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RELEARNING TESTS FOR INTEROCULAR TRANSFER FOLLOWING DIVISION OF OPTIC CHIASMA AND CORPUS CALLOSUM IN CATS[1]

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It has been found that pattern discriminations learned with one eye transfer readily to the untrained eye in cats that have had the optic chiasma divided in the midsaggital plane (2). If, in addition, the hemispheres have been separated by section of the corpus callosum, the discrimination performance drops to a chance level as soon as the blinder is shifted to the trained eye. The performance then remains at or near chance throughout 40 to 80 test trials with the untrained eye, suggesting complete amnesia for the habit learned with the first eye. Further, in these cats with chiasma and callosum both sectioned, opposing discrimination responses, normally incompatible, can be learned independently with right and left eyes, respectively (3). Together, the findings suggest that the interocular transfer in chiasma-sectioned cats is mediated centrally by the corpus callosum and cannot be obtained with the callosum sectioned.

The present investigation was undertaken to test the possibility that some latent transfer that remained undetected under the above conditions might be revealed in more rapid relearning of the discrimination with the second eye. The general plan was to compare the monocular learning of a series of visual discriminations with the relearning of the same discriminations through the other eye in cats with chiasma and callosum both sectioned.

METHOD

Subjects

Six cats were used, ranging in age from five to ten months at the start of the experiment. They were brought into the laboratory from various sources at ages ranging from two to eight months. The chiasma was sectioned first and then the callosum by the same surgical method used previously (2, 3) with an interval varying from 5 to 26 days between first and second operations. A minimum of four weeks was allowed for recovery from the second operation before training was started. Animals *Ptr* and *Rpt* were already acquainted with the discrimination box and the training procedure from an earlier experiment in which *Ptr* had 140 trials and *Rpt* 2,900 trials in learning to discriminate different types of triangular figures.

Apparatus

A darkened discrimination box was used in which the cats were trained to choose the correct one of two translucent patterns placed side by side in swinging doors at the end of the box (5, 6). Correct responses were rewarded with a morsel of food; incorrect responses activated a buzzer. One eye was kept covered by a rubber mask of the type devised by Myers (2). The pairs of patterns are illustrated in Figure 1. An attempt was made to select pairs of patterns that were quite dissimilar in order to avoid carry-over of generalization or interference effects from earlier to later learning tasks.

Procedure

The training schedule involved five daily sessions per week of 50 to 60 trials as a rule, though as many as 90 trials were given occasionally. The patterns were alternated from left to right in accordance with Gellermann's principles (1), except when it became necessary to break a position habit. If a position preference persisted for more than 10 trials, the correct pattern was placed on the nonpreferred side until *S* made two successive correct responses. Successive errors in excess of four made under these latter conditions were not included in the score tabulations.

The trials were recorded in groups of 10. A criterion for learning was selected as the attainment of 17 or more correct choices within two successive groups, provided 18 or more correct responses were made in the succeeding 30 trials, so that the performance was thereby maintained above the .01 probability level through 50 trials. The first of these 50 trials was taken as the point at which learning had occurred and overtraining started. After criterion had been reached by the second eye, additional overtraining was given to balance the number of trials for each eye in order to equalize any possible carry-over to subsequent problems. After one problem had been completed with both eyes, a rest interval of three to four days was given before starting the next problem.

An initial screening problem (*A* of Fig. 1) was presented to right and left eyes on alternate days to disclose any pre-existent gross asymmetry in visual capacity. Two cats not mentioned in the present report were discarded because vision was inferior on one side. (Neither this method for selecting cases with symmetrical vision nor the exact procedure for breaking

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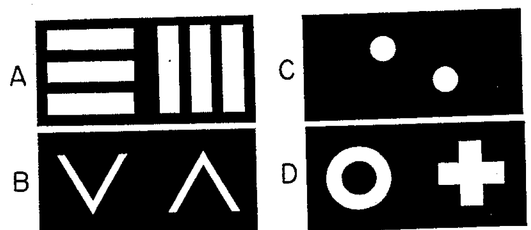

FIG. 1. Four pairs of stimulus patterns used for training visual discrimination.

position habits described above were applied in the preliminary observations.) All subsequent discriminations were trained and overtrained with one eye first and then relearned and overtrained with the other eye. Table 1 presents the order in which the problems were learned by each *S*. An additional discrimination problem not shown was given to cases *Hrr*, *Jrr*, and *Rpt*, but it was discarded because no sign of learning had appeared after more than 600 training trials. The two patterns in this problem were a luminous ring and a narrower ring with a central dot, the two equated for brightness.

