

## PERMANENT DEFICIT OF INTEROCULAR TRANSFER IN BINOCULARLY DEPRIVED CATS

Teresa ZABŁOCKA and Czesława DOBRZECKA

Department of Neurophysiology, Nencki Institute of Experimental Biology  
Pasteura 3, 02-093 Warsaw, Poland

*Key words:* binocular deprivation, interocular transfer, visual discrimination, cat

**Abstract.** Fifteen laboratory born cats were used: seven binocularly deprived, four reared under condition of daily alternating monocular exposure and four controls. At the 7th month of age four of the binocularly deprived cats and all the remaining cats were trained monocularly in a two choice apparatus. In the first stage of training the cats learned a test with the right eye and were tested for transfer to the left eye. In the second stage, a new test was learned with the left eye, after which transfer to the right eye was tested. Control and with alternating monocular exposure cats had a normal interocular transfer whereas the binocularly deprived cats showed an impairment. After this training all binocularly deprived cats had the hoods taken off for 8 months and were then trained with new tasks. Their interocular transfer was still impaired. Thus, binocular pattern stimulation in the early period of life — simultaneous or alternate — is necessary for normal interocular transfer.

### INTRODUCTION

In monocularly deprived cats interocular transfer (IOT) is impaired (2, 12). However, transfer is immediate in cats with daily alternating monocular exposure (4, 5, 15). Ganz et al. (5) found a high IOT in BD group (savings scores averaging + 70.8%). According to Ganz (4), experience is not an essential precondition for the IOT of simple form dis-

crimination. Those results were confirmed by Meyers and McCleary (9). The purpose of this study was a further analysis of interocular transfer in binocularly deprived cats. In particular, the permanence of the deficit was investigated.

#### METHODS

Fifteen laboratory born cats were used. They were kept with their mothers in cages for about 2 months. Then they were transferred to big cages,  $3.40 \times 1.15 \times 3$  m and were allowed to go out to open-air cages ( $4.5 \times 1.5 \times 1.70$  m). Seven cats were binocularly deprived of pattern vision for 6 months by means of linien hoods put on their eyes from the 7th day of life (BD group), four cats had daily alternating monocular exposure i.e. hoods with a hole on one side were changed daily (AME group), and four controls were reared without hoods (C group).

The experiment consisted of two discrimination trainings (the early and the late one separated by 8 months interval).

For the early visual discrimination training four BD cats (no. 94, 97, 125 and 132), and all AME and C cats were used. The training was monocular. BD cats had a hole cut in the hoods uncovering one eye, training started after 7 days of adaptation. BD and AME cats wore hoods (with one eye uncovered) also between the experimental sessions.

The cats were trained in a two-choice apparatus, consisting of start box and goal box separated by an opaque lift door (Fig. 1). Black visual patterns against white background  $3.5 \times 3.5$  cm were placed on swinging gates behind which raw meat for reward was available. The distance

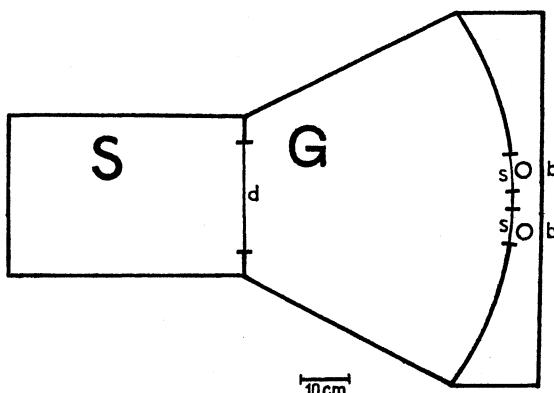


Fig. 1. Apparatus for visual discrimination training. S, start box; G, goal box; d, lift door; s, gate; b, bowl.

between door and the gates was 57 cm. During the first days of training the cats were familiarized with the apparatus. When they could open the gates and obtain meat, the proper training started.

Each daily session consisted of sixteen trials. Stimuli were presented at random order. In each trial the cats having opened the lift door, could enter the goal box and make a choice. If they opened the correct gate with a positive pattern, they were rewarded with meat and went back to the start box. If they tried to open the gate with the negative pattern, a rerun followed with identical pattern arrangement. The first error in a trial was called initial error. Those that followed were called repetitive errors. The animal was allowed no more than two repetitive errors. After three errors (one initial and two repetitive) the cat was guided to the correct gate in a so-called passive trial. The animals were trained to a criterion of no more than 10% initial errors in five consecutive sessions.

