

Figure-Ground Discrimination After Induced Altered Brain Function

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Studies of complex visual perception with altered brain function in man have not always yielded clear or consistent results. The disagreements may be due to many factors, such as differences in population studied, types of procedures employed, and difficulties in evaluating the degree of alteration in brain function. Electroconvulsive therapy (ECT), however, provides a unique opportunity for studying the effects of cerebral dysfunction in that more accurate control can be maintained over the degree of induced cerebral dysfunction and its measurement.

While most investigations of brain-injured populations have focused on the role of the locus of the lesion on behavior, current studies of ECT have emphasized individual differences. Marked variability has been shown for perceptual,¹² behavioral,⁷ and physiologic^{5,8} responses to ECT. Various personality^{6,11} and social factors^{9,10} have also been related to differences in response to treatment.

In the course of an investigation of the perceptual and behavioral changes with ECT, a convulsive-subconvulsive control study was undertaken. In this report, the performance on complex visual tasks is presented. Specifically, the aim was to determine whether perceptual change induced by ECT is related to the degree of altered brain function and clinical behavioral

change, and whether the pretreatment perceptual pattern is related to physiologic changes with treatment.

The method used in the study was the perception of embedded geometric figures—a technique which has been employed in recent years in studies of perceptual change in head trauma and brain tumor patients.^{1,13,14}

Method

1. *Population.*—Fifty-three consecutive patients referred for ECT were studied. These included 16 men and 37 women, the ages ranging from 22 to 66 years, with a median of 49 years. The patients were divided at random into two groups. A convulsive group, of 29 patients, received grand mal electrotherapy with thiopental (Pentothal) premedication three times a week, using either a Medcraft alternating-current instrument or a Reiter C-47 electrostimulator. A minimum of 12 treatments was given. The total number of treatments was determined by the supervising psychiatrist in charge of the treatment unit on the basis of clinical criteria. A subconvulsive group, of 24 patients, was treated in similar fashion except that only subconvulsive stimulation was given after the thiopental. Fourteen of the subjects in the subconvulsive group were subsequently given a regular course of convulsive therapy.

