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VISUAL-LIMBIC DISCONNECTION SYNDROME OF THE NON-HUMAN PRIMATE WITH THE EXPERIMENTAL BRAIN LESION

—SOME ASPECTS OF THE KLÜVER-BUCY'S SYNDROME WITH SPECIAL REFERENCE TO THE GNOSTIC ABILITY—

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ABSTRACT

The adult male monkeys (macaca fuscata fuscata) were used in this study. After ecological behavioral observations on three selected pairs, bilateral temporal lobes of the dominant monkeys were removed and submissive ones were operated with only exploratory craniotomy for the control study. Subsequently, the behavioral changes were observed individually and in the each same pair. Individual behavioral changes of the bilateral temporal lobectomized monkeys were those of the Klüver-Bucy's syndrome. Changes in pair suggested the "socio-agnostic" behavior.

Selected one of the operated dominant monkeys with persistent Klüver-Bucy's syndrome, psychometric examinations mediated visually, were performed to elucidate the mechanism of the agnostic behaviors which were observed ecologically, which was the main purpose of this study. The various visual discriminations (of color, form, size and brightness) were tasked on the bilateral temporal lobectomized monkey under proper conditionings with comparison to the sham-operated monkey as the control monkey. Eventually, the bilateral temporal lobectomized monkey could not learn the tasks after even 200 trials each, while the control monkey was able to reach to the criterion (20 consecutive correct responses) finally. The essential factor of the agnostic behaviors seem to be settled on the dissociation of the limbic function from the visual function.

INTRODUCTION

Klüver and Bucy's classical article on "Psychic blindness and other symptoms following bilateral temporal lobectomy in rhesus monkey", which appeared in 1937, has undoubtedly been the stimulus for an unprecedented interest in the neurological basis of the study of behavior[1]. They observed the following results that make up the Klüver-Bucy's syndrome[2];

(1) Visual agnosia (psychic blindness)

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The animal appeared to have lost the ability to recognize and to detect the meaning of the animate and inanimate objects on the basis of visual criteria alone. It seems that the animal can no longer rely on visual cues for detecting whether the object is edible or even dangerous.

(2) Oral tendencies

There appears an extremely strong tendency to examine all objects by mouth. Such an oral tendency consisted of putting the object into the mouth, licking, biting, chewing, touching with lips and smelling.

(3) Hypermetamorphosis

There is a very marked tendency to take a notice of and attend to every visual stimulus. Moreover, the animal, as if under the influence of some irresistable impulses, tends to touch every object in sight.

(4) Changes in emotional behavior

There is a diminution, or even a complete absence, of emotional responses in the sense of that there are no, or practically no, stimuli capable of eliciting the motor, vocal, and other forms of behavior that are generally associated with anger and fear reactions. Without hesitation the monkey approaches every animate or inanimate object, even an alive snake or objects which used to call forth extreme excitement, avoidance reactions or other forms of emotional behavior before the operation. The facial expressions of emotions are often entirely lost.

(5) Changes in sexual behavior

There is a striking increase in sexual activity and in the diversity of sexual manifestations.

(6) Changes in dietary habits

Following the operation, the monkey will accept and eat large quantities of kinds of meat offered. Furthermore, there may be a striking increase in appetite and food consumption.

The differentiation of more specific behaviors or emotions from diffuse excitement may be an ontogenetic process. One of the major concerns of those who experiment on the neurology of behavior or the physiological psychology seems to be how to take the Klüver-Bucy's syndrome apart[3]. Although it should be noted that many of the features of the syndrome were described in 1888 by Brown and Schaeffer[4], it was firstly suggested experimentally by the findings of Klüver and Bucy, following bilateral temporal lobectomy (neocortical and deep rhinencephalic structures) in the macaca mulatta that cortical mechanisms in vision extended beyond the limits of the striate cortex[5]. In other words, they observed psychic blindness or visual agnosia. Later, it was found that certain temporal lesions, which did not interfer the optic radiation, produced the impairment of visual discriminations[6][7][8][9]. Apparently, it occurred without producing analogous impairment in other sensory modalities[10][11][12].

Furthermore, the researchers in the field of the non-human primate ecology are dealing with unfolding the problems that there are many communicational expressions among the monkeys[13][14][15][16][17].

This study was undertaken to elucidate some of the gnostic elements of the Klüver-Bucy's syndrome in a communicational aspect and to explore the impaired neurological mechanisms of this syndrome.

MATERIALS AND METHODS

In this experiment, eight adult male monkeys (macaca fuscata fuscata) were used. Ages varied from 4 to 7 years old and weights varied from 7.0 to 16.0 kg. Behaviors of each monkey were observed individually and in pair before and after the operation. In pair, the superior-inferior rank relation-ship was clearly observed with the distinct attributable behavioral patterns after some observational time. This observational procedure on the non-human primate was used as "the confrontation test" by the non-human primate ecologist of the macaca fuscata when it is decided that which individual is dominant socially[15]. After pronounced dominant-submissive behavioral patterns revealed, the dominant one in pair was chosen as the bilateral temporal lobectomized monkey. The submissive one was subjected to the sham-operation as the control monkey. The operation was made under aseptic cares using the intravenous Nembutal anesthesia (averaging 25 mg/kg of body weight) in one stage or two at an interval of 7 days between the operations and the removals of temporal lobes were intended to be bilaterally symmetrical. The animal was positioned on the surgical table in supine and the head was turned laterally according to the operative side. A vertical straight incision was made upwards over one temporal bone, extending to the frontal bone at the midpoint of the zygomatic arch. The incised scalp was opened with self-retraining retractor anteriorly and posteriorly, and a trephine opening of the burr hole, 3 cm in diameter, was made as inferior as possible. The sham-operation was designed to this stage. Then the dura mater was opened in a cruciate fashion and with the use of Labbé's vein and the point which the central sulucus meets sylvian fissure as the landmark[18], the anterior temporal lobes, mainly the TG-area (temporal polar) and the TE-area (lateral-ventral temporal) of von Bonin and Bailey[19], was aspirated through a small suction tip. Bleeding was controlled with light coagulations. The bony defect was left uncovered by dura mater to serve as decompression for postoperative brain swelling. As one monkey died 5 days following operation, it was omitted from this study. After the completion of the experiments, the monkeys were sacrificed with an intravenous overdose of Nembutal. The brains were fixed by a 10 per cent solution of formalin and embedded in celloidin. The embedded blocks which contained lesions were sliced in 50 μ thickness serially in the coronal plane and every tenth section was saved and stained with cresyl violet and luxol fast blue for anatomical observation of the size and the site of the surgical lesions. The bilateral temporal lobectomized monkeys are called Case No. 1, No. 3, and No. 5, descriptively, while the corresponding sham-operated, submissive monkeys are called Case No. 2, No. 4 and No. 6, respectively. Behavioral observations were made for two years on the No. 1 and No. 3, and on the No. 5, for three years.

In this study the main interest is focused upon the various visual discrimination tests which was tasked on the No. 5, 3 years after the operation.

RESULTS

Individual and social behavioral changes of the bilateral temporal lobectomized monkeys were demonstrated in 16 mm motion picture and were presented to the 17th General Assembly of the Japan Medical Association in April of 1967 by Iwata, K., Usui, K., Ando, Y., Kawai, M., and Tsumori, A.[17] and will be described in detail by Iwata, K., *et al.* in other articles.

In this paper, I describe those behavioral changes in brief. All the bilateral temporal lobectomized monkeys (from now on, abbreviated as "the temporal monkey") showed that of Klüver-Bucy's syndrome except for the hypermetamorphosis in the sense of "stimulus-bound" (Klüver; 1952) and changes in dietary habits. The postoperative recovery of the syndrome was observed in an attenuated form in the temporal monkey, No. 1 and No. 3, as Klüver stated (Klüver; 1952)[20] but at the more earlier stages. The temporal monkey all showed a strong tendency to approach to animate and inanimate objects without hesitation. Without fear they approached to an alive snake or a lighted candle (Plate 1 and 2). Also, they became extremely tame or docile and did not display any attacking expressions such as an aggressive threat face with a backing-threat to observer's frightenings (Hinde and Rowell; 1962)[14] (see Plate 3). These monkeys were extraordinarily aggressive preoperatively. Furthermore, they exhibited no emotional reactions to a monkey's skin which provoked a fear-response before the operation and showed the hypersexuality either in true means or in a homosexual attitude. As regards to the hypersexualism, however, there remains a lot of questions to explain it unless endocrinological investigations are made in this respect, since a kind of friendly behaviors are intermingled.

