POSTTRAINING COMMISSURE SECTION AND INTEROCULAR TRANSFER OF DISCRIMINATION LEARNING IN RHESUS MONKEYS

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PROBLEMS

The persistence of an interocular transfer of brightness and/or color discrimination takes after transection of the optic chiasma and the forebrain commissures in cats (Meikle, 1964; Meikle & Sechzer, 1960), monkeys (Hara, 1974, 1981; Hara & Myers, 1970; Trevarthen, 1962, 1968), and chimpanzees (Black & Myers, 1968, 1969) suggest that some types of visual information transmission can occur through anatomical pathways other than the corpus callosum. Similar interpretation which have implicated multiple-level neural mechanisms in vision have been proposed by others (e.g., Bauer & Cooper, 1964; Blake, 1959; Hamilton & Lund, 1970; Mishkin et al., 1982a,b; Schneider, 1969; Thompson, 1965).

The present investigation attempts to define more precisely the functional characteristics of infra- and trans-callosal mechanisms which are involved in the interocular transfer of visual discrimination task learning. Following the paradigm originated by Myers (1962), a techniuque of posttraining section of the corpus callosum was employed on chiasma-sectioned monkeys in order to

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determine the distribution of trace development, i.e., whether trace establishment is restricted to the recipient hemisphere, whether it is bilaterally fixed, or whether it is primarily in the hemisphere receiving visual input during learning but contralaterally retrievable.

METHOD

Subjects

Twelve experimentally naive, juvenile rhesus monkeys were used. The subjects weighed 2.5–3.0 kg at the onset of the study.

Surgery

Prior to the initiation of any visual training, all subjects sustained a midline transection of the optic chiasma. A transbuccal approach was used for this surgery (Hara, 1988). Later, all subjects were subjected to the midsagittal section of the corpus callosum and anterior commissure (Downer, 1959; Myers, 1955). After cutting a large left-sided fronto-parieto-occipital free bone flap, the left hemisphere was gently retracted and the fibers of the commissures were transected utilizing a fine glass pipette and gentle suction. A Zeiss otological microscope illuminated the operation field and provided magnification of the structures being manipulated.

Postmortem examination of the perfusion-fixed brain specimens varified the completeness of severance of both the crossing retinal fibers at the optic chiasma and of the fibers of the corpus callosum and anterior commissure (see Myers, 1956). In no instance did injury to one or the other hemisphere appear on gross or microscopic examination.

Apparatus

An automated visual discrimination apparatus was used throughout (Hara, 1974). The 4 pairs of discriminanda used in the 4 discrimination tasks consisted of *brightness* (5% vs. 80% transmittances), *color* (Blue vs. green, matched for luminosity), *pattern* (horizontal vs. vertical striations), and *form* (circle vs. square of the same surface area). Except in relations to the *brightness* discriminations, where the darker stimulus was the rewarded one for all subjects, one of the two stimuli used in test task served as the positive stimulus for half of the subjects and the second of the pair for the other half.

Procedures

Adaptation. After recovery from the initial optic chiasma surgery, all subjects were shaped in the test apparatus with both eyes open and then with first one and then the other eye covered. Vision through one or the other eye was occluded by the insertion of opaque plastic eye-discs.

Discrimination learning and transfer test. Initial discrimination learning was carried out through the left and later transfer testing effected through the right eye. This order of eye testing was aimed at achieving the conditions most favorable for interocular transfer with reference to the side of craniotomy. The subjects were given 2 blocks of 50 trials per day.

A correction technique was used and has been described elsewhere (Hara, 1974). After the subjects reached a criterion of 45 or more correct responses out of 50 in a block, 400 further overtraining trials were given over the next 4 days. A week of recess followed during which the both eyes were uncovered. The eye occluder was then shifted to the second eye and transfer tests were carried out until the same criterion was met and another 400 overtraining trails completed.

Test sequence. All subjects were trained on the *brightness* discrimination first as a part of *preoperative adaptation* (I). The animals were next assigned to 6 groups of 2 each. The individual groups were assigned to one of the 6 possible permutations of the 3 different tasks with reference to their order of testing. The 3 task-sequences were designated *preoperative* (II), *posttraining commissure section* (III), and *postoperative* (IV) respectively. The operative procedures carried out on the forebrain commissures took place during the recess period before transfer testing on the third task (designated the *posttraining commissure section* sequence).

RESULTS

Table 1 depicts the trials required for the first achievement of criterion performances both during initial discrimination learning using the one eye and on transfer testing using the other eye. No significant differences appeared among the various groups with reference to the numbers of trials required for the initial specific task acquisition irrespective of the order of task presentation. However, significant group differences did appear on the transfer performances expressed as saving scores between the *preoperative* and *postoperative* sessions to *pattern*, *form* and *color* and with respect to *pattern* and *form* at *postoperative* testing (Mann-Whitney U-test: $U = 0$, $p = .014$ for all cases). Individual saving scores are shown in Figure 1.

