This study outlines a behavioral threshold measurement procedure useful for the study of sensory systems in vampire bats. Scholocating bats have considerable visual capabilities. The relatively large visual portion of the brain in vampire bats implies better visual ability than in insectivorous Microchiroptera. Knowledge concerning the visual, olfactory, and sound thresholds of this species could prove useful in determining their methods of prey detection. This report presents visual threshold data for two Desmodae using the outlined procedure. The study indicates that vampire bat and human rod visual sensitivity are quite similar.
BRIEF COMMUNICATION

A Technique for Visual Threshold Measurement in Vampire Bats

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SHUMAKE, S. A., R. D. THOMPSON AND C. J. CAUDILL. A technique for visual threshold measurement in vampire bats. PHYSIOL. BEHAV. 18(2) 325–327, 1977. — Two vampire bats, trained to lick tap water to receive small amounts of blood, were then conditioned with electric shock to stop licking whenever a light appeared. The bats were subjected to various intensities of light by the method of constant stimuli to measure the lower detection threshold. The mean threshold value for the bats was $-7.288 \log \text{ft-L}$ (1.60 x $10^{-6}$ cd/m$^2$). The threshold measurement technique gave stable visual thresholds and could probably be used to evaluate other sensory systems in the vampire bat as well as other bat species.

Visual thresholds | Vampire bat | Conditioned suppression | Conditioned licking

Many published reports [1, 2, 4, 6, 8, 11, 12, 15] have shown that echolocating bats have considerable visual capabilities. Visual acuity of vampire bats, *Desmodus rotundus*, was shown to be 0.7 degrees of visual angle or less using the optokinetic response technique [11]. Anatomically, the echolocating bats of suborder Microchiroptera appear to be hypermetropic [13]; however, this lens distortion is not great for distantly viewed fields. There is evidence [15] that these visual cues can enhance orientation when range limitations of the echolocating system are considered. The relatively large visual portion [7] of the brain in *Desmodus* implies better visual ability than in insectivorous Microchiroptera. Vampires find their prey, mainly domestic livestock, on moonless night periods when visual cues are extremely dim [3,14]. Knowledge concerning the visual, olfactory, and sound thresholds of this species should prove useful in determining their methods of prey detection. This study outlines a behavioral threshold measurement procedure useful for the study of sensory systems in vampire bats. Visual threshold data are presented for two *Desmodus* using this procedure.

METHOD

Animals

Two adult *D. rotundus* were maintained on cattle blood obtained twice a week for a local slaughter house. The animals were housed in two rodent cages fitted with drinking tubes.

Procedures

Both bats were trained to respond for small quantities of blood reinforcer in an operant conditioning chamber previously described in detail [10]. The bats were first trained to depress a lever with attached drinking cup to earn 0.5 ml quantities of a 75% cattle blood-25% water mixture. The bats quickly learned to press the lever using mandible or mouth pressure. Later, the bats were trained to earn reinforcer by licking on a drinking tube containing tap water. A brief flash from a cue light above the drinking cup preceded each reinforcer delivery. Both bats gradually learned to steadily lick the drinking tube on a VI-2 minute reinforcement schedule.

