A TEST OF LEVELT'S MODEL ON BINOCULAR RIVALRY

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Levelt's model is based on the assumption that the mean dominance time ($\bar{t}$) of one eye is a function only of the stimulus strength (λ) in the other eye. He concluded that the assumption was supported by his experiments which were the two-choice rivalry task. But under the two-choice alternation process the assumption can also be expressed by another way that the mean suppression time ($\bar{\tau}$) of one eye is a function only of λ in the same eye. Any experiments under the two-choice alternation process can not test which assumption is correct. The present experiment, whose alternation process was intermittent, was performed to examine which assumption was correct. It has been proved that $\bar{t}$ is a function of λ s in both eyes, but $\bar{\tau}$ is a function only of λ in the same eye. It seems that Levelt's model should have been based on the latter assumption.

It is said that there are two types of binocular rivalry, namely, contour rivalry and color rivalry. Levelt (1966) formed a model which could predict the alternation process of the former. His model is based on the following assumption.

The mean dominance time of left stimulus ($\bar{t}_l$) is not a function of the stimulus strength of the same stimulus (λ_l), but only of the stimulus strength of the contralateral stimulus (λ_r). And likewise $\bar{t}_r$ is a function only of λ_l

$$\bar{t}_l = f(\lambda_r), \bar{t}_r = f(\lambda_l) \quad (1)$$

where $\bar{t}$ is a monotonic decreasing function of λ . He assumes that stimulus strength, λ , is directly related to the effectiveness of a contour. Therefore, λ increases in proportion to the contrast of the stimulus and in inverse proportion to the distance from the contour of the stimulus.

Applying this assumption (Eq. (1)) to the two-choice rivalry task, he deduced four propositions.

I. Increase of the stimulus strength in

one eye will increase the predominance of this stimulus.

II. Increase of the stimulus strength in one eye will not affect $\bar{t}$ for the same eye.

III. Increase of the stimulus strength in one eye will increase the alternation frequency.

IV. Increase of the stimulus strength of both eyes will increase the alternation frequency.

But, it must be pointed out that as a result of the application of Eq. (1) to the two-choice rivalry task, $\bar{t}_l$ coincides with the mean suppression time of right stimulus ($\bar{\tau}_r$), because the appearance of left stimulus means the disappearance of right stimulus under the two-choice alternation process. And likewise $\bar{t}_r$ coincides with $\bar{\tau}_l$. Therefore, Eq. (1) becomes equal to Eq. (2)

$$\bar{\tau}_r = f(\lambda_r), \bar{\tau}_l = f(\lambda_l) \quad (2)$$

where $\bar{\tau}$ is also a monotonic decreasing function of λ .

It is also possible to deduce four propositions from Eq. (2) and they are equal to Levelt's propositions deduced from Eq. (1) except proposition II. That is to say, proposition II', which is deduced from Eq. (2) and corresponds to proposition II,

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is that increase of the stimulus strength in one eye will not affect $\bar{\tau}$ for the other eye. Proposition II is almost equal to the assumption (Eq. (1)). Therefore, to prove the validity of proposition II means to prove the validity of Eq. (1).

Levelt examined the validity of proposition II through his ring-disk rivalry experiments II and III (Levelt, 1966) and the validity of propositions I, III and IV through many experiments conducted by other investigators. He concluded that the results of these experiments supported the validity of his model. But there are at least the following two problems concerning his conclusion.

1. One is the ambiguity of definition of Eq. (1), because Eq. (1) is equal to Eq. (2) under the two-choice alternation process. He concluded that the results of his experiments II and III supported the validity of Eq. (1). But his experiments were the two-choice rivalry task. As has been stated, under the two-choice alternation process Eq. (1) is equal to Eq. (2). Therefore, the results of his experiments support the validity of Eq. (2) as well as Eq. (1). As $\bar{i}$ and $\bar{\tau}$ are indexes which differ with each other, the model that depends on Eq. (1) differ with the one that depends on Eq. (2) in the psychological meaning. Further experiments under other types of alternation, apart from the two-choice alternation, are necessary to decide which equation is correct.

