PERCEPTUAL PATTERNS DURING RECOVERY FROM GENERAL ANAESTHESIA *

BY 

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In a series of previous communications the examination of cutaneous sensation by the method of double simultaneous stimulation has been described (Bender and Furlow, 1944 and 1945; Bender, 1945; Bender and Teuber, 1946; Bender, 1948). When double rather than single stimulation is employed, the phenomena of extinction, obscuration, and displacement make their appearance. In these phenomena one of the two simultaneously applied stimuli is either not perceived at all (extinction), perceived as diminished in intensity (obscuration), or perceived as localized to a part of the body other than that stimulated (displacement) (Bender, 1951). Furthermore, these phenomena do not occur in a haphazard fashion. A repeatedly observed and predictable pattern of perception has been described in cutaneous testing by double simultaneous stimulation. Thus it is possible to predict which of the two stimuli will be accurately perceived, and which will be extinguished, obscured, or displaced. The accurately perceived stimulus has been termed the dominant one. After numerous studies of different parts of the body with double simultaneous stimulation, a pattern of dominance has been described. The face is most dominant, the hand is least dominant, and other body areas lie in a predictable order of dominance between the face and hand (Bender, Shapiro, and Schappel, 1949).

These phenomena and patterns of dominance were first described in patients with disease of the brain and spinal cord. They were later found to be a prominent feature of the response of normal children to double simultaneous stimulation (Bender, Fink, and Green, 1950). The normal adult may make errors on the first few trials of double simultaneous stimulation, provided the subject is not previously acquainted with the test and is given no preliminary instructions other than the command to close the eyes. In the errors made by normal adults on these initial trials of the "face-hand test" (simultaneous stimulation of face and hand with eyes closed) the pattern of face dominance has been clearly shown (Fink, Green, and Bender, in press). Following these initial errors the normal adult successfully perceives and localizes two simultaneous stimuli, and gives consistently correct responses on all subsequent trials. From this point on, in the absence of extinction and displacement phenomena, the patterns of dominance can no longer be investigated in the same subject.

The present study demonstrates that these patterns exist in the normal nervous system, but are inconspicuous unless certain reversible conditions of testing are introduced: in this case the clouding of the sensorium produced by a general anaesthetic. The method was suggested by the following observations.

We observed that the highest incidence of extinction and displacement phenomena in adults is found in patients with an organic mental syndrome, in whom there is an alteration in the state of consciousness; and that when these phenomena are observed in patients with organic disease of the brain, their severity and extent are increased by the intravenous administration of sodium amytal. It was also found that extinction and displacement occurred in patients without organic disease, but in whom mental confusion developed following electric shock therapy. This was especially true when a barbiturate had been administered preceding the convulsive therapy. With this in mind, a more profound pharmacological change in mental function, such as that produced by anaesthesia, was investigated. It is the purpose of this study to demonstrate these patterns of perception in the normal adult in whom a temporary reversible organic mental syndrome is produced by general anaesthesia.
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Material and Methods
The subjects were 34 patients chosen at random from the general surgical wards of Bellevue Hospital. No patients with disease of the brain or with mental changes were used in this series. With few exceptions, they had had common abdominal or gynaecological surgical procedures. All had had general anaesthesia for a minimum of one hour, many for two or three hours, or more. Three-fourths of the patients received cyclopropane, while the remainder received various combinations of intravenous barbiturates, nitrous oxide, and ether. The patients ranged in age from 13 to 73 years.

Initial examinations were performed at odd intervals during recovery from unconsciousness, varying from 30 minutes to seven hours following cessation of anaesthesia. Therefore, a large variety of mental syndromes were encountered. Most of the patients were sleeping, and had to be awakened for the examination. They were then told that a test to check the degree of recovery from anaesthesia was to be performed.

The cases tested in the early stages of recovery from anaesthesia showed a severe organic mental syndrome, with disorientation for time and place, loss of memory for the operation, rambling, confusion, disconnected speech, and inappropriate answers to questions. Some of the patients misidentified the examiner, others showed uninhibited behaviour, such as disrobing, striking or spitting at the examiner, and spontaneous discussion of intimate sexual material as in sodium amytal interviews. Some of the patients showed right-left disorientation when asked to hold up the right or left hand, but all could point to a single spot on their body that had been touched by the examiner.

