An investigation into hemisphere differences in adaptation to contrast

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Suggestions that the cerebral hemispheres differ in their ability to adapt to high-contrast visual stimuli were investigated using vertical sinusoidal gratings. In one experiment, subjects set thresholds for stimuli to the left or right of fixation before and after adaptation to high contrast. In another experiment, subjects detected the appearance and compared the relative suprathreshold contrasts of stimuli presented simultaneously to left and right of fixation before and after adaptation. In a third experiment, signal detection parameters were calculated. No systematic hemisphere differences were found in baseline sensitivity, in apparent suprathreshold contrast, in the magnitude or time-course of the threshold elevation aftereffect, or in apparent contrast after adaptation. Possible explanations for the hemisphere differences reported by other workers are discussed, and task complexity is suggested as a major factor which distorted previous results.

Tei and Owen (1980) have presented evidence that the two hemispheres of the brain may be differentially affected by adaptation to patterns of high contrast. They presented grating patterns for 0.5, 1, or 5 sec to different subjects, and measured the sensitivity, accuracy, and speed of reaction to changes in the orientation of a test grating that was exposed for 0.1 sec immediately after the adapting grating. As adaptation time lengthened, they found a decrease in sensitivity and accuracy and a lengthening of reaction time, but only for test gratings presented in the left visual field. No hemisphere differences were found for the 0.5-sec adaptation time. They concluded that "the right hemisphere is more readily affected by selective adaptation than is the left."

Beaton and Blakemore (1981) have also obtained data on laterality differences in adaptation to contrast. One of their subjects showed a consistently greater threshold elevation for stimuli in the right visual field (about 0.125 log units more than in the left field); the other subject did not show a consistent difference (their Figure 1). Beaton and Blakemore suggested that Tei and Owen's (1980) results might be due to a differential *rate* of adaptation between the hemispheres, while Beaton and Blakemore's data presumably reflected the saturated level of adaptation. However, recent work has suggested that the adapt-test-readapt-test . . . paradigm that Beaton and Blakemore used does not always yield a stable level of threshold elevation: the adapted threshold changes as a power function of time rather than as a saturating exponential (Rose & Lowe, 1982; Rose & Evans, in press).

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It is important to ascertain whether the above suggestions of hemisphere differences in adaptation are true. This is, first, because there is much evidence that adaptation to gratings is a function of the primary visual cortex (e.g., Movshon & Lennie, 1979). The discovery of hemisphere differences in adaptation would have implications not only for neurophysiological studies of area 17 but also for much recent work on basic visual mechanisms in humans (De Valois & De Valois, 1980; Julesz & Schumer, 1981), in which symmetry to left and right of fixation is assumed. Right-hemisphere superiority in certain visuospatial tasks such as the perception of line orientation (Fontenot & Benton, 1972) is usually interpreted in terms of asymmetry among higher centers (Fried, Mateer, Ojemann, Wohns, & Fedio, 1982; Moscovitch, 1979). However, these centers might act by feeding back onto the primary visual cortex to alter its functional properties (Bridgeman, 1982; Dobson, 1980; Harter, Aine, & Schroeder, 1982). In the present experiments, the simple perception of vertical gratings was studied as a first step in clarifying these questions.

EXPERIMENT 1

In this experiment, asymmetries in thresholds have been sought after periods of several minutes of adaptation, and the rates of buildup and decay of the aftereffect have been plotted directly, as suggested by Beaton and Blakemore (1981).

Method

Vertical sinusoidal grating patterns were generated electronically on an oscilloscope screen (P31 phosphor). For adaptation, the exposed area of the screen was a rectangle which subtended 4.5 deg horizontally $\times$ 3 deg vertically at the binocular viewing distance of

140 cm. This was centered in a surrounding screen of overall dimensions 40 deg horizontally $\times$ 25 deg vertically, which was uniformly illuminated with light of similar color and the same mean luminance (40 cd m^{-2}) as the grating. A black fixation cross (+) was visible 1.5 deg to the left of the midpoint of the left-hand edge of the grating, and a similar cross was positioned symmetrically 1.5 deg to the right of the grating. The grating had a Michelson contrast of 0.6 and a spatial frequency of 6.6 c/deg.