2. The other is the insufficiency of the examination of the validity of Eq. (1). In his experiments, the validity of Eq. (1) was examined only concerning the contrast which was one of the variables influencing the stimulus strength. However, it is also necessary to examine the validity of Eq. (1) using the distance as another variable.

The purpose of this paper is to examine the two problems mentioned above. It is necessary for this purpose to manipulate the two variables, namely, distance and contrast under other types of alternation

process different from the two-choice alternation process. The probe stimulus method, like the one used in Experiment I of Levelt (1966), fills these demands.

In the probe stimulus method, as seen in Fig. 1, a ring is presented to one eye and a spot (probe stimulus) is presented to the other. Therefore, two variables, distance and contrast, can be dealt with by changing the distance between the ring and the spot, and by changing the contrast of the ring and the spot. And at the same time two types of alternation can be dealt with in relation to the distance between the ring and the spot. One is the two-choice alternation: When the spot overlaps with the ring, both stimuli disappear alternately ($\bar{i}_i + \bar{i}_r = \bar{T}$, where $\bar{T}$ is an average cycle duration). But, only a part of the ring disappears, and so the two-choice alternation here is not so clear as the ring-disk rivalry. The other is the intermittent alternation: When the spot does not overlap with the ring, both stimuli appear and either of the two stimuli occasionally disappears ($\bar{i}_i + \bar{i}_r > \bar{T}$).

The probe stimulus method was used in our experiment after considering its properties mentioned above, and it was examined what tendency $\bar{i}$ and $\bar{\tau}$ of the spot had under the intermittent alternation which was different from the two-choice alternation.

By the way, the term, the probe stimulus method, was also used by Fox and Check (1966, 1968, 1972), Wales and Fox (1970), Blake and Fox (1974), Collyer and Bevan (1970), and Lack (1973). In their experiments the probe stimulus was presented briefly at the level of threshold. But in our experiment it was presented continuously at the level of suprathreshold. Their purpose and method were different from ours.

METHOD

Subjects

Three male university students served as

paid volunteer subjects. They were well-practiced in the observation of binocular rivalry. All had normal or corrected to normal vision.

Stimuli

The configuration of rivalry stimuli is illustrated in Fig. 1. At the center of both fields there was a cross which served as a fixation point. It subtended a visual angle of 20 min in length and two min in width. The ring on the left, whose center coincided with the center of the cross, had two deg in inside diameter and

FIG. 1. The stimulus configuration used in the experiment.

20 min in width. The spot on the right was 20 min in diameter and it was presented on the right of the cross. As the spot has only a small size, there hardly appears any fragmentation about the spot. The distances between the center of the spot and the cross were the following: 20, 30, 40 and 50 min, where the spot did not overlap with the ring; 60 min, where the spot overlapped with the inner contour of the ring; and 70 min, where the spot overlapped with the ring. Both fields had a constant luminance of 7.0 ft-L. On the other hand, the ring and the spot had three levels of luminance, 0.5, 3.0 and 5.4 ft-L which were respectively indicated by H, M and L for contrast.

Apparatus

A haploscope, which had two fields subtending 40×40 deg, was used. The stimuli were presented at 34 cm from the view point. Fields were transilluminated by fluorescent lamps. A head-and-chin rest was used to minimize head movements.

FIG. 2. The number of disappearances (n) of the spot as a function of the distance from the cross, and of the contrast of the spot (a), of the contrast of the ring (b). The vertical line at the 60 min means the position of the inner contour of the ring. (a) is combinations of spot-ring, and (b) is of ring-spot.