Considering about observations on the each selected pairs, though apparent stereotyped movements and postures are variable to some extent and even if they are useful in communication, this variability must be limited. So, checked behavioral patterns involved abstraction of those features which recurred with reasonable consistency one occasion to another. As previously stated, when two monkeys are put into the same pen and are confronted with each other —the confrontation test—, the order between two monkeys are firmly settled with different attributable behavioral patterns after facing for a moment or after some strugglings when their powers are close (Kawai, M.; 1964)[15]. For example, the dominant monkey takes exclusively an offered peanut with attributable behavioral patterns and this relationship is usually kept on at the next meeting. But on confrontation after the dominant monkey was operated, the dominant one-the temporal monkey-became not to be able to recognize the opponent meaningfully and the observed movements suggested that the temporal monkey was agnostic in communication, *i.e.* the promised symbolization was lost. Thus, we inclined to conclude that the nature of those relationship might be called as "socio-agnostic" (Iwata, K. *et al.*; 1966)[22]. The basic factor of this behavior seems to be situated in the loosening of the discrimination and recognition in the superior-inferior relationship among the monkey troop.

In this paper, as previously stated in the introduction, the main purpose is focused upon elucidating the mechanism of behavioral changes of the bilateral temporal lobectomized monkey especially on those agnostic components. Thus, for the purpose of making up for ecological observations which was briefly mentioned above, a kind of the psychometric procedures was undertaken: various visual discriminations were tasked on the bilateral temporal lobectomized monkey with persistent Klüver-Bucy's syndrome[23].

The detailed methods of examination of the visual discrimination test

The test was tasked on the temporal monkey, No. 5, three years after the operation with comparison to the control monkey. At the tasked stage, the temporal monkey kept abnormal behaviors essentially unchanged. The animal apparently did not lose his taming-effect to be handled easily without aggressive expressions and had lost still an escape-response from fear-motivated objects such as a monkey's skin (Plate 3). The animal also displayed peculiar expressions to the control monkey in pair. The temporal monkey allowed the control monkey to behave like a dominant one, for example, an offered peanut was occasionally picked up by the control monkey, while the temporal monkey did not display any attacking behaviors. Furthermore, the temporal monkey approached and muzzled to the control monkey with an expressionless feature, while the opponent showed defensive expressions such as an scared grin face with squeaks (Plate 4).

The visual discrimination tasks were done in an experimental room isolated from the group-cage using a modified Wisconsin General Test Apparatus (WGTA), while the room was designed so as not to distract a monkey's attention by means of proper masking of noises[24]. Before the experiment, some preparatory devices were made for habituating manupulatory manners to be demanded for the actual testing. Both the control monkey and the temporal monkey were gradually habituated to take a bait from a well covered partially or completely by a three-dimensioned stimulus-object. The wooden tray which have a well in the center, is movable on rails. Later, this tray was changed with another one which had three wells (Plate 4). This maneuver was devised so as to avoid getting into the positional habits in the actual testing. Between the investigator and the caged-in monkey there are two sheets of one-way vision screens to be able to lift up and down separately or simultaneously. The tray which is illuminated properly and situated between two screens are within reach of the animal. The investigator can observe the monkey through the one-way vision screen while lifting up the another screen in front of the cage. The latter screen is kept elevated until the animal uncovers the stimulus-object and takes a bait from the well. Responsive time is measured. In the meantime, a well is baited in and is covered with a stimulus-object. Thus, the two monkeys gradually habituated to correct manners and responded quickly after repeated trials (forty trials a day). It needed about four days in the control monkey and two weeks in the temporal monkey. The control monkey almost always responded within three seconds after lifting up the screen at the end of the habituation. On the contrary, the temporal monkey habituated more gradually to correct manners and responded fluctuantly with occasional self-induced violent behaviors: the animal crouched absent-mindedly for some intervals and abruptly shaked the cage violently for a few minutes. At the later stage the fluctuation waned but the animal did not always respond quickly. Through final fifty trials, the average responsive time was about ninty seconds. So, in the actual testing, the displayed-time of the paired discriminanda was limited in two minutes and the intertrial interval or pause was made for ninty seconds, respectively. Thus, the actual testing was begun using the tray which has two wells, one in the right and the other in the left, and various paired stimulus-objects (discriminanda) were placed in each well, one of which contained a bait and the other did not. The animal faced to uncover one well for which he desires, and he has only one chance to obtain a bait. When one chance is tried, successfully or unsuccessfully-rewardedly or unrewardedly, the screen in front of the cage is lowered immediately and a trial is made so strictly that the monkey cannot touch two stimulus-objects at one exposure. If the animal does not respond within the limited responsive time, the screen is decided to be remained raised until a response can be obtained. The paired discriminanda are designed so as to differ in color[a], form[b], size[c], and brightness[d] as Plate 5 shows. In the typical visual discrimination experiment, the animal is required to make responses to the right or the left of the tray and the investigator must present the positive stimulus either on the right or on the left of the tray according to some "random" or "chance" order. Usually these presentation series contain an equal number of rights and lefts, and only typical exception is when the animal shows a definite position habit. But other various chance factors such as habits of alternation may result in a high correct score (Gellermann; 1933)[25]. In this experiment, each monkey is naive to a kind of this tests and the arrangement of paired stimulus-objects, *i.e.* the manner of reinforcement, was made after the model of Gellermann's series[25]. As the positive reinforcement, commercial raisins were used since the food maintains the favourite tendency of the monkey more continuously than the other[26]. As mentioned before, the preparatory habituation determined the displayed-time of the discriminanda for two minutes and the intertrial interval is ninty seconds, respectively. Forty trials a day were tasked on an individual monkey and the animal was kept hungry for twelve hours before the test. The learning formation of each visual discrimination was judged from the fact that the animal made twenty consecutive correct responses. The tasks were made in the following order considering their facility (Pasik *et al.*; 1960)[27].

1) "color" discrimination
2) "form" discrimination
3) "size" discrimination
4) "brightness" discrimination
5) reversal "color" discrimination
6) successive "form" discrimination ('GO' or 'NO-GO' discrimination)

Results of the each discrimination test

(1) Color discrimination (Fig. 1)

In this discrimination, a blue-colored cup was always rewarded and a red-colored cup was made negative. In the beginning, probably, as the situation was changed in comparison with the preparatory habituation, the control monkey hesitated and the responsive time was slightly longer than in the habituation. But after then, the animal responded quickly and showed correct answers consecutively after sixth blocks of the trial as shown in Fig. 1. In Fig. 1, the upper diagramm shows the result in the color discrimination. The vertical axis shows the short total of the correct responses in five trials (one block) and the horizontal axis shows the number of blocks. The learning course of the control monkey was plotted by each block and was lined continuously. That of the temporal monkey was shown in the broken line. CM means the control monkey and TM means the temporal monkey. Correspondingly to the upper diagramm, the course of changes of the responsive time was plotted by each the average of one block in the lower diagramm. No connection between two dots or broken lines mean that no response was obtained within the limited

