THE VISUAL EVOKED CORTICAL RESPONSE AS A MEASURE OF STRESS IN NAVAL ENVIRONMENTS: METHODOLOGY AND ANALYSIS
(2) Rapid Flash Rates

by

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SUMMARY PAGE

PROBLEM

To evaluate the use of rapid flash rates as a technique for obtaining visual evoked responses (VER's) from the human cortex. With this method, the rate of presentation is purposely too rapid for a single evoked response to be completed before the next flash occurs.

FINDINGS

The technique results in VER's which are easy to quantify and interpret statistically. Furthermore these VER's appear to be composed of elements of the complete, evoked response and of an additional rhythmical response superimposed upon it.

APPLICATION

The method evaluated in this report plus those described in the previous paper, SMRL #669, together afford an excellent technique for assessing the VER. All were evolved in order that the VER can be used to measure man's response to typical Naval problems, such as the hyperbaric or narcotic conditions imposed on a diver.

ADMINISTRATIVE INFORMATION

The investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MR041.01.01-0130BOKL A Visual Test of Fatigue and Physiological Disturbances in Navy Divers and Submariners. The present report is No. 2 on that Work Unit. It was approved for publication on 6 October 1971 and designated as Submarine Medical Research Laboratory Report No. 681.

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ABSTRACT

This is the second of two reports whose goal is to evolve methodology for use in evaluating the visual evoked cortical response (VER). The first* presented techniques for obtaining and evaluating the complete evoked response; in this study, the method purposely results in VER's which are incomplete, by presenting the visual stimuli at rates that are too rapid to be responded to singly. Rapid flash rates are shown to produce VER's which are reliable and easy to interpret and assess statistically. Furthermore, they appear to be composed of factors in addition to elements from the complete evoked response. Together the methods evolved in the two papers provide efficient techniques for use of the VER as a tool in studying Naval problems.

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* NavSubMedRschLab 669

THE VISUAL EVOKED CORTICAL RESPONSE AS A MEASURE OF STRESS IN NAVAL ENVIRONMENTS: Methodology and Analysis, (2) Rapid Flash Rates

INTRODUCTION

The visual evoked response (VER) holds promise of becoming an objective test of the physiological status of intact human beings; we are attempting to use it as such in evaluating man's reaction to the variety of problems found in Naval submarines and diving. Numerous difficulties arise however in the attempt to use the evoked response in such a way; these center around the variability that occurs both within and among subjects. These problems were extensively discussed in a previous paper and two techniques, one statistical and one methodological, were reported and recommended for use in assessing the complete VER.[1] This paper reports on a third technique which purposely results in an incomplete VER.

By complete VER, we mean the complex waveform that follows stimulation by light and lasts for at least several hundred milliseconds after such stimulation. The waveform consists of negative and positive components of electrical activity each of which can vary in amplitude and latency. In order to obtain the complete VER, it is necessary to stimulate the eye with flash rates that are slow enough so that the response to one can be completed before the next flash occurs. Generally rates of two per second or slower are used. With more rapid flash rates it is obvious that some interaction is possible between the late response to the first stimulus and the earlier portion of the response to the second.

Investigations using rapid flash rates have shown that relatively simple sinusoidal-like VER's are obtained which show the same number of responses per unit time as the stimulus rate.[2] This results in at least two advantages over the complete VER: first, the response is easy to quantify, simply by using the peak amplitudes of the sinusoids; second, individual differences are minimized.

On the other hand, possible disadvantages accrue to this method. If, for example, the differences among individuals are smaller, it is likely that differences in waveform due to stimulus parameters are likewise minimized. Furthermore, it has been suggested[2] that the VER's to rapid stimulus rates are composites of the complete VER; that is, the "tail" of one response simply is added, perhaps linearly, to the beginning of another. If so, there is no new information to be obtained from rapid stimulus rates, but rather a confounding of the old information.

This study, therefore, is an assessment of the technique of using rapid flash rates to obtain VER's, to determine whether the method provides new or more reliable information as compared to the use of the complete VER.

APPARATUS AND PROCEDURE

VER's were recorded from bipolar electrodes placed over the occipital cortex on the midline 2 cm and 7 cm above the inion with a ground electrode on the ear. The potential was amplified by a Grass P511 pre-amplifier and summated by a Technical Measurement Corporation's Computer of Average Transients (CAT). A counter, set at 100, regulated the number of analysis sweeps of the CAT. The latter was programmed to collect samples of EEG activity with an analysis time of one second. Thus each VER consists of summated activity of 100 samples of one second duration.

The visual stimuli consisted of either a gray and white striped field or a blank field of gray, each 11 inches square. At the viewing distance of 4 ft, 3 inches, they subtended 12° on a side. The individual gray and white stripes were 30 minutes in width. The same gray was used to form the striped and blank fields; its reflectance was 20%.

The targets were illuminated by a Grass PS-2 photostimulator positioned above the subject's head. The duration of the flash was 10 μsec; the rate of flashing was 2, 4, 8, 12, or 20 times per second. The intensity scale of the photostimulator was set at "8"; this resulted in a luminance of 1.0 ft-Lambert for the gray target illuminated 8 times per second, as measured with a Luckiesh-Taylor brightness photometer.

Subjects were seated in a shielded room and instructed simply to look at the target, near its center.

In the first experiment, VER's were recorded for both the striped and blank fields at each flash rate, in a single session, in a random order. In the second experiment, only two flash rates were employed, 2 and 8 times per second, and these were alternated.

Subjects were six enlisted men in the U. S. Navy in the first experiment and three staff members in the second.

EXPERIMENT I - VER's to Rapid Flash Rates*

Results

Figures 1 and 2 show the VER's for two subjects as a function of the rate of flashing of the photostimulator; a full second of recording is presented for each rate. The slowest flash rate, 2 cps, results in two VER's each of which is essentially complete. As the flash rate is increased, the latter portions of the waveform appear to be lost and the pattern becomes less complex until at the highest rates, a fairly simple following response is obtained.

These simpler waveforms can be analyzed by obtaining means and standard deviations of the amplitude of the responses. Also, since the size of the standard deviation will reflect the absolute amplitude, a Z score ($Z=\frac{\overline{X}-0}{\sigma}$) is also reported. This measure gives the variability of the n responses (to a flash rate of n/sec) that is independent of the absolute amplitude.

The amplitudes, sigmas and Z scores of the VER's to the higher flash rates

The data for this experiment were collected as part of a thesis by Abraham Mensch in partial fulfillment of requirements for a Master's Degree in Psychology from Connecticut College, New London, Connecticut.