Those patients with severe organic mental syndrome due to anaesthesia had an extremely short span of attention, often falling asleep in the middle of a sentence. The majority of patients, however, were sufficiently recovered so as to be oriented for time and place, and, although drowsy and mildly annoyed at the examination, were extremely cooperative throughout the testing. They tended to remember the examination on subsequent days, while the group with severe organic mental syndrome often had no memory of the test or the examiner 24 hours later.

The patient was urged to stay awake, to pay attention, and to try to cooperate. He was then told to close his eyes and was touched briefly but firmly with the examiner's two forefingers on one cheek (face), and the contralateral hand (any part of the hand or fingers). Care was taken to apply the stimuli simultaneously, and with approximately equal pressure and duration. Immediately following this, the patient was asked to report what he had perceived, and then to indicate the location of the percept reported, if he had not already done so. In several of the most clouded cases, this procedure was insufficient to orient them to the test situation. They were then told that they would be touched on the skin and were to indicate where they felt the sensation. If the patient did not at any time report two stimuli, he was specifically questioned, toward the end of the test series, as to whether any other stimuli other than those reported were felt. This was usually unnecessary as most patients reported two simultaneous percepts at some time during the test. If the patient became drowsy and lost contact, he was repeatedly roused and the test instructions repeated.

In patients whose verbal reporting was confused by rambling, disconnected speech and extraneous associations, a localization could often be obtained by asking the patient to point to the spot stimulated.

The recording of responses was not begun in the more clouded cases until the patient was sufficiently cooperative and oriented to the examination to give a minimum of 20 consecutive responses. When defects in sensation were noted on the day of anaesthesia, the examination was repeated on subsequent days until responses showed the normal adult pattern, i.e., correct localization of two simultaneous stimuli.

The first few stimulus combinations were made to the face and hand as follows: (1) face and contralateral hand, (2) opposite side of the face and contralateral hand. Then the homolateral face and hand were stimulated on each side. Following this, other parts of the body were stimulated, such as face-face, hand-hand, shoulder-hand, etc., always returning to the face-hand combination.

When the extinction phenomenon is observed the part of the body where the stimulus is felt has been defined as dominant to the part where the applied stimulus is not perceived.

Results
All of our patients showed these effects on the initial trial, which will be considered separately from subsequent multiple trials.

Response on Initial Trial.—On the initial trial, which was always the "face-hand test" (one cheek and contralateral hand), 33 of the 34 patients reported the face stimulus, but not the stimulus applied to the hand. The single exception was an unusually alert patient who had recovered to the extent that she had no obvious mental changes. She reported the face stimulus and stated that she "was not quite sure if there was another one on the hand". She demonstrated obscuration of the hand stimulus as opposed to the extinction of the hand stimulus seen in the other 33 cases.

Thus, in this group of 34 patients in varying stages of recovery from general anaesthesia the incidence of face dominance was 100% on the initial trial of the "face-hand test".

Response on Subsequent Trials.—The examination continued for 20 to 50 trials per test period, or until responses were consistently normal. There were eight patients who gave a correct response to the "face-hand test" within the first four trials, and consistently correct responses thereafter, i.e., a normal adult response to the test. They tended to be the most cooperative, alert, and best oriented of the subjects. This correct response to the test
within four trials has been shown in a previous study to occur in 90% of normal adults (Bender and others, 1950).

There was another group consisting of seven patients who gave extinction or displacement responses for a greater number of trials, followed by occasionally correct responses, and finally consistently correct responses. This occurred within five or 10 minutes, i.e. within the first test period. It has been emphasized that the normal adult may make errors on the first few trials of the "face-hand test", but suddenly becomes aware of the aspect of "two-ness" of the test. From this moment in the examination, marked by the first awareness of the existence of the second stimulus, the normal adult is consistently accurate in his report of the two stimuli. Thus, these seven patients constitute a borderline, but nevertheless abnormal group inasmuch as their awareness of the double stimuli was still followed by extinctions or displacements, in contrast to the normal.

The remaining 19 subjects continued to show extinction and displacement responses throughout the first test period, 20 to 50 consecutive trials over a period ranging up to 20 minutes. These 19 subjects showed the severest mental changes following anaesthesia, and it was in this group that the defect in perception sometimes persisted for more than 24 hours.