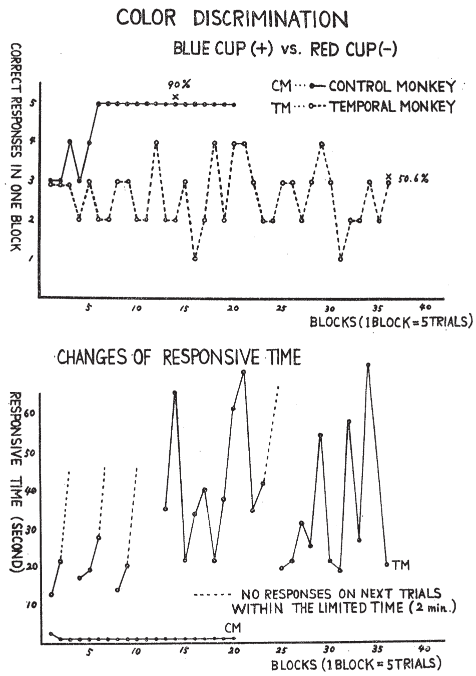

FIG. 1

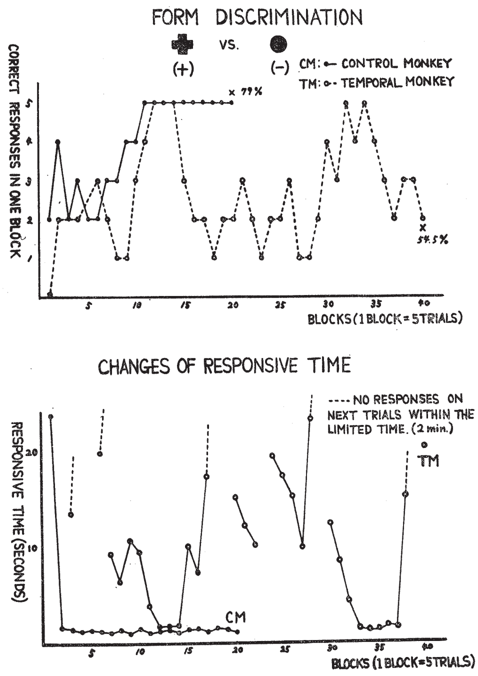

FIG. 2

responsive time (two minutes). But a response was obtained within ten minutes in maximun in such an occasion. These occasions were most frequently observed in the beginning of trials in the temporal monkey. The other figures presented later which shows the results of other tests, were similarly diagrammed as in the Fig. 1. The rate of the correct answers is ninty percents of success in the results. Contrary, the temporal monkey, No. 5, showed some delay in reaction when the stimulus-objects were displayed and sometimes did not respond with the limited time as the Fig. 1 shows.

In this discrimination, the temporal monkey had spent even ten minutes in maximum for a trial. The total correct score at the end of this test fell in almost chance-level (50.6%). Furthermore, responsive time was very fluctuant and the animal sometimes remained crouched indifferently for a few minutes without any attention to the displayed discriminanda. Apparently, the temporal monkey was poorly adaptable to the changed test-situation, while at the completion of the preparatory habituation, the animal responded in sequence within the limited time.

(2) Form discrimination (Fig. 2)

In this discrimination, a black cross-shaped plate was rewarded and a black round-shaped plate was made negative. This task seems to be slightly more difficult than the previous one. The control monkey made frequent erroneous responses until he reached to the criterion. And at the first block, the influence of the previous testing was revealed in the responsive time. During first five blocks the animal often hesitated to obtain the positive reward and sometimes started a self-grooming, being ignorant of the displayed stimulus-objects. Generally, the responsive time was slightly longer than the previous one. On the other hand, the temporal monkey responded in a similar fashion as in the previous task and the previous experience did not influence on the reaction.

Any learned tendency was not observed. But between the twelfth and fourteenth blocks, peculiarly, the animal answered correctly and in sequence, while the corresponded responsive time was extremely shortened. At these trials, the animal behaved with a very alert face like a strange monkey. These temporary arousal reactions were observed at the later blocks and the similar phenomenon is occasionally experienced when an aphasic is examined neurologically and psychometrically (Alajouanine and Lehrmitte; 1964)[23]. But in pair, the animal did not show any alerting expressions to the control monkey. After some correct responses as the Fig. 2 shows, the correct responses decreased sharply and then ran fluctuantly, being attested by irregular responsive time. In the meantime, the temporal monkey often showed a hesitating behavior which discriminanda should be chosen. At the last trial of the seventeenth block the animal responded incorrectly and then abruptly shaked the test-cage violently.

This interesting behavioral patterns were occasionally observed throughout the planned various discrimination tasks but more often at the first three tests. The animal, however, did not show any attacking behavior or threatening expressions and looked rather angry by himself. The animal also did not show any aggressive behaviors when observed individually before the test. In this discrimination, the temporal monkey also could not learn the discrimination.

(3) Size discrimination (Fig. 3)

Black round-shaped plates were used. A smaller one (4 cm in diameter) was rewarded and a larger one (7 cm in diameter) was made negative. The control monkey correctly responded in sequence after seventeenth blocks but the corresponded responsive time were not so much prompt as in the previous two tasks, usually within two seconds. The animal may be slightly weary of monotonous manners but the influence of the form discrimination was not clear in the responsive time. On the other hand, the responsive fluctuation of the temporal monkey decreased considerably, while the learning-score is still in a chance-level finally. The tasked manners shows the tendency to be generalizationed or to become "stimulus-bound" gradually (Klüver; 1952).

(4) Brightness discrimination (Fig. 4)

Identical square-shaped plates were used. One was painted white and the other was painted grey with 'black' mixed in a fourth. The tray had been

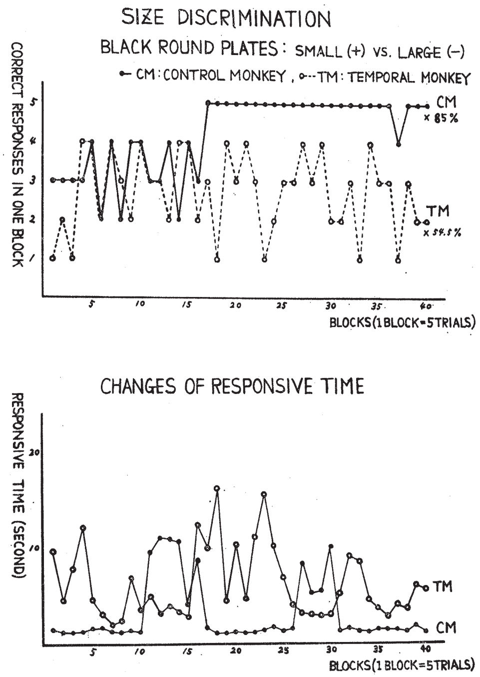

FIG. 3

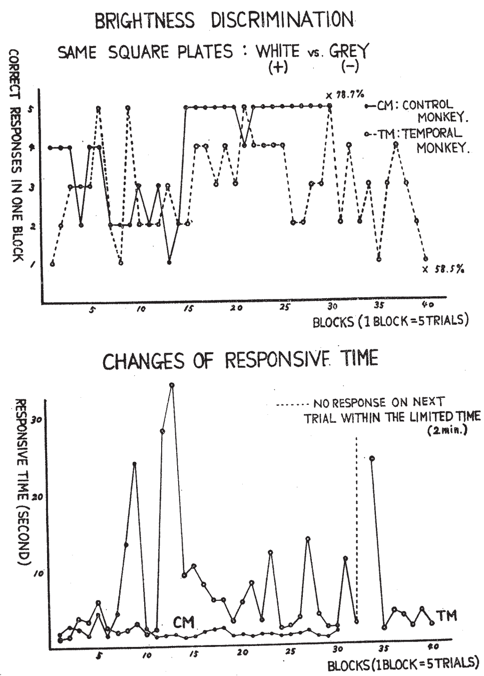

FIG. 4

painted grey but was more dark in contrast to the grey stimulus-object. A white plate was rewarded. Apparently, this task embarrassed the control monkey since much time was needed until the animal understood the discriminative nature, although the animal already learned to discriminate two different colors.

The monkey can discriminate the color-difference most easily (Pasik *et al.*; 1960)[27] but the size discrimination and the brightness discrimination seem to be more difficult as shown in the each course to reach to the criterion. Also, the learning tendency which was obtained in the previous task, appears not to be usefully transferred. The control monkey often behaved hesitatingly but the responsive time was almost uniform in contrast to the size discrimination. Self-restraint behaviors like self-grooming or crouching were more often observed in the size discrimination. The temporal monkey sometimes makes consecutive correct responses and learning scores elevated slightly. But in contrast to the control monkey, subtle transferring effects were not observed, though reactions to the stimulus-objects have tended to raise very gradually.

