

Preliminary evidence for color stimuli discrimination in the Asian small-clawed otter (*Aonyx cinerea*)

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Abstract Color discrimination ability can be determined through anatomy or perceptual ability. In this study we tested perceptual ability. Three Asian small-clawed otters (*Aonyx cinerea*), one male and two females, were trained via operant conditioning to discriminate stimuli within a training task. If they passed criteria for this task, they were tested on as many as six delayed matching-to-sample experimental tasks. These experimental tasks involved comparing varying saturations of the colors blue, green, and red against varying shades of gray, as well as against each other. The male reached criterion on five of the experimental tasks, indicating an ability to discriminate the stimuli. One female participated in only two tasks and did not achieve the criteria as set. The second female did not pass the training task, and thus was not experimentally tested. This study overall showed some early evidence that Asian small-clawed otters may have the ability to learn to discriminate different stimuli on the basis of color cues. Sensory studies conducted on two other otter species and the results of this study indicate that color vision may be a common trait across Lutrinae species.

Keywords Color Discrimination · Operant Conditioning · Perception · Lutrinae

Asian small-clawed otters (*Aonyx cinerea*) belong to the family Mustelidae, in which few species have been studied for color vision. Mustelids, as Koepfli et al. (2008) stated, are highly ecomorphologically diverse. They inhabit diverse habitats throughout the world, and vary in their behaviors. They

are typically characterized as having long bodies with large necks, small heads, short legs, dentition for eating flesh, and well-developed anal scent glands. The 59 species in 22 genera (IUCN, 2013) have historically been divided into two basic subfamilies, the Mustelinae and the Lutrinae.

The existing studies have primarily focused on testing anatomical structures to determine the existence of color vision. For the Mustelinae, the physiological mechanisms to see color (i.e., possessing at least two cones) are present for the mink (*Putorius lutreola*) (Dubin & Turner, 1977) and the ferret (*Putorius furo*) (Calderone & Jacobs, 2003). Three additional species were identified by Ducker (1964) to have color vision, but the results have been questioned (Jacobs, 1993). Within the second subfamily, Lutrinae, color vision has been examined in two species. The European river otter (*Enhydra lutris*) was found to have typical cone densities found for other diurnal mammals (Peichl, Behrmann, & Kroger, 2001). The sea otter (*Lutra lutra*) was shown to have functioning M/L and S cone pigments (Levenson et al., 2006), and the retinal structure and organization were found to be more like those of terrestrial mammals than that of aquatic mammals (Mass & Supin, 2007).

Asian small-clawed otters are an interesting species to test because of their amphibious nature; they are highly terrestrial, though their food sources are primarily aquatic. This could play a role in their ability to discriminate color, since the development of color vision may have been influenced by the spectral properties of the surrounding photic environment, along with adaptations to see specific images of interest within the environment (Griebel & Peichl, 2003; Griebel & Schmid, 1992; Kevan & Backhaus, 1998; Peichel et al., 2001). Other amphibious species have shown evidence for color vision, including the polar bear (*Thalarctos maritimus*) (Levenson et al., 2006; Ronald & Lee, 1981), the pygmy hippopotamus (*Choreopsis liberiensis*) (Peichl et al., 2001), and possibly the river hippopotamus (*Hippopotamus amphibious*) (Levenson

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& Dizon, 2003). However, a distinction has been made between terrestrial and aquatic species. Jacobs (1993) and Kelber, Vorobyev, and Osorio (2003) summarized numerous terrestrial species that are reported to have color vision, though color vision is lacking in strictly nocturnal species (Chausseil, 1992; Jacobs, 1993). Alternatively, aquatic mammals such as the cetaceans lack the capacity for color vision (Griebel & Peichl, 2003; Levenson & Dizon, 2003; Peichl et al., 2001), with the sirenians being the exception (Griebel & Peichl, 2003; Griebel & Schmid, 1996).

The visual acuity of Asian small-clawed otters has been studied, with characteristics showing a tendency for their vision to be more closely related to terrestrial species. Balliet and Schusterman (1971) found that the eye “was emmetropic in air with adaptations for underwater living” (p.305). Schusterman and Barrett (1973) showed that visual acuity is better on land than in water under dark lighting conditions, but is equivalent with appropriate brightnesses of light.