TABLE 1
Mean dominance time ($\bar{t}$; sec) and mean suppression time ($\bar{\tau}$; sec) of the spot as
a function of the distance (min) from the cross, and of the contrast

Contrast† of		$\bar{t}$						$\bar{\tau}$					
		20	30	40	50	60	70	20	30	40	50	60	70(min)
Spot	Ring												
H	H	60.0	24.5	7.2	4.0	3.7	4.5	0.0	0.3	0.4	0.5	0.5	0.5
M	H	60.0	25.1	6.1	3.6	3.1	3.2	0.0	0.5	0.6	0.7	0.7	0.8
L	H	60.0	14.8	4.9	2.6	2.0	2.2	0.0	0.7	1.0	1.0	1.7	1.8
H	M	60.0	35.4	8.1	4.1	4.3	5.3	0.0	0.3	0.4	0.5	0.6	0.5
M	M	60.0	23.4	6.6	3.6	3.7	4.7	0.0	0.4	0.7	0.7	0.7	0.6
L	M	60.0	22.2	5.9	3.1	3.0	3.3	0.0	0.7	0.9	0.9	0.9	0.9
H	L	60.0	35.7	8.5	4.7	5.1	7.5	0.0	0.3	0.4	0.5	0.5	0.4
M	L	60.0	25.0	7.3	4.0	4.2	6.5	0.0	0.4	0.7	0.7	0.8	0.6
L	L	60.0	24.4	6.2	3.5	3.8	5.2	0.0	0.7	0.9	0.9	0.9	0.8
Ring	Spot												
H	H	60.0	24.5	7.2	4.0	3.7	4.5	0.0	0.3	0.4	0.5	0.5	0.5
M	H	60.0	35.4	8.1	4.1	4.3	5.3	0.0	0.3	0.4	0.5	0.6	0.5
L	H	60.0	35.7	8.5	4.7	5.1	7.5	0.0	0.3	0.4	0.5	0.5	0.4
H	M	60.0	25.1	6.1	3.6	3.1	3.2	0.0	0.5	0.6	0.7	0.7	0.8
M	M	60.0	23.4	6.6	3.6	3.7	4.7	0.0	0.4	0.7	0.7	0.7	0.6
L	M	60.0	25.0	7.3	4.0	4.2	6.5	0.0	0.4	0.7	0.7	0.8	0.6
H	L	60.0	14.8	4.9	2.6	2.0	2.2	0.0	0.7	1.0	1.0	1.7	1.8
M	L	60.0	22.2	5.9	3.1	3.0	3.3	0.0	0.7	0.9	0.9	0.9	0.9
L	L	60.0	24.4	6.2	3.5	3.8	5.2	0.0	0.7	0.9	0.9	0.9	0.8

† The upper rows are combinations of spot-ring, and the under rows are of ring-spot.

Procedure

The task of subjects was to observe the spot while fixating on the cross, then to depress a key with his right hand when the spot disappeared, and to keep the key depressed as long as the spot did not appear. Key depressions were recorded on a paper tape which was running 30 mm/sec. Key depressions recorded on the tape represent τ of the spot and sections where there is no key depression represent t of the spot. Subjects were instructed to watch in a passive manner and to avoid actively influencing the rivalry.

A trial was one min and five sec long, the first five sec of which were not included in the data. After each trial there was a 30 sec rest, and after each set of five trials there was a five min rest.

A set of five successive trials was done under the same conditions of contrast and distance. Three sets were done under each condition per subject. After the first set was done under every condition the second set began. The order of the presentations of each condition (54 conditions = 3×3 contrasts $\times$ 6 distances) was random. The experimental room was dimly illuminated. Before each experiment, subjects dark-adapted for 15 min.