Learning rates are compared in Figure 2. Each curve represents the mean performance of all 4 subjects assigned to a specific discrimination at the same session (except for *preoperative adaptation* where all 12 subjects are included). Table 2 depicts the proportions of subjects which demonstrated statistically highly significant levels of performance on transfer testing implying transfer of training already established by the first 20 transfer trials.

DISCUSSION

There was a relative ease in the learning of *color* discriminations throughout all sessions as described in Table 1 as well as in Figure 2. No marked

Table 1.
Positive Discriminanda (+Cue) and Numbers of Trials for Initial Discrimination (I) and Interocular Transfer (T) Learnings

	I. Pre-Op. (Adapt.)		II. Pre-Op.		III. Post-Train. Comm. Sect.		IV. Post-Op.	
Ss	+Cue	I/T	+Cue	I/T	+Cue	I/T	+Cue	I/T
1	B-d	300/ 0	C-b	40/ 0	P-v	530/ 30	F-s	320/240
2	B-d	540/ 20	C-g	110/ 0	P-h	300/290	F-c	830/690
3	B-d	350/ 20	C-b	90/ 0	F-s	440/220	P-h	840/440
4	B-d	540/ 0	C-g	110/ 0	F-c	1330/300	P-v	710/510
5	B-d	540/120	F-s	810/ 80	C-g	20/ 10	P-v	1190/920
6	B-d	200/ 30	F-c	380/ 0	C-b	130/ 90	P-h	470/190
7	B-d	520/ 20	F-s	110/ 20	P-h	120/ 70	C-b	40/ 0
8	B-d	320/ 10	F-c	220/ 0	P-v	150/ 80	C-g	70/ 10
9	B-d	560/ 0	P-v	1050/130	F-s	760/710	C-b	930/160
10	B-d	340/ 0	P-h	460/ 80	F-c	210/ 0	C-g	140/ 30
11	B-d	320/ 0	P-v	210/ 0	C-g	130/ 0	F-s	170/ 90
12	B-d	150/ 0	P-h	850/ 0	C-b	10/ 0	F-c	460/320

Note:
B : Brightness — d : dark
C : Color — b : blue — g : green
P : Pattern — v : vertical — h : horizontal
F : Form — s : square — c : circle

