Stabilized images: Dependent variable specificity of pattern-specific effects with prolonged viewing*

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Two studies report results of viewing lines in different orientations in stabilized Maxwellian view. The first study examined the time course of four dependent variables—whole- and partial-fade frequencies and whole- and partial-fade durations. Whole-fade frequencies increased systematically throughout 10 min of the 15-min viewing session and were sensitive to line orientations. Partial-fade frequencies increased for 3-5 min, during which orientation specificity occurred. Thereafter, partial-fade rate was constant and pattern-specific effects disappeared. Mean fade duration, which increased throughout the 15-min session for whole fades but for only 5 min for partial fades, was not pattern-specific. The second study demonstrated that the pattern specificity of whole fades could not be accounted for in terms of time-dependent extraneous variables. It was concluded that partial and whole fades may reflect the operation of different visual processes. The complete fading of images was attributed to the operation of suprarretinal pattern processing units.

As a part of a program of studies designed to evaluate the use of stabilized image data to identify and describe pattern analytic processes in the human visual system, we reported a series of studies (Schmidt et al, 1971) which showed pattern-specific effects. During the course of those studies, it became clear that fragmentation data were more complex than the existing literature sometimes suggests. A good review of this literature prior to 1965 has been presented by Heckenmuller (1965). In general, it has been recognized that fragmentation is normally in terms of organized units of patterns (e.g., line, angles, parallel lines, etc.) and that both whole patterns and units of patterns may either fade in their entirety or may fade only partially. Moreover, whole fades may either occur gradually or suddenly. Numerous studies have merely reported descriptions of the events observed under stabilized view with no indication of the reliability, probability, or duration of the events described. Most reports in which quantitative summaries are given have been limited to the frequency with which whole or partial fades occur. Relatively few experiments have presented duration data for either whole or partial fades, and little attention has been given to the time course of these various events.

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Propaedeutic to the further development of stabilized image data as an analytic tool, the two studies reported here were undertaken in the interest of providing a more detailed study of the time and pattern specificity of selected stabilized image phenomena. In view of our major interest, central pattern processing mechanisms, we concentrate upon the analysis of dependent variables which seem to show most promise in that context.

EXPERIMENT 1

The first study was designed to assess the extent to which fragmentation data vary systematically over long viewing periods and to examine the extent to which such variation is pattern-specific. Continued viewing of a stabilized image has been found to alter quantitatively the fading of both patterned elements (Riggs, Ratliff, Cornsweet, & Cornsweet, 1953) and brightness gradients (Clowes, 1961, 1962). Cohen (1961) has shown that the fading frequency of lines increased for 5 min and remained constant for 10 min thereafter. We have reported preliminary data which show systematic changes over 5-min sessions (Cosgrove et al, 1971). In general, however, the literature is completely devoid of a quantitative analysis of pattern-specific effects over long viewing durations.

Observers

Three males, 24 (M.C.), 25 (M.S.), and 43 (D.F.) years of age, served as Os. Vision was corrected to 20/20 in

the left viewing eyes with individually fitted contact lenses. All Os were well practiced in stabilized image viewing.

Stimuli

Patterns appeared as black line segments, 50 by 2 min of visual arc, against a light-filled circular field subtending 5 deg 18 min in diam. Line segments were viewed in vertical, horizontal, and diagonal (45 deg from the vertical) orientations. These patterns were selected because earlier data (Schmidt et al, 1971) led us to expect pattern-specific effects for the three line orientations. Field luminance was maintained at 2 fL for all viewing sessions.

Optical System

An optical system, similar to that described by Clowes and Ditchburn (1959) and which presented O with a stabilized image of the stimulus in Maxwellian view, is shown schematically in Fig. 1. Stabilization was achieved by means of an optical lever reflected from a small mirror fixed to a contact lens worn on the viewing eye. The system was designed so that movements of the eye (and, therefore, movements of the contact lens mirror) produced the appropriate movement of the stimulus to keep it motionless with respect to the retina. In practice, some slippage of contact lenses causes stabilization to be less than absolute [see Riggs & Schick (1968) for a discussion of lens slippage and its consequences in a system of this type]. A biteboard allowed O to fix his head in the appropriate position.