RESULTS AND DISCUSSION

The number of disappearances (n) of the spot are given in Fig. 2 as a function of distance and contrast. The mean dominance time ($\bar{t} = \sum_{i=1}^n t_i/n$) and the mean sup-

TABLE 2

The results of the F test and measured tendency and predicted tendency as the contrast increased

Increase of contrast of	Contrast of	Measured tendency						Predicted tendency	
		20-50 Range			60-70 Range			$\hat{i}$	$\bar{\tau}$
		n	$\hat{i}$	$\bar{\tau}$	n	$\hat{i}$	$\bar{\tau}$		
Spot	Ring	De	In	De	De	In	De	Un	De†
	H	42.3*††	17.4*	155.3*	107.1*	178.4*	134.5*		
	M	26.7*	16.7*	141.6*	76.3*	79.0*	83.4*		
	L	25.8*	11.7*	98.8*	46.8*	139.0*	89.2*		
Ring	Spot	In	De	Un	In	De	Un	De	Un
	H	18.6*	8.7*	1.4	65.6*	66.7*	2.2		
	M	24.1*	0.5	0.4	127.3*	97.6*	1.2		
	L	40.2*	10.4*	2.4	204.1*	177.0*	21.6*		

* $p < .001$

† De: Decrease, In: Increase, Un: Unchange

†† It means that F -value about decrease of n is 42.3 when the contrast of ring is H and the contrast of spot increases.

pression time ($\bar{\tau} = \sum_{i=1}^n \tau_i/n$) of the spot are similarly given in Table 1. These data are the average of the three subjects.

The Effect of Contrast

The F test was separately applied to the 20-50 range ($df=2, 396$) and to the 60-70 range ($df=2, 264$) to examine what tendency n , $\hat{i}$ and $\bar{\tau}$ had as the contrast increased. The results of the F test and the tendencies predicted by Eq. (1) and Eq. (2) are given in Table 2.

Comparing the predicted tendencies with the measured tendencies at the 20-50 range, they coincide perfectly with each other at two cases for $\bar{\tau}$, but only at one case for $\hat{i}$. The case where they do not coincide for $\hat{i}$ is the key case of Eq. (1). These results mean that the correct equation is Eq. (2), not Eq. (1). Levelt (1966) concluded that the validity of Eq. (1) was supported by his experiments II and III. But as has been stated, his experiments were the two-choice rivalry task and Eq. (1) was equal to Eq. (2) under the task. Therefore his experiments could not have confirmed which equation was correct.

The truth is that the results of his experiments supported Eq. (2). Yet, it seems that Eq. (2) is not always correct, because $\bar{\tau}$ depends on λ of the contralateral stimulus under the condition that the contrast of the spot is L at the 60-70 range.

In our experiment $\hat{i}$ depends obviously on λ s of both stimuli. As regards $\hat{i}$, Eq. (3) is correct

$$\hat{i}_l = f(\lambda_l, \lambda_r), \quad \hat{i}_r = f(\lambda_r, \lambda_l) \quad (3)$$

where $\hat{i}_l$ is a decreasing function of λ_r and an increasing function of λ_l , and likewise $\hat{i}_r$ is a decreasing function of λ_l and an increasing function of λ_r .

The Effect of Distance

The F test was applied to the 20-50 range ($df=2, 132$) to examine what tendency n , $\hat{i}$ and $\bar{\tau}$ had as the distance from the cross increased. Under this condition, λ of the ring increases while λ of the spot is constant. As can be seen in Fig. 2 and Table 1, each tendency that n , $\hat{i}$ and $\bar{\tau}$ of the spot have is consistent for all combinations of contrast. Therefore, only the results of the F test concerning the contrast of both ring and spot H are given in Table

TABLE 3

The results of the F test at the 20-50 range and measured tendency and predicted tendency as the distance from the cross increased

Measured tendency			Predicted tendency	
n	i	$\bar{\epsilon}$	i	$\bar{\epsilon}$
In	De	In	De	Un†
299.6*	64.4*	22.2*		

