

Stimulus Characteristics and the Interocular Transfer of Discrimination Learning in the Forebrain Commissurectomized Rhesus Monkey*

Kazuo Hara

Midsagittal transection of the forebrain commissure fibres, or commonly called as split-brain technique, was first conceived independently and almost simultaneously at around 1920 by two great scientists; I. P. Pavlov and K. S. Lashley.

The idea did not wait its experimental implementation too long in the Soviet Union, and the interhemispheric transfer of classical conditioning has been pursued after by Anrep, Bykov and most recently by Mosidze (1968). In the United States, the idea was delivered from Chicago to Cal. Tech. by Sperry, and in the middle 1950, Ronald Myers tested split-brain cats in a Watson-type visual discrimination box. (1955)

Thus, respondent behavior by Russian dogs and operant behavior by American cats and monkeys, with helps of European rats and pigeons with spreading cortical depression, this approach has brought a tremendous contribution to our behavioral sciences. Today, we are to evaluate the therapeutic value of this technique applied to epileptic human patients.

Strangely enough, however, most of the studies on the interocular transfer of discrimination learning with split-brain animals have concerned only the degree of transfer in term of saving score or

* Paper read at the XXth International Congress of Psychology, Short Symposium: Mechanisms of Discrimination Learning in Animals and Men, on August 16, 1972.

its derivative measures. But, a question of theoretical importance is not only how much the transfer occurred after sectioning the commissure fibres, but also, which of behavioral components were altered by this treatment. As far as I know, the nature of interhemispheric transfer of learning from this point of view has been explored very little.

Although the following series of studies are methodologically fallen short in some respects, present report is made to invite criticisms in order to promote our research interests on this seemingly neglected problem.

The second goal of this presentation is to integrate various facts found in split-brain animals into a most appropriate brain model for discriminative learning.

The third goal, and probably the most challenging task of all, is to seek a common ground and the means to transform various concepts born of S-O-R psychology into those of S-R-SD psychology and vice versa.

Since the first report by Myers (1955), others have confirmed the finding that midline section of the corpus callosum and the anterior commissure fibres prevents the transfer of visual pattern discrimination from one eye to the other in chiasm sectioned animals. However, reports of studies concerning the transfer of brightness and color are still conflicting.

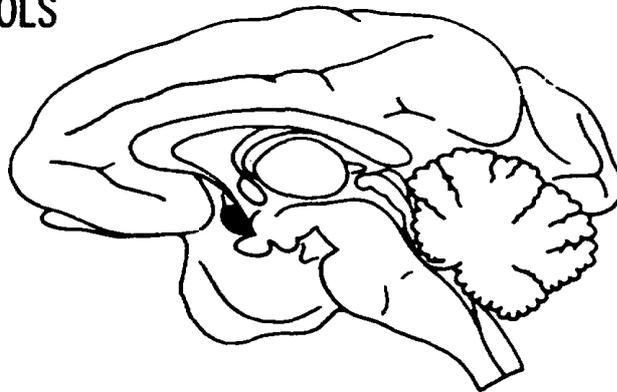
Both Downer (1959) and Hamilton and Gazzaniga (1964) who worked with monkeys failed to demonstrate such transfer, whereas others including Meikle and Sechzer (1960) in cats, Trevarthen (1962) in monkeys, and Black and Myers (1968, 1969) in chimps have reported positive evidences. The latter consequently hypothesize that, after total section of the forebrain commissures, brainstem mechanisms may function independently or vicariously in the transfer of simpler or more primitive learning such as the discrimination of brightness and color.

Therefore, the present study tried to reinvestigate this problem

paying particular regard to the question of whether the physical characteristics of the stimulus or the degree of sophistication of subjects with respect to discriminanda is more critical. Thus, five experiments (as designated) were designed to focus attention on the following variables; (Exp. 1: Reversal) original vs. reversal learning and different modes of visual stimuli, (Exp. 2: Relearning) familiarity vs. novelty of stimuli, (Exp. 3: Repeated Reversals) progressive improvement in successive reversals, (Exp. 4: Post-Training Commissure Section) interhemispheric transmission of memory trace and (Exp. 5: Sensory Deprivation) visually deprived hemisphere.

General Method

CONTROLS



EXPERIMENTALS

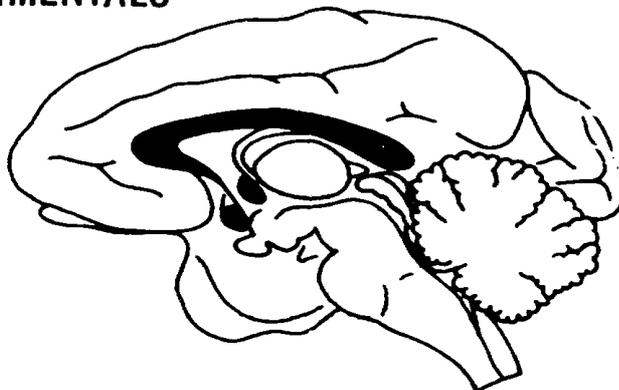


Figure 1. Loci of midsagittal section of the forebrain commissures.

The method common to all 5 experiments are described below.

Subjects Total of 34 rhesus monkeys of both sexes, all juvenile or young weighing 2.0-4.8 kg except for the last experiment which employed new-born infants, were used.

Surgery The controls (Cs) were subjected to the section of the optic chiasm only, while the experimentals (Es) were surgically separated on the corpus callosum and the anterior commissure in addition to the optic chiasm. The extents of the lesions carried out on these animals are schematized in Fig. 1.

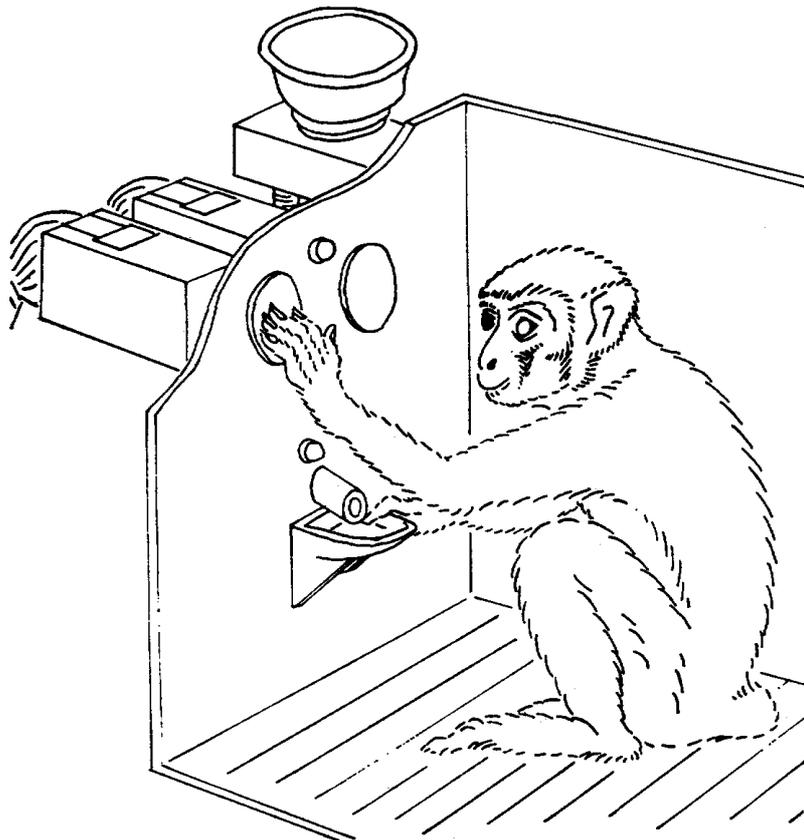


Figure 2. Visual discrimination apparatus used by the monocular monkey.