Contact lenses were scleral lenses

Fig. 1. Schematic diagram of the optical system used to achieve stabilization of the retinal image.¹

Fig. 2. Frequencies of whole and partial fades for lines in three different orientations. Each data point represents the mean frequency with which a line in a particular orientation faded during a 1-min interval of the viewing session. The heavy black line represents the mean frequency of fades for all three orientations combined.

individually molded to fit each O. A small stage (5 mm diam) was glued to the lens on the temporal side of the corneal bulge, a circular first-surface mirror (4 mm diam) was mounted on the stage, normal to the optical axis. Before each experimental session, O received one drop of Ophthalmic anesthetic, a proparacaine hydrochloride solution (Allergan Pharmaceuticals, Inc.) in the viewing eye.

Procedure

O inserted the contact lens and then fixated on the line stimulus to be viewed. Each O made one 15-min experimental run per day for 10 days for each line orientation. The stimulus orientations (0, 45, 90 deg) were balanced randomly for each O and each day. Responses were recorded on a two-channel event recorder (Brush Instruments Co., BL-202) activated by two telegraph keys. O was instructed to respond to a whole fade whenever the entire stimulus was faded from view by pressing the appropriate key with his finger and leaving it depressed for the duration of the fade. A partial

fade was likewise responded to when any part, but not all, of the stimulus was faded from view. The Os were highly practiced in this task. The three events—complete fading, partial fading, and the presence of a clear and complete image—were treated as mutually exclusive and exhaustive by the Os and are easily discriminated under the viewing conditions used. Consequently, we feel that highly reliable frequency and duration data were obtained.

Results and Discussion

The heavy black line in Fig. 2 shows the mean of the fade frequencies for the three line orientations for the 15-min viewing sessions. Whole-fade frequencies undergo a linear increase for the first 10 min of viewing and then asymptote at 3 fades/min. Partial fades, in contrast, increase sharply for the first 3 min and then show a slight systematic decrease for the last 5 min. Frequency curves for the diagonal, vertical, and horizontal orientations are highly similar in shape. Whole-fade frequencies are obviously sensitive to the different line orientations, with

the diagonal fading most and the horizontal, least. It is interesting to note that partial-fade frequency is not a sensitive measure of pattern differences except during the initial 5-min period when the partial-fade rate is changing. All three Os showed a high degree of agreement on the time course of the increase in whole- and partial-fade frequencies.

Duration data are summarized in Fig. 3, where the time course of mean fade duration is shown for both partial and whole fades. The mean length of whole fades increased slightly throughout the viewing period; the mean length of partial fades increased during only the first 5 min. When these curves were examined for the three orientations, the average length of neither the whole nor the partial fades was pattern-specific. As expected from Figs. 1 and 2 combined, the total time during the 15-min session in which the image was faded was highly similar to the frequency data.

Collectively, these data suggest that whole-fade frequencies are the most sensitive index of pattern effects, that partial-fade frequencies are pattern-sensitive only during the initial stages of viewing, and that the average length of a fade does not reflect pattern-specific operations.

The stochastic properties of fragmentation data may be of considerable theoretical interest in view of the possibility that the various phenomena observed in stabilized view may reflect some pattern of mutual dependency. It is surprising, therefore, that, with one exception (MacKinnon, Forde, & Piggins, 1969), stochastic data have not routinely been presented.

Given the occurrence of the

Fig. 3. Mean duration for whole and a partial fade in each 1-min interval of the viewing session.

Table 1
Conditioned Probabilities that an Event (N + 1) was Preceded by an Event N Summarized for the Three Events—a Whole Fade (W), a Partial Fade (P), or a Clear Image (C)—and the Three Line Orientations, Horizontal (H), Vertical (V), and Diagonal (D)

p(N + 1/N)	Line Orientation	Minutes			Total Viewing Time
		1-5	6-10	11-15	
p(W/P)	H	.14	.19	.20	.18
	V	.14	.30	.27	.24
	D	.24	.34	.36	.31
p(C/P)	H	.86	.81	.80	.82
	V	.86	.70	.73	.76
	D	.76	.66	.65	.69
p(W/C)	H	.08	.14	.18	.14
	V	.13	.22	.17	.17
	D	.14	.22	.32	.23
p(P/C)	H	.92	.86	.83	.87
	V	.87	.79	.83	.83
	D	.87	.78	.68	.78
p(P/W)	H	.07	.12	.15	.12
	V	.18	.18	.15	.17
	D	.23	.24	.28	.25
p(C/W)	H	.93	.88	.85	.88
	V	.82	.83	.85	.83
	D	.77	.76	.72	.75