RESULTS

Preliminary Observations

All cases except *Ptr* and *Rpt* were introduced to the training box by having them learn a simple brightness discrimination. The scores indicated little or no positive transfer except in the case of *Chn*, where the saving with the second eye was approximately 75 per cent.

Cases *Frr* and *Chn* were then trained and overtrained in the regular manner on discrimination problems A and B of Figure 1. From the scores it was evident that the vision of *Frr* was not equal on the two sides, owing presumably to asymmetrical damage incurred in sectioning the chiasma. When this was taken into account, there was indication of transfer only in the records of *Chn*, where the savings in relearning amounted to approximately 80 per cent and 70 per cent, respectively. However, in problem A, *Chn* had learned so rapidly (50 and 10 trials for first and second eyes, respectively) that the significance of the difference was questionable. In problem B (criterion attained in 300 and 90 trials, respectively) the higher score was associated with the introduction of a new and slightly modified training box and also with a long run of 86 trials required to break a position preference for the left side.

Chn was given one more problem, not illustrated, consisting of a central circle with three broad extending spokes versus a similar circle with six narrow spokes. It was learned with the left eye in 260 trials. When there was no sign of learning with the second eye after 657 trials, training was discontinued. This indication of a superiority of the left side tended to discount the apparent savings on the other problems except in problem A, the only other problem where the left eye was trained first.

On the whole these preliminary results pointed to an absence of any consistent marked saving effect in relearning with the second eye. In view of the scores of *Chn*, however, the possibility of occasional transfer in some instances could not be excluded. Accordingly, the experiment was continued with a more extensive series of tests as described below.

Main Experimental Tests

An attempt was made to eliminate some of the difficulties encountered in the foregoing by selecting cats at the start in which vision was approximately equal on both sides. Also, the training procedures were more strictly standardized as outlined above. Cases *Hrr*, *Jrr*, *Ptr*, and *Rpt* were trained to discriminate the sets of patterns illustrated in Figure 1. The order in which the problems were presented and the sequence in which the eyes were alternated are given in Table 1 along with the

TABLE 1

Summary of Training Sequence and Results

Subject	Discrimination Problem	Total Training Trials with (L)eft and (R)ight Eyes		Number of Trials Required for Learning		Saving Score (%)
		1st Eye	2nd Eye	Learn	Relearn	
Hrr	A*	R 170	L 130	80	70	+13
	B	L 560	R 520	170	160	+6
	C	R 1485	L 1260	850	830	+2
Jrr	A*	L 295	R 295	200	250	−25
	B	R 665	L 665	250	280	−12
	C*	L 1050	R 1145	570	490	+14
	D*	R 380	L 380	160	160	0
Ptr	A	R 210	L 270	180	190	−5
	B*	R 665	L 670	240	190	+21
	D	L 440	R 560	200	380	−90
Rpt	A	R 130	L 150	40	40	0
	B	R 820	L 830	300	340	−13

*An asterisk indicates that the pattern rewarded is placed to the right in Figure 1. Otherwise the left pattern of each pair was rewarded.