(5) Reversal color discrimination (Fig. 5)

This time, the previous stimulus-objects were rewarded reversely and alternatively; a red cup was always rewarded and a blue cup was made negative,

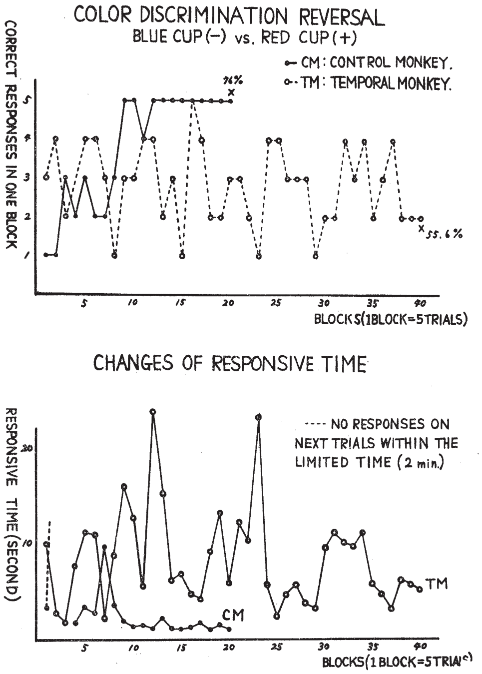

FIG. 5

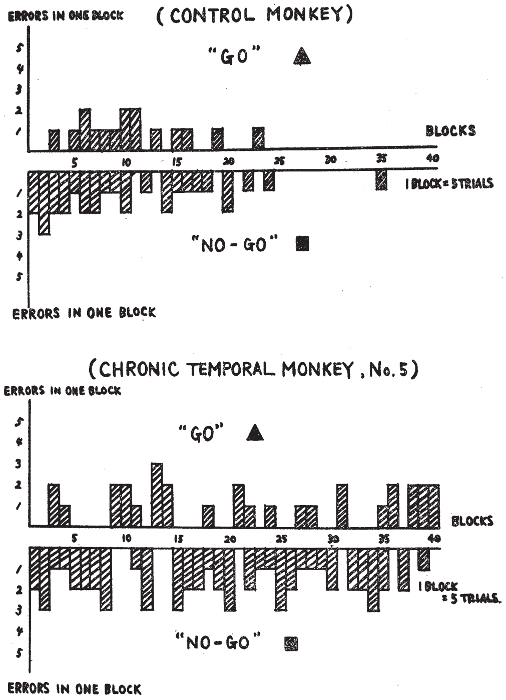

FIG. 6. Errors in succesive form discrimination.

The control monkey showed clearly that the discrimination was experienced previously and made a biased choice in the first two blocks with hesitations. But the animal learned more easily that the situation was different from the previous color discrimination with characteristic fluctuations to reach to the criterion as shown in the Fig. 5. On the contrary, the temporal monkey did not make any behaviors of which suggested that the same discriminanda were displayed previously, although the raising trends of learning scores were interrupted slightly. Being different from the previous color discrimination, the animal quickly responded to the discriminanda.

(6) Successive form discrimination ('GO' or 'NO-GO' discrimination)(Fig. 6)

In this study, unlike the previous five discrimination tests, the tray with one well in the center was used. The well was covered by one of the two discriminanda in succession randomly. So as to have an equal chance, the displaying arrangement was made after the model of Gellermann's series. A black plate of the triangle was rewarded (GO) and a black square plate was made negative (NO-GO). The animal must learn not to respond at the negative reward. Both the control monkey and the temporal monkey were responsible within one minute but this task seemed to be most difficult among the presented visual discriminations. Even the control monkey did not show consecutive correct responses until 125 trials. Since the monkey often makes a play, it may be difficult to learn to inhibit his touching desire to the stimulus-object. Nevertheless, the errors both in GO and NO-GO in the control monkey gradually decreases and eventually the animal reached to the criterion. On the contrary, as shown in the Fig. 6, the temporal monkey erred randomly in GO and NO-GO and errors seemed to occur more often in NO-GO reaction than in GO reaction. The temporary arousal reaction which was explained in the form discrimination, was also observed in this study but considering that responsive time shortened slowly discrimination after discrimination, this tendency, *i.e.* more errors in NO-GO reaction, may allude to imply the so-called hypermetamorphotic action if this change was not uncovered clearly on the ecological observations.

In brief, in all the visual discriminations presented here, the temporal monkey always stood by the chance-level in his learning-scores even after 200 trials each. Generally throughout these tests, the animal appeared to be loose in attention-directing. In the meantime, however, he behaved himself occasionally as if being indiligent in solving the problems in a sensible fashion. The temporal monkey showed consecutive correct resposes for few blocks with corresponded shortened responsive time. Also, the tame monkey which did not show any aggressive reaction or other emotional expressions to various visual stimuli, sometimes displayed a violent emotional reaction to his intrinsic conflict during the tests. In GO or NO-GO discrimination, the temporal monkey made much error in NO-GO response.

On the contrary, the control monkey could reach to the criterion (20 consecutive correct responses) finally or was able to learn the visual discrimination tasks in all.

Gross anatomical observation of the surgical lesions

The animal were sacrificed with an intravenous overdose of Nembutal and removed brains were fixed in 10 percent formalin solution. Then surgical lesions were prepared for the histological study. The cortical lesions were schematized on the map of von Bonin and Bailey (1947)[19] (see Fig. 7). The examination was done, being referred to the atlas of von Bonin and Bailey, and of Snider and Lee (1961)[29].

In the temporal monkey, Case No. 1 and Case No. 3, the removed areas of cortices were somewhat asymmetrical, left sided lesions being more posteriorly extended than the right sided ones. In both monkeys the right sided lesions were almost confined to the TG-area (temporal polar) and the TE-area (lateral-ventral temporal) of von Bonin and Bailey, while in the left, the TF-area and the TH-area (pyriform region) were also involved respectively as Fig. 7 shows.