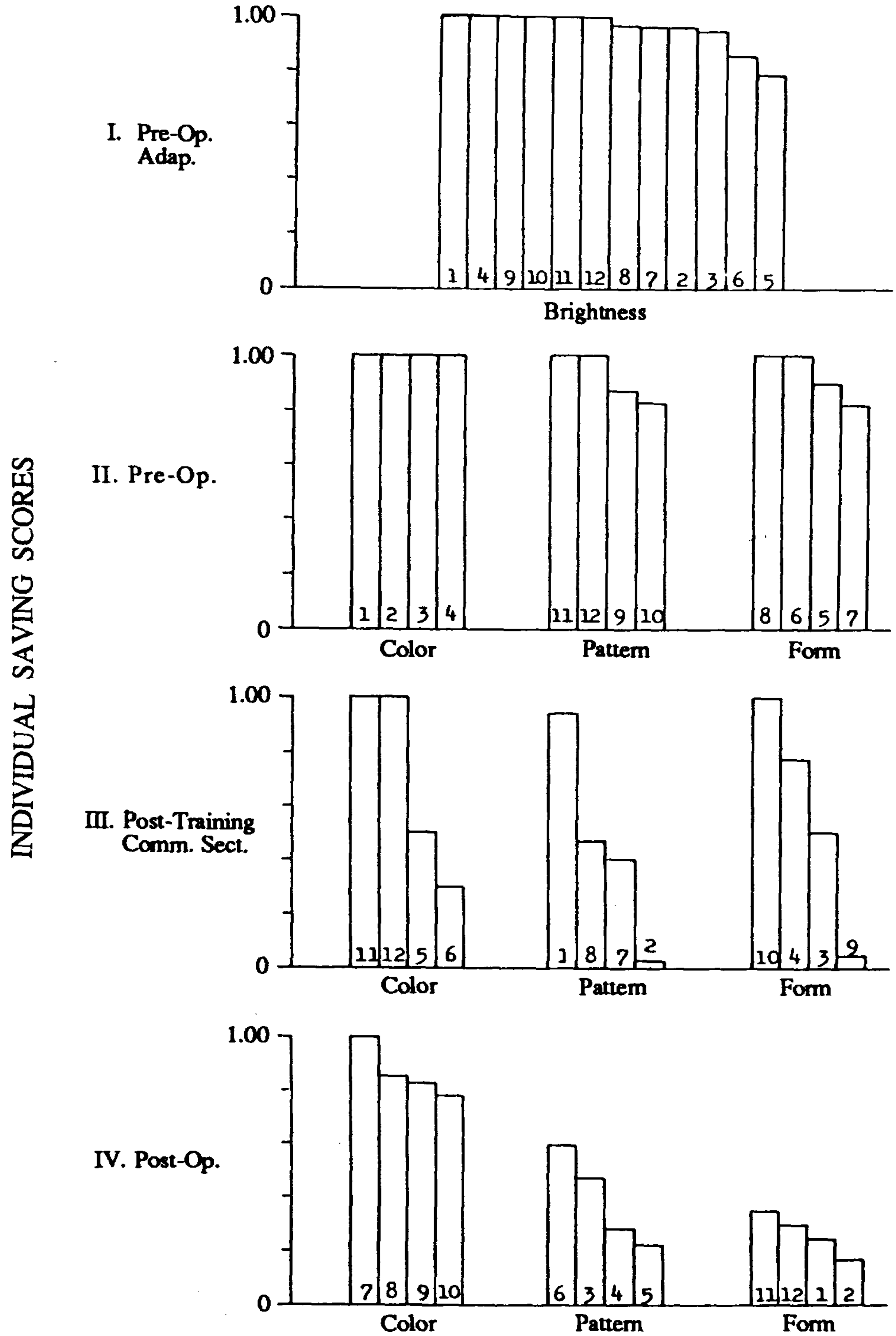

Figure 1. Individual saving scores for different stimuli at 4 test sessions. Numbers at the bottom of bars indicate the ID No. of individual subjects.

Table 2.
Proportion of the Subjects who Demonstrated Immediate Interocular Transfer at beyond 1% (5%) Significance Level

Session	Stimulus		
I. Preoperative Adaptation	Brightness		
	8/12 (9/12)		
	Color	Pattern	Form
II. Preoperative	4/4 (4/4)	2/4 (2/4)	4/4 (4/4)
III. Posttraining Commissure Section	1/4 (3/4)	0/4 (1/4)	0/4 (1/4)
IV. Postoperative	1/4 (2/4)	0/4 (0/4)	0/4 (0/4)

