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Visual Pattern Discrimination in the Oriental Discoloured Bat, *Vespertilio superans*

Kun Sang Chung, Ju Hyeung Lee and Shi Ryong Park

Department of Biology, Korea National University of Education, Chŏngwon, 363–791, Korea

The visual discrimination ability of *Vespertilio superans* was investigated with a male and a female. In a controlled experimental situation (two-choice apparatus), using a vertical bar and a circle of the same area of the bar, it was established that discrimination between different shapes of the same size was impossible. However, with patterns in which the surface areas substantially differed, the bats were able to discriminate between them to a statistically significant degree. Continuing with experiments in which the lightness of the 2 partterns was varied, the disrimination was possible with all but the slightest differences in lightness (a difference of lightness value 2).

KEY WORDS: **Visual discrimination, *Vespertilio superans*.**

Along with research into the echolocation of Microchiroptera, there has been rapid progress in studies centering on their sensory physiology. The orientation calls of Microchiroptera have an intensity of 70 dB-160 dB and a frequency of 20 kH_z-150 kH_z. Griffin (1953), Möhres (1953), Möhres and Neuweiler (1966), Müller (1968) and Neuweiler (1976) have shown that such orientation calls have a range of less than 20 m. It seems possible that apart from a memory of their surroundings, bats rely on visual orientation under conditions where echolocation is inadequate. The echolocation system of bats is completely sufficient for short-range orientation tasks such as navigating obstacles, evading predators and finding food. However, many bats must move several hundred kilometers every year from their hibernatory areas to their summer quarters. Also, in their hunt for food they must travel several kilometers per day (Roer, 1967; Griffin, 1970; Orr, 1979; Barclay et al., 1988). It seems possible that in long-distance travel visual orientation using the moonlight, the silhouettes of large trees and ridges is employed. William et al. (1966a; 1966b), Chase and Suthers (1969) and Shumake and Caudill (1972) assert that nocturnal bats can and do distinguish objects by sight using light from the night sky.

Davis and Barbour (1965) concluded that *Myotis* bats use vision for the determination of flight path in the experiments in which blindfolded specimens of *Myotis sodalis* had trouble navigating transparent obstacles. In earlier experiments Eisentraut (1950) succeeded in training *Eptesicus serotinus* to distinguish between black and white surfaces of the same size. Study of bats has so far centered on echolocation at the expense of research into their visual orientation abilities. Furthermore, there have been no studies with Chiroptera which are found only in Asia. Accordingly, we decided to study the visual discrimination ability of *Vespertilio superans* which are common in Korea.

Materials and Methods

The bats studied were a male and a female (♂A, ♀B) of *Vespertilio superans* captured in June

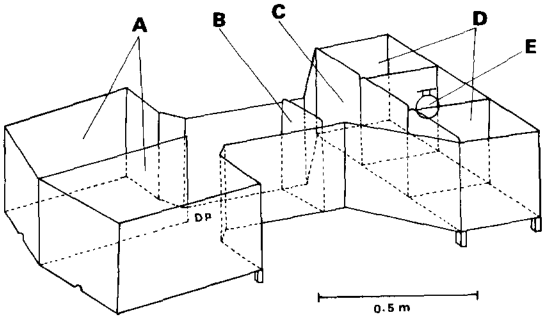
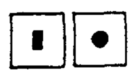


Fig. 1. Experimental apparatus (two-choice apparatus) A: choice boxes B: starting compartment C: sliding door D: home cages E: incandescent bulb DP: decision point

of 1988 in Danyang, Chung-buk. *Vespertilio superans* does not fly but ran in narrow spaces we used the experimental apparatus (two-choice apparatus) shown in Fig. 1. The apparatus consists of a starting compartment, decision area and separated runways. The patterns were placed at the ends of the runways. The home cages were separated from the training apparatus proper by means of sliding doors. A 20 W incandescent bulb placed in front of the targets provided the light source. The illumination intensity was controlled with the aid of a luxmeter.