For testing thresholds, the surrounding screen was replaced by one that was identical, except that the exposed area of oscilloscope screen was reduced to 2.5 deg horizontally $\times$ 2 deg vertically. The fixation crosses were therefore 2.5 deg away from each edge of the test grating. Subjects adjusted the contrast in 1-dB steps to threshold using an electronic attenuator; contrast was increased by pressing a button with one hand and decreased by pressing another button with the other hand.

Procedure. At least 12 initial settings of threshold were made while the subject looked at the left and right fixation crosses alternately for each setting (i.e., six settings with fixation to the left and six to the right). The subject then adapted for 3 or 10 min to the larger, high-contrast grating, moving his eyes slowly back and forth along the 0.25-deg-long horizontal bar of the fixation + in order to minimize the buildup of retinal afterimages. Every 10 sec, at the sounding of a buzzer, he transferred his gaze from one fixation point to the other. (Such intermittent adaptation produces a very similar effect to a single continuous period of adaptation; Rose & Lowe, 1982.) The recovery of threshold after adaptation was followed using the method of Rose and Evans (in press). Because the initial period of rapid recovery is difficult to measure accurately, threshold setting was initiated 1 min after the end of adaptation. Five or six settings were made with fixation to the left of the grating, and the same number of settings were alternately interleaved with fixation to the right. This was completed in less than 3 min, and the contrast on the oscilloscope screen was lowered well below threshold until the next group of five or six settings on each side was taken. These groups were initiated 1 min after adaptation, then 5 min after adaptation, and at 5-min intervals thereafter until recovery was complete. The average reading in each group was plotted against time on double logarithmic axes (Rose & Evans, in press). All experiments were repeated twice, once with fixation first to the left and then to the right of the grating (in all three periods: pre-, during, and postadaptation) and once with right-then-left fixation. Each experiment was performed on a different day.

Full results were obtained with the author as subject, and selected points were verified with two naive subjects. All subjects are right-handed with normal or corrected-to-normal vision.

Results

In no group of threshold settings after adaptation was there more than a 1.0-dB deviation from the pre-adaptation baseline asymmetry (which averaged 0.5 dB across subjects), and there was no systematic change in left-right asymmetry during recovery. Thus, for the author as subject, the threshold elevation, measured 1 min after 3 min adaptation, was 8.1 dB in the left hemifield and 7.8 dB in the right hemifield; after 10 min adaptation, the corresponding figures were 12.1 and 12.3 dB. Analysis of variance for each experiment shows the only significant effect to have been the main effect of adaptation [$F(1,18) > 85$, $p < .001$]. There was *no significant interaction between adaptation and hemifield* (F ratios < 0.03). Quantitatively similar results were obtained with the naive subjects (10 min adaptation).

The slopes of the buildup were also not significantly different between left and right for the author as subject ($F = 0.08$). The slopes of the recovery curves (on double-logarithmic coordinates) for the author after 3 min adaptation were -0.389 and -0.396 in the left and right hemifields, respectively, and after 10 min adaptation, -0.416 and -0.391 (mean $r = -0.974$). These slopes do not differ significantly between left and right at either adaptation time.

Discussion

These results do not support the idea that the rate of adaptation differs between the hemispheres. Recent descriptions show the rate of adaptation in foveal viewing to be a single power function, at least over the range of adaptation times of 5 sec to 20 or 30 min (Bjorklund & Magnussen, 1981; Rose & Lowe, 1982; Rose & Evans, in press), and there is evidence that the same mechanism extends at least down to 1 sec (Figure 5B of Rose & Lowe, 1982). The present results are entirely in accord with these findings, and to postulate a deviation from a unitary function below 5 sec in one hemisphere only would be a less parsimonious explanation than some alternative possibilities (see the General Discussion).