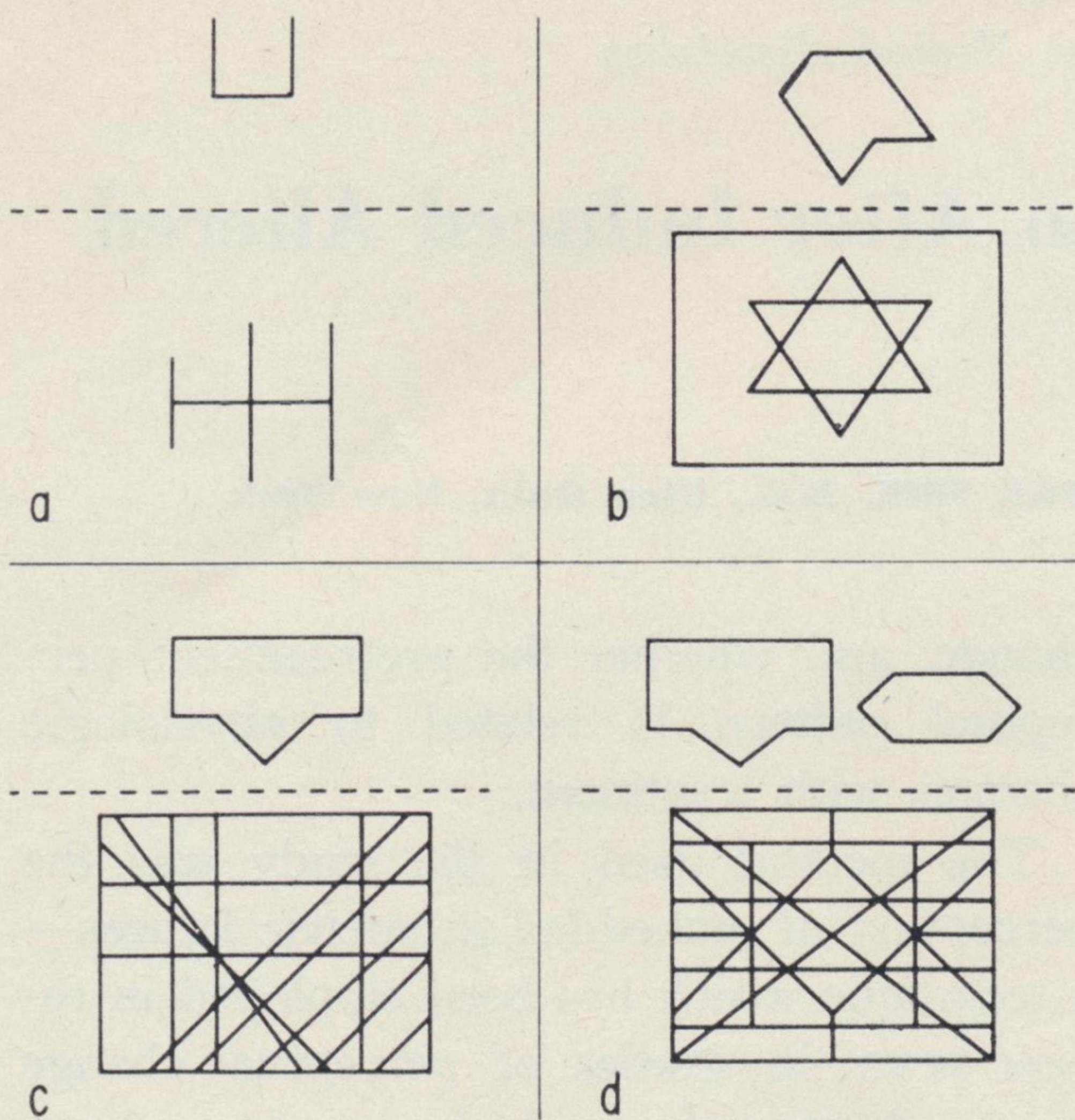
2. *Perceptual Task.*—In the week prior to treatment and on the day following the 12th treatment each patient was tested with a modification of the Gottschaldt hidden-figure test developed by Battersby et al.¹ The subject is presented with a page containing two forms—a simple geometric figure, and below it a complex figure in which the simple figure is embedded (Figure). The patient is asked to trace a specific geometric figure from the background by outlining it with a colored pencil. The discriminations range in complexity from relatively simple to more complex. There are 25 such discriminations. A maximum of two minutes is allowed for each. Performance is scored in terms of total number of errors. To minimize a practice effect, two equivalent forms of the test were used. The forms were alternated with

Accepted for publication Jan. 18, 1960.

From The Department of Experimental Psychiatry, Hillside Hospital.

Presented at the American Psychological Association, New York, August, 1957.

Aided by Grants M-927 and MY-2092 of the National Institute of Mental Health, National Institutes of Health, U.S. Public Health Service.



Figures in hidden-figures test. The preliminary sample used to acquaint the subjects with the task is shown in *a*; *b* and *c* are examples of test figures. In *d* the task is complicated by having the subject determine which of the two single figures can be found in the complex figure.

successive patients in pretreatment testing. During treatment the patient was reexamined with the form different from that given initially.

3. *Evaluation of Physiologic Change.*—Two measures of brain function—the electroencephalogram and the amobarbital test¹⁶—were given to each patient prior to and at weekly intervals during treatment. The electroencephalogram was evaluated as to the degree of induced slow-wave activity according to criteria previously published.⁵ The amobarbital test was noted as positive or negative for brain dysfunction according to standardized criteria.¹⁶ The results of these tests during the second, third, and fourth weeks of treatment furnished the criteria for physiologic change. A combined physiologic index was obtained by ascribing to each high-degree slow-wave EEG record and each positive amobarbital test a score of one. The range of physiologic alteration thus ranged from 0 to 6.