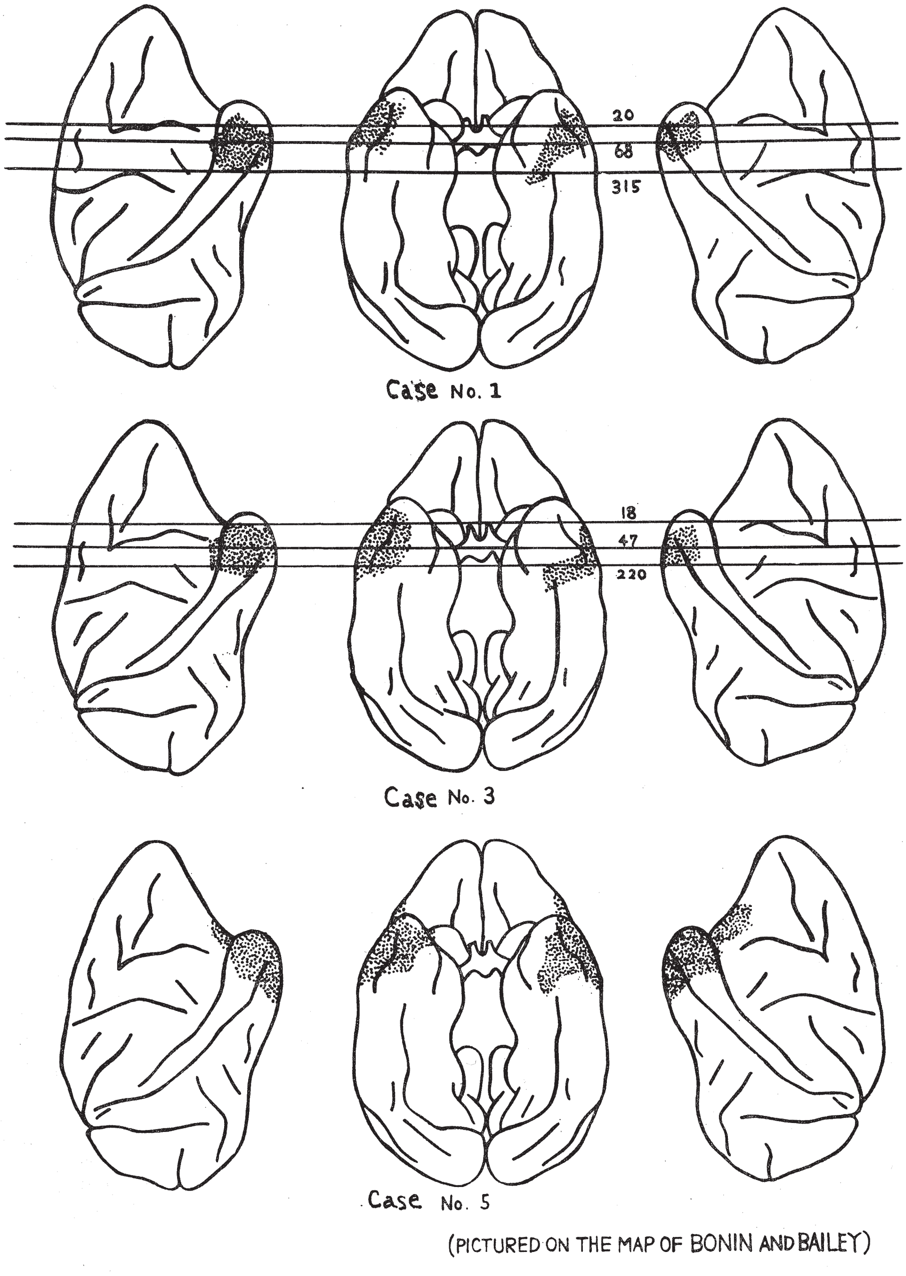

FIG. 7. Reconstruction of cortical lesions of monkeys, No. 1, 3 and 5, with selected coronal sections.

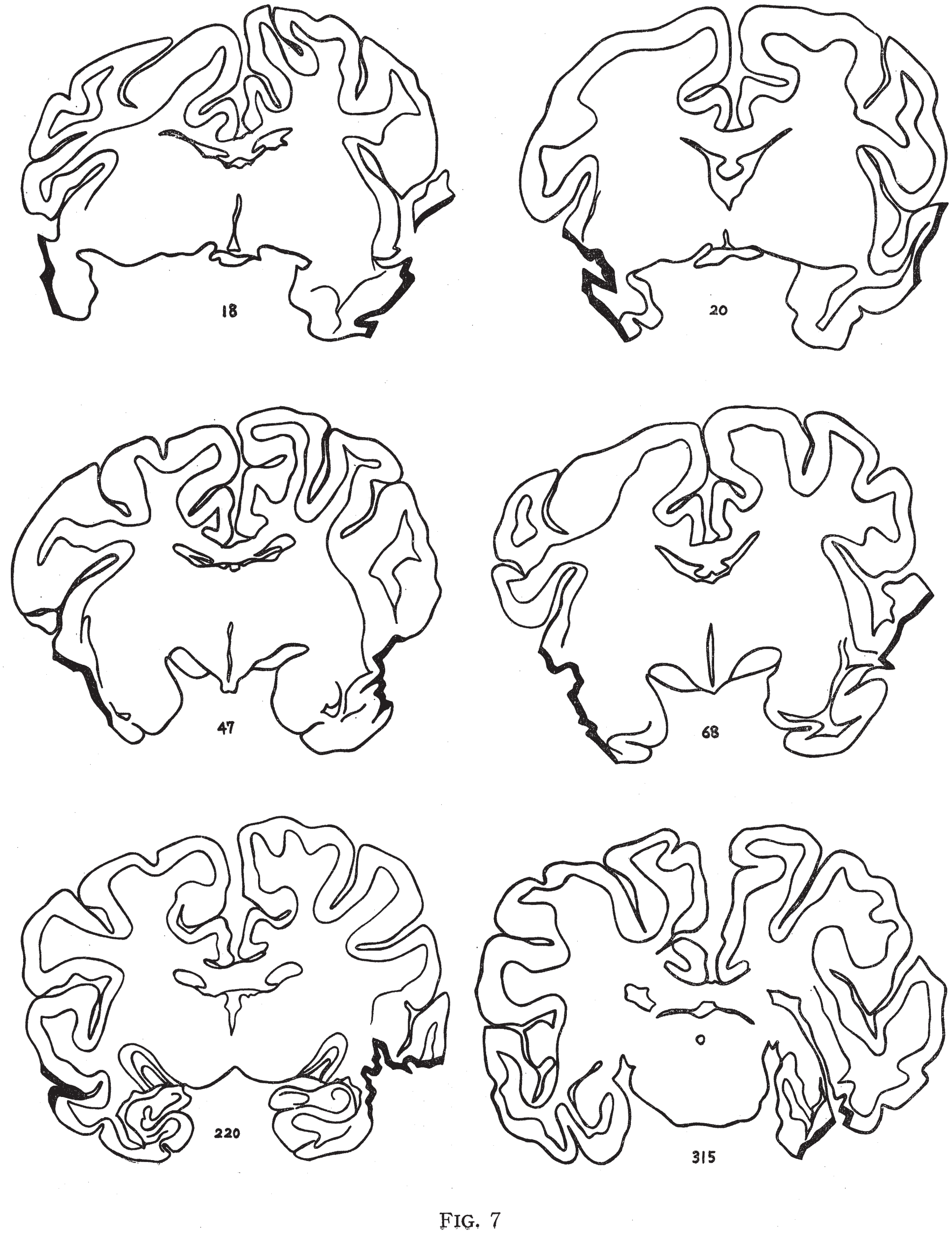

FIG. 7

In the temporal monkey, Case No. 1, the amygdaloid complex was partially damaged in the right hemisphere as the section, No. 20 in the Fig. 7 shows and the hippocampal gyrus was also involved in the left. In the temporal monkey, Case No. 3, the hippocampal gyrus was considerablly involved as the section, No. 220 in the Fig. 7 shows but the amygdaloid complex was not damaged noticeably. In both monkeys, the hippocampus was not involved. In the Case No. 1, the capsula extrema and putamen were involved with the insular region. In the Case No. 3, the extreme capsule and the putamen were involved slightly but the insular cortex were not. In the temporal monkey, Case No. 5, though the brain is now prepared for the elabolate confirmation of degenerative changes, the cortical areas were grossly symmetrical as Fig. 7 shows and involved areas were extended to the frontal areas.

In the right hemisphere, lesions were confined to the lateral frontal (FD-area), orbitofrontal (FF-area), temporal polar (TG-area), and lateralventral temporal (TE-area) regions. In the left side, the orbitofrontal (FF-area) region was not involved but the pyriform (TH-area) region was noticed to be involved. The frontal lobes were involved only superficially but the temporal lobes seemed to be damaged deeply. And rhinencephalic lesions involved appear to be most extensive in the Case No. 5 among three monkeys, being attested by the fact that the taming-effect was most persistent. The histological study presented here, will be published later in a more detailed form with the respect of degenerated changes to other structures.

DISCUSSION

In this experiment, the temporal monkey were subjected to the bilateral ablations mainly upon the anterior temporal lobes as well as the middle temporal and the inferior temporal convolutions as shown in Fig. 7, correspondingly to the TG-area and the TE-area of von Bonin and Bailey (1947). All the temporal monkeys showed that of the Klüver-Bucy's syndrome individually, although some recovery was observed on emotional changes. The recovery in two monkeys, Case No. 1 and Case No. 3, will be attributable to lesions to be almost confined to the neocortical parts without producing noticeable involvements of the rhinencephalic structures (Blum *et al.*; 1950, Klüver; 1952, and Mishkin and Pribram; 1954). And the temporal monkey, Case No. 5, showed persistent Klüver-Bucy's syndrome and could not learn the visually mediated discrimination. One of the interesting behavioral changes was the taming-effect. There exist undoubtedly some evidences that induces taming-effect besides the structures of the temporal lobes. Glees and coworkers (1950) reported that the lesions of anterior cingulate gyri produced tameness and reduction of aggressiveness which eventually lasted for two weeks and their monkeys did not show any impairment in visual tasks[30]. In the frontal lesions in monkeys (Wade; 1952, Oscar and Wilson; 1966), there is not any visual discrimination deficit without producing tameness[31)32].