EXPERIMENT 2

The alternating fixation procedure used in Experiment 1 was difficult for the naive subjects, and it may be criticized as lacking objective eye-movement recordings to show left-right equality of the duration and accuracy of fixation during adaptation. It also allowed the subject to direct his attention to one side at a time (Bashinski & Bacharach, 1980). Experiment 2 was designed to eliminate these factors and to gather some data about another consequence of adaptation: changes in apparent suprathreshold contrast.

Method

The oscilloscope screen of Experiment 1, with a dark surround and a central fixation mark, was viewed from 32 cm (with mild head restraint), where it subtended 23 deg horizontally $\times$ 18.5 deg vertically. During adaptation, the vertical sinusoidal grating had a contrast of 0.6 across the whole screen and a spatial frequency of 1.50 c/deg at the center of the screen (rising by simple geometry to 1.58 c/deg at the corners of the tangent screen). The test stimulus consisted of the above grating attenuated by various amounts (see below) and multiplied by two half-cycles of a 0.087-c/deg sine wave, one half-cycle in each of the outer (left and right) quarters of the screen. Thus, the central region of the screen, 11.5 deg wide $\times$ 18.5 deg high, was blank (apart from the fixation point in the exact center) and was flanked symmetrically by patches of vertical grating, 5.75 deg wide and 18.5 deg high, which faded gradually at the left and right edges of each patch. Mean luminance was constant (40 cd m^{-2}) across the entire screen and the peak contrast of the grating patches could be varied up to 0.6 in 1-dB steps.

Procedure. Naive, right-handed subjects (not used in Experiment 1) with normal or corrected-to-normal vision viewed the

screen binocularly. They were familiarized with the test stimulus at low contrast, and they were instructed to fixate the spot in the center of the screen. This instruction was repeated several times throughout the experiment. The following procedures were then run. (1) *Threshold balance*. The experimenter lowered the contrast of the stimulus to below threshold and then slowly raised it. Each subject was asked to say when the lines reappeared, and whether they were noticed first "on the left or on the right" (for half the subjects; "on the right or on the left" for the other half). If the lines appeared simultaneously on both sides, the subject was allowed to make an "equal" decision (see Discussion). The contrast was lowered below threshold as soon as the subject had made his decision. This procedure was repeated 10 times for each subject. The subjects scored 1 point for each "left" answer and 0.5 for each "equal" to give a left-right balance score out of 10. (2) *Suprathreshold balance*. Each subject was shown the test stimulus with a contrast of 5 dB (0.25 log unit) above his detection threshold and was asked whether the lines appeared equally clear on each side when he was looking at the central spot. If they were not equally clear, he was asked on which side they appeared to be clearer. This was repeated with peak contrast values of 0.11 and 0.60. This procedure typically lasted 10 to 20 sec. (3) *Adaptation*. Five minutes' exposure was given to the grating of uniform 0.6 contrast across the entire screen. For this procedure only, the subject was shown an area about 1.5 deg across centered on the fixation point and was instructed carefully how to move his point of gaze within that area to prevent formation of a retinal afterimage of the grating. (4) *Threshold balance*. This was a repeat of procedure 1. The first decision was taken typically about 15 sec after the end of adaptation, and the last about 2 min later. (5) *Suprathreshold balance*. This was a repeat of procedure 2. (6) The subject was shown a grating with uniform contrast across the entire screen, the contrast value being just enough for the bars to be visible as far as the edge of the screen when the subject was fixating the spot (typically, about 0.02 contrast units). The subject was asked whether the lines appeared to be equally clear on each side of the screen when he looked at the spot and, if not, which side was clearer. A vertical black masking bar, 1 deg wide, was then placed centrally down the entire height of the screen, and the subject was again asked about any apparent asymmetry in the now divided grating while he was looking at this bar.

Results

Ten subjects were run, who were not informed of the experimental purposes. (The Results are enumerated as in the Procedure above.)

(1) *Threshold balance before adaptation*. The balance scores averaged 4.65 (SD 1.00, range 3 to 6.5, $n=10$). This value is not significantly different from 5.0, which would indicate equal sensitivity to stimuli on the left and right of fixation. The average threshold value was 0.0065 contrast units.

