sence of the second click at 180 msec. Even had he been right (guessed long) for this trial in which the second click was delivered at 980 msec, absence of the second click at 180 and 580 would have delivered all the information. The actual occurrence of the second click at 980 msec would be redundant.

In all the cases where the occurrence of the second click delivers the information (labeled *a*), the positive-going component has a larger amplitude and is relatively peaked. In all the cases where the absence of the second click delivers the information (labeled *b*), the waveforms appear flattened.

In the *a*1 group, information delivery and the occurrence of the second click are both at 180 msec. In the *a*2 group, the second click and information delivery also coincide, but this point in time is now 580 msec. Therefore, these resemble the *a*1 group except for a time displacement. In the *b*1 group, ambiguity is reduced after a short interval and they resemble each other more than they do the *b*2 group, in which ambiguity is reduced after a medium interval. These findings have been replicated several times in one subject and repeated in two other subjects.

It is conceivable that both the peaked and flattened waveforms reflect the same underlying process. Perhaps the delivery of information releases an identical waveform whether information is delivered by the presence or absence of an external event. However, when the information is provided by the occurrence of an external event, precise phase-locking of the positive process to time of presentation can be achieved. This would result in larger amplitude, more peaked waveforms in the average response. When the absence of an external event delivers information, the point in time at which information is obtained can only be specified by the subject's internal time sense. In this experiment, unlike the situations described in Figs. 1 and 2, there are three time intervals which the subject must internalize. Therefore, it seems possible that this would create some inaccuracy in time estimation and, we believe, consequent time jitter of the positive component. Averaging would make this time jitter appear as a flattening of the waveform. (These differences in the positive process in relation to the presence or absence of the second event may also be seen in the data of Fig. 2.) These conclusions might be tested by finding an effective way of fractionating populations of individual waveforms into like structured subgroups.

It seems unlikely that these findings merely reflect generalized fluctuations of arousal or activation, although the conditions which produce larger response amplitudes may be considered to raise the arousal level. The long latency of the positive process, its independence of the eliciting sensory modality, and the fact that it is best recorded from the vertex would seem to implicate the diffuse projection system. Yet there are features of the data which indicate that the increased responsiveness is differential and selective. The situations we have described are not characterized by generalized arousal so that the occurrence of *any* stimulus releases higher amplitude activity. Rather, the experimental conditions are devised to attach specific meaning to a particular type of stimulus. The mechanism which mediates the amplitude of the late positive component is capable of fine discriminations, and can be preset for release by a stimulus with a particular significance. Under certain conditions, the releasing external stimulus may be absent. In other words, the late positive process may be initiated endogenously. These considerations lead us to interpret the fluctuations in the late positive component of the evoked potential as a reflection of the information content of the stimulus.

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Effects of Visual Form on the Evoked Response

Abstract. *The average visual evoked potentials elicited from relaxed human subjects are different for a blank visual field and one containing a geometric form, are different for different geometric forms of* equal *area, are similar for versions of the same geometric form of* unequal *area, and are different for two printed words equated for total letter area. These findings suggest that the waveform of evoked responses is not determined solely by the set of peripheral receptors which is stimulated, but it also reflects the perceptual content of the stimulus.*

Systematic relations between certain features of the visual evoked potential and such stimulus features as intensity, area, or color have been reported (*1*). However, the waveshape of the evoked response is not solely determined by the physical characteristics of the stimulus; it can be changed by procedures which direct attention to specific visual (*2*) or auditory (*3*) stimuli, or which alter subjective expectancy (*4*). Further, correlations between features of the averaged evoked response and psychophysical measurements have been reported in perceptual studies (5). However, one set of findings seems inconsistent with these conclusions (6).

Although the human experiments cited indicate that evoked potentials may change as a function of alteration in stimulus features or in the focus of attention, and that they may be correlated with aspects of subjective experience, the relations between the perceptual content of a stimulus and the evoked potential have not been examined. Changes in waveshape can be observed when a stimulus is made meaningful without significant alteration in physical energy (7). Such changes have usually been regarded as unspecific and have been attributed to task relevance, interest, affect, or field contrast. We now report the results of a study exploring the relation between the waveshape of the evoked potential and the geometric form of visual stimuli (8).

Data were obtained from monopolar scalp recordings, with the active electrode located on the midline 3 cm above the inion; the right earlobe was used for reference. Potentials were amplified by an Offner type T electroencephalograph, side-tapped at the power amplifiers to provide an output of ± 3 volts to an average response computer (CAT 400). Amplifier time-constant settings were 0.3.

