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Reversal of visual discrimination and visual acute extinction in cats with poor or limited early visual experience

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Abstract. Transformation of visual instrumental conditioned reflexes rewarded with food was compared in cats binocularly deprived of pattern vision in the early period of life (BD cats), control cats reared also in the laboratory but with open eyes (C cats) and cats reared in normal environment (N cats). In Expt. I the cats were given 4 sequential reversal trainings of cross vs. disc discrimination and in Expt. II a response to a gate marked with a cross or a disc was submitted to 4 sequential acute extinctions and restorations. The results show that both visual deprivation and rearing in monotonous laboratory environment moderately affect transformation of associations between visual stimuli and hunger drive and instrumental responses. However, in BD cats transformation learning is less impaired than previously studied visual discrimination learning.

Key words: visual deprivation, cat, lab-rearing, visual acute extinction, visual discrimination reversal

INTRODUCTION

Several experiments (Riesen 1965, Ganz et al. 1972, Żernicki 1991, 1993, Zabłocka and Żernicki 1991, 1996) indicate that fine visual discrimination learning is severly impaired in cats submitted to early binocular deprivation (BD cats) as compared to cats reared in a normal environment (N cats) and control cats reared with open eyes in the laboratory (C cats). In addition, C cats are somewhat inferior to N cats in such discrimination. In contrast, neither visual detection learning, i.e., stimulus vs. no stimulus discrimination (Rodriguez and Żernicki 1982, Zabłocka and Żernicki 1988, 1990), nor crude visual discrimination learning (Riesen 1965, Ganz et al. 1972, van Hof-van Duin 1979, Zabłocka and Dobrzecka 1986, Zabłocka and Żernicki 1991, 1996, Żernicki and Zabłocka 1993) are impaired in BD and C cats.

These data lead to the following conclusions: (1) Difficult perceptual learning, presumably consisting in elaboration of separate perceptual assemblies for similar stimuli, is impaired in BD cats and also somewhat in C cats. (2) Perception itself and easy perceptual learning are not impaired in BD and C cats. (3) Easy associative learning, consisting in elaboration of associations between visual stimuli and the hunger and instrumental responses, is also not impaired in BD and C cats.

In the present study a transformation of such associations, presumably a difficult associative task, was compared in N, C and BD cats.

In Expt. I, a reversal of cross vs. disc discrimination was investigated. Such crude discrimination itself is not impaired in BD and C cats (Zabłocka and Dobrzecka 1986, Żernicki and Zabłocka 1993).

In Expt. II, acute extinction was investigated. One-gate and two-gate situations were used. In the latter, extinction occurred in a stimulus detection situation and so it should be more difficult than that in one-gate situation.

GENERAL METHODS

Twenty-four cats were used. Eight BD cats were binocularly deprived of pattern visual experience by means of double linen masks fitted on their heads during the first 6 months of life. Two other groups consisted of 8 C cats, litter mates of BD cats and raised with open eyes together with BD cats in a mesh pen, and 8 N cats brought to the laboratory when they were 4 months of age. The details of the deprivation technique and rearing conditions used in our laboratory have been described in detail elsewhere (Żernicki 1991).

The training apparatus consisted of a start compartment and a goal compartment separated by an opaque guillotine door. In the goal compartment, the animal could see two white gates (Expt. I and the two-gate situation in Expt. II) or one white gate (the one-gate situation in Expt. II). The stimuli were a black cross and a black disk mounted on the gates. The apparatus and the stimuli have been described in detail elsewhere (Żernicki 1991). The cats were trained 5 days per week. The results were examined by independent two two-way and one three-way mixed design analyses of variance (ANOVA) for repeated measures and post-hoc Duncan tests.

EXPERIMENT I: REVERSAL LEARNING

Methods

Four N cats (N1-N4), four C cats (C1-C4) and four BD cats (BD1-BD4) were used. These cats had been used in a previous study (Żernicki and Zabłocka 1996): they had then been trained in object discrimination (a black three-dimensional cross vs. a black ping-pong ball) and subsequently in discrimination of corresponding figures (a black cross vs. a black disk). In the previous study the cats had been numbered according to the numbers of initial errors (see below) in object discrimination learning, i.e., the best cat in each group became number 1 and the worst number 4, and these cat numbers were kept in the present study. When the present training started, all cats were about 15 months of age.

Immediately after reaching criterion performance in the cross vs. disk task in the previous study, the cats were used in the present study and were trained in the first discrimination reversal; that is, the cats that had been reinforced previously for selecting the cross were now reinforced for selecting the disk, and *vice versa*. Altogether, the cats were given 4 reversal stages: the original meaning of the stimuli was changed in reversals 1 and 3 and it was restored in reversals 2 and 4.