Apparatus A fully automated visual discrimination apparatus with 2 circular stimulus-and-response panels, 2 small signal lamps and a food cup illustrated in Fig. 2 was employed throughout. Visual stimuli were projected onto the panels from the outside. Correct

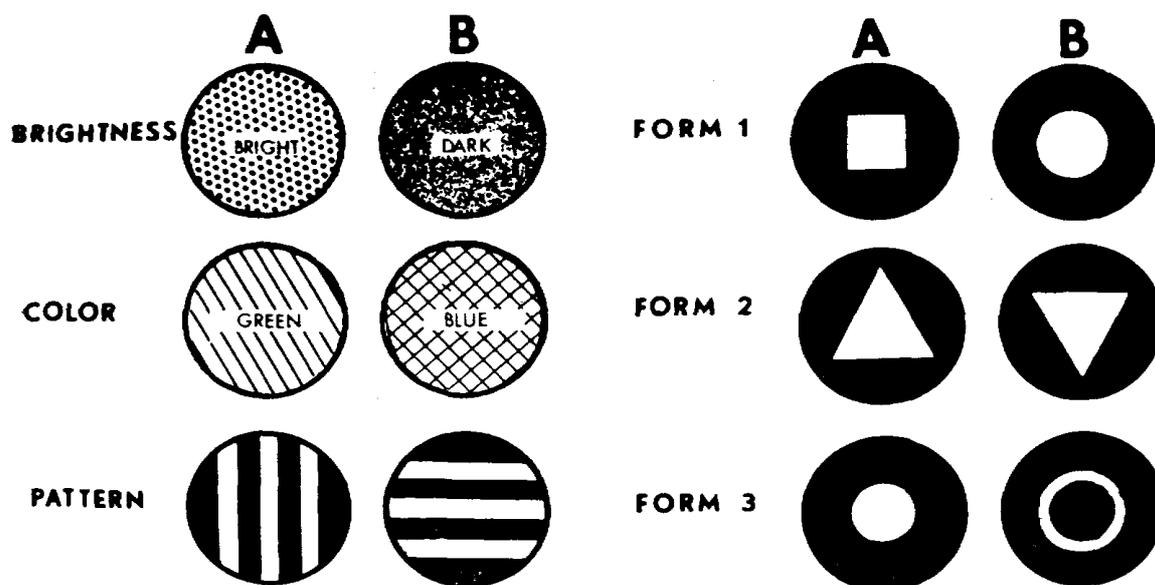


Figure 3. Stimulus pairs employed for visual discrimination and their interocular transfer tests.

responses were rewarded by sugar pellets, while incorrect responses lit the signal lamps and delayed the next stimulus projection.

Six pairs of stimuli appear in Fig. 3 were provided for the present series of experiments. They were designated as *Brightness* (bright vs. dark; gray filters of approximately 20 and 80 per cent transparencies), *Color* (blue vs. green; Kodak wratten filters of the same transparency), *Pattern* (horizontal vs. vertical stripes), *Form-1* (square vs. circle), *Form-2* (upright vs. inverted triangles) and *Form-3* (solid circle vs. ring).

Behavioral Test After acquiring adequate habits to respond to the apparatus, monocular training was attained by application of a plastic opaque eye-occluder, which was left on one or the other eye throughout the experimental period and was shifted one day prior to the beginning of next problem. Occasional application of the neomycin sulfate assured no injury nor abnormality.

The subjects were given 100 trials daily. When a criterion performance of 45 correct responses in 50 trials was met, an additional 400 overtraining trials were administered before the transfer test with the opposite eye.

Degrees of impairment of immediate recall through the untrained eye were measured by both a transfer index calculated from the number of trials taken by each eye ($TI = \frac{1st-2nd}{1st+2nd}$) and an initial level of transfer performance (ILT = %age of correct responses in the first 20 transfer trials). The former provides the range from +1 to -1; perfect retention and complete impairment. In the latter, any performance level greater than 2 standard errors apart from the 50% chance level was considered as positive transfer and those performances dropped within the error margin were interpreted as a lack of evidence for immediate recall, or no transfer.

Experiment 1 : Original Learning and Reversal Learning

Fourteen monkeys consisting of 8 Es and 6 Cs participated, and 4 pairs of stimuli consisting of *Brightness*, *Color*, *Pattern* and *Form-1* were used. Each problem consisted of 4 phases: they are

Table 1. Mean Transfer Indices

| Experiment | Problem | | | | | |
|----------------------|---------|------|-------|-------|-------|------|
| | B | C | P | F-1 | F-2 | F-3 |
| 1. Original: C | .63 | .92 | .94 | .95 | | |
| E | .35 | .55* | -.02* | -.07* | | |
| Reversal: C | .80 | .90 | .96 | .90 | | |
| E | .39* | .23* | -.02* | .01* | | |
| 2. Relearn.: C | 1.00 | 1.00 | .83 | .96 | .81 | 1.00 |
| E | .52 | .87 | .44 | .63 | -.05* | .15* |
| 3. Rep. Rev.: Pre-Op | | | .95 | | | |
| Post-Op | | | .18* | | | |
| 1 - 4 | | | .52* | | | |
| 5 - 8 | | | .45 | | | |
| 9 - 10 | | | .51 | | | |
| 4. P. T. C. S.: II | .97 | 1.00 | .93 | .94 | | |
| III | | .78 | .42* | .48* | | |
| IV | | .73 | .24 | .16 | | |
| 5. Sens. Depriv. | | -.52 | -.68 | | | |

* Significant group difference at 5 or less % level.