The time of the first test period ranged from one to seven hours after the patient was returned from the operating room. In general, the severity of the perceptual defect depended upon the length of time elapsed between cessation of anaesthesia and the first examination. The longer the interval, the less the probability of abnormal responses. This was a general trend. However, there was considerable overlapping in speed of recovery from patient to patient, probably due to a host of factors, such as depth of anaesthesia, age of patient, variation in preoperative medication, narcotics given postoperatively, amount of pain being experienced during testing procedure, personality and cooperativeness of patient, etc. A tendency for the older patients to recover more slowly was observed.

In six patients whose course of recovery was slow, the test periods fell in comparable time intervals, so that the decrease in errors on the "face-hand test" may be depicted graphically. In these six cases the first test period fell within one to three hours following anaesthesia, the second from three to seven hours, and the third from 27 to 32 hours respectively. The averaged errors on the first four trials of the "face-hand test" in each test period have been plotted against the time following anaesthesia. All six patients eventually made no errors when recovery was complete. However, the anaesthetic prolonged the "learning" of the response from the few seconds required by the normal adult to many hours as shown on the graph (Fig. 1).

Phenomena of Extinction and Displacement.—The errors fell into two categories. In the first, only one of the two stimuli was felt (dominance of one and extinction of the other), and in the second both stimuli were felt, one correctly localized, but the other mislocalized (dominance of one and displacement of the other). Thirty-three of the 34 patients showed the extinction phenomenon, although in the eight who gave normal records, extinction was only observed within the first four trials of the face and hand.

Twenty patients showed ipsilateral displacement, such as from the hand to the face on the same side. Eight patients showed allesthesias (displacement of stimuli across midline to the opposite side of the body). However, the occurrence of allesthesias was rare even in patients giving this response. Ipsilateral displacement was much more common than allesthesias, and was often seen persistently throughout the testing period. Extinction was most common.

Patterns of Dominance.—When extinction was observed, the face was seen to be dominant to the shoulder, hand, and foot. The shoulder was dominant to the hand and the foot was dominant to the hand. These phenomena confirm results of previous studies. This last pattern of dominance (foot over hand) was especially striking in view of the fact that the bedclothes were never removed from the feet of these post-operative patients, the stimuli being administered to the blanket-covered toes and to the skin of the hand. Extinction of the hand stimulus still occurred more frequently.

There were occasional exceptions to all these patterns, but statistically the percentage of response which fell into the patterns far outweighed the exceptions. The pattern of face dominance over the hand seemed to be most conspicuous. Defects in the face-hand test could often be elicited long after double simultaneous stimuli could be correctly localized on other parts of the body. In this connexion it must be reiterated that the face is highest and hand is lowest in the order of dominance.

When displacement occurred the error was usually in the direction of the dominant stimulus. Again it was most frequent in the face-hand combination. The most commonly observed displacement response was on stimulation of one side of the face and the contralateral hand, in which case the patient reported percepts on both sides of the face.
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Discussion

During recovery from anaesthesia, patients have been examined by the method of double simultaneous stimulation of cutaneous modalities. Many errors are made in perception and localization of the stimuli, but it has been found that the errors are consistent and show a pattern in all cases tested. One can predict which of the two stimuli will be accurately perceived (defined as the dominant stimulus), and which will be mislocalized (displacement), or not perceived at all (extinction). Thus a pattern of dominance can be found for any two non-homologous areas of the body, and is seen most clearly when the face and hand are the areas tested. We have observed that following a prolonged period of unconsciousness, produced by a variety of anaesthetic agents in the normal nervous system, these patterns were clearly demonstrable. They occasionally persisted for a period of days. Thus, on the initial trial of the "face-hand test", up to seven hours following general anaesthesia, all 34 of our patients showed face dominance. In a previous article the incidence of face dominance on initial trial of the face-hand test has been found to vary among the different populations tested (Fink and others, in press). Results are shown in Table I.

**Table I**

<table>
<thead>
<tr>
<th>Group Tested</th>
<th>Incidence of Face Dominance on Initial Trial of &quot;Face-Hand Test&quot; (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal subjects (above age 12 years)</td>
<td>48</td>
</tr>
<tr>
<td>Normal children (age 7 to 12 years)</td>
<td>47</td>
</tr>
<tr>
<td>Normal children (age 3 to 6 years)</td>
<td>82</td>
</tr>
<tr>
<td>Organic mental syndrome</td>
<td>90</td>
</tr>
</tbody>
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It is apparent that during recovery from anaesthesia the defect in sensation, as judged by this test, is comparable in degree to that in severe disease of the brain and in very young children.

