expected if retention failures were due to absolute levels of some rhythmic factor. The suggestion that the Kamin effect may represent a state-dependent phenomenon is not new (*8, 16*). There is evidence that retention of conditioned suppression of operant responses is stronger when tested at the same "biological time" as training than when tested at any other time of the 24-hour cycle (*17*), a result similar to our results. Finally, we cannot completely exclude the possibility that something analogous to a stress response or some other psychophysiological reaction induced by the training procedure may itself become entrained to a rhythmic variable and interact with the retention performance.

Efforts to relate the Kamin effect to alterations (due to induced stress or biorhythms) in the activity of the pituitary-adrenal axis have largely been negative (*18*). However, scopolamine was recently reported to be effective in blocking the appearance of the Kamin effect (*19*). Since there also is evidence for a 24-hour cycle in acetylcholine levels of various parts of the rat brain (*20*), manipulation of central cholinergic activity may be a fruitful approach in understanding the fluctuations in retention found in the present study.

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References and Notes

1. L. J. Kamin, *J. Comp. Physiol. Psychol.* **50**, 457 (1957).
2. M. R. Denny and J. O. Thomas, *Science* **132**, 620 (1960); L. J. Kamin, *J. Comp. Physiol. Psychol.* **56**, 713 (1963); D. J. Zerbolio, *Psychonom. Sci.* **15**, 57 (1969); F. Robustelli, A. Geller, M. E. Jarvik, *ibid.* **20**, 129 (1970).
3. J. P. J. Pinel and R. M. Cooper, *Psychonom. Sci.* **4**, 17 (1966).
4. M. R. Denny and M. E. Ditchman, *J. Comp. Physiol. Psychol.* **55**, 1069 (1962); R. Kumar, *ibid.* **70**, 258 (1970).
5. W. C. Halstead and W. B. Rucker, in *Molecular Approaches to Learning and Memory*, W. L. Byrne, Ed. (Academic Press, New York, 1970), pp. 1–14; J. L. McGaugh, *Science* **153**, 1351 (1966).
6. J. Bintz, W. G. Braud, J. S. Brown, *Learn. Motiv.* **1**, 170 (1970).
7. R. J. Barrett, J. J. Leith, O. S. Ray, *J. Comp. Physiol. Psychol.* **77**, 234 (1971)
8. F. R. Brush, J. S. Myer, M. E. Palmer, *ibid.* **56**, 539 (1963); N. E. Spear, S. B. Klein, E. Riley, *ibid.* **74**, 416 (1971).
9. S. B. Klein and N. E. Spear, *ibid.* **71**, 165 (1970).
10. F. A. Holloway, *Psychopharmacologia* **25**, 238 (1972).
11. Care was taken to minimize differences attributed to handling and placement in the apparatus. All animals were transported to and from the experimental room and apparatus in their home cages. Placement in the apparatus was accomplished in as stereotyped fashion as possible. Experimental animals (shock during training) and control animals (no shock during training) were tested concomitantly.
12. Mann-Whitney U-test comparisons on the STL measure and median chi-square analyses of number of subjects meeting the 300.0-second STL criterion during testing involved the following comparison groups: 15 minutes and 6 hours; 12 and 18 hours; 24 and 30 hours; 36 and 42 hours; 48 and 54 hours; and 60 and 66 hours.
13. Six-hour intervals were chosen because of pilot work in which the maximum retention deficit between TTI's of 2 and 8 hours was at 6 hours and that between 24 and 32 hours was at 30 hours. In this study every 2-hour interval was sampled.
14. J. W. Mason, *Psychosom. Med.* **30**, 774 (1968); *ibid.*, p. 791.
15. In a later study (F. A. Holloway and R. A. Wansley, *Behav. Biol.* in press), we found that systematically altering the time of training for either a passive-avoidance task (the same as in the present study) or a one-way active avoidance task did not eliminate the retention impairment in the 6- or 18-hour TTI groups.
16. J. Bintz, *Learn. Motiv.* **1**, 382 (1970).
17. C. F. Stroebel, in *Comparative Psychopathology*, J. Zubin and H. F. Hunt, Eds. (Grune & Stratton, New York, 1967), pp. 158–172.
18. H. A. Marquis and M. D. Suboski, *Proceedings of the 77th Annual Convention of the American Psychological Association* (1969), pp. 207–208, P. Kasper-Pandi, R. Hansing, D. R. Usher, *Physiol. Behav.* **5**, 361 (1970); N. Snider, H. A. Marquis, M. Block, M. D. Suboski, *Psychonom. Sci.* **22**, 309 (1971); R. J. Barrett, N. J. Leith, O. S. Ray, *Physiol. Behav.* **7**, 663 (1971).
19. R. W. Thompson and C. Nielsen, *Psychonom. Sci.* **28**, 140 (1972).
20. A. H. Friedman and C. A. Walker, *Arch. Toxikol.* **29**, 39 (1972).
21. Supported by NIMH grant MH 14702.