Furthermore, the stereotaxic lesions of the mid-brain reticular formation in monkeys produced a confusional state resembled to taming-effect but the monkey in such a state could not learn even how to carry on the procedure to be needed for the tasks (Proctor *et al.* 1957)[33]. Bilateral hippocampectomy also produced the taming-effect with no other elements of the Klüver-Bucy's syndrome but no persistent impairment of acquisition or retention in the operant conditioning of lever pressing was observed (Gol *et al.*; 1963)[34]. So, the taming-effect produced by the temporal lobe lesions seems apparently to be different from that which produced by other parts of limbic structures or of the mid-brain reticular formation. The long-lasting taming-effect in the monkey, Case No. 5, is probably attributable to the involvement of the amygdaloid complex (Weiskrantz; 1956, Schwartzbaum; 1964, 1965)[35)36)37]. Therefore, there is a question: does the taming-effect occur due to the single reduction of motivation and also, is the visual discrimination impairment attributable to it ?. By Douglas (1966), the amygdaloid complex is postulated to be a vital substrate of an attention-directing system in which the probability of attention to a stimulus is increased as a function of reinforcement. This system is basically reward-sensitive, error-insensitive and its disrupttion through removal of the amygdaloid complex is postulated to result in an animal whose behavior is now largely determined by a remaining system (associated with hippocampus) which is error-sensitive, reward-insensitive[38]. Our experimental observations are largely compatible with this postulation. There was, however, not observed the tendency to transfer training from one discrimination problem to another which was reported by Bagshow (1965)[39]. McCleary (1961) stated that it is possible that amygdaloid lesions disrupt a response tendency requiring an animal to flee from noxious stimuli (active avoidance conditioning) but have no effect on inhibition of response performance (passive avoidance conditioning)[40]. Thus, it seems that oral tendency and agnostic approaching to an alive snake are explained as the former element, while the hypermetamorphotic reaction observed in our monkey, Case No. 5, in the successive form discrimination are explained as the latter element. But Robinson (1963) observed that the amygdaloid lesions induced overarousal reaction to fear or deficit in active avoidance[41]. These reports show the motivational apathy could not be simply responsible for the learning and retention disturbances seen in visual discriminations in this experiment. On the other hand, visual discrimination impairments are observed without taming-effect in the inferotemporal lesions as Mishkin and others demonstrated (Mishkin and Pribram; 1954, Chow; 1954, Pasik *et al.*; 1960)[7)27)42].

In the respect to the social interactions between monkeys, Fulton (1954) stated that no effect on dominance rating with respect to feeding or grooming behavior could be observed when either the most dominant or the next to the most submissive animal in the group was operated upon the anterior cingulate gyrus, and of the pre- and subcallosal and medial frontal as well[43]. This observations are different from ours. Brody as well (1952), stated that after the frontal lobotomy of the monkey, the stability of the hierarchy was lost because of the diminution of the learned avoidance responses in operated low status animals with an increase in upwardly directed aggressions[44]. In Brody's experiment, the social structure was not reconstructed in its original form but the operated monkeys were not indifferent socially. Furthermore, Rosvold (1954) observed after the bilateral temporal lobectomy of rhesus monkeys, that the group situation of each monkey was reversed in hierarchy though they paid only a little attention to gross affective behaviors[45]. Except for Fulton's report, the reasonable behavioral analysis was not performed in the social interactions in these reports. The rank relationship between two monkeys which was observed strictly from the point of attributable behavioral patterns in our study, was not reversed but suggested that operated monkeys as if the animal lost their symbolization promised to the opponent—"socioagnostic" (Iwata, K. *et al.*; 1967)[17], though friendly behaviors suspectful of sexual contents were intermingled[46]. Furthermore, the temporal monkey behaved agnostically to an alive snake, a monkey's skin and a lighted candle without showing any fear reaction. The animal exhibited no limbic reactions to fear-provoking objects. On the contrary, in this experiment, the temporal monkey which was tasked on various visual discriminations, though eventually could not learn the problem, often showed the alert or arousal reactions in which time the animal responded promtly and correctly in sequence. And the learning score gradually raised only a little and fluctuation of the responsive time waned discrimination after discrimination. These observational facts may support involvements of the attention-directing system as Douglas postulated[33]. But the animal was apparently tame to visual stimuli, while he showed a violent affective reaction to an intrinsic conflict such a time when the animal made error choices consecutively after some arousal reactions as described previously. A similar fact was noticed by Akert *et al.* (1961). These phenomenon, in another words, perceptive ability is made vivid temporally with ill-humoured reactions, are sometimes observed in the manner of language disorders as an aphasic feature (Efron; 1963, Hecaen and Angelergues; 1964)[43)49]. Considering about the behavioral changes in pair, these features in discrimination tests seems to show an aspect of the communication disorders (Iwata, K. and Ando, Y.; 1967)[21].

Visual agnosia is really a dissociation between higher and lower visual functions with disruption of higher aspect (cognitive) of vision. Furthermore, in the observations of animal behaviors, both agnosia and apraxia can be conceived as a narrowing of the range of equivalence; in agnosia, restriction of response equivalence and in apraxia, restriction of stimulus equivalence (Semmes; 1953)[50]. But our animal did not show any apraxic manners in discrimination tasks and showed lack of customary reaction to familiar objects. Any cortical lesion large enough to produce symptoms has a double effect; a specific one, depending on localization and a general one, perhaps depending on size (Teuber; 1955)[3]. As a specific effect, subtle changes in primary visual function including optic radiation (*e.g.*, abnormal rapid fading) may produce a resemblance of agnosia without selective impairment of cognitive function of vision in man (Bay; 1953), but anterior temporal lesions which showed visual discrimination deficits did not always involve optic radiations (Chow; 1953, Bucy and Klüver; 1955, Akert *et al.*; 1961)[47][52][53]. As a general effect, one essential cause which may impair the comprehension of the complicated situation, namely feeble-mindedness, is liable to reduce sensible reaction to objects without sensory impairment and aphasia may act in the same manner (Bay; 1953)[51]. But Zangwill (1964) stated that an aphasic is not so poor in intelligence scales[54]. On the other hand, the deficits in visual discrimination are something more than amnesia. The animal not only lost the habits to which they had been trained before operation, but had abnormal difficulty in acquiring them (Chow; 1952, Pasik *et al.*; 1960)[47][52]. And also the defficits are specific to vision and they are dissociable from other symptoms (Teuber; 1955, Ettlinger; 1959, Stepien *et al.*; 1960, and Brown; 1963)[3][9][12][55]. The locus of the minimal sufficient lesion for visual discrimination deficit is as yet undetermined but it is apparent that nearly complete ablations of bilateral inferotemporal areas (TE-area) in the monkey produces visual discrimination deficits, and the ablations of parastriate areas of monkeys also probuces mild deficits of visual learning, while added inferotemporal ablations abolishes visual learning completely (Riopelle and Ades; 1953, Wilson and Mishkin; 1959)[56][57].

In our temporal monkey, Case No. 5, comprehension of its deficits are more complicated since rhinencephalic structures are probably involved together. Bailey *et al.* (1943) and others (Pribram *et al.*; 1950) demonstrated in rhesus monkeys that temporal polar area sent fibers to orbitofrontal area (FF-area), anterior part of the pyriform gyrus (TH-area), and the uncus (H-area) using strychinine neuronography technique[53][59][60]. And there are evidences to show that intercortical rich connections exist between the parastriate area and the infero-lateral temporal area in the monkey, ipsilaterally (Akert *et al.*; 1961, Kuypers *et al.*; 1965)[47][61]. Whitlock and Nauta (1965) found that a lesion of inferotemporal gyrus and of temporal polar region led to degenerative changes in the amygdaloid complex and in the hippocampus using Nauta-Gygax mrthod[62], and confirmed neurophysiological findings (Stoll *et al.*; 1951, Segundo *et al.*;

1955, Gloor; 1955)[63)64)65)66)]. Moreover, Nauta (1962) suggested the notion of an amygdalo-thalamo-orbitofronto-temporal organization with multiple discharge pathway to the hypothalamus, subthalamus, and mesencephalic reticular formation[67)]. Thus, it can be said that lateral-ventral temporal areas (TE-area) and temporal polar areas (TG-area) in the monkeys are to be regarded as an association cortex of the limbic system (Geschwind; 1965)[68)], while further strengthened by the fact that it is very these areas of the temporal lobes that utilize the anterior commissure (non-callosal temporal cortex), rather than the corpus callosum for their connections to the opposite structure (McCulloch and Garol; 1941, Fox *et al.*; 1941, Akert *et al.*; 1961)[47)69)70)]. Again, the temporal neocortex of anterior parts was described as the non-thalamic radiation sector (McCulloch; 1944)[71)]. These anatomical and neurophysiological observations suggest that the higher visual functions and the various limbic functions intermingle each other in the anterior temporal regions.