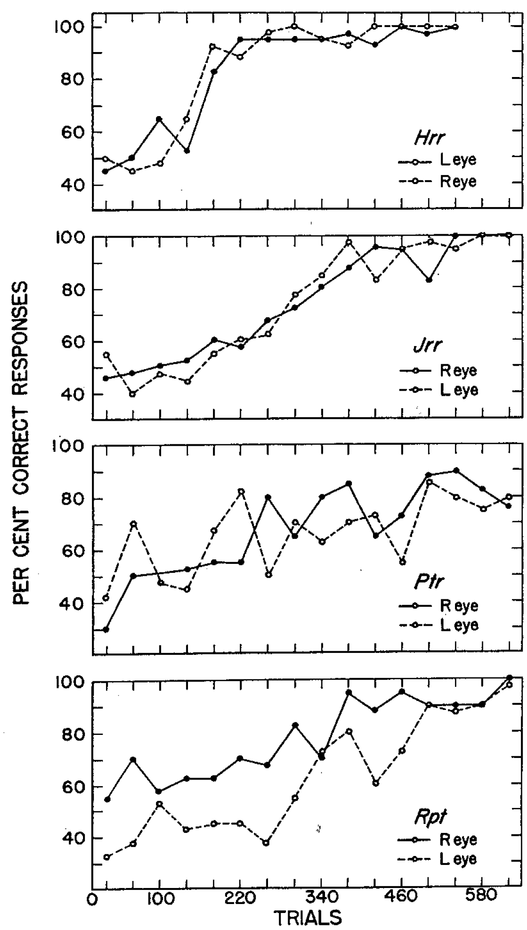

FIG. 2. Learning (solid line) and relearning (dotted line) curves for four animals on discrimination problem B of Figure 1.

number of trials required to reach criterion. The total number of trials for each eye, including overtraining, is shown in columns 3 and 4. The degree of transfer from first to second eye is given in the last column as the saving score. This saving score is the ratio of the trials saved in relearning to the trials required in initial learning, stated as a percentage. The saving scores are negative where relearning was slower than the initial learning. The scores for A, the screening problem, are included in the table since the total result indicated that learning with the separate eyes proceeded independently. Only on the basis of complete independence are the A scores comparable in meaning to the others.

The score of *Ptr* on problem D appears less out of line with the others when considered in terms of the complete learning curves (Fig. 4), where it can be seen that *Ptr* during relearning performed just below the criterion level for approximately one hundred trials before attaining 17 correct responses out of 20. If the saving score in this case is computed for the .05 instead of the .01 level of probability (i.e., 15 instead of 17 correct out of 20), it becomes −45 per cent.

The median percentage savings for all problems for each *S* are: 6 for *Hrr*, −*6* for *Jrr* and *Rpt*, and −5 for *Ptr*. The median of the scores for all cats on each problem are: −2 for A, −3 for B, 8 for C, and −45 for D. The 12 problems, as shown by Table 1, yielded 5 negative, 2 zero, and 5 positive saving scores resulting in a median saving of zero.

The saving scores can be more satisfactorily evaluated after consideration of the complete learning curves. Comparisons between the initial learning and relearning curves for the three principal test discriminations are presented in Figures 2, 3, and 4. The points on these curves represent the percentage of correct responses for successive blocks of 40 trials in Figures 2 and 4, and for blocks of 80 trials in Figure 3. In general, the curves, like the saving scores, indicate lack of transfer.

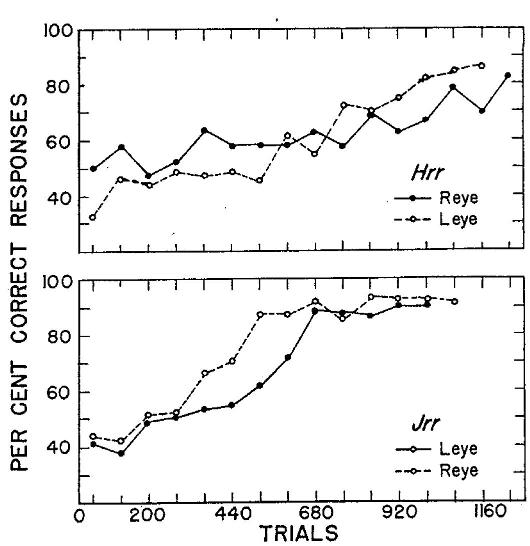

FIG. 3. Learning (solid line) and relearning (dotted line) curves for two animals on discrimination problem C of Figure 1.

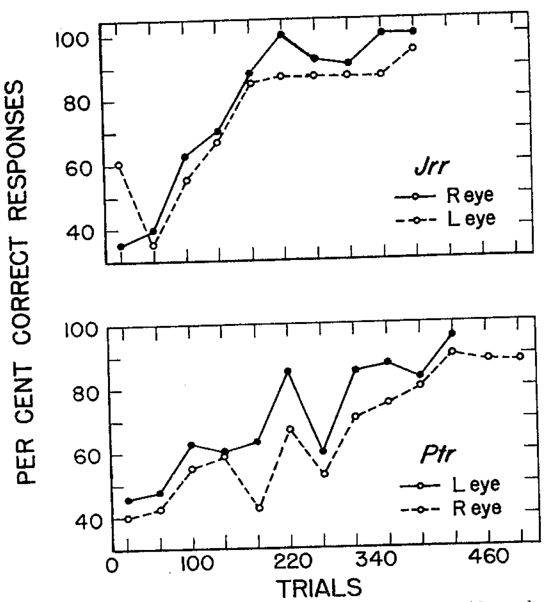

FIG. 4. Learning (solid line) and relearning (dotted line) curves for two animals on discrimination problem D of Figure 1.