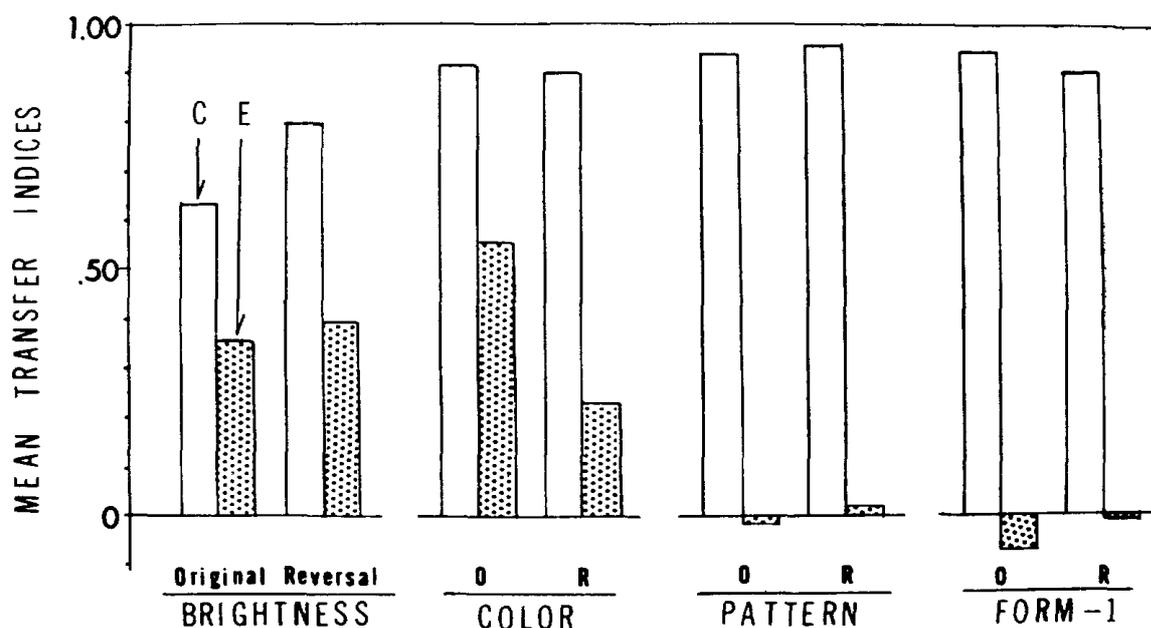


Figure 4. Mean transfer indices on both original and reversal phases of 4 problems. C: Controls, E: Experimentals.

initial learning (IL) through one eye, first transfer test (T1) through the opposite eye, reversal learning (RL) with the eye used for the initial learning and the second transfer test (T2) with the opposite eye. Thus, 4 learning curves were obtained for each problem by each subject.

Mean transfer indices of each group on original and reversal phases of the 4 problems are shown in the first 4 rolls of Table 1 and Fig. 4.

The Cs showed nearly perfect transfer throughout, whereas the Es manifested moderate degrees of transfer on *Brightness* and *Color*, but no transfer on *Pattern* and *Form-1*. Group differences between the Cs and the Es are all significant except for the first phase of *Brightness*.

Thus, if the transfer index were taken as a measure, it must be admitted that interocular transfer did occur to a certain degree in the commissure sectioned animals for *Brightness* and *Color*, but not for other stimuli.

Figure 5 represents the number of correct responses made in the first 20 trials of each phase, which correspond to the first 4 rolls

Table 2. Mean Initial Levels of Transfer

| Experiment | Problem | | | | | | |
|-----------------|------------------|----|-----|-----|-----|-----|-----|
| | B | C | P | F-1 | F-2 | F-3 | |
| 1. Original: | C | 69 | 79 | 84 | 85 | | |
| | E | 62 | 58* | 61* | 56* | | |
| | Reversal: | C | 77 | 82 | 80 | 80 | |
| | | E | 56* | 56* | 55* | 53* | |
| 2. Relearn.: | C | 91 | 91 | 85 | 95 | 88 | 95 |
| | E | 85 | 79 | 65 | 75 | 58* | 65* |
| 3. Rep. Rev.: | Pre-Op | | | 94 | | | |
| | Post-Op | | | 51* | | | |
| | 1 - 4 | | | 71 | | | |
| | 5 - 8 | | | 77 | | | |
| | 9 -10 | | | 84 | | | |
| 4. P. T. C. S.: | II | 82 | 98 | 81 | 85 | | |
| | III | | 73* | 61 | 56* | | |
| | IV | | 73 | 55 | 61 | | |
| | 5. Sens. Depriv. | | 48 | 50 | | | |

* Significant group difference at 5 or less % level.

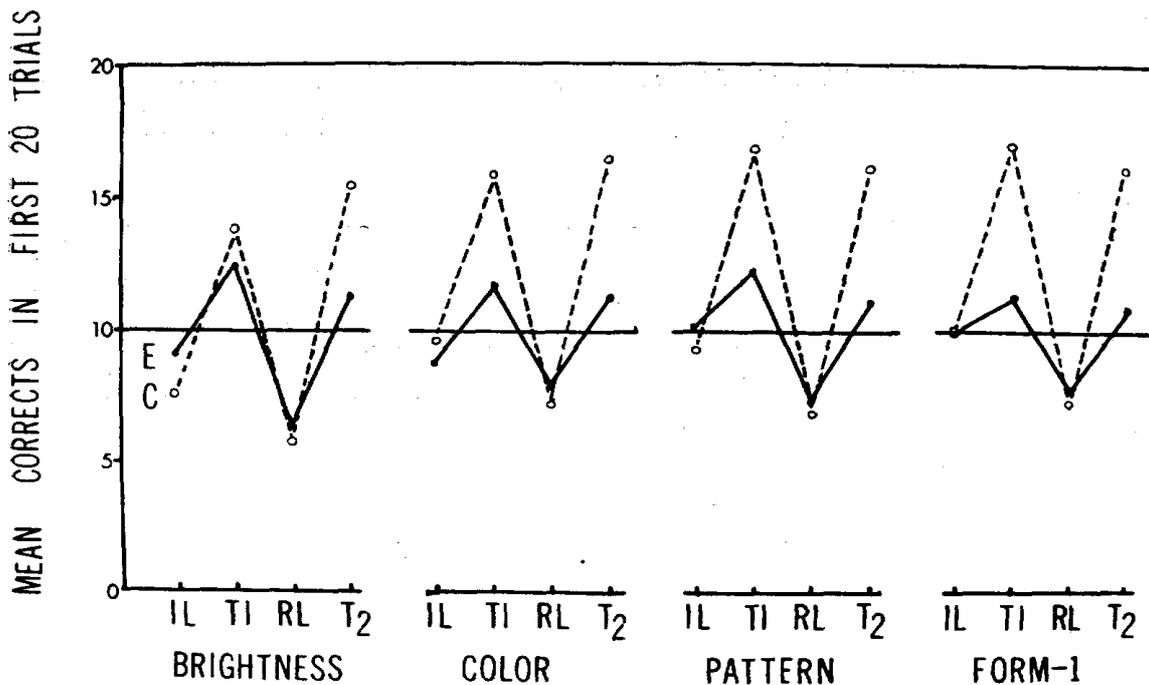


Figure 5. Mean numbers of correct responses in the first 20 trials of each problems. C: Controls, E: Experimentals.

of Table 2. It is revealed here that the performance of the Es shown in solid lines are much poorer and stayed around the chance level for all problems, whereas the Cs on broken lines manifested significantly higher performance levels at every transfer test. Therefore, as far as this measure is concerned, there was no essential difference among the problems and it should be concluded that there was no interocular transfer for all stimuli, including even *Brightness* and *Color*, in split-brain monkeys.