During training cats were deprived of food, they ate only during experimental sessions (16 teaspoons of meat). In the home cages they drank milk.

The training was performed in two stages. In the first stage the cats learned to discriminate monocularly with the right eye a cross vs. a circle until they reached criterion (Fig. 2A). Then the right eye was cov-



Fig. 2. The visual patterns used in stage I and stage II in the early (A) and late (B) training.

vered and the left opened and after one week of adaptation period interocular transfer was examined. The interocular transfer was considered immediate when the cat kept criterion, i.e. made no more than 8 initial errors in the first five sessions. If the cat did not have an immediate interocular transfer, training with the left eye continued until criterion.

In the second stage the cats learned to discriminate a filled triangle from an open square (Fig. 2) with the left eye and were tested for interocular transfer with the right eye. In this way each eye was tested as "naive" (stage I) and as "trained" eye (stage II). The second stage of training started on the day following the opening of the left eye.

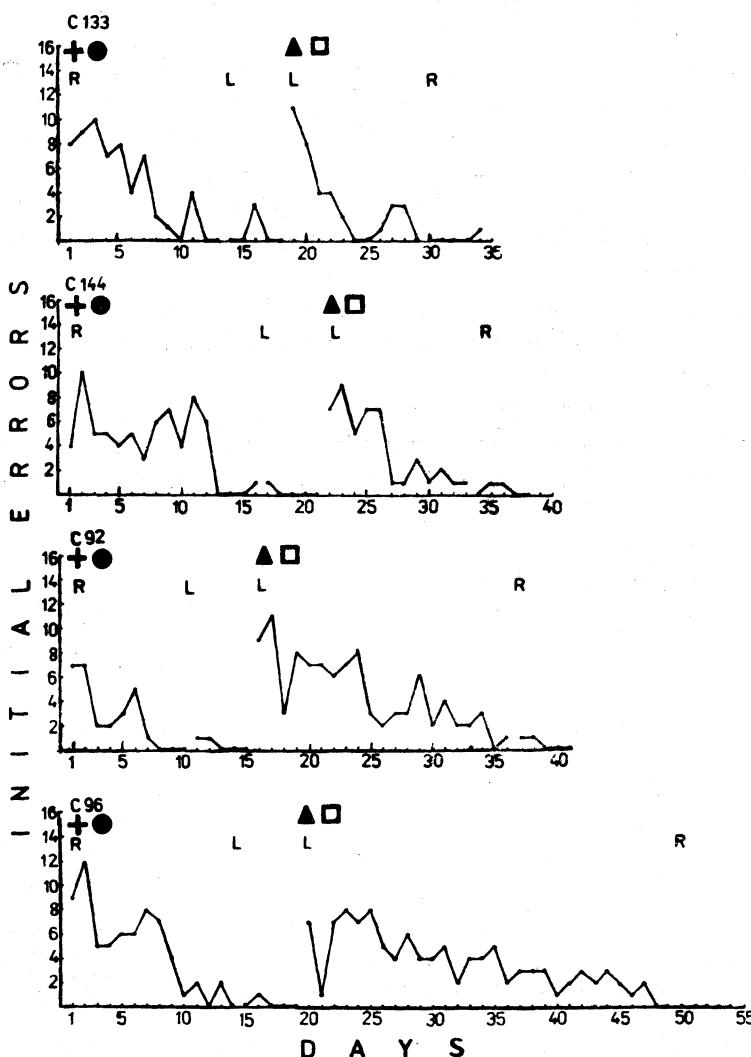


Fig. 3. Day-to-day performance in learning discrimination and in (IOT) in control (C) cats. Above each graph the number of the cat and pairs of presented patterns are indicated. R, right eye open; L, left eye open. Only the days of training are indicated.

In the late training six BD cats (three naive: 172, 185 and 186 and three trained: 94, 125 and 132) were allowed to spend 8 months without hoods. Then the original training procedure started again, with cats wearing hoods with one open hole only during the training sessions. In the first stage the cats learned "L" vs. "T" discrimination with the right eye and interocular transfer was tested with the left eye. Then the animals learned "H" vs. "F" discrimination with the left eye and transfer to the right eye was tested (Fig. 2B).