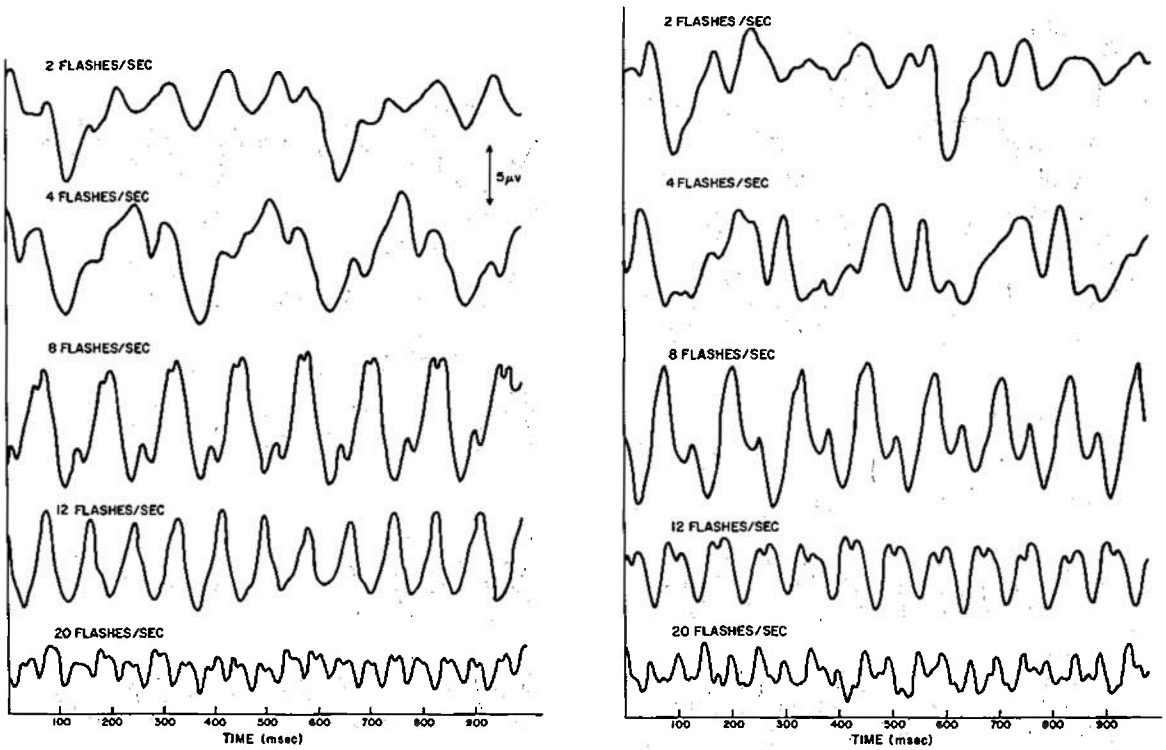

Fig. 1. VER's for subject GW with the target illuminated by light at different flash rates. Striped target on the left; blank field on the right.

have been measured in this manner for each subject and the average results are given in Table I. Here the effect of flash rate and of stimulus condition, striped vs. blank field, can be compared both in terms of size and variability of response. Note that there is a highly significant decrease in the amplitude of the response as flash rate is increased. This is accompanied, for all subjects, by an increase in variability (lower Z score) at 20 flashes per second and, for some subjects, at 12 flashes per second. This increased variability is an early indication of the fact that most subjects cannot respond separately to flashes much more rapid than 20/sec and their VER's at these rates would deteriorate into noise. The differences in amplitude between a striped and a blank field are not significant.

One caution need be noted, however, in interpreting the amplitude of VER's to higher flash rates: that is, the extent to which these VER's represent composites of the basic response, the less meaningful are amplitude differences. Thus a VER of small amplitude might be simply the result of adding a "tail" with a large negative component to the primary response with a large positive component. The question of the fundamental basis of the VER's to

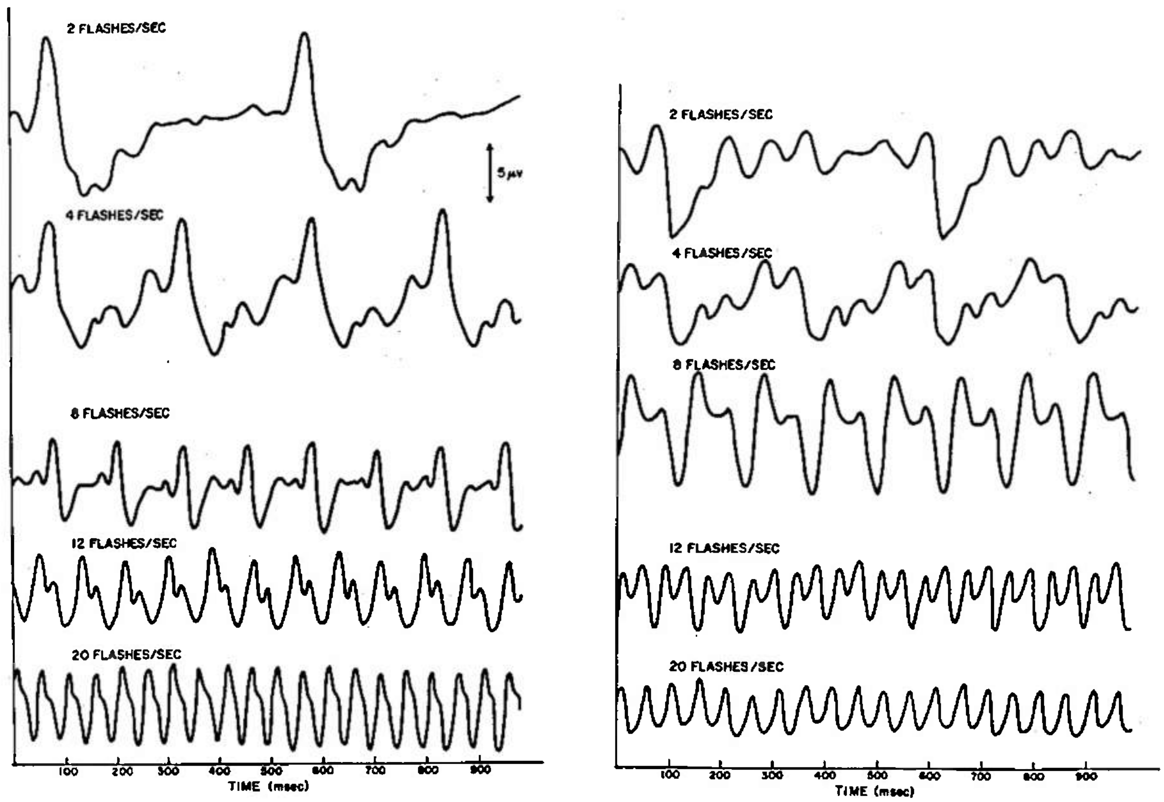

Fig. 2. VER's for subject JR with the target illuminated by light at different flash rates; striped target on the left; blank field on the right.

rapid flashes thus becomes of primary importance in their interpretation. One cannot even logically ask whether striped or blank fields yield larger responses without first answering this fundamental inquiry.