The foregoing evidence disclosed both the similarity and the difference between brightness and color on one hand and geometric figures for another which provide the bases for each of the two schools of thought; one claims the interocular transfer of brightness and color, and another denies such transfer for any stimuli.

Experiment 2 : Relearning

In an attempt to provide a proper explanation to the above discrepancy, this study was designed with a hypothesis that a familiarity of discriminanda to the subjects rather than the difference in physical characteristics of stimuli plays a critical role in the intero-

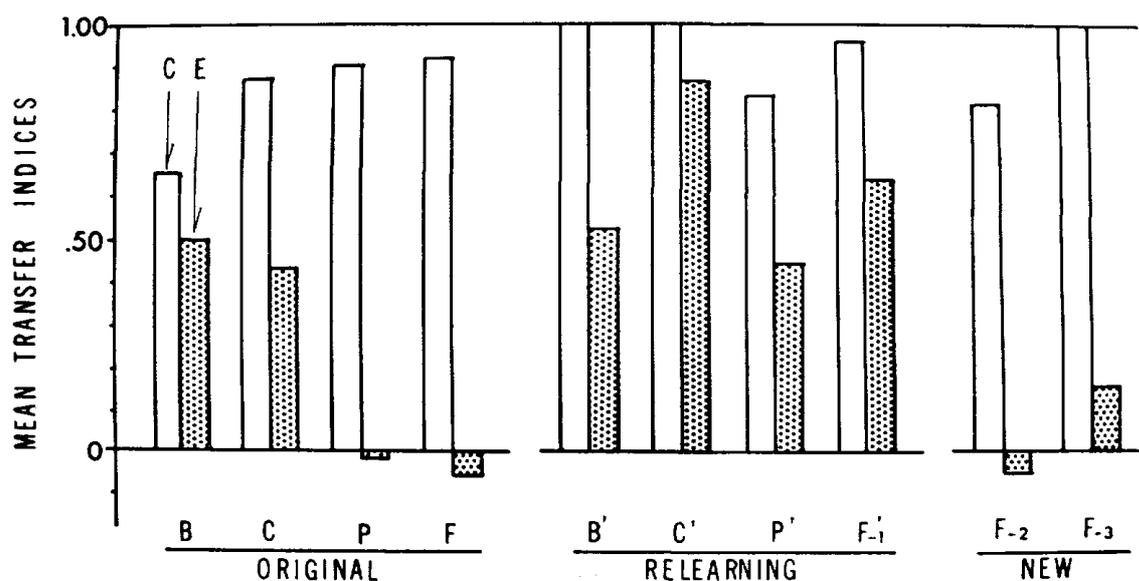


Figure 6. Comparison of mean transfer on the original learning and relearning of the same problems and on the learning of new problems.

cular transfer of learning.

Thus, 6 months after Experiment 1, 8 monkeys consisted of 4 each from both C and E groups, were tested again. Adding to the same 4 pairs of stimuli, 2 more pairs of form problems, *Form-2* and *Form-3*, were newly provided.

The means of transfer index are shown in Fig. 6, together with the data of the very same subjects in Experiment 1 on the left side of the figure for comparison.

For the relearning of those 4 old problems, the transfer indices of the Es were considerably higher than those of their original learnings, and no significant group difference between the Es and the Cs could be found this time. However, when the new problems were introduced, the Es showed practically no interocular transfer, just

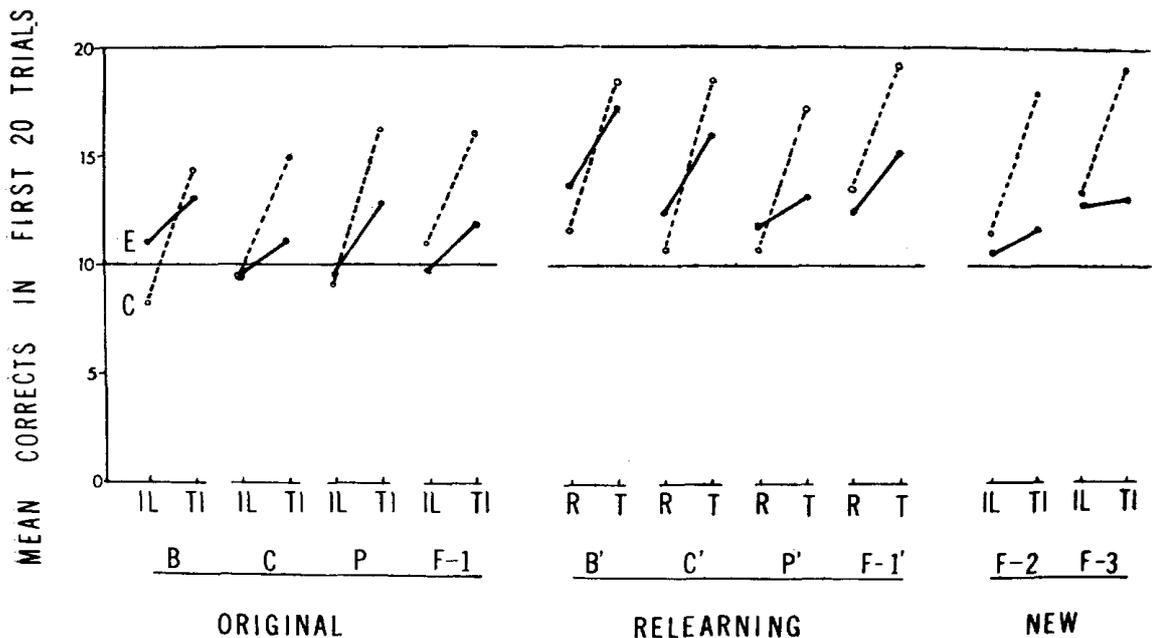


Figure 7. Comparison of the means of correct responses in the first 20 trials of each problem on the original learning, relearning and new learning.

like they did for the *Pattern* and *Form-1* at the first time, and the group differences reappeared in highly significant levels. The 5th and 6th lines of Table 1 also reveal the above.

The levels of initial transfer performance of the Es on the re-

learning were generally higher than the ones for the original, and thus, no group difference was observed in these 4 relearnings. However, significant group differences were restored when the new form discriminations were tested, as shown in the 6th line of Table 2 as well as in Fig. 7.

Our data, therefore, support the view that the familiarity of the subjects toward the stimulus employed, rather than the physical characteristics of a particular stimulus, is critical to determine the degree of interocular transfer.

Experiment 3: Repeated Reversals

The following study aims at the examination of the role of the forebrain commissure fibres on interocular transfer of more complex learning task, namely, the "reversal-learning-set-formation."

Assuming the equivalence of repeated discrimination reversals to ordinal learning-set-formation proved by Schusterman (1962) and Rumbaugh and Prim (1964), present study employed this technique for seeking a functional dissociation of neuroanatomical substrata, namely, the neocortical versus sub-cortical elements in learning set formation.

