southward extension of the Lasalle Anticline and the generally east-west trending Shawneetown–Rough Creek fault zone along which left-lateral movement has been postulated (*7*).

Some sedimentation patterns are also possibly reflective of the projected zone. The deepest part of the Oquirrh Basin (*8*) occurs athwart the 40th parallel near where the east front of the Central Rockies eventually developed. Also in a general way the greatest thickness of Upper Cretaceous deposits (*9*) in the western interior occurs north of a possible east-west hinge line approximately coincident with the 40th parallel. Two of the areas of thickest Upper Cretaceous deposition are along the hinge line. The central part of the extensive, early Paleozoic North Kansas Basin as interpreted by Lee (*10*) is in southeast Nebraska only 25 miles north of the 40th parallel. Other gross patterns of sedimentation may reflect the zone.

Although the Greenleaf Anomaly, described by Lyons (*11*) as the most significant gravity maximum anomaly in North America, is traceable from the Anadarko Basin to Lake Superior, its positive character is prominently interrupted at 40°N, the 40th parallel. Southward it is much subdued. There is also a prominent inflection in its trend suggestive of possible westward shifting along the 40th parallel. Lyons also noted a curious westward extension of denser basement rocks at the Kansas-Nebraska line—the 40th parallel.

Christiansen (*12*) noted a change of trend from N30°E to N12°W (counterclockwise) in the Wasatch Line near Springville, Utah, just north of the 40th parallel. Many other major structures show a change in trend near the 40th parallel comparable to that of the Wasatch Line both in magnitude and in direction.

Because of the range in age of the features thought to have been influenced, it is believed that the zone has been intermittently effective since Precambrian time.

In general, then, it appears that a major line of weakness along which there has been left-lateral movement as well as intense subsidence occurs along the 40th parallel coincident with the projection of the Mendocino fracture zone. Also, it is suggested that continuation of this zone in combination with the uplifts that trend roughly north-south contributes to a major segmentation of the central United States. More intense subsidence has occurred near some of the intersections of the two trends.

Studies are continuing with the following as working hypotheses: (i) The Mendocino fracture continues through or below North America. (ii) Left-lateral movement (no magnitude is implied) has occurred along it. (iii) Along with north-south structures, it has contributed to the location of basins. (iv) It is probably as old as Precambrian. (v) Other fractures of the Pacific may continue similarly.

WILLIAM N. GILLILAND
Department of Geology, University of Nebraska, Lincoln 8

References

1. H. W. Menard, *Bull. Geol. Soc. Am.* **66**, 1149 (1955).
2. ———, *Sci. Am.* **205**, No. 6, 52 (1961).
3. V. C. Kelly, *Univ. New Mex. Publ. Geol. No. 5* (1955).
4. T. S. Lovering and E. N. Goddard, *U.S. Geol. Surv. Profess. Paper 223* (1950).
5. M. F. Norton, *Intern. Geol. Congr. 21st Session, pt. 18* (1960), pp. 69–80.
6. H. E. Wheeler, W. F. Scott, T. L. Thompson, *Bull. Geol. Soc. Am.* **60**, 1928, abstr. (1949).
7. S. K. Clark and J. S. Royds, *Bull. Am. Assoc. Petrol. Geologists* **32**, 1728 (1948).
8. J. W. Reid, "The structural and stratigraphic history of the Carboniferous (Mississippian and Pennsylvanian) of the Wasatch Plateau and environs," in *Guidebook*, 5th Ann. Field Conf., Intermountain Assoc. Petrol. Geol. (1954), pp. 18–24; H. J. Bissel, *Pennsylvanian and Permian Rocks of the Cordilleran Area: Pennsylvanian System in the United States, a Symposium* (Amer. Assoc. Petrol. Geol., Tulsa, Okla., 1962), pp. 188–263.
9. J. B. Reeside, *U.S. Geol. Surv., Oil and Gas Invest. Prelim. Map 10* (1944).
10. W. Lee, *U.S. Geol. Surv., Oil and Gas Invest. Prelim. Map 48* (1946).
11. P. L. Lyons, *Kansas Geol. Surv. Bull. 137* (1959), pp. 105–120.
12. F. W. Christiansen, *Program Ann. Meeting Rocky Mt. Sec., Geol. Soc. Am.* (1962), p. 18, abstr.