The subject sat relaxed in a contour chair in a darkened room. He was instructed only to observe what was before him. Stimuli were presented either as black metal plaques or as black figures drawn on sheets of white carboard mounted on a white wall 150 cm in front of the subject. The stimuli were illuminated by two Iconix flash units placed behind the subject and facing the rear of the experimental chamber. Silent flashes were produced by a square wave, 20 msec in duration at 20 volts, at a rate of 2 per second. Flashes were rather dim; intensity at the plane of the stimulus object was 0.585 lu/m^2.

The responses evoked by four pairs of stimuli were compared in these studies: a blank visual field versus a field containing a geometric shape, one shape versus a different shape of equal area (squares, diamonds, circles), two identical shapes of different area, and two words, "square" and "circle" printed with capital letters equated for area. In each experiment, four averaged evoked responses were computed from blocks of 25 or 50 presentations of each stimulus of a particular pair. These blocks were ordered according to a Latin-square design. This procedure provided two replications of the average response to each of two different stimuli within every experimental session; it also provided controls for habituation, fatigue, and recency.

Table 1. Distribution of lambda. The sample size is 30 for both epochs; at 350 msec the mean is 1.336 and the standard deviation is 0.286; at 500 msec the mean is 1.251 and the standard deviation 0.192.

Interval	Analysis epoch	
	350 msec	500 msec
< .9	0	0
.9–1.0	1	3
1.0–1.1	6	4
1.1–1.2	7	5
1.2–1.3	2	8
1.3–1.4	3	6
1.4–1.5	2	1
1.5–1.6	4	1
1.6–1.7	2	1
> 1.7	3	1

Figure 1 illustrates some of the findings. Waveforms 1 and 2 show the replicability of average responses computed during 100 presentations of a large, square-shaped stimulus. Both of the responses to diamond-shaped stimuli, waveforms 3 and 4, contain a second positive component, indicated by the arrows, which is absent from the responses to the square stimuli. This component was altered slightly in size and latency when the stimulus area was reduced.

The bottom four responses of Fig. 1 were obtained from the same subject after an interval of 30 minutes. Waveforms 5 and 6 again show replications of the average response to the large square and closely resemble waveforms 1 and 2. When that square was rotated 45°, so that it was perceived as a diamond, the second positive component reappeared, as indicated by the arrow in waveform 7. A diamond of intermediate size elicited the response shown in waveform 8. The second positive component, marked by the arrow, again changed in size and latency when the stimulus area was reduced. Waveforms 7 and 8 closely resemble waveforms 3 and 4.

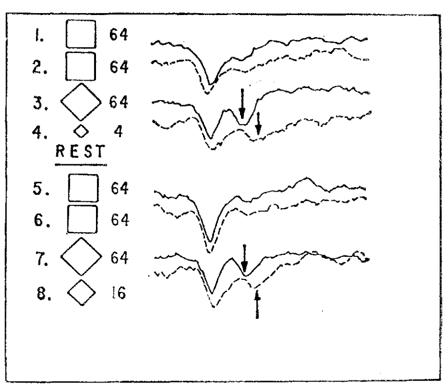

Fig. 1. Averaged responses from two sessions separated by 30 minutes with the same subject (P.S.). All averages based upon 100 repetitions of the stimulus, and a 500-msec analysis epoch. Negative deflections are upward. Responses 1, 2, 5, and 6 were to squares with an area of 64 sq. in. (412.8 cm^2), responsse 3 and 7 to diamonds 64 sq. in. (412.8 cm^2) in area, response 4 to a diamond of 4 sq. in. (25.8 cm^2), and response 8 to a diamond of 16 sq. in. (103.2 cm^2).

Figure 2 illustrates additional results obtained with four sets of stimuli. Each rectangle shows the results of a separate experiment, presented in two different ways. On the left side of each rectangle, the averaged responses to similar stimuli are compared, while on the right side the same four responses are rearranged to permit direct comparison of the responses to dissimilar stimuli. In this way, both the replicability of waveforms elicited by the same stimulus and the reproducibility of differences between responses to different stimuli can be evaluated.

In order to obtain an estimate of the waveshape of the evoked response and reproducibility under natural conditions, no attempt was made to constrain the point of fixation, attention, direction of gaze, or eye movement of the subjects in most of these experiments. However, in a few control studies eye movements were assessed with oculograms. Eye movements were generally slight in this experimental situation, and oculograms averaged during the different stimulus presentations were essentially identical. The possible contribution of changes in pupillary dilation, accommodation, or differential gaze was prevented by the use of homatropine and an artificial pupil. Differential feedback from the vocal musculature was prevented by requiring the subject to count the stimuli in each sequence. The results obtained while taking these various precautions were essentially the same as those elicited under more natural conditions, indicating that the phenomena described are of central origin.