sequence of events, N - 1, N, and N + 1, two interesting sets of conditional probabilities can be computed relative to N. The first, p(N + 1/N), gives us for each event N—a partial fade, a whole fade, or the presence of the clear total image—the probabilities with which the other two states, N + 1, were reported as the next event. The other, p(N - 1/N), yields the probability with which each state occurred given the other two states on the immediately preceding trial. If we let A, B, and C denote the three events and N - 1, N, and N + 1, the sequence, then the relation between p(N + 1/N) and p(N - 1/N) is, for instance, $p(A_{N-1}/B_N) p(B) = p(B_{N+1}/A_N) p(A)$. The p(N + 1/N) conditional probabilities averaged over Os and trials separately for each orientation and for blocks of 5-min duration, are summarized in Table 1. Table 2 summarizes the simple probabilities for the various observed events. The total number of whole fades was 1,773. The total number of partial fades was 6,641.

From Tables 1 and 2 combined it is reasonably clear that the three events are independent of each other. Whole fades are relatively rare, while both partial fades and clear images have approximately equal probabilities of occurring. The important datum is that when they occur, whole fades are preceded by partial fades and clear images with about equal probability. Moreover, the pattern-specific effects associated with whole-fade frequency also occur independently of the preceding event. The fact that pattern effects are reflected in all of the conditional probabilities can be attributed to the whole-fade

frequencies, since Table 1 is redundant [$p(W/P) + p(C/P) = 1.00$, $p(W/C) + p(P/C) = 1.00$, $p(P/W) + p(C/W) = 1.00$, and $p(W) + p(P) + p(C) = 1.00$].

The p(N - 1/N) values are not presented here, since they may be computed from Tables 1 and 2. In general, they provide no new information concerning these data, with the exception that $p(P_{N-1}/W)$ and $p(C_{N-1}/W)$ are approximately equal (.54-.56 and .44-.46, respectively), showing quite clearly that whole fades are equally likely to "come from" partial fades and clear images.

EXPERIMENT 2

In the first study, there was no control for time-specific variables which may have operated to produce the systematic changes but which are not directly related to pattern processing. Paramount among such variables are those associated with lens slippage, a topic which has received considerable attention in the literature

and which is related to any hypothesis concerning the locus—retinal or central—of disappearance and reappearance of units of stabilized patterns. At one extreme, Cornsweet (1970, p. 408) takes the position that the reappearance of a stabilized image, even afterimages, can potentially be accounted for in terms of displacement of the image on the retina. The fact that entopic phenomena are not normally seen (Ratliff, 1958), that perfect stabilization results in an image which fades and never reappears (Cornsweet & Dwelley, 1962), and that free viewing, afterimages, and the use of optical lever systems such as ours always potentially involve retinal displacement make this position difficult to discount. In contrast to this position, however, Riggs and Schick (1968) have evaluated slippage for an optical system of the type used here and have concluded that it is possible to reduce stabilization errors for short viewing periods to the point that they do not appear to have important visual effects. Our position with regard to this point will be developed more completely in the discussion section of this paper.

The second study was designed to demonstrate that the long-duration effects observed in the first study cannot be attributed to details of the methodology, including the problem of stabilization as well as any other uncontrolled but duration-specific effects.

Observers

Two of the Os (M.C. and M.S.) were tested.

Stimuli

The horizontal (H) and diagonal (D) lines from Experiment 1 were used.

Procedure

The procedure was identical to that used in Experiment 1, except that at the end of 15 min of viewing, the lines (H or D) were rotated (D or H) for the remainder of a 30-min session. Over

Table 2
The Simple Probabilities of a Whole (W) or Partial (P) Fade or a Clear Image (C) of the Horizontal (H), Vertical (V), and Diagonal (D) Lines

		Minutes			
	Line Orientation	1-5	6-10	11-15	Total
p(W)	H	.10	.14	.16	.13
	V	.12	.21	.19	.17
	D	.17	.22	.23	.21
p(P)	H	.46	.39	.40	.41
	V	.41	.40	.37	.39
	D	.40	.36	.36	.37
p(C)	H	.44	.47	.45	.46
	V	.47	.39	.45	.44
	D	.43	.42	.41	.42

Fig. 4. Mean frequencies of whole and partial fades of the stimulus line. The vertical dividing line represents the point at which the orientation of the stimulus line was changed.

six sessions, on 6 separate days, the H-D and D-H shifts were each observed three times for each O. The sequence was randomized for each O.