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Harmonic Analysis of Visual Stimuli below Fusion Frequency

Abstract. Data which represent the relation between modulation amplitude and frequency of a sinusoidally modulated light stimulus for constant flicker appearance have been employed to predict characteristics of rectangular waveforms which will be of the same flicker appearance. Predictions are compared with the results of an experiment in which such rectangular waveforms were employed.

The eye is quite sensitive to variations in rate of intermittent photic stimulation at frequencies below fusion (*1*). Such sensitivity provides a basis for extending the application of techniques of harmonic analysis to the response of the visual system below fusion. At fusion, response is limited by low-pass filtering action. Unless they are of very high amplitude, contributions of higher-order frequency components appear to be eliminated before perception occurs (*2*). With a criterion of equivalent flicker appearance such that frequency is appreciably below fusion, more of the higher-order frequency components of a complex waveform may contribute to the perceptual process.

Veringa (*3*) studied the relation between frequency and modulation amplitude of a visual stimulus for constant flicker appearance at a fixed average retinal illuminance of 1000 trolands. For each of six standard modulation-amplitude and frequency combinations, modulation amplitude of the comparison stimulus was adjusted for a series of frequencies in order to match the "depth of modulation" of the standard.

Veringa's results provide "frequency response characteristics" of the visual system at one retinal illumination for each of six levels of "output" other than fusion. It is of interest to consider whether they can be employed to predict conditions for invariance of appearance with other than sinusoidal modulation. The type of experiment of particular interest in relation to Veringa's experiment is one which illustrates variations which can be made in the characteristics of a complex waveform of constant average luminance without change in flicker appearance.

Such an experiment was performed by Forsyth and Brown (*4*). Observers viewed a test patch which was alternately illuminated by a standard train of square pulses separated by intervals of darkness of equal duration and a comparison train which consisted of alternating square pulses of duration $A/2$ and $B/2$, each followed by a dark interval of equal duration. The relation of A and B such that the appearance of the comparison train matched that of the standard train was determined for each of three standard frequencies.

As Levinson (*5*) has pointed out, with the temporal pattern of stimulation employed by Forsyth and Brown, the amplitude of the fundamental Fourier component may be relatively low as compared to the amplitude of the second component. Although the range in which this is true is very small when fusion is the criterion of visual effect, there may be a broad range of combinations of A and B for which the effectiveness of the second component is close to, or higher than, that of the fundamental with criteria of equivalent flicker appearance. This follows from an application of Veringa's results in an analysis, based on one made by Levinson (*5*), of the stimulus pattern employed by Forsyth and Brown.

The data of Veringa may be described by an equation of the following form:

$$m = m_o + kf^q \quad (1)$$

where m represents modulation amplitude in percentage of the average luminance level; m_o represents a minimum modulation percentage which is characteristic of the criterion and has a value of zero for a criterion of fusion (see *5*); and f is frequency. (It is probable that m_o, k, and q would also be influenced by the observer, by average luminance, and by other stimulus characteristics.) Values of m_o were estimated from Veringa's results. His curves were then replotted in terms of log $(m - m_o)$ versus log f. Values of k and q were taken from the intercept and slope constants of the resulting straight lines.