Each session consisted of 16 food-rewarded trials. Behind the gate with a positive stimulus, a piece of meat was available in a bowl, whereas the bowl behind the other gate was empty. The cross was the positive stimulus in cats N1, N4, C2, C3, BD2 and BD3 and the disk in cats N2, N3, C1, C4, BD1 and BD4. The left-right location of the stimuli was shifted on the basis of the

Gellermann (1933) sequences. After eating the meat or after an error the cat either returned to the start compartment spontaneously or was taken back by the experimenter. After an error was made a re-run followed. The first error was labelled an initial error, while those of the re-runs were called repetitive errors. The animals were allowed two repetitive errors. The third re-run was passive: the cat was pushed by hand to the gate with the positive stimulus. The cats were trained to a criterion of 10% or less initial errors for 5 sessions in a row.

Results

Numbers of initial and repetitive errors in all cats during 4 reversals are shown in Fig. 1. In all cats the initial errors usually decreased in sequential reversals. A 3 (group) x 4 (reversal) ANOVA for repeated measures yielded only significant reversal effect ($F_{3/27}$ = 4.99, $P<0.007$). The post hoc Duncan tests showed that the number of initial errors was higher in reversal 1 than in reversal 4 ($P<0.01$). No other comparisons reached a level of significance.

In all cats there was a clear tendency to decrease the number of repetitive errors, especially in reversal 2 as compared with reversal 1. The C cats showed the highest number of repetitive errors in reversal 1 and the fastest decrease during the sequential reversals comparing to the other animals. This was confirmed by an independent 3 (group) x 4 (reversal) ANOVA for repeated measures, which showed not only group ($F_{2/9}$ = 5.38, $P<0.03$) and reversal ($F_{3/27}$ = 12.07, $P<0.001$) effects, but also group x reversal interaction ($F_{6/27}$ = 4.92, $P<0.002$). Further Duncan tests revealed that the number of repetitive errors during reversal 1 was significantly higher ($P<0.001$) than in other reversals, which did not differ each from others. The C cats committed significantly more repetitive errors than N cats ($P<0.05$). The BD cats tended to commit more repetitive errors than N cats but less than