Synthesis of VER's

In order to test whether or not VER's to the more rapid rates could be considered a simple summation of the complete responses to the slow rate, the following analysis was performed. The data given in Fig. 1-a for GW with a striped field, are used as an illustration throughout, but similar analyses were performed for other subjects with the same results. First, the VER obtained with the slowest flash rate, 2 cps, was selected as representative of the complete evoked response and was divided into sections on the basis of the time at which the second flash would occur at the higher flash rate. In order to predict the VER to a 4 cps stimulus, for example, the amplitude of component B (or "tail") shown in Fig. 3, is simply added to that of component A, since the second flash occurs at 250 msec. Similarly, for prediction of an 8 cps VER, the amplitude of the waveform

Table I. Mean amplitudes, standard deviations, and Z scores for VER's to different flash rates (in μvolts)

S		Striped Field					Blank Field				
		Flash rate (n/sec)					Flash rate (n/sec)				
		2	4	8	12	20	2	4	8	12	20
SL	$\overline{X}$	6.02	10.10	6.05	4.52	3.01	6.79	10.05	8.85	6.09	3.01
	σ		.72	.60	.74	.49		.81	.79	1.16	.81
	Z		14.03	10.08	6.11	6.14		12.41	11.20	5.25	3.72
SF	$\overline{X}$	4.42	4.07	4.05	3.19	2.15	4.59	6.11	3.26	3.52	3.08
	σ		.32	.39	.39	.37		.48	.39	1.16	.32
	Z		12.72	10.38	8.18	5.81		12.73	8.36	3.03	9.62
GW	$\overline{X}$	8.80	7.16	8.85	8.06	2.62	8.59	6.09	10.28	4.72	2.68
	σ		.53	.70	.79	.83		.55	.90	.86	.63
	Z		13.51	12.64	10.20	3.16		11.07	11.42	5.49	4.25
CW	$\overline{X}$	3.56	6.32	3.17	2.57	1.97	2.73	6.81	5.24	3.01	1.11
	σ		.25	.69	1.06	.53		.58	.42	1.04	.44
	Z		25.28	4.59	2.42	3.72		11.74	12.48	2.89	2.52
JR	$\overline{X}$	12.81	11.28	5.56	4.91	5.93	7.11	4.75	6.97	6.00	3.52
	σ		.37	.35	.40	.46		.26	.35	.37	.30
	Z		30.49	15.89	12.28	12.89		18.27	19.91	16.22	11.73
GP	$\overline{X}$	6.30	6.16	5.35	4.22	3.38	5.95	6.00	5.05	4.44	2.16
	σ		.23	.25	.26	.48		.23	.25	.21	.35
	Z		26.78	21.40	16.23	7.04		26.09	20.20	21.14	6.17
	$\overline{X}$	6.98	7.52	5.50	4.58	3.18	5.96	6.64	6.61	4.63	2.59

between 0 and 125 msec are added to those between 125 and 250 msec. For the 20 cps rate, only the first 100 msec of the VER in Fig. 2 are used, component A consisting of 0 to 50 msec and component B of 50 to 100 msec.

The results of this analysis are shown in Fig. 4 in which the synthetic and the empirical waveforms are compared; the agreement is generally good. Not only is the shape well predicted but the amplitudes agree also. The addition

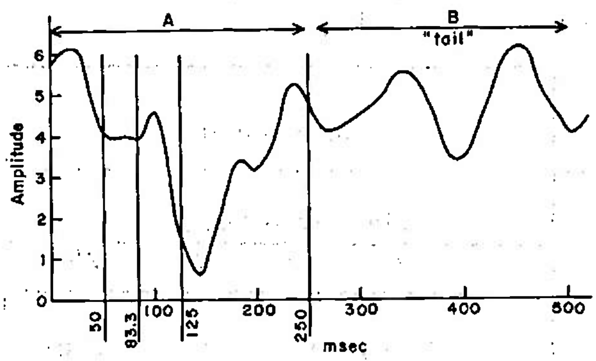

Fig. 3. The complete VER of subject GW, divided into components, for addition to predict responses to high flash rates.

of a third component, in a way completely analagous to the summing of two, was attempted with no improvement of the fit between empirical and synthetic curves.

Another typical example of the composite nature of the VER is shown in Figs 5 and 6 for a different subject. Four complete VER's (Fig. 5) determined on different dates show similar patterns but large differences in the amplitude of the components. Figure 6 compares the real VER's (6-a) for a flash rate of eight times per second with the synthetic curves generated from two segments of the appropriate complete VER (6-b). The overall amplitude of the real VER's is well predicted by the synthetic; the shape of the waveforms agree exceptionally well on two days but poorly on the other two. Figure 6-c shows that the addition of the third component, from 250 to 375 msec for 8 flashes/sec, does not improve the predicted curves. Similar analyses have been performed on many sets of data with the same results; that is, the agreement between real and synthetic is generally very good, but failures in prediction also occur regularly.

The results of the analyses thus far support the general thesis that VER's to high flash rates are composites of the various portions of the complete

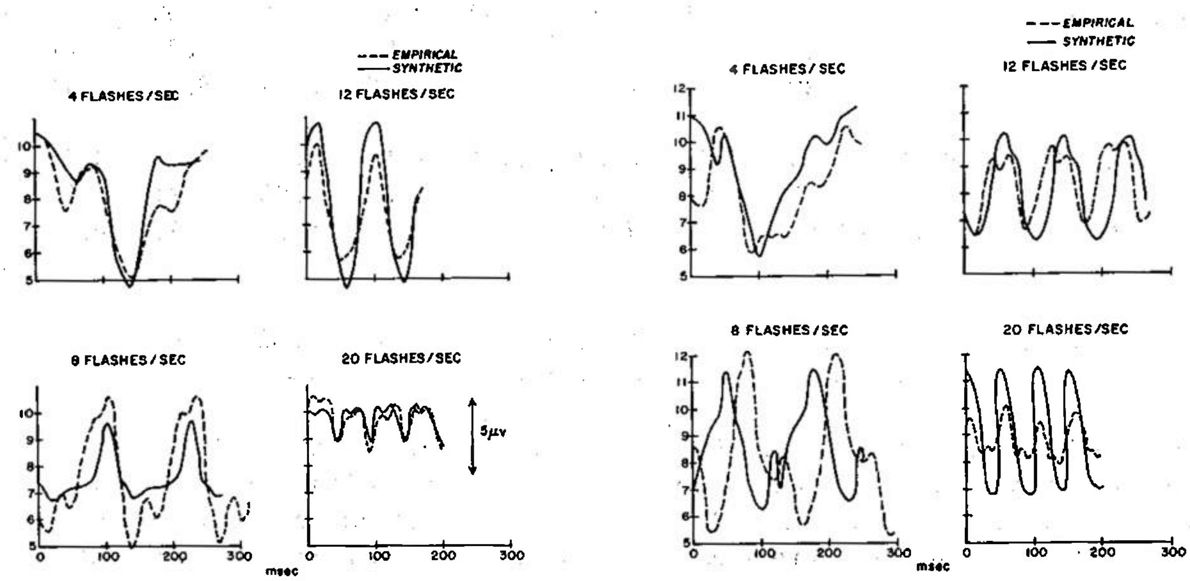

Fig. 4. Comparison of empirical and synthetic waveforms for subject GW. The latter have been formed by adding together the amplitude of VER to a second flash to the "tail" of the response to the first flash. Striped field on the left, blank field on the right.