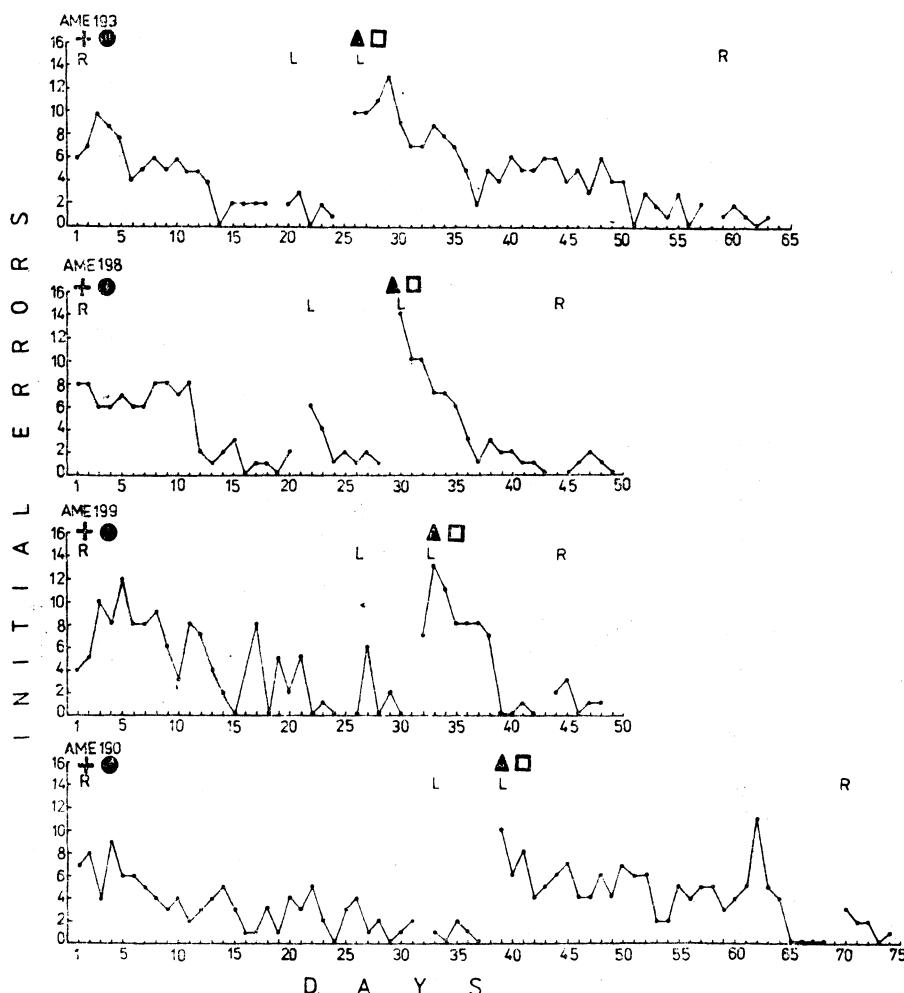


Fig. 4. Day-to-day performance in learning discrimination and in IOT in cats with daily alternated deprivation (AME). Denotations as in Fig. 3.