Four young male rhesus monkeys with 2 pairs of geometric figures, *Pattern* and *Form-1*, were employed.

Like all other studies, midsagittal section of the optic chiasm was performed prior to the initiation of the first problem. After testing the initial discrimination (I_1) by the left eye and the transfer learning (T_1) by the right eye on the first problem, forebrain commissurectomy was conducted.

Postoperatively, subjects were trained to the second problem, again first by the left and its transfer by the right eye. Shifting the eye back to the left, 4 successive reversals were conducted, and then 4 more reversals by the right eye. Lastly, one more reversal for each eye was conducted. Thus, both eyes were employed once preoperatively and 6 times postoperatively.

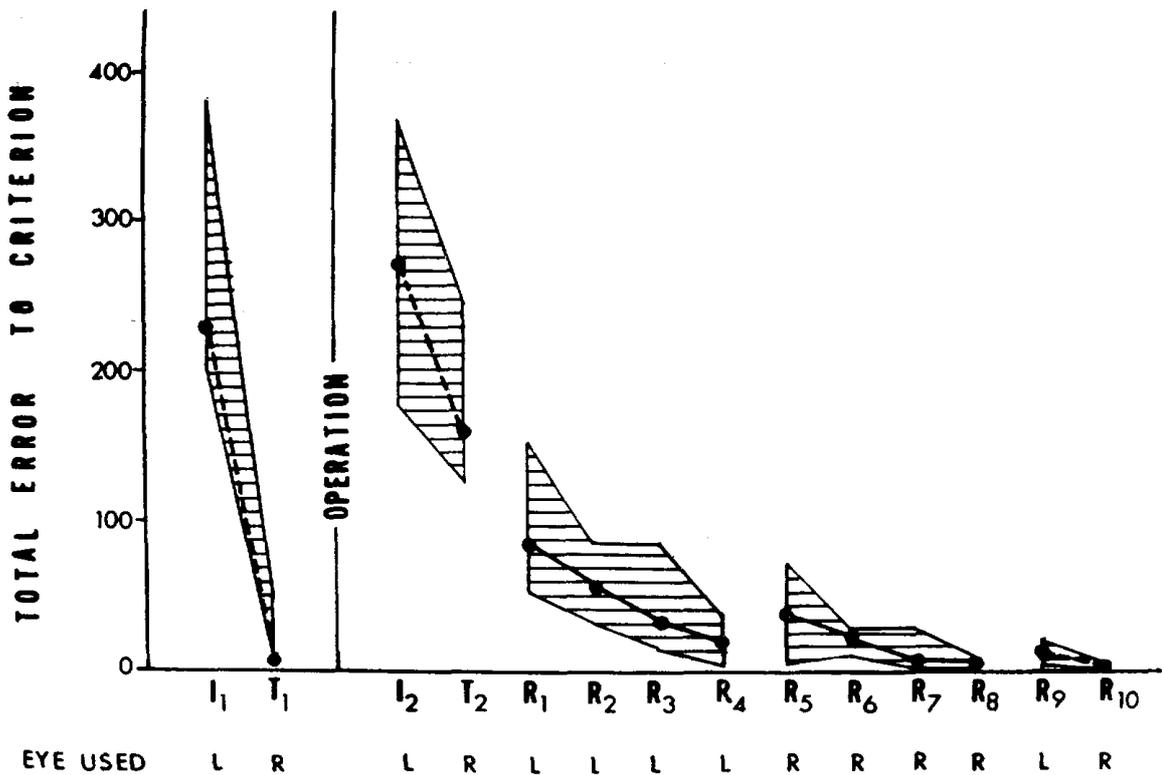


Figure 8. Ranges and medians of errors at each stage of repeated reversals.

Ranges and the medians of the total numbers of errors made in each discrimination learning are illustrated in Fig. 8. The effect of commissurectomy is clearly demonstrated in Fig. 9 as a marked postoperative change, i. e. the shift from nearly perfect preoperative interocular transfer, to very little saving at immediate postoperative period.

In repeating discrimination reversals with the same pairs of discriminanda for several times, the numbers of errors to criterion rapidly decreased and the formation of reversal-learning-set seemed to be manifested.

In confirmation to the above impression, the analyses of variance reveals that the total numbers of errors for postoperative discrimination learnings decrease across reversal sessions in high significance. Also, interocular transfer between two series of repeated reversals as well as a session \times transfer interaction was also highly significant. Transfer indices, however, recovered to a modera-

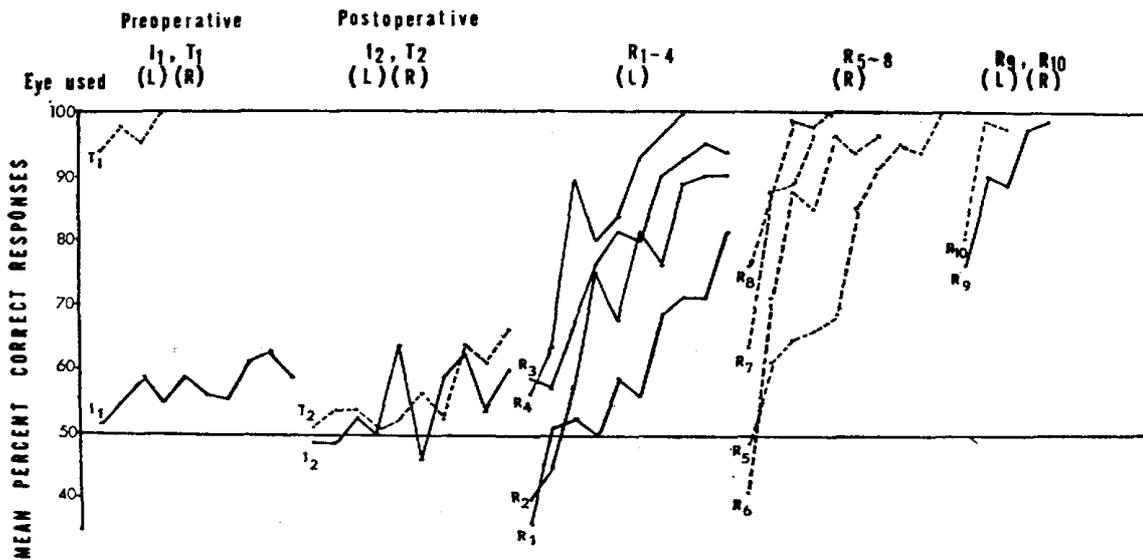


Figure 10. Learning curves at the each stage of repeated reversals. Solid line: left eye, broken line: right eye.

teraction.

The resemblance to the characteristics of one-trial-learning which appears at the later stages of ordinal learning-set-formation paradigm, the gradients of these learning curves increased gradually as the repetition of reversals progressed. Nevertheless, the efficiency for reversals, i. e., the inhibition of previously acquired tendency, whose failure would be designated as "response-shift-error" by Harlow (1959) or whose success be designated as "win-stay, lose-shift strategy" by Levine (1959), does not seem to transfer from one eye to another.