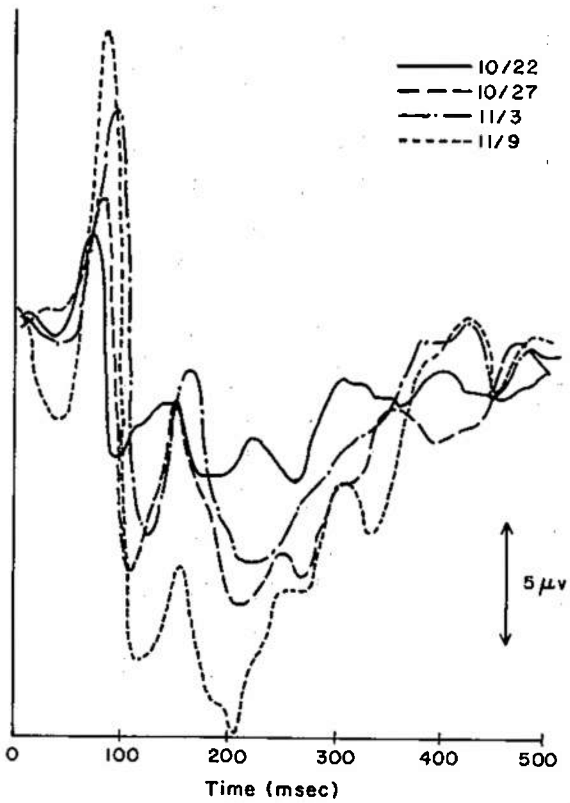

Fig. 5. Four complete VER's for subject SD, recorded on different days with a flash rate of 2 per second.

VER. The agreement between synthetic and empirical responses is too good to be a matter of chance. In fact, a model consisting of the linear addition of the first two components is more successful than one including the addition of a third component.

On the other hand, there are notable failures in each set of predictions; note for example, GW's response to the blank field at 8 and 20 flashes per second (Fig. 4-b) and the data from 11/3 on Subject D (Fig. 6). It is always possible that these discrepancies are due to changes in the complete VER over time since there is necessarily a temporal interval between the recording of the complete VER and its supposed composite. In order to assess this possibility, and to determine the limitations of the linear addition model, a second experiment was performed.

EXPERIMENT II - Prediction of Differences in Waveform

Procedure

VER's for three subjects were recorded to flash rates of two and eight times per second under the same conditions as in previous experiments except that an attempt was made to minimize variations over time. The recording of the complete VER at two flashes/second was immediately followed by a recording at 8 flashes/sec; a second complete VER was then obtained and the data were judged acceptable for synthesis only if the two complete VER's were very similar.

Synthetic curves were generated from the complete VER by linear addition of two components, as previously described. In addition, the real and synthetic curves for 8 flashes per second were superimposed on the same scale and one subtracted from the other. If the two curves were identical, this difference or remainder would, of course, be zero.

Results

Figure 7 shows ten different determinations of a VER to a flash 8 times/second for the same subject; at the top are five responses at a Photostimulator intensity of 4; at the bottom, five at an intensity of 16. The waveforms are all

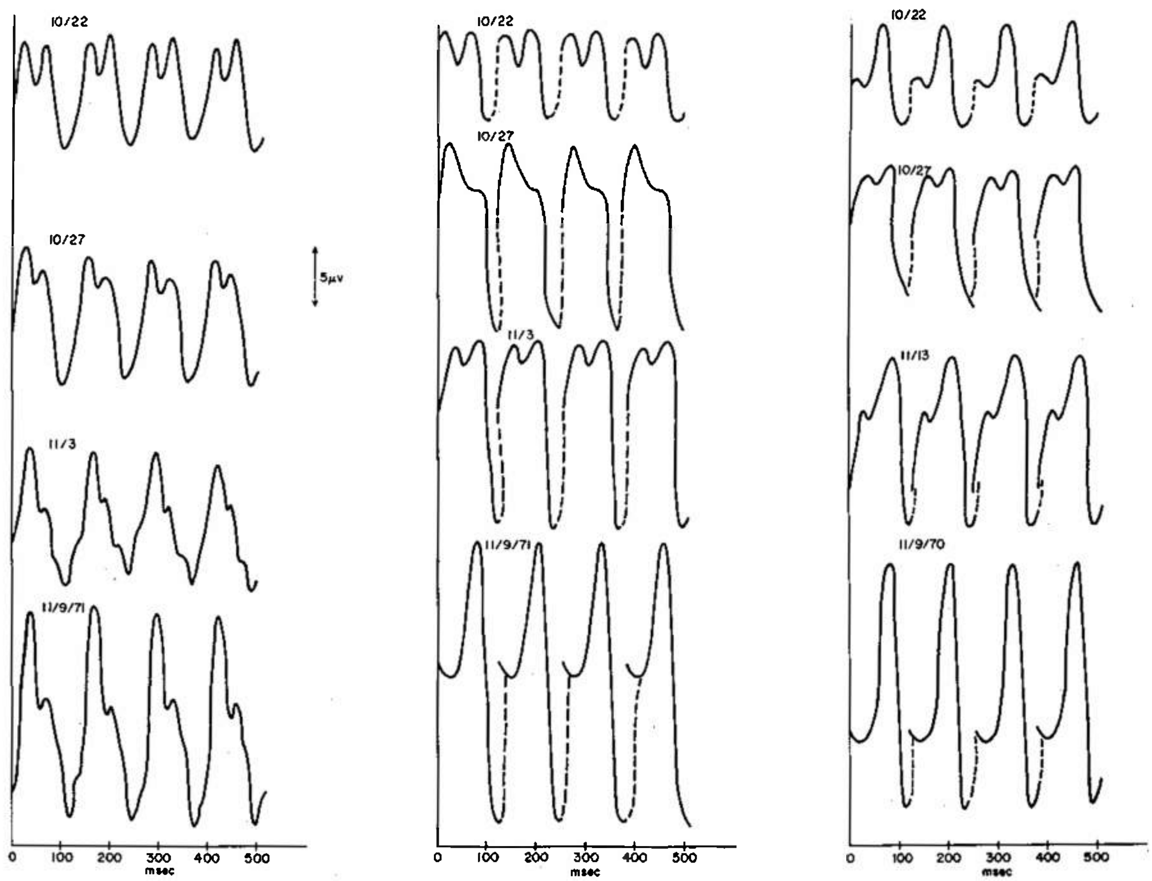

Fig. 6. Comparison of VER's for 8 flashes per second, for subject SD, with the empirical curves at the left, synthetic curves from two components in the middle, and from three components at the right.

similar but those at the higher intensity are somewhat more variable. The complete VER's, determined at contiguous times, are given in Fig. 8. Once again the responses to the more intense light are more variable and the second peak around 160 msec tends to be larger than in response to the dimmer light.