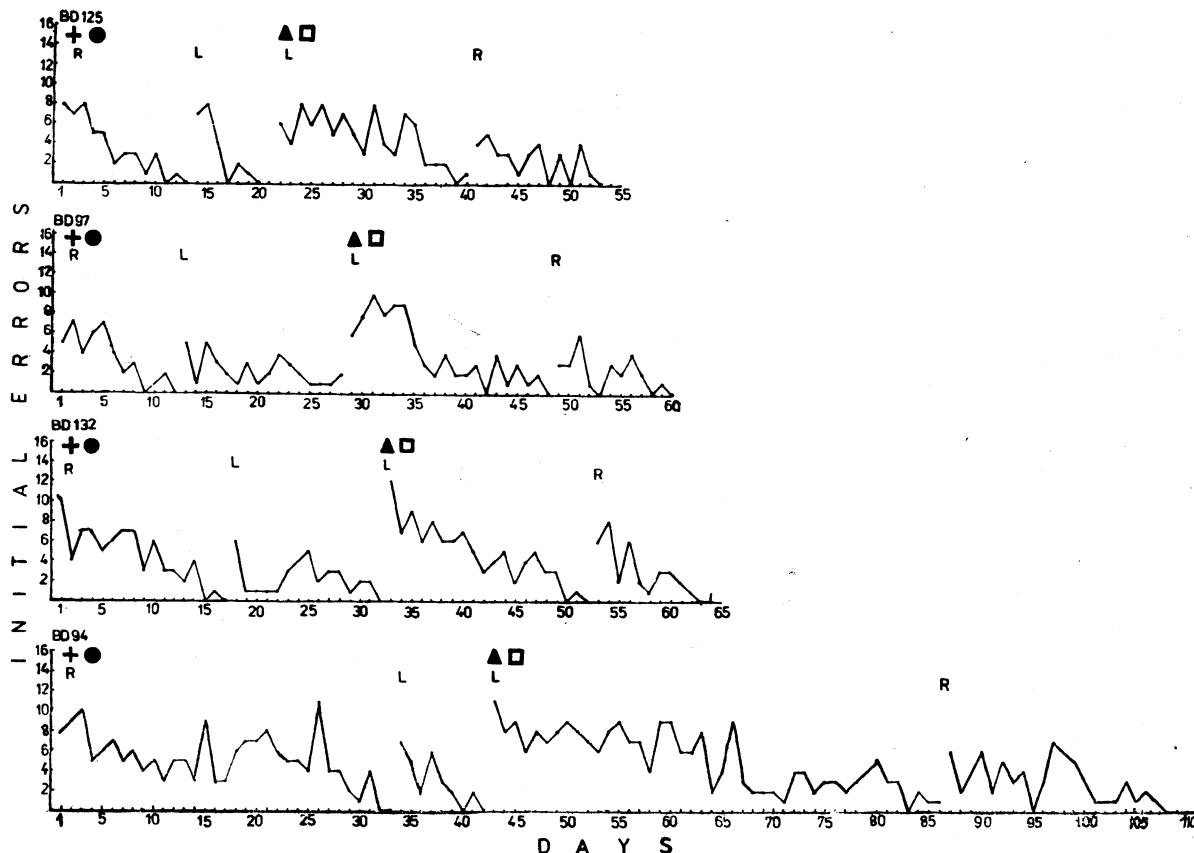


Fig. 5. Day-to-day performance in learning discrimination and in IOT in binocularly deprived (BD) cats. Denotations as in Fig. 3.

## RESULTS

Figures 3-6 show the results of learning and IOT in C, AME and BD cats in the early training. Figures 3-5 present the day-to-day discrimination learning with the right eye, transfer to the left eye, learning another test with the left eye and transfer to the right eye. Figure 6 summarizes the results. Although there were some differences between the subjects the discrimination tests were rather easy for all groups.

The main difference between BD cats and other groups was in the interocular transfer. Figures 3, 4 and 6 show that the C and AME cats had an immediate transfer: on the graphs were plotted only the results of five criterion sessions, because in these two groups no learning in

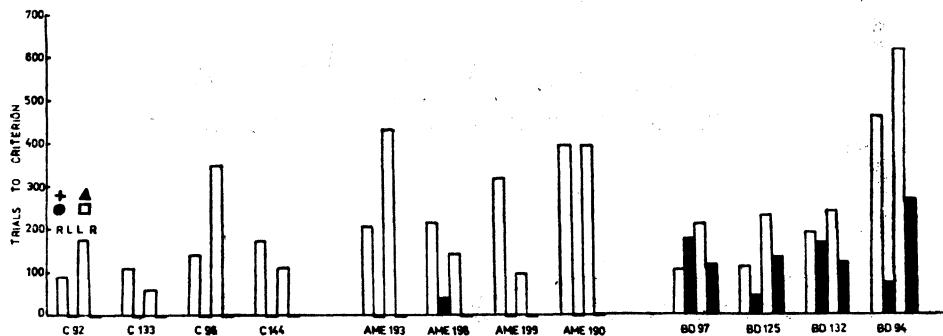


Fig. 6. Comparison of number of trials to criterion during learning and IOT in C, AME and BD cats. The criterion trials are excluded. White bars, learning; black bars, transfer; immediately transfer is marked under the abscissa. Other denotations as in Fig. 3.

the transferred eye was necessary. The C and AME cats showed a small number of errors on the first day of interocular transfer testing, because they were on the criterion level with the transferred eye.