(2) *Suprathreshold balance before adaptation*. At 5 dB above threshold (average contrast 0.012), six subjects reported the lines to be equally visible on both sides, two subjects said they were clearer on the right, and two subjects said they were clearer on the left. At contrasts of 0.11 and 0.60, the corresponding figures are 9 equal and 1 left, and 8 equal, 1 left, and 1 right, respectively.

(4) *Threshold balance after adaptation*. The mean balance score across subjects was 4.60 (SD 1.31). This does not differ from the corresponding value obtained before adaptation (one sample $t=0.09$, n.s.). The amount of threshold elevation after adap-

tation was 8 dB for the first presentation of the test stimulus (about 15 sec after adaptation) and 4 dB during the last eight presentations. On the first presentation, lines were initially detected by four subjects on the left, by four on the right, and by two equally on the left and right.

(5) *Suprathreshold balance after adaptation*. At all contrast levels, all subjects reported the lines to have equal clarity on left and right, except for two "left" and two "right" decisions 5 dB above threshold, three "right" at contrast 0.11, and one "right" at 0.6. Six subjects showed exactly the same left-right bias in their responses here as they did in procedure 2 (before adaptation), three changed such that apparent contrast increased on the right after adaptation, and one changed in the opposite direction. None of the changes that did occur were biased systematically to one side (binomial tests).

(6) Two subjects thought the stripes of the uniform grating looked clearer on the right. With the vertical dividing mask present to enhance simultaneous contrast, three subjects thought the stripes were clearer on the left. All other decisions were "equal."

Additional observations. For three subjects, the detection threshold for the test stimulus was reassessed after procedure 6 in order to check that the effects of adaptation had persisted. Their threshold elevation at this time, about 3 min after adaptation, was still 4 dB on average, the same as the later settings during procedure 4. This slow rate of recovery at this time is in accord with previous observations (Rose & Evans, in press; Rose & Lowe, 1982).

Some further tests were made to check whether the techniques used here were sensitive enough to detect any change in function between the hemispheres. It was not possible with the present apparatus to present unequal contrasts on each side of the screen, but the following observations were made. (1) Subjects ($n=3$) were reliably able to detect and discriminate bilateral increases or decreases in contrast of 1 dB in the just suprathreshold region. (2) Two subjects (not included in the main experiments) gave balance scores of 1 and 0 when the fixation point was placed 13 and 26 min of arc, respectively, to the right of the exact center of the screen. (After adaptation, their balance scores were 1.5 and 0, respectively.)

Discussion

These results, like those of Experiment 1, are entirely consistent with equality of function between the hemispheres before and after adaptation. This is true of apparent suprathreshold contrast as well as of detection at threshold.

With negative findings such as these, it is important to establish that the method was sufficiently sensitive to detect any effects, at least of the magnitude expected. For example, Tei and Owen (1980) found about a 25% drop in their measure of "sensi-

tivity" in the left hemifield after 5 sec adaptation. In the present experiments, subjects were found empirically to be able to detect at least 1-dB (12%) changes in contrast near threshold, and to give a significant change in balance score with 13 min of arc deviation from centrality of eye position (which would cause 0.33 dB or 4% difference in threshold between the left and right stimuli, according to the data of Beaton and Blakemore, 1981). The use of an "equal" detection or apparent contrast category may have reduced sensitivity relative to a two-alternative forced-choice ("left"- "right") method, but it was necessary to include the "equal" alternative because no false-alarm trials were included to measure response bias and, in pilot experiments, subjects had reported that large guessing factors were distorting their answers in a nonstationary fashion on trials when the stimulus appeared to be subjectively equal on the two sides. In the experiment, none of the subjects used the "equal" response to the total exclusion of "left" or "right" decisions, so the two response criteria they used were not too widely apart to be exceeded. Finally, in procedure 6, no difference in apparent contrast was detected after 5 min adaptation, even with a black line running down the vertical meridian, a procedure which would facilitate simultaneous contrast between each side of the visual field. It is concluded that the techniques were able to detect small changes in contrast sensitivity, and that the failure to find any left-right asymmetry indicates that any such asymmetry was minimal.