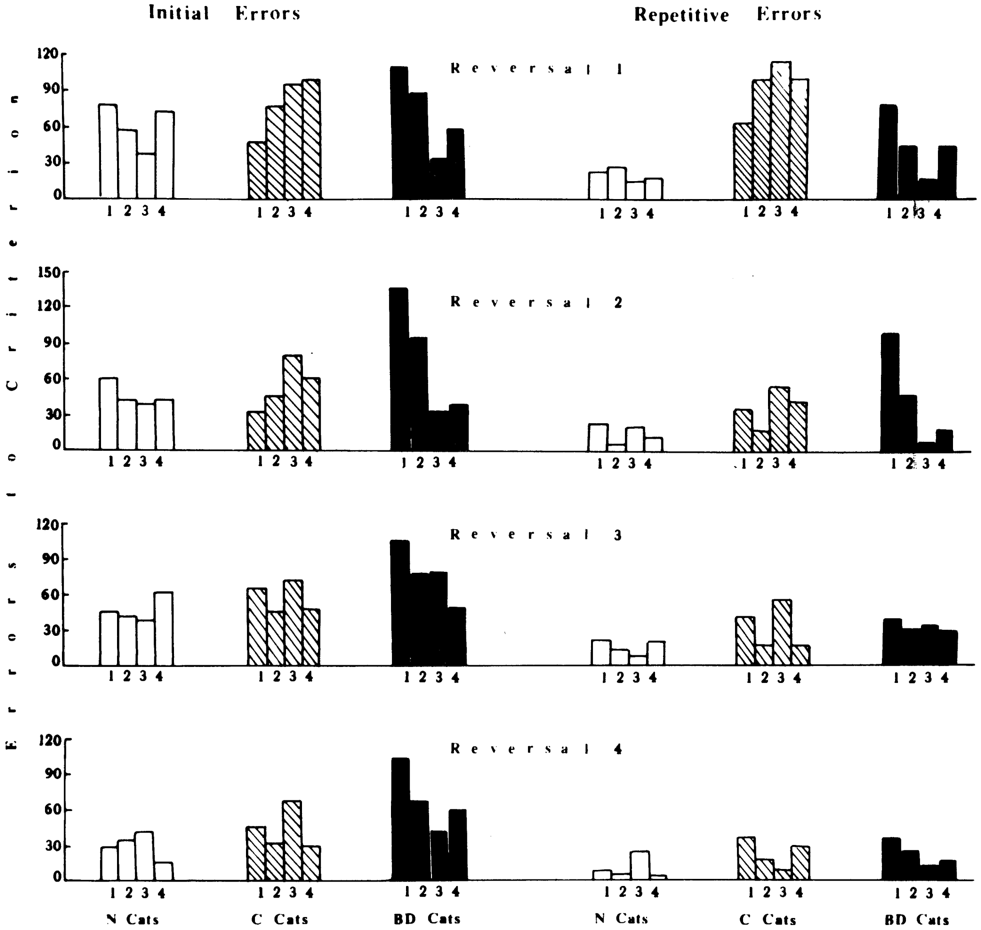

Fig. 1. Numbers of initial and repetitive errors to criterion during 4 reversals in individual cats in Expt. I. Criterion sessions are included.

C cats. However these differences did not reach the level of significance (BD vs. N cats, $P<0.07$; BD vs. C cats, $P<0.25$).

Discussion

That only C cats were significantly inferior to N cats can be explained by two factors considered jointly:

1. Earlier observations (Rodriguez and Żernicki 1982, Zabłocka and Żernicki 1988, 1990) indicated that BD cats can be better learners than C cats and even than N cats in detection tasks, i.e., in very easy perceptually tasks. A mechanism of such beneficial effects of visual deprivation may be due to a lesser distractibility of BD cats by external stimuli (see Żernicki 1991).
2. Although C cats have some early visual experience, they can certainly rarely utilize visual stimuli in the alimentary behaviour: they do not fight for food but are simply fed. Thus, C cats, apparently superior to BD cats in visual perceptual experience, may be less superior in-visual-alimentary associative experience.

That significant difference between C and N cats was found only for repetitive errors was rather unexpected. Such effect has not been found indeed in earlier studies. However, an exception was just the previous study in which the cats used presently had their original training on object discrimination (Żernicki and Zabłocka 1991). Then, the C and BD were significantly deficient only in repetitive errors.

Anyhow, the mechanisms responsible for initial and repetitive errors, respectively, are certainly not identical. A repetitive error is generally less likely to appear since a correct choice during re-run is based not only on long-term and short-term memory of meaning of discriminated stimuli but also on short-term memory of effectiveness of a previous direction choice. Thus, a deficit in spatial short-term memory might be partially responsible for the reversal learning impairment.

EXPERIMENT II: ACUTE EXTINCTION

Methods

Four N cats, 4 C cats and 4 BD cats were used. The cats were naive and 8-12 months of age when training started. Six cats (N5, N6, C5, C6, BD5, BD6) were used in the one-gate situation and six (N7, N8, C7, C8, BD7, BD8) in the two-gate situation. The stimulus was the cross in cats N5, N8, C6, C7, BD6 and BD7 and the disc in cats N6, N7, C5, C8, BD5 and BD8. Each session consisted of 12 food-rewarded trials.

In the one-gate situation, the cats simply learned to push the gate (marked with a stimulus) and take the food behind it. They were given 10 pre-extinction training sessions.

In the two-gate situation one gate was marked with a stimulus and the second was blank with no meat behind it. The left-right location of the stimulus was shifted on the basis of the Gellermann (1933) sequences. During the first few sessions, the cats learned to push the gates and take the food. During the following detection training the same procedure as described for discrimination training in Expt. I was used.

Each cat was given 4 extinction sessions. They were separated by 4 normal sessions. Each extinction session consisted of only non-rewarded trials. In the two-gate situation the left-right location of the stimulus continued to be shifted. A cat was allowed to push a gate (to make an error) during 30 s. After pushing a gate (any gate in the two-gate situation) or after a flight (see below) or after 30 s remaining in the goal compartment it was taken by the experimenter to the start compartment. The criterion of extinction was 5 trials in a row without pushing the gate (any gate in two-gate situation).

Results

In the one-gate situation the cats learned the original task immediatelly, they pushed the gate in all trials of all pre-extinction sessions. In the two gate-situation the original learning was also rapid. Cats N7, N8, C7, C8, BD7 and BD8 committed to criterion, respectively, 8, 3, 4, 7, 8 and 6 initial errors and 2, 0, 1, 0, 1 and 0 repetitive errors.

