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Unconditional Discrimination as a Paradigm for Investigating Visual Processing in the Avian Brainstem

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Running title: Visual processing in the avian brainstem

ABSTRACT

Visual discrimination between colors and patterns was studied in telencephalotomized chicks of Japanese quail lines that were artificially selected for early approach preferences for particular colors and patterns. Since these preferences are not conditional on prior learning, they provide an effective experimental paradigm in which to study visual discrimination without reliance on acquired stimulus discrimination. The data indicate that the quail's brainstem-thalamus complex is sufficient for relatively fine discriminations between various colors and achromatic patterns.

KEY WORDS

Japanese quail, decerebration, visual discrimination, unconditional preferences, selected lines

INTRODUCTION

Much of the extant knowledge about the avian visual system has been derived from data on the effects of brain lesions on trained visual discriminations. However, this procedure does not permit direct assessment of the visual competence of the brainstem. This is so, because isolating the brainstem by telencephalic lesions may interfere with the memory necessary for acquired stimulus discrimination quite apart from the bird's visual competence (2, 11). The unconditional discrimination paradigm used in the present experiment did not depend on prior learning. It does permit the elimination of telencephalic influences in the processing of visual information by complete bilateral hemispherectomy.

Naive Japanese quail chicks approach any conspicuous stimuli shortly after hatching, and exhibit distinct preferences for particular patterns and colors (9). Such preferences are not conditional on prior experience with the stimuli, and they can be readily modified by artificial selection (8, 10). A system of quail lines has been developed in our laboratory by bi-

directional selection for unconditional approach choices between particular colors and patterns. Chicks of the "Blue Line (BL) and "Red Line (RL) exhibit nearly errorless preferences for blue or red light stimuli. Another selected line exhibits similar though not quite as extreme preferences for an achromatic pattern: vertical grating over circular dots ("Vertical grating Line": VL). Microspectrophotometric analysis of visual pigments and oil droplets (1), together with earlier psychophysical studies (9) indicated that the effects of selection for color preferences were not mediated by peripheral mechanisms of color vision.

The selected preferences were expressed in choices between stimulus combinations not used in the selection. For example, BL chicks reliably preferred the shorter over longer light wavelength in various paired combinations of colored stimuli, whereas RL subjects preferred the longer wavelength (9). Recently, we found that complete telencephalectomy did not

abolish the selected color and pattern preferences in BL, RL, and VL chicks (5). In the present experiment we examined whether more refined visual discrimination indicated by the earlier psychophysical data might be also spared by decerebration.

MATERIALS AND METHODS

Subjects were newly-hatched Japanese quail chicks drawn from an unselected "Control Line" (CL) and three genetic lines described above (BL, RL, and VL). They were either anesthetised only (NON-OP) or were telencephalectomized (TEL-X) under deep anesthesia (Ketamine: xylazine mixture, 3 mg : 0.02 mg / 10 g body weight). The cerebral hemispheres were removed by aspiration rostral and dorsal to the ventral portion of the tractus septomesencephalicus (TSM) by a standard procedure worked out previously (6). Visual discrimination was tested 24-28 hours following treatment by the same mass-screening apparatus that was used in artificial selection (9).

The apparatus consisted of 28 identical choice compartments arranged hierarchically, so that a single compartment was on top ("starting box"), two compartments were in the second row, three in the third row, and so on, until eight collection boxes on the ground floor. Two light stimuli were presented at the two corners of the back wall of each choice compartment. The stimuli were backlit by fluorescent light sources and were identical in size (2.5 x 2.5 cm), shape (rectangular), luminance (10.1 lux) and intermittence (3 Hz of equal light-dark cycles), but different in color or pattern.

Color discrimination was tested in CL and BL chicks by their approach choice of blue or green versus red stimuli, and in RL chicks by choice of red or yellow versus blue stimuli. The blue, green, yellow, and red stimuli were presented at 480 nm, 540 nm, 580 nm, and 630 nm of peak wavelength with spectral characteristics corresponding to No. 45, No. 58, No. 16, and No. 29 Wratten gelatin filters, respectively (see Kodak manual No. B-3). VL chicks were tested for pattern discrimination by approach preference for vertical gratings over circular dots, and for vertical over horizontal gratings. The pattern stimuli were identical in relative black and white areas (approximately 32% white).

The chicks were placed in the starting box individually at about 2 minute intervals. The chicks approaching either of the two flashing light stimuli to within 7.5 cm stepped on a trap door, and slid into one of the compartments in the next row. After completing 7 trials the chicks arrived at one of the 8 collection boxes in the 8th row. The serial number of the collection box

(0 - 7) indicated the number of choices of one over the other stimulus. Each subject was individually scored and returned to the starting box for the completion of a second run of seven trials.

Chicks were allowed 45 minutes to complete 14 approach choices. Preferences were defined as probabilities of choosing one stimulus over the other stimulus. Preferences were compared to random choices by Student's t-test (after arcsine transformation). Contributions to choice variations by genetic background, telencephalectomy and stimulus combination were assessed by 3-way ANOVA.