A parallel establishment of reversal-learning-set casts an alarm to the uncritical interpretation of any positive saving in interocular transfer in terms of subcortical mediation of memory storage, but this fact rather emphasizes that the role of cortical function might be much more significant than previously recognized.

Experiment 4: Post-Training Commissure Section

The fourth study was conducted to examine the concepts of multiple neuromechanisms for vision proposed by many, such as, Bauer and Cooper (1964), Blake (1959), Hamilton and Lund (1970) and Schneider (1967), and to detect the loci of memory trace: whether

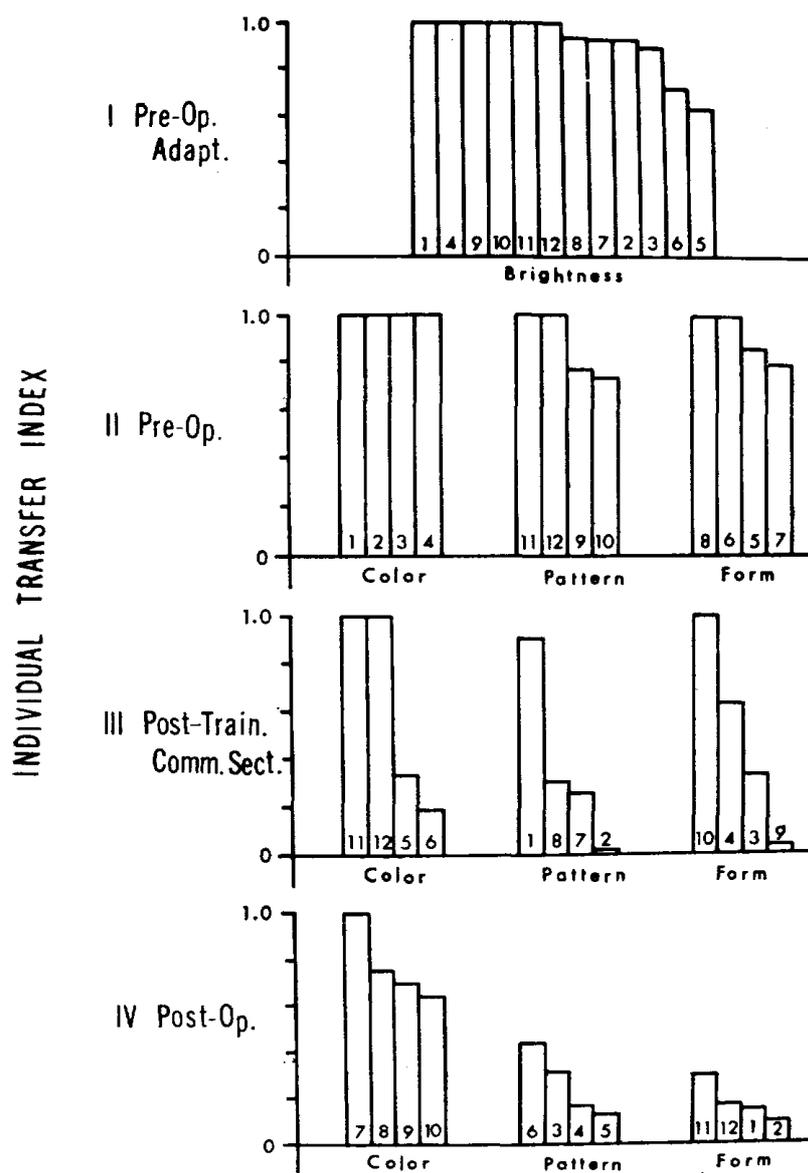


Figure 11. Individual transfer indices at different stages of commissurectomy.

it is strictly ipsilateral, bilateral, or homolateral to the sensory input but contralaterally retrievable.

Twelve monkeys with optic chiasm sectioned were employed. After shaped by *Brightness* problem, each subject was trained to 3 problems in *Color*, *Pattern* and *Form-1* arranged in random order; and right after the initial learning of the second problem, commissurectomy was performed. Individual transfer indices shown on Fig. 11 reveal that there were significant group differences between preoperative and postoperative sessions in both *Pattern* and *Form-1*,

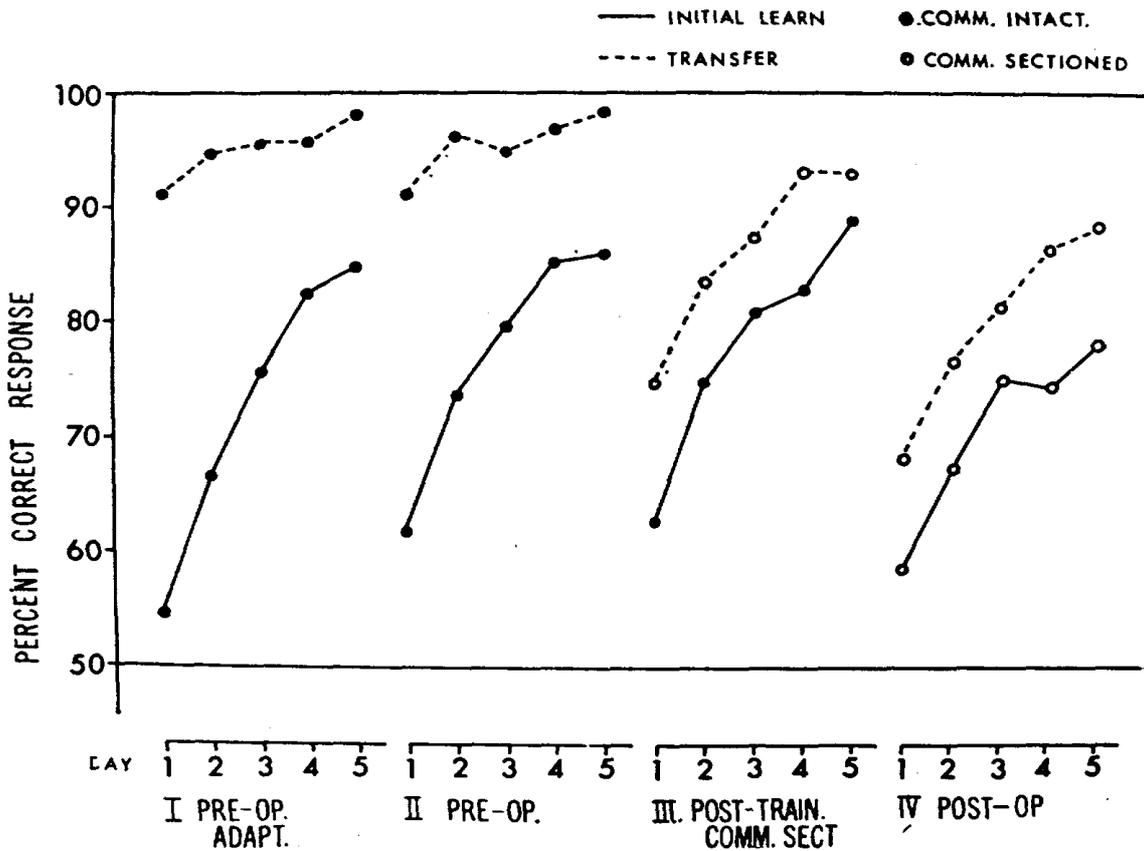


Figure 12. Group learning curves at different stages of commissurotomy. and between *Color* and either *Pattern* or *Form-1* at the postoperative session.