In BD cats the transfer was impaired, no matter whether the eye was naive or formerly trained in stage I (Figs. 5 and 6). Remarkably, the first day of transfer testing began with a large number of errors as observed on the first day of learning. The BD cats were not on criterion level with the transferred eye and they had to be trained to reach criterion.

Interocular transfer can be expressed in terms of percent savings:

$$S = \frac{\text{number of trials with first eye} - \text{number of trials with second eye}}{\text{number of trials with first eye} + \text{number of trials with second eye}} \times 100$$

For the C and AME cats the saving was 100% with exception of cat AME 198 with 75% of saving in stage I. The BD cats had in most cases saving below 50% (Table I).

In the late training only BD cats were investigated, 3 naive and 3 previously trained. The results of pattern discrimination learning and

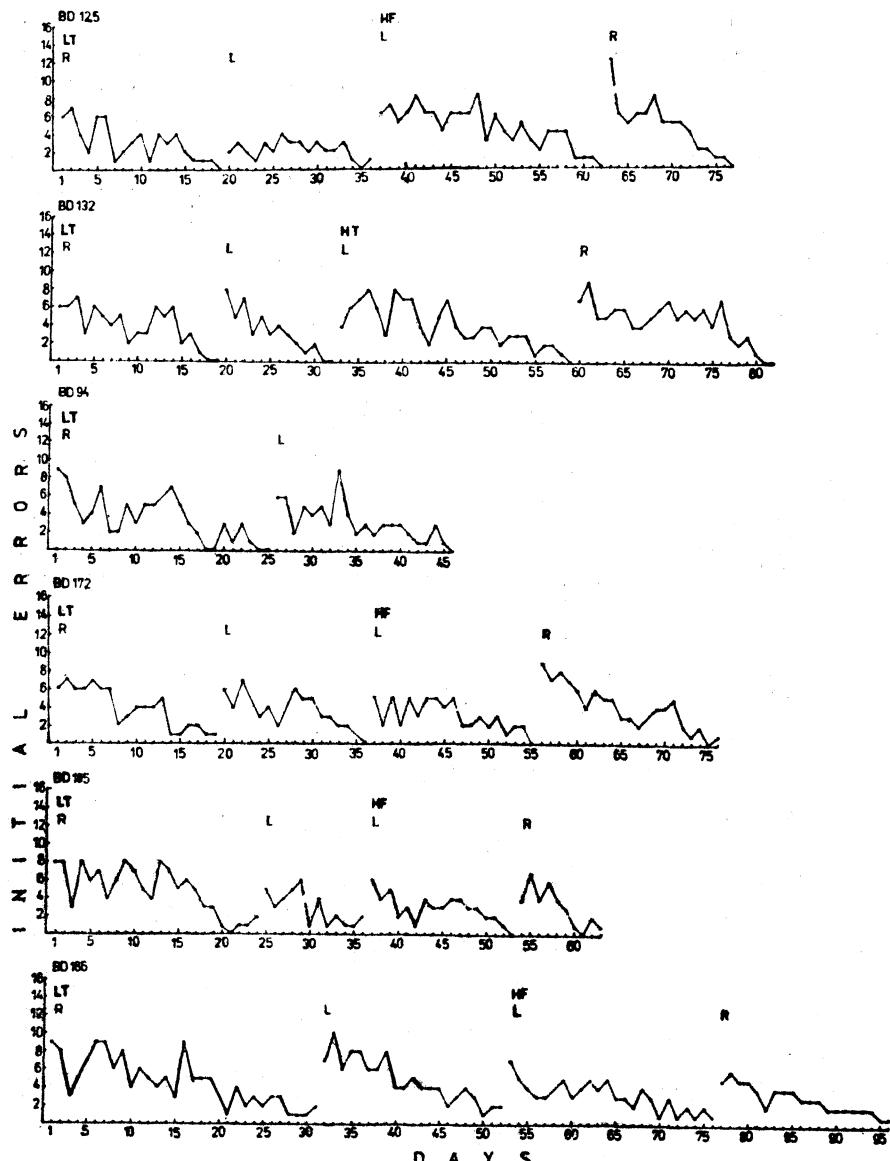


Fig. 7. Day-to-day performance in learning discrimination and IOT training in BD cats after a recovery period of 8 months. Denotations as in Fig. 3.

interocular transfer are presented in Figs. 7 and 8. No cat had an immediate transfer, thus the deficit of IOT was permanent, and after 8 months of normal conditions no recovery of IOT was observed. Similarly to the early training on the first sessions of transfer testing, the number of errors was high (Fig. 7). The percentage of saving in IOT in these cats is shown in Table I.