And the lesion in this area as seen in our monkey, No. 5, might effectively cut the pathway between the visual cortex and the limbic system and thus taming-effect could co-exist with the visual discrimination impairment and other agnostic behaviors. The hyper-oral tendency, mild hypermentamorphotic actions observed in the successive form discrimination and other behavioral changes would be a complicated release phenomenon from the amygdaloid complex, hippocampus, and other deep rhinencephalic structures.

As regards to communicational expressions, in the non-human primate, the sensory-limbic transfers could be easily settled, while in humans the cross-modal, sensory-sensory transfers are readily established and so language can develop (Burton and Ettlinger; 1960)[72)]. Therefore, behavioral patterns like the patient of a communication disorder observed in this study seem to be essentially different from human cases. Accordingly, in a viewpoint of functional study of experimental brain lesions, the symptoms may be more feasibly understood as the "Visual-Limbic" disconnection syndrome.

SUMMARY

The monkeys (macaca fuscata fuscata) were used as the experimental animal. The behavioral changes of the bilateral temporal lobectomized monkeys, which were chosen as the dominant monkey after the confrontation test, were described in brief. The individual behavioral changes of the bilateral temporal lobectomized monkeys were those of the Klüver-Bucy's syndrome and the changes in pair between the bilateral temporal lobectomized monkey and the control monkey (the submissive one on the confrontation test) showed "socio-agnostic" behaviors. For the purpose of making up for ecological observations, the various visual discrimination tasks were performed on the one monkey of

three operated dominant monkeys which had persistent Klüver-Bucy's syndrome ; it is the main purpose of this study that psychometric examinations mediated visually, seems to elucidate the mechanisms of agnostic behaviors.

Discriminations were varied in color, form, size, and brightness. Eventually, the bilateral temporal lobectomized monkey could not learn the various visual discriminations even after 200 trials each, while the control monkey could reach to the criterion (20 consecutive correct responses). The bilateral temporal lobectomized monkey, however, occasionally behaved himself as if being indiligent in solving the problems in a sensible fashion. The animal answered correctly and in sequence, while the responsive time was extremely shortened during that temporary arousal reactions. Also, the tame animal showed a violent emotional reaction to his intrinsic conflicts. These interesting behavioral changes in discriminations resemble to an aphasic feature and seems to show an aspect of the communication disorder. But there are evidences that in the non-homan primate, sensory-limbic transfers are easily settled, while in humans sensory-sensory transfers are readily established in their ontogenetic process. So, the communicational aspect appears to be essentially different from each other. Moreover, the TE-area which was involved in the animal, have been known to produce deficits of the visual discrimination without taming-effect. The consideration of anatomical and neurophysiological literatures about the anterior temporal region inclined me to conclude that the deficits produced by lesions would be more feasibly understood as a visual-limbic disconnection syndrome.

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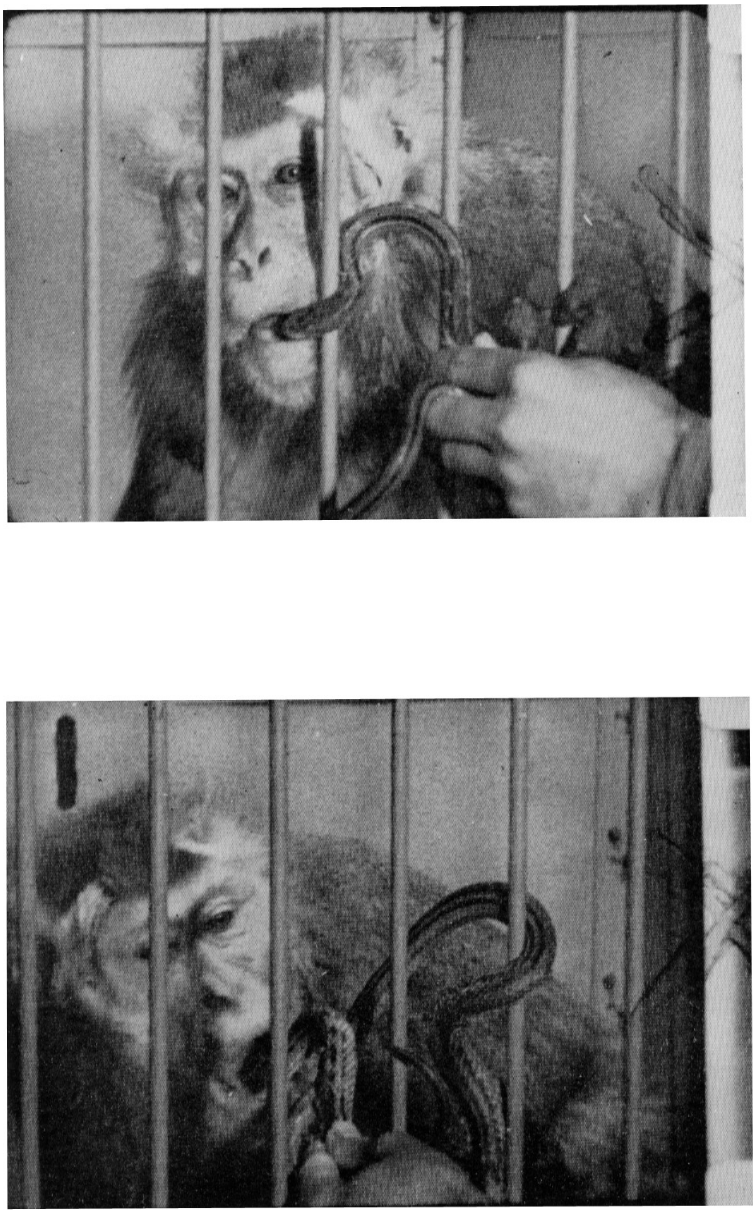


PLATE 1. Approaching to a alive snake without fear.