EXPERIMENT 3

There remains a possibility that response criterion effects were acting in the previous experiments to cancel out changes in visual sensitivity. The present signal detection experiment was therefore run following acquisition of an on-line laboratory computer. It has been claimed that systematic deviations of fixation can occur during certain types of task (Bakan, 1969), and although this effect is not reliable (Ehrlichman & Weinberger, 1979) and cannot account for the results of Experiment 2, nevertheless the paradigm here was such that further analysis of this point could be made.

Method

The visual display was identical to that in Experiment 2 for both testing and adaptation, except that during testing the grating was presented during a time-window and could appear on one side of the screen only, on both sides simultaneously, or not at all. Subjects responded with a pattern of keypresses that was designed, as in Experiment 1, to equalize the amount of motor activity generated by each hemisphere.

Each test trial was initiated by the subject's pressing a key on the console of the computer (Cromemco System 3) with his left thumb. The computer then determined, from a random-number generator, whether to present a stimulus on the left of the screen or not on that trial; this process was repeated for a stimulus on the

right before stimulus presentation began. The contrast of the stimulus was modulated with a Gaussian temporal envelope of standard deviation 309 msec and truncated at ± 5.7 SD so that total trial length was 3.5 sec with peak contrast achieved 1.75 sec after the initiating keypress.

The task of the subject on each trial was to make two independent decisions, one about whether he saw a stimulus on the left and one about whether he saw one on the right. He knew that these presentations were random, with each side having an independent 50% probability of stimulus presentation. If he saw a stimulus on the left, he pressed another console key with his left hand, and if he saw a stimulus on the right, he pressed another key with his right hand. The order of keypresses (on trials on which he pressed twice) was unimportant. Finally, he pressed another key with his right hand to indicate completion of response. These responses could be given at any time; on pressing the end-of-trial key, or at termination of the stimulus time-window, the screen became uniformly blank (without change of mean luminance) until the subject began the next trial. All keypresses caused an audible feedback beep from the console.

Procedure. At least 30 practice trials were given at the beginning of each experiment, followed by 74-158 (mean 111) baseline trials. Five minutes of adaptation were then given as in Experiment 2. The screen was then blank for 60 sec while the rapid phase of recovery took place. Postadaptation trials were given for the next 4 min, which is when the rate of recovery is slowest (Rose & Lowe, 1982); post hoc analysis of the data revealed only a 17% change in d' between the first (1-3 min after adaptation) and second (3-5 min) halves of this period. Between 56 and 85 (mean 69) trials were completed in these 4 min. All the data were stored on magnetic disk and were later analyzed off-line. The signal detection parameters d' and beta were computed from the "yes-no" data, under the assumption of equal variance signal and signal-plus noise distributions (e.g., McNicol, 1972), separately for the left and right hemifields and for before and after adaptation. Each experiment took place on a different day.

Results

The values of d' obtained at various test contrasts with the author as subject are shown in Figure 1. Postadaptation data from experiments in which the test contrast after adaptation was less than 0.0126 yielded d' values close to zero, and these have been

Figure 1. Values of d' obtained in Experiment 3. The regression lines shown have a mean slope of 7.87 d' units per log unit of contrast before adaptation and 9.57 after.¹

omitted from Figure 1 for clarity. The slopes of the regression lines in Figure 1 do not differ significantly between left and right either before or after adaptation.¹ For the data in Figure 1, before adaptation sensitivity on the left was, on average, 0.88 d' units higher than it was on the right; after adaptation, it was 0.128 d' units higher. This change is not significant ($t=0.26$). A 2×2 analysis of variance (collapsing across test contrast) confirms that left versus right visual-field differences ($F=0.32$) and their interaction with adaptation ($F=0.01$) are both insignificant. A similar analysis for the natural logarithm of beta (a more linear measure than beta; McNicol, 1972) did not yield any significant effect (F values < 0.02) or any correlation with contrast ($|r| < 0.26$) or with d' ($|r| < 0.31$).