Historically, most mammals were originally thought to be colorblind (Padgham & Saunders, 1975; Walls, 1942). This idea has changed over the years, with a large number of terrestrial diurnal mammals being shown to possess at least two cone receptors. Most of these studies have directly looked for functioning cones to answer this question, rather than using behavioral testing methods (Jacobs, 1981). Kelber et al. (2003) summarized different techniques for testing either physical evidence (i.e., using electroretinograms or spectrophotometry, or determining the amino acid composition of the opsin), or behavioral evidence (i.e., using gray-card experiments, monochromatic stimuli, or adjusting broadband stimuli at different intensities). Ideally, both behavioral and anatomical testing should be undertaken to conclude whether an animal possesses color vision. As Pichaud, Briscoe, and Desplan (1999) stated, “the presence of different pigments with specific wavelength sensitivity is a pre-requisite for color vision, the subsequent neural wiring determines whether the organism has simply wavelength-specific behavior or true color vision” (p.622). This notion is supported by the conflicting experimental results shown in some species, such as the domestic cat (Gregg, Jamison, Wilkie, & Radinsky, 1929; Loop, Millican, & Thomas, 1987; Ringi, Wolbarsht, Wagner, Crocker, & Amthor, 1977) and the bottlenose dolphin (*Tursiops truncatus*) (Fasick, Cronin, Hunt, & Robinson, 1998; Griebel & Schmid, 2002; Levenson & Dizon, 2003; Peichl et al., 2001). Within these studies, sensory work typically shows a lack of the necessary cones for color vision, though the same species can pass behavioral tasks that would suggest that the ability to differentiate colors exists.

Gray-card experiments have been used to test various species, such as the American black bear (*Ursus americanus*) (Bacon & Burghardt, 1976), California sea lion (*Zalophus californianus*) (Griebel & Schmid, 1992), coatis (*Nasua*) and kinkajou (*Potos flavus*) (Chausseil, 1992), and the giant

panda (*Ailuropoda melanoleuca*) (Kelling et al., 2006). Throughout these studies, differing shades of gray, 18 to 30 in all, were tested against shades of blue, green, and red. In each, the subjects were trained to hold in one location (i.e., a holding cage/box, a trainer, or remote wooden board), were released to make a selection from two or three stimuli at some given distance away, and would then return to a holding location. All of the stimuli had measured reflectance readings and were presented in random pairings to control for brightness cues, which historically have been an issue (Jacobs, 1981). The number of sessions and required tasks have varied for these experiments. However, evidence was found that each of these species has at least dichromatic vision.

This study was one of the first to use discrimination testing to determine whether a Mustelid possesses color vision. Traditional operant conditioning was used to train the subjects to select one stimulus in a discrimination task. Brightness was controlled using random presentations of varying saturations of the color serving as the positive stimulus against varying shades of gray or another color serving as a negative stimulus. The methodology was based on that used to test for color vision in other carnivore species.

Method

Subjects

Three Asian small-clawed otters, one male and two females, housed at Zoo Atlanta were trained to take part in the study, starting in 2009. These otters were the dominant breeding female, “Nava,” and two offspring from separate litters, “Harry” and “Bugsy.” Nava was born October 2000, female Harry was born March 2005, and male Bugsy was born September 2005. These individuals were selected to participate on the basis of their overall temperament and their previously demonstrated aptitude for learning new behaviors (i.e., “up,” “down,” “turn around,” “on it,” etc.) via operant conditioning.

Each was trained and tested, emphasizing positive reinforcement. Their regular diet, consisting of capelin, smelt, and canned cat food, was used as a primary food reinforcer. The subjects received their entire daily diet, regardless of performance during study sessions, after testing was completed. Training and testing occurred during a regularly scheduled feeding, between 1330 and 1400 h. The testing area (Fig. 1) was an off-exhibit, indoor enclosure measuring 5.64 m long by 3.35 m wide. This space included a flat upper area (3.20 m long × 3.35 m wide) and a lower pool area (2.44 m long × 3.35 m wide) with steps. The floor of the enclosure was cement. The walls were cement block and chain link. Subjects were housed in a family group outside of study sessions and were separated from each other during study sessions.