The synthetic curves, constructed from the appropriate complete VER's, are shown in Fig. 9. At the low intensity, the response is similar in shape and latency of components to the empirical curves. The prominent peak at 80 msec represents the same component in the complete VER; the first peak at about 15-20 msec represents the peak at 140-150 msec (140-125 = 15 msec). The predicted size of this first peak, determined from the complete VER, is much more variable than occurs in the actual records.

At the high intensity the predicted curves are likewise much more variable than are the empirical data. In addition, there is no longer good agreement between the shape and latency of components; for example, negative

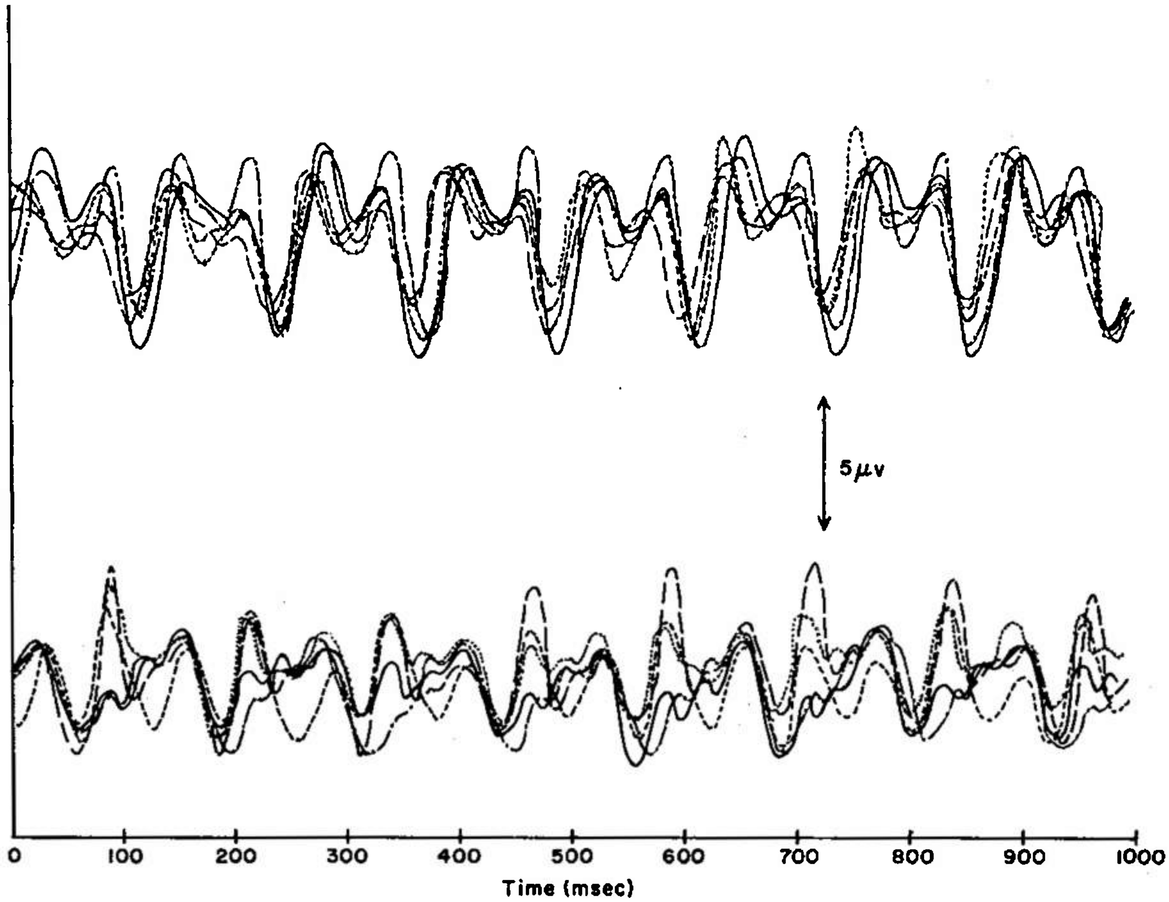

Fig. 7. Empirical VER's for 8 flashes per second at a low intensity, top, and one four times as intense, bottom. Subject CM.

activity is predicted in all cases at 90 msec but the real responses display a positive peak in this region.

Comparisons among five empirical VER's and synthetic curves for the other two subjects are given in Figs. 10 and 11. Once again, the real VER's are much more similar in shape to each other than are the synthetic curves.

The results of subtracting the synthetic VER's from the empirical records at 8 flashes per second are shown in Fig. 12. At the top left, the remainders for CM at the low intensity are very small, revealing again the rather good fit between real and synthetic for this condition. The other three sets of data, however, all show sizeable discrepancies; these remainders are similar in shape within a subject but the pattern is very different among subjects. Figure 12 shows only one cycle of a response; essentially the same remainders will be repeated seven more times in a second thus producing a rhythmical response pattern.