The target patterns (see Table 1) were 33.0 cm by 33.0 cm (square). They consisted of black and white photographs of a vertical bar (positive) and a circle (negative) of diameter equal to the bar's width, with variations in size and angle, background and foreground colors (black on white, white on black). The light intensity was maintained 1 lux at the pattern by use of slits. At first the bats were allowed to become accustomed to the

Table 1. Patterns used in the experiment.

No.	pattern + −	pattern size	No.	pattern + −	pattern size
I		+: 4 × 17 cm −: ϕ 9.3 cm	VIII		+: 10 × 10 cm −: lightness value 0
II		+: 17 × 4 cm −: ϕ 9.3 cm	IX		+: 4 × 17 cm −: lightness value 0
III		+: lightness value 0 −: lightness value 10	X		+: 17 × 4 cm −: lightness value 0
IV		+: 4 × 17 cm −: ϕ 9.3 cm	XI		+: 4 × 17 cm −: lightness value 0
V		+: 17 × 4 cm −: ϕ 9.3 cm	XII		+: lightness value 3 −: lightness value 10
VI		+: 10 × 26 cm −: ϕ 18.2 cm	XIII		+: lightness value 7 −: lightness value 10
VII		+: 15 × 26 cm −: ϕ 22.3 cm	XIV		+: lightness value 8 −: lightness value 10

(+; positive, −; negative)

apparatus. After the bats had become habituated they were tested on patterns I through XIV. The bats were started from the starting compartment and were rewarded with a meal worm on a correct choice at the decision point. A wrong choice lead to negative reinforcement in the form of "chit" sounds and a return to the starting point. Each animal made 20 or 30 run per day. The placing of the positive and negative patterns was varied randomly. The positive choices for each pattern were sequentially analyzed and the statistical computations used a binomial distribution with significance at the 0.01 level.

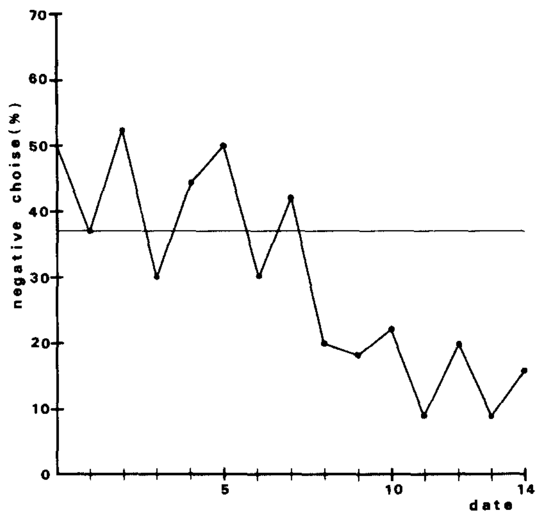


Fig. 2. The learning curve for bat ♂ A with pattern III. ——: $p < 0.01$

Results

The learning process for bat ♂ A with pattern III shows clear signs of learning 7 to 8 days after starting (Fig. 2). This shows that research into the visual discrimination ability of *Vespertilio superans*

The positive choice ratio for ♂ A with pattern I was 54.9% and for ♀ B 54.8%. With pattern II requires at least 10 days. Owing to the learning ability of this species, the trials of each pattern were evaluated after a ten–day learning period. the ratios were 50.5% and 48.9% respectively. The ratios are nearly the same for bats ♂ A and ♀ B (Table 2). The positive choice ratios for bat ♂ A on patterns IV, V, VI and VII were 47.0%, 48.7%, 50.0% and 49.0% respectively. The results for bats ♂ A and ♀ B on patterns I and II

Table 2. Experimental results about pattern discrimination

Pattern No.	Bat	No. of trials	No. of positive choice	Positive choice choice ratio(%)
I	♂ A	122	67	54.9
I	♀ B	124	68	54.8
II	♂ A	529	267	50.5
II	♀ B	350	171	48.9
III	♂ A	100	87	87.0*
IV	♂ A	100	47	47.0
V	♂ A	37	18	48.7
VI	♂ A	122	61	50.0
VII	♂ A	51	25	49.0
VIII	♂ A	20	17	85.0*
IX	♂ A	38	34	89.5*
X	♂ A	74	69	93.2*
XI	♂ A	30	28	93.3*
XII	♂ A	33	29	87.9*
XIII	♂ A	45	38	84.4*
XIV	♂ A	48	27	56.3