* $p < .001$

† De: Decrease, In: Increase, Un: Unchange

3. And the tendencies predicted by Eq. (1) and Eq. (2) are also given in Table 3.

Comparing the predicted tendencies with the measured tendencies, they coincide with each other for i , but not for $\bar{\epsilon}$. But the results do not support the validity of Eq. (1). For, the key point of Eq. (1) is that increase of the stimulus strength in one eye will not affect i for the same eye, and, as regards the distance, unfortunately this experiment can not test the key point. Equation (3) can also predict the tendency toward decrease that i has as well as Eq. (1). Therefore the results in Table 3 mean that $\bar{\epsilon}$ depends on λ s of both stimuli when the stimulus strength is a function of distance. That is to say, as for the distance, Eq. (2) is not correct, but Eq. (4) is correct

$$\bar{\epsilon}_r = f(\lambda_r, \lambda_l), \quad \bar{\epsilon}_l = f(\lambda_l, \lambda_r) \quad (4)$$

where $\bar{\epsilon}_r$ is a decreasing function of λ_r and increasing function of λ_l . Likewise $\bar{\epsilon}_l$ is a decreasing function of λ_l and an increasing function of λ_r .

The number of disappearances of the spot increases as the interocular separation between the ring and the spot decreases. This is consistent with the findings of Levelt (1966), Kaufman (1963), Collins and Blackwell (1974). And this result confirmed Levelt's proposition III.

Levelt deduced proposition IV from a view that increase of λ_l and λ_r leads to reduction of both i_l and i_r , and hence of $\bar{T}$.

When the contrast of both ring and spot simultaneously increases in our experiment, as he expected, n at the 60-70 range where the two-choice alternation occur increases ($F=7.32$, $df=2$, 264). But at the 20-50 range where the intermittent alternation occurs n does not increase ($F=0.24$, $df=2$, 396). These results seem to show that proposition IV is valid only in case of the two-choice alternation.

CONCLUSION

Levelt's model on binocular rivalry is based on the assumption which is represented in the form of Eq. (1). But Eq. (1) is equal to Eq. (2) under the two-choice rivalry task. He examined the validity of Eq. (1) through his experiments II and III, and he concluded that the validity of Eq. (1) was supported. But, his experiments were the two-choice rivalry task which could not distinguish which equation was correct. Therefore, it was examined which equation was correct under the intermittent alternation process. The results showed that i always depends on λ s of both stimuli. On the other hand, $\bar{\epsilon}$ of one eye depends on λ only of the same stimulus, so far as the contrast is concerned. But $\bar{\epsilon}$ depends on λ s of both stimuli when the variable is the distance. These results support Eq. (2), but not Eq. (1), and seem to show that Levelt's model should have been based on the latter assumption.

Yet Levelt's propositions I, III and IV are still valid though Eq. (1) was rejected by our experiment. For, the four propositions deduced by Eq. (2) are equal to those of Eq. (1) except proposition II, and propositions I and III were confirmed by the results of our experiment, and proposition IV was confirmed as well when the alternation process was the two-choice.

Meanwhile, Eq. (3) is inconsistent with the results of Levelt's experiments. According to Eq. (3), as λ_l was changed in his experiments, i_l as well as i_r ought to

have changed, but i_i did not change. It seems that this inconsistency is due to a speciality of the ring-disk rivalry experiment. In the ring-disk rivalry there is only a few fragmentations, so the reappearance of a suppressed stimulus means only the disappearance of the contralateral stimulus. A reappearing stimulus may have a strong power to suppress the contralateral stimulus immediately after the reappearance, as can be indirectly seen from the experiment of Somiya and Somiya (1968). Thus $\bar{\tau}$ determines the alternation process in the ring-disk rivalry and $\bar{\tau}$ does not depend on λ of the contralateral stimulus. Therefore, in Levelt's experiments λ_i did not change $\bar{\tau}_r$, so i_i which was the reverse of $\bar{\tau}_r$ did not change.

It has been almost arbitrary which index, i or $\bar{\tau}$, investigators choose in the study of binocular rivalry. It does not come to question, so far as the two-choice rivalry alternation is concerned. But i and $\bar{\tau}$ do differ in quality with each other. One of the evidences is the results of our experiment. Therefore under the experiments in which the intermittent alternation appears, careful attention must be paid to the fact that i and $\bar{\tau}$ differ in quality.

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