Similar, but less extensive, data and results were obtained from a naive right-handed subject. With the author as subject, similar results have also been obtained with the spatial frequency of the grating three times higher. With the test grating (at the normal spatial frequency) presented as a single temporal impulse which began 1.71 sec after the initiating keypress and which had a rectangular waveform of 87.5 msec duration, the results were again similar (although threshold elevation was less, as expected with a stationary adapting pattern; Rose & Lowe, 1982).

Values of d' were also calculated from the above data separately for stimuli presented bilaterally or unilaterally (taking false-alarm rates only from trials on which no stimulus occurred). Adaptation had no significant effect on the baseline left-right differences in sensitivity for either type of stimulus presentation ($t < 1.2$). This was found for all the stimuli and subjects used.

Discussion

These results provide further confirmation that hemispheric differences in contrast detection are not revealed by adaptation. They also eliminate changes in response criterion, and in the pattern of eye movements which would have affected the balance between sensitivity for unilateral and bilateral stimuli. The results with brief (87.5 msec) stimulus exposure (comparable to the 100 msec used by Tei & Owen, 1980) are important not only in that this duration is too short for reflex eye movements to occur, but also because they extend the conclusions to transient as well as sustained visual channels (Blake & Mills, 1979; Legge, 1978; O'Toole, 1979; Wilson & Bergen, 1979; Rao, Rourke, & Whitman, 1981; Rose & Lowe, 1982).

GENERAL DISCUSSION

Simple adaptation to contrast was found not to differ in its properties between the hemispheres in

these experiments. This is in line with psychophysical and physiological studies which ascribe adaptation to the primary visual cortex, at which level hemisphere differences have not been reported (De Valois & De Valois, 1980; Julesz & Schumer, 1981; Movshon & Lennie, 1979). Findings of left-right differences in baseline unadapted sensitivity (Beaton & Blakemore, 1981; Rao et al., 1981; Rovamo & Virsu, 1979) have not been replicated in other studies (Blake & Mills, 1979; Rijdsdijk, Kroon, & van der Wildt, 1980; present experiments) and were probably due to individual differences in nasotemporal asymmetry (which can occur; Rijdsdijk et al., 1980), since all except the present study used monocular viewing and only in the present study and that of Blake and Mills (1979) were more than two subjects used. Other functions ascribed to the primary visual cortex for which hemisphere differences have not been found include the strength and time course of simple adaptation (present experiments) and the apparent contrast of suprathreshold stimuli (present experiments; Georgeson & Turner²).

How, then, can previous reports of left-right asymmetry in the effects of adaptation be explained? Beaton and Blakemore (1981) found asymmetry in only one subject; they assumed that the adaptation process was at a saturation level in their experiments (cf. Rose & Evans, *in press*) and may, instead, have demonstrated a nasotemporal difference, since they used monocular viewing. (The present experiments used binocular viewing in order to balance out any nasotemporal differences.)

The results of Tei and Owen (1980) have several possible explanations. First, factors other than adaptation to contrast could have caused the asymmetry in their experiments, such as adaptation to luminance or the formation of retinal afterimages (because their subjects fixated during adaptation; Corwin, Volpe, & Tyler, 1976). However, these may be considered unlikely to be lateralized. Tei and Owen's experiments were also such as to induce metacontrast masking, which can differ between the hemispheres (at least for verbal material; Cohen, 1976; McKeever & Suberi, 1974; Turvey, 1973) and changes in visible persistence (Di Lollo, 1981; Meyer, Lawson, & Cohen, 1975; Meyer & Maguire, 1981). However, neither of these effects would be large enough to account for the changes in reaction time of hundreds of milliseconds which Tei and Owen reported.

Second, Tei and Owen did not specify certain other important factors, including the relative spatial phase of the test and adapt stimuli (which might on some trials have been such as to induce phi-type apparent motion) and the variation of threshold and apparent orientation with differences in the orientations of the two stimuli (Gilinsky & Cohen, 1972; Gilinsky & Mayo, 1971; O'Toole, 1979; Tolhurst & Thompson, 1975; Wallace, 1975).