Modulation amplitude m_1 of the Fourier fundamental of the waveform employed by Forsyth and Brown (*4*) may be represented as follows:

$$m_1 = (400/\pi) \cos \pi \, [A/(A+B)] \quad (2)$$

where m_1 is modulation amplitude in percentage of average luminance and A and B represent durations of the alternating rectangular light pulses and their associated dark intervals. Modulation amplitude of the second component may be represented as follows:

$$m_2 = (400/\pi) \sin^2 \pi \, [A/(A+B)] \quad (3)$$

Equation 1 may be rewritten in the following form:

$$m_n = m_o + k \, [n/(A+B)]^q \quad (4)$$

where m_n represents the modulation amplitude of any component n of the complex stimulus of Forsyth and Brown. By combining Eqs. 2 and 4 or 3 and 4, equations are obtained in A and B which represent all combinations of these variables for which modulation amplitude of either the Fourier fundamental or the second component of the complex stimulus conforms to the conditions represented by Veringa's curves for constant apparent "depth of modulation." Relations between A and B have been calculated from such equations for both the fundamental and the second component of a stimulus of the kind employed by Forsyth and Brown for each of Veringa's criteria of flicker appearance (labeled a through f) and for fusion. The results are presented in Fig. 1, along with data of Forsyth and Brown (*4*). Both sets of curves are symmetrical about the line $A = B$.

Although the stimulus conditions of Veringa differed from those of Forsyth and Brown, some interesting qualitative similarities are apparent. For both sets of functions a broadening of the form of the relation about the line $A = B$ occurs with decrease in criterion frequency, and the relation is displaced along the line $A = B$ to higher values. Both sets of functions show that for certain values of A there will be two and sometimes three values of B which will yield the same appearance.

A striking difference in the calculated and experimental curves occurs in the region where A and B reach a maximum. The experimental curves have a smoothly rounded form. The calculated curves rise to sharp peaks, which represent intersections of the curves for the fundamental and the second component. It is in this region of the AB plane that the modulation amplitudes of the fundamental and the second component assume values such that, if seen alone, they would be equally effective in inducing a given flicker appearance. The difference between the calculated and the experimental curves indicates that perception is not dependent on either the fundamental or the second component of a complex stim-