Results and Discussion

The major data, mean fade frequency for whole and partial fades both before and after the shift, are shown in Fig. 4. These data are means over both Os and days (H-D and D-H shifts). The data for whole fades are very clear. Changing the orientation of the pattern after 15 min of stabilized viewing leads to results which are almost identical to those at the beginning of the session. The results are, therefore, a function of the duration of viewing of the particular stabilized pattern itself, since absolutely no change occurred at the end of the 15-min duration, except for the rotation of the target slide in its holder. The partial-fade frequency data are less clear. There is a small apparent reduction in the occurrence of partial fades after the shift. This dip is, however, small relative to variability of points on the curve. As in Experiment 1, we are inclined to assume that partial fades do not reflect pattern-specific effects over long viewing periods.

Although data have not been formally presented here, it should also be pointed out that all of the dependent variables exhibit large differences over sessions and days. These differences do not appear to be stimulus-specific. Rather, they appear to reflect some kind of base-rate effects, reasons for which we have not been able to isolate. For instance, our Figs. 1 and 3 show mean fade frequencies which in Experiment 2 are almost double those of Experiment 1. Since identical Os, optical systems, and stimuli were used, calibration was carefully checked, and recording errors were unlikely, we cannot explain the differences. We do suggest that experimental conditions should be balanced within experimental sessions as a control for such variability until the relevant variables are identified.

GENERAL DISCUSSION

Other than the fact that our data emphasize the need for the quantitative description of stabilized image phenomena, these studies suggest that partial and whole fades may reflect the operation of different processes within the visual system. Partial fades appear to be relatively insensitive to pattern effects; whole

fades consistently reflect pattern differences. Moreover, whole fades appear to be independent of other states of the image.

It could be argued, as Cornsweet (1970) has, that these data and others like them can be attributed to the fact that stabilization is imperfect. There are two good arguments against such a position. First, there is general agreement concerning the nature of stabilized image data obtained from free viewing, afterimages, and the use of optical systems such as ours. Unfortunately, only one good study has been reported in which a direct comparison was made among methods (MacKinnon et al, 1969). While more work of this nature is needed, their data were very similar across methods. Although retinal displacement of images cannot be ruled out completely with any of these methods, it seems highly improbable that similar data would be generated by displacement varying both in kind and magnitude.

Our second argument is that the concern with stabilization errors may be totally irrelevant to the question at hand. If we assume that perfect retinal stability invariably leads to the complete and permanent loss of pattern vision, then we may assume that partial- and whole-image regeneration results from image displacement. This in no way rules out the possibility that the resulting phenomena may provide important insights into the nature of the visual process and into the locus, central or peripheral, of such processes.

In the case of our data, we believe that partial and whole fades may reflect the operation of different processes. Partial fades appear to be largely insensitive to pattern effects; whole fades consistently reflect pattern differences. In addition to the well-known electrophysiological data concerning cortical pattern analysis, there are very good reasons for believing that image fading involves postretinal processes (Krauskopf & Riggs, 1959; Owen & Chalfant, 1970; Gerrits, DeHaan, & Vendrik, 1966; Keesey & Nichols, 1967). It is difficult to account for the data of our second study by attributing them to methodological errors. The data are easily accounted for if one assumes that whole fades reflect the selective adaptation or inhibition of pattern-specific units. When a new pattern is introduced, new units are involved. A stronger case for this interpretation would result if selective nonstabilized adaptation to both patterned and nonpatterned fields should lead to differential results for subsequent partial and whole fades of patterns which are stabilized on the same retinal area. Even stronger

support would result if such data could be obtained dichoptically. Based upon preliminary data now available, we expect to provide such support in subsequent papers in this series.

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NOTE

1. Light from a tungsten ribbon filament source is collimated by Lens L_1 , focused at the plane of a circular aperture by Lens L_2 , recollimated by Lens L_3 , and passed through the target slide. The axis of interest passes undeflected through a beamsplitter and Lens L_4 onto the contact lens mirror (CLM). Light reflected from CLM passes back through L_4 and into the viewing eye by means of the beamsplitter, pentaprism (PP), Lens L_5 , and Mirrors M_1 and M_2 . The reflected beam from CLM is deflected by an angle 2θ for every angle θ of eye movement; in order to achieve stabilization, the image is, therefore, viewed through a distance twice that of the projection distance from CLM. Viewing path EYE- M_2 - M_1 - L_5 -PP-image is 400 mm; projection path CLM- L_4 -beamsplitter-image is 200 mm. Lenses L_4 and L_5 constitute a $\frac{1}{2}$ -power telescope; L_5 produces a source image in O's pupil plane; the lens of O's viewing eye forms a target image on the retina. Thus the requirements for Maxwellian view are satisfied.

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