4. *Behavior Ratings.*—Each patient's behavior was evaluated at weekly intervals. After the 12th treatment, a rating for the degree of behavioral change was made according to four classes: marked, moderate, minimal, or none. These ratings of change were not value judgments as to the quality of change but, rather, quantitative estimates of differences in behavior patterns under similar conditions of observation. Thus, such behavior patterns as euphoria, paranoia, and withdrawal might all be rated as equivalent for degree of quantitative change, although the implications of each for the qualitative evaluation of improvement may be different.

TABLE 1.—*Intragroup Comparisons for Number of Errors Before and During ECT*

Type of Treatment	No.	Before ECT	During ECT	Difference	P*
Subconvulsive	24	10.0	7.7	-2.3	<0.02
Convulsive	43	9.5	11.8	+2.3	<0.02

* Intragroup analyses in this and in subsequent tables are based on Wilcoxon's method of paired replicates.

Results

The pretreatment and treatment scores and the mean change in the number of errors with treatment are shown for each group in Table 1. Intragroup analysis shows that the subconvulsive group made significantly fewer errors during treatment, whereas the convulsive patients made significantly more.

Prior to treatment, subconvulsive patients made approximately the same number of errors as those in the convulsive group, a mean difference of 0.5 error. During treatment, however, the difference between these groups (4.1 errors) was significant at better than the 1% level of confidence. When the data are analyzed with respect to physiologic change, significant increases in errors are found only for those patients with greater degrees of physiologic change. This relationship is present in the analysis of the amobarbital test and the EEG as separate

TABLE 2.—*Intragroup Comparisons for Number of Errors Before and After ECT in Relation to Degree of Physiologic Change*

Physiological Index	N	Mean Difference in No. of Errors During Treatment	P
Amobarbital Test			
None or one positive	13	-0.2	Not significant
Two or three positive	28	+3.7	<0.01
Electroencephalogram			
None or one high delta	23	+1.7	Not significant
Two or three high delta	18	+3.3	<0.05
Combined Physiologic			
0 to 3	21	+1.0	Not significant
4 to 6	20	+3.9	<0.01

FIGURE-GROUND DISCRIMINATION

TABLE 3.—*Intragroup Comparisons for Number of Errors Before and During ECT in Relation to Degree of Behavioral Change*

Degree of Behavioral Change	N	Mean Difference for Number of Errors During Treatment	P
Marked	24	+3.6	<0.01
Moderate	14	+1.0	Not significant
Minimal or none	5	-0.4	Not significant

indices, and when the two tests are combined (Table 2).

The relationship between the degree of behavioral change and the change in number of errors during treatment is shown in Table 3. Those patients with minimal or moderate behavior changes did not show an appreciable difference in number of errors. Those with marked behavior changes, however, made significantly more errors during treatment.

Analysis of the pretreatment error scores in relation to the degree of physiologic change is shown in Table 4. A significant relationship is shown between the pretreatment error scores and the degree of physiologic change during treatment. Patients with minimal physiologic change during convulsive therapy had a mean pretreatment score of 7.9 errors, while those who developed marked physiologic effects had a mean pretreatment score of 13.2. The tri-serial correlation of pretreatment score and physiologic change is +0.34, significant at the 0.05 level of confidence.

Qualitative Data.—Alterations in size of figure or in minor aspects of form were common types of error during both testing periods. Certain qualitative patterns were frequently noted during treatment, which occurred only rarely in the pretreatment period. It was common for patients to make no attempt to trace the more complex figures. This failure was often associated with a generalized withdrawal reaction in which the patient was unresponsive to any stimulus or procedure. Others became hostile and negativistic toward the testing. Patients with the greatest amount of physio-

TABLE 4.—*Relation of Pretreatment Errors to Eventual Degree of Physiologic Change During Treatment*

Physiologic Change	N	Mean No. of Errors Pretreatment
0 to 2	16	7.9
3 and 4	19	11.2
5 and 6	8	13.3

logic change had frequent difficulty following instructions. They would trace the lines indiscriminately, without regard for the specific figure to be traced, repeat a previous figure despite changes in the test figure, draw lines where none actually existed, and attempt to trace the stimulus figure while ignoring the more complex test figure. Such patients were likely to respond quickly and impulsively, and showed little concern about making an error even when spontaneously commenting, "I know that's not right."