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Visual Temporal Order: A New Illusion

Abstract. *Brief visual stimuli presented in rapid sequence, one to the left and one to the right, appear to occur left first, then right, regardless of the actual order of presentation. This illusion persists under conditions of forced-choice testing and does not vary with presentation to the same or opposite retinal hemifields. A series of experiments suggests that this illusion may be the product of an internal mechanism that scans visual inputs in a left-to-right order.*

Two small targets, side by side in the visual field, are flashed in rapid succession. Observers tend to report that the left target flashed before the right target, regardless of the actual order in which they were presented. A series of experiments on this new illusion of visual temporal order demonstrates its persistence under a variety of conditions and suggests that it is the product of neither response bias nor hemispheric and hemiretinal asymmetries. Moreover, the results are consistent with an explanation based upon an internal mechanism that scans visual inputs in a left-to-right order.

The illusion was discovered during informal test sessions in which subjects sat, with nonpreferred eye occluded, 57 cm from a cathode-ray tube display. On each trial the following sequence of events occurred. (i) A horizontal matrix of dots (visual angle, 10° by 48′) appeared in the center of the screen. A vertical strip 36′ wide was left blank in the center of the matrix to provide a convenient fixation region. The matrix remained on for 1 second. (ii) At 100 msec after the offset of the matrix, two different letters appeared sequentially, with no delay between the offset of the first and the onset of the second, one 1° to the left of fixation and the other a like distance to the right. Each letter lasted 10 msec, had a visual angle of 48′ by 21′, and was chosen randomly from a set of 12 easily discriminable letters. (iii) At 100 msec after the termination of the second letter, the matrix of dots was again presented, for 1 second. On any trial a computer chose randomly which letter, the left or the right, would occur first, thus creating two different temporal sequences, left-right and right-left (*1*). The subject indicated on a teletypewriter his judgment of which letter was first and which was second. Subjects correctly identified about 60 percent of the left-right sequences but only 30 percent of the right-left sequences. In both cases they tended, when making an error, to reverse the sequence of presentation rather than to misidentify the letters (*2*).

Several plausible explanations for this illusion have been suggested, and we undertook an experimental program to choose among them (*3*). One hypothesis assumes that for an observer to identify the order of two stimuli, the neural representations of those stimuli must arrive at a single center in the nervous system (*4*). If this center were located in the right hemisphere, the arrival of stimuli appearing to the right of fixation would be delayed, because these stimuli project to the left hemisphere and their representations could reach the right hemisphere only after crossing the corpus callosum. Stimuli appearing to the left of fixation would not be handicapped in this manner, because they project more directly to the right hemisphere. We tested this hypothesis by introducing conditions in which we would expect both stimuli to project to the same hemisphere, without the necessity of crossing the corpus callosum to reach the supposed simultaneity center. Conditions were as just described, except that in a third of the trials the letters both appeared to the right of fixation, in a third they were centered about fixation, and in a third both were to the left of fixation. In the first and last of these conditions both stimuli project to the same visual hemisphere, while in the center condition the stimuli project to opposite hemispheres. The brief exposures foreclosed the possibility that the subject could shift his gaze from one target to the other while they were on the screen (*5*). When the stimuli were flashed eccentrically in either hemifield, the centers of the letters were approximately 1° and 3° from fixation. Twelve volunteers were studied, each receiving 30 trials per combination of stimulus position (left, center, or right) and order (left-right or right-left). The mean percentage of correct order identifications for the left-right sequence trials was 69, whereas the mean percentage for the right-left trials was 33. This difference between the two orders was virtually unaffected by the hemifield of presentation. An analysis of variance showed a significant effect of order ($P < .01$). Neither the main effect of hemifield nor its interaction with order approached significance (both $P > .25$).