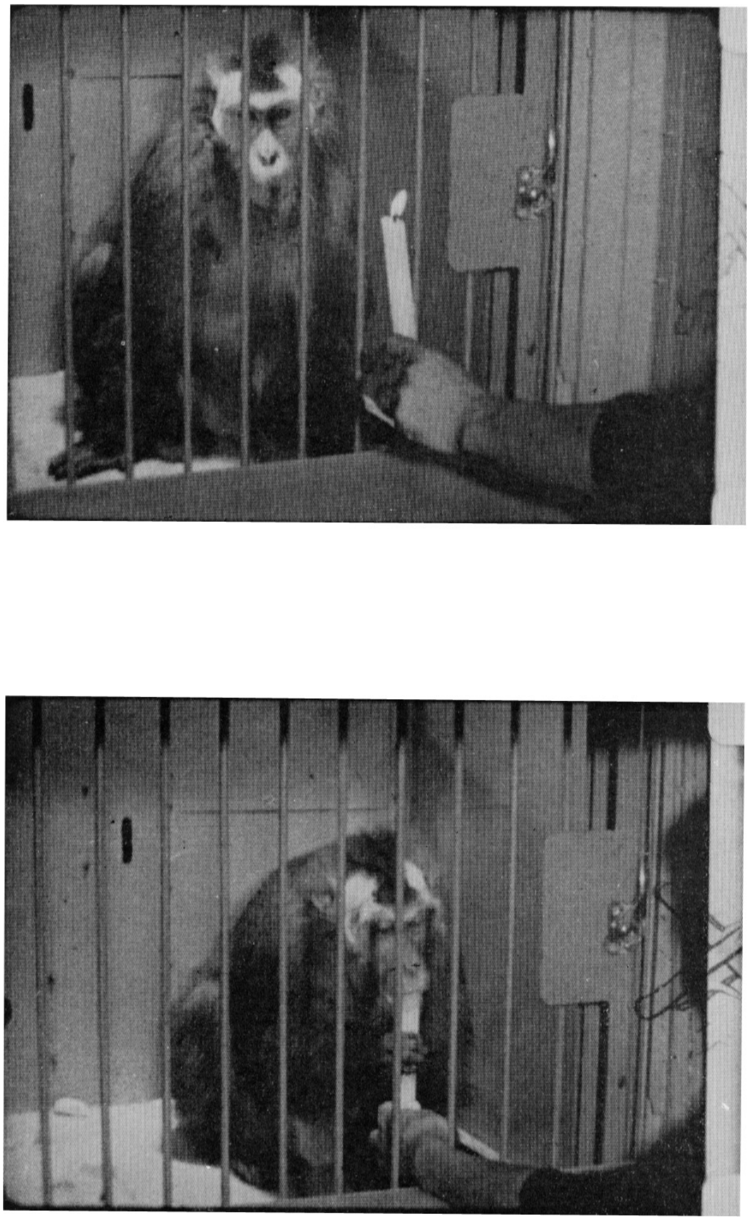
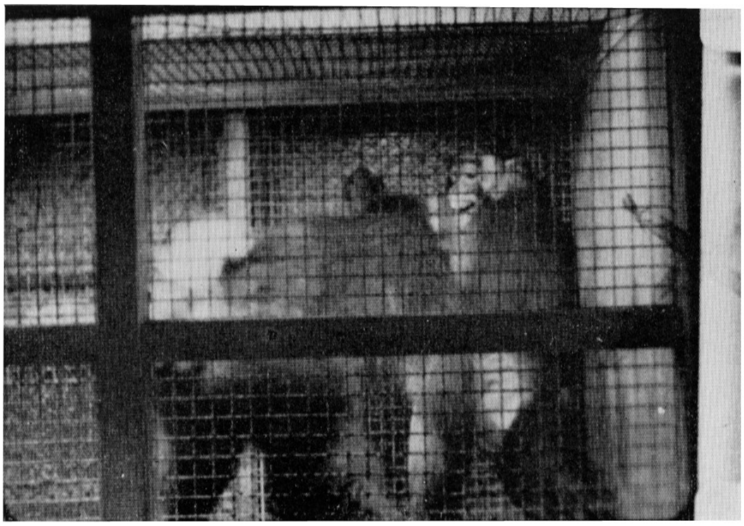


PLATE 2. Reaction to a lighted candle.

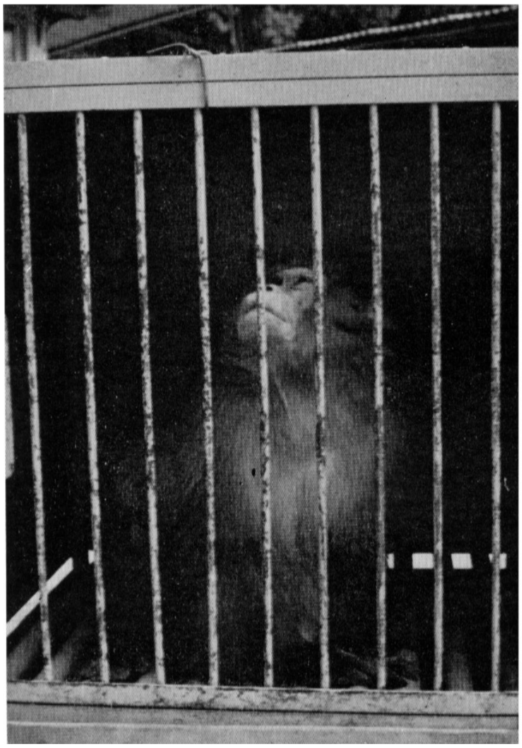
An aggressive threat face (preoperative)

Expressionless to a monkey's skin.

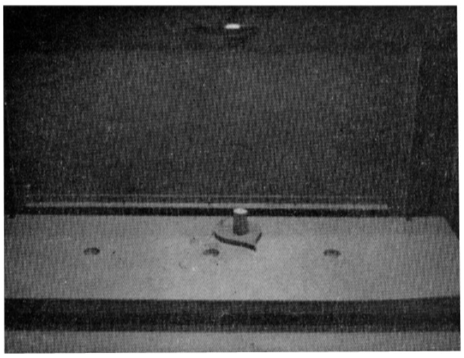
PLATE 3



A scared grin face.

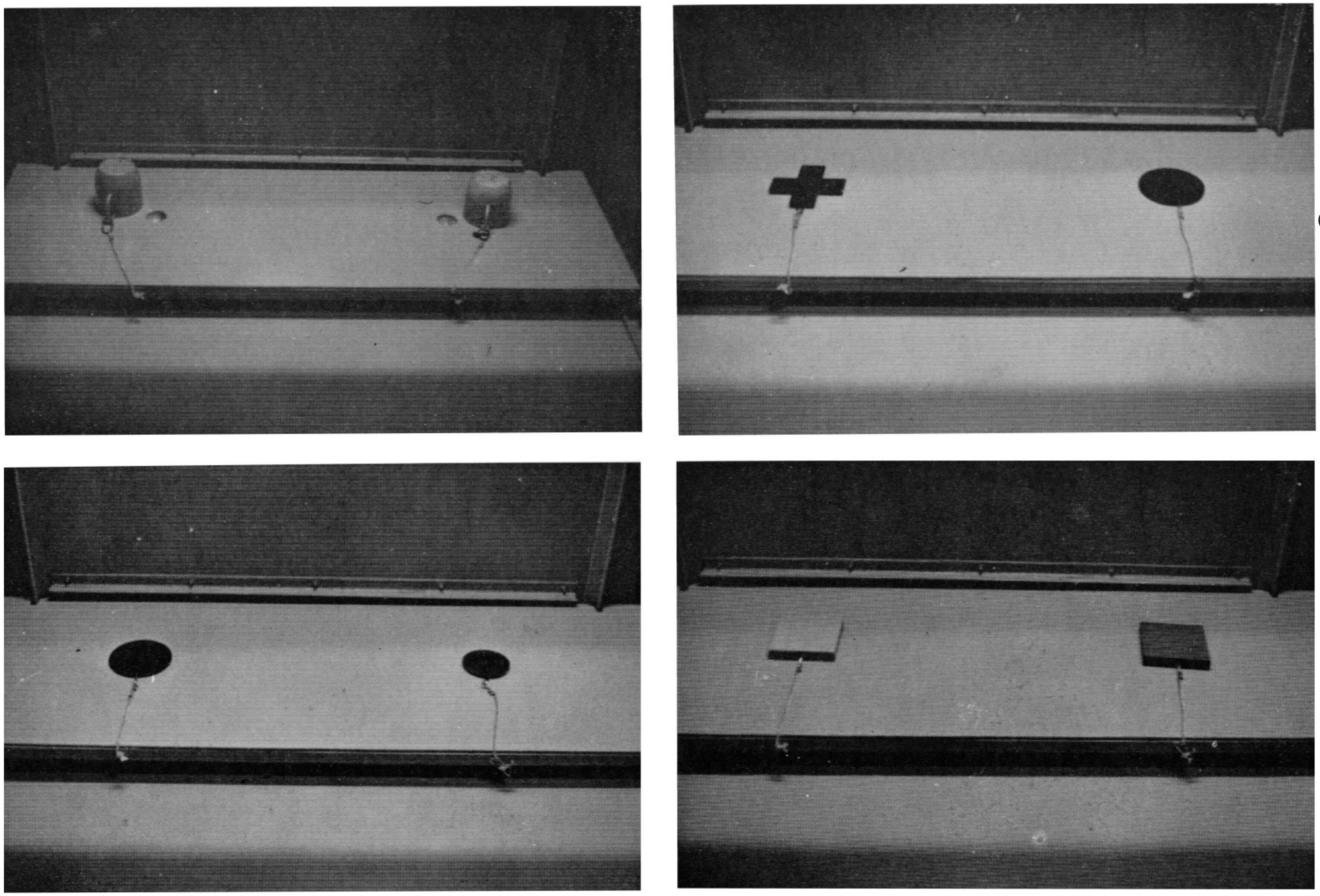


Tame and indifferent expression (postoperative).



The three-welled tray.

PLATE 4



(a) (b)

(c) (d)

PLATE 5