Comment

This study demonstrates a relationship between the degree of cerebral dysfunction and the degree of perceptual alteration as measured by errors on the embedded-figures test. Patients with subconvulsive stimulation made fewer errors on retesting. Patients receiving convulsive therapy, in whom only minimal physiologic changes were recorded, manifested slight increase or no change in errors. The convulsive patients, however, with the more marked physiologic alterations, showed a significant increase in errors. This interrelationship of brain function and perception may be related both to the perceptual patterns with neurologic disorders and to the mode of action of convulsive therapy.

It is evident that perceptual responses systematically vary with the degree of diffuse cerebral dysfunction. In relating these patterns to concepts of localized pathology, the role of generalized, nonspecific cerebral dysfunction must be considered. For example, unilateral spatial "inattention," frequently attributed to parietal lobe lesions alone,^{3,4} has been reported with a variety

of lesions provided there was a somatosensory defect and an associated generalized mental impairment.^{2,16} Teuber and Weinstein¹⁴ found that performance on an embedded-figures test was unrelated to locus of lesion in cases with penetrating brain wounds, but that aphasic patients made significantly more errors than a nonaphasic group. Pollack et al.,¹³ using a test identical with that in this study, reported no relationship between errors and the location of lesion in tumor patients. They noted, instead, that the number of errors was related to the severity of general mental changes, manifested as disorientation for time and place. The present observation that perception of embedded figures is related to the degree of diffuse brain dysfunction is in accord with these studies of patients with head injuries and brain tumors.

In previous investigations of the mode of action of convulsive therapy, we have shown that clinical behavioral change is related to the degree of altered brain function.^{5,7,8} The present study reinforces this observation, the objective criterion of perceptual errors being used as an index of behavioral change. As a group, the patients who showed the greatest increase in errors with treatment were those who also showed the most pronounced change in clinical behavior, as assessed by conventional psychiatric evaluation.

There appeared to be considerable comparability in the type, as well as the degree, of clinical behavioral change and the qualitative aspects of performance on the embedded-figures test. Failure to attempt the task characteristically accompanied withdrawal or paranoid hostility. A lack of concern in correcting errors was associated with clinical euphoria or hypomania. From these behavioral observations, the increases in errors may be attributed to a change in attitude toward the task or examiner, as well as to a specific defect. The altered brain function modified the total pattern of interaction with the environment, of which

the performance on a complex perceptual task is just one aspect.

Previous studies have shown that there is a relationship between the clinical response to convulsive therapy and aspects of personality, defined as the habitual or characteristic modes of response and adaptation.^{6,10,11} In this study it has been shown that the pre-treatment perceptual performance is related to the physiological response during treatment. This finding suggests that the individual differences in the development of physiologic change may also be related, in part, to personality factors.

Summary and Conclusion

Fifty-three consecutive patients referred for electrotherapy were studied before and after treatment on their ability to perceive embedded geometric figures. An experimental group of 29 patients received a course of grand mal therapy with thiopental (Pentothal) premedication. A control group of 24 patients received subconvulsive stimulation with thiopental premedication only.

The experimental group made significantly more errors after treatment than did the controls.

Within the experimental group there was considerable variability. Increase in errors was significantly related to the degree of altered brain function and to the degree of behavioral change.

Qualitative aspects of perceptual behavior mirrored the pattern of behavioral change observed clinically.

Pretreatment error scores were significantly related to the degree of altered brain function developed during treatment. The significance of this observation in terms of personality factors is indicated.