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To condition each bat to suppress licking in response to a light, a length of fiber optics 0.635 cm in diameter was positioned to stimulate the bat's right eye. The bats were unrestrained and no attempt was made to control for fixation other than observation of the licking pattern before light stimulation trials. When the bats were steadily licking, essentially all of their right retinas could be stimulated. The light source was a 500 W iodine lamp (5000 degrees K color temperature) with intensity controlled by a system of neutral density filters. A 15 sec light stimulus at an intensity of 2.7 log ft-L was used for suppression training. Light to the fiber optics was controlled by a Ledex rotary solenoid. Light offset was paired with a 40 msec 0.10 mA AC scrambled grid shock to the bat's feet. The number of licks on the licking tube were tabulated on impulse counters for the 15-sec period immediately before light onset, and for the 15-sec light stimulation period. For each light stimulus trial, a suppression ratio [5] was used to quantify the suppressed licking. The ratio, prestimulus licks minus licks during the light divided by prestimulus licks, yields values of +1.00 for total suppression, 0.00 for no suppression, and minus values for facilitated licking. Shutter control trials were interspersed with light trials to evaluate solenoid sound effects on lick suppression. By running 10 light trials and 10 shutter control trials per session, we were able to achieve complete lick suppression on 95 percent of the light trials and no more than 0.15 suppression ratio (S.R.) values for shutter control trials. For threshold testing, the light stimulus period was reduced to 1.0 sec with the time between light onset and shock held constant at 15 sec. Each bat was dark adapted 40 min before we began a threshold test, and the test chamber was completely darkened during threshold trials. The descending method of limits was first used to approximate each bat's visual threshold. Subsequently we used a method of constant stimuli whereby eight stimulus intensities ranging 4.0 log units were randomly presented along with six shutter control trials. Reliability of this suppression technique was evaluated by direct replication.

RESULTS

Both bats learned to completely suppress operant licking in the presence of the 2.7 log ft-L light after approximately 40 to 50 light-foot shock pairings. Approximately 100 replications were required to gradually reduce the light stimulation period from 15 sec to 1.0 sec and still maintain lick suppression until the foot shock was delivered. Two replications of the visual threshold measurement curves of the two bats are shown in Fig. 1. With the possible exception of the stimulus value -4.3 log ft-L for the first replication with Bat No. 1, lick suppression of both animals remains consistently high until values of -7.3 to -7.8 log ft-L are reached. There is an abrupt drop in suppression for the bats in this range which allows inference about perceptual ability at these low light levels. The dashed line at the 0.50 mean suppression ratio value represents the theoretical response of an animal suppressing 50 percent of the time to the light. If two perpendiculars are dropped from this dashed line at the intercept with the bat suppression curves to the abscissa, the threshold values of -7.150 and -7.425 log ft-L are obtained. The two replications on each bat gave thresholds within 0.10 log ft-L. Throughout the threshold measurement procedure, the mean daily suppression ratios for shutter control trials approached zero. For three replications, mean S. R.'s for shutter control trials were -0.07, -0.27, and -0.07 for Bat No. 1, and 0.04, -0.41, and 0.21 for Bat No. 2. Two humans (males 25–30 years old) gave thresholds of -7.493 log ft-L and -7.132 log ft-L using the same optical system and flash duration with the stimulus imaged around 19 degrees temporally off the optic axis. The mean threshold for the bats -7.288 log ft-L (1.60 x 10^4 cd/m^2) compared to the mean threshold for the humans -7.313 log ft-L (0.66 x 10^4 cd/m^2) is not appreciably different.

DISCUSSION

The usefulness of the licking response to measure operant behavior in vampire bats has been previously emphasized [10]. Not only is licking a relatively effortless response for the bats that weigh under 30 g, but also, the form of response remains stable over sessions. The bats learn the operant task with no hand shaping or experimenter interference.

The efficiency and reliability of the conditioned suppression technique for measuring animal thresholds has been reported elsewhere [9]. The present study has extended this technique to the vampire bat. This animal adapts well to the conditioned suppression technique indicating that other sensory systems such as olfaction or sound thresholds could be similarly measured. Learning and motivational variables affecting threshold measurement can be better controlled with the conditioned suppression procedure than with discrimination learning [8] or reflex response [11] methods.

We obtained visual threshold values indicating that vampire bat and human rod visual sensitivity are quite similar. This agreement between thresholds is somewhat unusual because several parameters were changed between species. The visual angles were different (3° 3' for humans vs. 28° 10' for bats), the retinal area stimulated in humans was far less than in the bats, and the two species probably have different rod densities even though the light was imaged 19° temporally off the fovea in the humans.
REFERENCES