*; $P(x) < 0.01$

The total number of the trials carried out was 2,539 with 2,065 for ♂ A and only 474 for ♀B due to its death during the experiment. Accordingly, patterns III to XIV were tested only for ♂ A. were not significant; they could not distinguish between the positive and negative patterns (Fig. 3). The results for ♂ A with patterns IV, V, VI and VII ware also insignificant, indicating its inability to discriminate between the choices (Fig. 4). Thus, the results led to conclusion that discrimination between differently-shaped patterns with the same surface area is impossible.

The positive choice ratios for pattern III, VIII, IX, X, XII and XIII were over 80% and all significant

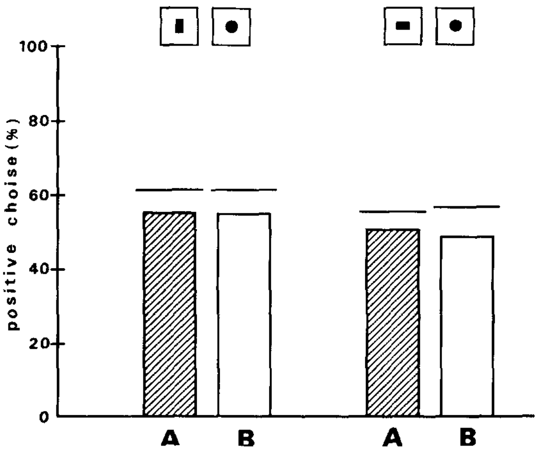


Fig. 3. Positive choice ratios for bat ♂ A and bat ♀B with patterns I, II. ——— : $p < 0.01$

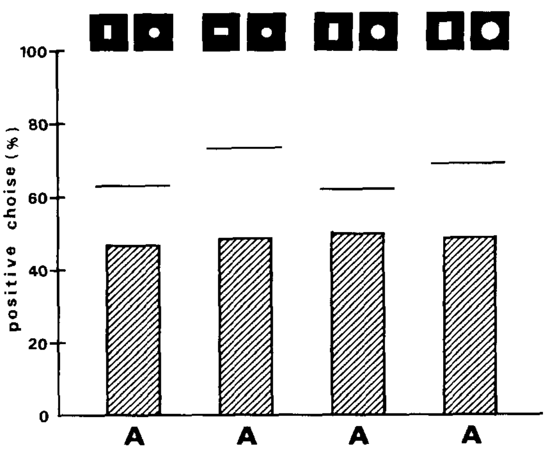


Fig. 4. Positive choice ratios for bat ♂ A with patterns IV, V, VI, VII. ——— : $p < 0.01$

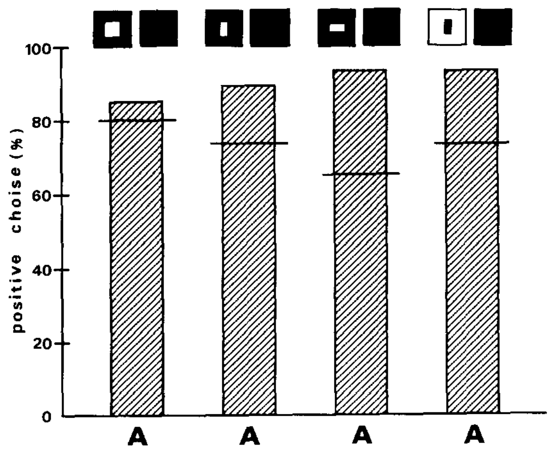


Fig. 5. Positive choice ratios for bat ♂A with patterns VIII, IX, X, XI. ——— : $p < 0.01$