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**Aided by grants M-927 and MY-2092 of the National Institute of
Mental Health, National Institutes of Health, U.S. Public Health
Service.**

**Presented at American Psychological Association, N.Y., August 1957
VI: 10-59**

Figure-Ground Discrimination in ECT

Figure-ground Discrimination After Induced Altered Brain Function

Studies of complex visual perception with altered brain function in man have not always yielded clear or consistent results. The disagreements may be due to many factors, such as differences in population studied, types of tools and procedures employed, and difficulties in evaluating the degree of alteration in brain function. Electroconvulsive therapy (ECT), however, provides a unique opportunity for studying the effects of cerebral dysfunction in that more accurate control can be maintained over the degree of induced cerebral dysfunction and its measurement.

While investigations of brain-injured populations have focussed for the most part on the role of location of lesion on behavior, current studies of ECT have emphasized the factor of individual differences. Marked variability has been shown for perceptual (8), behavioral (4), and physiological (2,5) responses to ECT. In addition, various personality (3) and social factors (6,7) have been related to differences in response to treatment.

In the course of an investigation of the perceptual and behavioral changes with ECT, a convulsive-subconvulsive control study was undertaken. In this report, the performance on complex visual tasks is presented. Specifically, the aim was to determine whether perceptual change induced by ECT is related to the degree of altered brain function and clinical behavioral change; and whether the pretreatment perceptual pattern is related to physiologic changes with treatment.

The method used in the study was the perception of embedded geometric figures - a technic which has been employed in recent years in studies of perceptual change in head trauma and brain tumor patients (1, 8, 10).

Method:

1) Population: Fifty-three consecutive patients referred for ECT were studied. These included 16 men and 37 women, with ages ranging from 22 to 66 with a median of 49 years. The patients were divided at random into two groups. A convulsive group of 29 patients received grand mal electrotherapy with pentothal premedication three times a week, using either a Medcraft alternating current instrument or a Reiter C-47 electrostimulator. A minimum of 12 treatments were given. The total number of treatments was determined by the supervising psychiatrist in charge of the treatment unit on the basis of clinical criteria. A subconvulsive group of 24 patients was treated in similar fashion, except that only subconvulsive stimulation was given following the pentothal. Fourteen of the subjects in the subconvulsive group were subsequently given a regular course of convulsive therapy.

2) Perceptual task: In the week prior to treatment and on the day following the 12th treatment each patient was tested with a modification of the Gottschaldt hidden figure test developed by Battersby et al (1). The subject is presented with a page containing two forms - a simple geometric figure, and below it a complex figure in which the simple figure is embedded (fig. 1). The patient is asked to trace a specific geometric figure from the background by outlining it with a colored pencil. The discriminations range in complexity from

Fig. 1

relatively simple to more complex. There are 25 such discriminations. A maximum of two minutes is allowed for each. Performance is scored in terms of total number of errors. To minimize a practice effect two equivalent forms of the test were used. The forms were alternated with successive patients in pretreatment testing. During treatment the patient was re-examined with the form different from that given initially.

3) Evaluation of physiologic change: Two measures of brain function - the electroencephalogram and the amobarbital test (11) were given to each patient prior to, and at weekly intervals during treatment. The electroencephalogram was evaluated as to the degree of induced delta activity according to criteria previously published (2). The amobarbital test was noted as positive or negative for brain dysfunction according to standardized criteria (11). The results of these tests during the second, third and fourth weeks of treatment furnished the criteria for physiological change. A combined physiological index was obtained by ascribing to each high degree delta EEG record and each positive amobarbital test a score of one. The range of physiological alteration thus ranged from zero to six.

4) Behavior ratings: Each patient's behavior was evaluated at weekly intervals. After the 12th treatment, a rating for the degree of behavioral change was made according to four classes: marked, moderate, minimal or none. These ratings of change were not value judgements as to the quality

of change, but rather quantitative estimates of differences in behavior patterns under similar conditions of observation. Thus, such behavior patterns as euphoria, paranoia or withdrawal might all be rated as equivalent for degree of quantitative change, although the implications of each for the qualitative evaluation of improvement may be different.

Results:

The pretreatment and treatment scores and the mean change in the number of errors with treatment are shown for each group in Table I. Intragroup analysis shows that the subconvulsive group made significantly fewer errors during treatment, while the convulsive patients made significantly more.