The visual order illusion thus persists under conditions incompatible with the hypothesis that attributed the illusion to transcallosal delay. Since there are reports that certain hemifield differences are dependent upon the use of alphabetic materials (*6*), we wondered whether our results generalized to nonalphabetic stimuli. Therefore, a cross of Lorraine, a vertical line with two shorter horizontal crossbars, was substituted for the alphabetic characters used in our previous experiments. This target had the same dimensions as the letters. In addition, subjects now responded with a switch throw to the right if they thought the stimulus order was left-right, and to the left if the order seemed right-left. This response mode also served to eliminate differential order of report (*7*) as a possible cause of our results.

To permit an internally consistent comparison between the order illusion with alphabetic and nonalphabetic stimuli, we collected new data using both kinds of stimuli. Subjects were tested in four blocks of 60 trials each. In any block, all stimuli were either crosses of Lorraine (C) or alphabetic characters (A). Half of the subjects were tested in the order C-A-A-C, and half were tested in the order A-C-C-A. The visual order illusion was about the same magnitude as in the first experiment, with mean percentages correct of 62 and 39 for all left-right sequences and all right-left sequences, respectively ($P < .05$). The difference between cross and alphabetic stimuli was not statistically significant ($P > .50$). Moreover, none of the interactions with type of stimulus approached statistical significance. In addition, varying the hemifield of stimulation (left, center, or right presentation for the pair) again proved ineffective ($P > .50$). This experiment ruled out alphabetic stimulus properties as critical for the visual order illusion.

Although the illusion does not seem to be the result of hemifield or hemispheric asymmetries, it is possible that, regardless of their perceptions, subjects are biased to respond that left precedes right; such a response bias, whatever its source, could have accounted for the significant effect of order in all our experiments. In accord with developments in the theory and methodology of signal detectability (*8*), we eliminated response bias by determining whether the illusion persisted under conditions of forced-choice testing. In our final experiment, a two-interval temporal forced-choice was used. Each trial was divided into two distinct halves: in one half, two stimuli were sequentially presented (either left-right or right-left); and in the other, the two stimuli were presented simultaneously. Instead of having to judge whether the stimuli were left-right or right-left, the subject had to judge whether the first or second pair on that trial was the simultaneous pair. All stimuli were letter O's. For a simultaneous pair, the computer repeatedly plotted one letter and then the other. Both letters appeared simultaneous and continuously present for 20 msec, with no visible flicker. In successive presentations, each stimulus was flashed for 10 msec, as in the earlier experiments. Unlike those experiments, a delay was introduced between the two stimuli. With equal frequency, this interstimulus delay was 2, 4, 8, 16, or 32 msec. For each of the five delay values, half the stimulus sequences were left-right and half were right-left. In 80 percent of the trials, a simultaneous pair was presented in half of the trials and a successive pair appeared in the remaining half. The simultaneous pair was presented first in half of these trials (chosen randomly) and second in the remaining trials. In addition, in 20 percent of the trials both stimulus pairs were simultaneous. All stimuli were presented at the same loci, centered about the fixation region, the width now reduced to a visual angle of 6′. A tone sounded when the subject was wrong, giving knowledge of results to ensure that the subject could maximize performance. On trials where both pairs were simultaneous, the tone sounded with a priori probability of .5.

Four subjects were tested in four sessions of 250 trials each. Figure 1 shows the mean percentage of correct identification of the simultaneous pair as a function of the interstimulus interval between the nonsimultaneous pair. For comparable interstimulus intervals, a left-right pair is more easily discriminated from a simultaneous pair than is a right-left pair. An analysis of variance supports this interpretation by showing the main effects of order and interstimulus interval to be as significant sources of variance (both $P < .01$). The interaction between these variables was nonsignificant ($P > .25$). There was no systematic effect of practice, a result implying that our phenomenon is stable at least over as many trials as we ran.