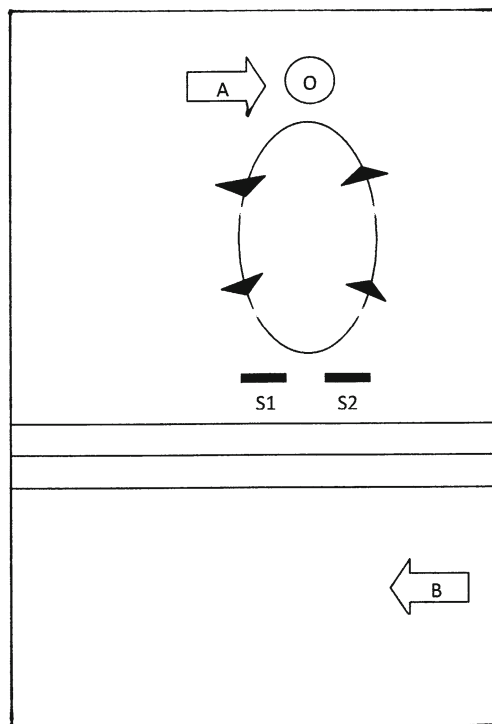


Fig. 1 Testing field, with the locations of both experimenters (A and B), the otter (O), and the two stimuli (S1 and S2). The arrows associated with both experimenters represent the directions in which they would look during a trial. The circular line with arrows represents the movement of the otter during a trial.

Stimuli and apparatus

Stimuli were presented as a delayed matching-to-sample task. The positive stimuli consisted of white or one of five saturations of each color (blue, green, and red), which differed in their saturation levels. The negative stimuli consisted of eleven shades of gray for the training task and the first three experimental tasks (1–3). For the remaining experimental tasks (4–6), green or red served as the negative stimuli when a color was paired with another color. Each stimulus was a rectangular card measuring 13×17 cm that was laminated to prevent deterioration. These were the same color rectangles used by Kelling et al. (2006) to test color discrimination in giant pandas. These cards were created via Microsoft Paint Version 5.0 and were printed from a color laser printer. Each stimulus card was labeled on the back for identification. The magnitude of the number signified the saturation of the color or gray (see Table 1). Reflectance was measured using a Spectrascan 650 for all stimuli after lamination, and was calculated as a percent reflectance based on white.

The station consisted of a 90-cm length of 0.6-cm-diameter wooden dowel rod (Fig. 2) with a laminated card that was either white or the corresponding middle saturation (labeled as #3) of blue, green, or red (depending on the task) attached to the rod with Velcro. Two individual stimulus holders were

used (Fig. 3) and placed on premarked areas of the testing field during each trial of the session. The front of each holder consisted of a 15×15 cm flat board with 0.6-cm metal U-channels on three sides to hold the stimuli in place. Attached to the back was a 30-cm-long handle made of a 1.3-cm square dowel rod with a piece of 1.3-cm plywood attached to half of the length of the handle. This kept the stimuli perpendicular to the floor, to reduce any potential glare from overhead lighting. Holders were positioned approximately 2.3 m from the station and 30 cm apart from each other.

Training overview and task

A new behavior called “select” had to be shaped before testing could occur. This was accomplished in two phases, and their behaviors were later chained together. First, a cue called “select” was shaped while habituating the subject to the stimulus holder. The “select” stimuli consisted of the verbal cue “select” and a physical cue in which the trainer opened a closed fist, with splayed fingers. Second, a “hold” command was shaped that required the subject to remain immobile in front of, and facing, the station. In addition, the subjects needed to become accustomed to two experimenters being present within the holding space. Experimenter A was responsible solely for giving the cues and rewarding the otter, whereas Experimenter B gave the bridge (a conditioned auditory reinforcer), changed the stimuli, and recorded the selection. The final “select” behavior consisted of the following sequence of events: Experimenter A would give the cue, the otter would leave and make a selection, Experimenter B would bridge if a correct choice was made, the otter would return to Experimenter A for a potential reward, and finally the otter would reposition itself to be asked to select again. The movement of the otter and the use of two experimenters was a similar setup to that employed while testing the California Sea Lion (*Zalophus californianus*) (Griebel & Schmid, 1992).

