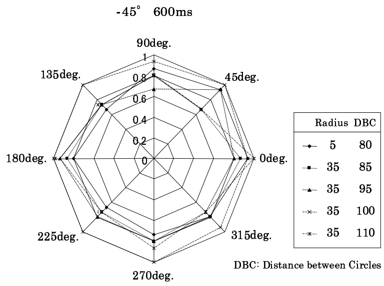


Fig. 1. Aperture Problem

Fig. 2. Perceptual Rate of -45 Degreee

– An experiments in which the ratio of the radius to the distance between the circles was kept the same.

First, we observed perceptual grouping under the condition where the moving direction of the base line and the stimulus line are varied. Five subjects in their twenties performed experiments and each underwent three iterated trials. At each trial, the radius was kept at 35mm while the following conditions were varied as follows:

- Display Time(ms) : 50, 100, 200, 400, 600, 800, 1000, 1200.
- Distance between Circles(mm) : 80, 85, 95, 100, 110.
- Direction of Base Line (degree) : 0 (horizontal and right direction), 45, 90, 135, 180, 225, 270, 315.
- Direction of Stimulus Line(degree) : -45, 0, +45.

Figure 2, 3 and 4 show the most typical three results among all experiments. The numbers above each graph indicate the direction of the stimulus lines and the display time. An axis indicates the direction of the base line's motion. The circles in each graphs shows the perceptual rate at the various combinations of the angle of the base line's motion and the angles of the stimulus line's motion. For example, in the graph of Figure 2, the 90 degree axis indicates the perceptual rate, when the base line's direction angle is 90 degrees and the stimulus line's angle is -45 degrees. The perceptual rate is calculated from the ratio of the number of perceptual groupings recognized in all trials. From the three figures, we see that the smaller the distance between the circles is, the higher the perceptual rate is. Alternatively, the perceptual rate is relatively higher when the base lines moves horizontally and vertically than when moving into other directions. These results support Nishina[7], Castet[9] and etc.

Next, we observed perceptual grouping when the display time was changed while the distance of the circles, that is the radius of the circles, was not changed. In this experiment, the angle of the base line's motion is set at 135 degrees and

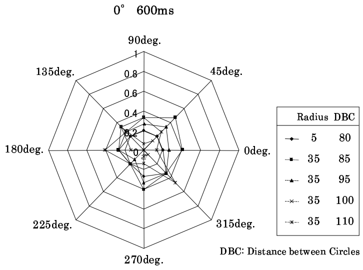


Fig. 3. Perceptual Rate of 0 Degreee

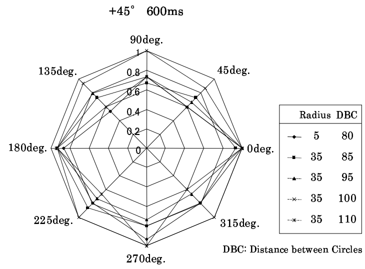


Fig. 4. Perceptual Rate of +45 Degreee

the angle of the stimulus line's motion is fixed at -45 degrees. Three subjects in their twenties performed experiments and underwent ten iterated trials. At each trial, the distance between circles was kept at 95mm and the following conditions were changed as follows:

- Display Time(ms) : 100, 250, 400, 550, 700, 850, 1000, 1150.
- Radius(mm) : 30, 35, 40, 45.

The perceptual rate is shown in Figure 5. The perceptual rate depends on the length of radius. The longer the radius is, the higher the perceptual rate is.

In the next experiment, three subjects in their twenties performed experiments and each did ten iterated trial. At each trial, the radius was kept at 95mm and the following conditions were changed as follow:

- Display Time(ms) : 100, 250, 400, 550, 700, 850, 1000, 1150.
- Distance between Circles(mm) : 85, 95, 105, 115.

The perceptual rate is shown in Figure 6. The perceptual rate depends on the distance between circles from the in both latter two experiments. As in both of Figure 5 and 6, the perceptual rate strongly depends on the display time. Those results also support to Nishina's claim. However, we should notice that the perceptual rate at the display time from 550ms to 1150ms tends to be decreasing.

In order to clarify the dependence of the perceptual rate to a combination of the radius and the distance of circles, we observed the perceptual rate when the gap ratio of the radius to the distance between circles was kept at 0.37. We had three subjects in their twenties go through ten iterations. The following conditions were changed as follows:

- Display Time(ms) : 100, 250, 400, 550, 700, 850, 1000, 1150.
- Combination (radius(mm), distance(mm)) : (30, 81.4), (35, 95), (40, 108.6), (45, 122.1).

The resultant perceptual rate is shown in Figure 7. Since the perceptual rates overlap each other, it is obvious that the perceptual rate depends on the combination of the radius and the distance between the circles and that the subject

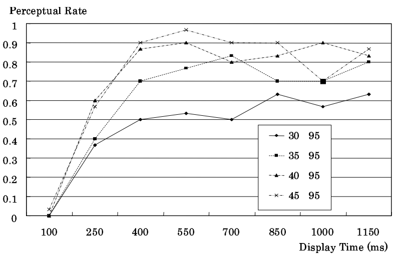


Fig. 5. Perceptual Rate Changing Radius

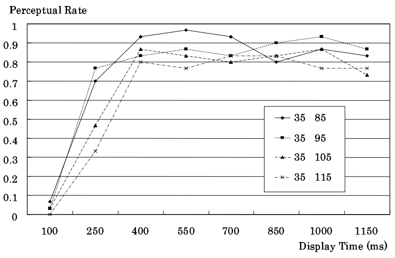


Fig. 6. Perceptual Rate Changing Distance between Circles

judge each combination as the same perceptual grouping even though the real scale is different.