Rates of learning are compared in Fig. 12. Regardless of the mode of stimuli, all interocular transfer were at high level at the preoperative sessions.

When the forebrain commissures were transected after monocular training of initial discrimination was completed, i. e., stage III of P. T. C. S. or line 13 of both Tables 1 and 2, the level of transfer by the opposite eye declined. The depression was so great that the probability of correct responses after the eye shift dropped into the margin of chance score, manifesting the characteristics of relearning rather than one to be interpreted as the immediate transfer of discriminative habit.

No considerable deficit for initial discrimination learning was manifested by the disconnection of two hemispheres in the post-

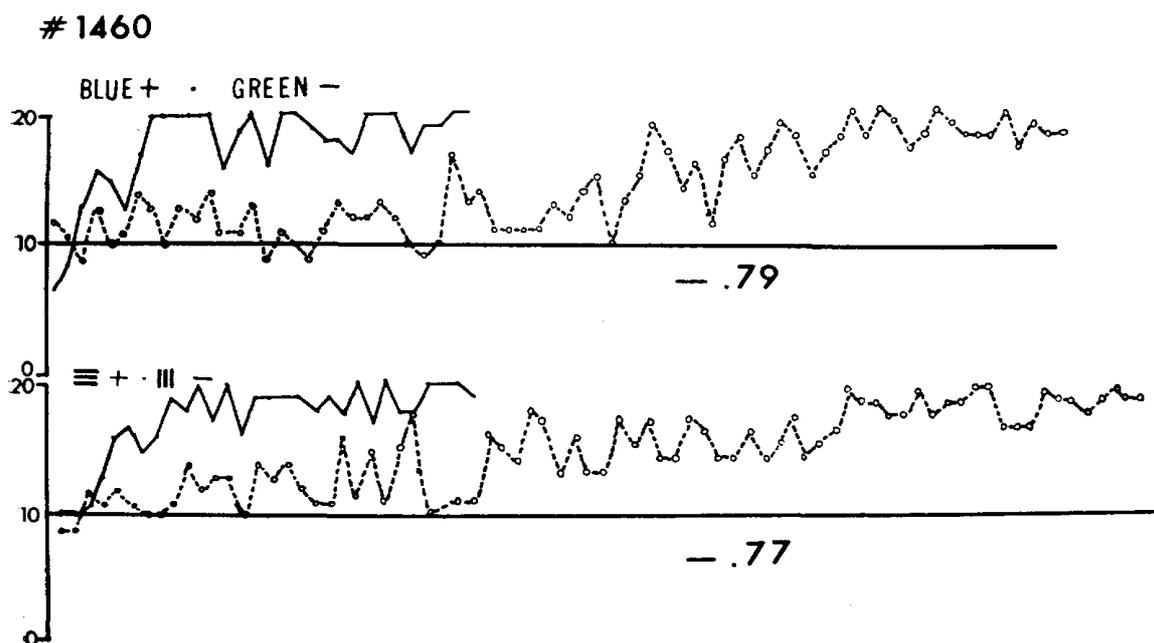


Figure 13. Samples of interocular transfer learning curves by a sensory deprived monkey.

operative session. It means that the initial learnings on solid lines in Fig. 12 have almost the same rate of learning for all 4 stages.

Experiment 5 : Sensory Deprivation

The last experiment employed 4 laboratory-raised infant monkeys. Total section of the optic chiasm and the forebrain commissures were performed during the first 3 weeks after their births. The eyelids of one eye were sutured immediately after the commissurectomy. They were raised by human hand and were later housed together with others in a large cage for 12 months. When one year of sensory restriction period was terminated, the sutured eyelids were reopened and a thorough monocular training of light detection was given before the initiation of discrimination learning.

An example of such sensory deprived cases is illustrated in Fig. 13. Interocular transfer shown in broken line took much longer time and the slope of curve was much gradual.

Despite of a prolonged sensory restriction, when these animals had only restrained eye, they seemed to show no difficulty of eye-hand coordination to perform an operant behavior in the appa-

tus. However, the rates of learning by these eyes were deficient for both color and pattern, which are shown as negative values in the last line of Table 1, suggesting that the retardation may be due to the inefficiency of "cortical", "sensory-instigated, integrative function."

Followings are the recapitulation of the main findings.

First, split-brain monkeys transfer brightness and color interocularly in high degrees, but they fail to show immediate recall by untrained eye.

Second, repeated use of the same discriminanda increases the degree of interocular transfer, but this high efficiency could not be generalized to other stimuli.

Third, progressive improvement manifested in serial reversals develop almost independently in each hemisphere.

Fourth, section of the commissures after initial training disrupts interocular transfer in as much the same degree as for the subjects with split-brain from the beginning.

Fifth, surgically separated and visually deprived hemisphere manifest learning deficit with similar degrees in both color and pattern.

All data hitherto described point toward one general notion that it is not the transmission of specific sensory information from one hemisphere to another, but the subcallosal existence of some non-specific and facilitatory factor for discrimination in the absence of the forebrain commissure fibres in monkeys.

Consequently, it is necessary to hypothesize 2 distinctive functional components in the interocular transfer of discrimination in the absence of the forebrain commissure fibres in monkeys.

One is a discriminative property or "analyzer", which differentiates incoming sensory inputs and builds some behavioral strategies under a specific stimulus condition. This property is located cortically, established homolaterally and is transcallosally retrievable

in intact animals but it is not so after the section of the forebrain commissures.

Another is a reinforcement property or "operator", which is non-sensory specific and subcortical and, therefore, bilaterally available in this kind of split-brain preparation, though no one is yet sure whether it is established bilaterally at the time of learning or homolaterally at first but is contralaterally retrievable when the opposite side requests that stored informations.

Then, the question arised that what sort of conceptual scheme would be most appropriate for the understanding of these 2 components in the interocular transfer ?

These 2 components revealed in this study have much resemblance to the various types of 2 stage theories for discrimination learning, such of follows: Sutherland's (1959) analyzer to switch in vs. attachment of correct response, Lovejoy's (1966) naming response vs. request or demand, Mackintosh's (1965) attend vs. choice-response learning, Meier and McGee's (1959) differentiation of stimuli vs. connection of reward and discriminanda, Epstein's (1967) exploratory vs. attending to the reward contingency, and Motoyoshi and Mitani's (1965) distinction between perceptual learning and exploratory drive. These are only a few to name.

Also, it should be examined whether the present 2 components may correspond to 2 single or combination of some factors in such multi-factor theories for leaning-set, as Harlow's (1959) differential cue and response shift, Restle's (1958) Type-a (valid, common, abstract and indirect) and Type-b (intraproblem, direct and objective), cues or Levine's (1959) win-stay, lose-shift and other kinds of hypthses.