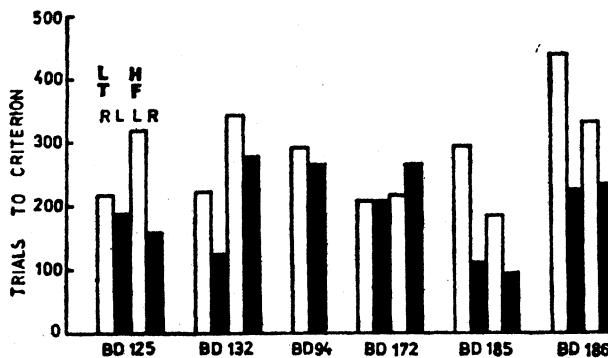


Fig. 8. Comparison of number of trials to criterion during learning and IOT in BD cats after a 8 months recovery period. The criterion trials are excluded. Denotations as in Fig. 6.

TABLE I

Percent of saving in interocular transfer in BD cats. The criterion trials are excluded

Cat	Stage I	Stage II
<b>Early training</b>		
BD97	-0.25	30
BD94	75	39
BD125	55	29
BD132	9	36
<b>Late training</b>		
BD94	2	no data
BD125	7	35
BD132	27	10
BD172	0.2	-10
BD185	46	33
BD186	22	25

## DISCUSSION

Our results show that binocular visual deprivation causes serious and presumably irreversible handicap of interocular transfer. No recovery was noticed after 8 months of living with both eyes open. For unknown reasons our results differ from those by Ganz et al. (5) and Meyers and McCleary (9). In Ganz et al's study the interocular transfer was good in the BD group (savings scores averaging 70.8%) and in the monocular alternators. Meyers and McCleary reared cats in darkness, with periodic exposure to diffused light. Then the animals were tested monocularly on pattern discrimination and IOT by using leg flection as conditioned response and the transfer was found to be good. The authors concluded that the neural mechanism necessary for transfer is present innately.

Binocular deprivation in diffused light causes some changes in visual cortex, including a decrease in number of binocularly activated neurons (1, 5, 7, 10-13, 15-17). In a study in our laboratory on BD cats deprived in the same way and for the same period of time Michalski et al. (10) found that only 10% of all cells in area 17 were activated binocularly in an equal degree. This decrease in binocularity could be the reason of affecting IOT. However this supposition is not supported by results from AME cats with unaffected IOT and reduced number of binocularly activated neurons (1, 5, 14, 15). Moreover normal IOT has been found in Siamese cats who have no binocularly activated neurons at all (8).

The method of monocular deprivation applied by Riesen et al. (12), the one used by von Grünau and Singer (15), and also our method (BD) lead to decrease in binocularly (10). Riesen et al. (12) failed to observe IOT when one eye of the cat was exposed to diffused light and the other to patterned environment, but von Grünau and Singer described undisturbed IOT in AME cats. Our results on AME cats are consistent with this data. They show presumably permanent impaired IOT as a result of binocular deprivation. This indicates in agreement with studies by Ganz et al. (5) and von Grünau and Singer (15) that IOT is not related to the number of binocular neurons in the visual cortex.

From the results of experiments on monkeys Chow and Nissen (2) concluded that IOT is not impaired in case of eye equivalence, as to patterned stimulation of both eyes, simultaneous or alternate.

Some authors (7, 11) point to a difference in effect of deprivation by lid suturing and by dark rearing. During dark rearing no visual stimulation, takes place while lid-suturing allows an abnormal and asynchronous light stimulation (7). Whereas dark rearing leaves the visual system capable of modification, apparently indefinitely (3, 11), rearing

in diffuse light penetrating through the sutured eye lids constitutes a factor modelling the cat's visual system in the critical period (11).

All these data suggest that the influence of patterned environment on both eyes in the critical period is a necessary factor for normal interocular transfer. We believe that in our experiments two factors were responsible for the lack of transfer: the absence of patterned stimulation during the critical period and diffused light modelling the visual system in the period of its greatest sensitivity. Long-term BD by hood rearing affects or prevents the development of IOT of information indispensable for pattern recognition, and recovery is not possible.