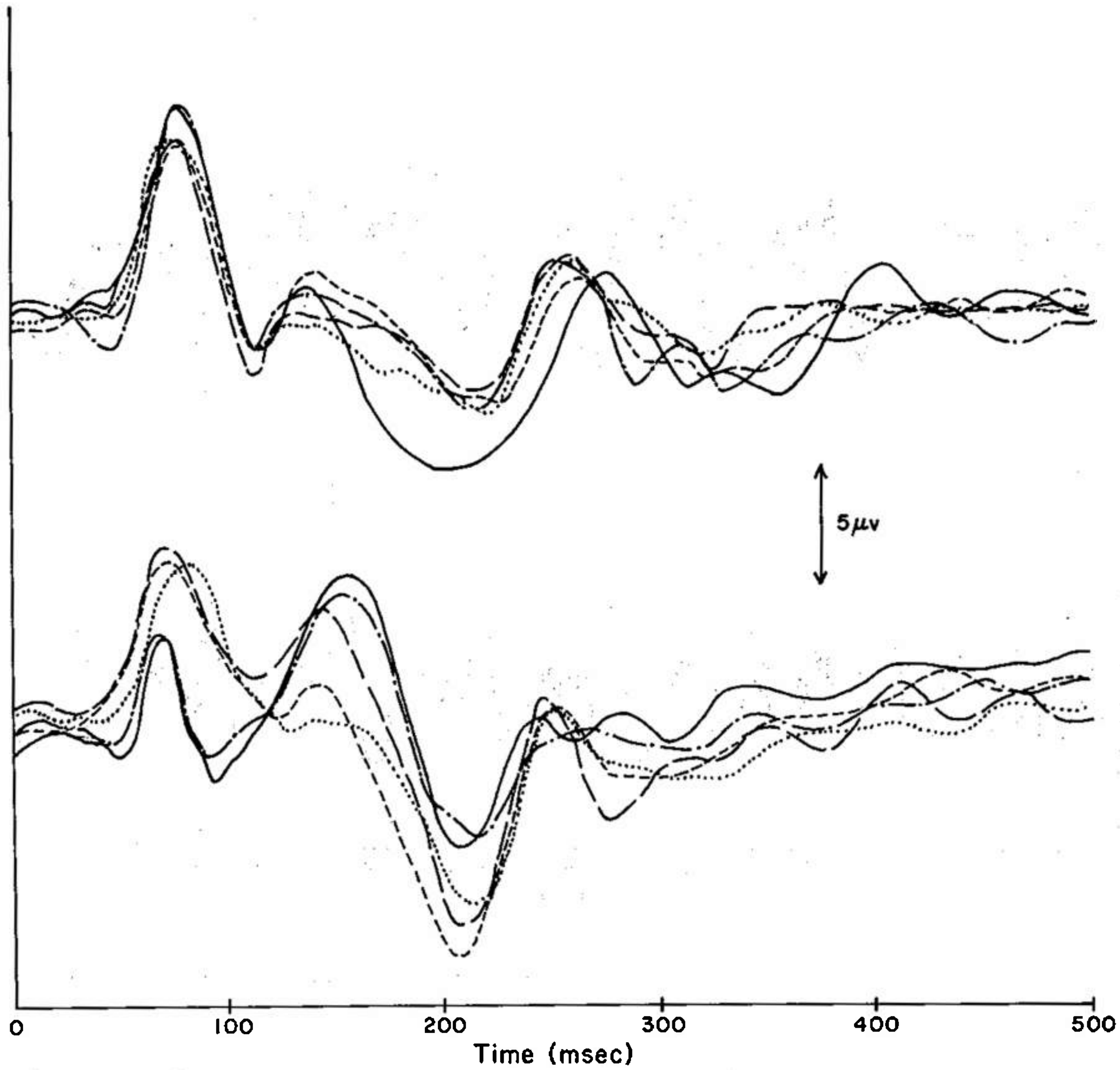

Fig. 8. Empirical VER's for 2 flashes per second at a low intensity, top, and one four times as intense, bottom. Subject CM.

Discussion

The results of this experiment do not support the supposition that discrepancies between real and synthetic responses to rapid flash rates are due to changes over time in the basic VER. When every precaution is taken to eliminate temporal variations in complete VER's, the empirical curves are more consistent or stable over time than are the predicted curves.

On the other hand, the results do suggest the presence of another factor or component in the VER's to rapid flash rates, in addition to the composite of the basic response. This factor

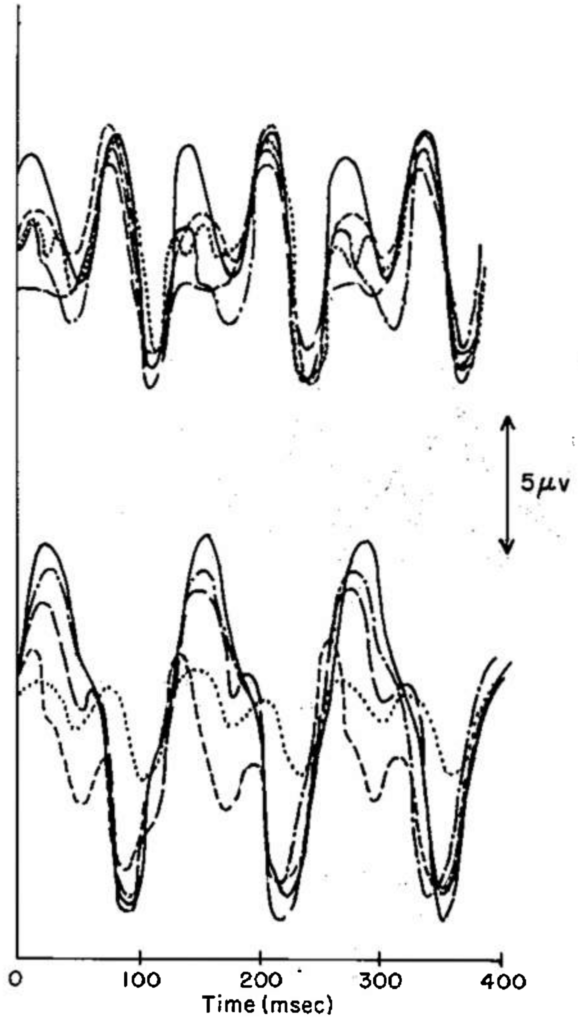

Fig. 9. Synthetic VER's for 8 flashes per second, composed from two components of the VER's given in Fig. 8.

appears to be a rhythmical response superimposed upon the composite response; its presence is quite stable for a given subject under the same condition but it may or may not appear in the same subject under different conditions. Thus the rather perplexing, but very common finding, that agreement between real and synthetic VER's is sometimes very good and sometimes poor, could be explained by the presence or absence of the additional factor.

Eason, Oden, and White[3] have made a similar suggestion to account for their data; that is, the primary evoked response acts as a trigger stimulus which temporarily synchronizes populations of neural elements. Furthermore such a multiple origin for VER's to fast rates accounts for the fact that, under certain unusual environmental conditions, the VER to rapid stimulation may deteriorate while the complete VER is unaffected.[4]