The absence of an interaction between order and interstimulus interval

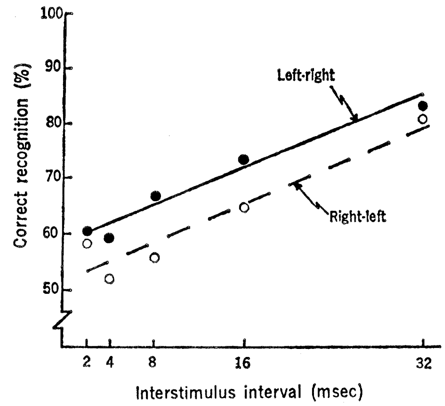

Fig. 1. Percentage of correct recognition of the simultaneous stimulus pair in the two-alternative forced-choice experiment, as a function of the interstimulus interval between the companion successive pair. The sequence of stimuli in successive pair is left first, then right (left-right); or right first, then left (right-left). Shown also are lines of best fit determined under the constraint that both lines have identical slope, with variation in Y intercept permitted.

encouraged us to approximate the two sets of data, for left-right and right-left, with curves of the same slope but different intercept. Such curves, determined by least squares procedures, are shown in Fig. 1.

That left-right pairs were more easily discriminated from simultaneous pairs than were right-left pairs is another manifestation of the visual order illusion found in the experiments in which forced-choice was not used. With interstimulus interval held constant, a left-right sequence seems more clearly sequential (that is, nonsimultaneous) than does a right-left sequence. The horizontal distance between the curves in Fig. 1 provides an estimate of the time differential between left-right and right-left pairs. To equalize the apparent sequential character of left-right and right-left pairs, the interstimulus interval for the right-left pair would have to be about 10 msec greater than that for the left-right pair.

A possible explanation for the illusion may be found in Lashley's suggestion that the brain imposes a temporal order on simultaneous visual information (*9*): "Even with tachistoscopic exposures, the after-discharge permits a temporal survey, and with visual fixation, shifts of attention provide an effective scanning." The first part of Lashley's proposal, the idea of a brief poststimulus iconic or visual image, has gained common acceptance (*10*). The existence of a scanning mechanism which reads out from this store, the second part of Lashley's proposal, remains controversial. Heron (*6*) tried to account for various findings from studies of word recognition by postulating a readout mechanism that jumps from a rest position, near fixation, to the leftmost end of a stimulus array and then scans rightward. Others (*11*) have disputed the existence of such a scan.

A left-to-right scanning mechanism of the sort proposed by Heron could account for the prepotency of left-right perception of visual sequences. In scanning the temporary iconic store, information from the left portion of the field would be read out slightly before information from the right portion. Consequently, a sequence that was actually right-left, with a very short interval between the two stimuli, would appear left-right. If such a scanning mechanism jumped from its rest position to the locus of the leftmost stimulus (*6, 12*), then the lateral separation of the curves in Fig. 1, about 10 msec, could be used as a first approximation to the time required for the scan to go from rest to the leftmost stimulus position. Since we have not yet determined the locus of the rest position, we cannot yet translate this estimate of 10 msec into a measure of the speed of the proposed scan. Parametric variation of the location of targets may provide a more direct test of the scanning hypothesis, along with a quantitative description of the scan operation.

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References and Notes

. Hirsh and C. Sherrick [*J. Exp. Psychol.* **62**, 423 (1961)] reported that about 20 msec is the smallest time difference discriminable by the human visual system. However, because they used no temporal differences between 0 and 20 msec, their estimate must be regarded as a rough one at best. Others subsequently reported temporal discriminations of 1 or 2 msec for the visual system; the performance of our subjects is consistent with these later estimates [D. N. Robinson, *Science* **156**, 1263 (1967); G. von Békésy, *Proc. Nat. Acad. Sci. U.S.A.* **64**, 142 (1969)].