Another problem is learning in BD cats. In our previous study (18) the BD cats had an impaired ability of visual discrimination learning, which did not occur in this study using a less complicated apparatus. The binocular deprivation by means of linen hoods certainly does not impair the ability of visual discrimination learning of geometrical patterns and the deficit found previously was probably due to more complicated experimental situation.

As in our experiments we deal with animals deprived by means of linen hoods, some attention should be paid to the question whether this method can be compared to the method of lid suturing used by various authors. The amount of light passing through linen hoods is comparable to the amount that penetrates through closed eyelids (6). Therefore it see reasonable to accept that hood rearing influences the visual system neurons similarly as eyelid suturing.

#### REFERENCES

1. BLAKEMORE, C. 1976. The conditions required for the maintenance of binocularity in the kittens visual cortex. *J. Physiol.* 261: 423-444.
2. CHOW, K. L. and NISSEN, H. W. 1955. Interocular transfer of learning in visually naive and experienced infant chimpanzees. *J. Comp. Physiol. Psychol.* 48: 229-237.
3. CYNADER, M. and MITCHELL, D. E. 1980. Prolonged sensitivity to monocular deprivation in dark-reared cats. *J. Neuroph.* 4: 1026-1040.
4. GANZ, L. 1978. Innate and environmental factors in the development of visual form perception. In R. Held, H. Leibowitz and H. L. Teuber (ed.), *Handbook of sensory Physiology*. Springer-Verlag, Berlin, p. 440-488.
5. GANZ, L., HIRSCH, H. B. and TIEMAN, S. B. 1972. The nature of perceptual deficits in visually deprived cats. *Brain Res.* 44: 547-568.
6. KOSSUT, M., MICHALSKI, A. and ŹERNICKI, B. 1978. The ocular following reflex in cats deprived of pattern vision from birth. *Brain Res.* 141: 77-87.
7. KRATZ, K. E. and SPEAR, P. D. 1976. Effects of visual deprivation and alternations in binocular competition on responses of striate cortex neurons in the cat. *J. Comp. Neurol.* 170: 141-151.
8. MARZI, C. A., SIMONI, A. and DI STEFANO, M. 1976. Lack of binocular dri-

ven neurons in the Siamese cat's visual cortex does not prevent successful interocular transfer of visual discrimination. *Brain Res.* 105: 353-357.

- 9. MEYERS, B. and McCLEARY, R. 1964. Interocular transfer of pattern discrimination in pattern deprived cats. *J. Comp. Physiol. Psychol.* 57: 16-21.
- 10. MICHALSKI, A., KOSSUT, M., TURLEJSKI, K. and CHMIELOWSKA, J. 1983. Responses of area 17 neurons in cats binocularly deprived by rearing in hoods. *Acta Neurobiol. Exp.* 43: 263-272.
- 11. MOWER, G. D., BERRY, D., BURCHFIELD, J. L. and DUFFY, F. H. 1981. Comparison of the effects of dark rearing and binocular suture on development and plasticity of cats visual cortex. *Brain Res.* 220: 255-267.
- 12. RIESEN, A. F., KURKE, M. J. and MELLINGER, J. C. 1953. Interocular transfer of habits learned monocularly in visually naive and visually experienced cats. *J. Comp. Physiol. Psychol.* 46: 166-172.
- 13. SHERMAN, S. M. and SPEAR, P. D. 1982. Organization of visual pathways in normal and visually deprived cats. *Physiol. Rev.* 62: 738-855.
- 14. TIEMAN, D. G., McCALL, M. A. and HIRSCH, H. V. B. 1983. Physiological effects of unequal alternating monocular exposure. *J. Neurophysiol.* 49: 804-817.
- 15. VON GRÜNAU, M. W. and SINGER, W. 1979. The role of binocular neurons in the cat striate cortex in combining information from the two eyes. *Exp. Brain Res.* 34: 133-142.
- 16. VON GRÜNAU, M. 1979. Binocular summation and the binocularity of cat visual cortex. *Vision Res.* 19: 813-816.
- 17. WIESEL, T. N. and HUBEL, D. H. 1965. Comparison of the effects of unilateral eye closure on cortical unit responses in kittens. *J. Neurophysiol.* 28: 1029-1040.
- 18. ZABŁOCKA, T., KONORSKI, J. and ŻERNICKI, B. 1975. Visual discrimination learning in cats with different early visual experiences. *Acta Neurobiol. Exp.* 35: 389-398.

Accepted 5 July 1986