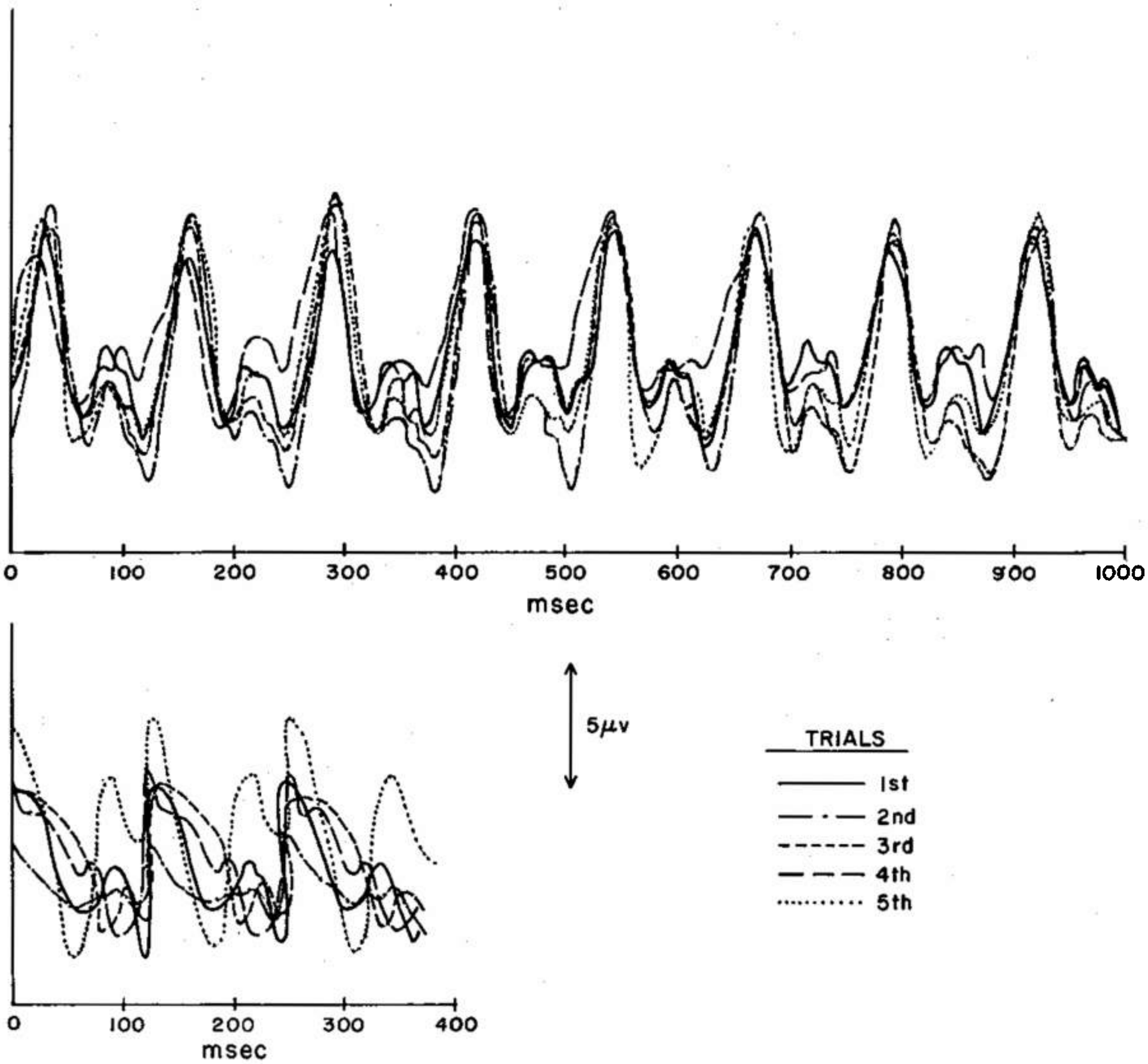

Fig. 10. Empirical VER's compared with synthetic VER's for subject JK.

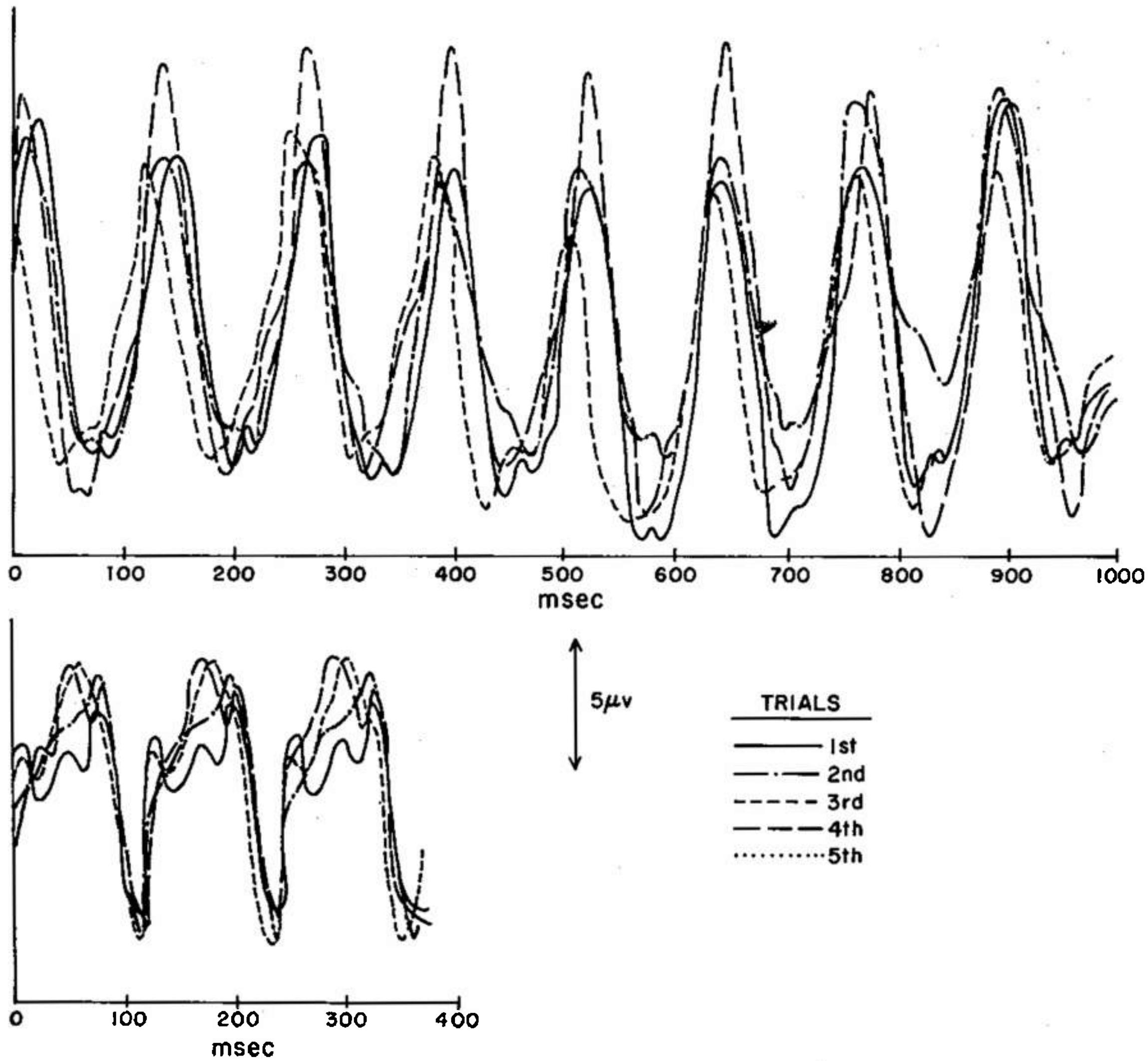

Fig. 11. Empirical VER's compared with synthetic VER's for subject RH.