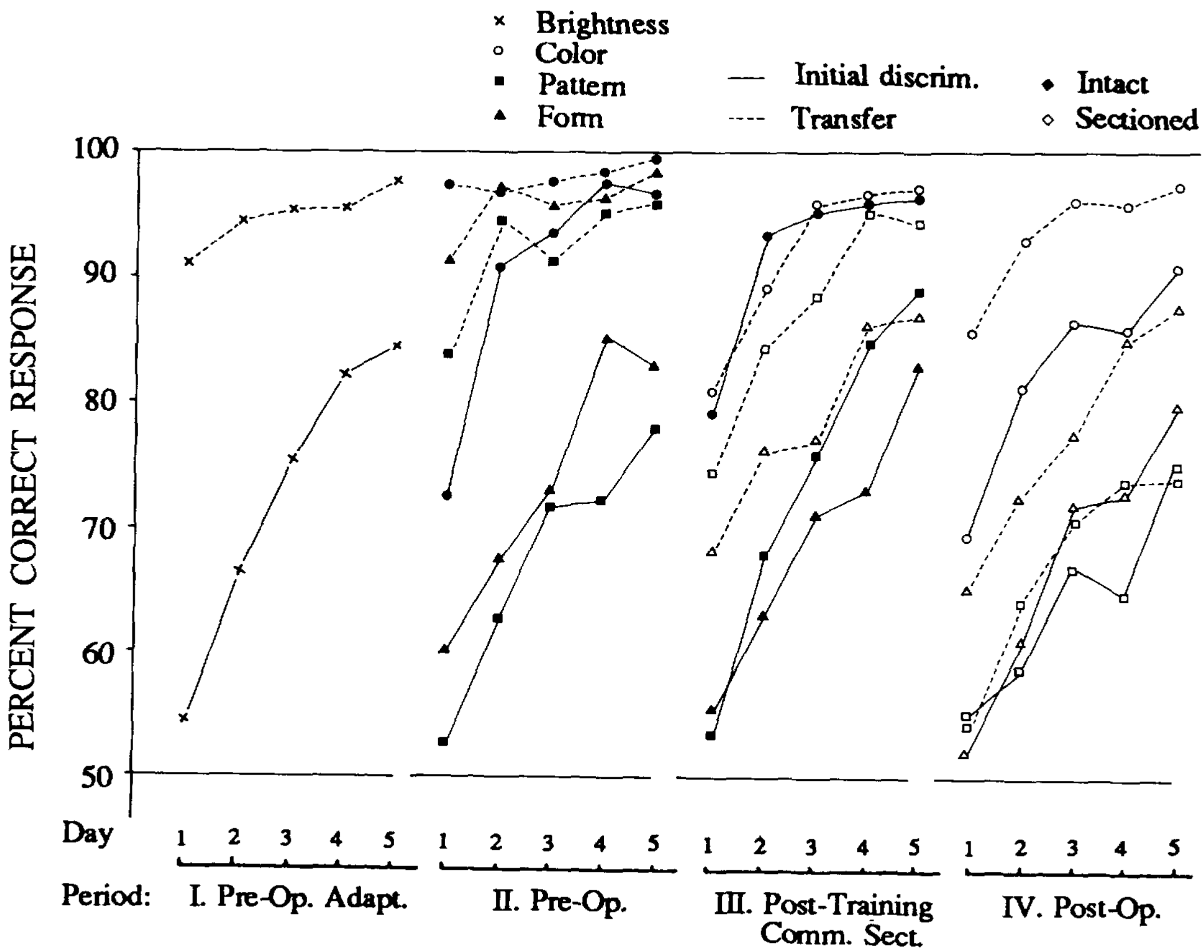

Figure 2. Percent correct responses in 50 trials/day block for first 5 days of initial discriminations and their transfer learnings.

differences appeared in the ease of learning of *pattern* and *form* discriminations among the present subjects. However, regardless of the type of task, interocular transfer was at a high level in the first 2 preoperative sessions (I and II). Though the learning curves on transfer testing in preoperative sessions I and II show slight initial depressions of performance on the *pattern* and *form* discriminations, the differences between the initial learning and the transfer learning were not statistically significant. This same tendency has been reported as a general characteristics for ordinal interocular tranfer by commissure intact, chiasma-sectioned naive monkeys (e.g., Gazzaniga, 1966).

When the forebrain commissures were sectioned after mastering the first eye discrimination learning on session III, the levels of transfer performance by the opposite eye declined. The degree of decline was least pronounced in the *color* discrimination task, the easiest of the three tasks. This result agrees with an earlier study that demonstrated that the degree of contralateral trace establishment depends on problem difficulty (Myers, 1962). Notwithstanding, the characteristics of these curves suggest the necessity for a relearning process through the second eye rather than the retention of a clean-cut transfer of training following the post-training commissure section.

Following post-training commissure transection, the probability of making correct responses immediately after the eye shift frequently dropped into the zone identifying a chance level of performance and in individual variations. Figure 2 shows that the performance levels during transfer testing following post-training section were greatly depressed compared to the situation of commissure intact, though the general level of performance tended to be higher than that of the initial learning.

No marked difference appeared in the relearning learning rates among the different discriminations. The ranges of the saving scores, or the individual variations within the discrimination groups, were greatest in this session. This effect may relate to the wide differences in the degrees to which different animals utilize the information transmitting capacity of the corpus callosum as has already been described (Myers, 1962).

No clear depressing was observed in the rates of acquisition of new tasks learning following destruction of the forebrain commissure as observed in the last postoperative training and testing sessions. In this last period, the transfer of *pattern* and *form* discriminations became more difficult than did *color* to the extent that differences in their performances reach high level of significance. The transfer curves of the *pattern* and *form* discriminations almost overlapped their initial learning curves, indicating the necessity for a complete relearning through the opposite eye. Thus, no interocular transfer effect was recognized for these two stimuli under this circumstance.

Therefore, it can be concluded that post-training sectioning of the corpus callosum leads to (1) reductions in interocular transfer levels for those tasks already monocularly learned, (2) the degrees of diminution in this transfer performance varied among the kinds of discrimination, (3) the initial levels of transfer under this circumstance were all low to the point that chance levels of performance obtained at that time even when high saving scores were ultimately obtained, and (4) the learning rates for new tasks were not significantly altered by the surgery. These results accord with previous findings using both cats (Myers, 1962) and monkeys (Hara & Myers, 1970; Hara et al., 1974; Noble, 1973) and monkeys with respect to tactile discriminations (Ebner & Myers, 1962 a,b).

SUMMARY

Twelve juvenile rhesus monkeys with midline section of the optic chiasma were monocularly trained and tested the interocular transfer of four discrimination problems: brightness first, and, thereafter in random order, color, pattern and form. The corpus callosum and anterior commissure were transected following

acquisition of the third problem.

The near perfect interocular transfer of all tasks demonstrated by the commissure-intact animals was interrupted by the section of the forebrain commissures—more severely for pattern and form than for color. Postoperative testing, however, disclosed some impairments of immediate recall through the untrained eye for all stimuli. It is concluded that, although an ipsilaterally induced discriminative habit is more favorable to color stimuli than others, nevertheless, a subcallosally transmitted, contralaterally retreivable memory trace seems as non-sensory specific in nature.

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