Numbers of gate pushes (errors) in all cats during 4 extinction sessions are shown in Fig. 2. In the two-gate situation, the cats pushed the blank gate rarely. In all extinction sessions together, cats N7, N8, C7, C8, BD7 and BD8 committed, respectively, 7, 6, 9, 4, 8 and 6 errors. Generally, the extinction was slower in the two-gate than in the one-gate situation, especially during two first extinctions. The slowest extinction was seen in BD cats. The 2 (situation) x 3 (group) x 4 (session) mixed design ANOVA for repeated measures yielded situation ($F_{1/6} = 40.01$, $P<0.001$), group ($F_{2/6} = 8.59$, $P<0.02$) and extinction ($F_{3/18}=7.61$, $P<0.002$) effects, but without any significant interactions. Further Duncan tests showed that

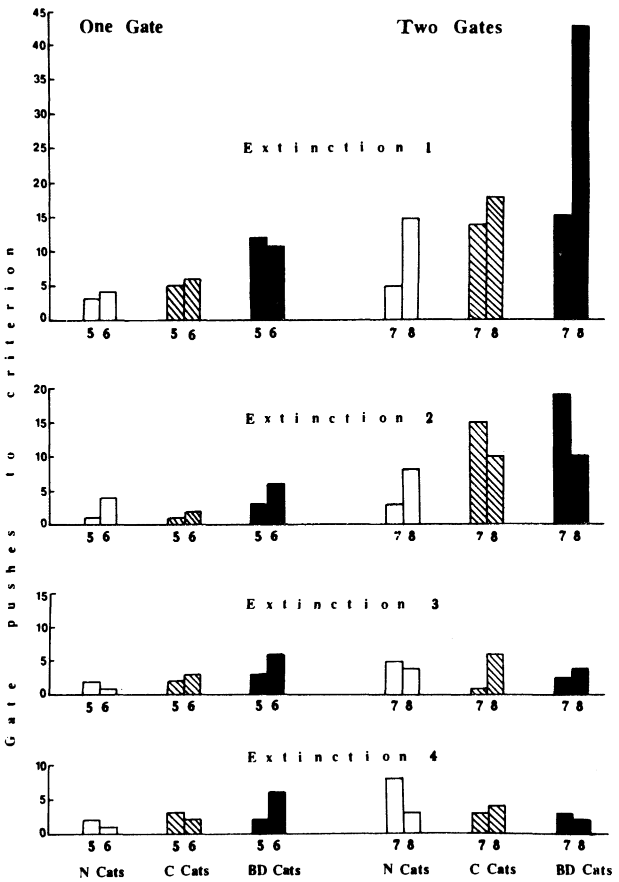

Fig. 2. Numbers of push responses (errors) to criterion during 4 extinction sessions in individual cats in Expt. II. Criterion trials are included. In the two-gate situation (on right) the bars represent pushes of both marked and blank gates.

all cats needed more trials during extinction 1 than during extinctions 2 to 4 (P's<0.01 or better). The BD cats extinguished push responding slower than N (P<0.03) and C (P<0.02) cats. The C cats tended to extinguish slower than N cats, but the difference was insignificant.

During extinction sessions the latency of push responses gradually increased in all cats and occasionally lasted even above 20 s. When not pushing the gate, all cats were usually restless. In the one-gate situation they usually walked briskly in the goal compartment and sometimes jumped out of it (Table I). In the two-gate situation jumping out was typical in all cats.

Recovery from extinction was spontaneous in all cats. Only the latency was somewhat longer in the first trials of each first post-extinction session in 6 cats (except N5 and BD8) and cat BD6 did not push the gate in the first run of each first post-extinction session.

Discussion

The acute extinction is certainly partly based on short--term memory. Thus, the present result suggests that not only inhibitory associative learning itself but also inhibitory associative short-term memory is impaired in BD cats and perhaps in C cats. This is consistent with earlier results (Ławicka 1989, Stasiak and Żernicki 1991) that delayed-response learning, a task also based on short--term memory, is impaired in BD and C cats.

GENERAL DISCUSSION

The results indicate that early visual deprivation affects less visual transformation learning than previously studied (see Introduction) visual discrimination learn-

TABLE I

Total numbers of different types of behaviour in non-push trials (criterion trials included) in 4 extinction sessions in Expt. II. The cats remained in the start compartment (rest) or walked briskly in the choice compartment (walking) or jumped out of the choice compartment (flight)

One-gate situation				Two-gate situation			
Cat	Rest	Walking	Flight	Cat	Rest	Walking	Flight
N5	0	8	1	N7	0	2	39
N6	6	14	0	N8	3	6	14
C5	0	18	3	C7	0	3	30
C6	0	21	3	C8	0	2	29
BD5	1	15	4	BD7	0	7	27
BD6	0	12	10	BD8	0	1	28

ing. In other words, BD cats are less impaired in association learning than in visual perceptual learning.

A moderate deficit in transformation learning seemed to be comparable in BD and C cats. Thus, this deficit is rather not due to visual deprivation itself, but to low early opportunity in utilization of stimuli in behavioural acts, i.e., to a handicap common to some extent to both BD and C cats.

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