Finally, there are explanations based on higher level functions. These fall into two classes which postulate hemisphere differences either in selective attention or in specialized information processing (reviewed by Schwartz & Kirsner, 1982). The former are supported by experiments in which a cuing or priming stimulus facilitates the perception of a subsequently presented *similar* stimulus (e.g., Cohen, 1975; Schwartz & Kirsner, 1982), perhaps associated with an increase in expectancy (Jonides, 1979) or a decrease in uncertainty (Ball & Sekuler, 1981; Davis, Kramer, & Graham, 1983). However, Tei and Owen (1980) found that long preexposure to a grating instead caused a deterioration in the perception of test gratings whether they were the same as or different from the adapting grating (in the left visual field; performance in the right visual field was constant). Specialized information-processing models, especially those in which the direct access of sensory input to one hemisphere determines functional lateralization (Moscovitch, 1979), also do not easily accommodate the fact that Tei and Owen found visuospatial information to be handled less adequately by the right hemisphere than by the left.

Some models posit that there is a limited capacity for handling information, or for attending, which differs between the hemispheres. If this capacity is occupied by concurrent tasks, then the subject's performance on the test task can be affected (Hellige, Cox, & Litvac, 1979; Moscovitch, 1979). It thus becomes important to consider what else the subject is doing during the experiment which might occupy his right hemisphere's capacity. For instance, Tei and Owen (1980) did not state which hand their subjects used to press the response lever (cf. Jonides, 1979); in the present Experiments 1 and 3, the subjects used both hands, and in Experiment 2, they gave verbal responses. The difficulty of the task itself can affect lateralization (Jonides, 1979). Tei and Owen's task was more demanding than those in the present experiments (note as evidence the very long reaction times in their experiment—more than 1 sec). Their subjects had to detect activity in two different orientation channels, and there is evidence that this is not a straightforward task but one which requires lengthy computation by the visual system (Mayhew & Frisby, 1978). *It could well be that this heavy processing load occupied the right hemisphere, and this would then explain Tei and Owen's results.* This might also explain other findings (reviewed by Greenwood et al., 1980), which suggest that it is only in tasks which require the comparison of stimuli that hemisphere differences emerge, not in simple detection tasks.

The conclusion is, therefore, that Tei and Owen's (1980) experimental task was too complicated to provide an unequivocal demonstration of hemisphere differences in basic sensory processes. It is possible that several of the above-discussed mechanisms were operative (perhaps cancelling each other out in the

right visual field, for example), or more likely that the observed asymmetry in performance was induced by the cognitive demands of the task. The present experiments were somewhat simpler and did not find any hemisphere differences in adaptation to contrast. Further investigations of claims for the lateralization of this and other aftereffects (Beaton, 1979; Meyer, 1976) must distinguish between low- and high-level perceptual processes and the nonperceptual aspects of the task.

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NOTES

1. Klein and Stromeyer (1980) plotted d' as a power function of contrast. The present data are in slight disagreement with this, in that logarithmic transformation of the d' axis in Figure 1 or linearization of the contrast axis decreases the correlation coefficients. However, when the regression lines in Figure 1 are extrapolated, the before and after adaptation lines do not meet at the adapting contrast as might intuitively be expected, but well below it. The same is true for double linear axes. Only on double logarithmic axes are the intersections close to the adaptation value of contrast along the abscissa (i.e., the lines are closest to parallel, as plotted by Klein & Stromeyer, 1980). The significance of this is beyond the scope of the present investigation to assess.

2. Three factors may be important here: the number of channels, their breadths of tuning, and their gain functions (Rose & Blakemore, 1974). Specifically, the breadth of orientation tuning does not vary between the hemispheres (Beaton & Blakemore, 1981), and although overall hemisphere differences in apparent contrast can occur (Georgeson & Turner, Note 1, Note 2), the direction of the asymmetry varies between individual observers without systematic bias to one side.

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