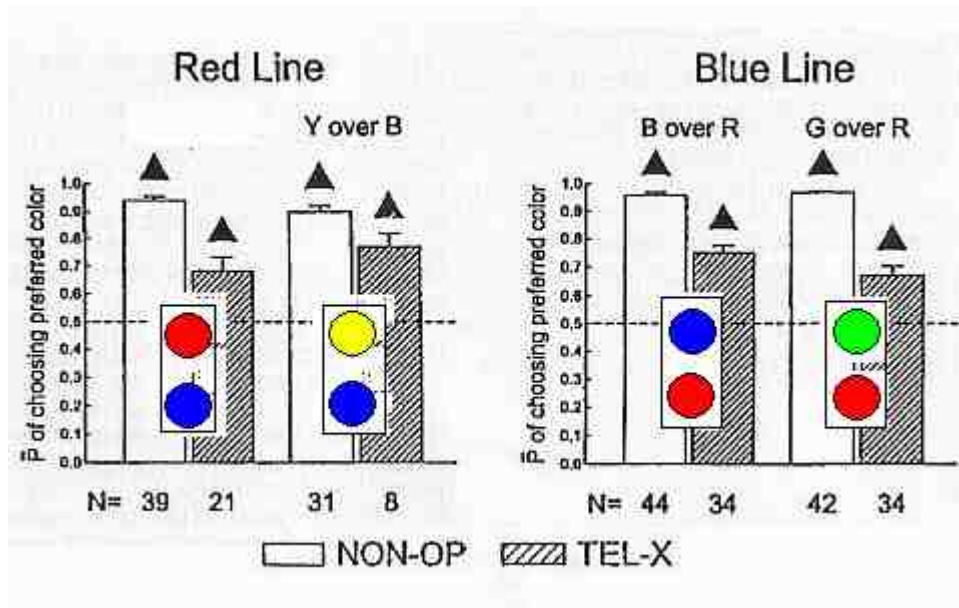
Approximately half of the chicks were decapitated after the preference test at day two for histological verification of the lesions. Others were used in a subsequent behavioral study for two weeks to reduce the number of subjects undergoing surgical procedures. Lesions were examined on 20 μ m coronal sections stained according to Kluver and Barrera (7) in brains of 3 or 16 day old birds.

Results and Discussion

Histological examination revealed that apart from a small variation in the amount of tissue at the telencephalic-diencephalic juncture the cerebral hemispheres were completely removed in every subject. No traces of higher visual areas (ectostriatum, visual Wulst), and the neostriatum or paleostriatal complex were detected in the lesioned brains.

Decerebration attenuated preferences in the lines tested for discrimination between colors (ANOVA, effects of surgery in RL, BL, and CL: $F=146.8$, $DF= 1$; $P<0.0001$) as well as patterns (ANOVA, effects of surgery in VL: $F=14.4$, $DF= 1$; $P<0.0001$). Low, but statistically reliable green preference in NON-OP CL birds ($t=4.59$; $DF=28$; $P<0.001$) was completely abolished by surgery ($t=1.59$; $DF=29$; $P>0.05$). Interestingly, though preference for blue over red stimuli was not significantly different from random choice in intact CL birds ($t=1.38$; $DF=28$; $P>0.05$), it was highly significant after telencephalectomy ($t=4.89$; $DF=32$; $P<0.001$).

In non-operated as well as in telencephalectomized RL birds, preference for long wavelength was expressed both in red versus blue and in yellow versus blue stimulus choices ($P<0.001$; see Fig. 1). Similarly, short wavelength choices in every BL group were significant, i.e. in blue and red as well as in green and red choices ($P<0.001$).



Telencephalectomized VL chicks exhibited significant preferences for vertical grating not only over the circular dot pattern ($t=3.6$; $DF=21$; $P>0.01$), but also over horizontal grating ($t=2.7$; $DF=19$; $P<0.02$).

The present data thus corroborated our previous findings that the telencephalon was not critical for the early expression of genetically selected preferences in the Japanese quail (5). More importantly, preference generalization after telencephalectomy indicated that the avian brainstem-thalamus complex is sufficient for relatively fine visual processing, such as discrimination between green and red, blue and yellow stimuli or between achromatic vertical and horizontal gratings. Thus the present findings together with earlier studies in other species (12, 3, 4) indicate prominent visual competence of brainstem-thalamic areas in the absence of telencephalic influences. The genetically selected quail lines should provide a hitherto unavailable opportunity to investigate the subtelencephalic mechanism of the avian neural mediation of fine visual discrimination between colors and patterns.

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Figure legends

Fig. 1. The expression of short and long wavelength, and vertical grating pattern preference in the unconditional discrimination test. Performances of intact (NON-OP) and telencephallectomized (TEL-X) chicks of the genetically selected lines were significantly different from random choice (by Student's t-test, at $P < 0.02$, depicted by triangles above bars). Number of subjects in each group (N) is indicated under bars. (B: blue, G: green, Y: yellow, R: red, V: vertical, and H: horizontal grating, D: circular dots stimuli.)

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