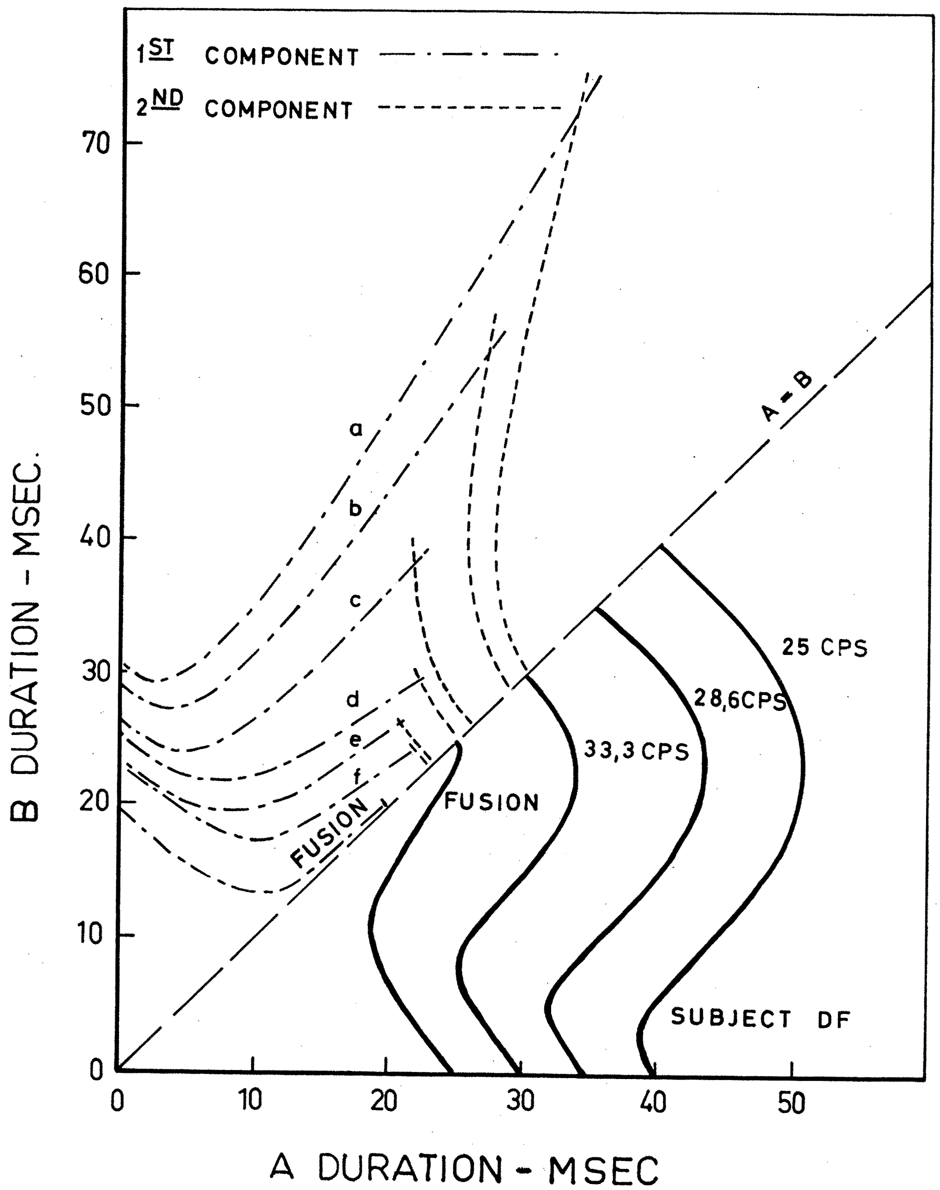

Fig. 1. The relation between periods (A and B) of alternating rectangular light flashes for constant flicker appearance. The curves at upper left were derived from data of Veringa (*3*) for fundamental and second Fourier components of the rectangular stimulus pattern. The curves at lower right represent experimental results of Forsyth and Brown (*4*).

ulus alone under such circumstances.

Levinson (*6*) has shown that this is also true for fusion when the modulation amplitudes of two sinusoidal components of a stimulus are both near threshold. He found that modulation amplitude of the combined stimulus had to be lower for fusion threshold than the modulation amplitude predicted on the basis of the individual components. The present analysis indicates that, for a given criterion of appearance, frequency must be higher than that predicted on the basis of individual components. Both of these differences—lower modulation amplitude and higher frequency—serve to reduce the appearance of flicker. It is evident that the appearance of flicker may be enhanced by the combination of sinusoidal components (*7*).

JOHN LOTT BROWN

Department of Physiology, School of Medicine, University of Pennsylvania, Philadelphia

References and Notes

1. J. W. Gebhard, J. H. Mowbray, C. L. Byham, *Quart. J. Exptl. Psychol.* **7**, 49 (1955).
2. H. de Lange, *J. Opt. Soc. Am.* **48**, 777 (1958).
3. F. Veringa, *ibid.* **48**, 500 (1958).
4. D. M. Forsyth and C. R. Brown, *ibid.* **49**, 760 (1959).
5. J. Levinson, *Science* **130**, 919 (1959).
6. ———, *ibid.* **131**, 1438 (1960).
7. This study was supported by U.S. Public Health Service award No. GM-K3-15277-C2.

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Autoimmune Response in Rabbits Injected with Rat and Rabbit Liver Ribosomes

Abstract. Autoimmune hemolytic anemia and leukopenia, circulating autoantibodies for erythrocytes, leukocytes, and ribosomes; pathological changes in liver, spleen, heart, brain, and kidneys were produced in rabbits injected with rat or rabbit liver ribosomes. The hematologic and pathologic changes were reproduced by injection of anti-ribosomal serum into normal rabbits. The autoantibody specificity was related primarily to nucleotides and nucleosides.

Autoimmune human diseases (*1*) and experimental "autoallergic" diseases in animals indicate that autoimmunization occurs under certain conditions, although the nature and role of the autoantibodies have been questioned (*2*). An apparent contradiction exists in the facts concerning acquired specific immune tolerance (*3*) by which the body distinguishes "self" from foreign antigens, and that embryonic and adult animals can be made unresponsive to some foreign antigens (*4*). The dilemma can be resolved only by the production of autoimmune disease in experimental animals accompanied by circulating antibodies to tissue antigens of mesodermal origin and by reproduction of the pathology in other animals injected with serum from the actively autoimmunized animals.