To prevent unintentional cueing of subjects, both experimenters’ positions and movements were prescribed and unvarying. Experimenter A remained in the same position throughout the testing session. This position was perpendicular to the stimuli presented for selection. Thus, Experimenter A was behind the otter and out of its view when it made its selection. Experimenter A did not look at the stimuli presented and did not bridge the otter. The otter was always “held” in front of the station, facing Experimenter A, while the physical cue was given at hip height, as described earlier. Experimenter B only moved to change the stimuli between the trials. After changing the stimuli, Experimenter B stepped to the side and waited in the same position perpendicular to the stimuli. This allowed no eye contact to be made between the experimenter and the otter, but still allowed Experimenter B to see a touch

Table 1 Relationship of the transmission spectra of six shades of gray and five saturations of the colors used in the tasks. For each stimulus, the percent reflectance as compared to white is shown at its greatest wavelength

Stimuli	Gray 1	Gray 3	Gray 5	Gray 7	Gray 9	Gray 11	Blue 1	Blue 2	Blue 3	Blue 4	Blue 5
% Reflectance	10.96	16.11	34.14	60.55	111.01	121.9	26.33	39.62	51.54	58.28	80.14
Max. wavelength	768	768	780	780	768	780	452	452	448	448	448
Stimuli	Gm 1	Gm 2	Gm 3	Gm 4	Gm 5	Red 1	Red 2	Red 3	Red 4	Red 5	
% Reflectance	37.84	44.72	54.63	58.72	76.82	53.96	53.73	96.98	95.83	107.01	
Max. wavelength	512	512	516	512	512	708	708	708	708	708	

by the otter. Experimenters A and B were the same people throughout testing.

Before experimental testing occurred, each otter participated in a training task requiring it to select a white positive stimulus rather than a randomly chosen shade of gray. The positions of the positive and comparison stimuli were also randomly determined, to eliminate any bias. Alterations were only made to prevent the positive/negative stimulus from occurring more than three times in a row on one particular side. Also, the same negative stimulus was not used more than three times in a row, regardless of its position. The training task ensured that the subjects learned the “select” command

and that they could differentiate between varying stimuli. The subject’s selection during this training task, as well as during the experimental tasks, was defined as the first stimulus touched. In order to move on to the experimental tasks, the subject had to reach a criterion of 12 correct out of 15 trials (80%) for two consecutive days.

Testing

The procedure used for the experimental tasks was the same as that described for the training task. Specifically, the positive stimuli (five possible saturations of green, blue, or red) and negative stimuli (one of 11 shades of gray for the first three tasks, or saturations of green or red for the last three tasks) were presented in random positions chosen prior to the start of each session (Table 2). All commands employed were also the same. By constantly changing the stimulus used and its position, the possibility of brightness or side preference influencing choices was eliminated, since at any given time the positive stimulus could be brighter than, dimmer than, or potentially equivalent in reflectance to the negative stimulus (Table 2). Each color had been shown to have relatively stable wavelengths (Table 1), resulting in their differences being in the saturation level of the color.

Six experimental tasks were planned: *Task 1* (blue vs. gray), *Task 2* (green vs. gray), *Task 3* (red vs. gray), *Task 4* (blue vs. green), *Task 5* (blue vs. red), and *Task 6* (green vs. red). Between tasks, no learning period was provided for the subject to decipher the change made to the positive stimuli prior to testing.

One alteration to the procedure was made for Harry. Beginning with *Task 2*, she was allowed to decide what the positive stimulus would be for each session. The positive stimulus was defined as the first stimulus that she touched during the first trial of a session. Thus, the positive stimulus could be either green or gray.

Criterion

The criteria for the six experimental tasks were set at two different levels based on previous methods used with other

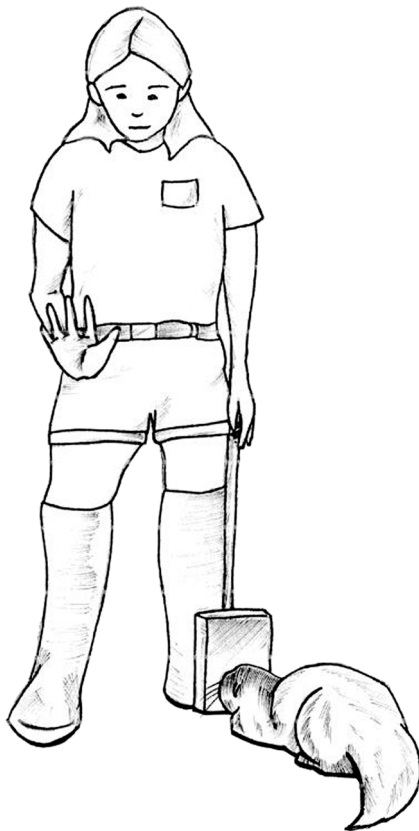


Fig. 2 Example of subject Bugsy’s body position while he was given the “hold” command by Experimenter A.