Following the initial test, eight of our patients revealed the normal pattern of response, i.e. within approximately four trials of the "face-hand test"; they localized the two stimuli correctly, and made no further errors. However, the remaining 26 patients showed a response pattern comparable to that seen in young children and in patients with...
organic psychosis. The three groups are similar with respect to the patterns of dominance and the persistence of extinction or displacement responses beyond the first few trials of double simultaneous stimulation. The difference in these three groups is that the errors in patients with mental changes due to anaesthesia last only a few minutes to hours, depending upon the severity of the anaesthesia and post-anaesthetic period.

It should be emphasized again that once a normal adult “gets the idea of two-ness” in the test, as evidenced by a correct response to double stimulation, he is remarkably accurate on all subsequent tests, even with days intervening. Yet patients with an organic mental syndrome, normal children, and the 26 of our cases showing abnormal records, still gave extinction or displacement responses following one or more correct responses to double simultaneous stimulation. That these 26 abnormal records resulted from the anaesthesia and not from disease of the nervous system is proved by the return of all patients to normal adult responses some days following the anaesthetic. Patients with organic brain disease make persistent errors on subsequent days, no matter how long the testing is continued.

Many of the patients used in this study were drowsy and therefore inattentive. We know that attention is a variable affecting our results, as well as factors of type and intensity of stimulus, timing, area tested, etc. But the assertion that inattention is an explanation of these phenomena is clearly negated by the patterns of the errors observed (Critchley, 1949). If inattention were the entire explanation, we would expect the errors to be random, so that defects would occur in face as well as in hand perception. On the contrary, they were predictably patterned, and the patterns were comparable, regardless of the degree of attention of the patient. Occasionally, more severe, yet still predictable and consistent defects, were noted in patients sitting up in bed and anxious to cooperate, than in drowsy patients who fell asleep between stimuli and begged the examiner to “let me alone.”

The significance of this study lies in the demonstration of extinction, displacement, and patterns of dominance when neural function is altered pharmacologically in adult subjects with normal nervous systems. The data reported here may be correlated with three sets of previous observations, namely the demonstration of similar phenomena in normal children with decreasing incidence as older age groups are tested; the high incidence of similar phenomena in patients with organic mental syndrome, in whom there is clouding of the sensorium (Fink and others, in press); and the pattern of face dominance seen in normal adults on the initial trials of the “face-hand test”, but the absence of face dominance on subsequent trials.

In the light of the foregoing, one might speculate that the capacity to perceive and localize two simultaneous stimuli is related to maturation of the nervous system, and that before this capacity is fully developed the patterns of dominance are clearly in evidence, as seen in children. Our results show that these patterns of childhood sensory organization are a latent potentiality of the normal adult nervous system. The variety of drugs found to be capable of eliciting these patterns are all in the class of general anaesthetics. All are known to act upon the central nervous system in such a way that the “higher psychic functions” and state of consciousness are predominantly affected.

Henry Head stated that “should the disturbing agent exert a universal effect, as is the case with chloroform, one function after another disappears in order, beginning with those of highest rank and culminating with the most mechanical and pre-ordained response” (Head, 1923). He also noted that regression and recovery of function traverse the same steps, but in opposite directions (Head, 1926). Thus, the organic mental syndrome is one of the earliest effects of the administration of a general anaesthetic and one of the last effects to disappear during recovery. Correlated with this alteration of consciousness is the appearance of normally inconspicuous patterns of perceptual organization. In a sense the maturation of perceptual function has been transiently reversed, a so-called “regression”. Pharmacological interference with the most highly integrated levels of function leaves the more basic patterns of organization functionally isolated. This is in keeping with Jackson’s (1887) concept of levels of integration in which the breakdown of “higher” integrative functions results in a release of “lower” types of organization.

Summary

When two simultaneous stimuli are applied to widely separated cutaneous areas one of the stimuli may not be perceived (phenomenon of extinction), or may be perceived but mislocalized (phenomenon of displacement).

Phenomena of extinction and displacement have been elicited in subjects who show no disease of the nervous system, as temporary findings during the course of recovery from various general anaesthetics.

Patterns of sensation described in previous studies of patients with organic mental syndrome,
of normal children, and of normal adults have been confirmed.

The existence of these patterns has been demonstrated in a transient, pharmacologically induced alteration of neural function.

REFERENCES


Fink, M., Green, M., and Bender, M. B. Neurology (in press).