Anatomical Checks

Cats *Chn* and *Frr* were sacrificed; the remainder have been retained for use in other experiments. In these two cases the corpus callosum was found to have been completely sectioned. The optic chiasma also was completely sectioned in *Frr*, but the cut was nearly 1 mm. to the left of the mid-line, and the left optic tract was thinner and flatter than the right, indicating greater atrophy. In *Chn* the chiasma lesion and the inserted piece of tantalum foil were somewhat displaced posteriorly. In dissection under a stereoscopic microscope, it appeared that a small, ribbon-like bundle of fibers at the anterior edge of the chiasma in *Chn* had escaped section. The intact ribbon represented not more than approximately 8 per cent of the total cross-sectional area of one optic nerve in front of the chiasma. Since the data pointed to absence of transfer in the other four cases, further anatomical checks were considered unnecessary.

DISCUSSION

The results of the main series of tests, summarized in Table 1 and Figures 2, 3, and 4, are generally opposed to any visual transfer. The positive saving scores are seen to be small in all cases, not exceeding 21 per cent, and they are counterweighted by negative saving scores of approximately the same or greater magnitude. The difference in learning scores for first and second eyes is well within the range of normal variation that we commonly see in the learning of the same problem by different cats or in the learning of different problems of similar difficulty by the same cat.

The highest saving score in the main series, that of *Ptr* on problem B, is partially invalidated by the extreme fluctuation of the learning curve. The strongest indication of any positive transfer in the combined learning curves and saving scores of this series is found in the performance of *Jrr* on discrimination problem C. Even here it was not until after the three-hundredth relearning trial that any transfer effect was manifest. This result is counterbalanced by a comparable divergence in the opposite direction in the curves of *Rpt* on problem B. Both of these may be nothing more than ordinary variations in the learning process. If it could actually be shown that the small improvement with the second eye in *Jrr* were significant, it still would not necessarily follow that it represented visual transfer. Conceivably bilateral proprioceptive feedback from head and eye movements might be sufficiently simple, consistent, and directional in this particular "high-low" discrimination to serve as learning cues.

The preliminary findings, except for the scores of *Chn*, are not inconsistent with the main series. The apparent transfer in *Chn* seems to be discredited by the incompleteness of the chiasma section and the possible superiority of vision on the left side, as well as the extreme speed of learning in A and the uncorrected position preference in B.

It was somewhat unexpected that greater positive saving was not obtained in the initial discrimination problems that were used to accustom the animals to the training situation. The nonvisual aspects of the learning experience not unilaterally restricted ought presumably to carry over and aid in relearning. Perhaps the nonvisual phases of the learning proceeded so rapidly that the small number of trials involved constituted only an insignificant fraction of the total score. Also, it is possible that the nonvisual cues under conditions such as these tend to be associated with the visual to a large extent, with the result that the hemisphere with vision tends to be dominant with respect to the nonvisual as well as the visual features of the learning process.

Taken as a whole the findings point to the conclusion that visual mnemonic effects implanted through one eye under the above experimental conditions are inaccessible when the other eye is used. In other words, the function of the two hemispheres with respect to visual learning and memory remains entirely independent. The present results do not exclude the possibility of interocular transfer under other conditions as, for example, after excessive overtraining to a high level of automaticity. Particularly in the case of brightness discrimination, which is still present after removal of striate cortex in the cat (4), one might expect to find conditions that would make transfer possible at the subcortical level. Finally, it is interesting that the learning curves for left and right hemispheres of the same animal, despite their independence and individual variation, are found to be much more alike in character than are those from different animals.

SUMMARY

Six cats with optic chiasma and corpus callosum sectioned in the midsagittal plane were tested for interocular transfer. The monocular learning of a series of visual discriminations was compared with the relearning of the same discrimination tasks with the opposite eye. The object was to find out whether the learning with the second eye would be improved by the initial experience with the first eye. No significant saving was found in the relearning scores except in one case, which proved to have incomplete section of the optic chiasma. The results indicate that under the conditions of the experiment visual learning and memory proceed independently in right and left hemispheres.

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