Contour synchrony in binocular rivalry*

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Afterimages of rivalrous vertical and horizontal lines were generated simultaneously in each eye. Either a horizontal and a vertical line or two vertical lines were presented to one eye with the complementary rivalrous pair to the other eye. Synchrony of line pairs presented to the same eye was longer than predicted on the basis of independence, irrespective of the monocular configuration. Furthermore, there appeared to be a facilitatory effect for lines of the same orientation if they were presented to one eye rather than combined from both eyes.

Binocular contour rivalry is studied by presenting contours of different orientations to each eye. Under these conditions, one or the other orientation dominates for most of the time, but composites in which different orientations dominate in different parts of the field are also apparent. This latter aspect of rivalry has received relatively little attention, and it demonstrates that some degree of independence is operating for different parts of the visual field within the same eye. The typical rivalry experiment, however, does not permit assessment of the degree of contour independence due to the possible interaction of the similarly oriented contours presented to one eye. That is, there may be two factors operating in binocular contour rivalry: first, the synchrony of contours presented to one eye and, second, synchrony of contours having the same orientation irrespective of the eye to which they are presented.

In one experiment of a series addressed to this problem, Whittle, Bloor, and Pocock (1968) sought to determine whether a pair of lines in one eye, separated by about 2 deg, would undergo rivalry with a complementary pair in the other eye independently of one another. The lines were either vertical or horizontal and were presented with either the same or different orientations to one eye. Departures from predictions of independence were evident for the conditions in which lines of the same orientation were presented to one eye, and they were more marked for the visibility of vertical than of horizontal lines. They postulated some form of linkage between similarly oriented contours to account for their data.

One of the factors that has been considered to influence alternations in binocular rivalry is the slight movements of one eye relative to the other (Levelt, 1965). Such nonconjugate eye movements are more pronounced in the horizontal than in the vertical direction (Kaufman, 1963). Consequently, the difference between the vertical and horizontal line pairs

in Whittle et al's experiment may have been due to this asymmetry of eye movements. That is, movement of one eye horizontally relative to the other would result in the stimulation of a new set of receptors for the vertical lines presented to that eye, but not for the horizontal lines, with a consequent increase in their dominance duration.

The purpose of the present experiment was to examine whether line pairs stabilized on the retina by means of prolonged afterimages underwent rivalry independently of one another. By requiring S to indicate the visibility of the lines separately, it was possible to measure the synchrony of the various line pairs and to compare these durations with those predicted on the basis of independence.

APPARATUS AND PROCEDURE

The stimulus configurations employed were similar to those used by Whittle et al. and they are represented in Fig. 1. The lines, which were apertures in black masking card, subtended $1 \times \frac{1}{4}$ deg at the eye, and their centers were separated by 3 deg. The stimuli were mounted in a stereoscope, which permitted independent adjustment of each field so that the central fixation

Fig. 1. The four stimulus configurations used in the experiment.

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Table 1
Percentage Durations Observed for Single Lines and Synchronous Pairs (O) With the Expected Durations (E) on the Basis of Independence

		Stimulus Configuration	
		UT vs IT	2V vs 2H
Upper Pair	UV	37.1	41.0
	UH	38.3	42.2
Lower Pair	LV	30.0	31.7
	LH	29.8	33.6
2V	O	11.1 (3.9)	22.0 (6.3)
	E	12.1	13.6
	O-E	-1.0	+8.4 ⁺
2H	O	11.9 (4.0)	22.0 (6.0)
	E	12.3	15.0
	O-E	-0.4	+7.0 ⁺
IT	O	15.5 (4.2)	9.6 (2.6)
	E	11.6	14.2
	O-E	+3.9*	-4.6 ⁺
UT	O	15.9 (4.6)	9.4 (2.9)
	E	13.0	13.8
	O-E	+2.9*	-4.4 ⁺

* $p < .05$ ⁺ $p < .01$

Note—The frequencies of occurrence of each pairing are given in parentheses.

dots could be superimposed with resultant centering of the rivalrous line pairs.

Afterimages were generated by the discharge of a Multiblitz Report flashgun (with an output of 120 J in 2 msec) mounted directly behind the apertures. A dim light was on prior to the flash to enable superimposition of the fixation dots; otherwise, the room was dark.

Four switches were positioned on a table in front of S; these activated timers, counters, and separate channels of a Rustak event recorder. The switches were arranged in the form of a square, the left pair of which corresponded to the vertical lines and the right pair to the horizontal; within a pair, the far switch represented the upper line and the near switch, the lower line.

Sixteen Ss, mainly graduate members of Dundee University, participated in the experiment. All had normal or corrected-to-normal vision.