Table 1. Hematology of a rabbit injected intravenously with serum from a ribosome immunized animal.

Days after injection	Hemoglobin (g)	Hematocrit (%)	Blood cells (thousands) White	Blood cells (thousands) Red	Reticulocytes (%)
0	12.9	38	6.00	5730	0.5
1	12.0	36	7.10	5060	0.8
2*	14.7	43	9.00	5310	2.2
3	10.8	33	7.30	2710	3.0
4*	10.6	31	7.65	4180	6.7
5	8.2	27	5.20	3280	10.2
6*	<6.3	16	3.75	2280	7.8
7	9.3	30	5.40	3700	9.5
9	10.8	36	5.75	4290	9.0
12	12.0	41	6.20	4680	6.4
15	11.6	41	6.85	5240	3.3
19	11.1	39	5.05	5340	2.9
23	9.7	38	4.90	4130	2.2

* Free hemoglobin present.

Six rabbits were injected intramuscularly with rat liver ribosomes (*5*) in Freund's adjuvant. Dosage ranged from 83 to 140 mg of protein, representing approximately 50 percent of the material injected. Three animals survived 77 to 78 days. Between 70 and 77 days these animals had developed a marked hemolytic anemia and leukopenia. Data on one animal, representative of the group, showed a decrease in hemoglobin from 13.3 to less than 6.3 g; hematocrit index from 39 to 13 percent; red blood cell count from 5,500,000 to 2,430,000; and white blood cell count from 11,850 to 3,450. The anemia and leukopenia were verified further by differential blood smear examinations and evidence of red cell destruction in histologic sections of spleens. Autoantibody was indicated as early as 2 to 3 weeks after injection by agglutination of the red cells of the animals in antirabbit globulin chicken serum. Electrophoretic analysis of the serum showed an increase in the amount of gamma globulin and a decreased amount of alpha globulin and albumin. Blood cultures were consistently negative.

The animals were sacrificed and microscopic examination of the tissues showed marked loss of cytoplasm of liver cells and focal collections of plasma cells in the connective tissue septa of the liver. Spleens usually contained a perifollicular deposit identified histochemically as glycoprotein, which was not amyloid or hyaline. Focal myocarditis and various glomerulonephritic-like changes were observed. Some aspects of the pathology of the nervous system are compatible with changes observed in isoallergic encephalitis (*6*).

Table 1 shows representative findings in one of 12 rabbits injected intravenously with 1 to 5 ml of serum from donors injected with ribosomes. Hemolytic anemia, antiglobulin-positive reo cells, and hemoglobinemia were evident in 2 days. Anemia was maximal on the 6th day and evidence of it persisted for 23 days, at which time the animals were sacrificed. Leukopenia was moderate but definite by the 6th day. Occasionally, blood from these animals failed to clot after storage for 24 hours in the refrigerator. Histological changes practically identical to those described in donor animals, or in some cases more severe, were observed in recipients.

Autoantibodies were detected in the serum of rabbits injected with rat ribosomes as: (i) anti-rabbit ribosomes demonstrable as a hemagglutinin for human erythrocytes to which ribosomes were coupled with bis-diazotized benzidine (*7*); (ii) leukoagglutinins for rabbit leukocytes by the method of Wilson *et al.* (*8*); (iii) incomplete antibody for rabbit red cells by agglutination or normal erythrocytes previously sensitized by anti ribosomal serum, in antirabbit globulin chicken serum; and (iv) autoantiglobulins were detected in one animal as hemagglutinins to rabbit serum globulin fractions gamma, alpha IV, alpha IV-1, alpha IV-4, and beta (**9**). Autoantibodies were demonstrable in gamma globulin fractions separated by continuous flow electrophoresis. Intravenous injections of these fractions into rabbits produced the same hematological and histological changes as those obtained in the recipients of anti ribosome serum.