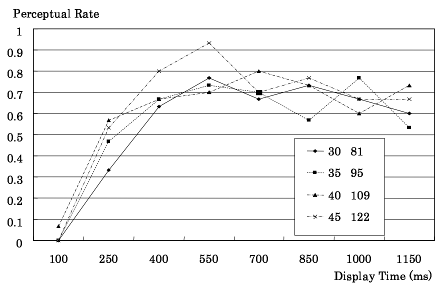


Fig. 7. Perceptual Rate Keeping Gap Ratio

3 Analysis for Aperture Experiments

We found that the perceptual rate seems to depend on the display time. In order to clarify it more, we calculated the variance analysis here, using the F distribution value. We assumed the following two hypotheses:

- Null Hypothesis: the display time does not have an influence on the perceptual rate.
- Alternative Hypothesis: the display time has an influence on the perceptual rate.

The result is shown in Table 1. The F value, 13.364, for the display time 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 grouping on the display time was confirmed at the significance level of 1%. Moreover, the dependence of the subject characteristic was confirmed at the significance level of 1% since the F value, 31.996, is bigger than the critical value, 6.51.

Table 1. Dependence of Display Time to Perceptual Grouping

Elements	Square Sum	Free Deg.	Ave. Sq. Val.	F Val.	Sig. Val.
D. Time	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 Perceptural Rate between 550-1150ms

		Dispaly Time			
		700	850	1000	1150
Fig.5	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.6		-0.063	-0.083	-0.106	-0.149

On the other hand, we should notice that the perceptual rate at the display time from 550ms to 1150ms is decreasing. In order to clarify the phenomenon, we observed the perceptual rate in the following two experiments.

- An experiment within either shorter or longer of display times.
- An experiment either informing subjects the display time or not informing subjects the display time.

We had a suspicion that the subjects might have convinced themselves to have experienced the change in their perception prematurely, in order to score higher, when the display time was longer. Therefore, we first observed the perceptual rate in both short and long order of the display time. One subject in his twenties underwent the experiments ten times iterations, with the radius fixed at 35mm, the distance between the circles changed from 85mm to 115mm per 15mm, and the display time changed from 100ms to 1150ms per 150ms. The resultant perceptual rate is shown in Figure 8 and 9. The perceptual rate at the display time from 550ms to 1150ms also decreases without showing any correlation to the orders of the display time.

Next, we observed the perceptual rate when the display time was informed to the subjects. Two subjects in their twenties performed the experiment ten times, with the radius fixed at 35mm, the distance between the circles changed from 85mm to 115mm per 15mm, and the display time changed from 100ms to 1150ms per 150ms. In the case in which the length of the display time was informed to the subject, the perceptual rate at the display time from 550ms 1150ms did not decrease but was level. In the case that the display time was not informed to the subject, the perceptual rate decreased. Since the both perceptual rates are different from each other and the shape of the perceptual rate is different from Figure 5 to 7, we concluded that the perceptual rate at the display time from 550 to 1150ms was not influenced by the display time, even when the subjects were informed.

We used HSD method of Tukey and trend analysis to calculate the decreasing perceptual rate, but no valid results were obtained. Therefore, we calculated the

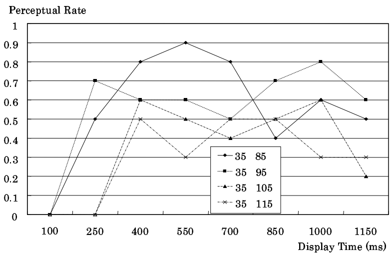


Fig. 8. Perceptual Rate Ordering the Longer Display Time

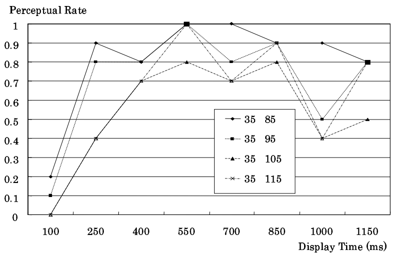


Fig. 9. Perceptual Rate Ordering the Shorter Display Time

deviation of the perceptual rate from 700ms, 850ms, 1000ms and 1150ms to 550ms. The resultant deviations are shown in Table 2. Almost all the deviations are minus. Therefore, we conclude that there is some regularity in the decrease of perceptual rate at the display time from 550ms to 1150ms. We suspect it concerns the attention mechanism.

4 Conclusions

We discussed the perceptual grouping in these experiments. The results support Nishina's claim and found some regularity in the decrease of perceptual rate when the motion of the lines are slow. In the near future, we have to discuss it more from the perspective of the attention mechanism.

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