2. Observations were made with moderate background illumination. The illusion could not be observed when background illumination was reduced. This was because the luminance of the cathode-ray tube phosphor (P31) after presentation of the first letter did not decay to below visual threshold before the second letter was presented; the resulting temporal overlap made judgments of order difficult. For the first and third experiments the targets and mask had a luminance of approximately 21 cd/m²; the background luminance was 7 cd/m². For the second experiment the corresponding values were 2.0 and 1.0 cd/m².
3. At the outset we considered whether we were dealing with a variety of apparent motion. We rejected this possibility because the temporal characteristics of our stimuli were more than an order of magnitude different from those that produce good apparent motion [F. J. Sgro, *J. Exp. Psychol.* **66**, 281 (1963)]. Indeed, our conditions did not produce apparent motion. Moreover, we have not been able to find in the literature on apparent or real (continuous) motion the kind of directional asymmetry that one would expect if our phenomenon were actually related to motion perception.
4. This experiment also eliminates as an explanation for the illusion a possible latency difference between temporal and nasal hemiretinas. A similar explanation for the illusion might be a gradient of latency running across the entire retina, the right hemiretina responding faster than the left. This hypothesis can be ruled out by several studies that show latency increases with distance from the fovea, for both left and right hemiretinas [M. Lichtenstein and C. T. White, *J. Opt. Soc. Amer.* **51**, 1033 (1961); J. D. Rains, *Vision Res.* **3**, 239 (1963); R. Rutschmann, *Science* **152**, 1099 (19 W. H. Payne, *Vision Res.* **6**, 729 (1966); *Science* **155**, 481 (1967)].
5. M. Alpern, in *The Eye*, H. Davson, Ed. (Academic Press, New York, 1962), vol. 3, p. 90.

W. Heron, *Amer. J. Psychol.* **70**, 38 (1957).

7. W. A. Winnick and G. E. Bruder, *J. Exp. Psychol.* **78**, 528 (1968); M. J. White, *Psychol. Bull.* **72**, 387 (1969).
8. D. M. Green and J. A. Swets, *Signal Detection Theory and Psychophysics* (Wiley, New York, 1966).
9. K. S. Lashley, in *The Neuropsychology of Lashley*, F. Beach, D. O. Hebb, C. T. Morgan, H. W. Nissen, Eds. (McGraw-Hill, New York, 1960), p. 521.
10. G. Sperling, *Psychol. Monogr.* **74**, 11 (1960); U. Neisser, *Cognitive Psychology* (Appleton-Century-Crofts, New York, 1967).

M. Coltheart and B. Arthur, *Amer. J. Psychol.* **84**, 355 (1971); M. C. Smith and S. Ramunas, *J. Exp. Psychol.* **87**, 23 (1971).

12. S. C. McLaughlin, *Percept. Psychophys.* **2**, 359 (1967).
13. Supported by grant NS-10094 from the National Institute of Neurological Diseases and Stroke and grant EY-00321 from the National Eye Institute.

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Tobacco and Evoked Potential

Abstract. *Significant changes were found in two indices of the averaged visual evoked potentials in nine smokers after 12 and 36 hours of abstinence and after resumption of smoking. There was a decrease of the amplitude envelope accompanying withdrawal and an increase with resumption of smoking. These changes are consistent with the contention that tobacco increases arousal. Amplitude changes were found in a specific component of the evoked potential occurring between 100 and 125 milliseconds after the onset of the flash. The latter changes suggest the possibility that smoking selectively enhances the perception of weak stimuli.*

We have studied the neurophysiological effects of smoking withdrawal and resumption as reflected in the average visual evoked potential (AVEP). Electroencephalographic (EEG) changes commonly associated with lowered arousal have been reported during smoking withdrawal. These changes were reversed on resumption of smoking (*1*).

Numerous studies of smoking and nicotine administration (in doses comparable to those obtained from smoking) show a predominant arousal effect (*2, 3*). Improvement of learning with nicotine, possibly associated with increased vigilance, has been reported (*4*). Association of the amplitude of the AVEP with arousal and vigilance has been reported (*5*). It was predicted that the smoking-satiated state would be associated with higher amplitudes than the abstinent state, notwithstanding a report of an opposite trend (*6*) and an-