One hundred seventy-four experiments were conducted on 20 subjects. Twelve of these subjects showed consistent and replicable shape-related responses to all sets of stimuli which were presented. Of these twelve, seven showed consistent response patterns when tested repeatedly with all four sets of stimuli over periods up to 4 months. The results obtained from 60 percent of our subjects support the following conclusions: (i) the response evoked by a blank visual field is altered by the presence of a geometric form in the field; (ii) different shapes of equal area elicit different responses; (iii) similar shapes of different area elicit similar responses; and (iv) different words printed with letters equated for area elicit different responses.

These conclusions were based upon visual inspection of the results. In order to provide a more quantitative measure of the degree to which the averaged responses evoked by similar stimuli resemble each other more than responses to dissimilar stimuli, waveforms were digitized and the descriptor λ was computed. The descriptor λ is the ratio of the root-mean-square (r.m.s.) difference between two sets of waveforms evoked by dissimilar stimuli to the r.m.s. difference between two sets of replicated waveforms evoked by similar stimuli:

$$\lambda = (d_{1,3} + d_{2,4})/(d_{1,2} + d_{3,4}) \quad (1)$$

where d_{ij} is the r.m.s. difference between waveforms i and j. The subscripts 1 and 2 denote the two replicated responses to one stimulus, while 3 and 4 denote the replicated responses to the second stimulus of the pair.

When λ exceeds unity, the differences in averaged responses between two types of stimuli are greater than the differences in replicated responses within a single type of stimulus. When λ equals unity, the differences between waveforms do not vary systematically. If λ is less than unity, responses to successive stimulus blocks resemble each other more closely than those to similar stimuli. The quantity λ is a descriptor and cannot be assigned a significance level, since its statistical properties are not known, and should be regarded as only an estimate of similarity in the pattern of response. This estimate was computed for 30 experiments selected from the results obtained from the 12 subjects who had consistent responses. The distributions, means, and standard deviations of λ which were obtained are shown in Table 1. The preponderance of values greater than unity in the table suggests that in the set of selected experiments thus examined, the responses to stimuli of similar shape were more alike than those to dissimilar stimuli.

Individuals differed not only in the shape of the evoked responses, but in their reproducibility, and hence the ease with which shape-related differences could be evaluated. Of the remaining eight subjects tested, seven showed marked and reproducible differential responses to at least one of the pairs of stimuli in one or more comparisons. However, six of these subjects showed great variability within a single experimental session and reproducible responses were seldom obtained. Two of the eight subjects displayed essentially similar waveshapes in response to most stimuli. In a number of instances reproducible differences between replicated averages based upon 25 or 50 stimulus presentations diminished or disappeared when the same size was increased to 100 or 200, or as the experimental session continued. This observation suggests that habituation may increase the similarity between responses. In general, differences in waveshape evoked by different stimuli could be demonstrated whenever waveforms to the same stimulus were well replicated. The factors contributing to the lability or homogeneity of response which characterizes some individuals were not uncovered. Randomization of stimuli by trial and constraints on attention might contribute to the stabilization of differential responses. However, since we have not yet achieved such stabilization, we must maintain some reservations about the generality of our conclusions.

The differences between responses elicited by stimuli of different shape but equal area cannot reasonably be attributed to discrepancies in the amount of physical energy, but must originate in the stimulation of different sets of retinal cells by the two shapes. On the other hand, similar shapes grossly different in size produced similar responses in spite of the discrepancies in the retinal area stimu-