TABLE I

Prior to treatment, subconvulsive patients made approximately the same number of errors as those in the convulsive group with a mean difference of only 0.5. During treatment, however, the difference between these groups (h.l errors) was significant at better than the 1% level of confidence. When the data is analyzed with respect to physiologic change, significant increases in errors are found only in those patients with greater degrees of physiologic change. This relationship is present in the analysis of the amobarbital test and the EEG as separate indices, and when the two tests are combined (Table II).

TABLE II

The relationship between the degree of behavioral change and the change in number of errors during treatment is shown in Table III. Those patients with minimal or moderate

behavior changes did not show an appreciable difference in number of errors. Those with marked behavior changes, however, made significantly more errors during treatment.

TABLE III

Analysis of the pretreatment error scores in relation to the degree of physiological change is shown in Table IV. The results show a significant relationship between the pretreatment error scores and the degree of physiological change during treatment. Patients with minimal physiological change during convulsive therapy had a mean pretreatment score of 7.9 errors, while those who developed marked physiological effects, had a mean pretreatment score of 13.2. The triserial correlation of pretreatment score and physiological change is +.34, significant at the .05 level of confidence.

TABLE IV

Qualitative Data:

Alterations in size of figure or in minor aspects of form were common types of error during both testing periods. Certain qualitative patterns were frequently noted during treatment however, which occurred only rarely or to a lesser extent in the pretreatment period. It was common for patients

TABLE I

Intragroup Comparisons for Number of Errors
Before and During ECT

<u>Type of Treatment</u>	<u>N</u>	<u>Before ECT</u>	<u>During ECT</u>	<u>Difference</u>	<u>p*</u>
Subconvulsive	24	10.0	7.7	-2.3	<.02
Convulsive	43	9.5	11.8	+2.3	<.02

* Intragroup analyses in this and subsequent tables based on Wilcoxon's method of paired replicates.

TABLE II

Intragroup Comparisons for Number of Errors Before and After ECT in Relation to Degree of Physiological Change

<u>Physiological Index</u>	<u>N</u>	<u>Mean Difference in Number of Errors During Treatment</u>	<u>p</u>
<u>Amobarbital Test</u>			
None or one positive	13	-0.2	Not significant
Two or three positive	28	+3.7	.01
<u>Electroencephalogram</u>			
None or one high delta	23	+1.7	Not significant
Two or three high delta	18	+3.3	.05
<u>Combined Physiological</u>			
0 to 3	21	+1.0	Not Significant
4 to 6	20	+3.9	.01

TABLE III

Intragroup Comparisons for Number of Errors Before and During
ECT in Relation to Degree of Behavioral Change

<u>Degree of Behavioral Change</u>	<u>N</u>	<u>Mean Difference-Number of Errors During Treatment</u>	<u>p</u>
Marked	24	+3.6	.01
Moderate	14	+1.0	Not significant
Minimal or None	5	-0.4	Not significant

TABLE IV

Relation of Pretreatment Errors to Eventual Degree of Physiological
Change During Treatment

	<u>N</u>	<u>Mean Number of Errors Pretreatment</u>
<u>Physiologic Change:</u>		
0 to 2	16	7.9
3 and 4	19	11.2
5 and 6	8	13.3

to make no attempt to trace the more complex figures. This response was often associated with a generalized withdrawal reaction in which the patient was unresponsive to any stimulus or procedure. Others became hostile and negativistic toward the testing. Patients with the greatest amount of physiological change often had difficulty following instructions. They would trace the lines indiscriminately without regard for the specific figure to be outlined; repeated a previous figure despite changes in the test figure; drew lines where none actually existed; and attempted to trace the stimulus figure while ignoring the more complex test figure. Such patients were likely to respond quickly and impulsively, and showed little concern about making an error even when they might spontaneously comment, "I know that's not right."