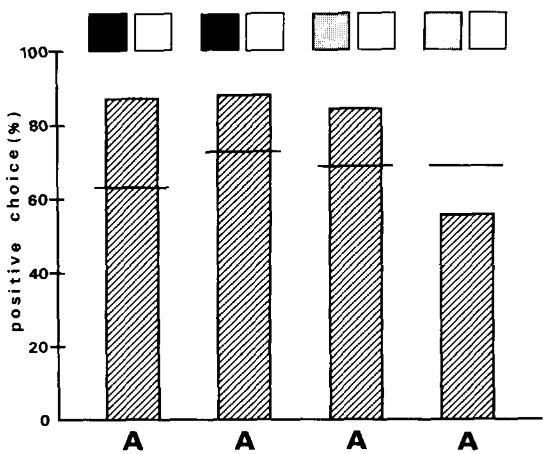


Fig. 6. Postive choice ratios for bat ♂ A with patterns III, XII, XIII, XIV. ——— : $p < 0.01$

at the $P < 0.01$. This implies that visual discrimination is made between patterns with different surface areas (Fig. 5). On tests where only the lightness of the patterns was different all were discriminated except for the trial in which the difference in lightness value was 2 (Fig. 6).

Discussion

Histological experiments on Microchiroptera eyes have not yet fully explained the sight mechanism. Kolmer (1924) has found rods in the retinas of 16 bat species and Chase (1970) has found sensory cells similar to cones in *Saccoptery bilineata* and *Rynchonycteris nas*. It is possible to judge that the number of color-sensitive cells in bats are too small for color discrimination. But it seems almost certain that vision is used along with echolocation in identifying objects.

Masterson and Ellins (1973) conducted experiments with *Myotis lucifugus* under 3 different illumination states (bright, dim and completely dark) using vertical line obstacles. The results showed that when the obstacles were distinct from their surroundings the bats navigated better under dim illumination than when completely dark. When the obstacles were not so distinct, the bats, under dim illumination, crashed as much as or more than when completely dark. Also, the bats crashed a lot under bright illumination. The different results under bright and dim illumination show that *Myotis lucifugus* uses vision when flying.

Jastrazebski (1958), with triangular, circular and rectangular patterns found that the visual discrimination of *Myotis myotis* was only possible when the surface areas were different. Suthers and Chase (1966) and Suthers *et al.* (1969) conducted experiments on the vision of neotropical Phyllostomatiden with patterns in which the surface areas were same and only the shapes were different. *Anoura geoffroyi* could distinguish between bars and circles of the same area and with triangular targets between upward-pointing and upside-down triangles. *Carollia perspicillata* could discriminate with 4 different pattern pairs (vertical bar/horizontal bar; vertical bar/45° slanted bar; square/circle; diamond/circle). Manske and Schmidt (1979) showed that *Desmodus rotundus* can discriminate between vertical bars and circles of the same area.

In this study with *Vespertilio superans*, discrimination between vertical bars and circles of the same area was impossible and only possible when the surface area was different. It seems that *Vespertilio superans* has similar visual discrimination ability to the *Myotis myotis* (Jastrazebski, 1958). According to Shumake and Caudill (1972) and Ellins and Masterson (1974) bats can visually discriminate between many different shades (lightness values). Thus, though bats vary in their visual discrimination abilities it seems plausible that nearly all can discriminate at least the brightness of objects. So, since *Vespertilio superans* can use visual orientation we suggest that they employ vision utilizing moonlight, the silhouettes of buildings and ridges etc. in long-distance travel.

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안주애기박쥐 (*Vespertilio superans*)의 시각에 의한 물체 식별 능력

정건상 · 이주형 · 박시룡(한국교원대학교 생물교육과)

암수 2개체의 안주애기박쥐(*Vespertilio superans*)를 가지고 시각에 의한 물체 식별 능력의 실험을 실시하였다. 통제된 실험 장치(two-choice apparatus)하에 이 박쥐들이 수직막대 모양의 표적과 이것과 면적을 같게한 원형 표적을 식별 가능한지의 결과, 면적이 같고 모양이 다른 두 표적은 전혀 식별하지 못했다. 이에 반하여 면적의 크기가 다소 차이를 갖게한 표적에서는 식별 능력에 있어서 유의 수준의 차이를 보였다. 계속된 실험 결과 같은 두 표적 간에 명암의 정도를 달리하였더니 명암이 근소한 차이(명도 2)를 제외하고는 쉽게 식별이 가능했다.