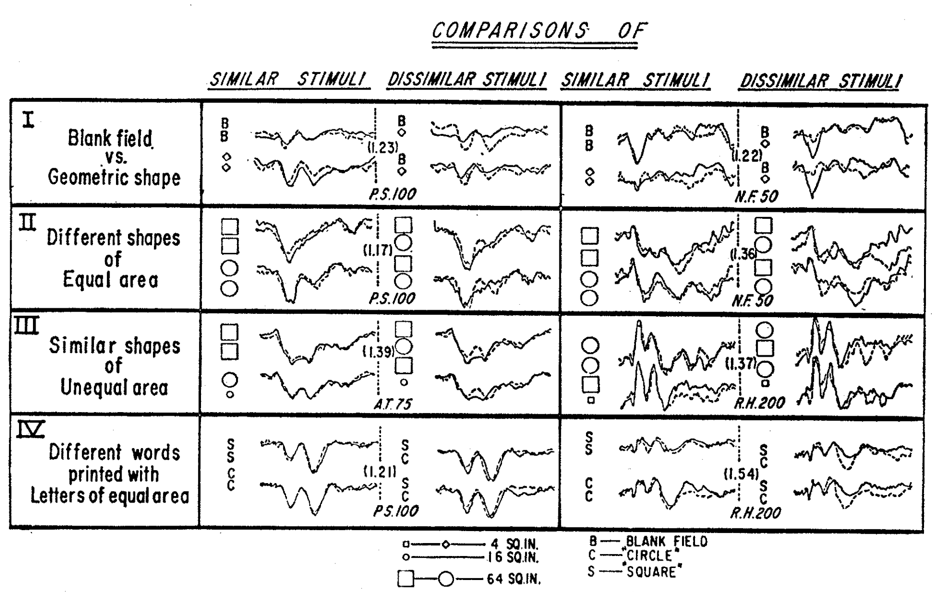

Fig. 2. Average response waveforms from four different types of experiments. Analysis epochs were 500 msec; negative deflections are upward. Responses of two subjects have been provided for each set of stimuli. The letters and numbers at the bottom of each rectangle indicate the initials of each subject and the sample size on which the average response is based. In each rectangle there are four pairs of waveforms. Two replicated responses to one stimulus are superimposed on the upper left, and two replications of response to the second stimulus are superimposed on the lower left. On the right, the same four responses are rearranged by superimposing waveforms obtained to dissimilar stimuli. The stimuli which elicited each response are identified by the symbols to the left of every waveform. When the difference between responses to dissimilar stimuli exceeds the difference within responses to similar stimuli, the descriptor λ in parentheses in the center of the rectangle exceeds unity.

lated. The evoked potential differences reported are therefore related more to the shape of the stimulus than to its size, and seem to constitute a physiological correlate of perceptual rather than sensory processes.

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Mental Retardation

"In the Soviet Union," writes Zigler in *Science* (*1*), "no distinction is made between retardates having known organic impairment and that larger group whose retardation is of unknown etiology, nor are genetic or cultural factors considered to be determinants of mental retardation." This is not quite true, though both Russian and American commentators have contributed to the confusion. Pevzner, a leading Russian authority, in her book *Oligophrenia: Mental Deficiency in Children* (*2*), says explicitly, "In my definition of oligophrenia I include those forms of mental deficiency which arise as a result of intrauterine or early lesions of the central nervous system and which show no tendency to progress. . . . Foreign psychiatrists often include mentally deficient and backward children in one group. This unjustifiable widening of the concept of oligophrenia leads to erroneous conclusions regarding its etiology, pathogenesis and clinical pattern. Our investigation is directed to the study of a narrower group of conditions—namely, to oligophrenia." A distinction is thus clearly made between (i) forms of mental retardation due to demonstrated or presumed biological defect and (ii) the backwardness in mental development due to psychosocial or other causes. Children showing retardation of the former type are regarded as fit subjects for educational segregation and pathophysiological study; those showing backwardness of the latter type are regarded as primarily problems for corrective pedagogy in regular classes.

Psychometric testing and intelligence quotients were abandoned decades ago in the Soviet Union, and children are ordinarily not assigned to special educational facilities for defectives until they have been observed and taught for a year in a regular class and are then thought to be incapable of mastering a regular curriculum. They are then examined by a multidiscipline commission, for validation of the assumption of biological deficiency, before they can be remanded to special classes. As a result, only a fraction of 1 percent of the children are diagnosed as retardates, whereas the common use, in the United States, of the criterion of two standard deviations from the I.Q. mean inevitably results in classification of at least 3 percent of our children as retardates. Furthermore, since the Stanford-Binet test, the intelligence test most widely used in the United States, was standardized on the basis of a white and somewhat middle-class population, percentages of supposed retardation may run as high as 20 or 30 percent in some age groups of our poor Negro urban population (*3*).

In cases of retardation with an organic basis there is much to suggest that, regardless of etiology, the most common biological result is diffuse and minimal brain damage or defect. This is notoriously difficult to diagnose in infants by conventional neurological examination, and must usually be deduced from a compromising pregnancy, birth, or medical history; early developmental lag; motor awkwardness; articulatory speech defects, and strabismus or other "soft" neurological signs.

Psychosocial deprivation is related to poverty, and the good things of life are not distributed parametrically on a bell-shaped curve: there is, in fact, a considerable skewing to the left. Neither is pathology distributed on a Gaussian curve, since there is no hypernormality to balance the incidence of birth injury or the hazards of prematurity so commonly encountered among the poor. That is why no intelligence test has ever been found, in practice, to yield a normal curve.

In the context of these considerations, the "normal" variations of innate intellectual capacity, which undoubtedly exist, appear to play a relatively minor role; the psychological aggravation that comes from the chronic frustrations of backwardness also exists, but its relative importance can be questioned. The problem could be dealt with more effectively if we made a sharper distinction between biological and nonbiological types of retardation. The biological types would include a small proportion of individuals with medically diagnosable conditions and a large proportion of really defective individuals whose precise trouble we cannot diagnose. The nonbiological types would involve a large element of poverty, physical neglect, and psychosocial deprivation and a small element of frustration, poor motivation, and demoralization.

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