The task involved S depressing the switch or switches corresponding to the line or lines that were visible in their entirety. This procedure was employed because it was possible to see a single line in isolation as well as paired with another line. After a description of the apparatus and procedure, S was given a practice trial which was followed by 10 min of dark adaptation. The stimulus configurations for a given rivalry condition were then aligned and afterimages were generated. These were observed with eyes closed for 2 min, during which S indicated the sequence and duration of line visibilities by means of the switch depressions. A further 5 min dark adaptation was given before another set of afterimages was generated. This procedure was repeated for the four rivalry configurations: two verticals, two horizontals, upright T, and inverted T forms (2V, 2H, UT, and IT, respectively, following Whittle et al's usage) presented to one eye with the complementary configuration to the other. The order of presentation was counterbalanced over Ss, with the constraint that the 2V vs 2H and UT vs IT pairs follow one another.

RESULTS AND DISCUSSION

The data for the two 2V vs 2H and UT vs IT

conditions were averaged to control for any eye dominance effects. The mean percentage durations of visibility for each of the possible pairings are given in Table 1, together with their mean frequencies of occurrence. The rivalry between the line pairs was unitary as Ss made no reports of the visibility of crosses.

It is clear that 2V and 2H were synchronous for approximately twice as long as UT and IT when the former were presented to the same eyes. The reverse was the case for the latter pairings when they were presented to the same eyes, but to a lesser extent.

Statistical treatment of the duration data yielded a significant effect over visibility categories [$F(3,15) = 4.40$, $p < .01$]. Post hoc comparisons indicated that this was due mainly to the difference between the 2V and 2H synchronies relative to those for UT and IT. Afterimages were visible for longer in the 2V vs 2H condition than in the UT vs IT condition [$F(1,15) = 5.62$, $p < .05$]. This suggests that, even though the centers of the lines were separated by 3 deg, some interaction of contours within the same eye was operative. The statistical interaction between visibility categories and stimulus configurations was significant [$F(3,45) = 20.59$, $p < .001$]. The synchrony of line pairs presented to the same eye was greater than that presented to different eyes, irrespective of the configuration. For example, the duration of visibility of UT was greater when one eye was presented with this configuration than when it was formed from lines presented to separate eyes.

The frequencies of occurrence showed a similar pattern of results. 2V and 2H were synchronous more frequently than UT and IT for 2V vs 2H, and there was a slight tendency in the reverse direction for UT vs IT. Broadly speaking, the ratios of duration/frequency were commensurate for all conditions, the average being about 4 sec. The visibility categories yielded significant differences [$F(3,45) = 6.79$, $p < .01$]; again, this was due to the comparison between like oriented and differently oriented pairings. Frequencies did not differ over stimulus configurations [$F(1,15) = 0.70$, $p > .05$], but the interaction between synchronous pairs and configurations was significant [$F(3,45) = 26.06$, $p < .001$]. In a similar manner to durations, the frequency of occurrence of the line pairs presented to the same eyes was greater than that presented to different eyes.

The duration of visibility of each line was measured independently of synchronies to enable examination of the independence hypothesis in the manner employed by Whittle et al (1968). The percentage of the observation period that the single lines were visible is given in Table 1. The upper lines were visible for longer than the lower and the durations for 2V vs 2H were slightly longer than those for UT vs IT. The percentage duration expected (E) on the basis of independence was calculated for each S (see Whittle et al for the details of computation), and the mean values are shown in Table 1 together with the difference between the observed (O)

and expected durations. Significant departures from independence (as determined by *t* tests) were evident for all pairs presented to one eye. The departures were much more marked for the synchrony of similarly oriented lines. In this latter respect, the results may be taken as supporting those of Whittle et al, except that no difference was apparent between the synchrony of vertical and horizontal pairs. Their conclusions regarding the absence of intra-eye linkage, however, require qualification. When eye movements are stopped, contours presented to one eye are synchronous for longer than would be expected by chance. This outcome may appear paradoxical as nonconjugate eye movements might seem to favor an intra-eye linkage, but this is so only for the conditions in which similar orientations are presented to one eye. Otherwise, as suggested in the introduction, such relative eye movements favor specifically oriented contours. The similarity of the results for 2V and 2H reported here lend support to this contention.

Thus, there do seem to be two processes operating to produce the above pattern of results. First, contours presented to one eye are visible together for longer than would be expected by chance when rivalrous with contours in the other eye. Such was the case for all stimulus configurations. Second, some facilitatory interactions occur between contours of the same orientation presented to one eye. Accordingly, in the 2V vs 2H condition, both factors were operating to yield large departures from chance expectancy for 2V and 2H and also the significantly shorter UT and IT durations. For UT vs IT, only the first factor was operative and, consequently, the 2V and 2H synchronies did not depart

from chance expectancy. Support for the occurrence of intra-eye facilitation of like oriented contours has been produced by Atkinson (1972). She found that the components in afterimages like the IT figure viewed monocularly were independent of one another at separations where vertical or horizontal line pairs yield much higher levels of synchrony.

In conclusion, there appear to be at least two factors operative in binocular contour rivalry. One favors stimuli presented to the same eye, irrespective of their configuration, and the other favors stimuli of the same orientation, provided that they are presented to the same eye. It is suggested that the discrepancy between the results of this experiment and those of Whittle et al is due to the absence of the effects of nonconjugate eye movements when observing rivalrous afterimages.

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