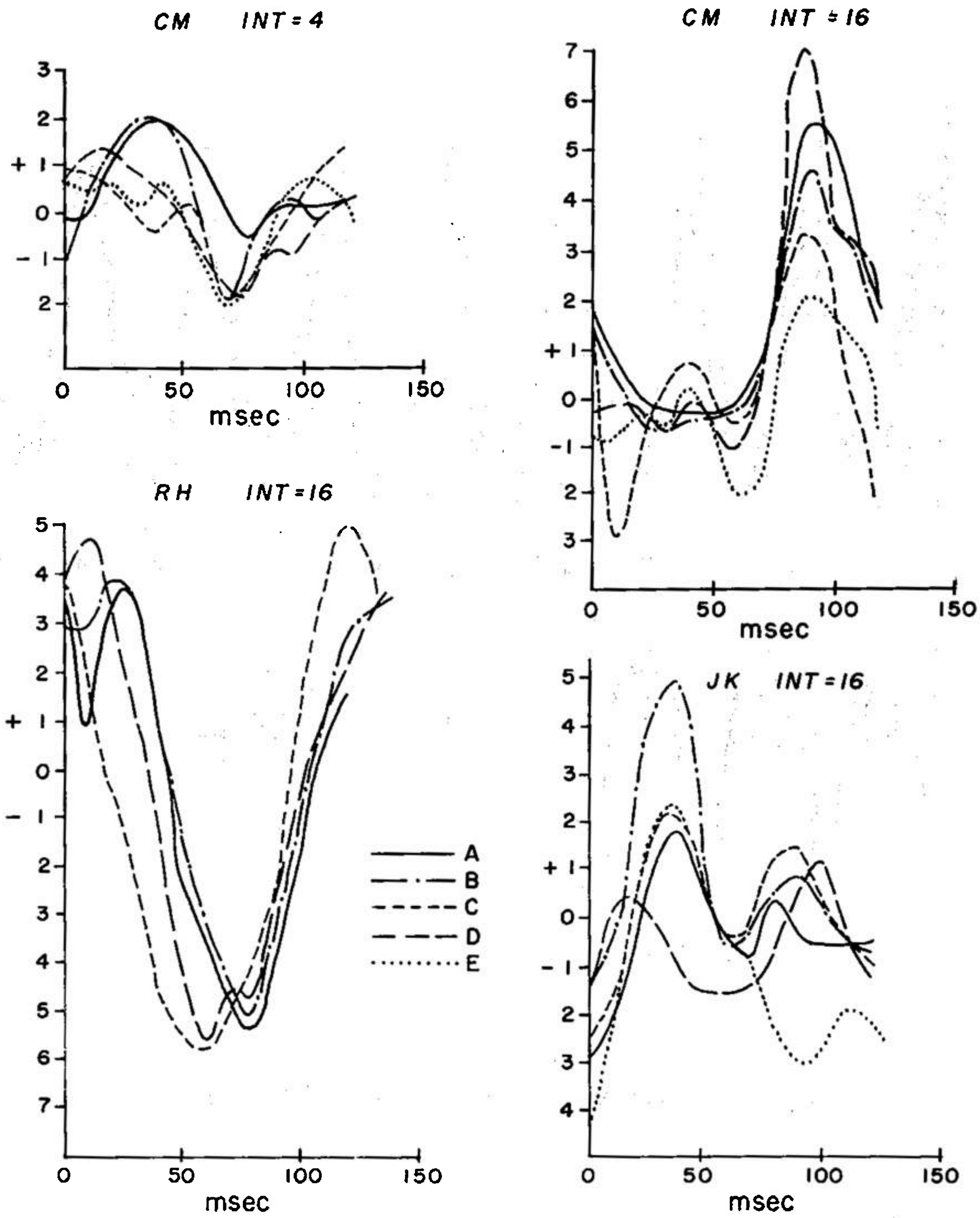

Fig. 12. The remainder after subtracting the synthetic VER's from the empirical VER's for the data shown in Figs. 7-11.

SUMMARY

The use of rapid rates of stimulation to obtain VER's results in simple responses which can be described in terms of means, sigmas, and Z scores. Subsequent analysis for differences among subjects or experimental conditions is straightforward, since the data are available for use in any statistical test such as t tests or analysis of variance. The advantages of this technique over the rather complex analyses required for the complete VER, by amplitude and latency of component, are obvious.

On the other hand, some authors have pointed out the possibility that VER's to rapid stimulations may be the result of addition of different segments of the complete VER; as such, changes in amplitude of these VER's may not represent real differences but only confounding of the response by addition and subtraction.

In answer to this question we have found first that synthetic responses generated from segments of the complete VER are frequently very similar to empirically determined VER for the same condition. Thus, the gross features of the waveform are predictable both in terms of form and of amplitude.

On the other hand, not all features of the waveform are well synthesized from the complete VER. The following discrepancies are commonly noted: small details of shape in the waveform to higher rates do not have an apparent counterpart in the complete VER; for certain subjects or certain experimental conditions, the agreement between synthetic and empirical curves may be excellent, while for others it is poor; and the empirical responses to the higher stimulus rates are much more regular or similar to one another than predicted from individual complete VER's. It is suggested that the VER to higher stimulus rates may be a composite of fragments of the basic VER and an additional rhythmical component. Therefore, the most effective method of obtaining VER's is the use of both a slow and a rapid rate of stimulation.

REFERENCES

1. Kinney, Jo Ann S., McKay, Christine L., Mensch, A., and Luria, S. M. The visual evoked cortical response as a measure of stress in naval environments: Methodology and analysis (1) slow flash rates. Naval Submarine Medical Center, Groton, Conn. NSMRL Rep. No. 669, June 1971.

2. Perry, N. and Childers, D. The Human Visual Evoked Response, Thomas, Springfield, Ill., 1970, pp 46-48; Mezan, I., Remond, A., & Pozo Olano, S. Potentials evoques visuels et frequence de stimulation. Rev. Neurol., 117, 212-214, 1967.

3. Eason, R. G., Oden, D., and White, C. T. Visually evoked cortical potentials and reaction time in relation to site of retinal stimulation. Electroenceph. clin. Neurophysiol., 22, 313-324, 1967.

4. Kinney, J. A. S., and McKay, C. L. The visual evoked response as a measure of nitrogen narcosis in Navy divers. Naval Submarine Medical Center, Groton, Conn., NSMRL Rep. No. 664, Apr 1971.

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13. ABSTRACT

This is the second of two reports whose goal is to evolve methodology for use in evaluating the visual evoked response (VER). The first presented techniques for obtaining and evaluating the complete evoked response; in this study, the method purposely results in VER's which are incomplete, by presenting the visual stimuli at rates that are too rapid to be responded to singly. Rapid flash rates are shown to produce VER's which are reliable and easy to interpret and assess statistically. Furthermore, they appear to be composed of factors in addition to elements from the complete evoked response. Together the methods evolved in the two papers provide efficient techniques for using the VER as a tool in studying Naval problems.

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