Besides the theories of acquired distinctiveness of cue by Lawrence (1949), selective attention by Mackintosh (1965) or learning set formation by Harlow (1949), these data should be examined by the view of reinforcement theory, especially the role of inhibition which, according to Larsen and others (1969), transcommissurally

interacts.

Interesting enough, Stell Russell (1971) also recently came to suggest a guiding contribution from trained hemisphere to naive hemisphere to the salient information during the transfer trials in functionally split-brain preparation.

What is, then, this facilitatory factor or guiding contribution? A quite different interpretation can be made from this study. Those stimuli with which some positive transfers occurred were found in the natural habitat or significant value in the past for individual organism, and may have some *social* or *affective* signal values in them.

Hamilton (1968) says, if the psalterium were only partially sectioned and the hippocampal commissure was intact, these structures may be capable to mediate different aspects of visual perception. Similarly, according to Trevarthen (1968), particular moods or states of attention might be able to induce the monkey to utilize subcortical mechanisms.

In any case, a hypothesis of differential neuromechanisms for different modes of visual stimuli or for different degrees of problem difficulty must be rejected at first. This does not mean that we should neglect the fact of phylogenetic, structural differences which play significant roles for the varieties of visual discrimination among animals. But rather, the dynamics of perceptual learning should be counted, or if it is permitted to say, the developmental aspect of stimulus control, with the notion of whole processes of adaptation in both short and long time ranges, must be taken into account more seriously than before.

Also, this is not feasible to propose any single unit of neuromechanisms, such as the centrencephalon proposed by Penfield (1952) and extended by Robert Thompson (1965) or any simple hypothetical construct of memory trace, to explain a whole phenomenon of interocular transfer, unless we ignore the multidimensional qualitative differences between intact and commissure sectioned animals.

In concluding, the phenomena thus far obtained in this series can be persimoniously interpreted as a deprivation of transhemispheric sensory information with the subcortical preservation of discriminative learning habit.

REFERENCES

- Bauer, J. H. & Cooper, R. M. Effects of posterior cortical lesions on performance of a brightness discrimination task. *Journal of Comparative and Physiological Psychology*, 1964, 58, 84-92.
- Black, P. & Myers, R. E. Brainstem mediation of visual perception in a higher primate. *Transactions of the American Neurological Association*, 1968, 93, 191-193.
- Black, P. & Myers, R. E. Behavioral studies in the commissure-sectioned chimpanzee: Interhemispheric transfer of visual information. *Recent Advances in Primatology*, 1969, 3, 64-67.
- Blake, L. The effect of lesions of the superior colliculus on brightness and pattern discrimination in the cat. *Journal of Comparative and Physiological Psychology*, 1959, 52, 272-278.
- Downer, J. L. de C. Changes in visually guided behaviour following midsagittal division of optic chiasm and corpus callosum in monkey (*Macaca Mulatta*). *Brain*, 1959, 82, 251-259.
- Epstein, W. *Varieties of perceptual learning*. McGraw-Hill, 1967. p. 116.
- Hamilton, C. R. Effects of brain bisection on eye-hand coordination in monkeys wearing prisms. *Journal of Comparative and Physiological Psychology*, 1968, 64, 434-443.
- Hamilton, C. R. & Gazzaniga, M. S. Lateralization of learning of color and brightness discrimination following brain bisection. *Nature*, 1964, 201, 220.
- Hamilton, C. R. & Lund, J. S. Visual discrimination of movement: Mid-brain or forebrain? *Science*, 1970, 170, 1428-1430.
- Harlow, H. F. The formation of learning sets. *Psychological Review*, 1949, 56, 51-65.
- Harlow, H. F. Learning set and error factor theory. In Kock, S. (Ed.): *Psychology: A Study of a Science*. Vol. 2. McGraw-Hill, 1959, pp. 492-537.

- Larsen, J. W., Winans, S. S. & Meikle, T. H. Jr. The effects of forebrain commissurotomies on the rate of learning a dark-light discrimination by cats. *Brain Research*, 1969, 14, 717-731.
- Lawrence, D. H. Acquired distinctiveness of cues: I. Transfer between discriminations on the bases of familiarity with the stimulus. *Journal of Experimental Psychology*, 1949, 39, 770-784.
- Levine, M. A model of hypothesis behavior in discrimination learning set. *Psychological Review*, 1959, 66, 353-366.
- Lovejoy, E. Analysis of the overlearning reversal effect. *Psychological Review*, 1966, 73, 87-103.
- Mackintosh, N. J. Selective attention in animal discrimination learning. *Psychological Bulletin*, 1965, 64, 124-150.
- Meier, G. W. & McGee, R. K. A re-evaluation of early perceptual experience on discrimination performance during adulthood. *Journal of Comparative and Physiological Psychology*, 1959, 52, 390-395.
- Meikle, T. H. Interocular transfer of brightness discrimination in splitbrain cats. *Science*, 1960, 132, 734-735.
- Mosidze, V. M. & Rizhinashvili, R. S. Role of commissural connections and brainstem structures in interhemispheric interaction. *Zhurnal Vysshei Nervnoi Deyatel'nosti imeni I. P. Pavlova*, 1968, 18, 83-87.
- Motoyoshi, R & Mitani, K. The problem of experience effect in the Hebb-Williams intelligence test. *Japanese Psychological Research*, 1965, 7, 38-45.
- Myers, R. E. Interocular transfer of pattern discrimination in cats following section of crossed optic fibers. *Journal of Comparative and Physiological Psychology*, 1955, 48, 470-473.
- Penfield, W. & Roberts, L. *Speech and brain mechanisms*. Princeton Univ. Press. 1959.
- Restle, F. Toward a quantitative description of learning set data. *Psychological Review*, 1958, 65, 77-91.
- Rumbaugh, D. M. & Prim, M. M. Temporary interference on insolvable discrimination reversal training upon learning set in the squirrel monkey. *Journal of Comparative and Physiological Psychology*, 1964, 57, 302-304.
- Russell, I. S. Neurological basis of complex learning. *British Medical Bulletin*, 1971, 27, 278-285.

- Schneider, G. E. Two visual systems. *Science*, 1969, 163, 895-902.
- Schusterman, R. J. Transfer effects of successive discrimination reversal training in chimpanzees. *Science*, 1962, 137, 422-423.
- Sutherland, N. S. Stimulus analysing mechanisms. *In Proceedings of a symposium on the mechanization of thought processes*, Vol. 2. Her Majesty's Stationary Office, 1959. pp. 575-609.
- Thompson, R. Centrencephalic theory and interhemispheric transfer of visual habits. *Psychological Review*, 1965, 72, 385-398.
- Trevarthen, C. B. Double visual learning in split-brain monkeys. *Science*, 1962, 136, 258.
- Trevarthen, C. B. Two mechanisms of vision in primates. *Psychologische Forschung*, 1968, 31, 299-337.