Discussion:

This study demonstrates a relationship between the degree of cerebral dysfunction and the degree of perceptual alteration as measured by errors on the embedded figures test. Patients with subconvulsive stimulation make fewer errors on retesting. A slight decrease or no change in errors occurred in those patients receiving convulsive therapy who showed only minimal physiological changes. The convulsive patients, however, with the most marked physiological alteration, showed a significant increase in number of errors. This interrelationship of brain function and perception of embedded figures is in accord with studies of patients with altered brain function due to head injury and brain tumor. Teuber and Weinstein (10) applying a similar technic in cases with penetrating brain wounds, concluded that performance was unrelated to locus of lesion but that aphasic patients made significantly more errors than a non-aphasic brain-injured group. Pollack et al, (9), using the identical test as in this study, reported no relationship between errors and the location of lesion in tumor patients. They reported, instead, that the number of errors was related to the severity of such mental changes as disorientation.

It should be pointed out that the total pretreatment mean score for all patients referred for convulsive therapy was 10.4 errors, a score almost identical to that found by Pollack et al, (9) in their brain tumor patients. Since the two populations are comparable in terms of other parameters as age and education, the defects in figure ground discrimina-

tion cannot be regarded as reflective of cerebral dysfunction as an isolated entity abstracted from the totality of behavior. Rather than being in a one to one relationship, poor performance on such tasks may be due to the interaction of many factors, brain dysfunction being only one. Thus, there are many patients with marked cerebral damage who make fewer errors in this task than control subjects with intact cerebral function. In the present study the range of differences among the patients prior to treatment was greater than that obtained even with maximum physiological change. While a patient in the subconvulsive group with a high number of pretreatment errors may show a practice effect on retesting with a reduction in errors, his absolute error score may still be higher than that of a patient receiving convulsive therapy who had few pretreatment errors and has shown increased difficulty with treatment. These observations suggest that difficulty in perceiving embedded figures is related to certain personality aspects as well as to brain dysfunction. Consistent with this conception, Witkin (12, 13) has noted that the marked individual differences in the perception of hidden figures among college students are related to personality factors.

The relationship of perceptual alteration to behavioral change during treatment is clearly demonstrated. As a group the patients who showed the greatest increase in errors during treatment were those who also showed the most pronounced change

in clinical behavior. They manifested behavior patterns of euphoria, hypomania, withdrawal, somatization or paranoia. Comparable to these are the qualitative aspects of performance on the embedded figure test during treatment. Failure to attempt the task was frequently related to an evasion or withdrawal reaction in some cases, and to a paranoid hostility in others. A lack of concern in correcting errors was associated with clinical patterns of euphoria and hypomania. Thus, the increase in errors may be attributed to a change in motivation or attitude toward the task or examiner as well as to any aspect of the alteration in brain function. Changes in performance on this complex perceptual task can be understood as one reflection of a change in the pattern of interaction with the environment.

The finding of the relation of the pretreatment score to the physiological response has important implications for the theory of the mode of action of convulsive therapy. In previous investigations we demonstrated that a change in brain function is a necessary condition for behavioral change in convulsive therapy (2, 5). The present observation, however, indicates that the development of a marked degree of change on physiological measures may also be related to aspects of personality.

Summary and Conclusion:

1. Fifty-three consecutive patients referred for electrotherapy were studied before and after treatment on their ability to perceive embedded geometric figures. An experimental group of 29 patients received a course of grand mal therapy with pentothal premedication. A control group of 24 patients received subconvulsive stimulation with pentothal premedication only.

2. The experimental group made significantly more errors following treatment than did controls.

3. Within the experimental group there was considerable variability. Increase in errors was significantly related to the degree of altered brain function and to the degree of behavioral change.

4. Pretreatment error scores were significantly related to the degree of altered brain function developed during treatment. The significance of this observation in terms of personality factors is indicated.

5. Qualitative aspects of perceptual behavior mirrored the pattern of behavioral change observed clinically.

Legend:

Fig. 1. Illustration of test figures. The preliminary sample used to acquaint the subjects with the task is shown in a. In d the task is complicated by having the subject determine which of the two single figures can be found in the complex figure.

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