Fig. 3 Drawing of Bugsy running toward the stimulus holders just before making a selection, showing the position of Experimenter A during the process. This shows the size of a stimulus versus the size of the otter.

species. Each subject was expected to pass both criteria before a new task could be started. Each session included 15 trials. Only one session was conducted per testing day. For Criterion 1 (performance on a day), 12 out of 15 correct trials on two consecutive testing days were required, or 80% (Hanggi, Ingersoll, & Waggoner, 2007; Kelling et al., Kelling et al. 2006). This yielded a chance probability of 1.758×10^{-2} for each session, or 7.155×10^{-4} combined. For Criterion 2 (performance over time), the last 90 trials conducted were examined, and the subject was required to obtain at least 54 correct responses, or 60% correct (Araujo et al., 2008; Neitz & Jacobs, 1986; Pessoa, Tomaz, & Pessoa, 2005; Riol, Sanchez, Eguren, & Gaudioso, 1989). This yielded a chance probability of 3.627×10^{-2} . According to a binomial distribution

calculation for both criteria, criterion performance was higher than that of chance performance ($p < 0.05$).

Results

Bugsy

Bugsy completed the training task after 34 sessions. In Sessions 33 and 34, he made 12 out of 15 correct selections, with a combined chance probability of 7.155×10^{-4} . He subsequently reached both criteria for the first five tasks (Table 3), only failing to reach the criteria on Task 6 (Figs. 4 and 5). Task 6 was ended because of the lack of behavioral

Table 2 Session 1 on Task 2 (green vs. gray), which was undertaken by both Bugsy and Harry, showing the stimulus placement, the relationship of the colors based on their reflectance values, as well as correct selections made

Session 1: Green vs. Gray		% Reflectance @ Maximum Color Wavelength		Color Relation to Gray Stimulus	Correct Response: Bugsy	Correct Response: Harry
Gray 5	Green 4	20.23	58.72	Darker		
Green 5	Gray 7	76.82	41.85	Darker	X	
Gray 5	Green 4	20.23	58.72	Darker		X
Gray 3	Green 5	10.51	76.82	Darker	X	X
Green 1	Gray 10	37.84	81.77	Lighter		X
Gray 9	Green 2	71.1	44.72	Lighter	X	X
Green 4	Gray 9	58.72	71.1	Lighter	X	X
Gray 2	Green 2	8.14	44.72	Darker	X	
Gray 8	Green 3	60.61	54.63	Lighter	X	
Gray 6	Green 2	31.31	44.72	Darker		X
Green 5	Gray 4	76.82	15.59	Darker		
Green 2	Gray 1	44.72	7.42	Darker	X	
Gray 4	Green 2	15.59	44.72	Darker		
Green 4	Gray 11	58.72	96.56	Lighter	X	
Green 3	Gray 10	54.63	81.18	Lighter	X	X

Table 3 Chance probabilities, determined by a binomial distribution, for Bugsy for all completed experimental tasks

	Criterion 1	Criterion 2
Task 1	1.625×10^{-4}	2.230×10^{-2}
Task 2	1.625×10^{-4}	4.864×10^{-4}
Task 3	7.155×10^{-4}	$5.398 \times 10^{-4*}$
Task 4	7.155×10^{-4}	1.315×10^{-2}
Task 5	7.155×10^{-4}	5.451×10^{-6}

* Chance probability was determined out of 75 trials rather than 90, because Criterion 1 was attained in just 75 trials.

evidence that Bugsy was able to distinguish saturations of green from saturations of red.

Harry

In the training task, Harry required only four sessions to reach criterion. In Session 3 she had 12 of 15 correct responses, and in Session 4 she had 13 of 15 correct, resulting in a chance probability of 1.625×10^{-4} . However, she participated in only the first two experimental tasks. For Task 1, she completed 48 sessions, but did not reach either criterion (Fig. 6). On the basis of no observational or experimental evidence that she was learning that blue was the positive stimulus, this task was abandoned and Task 2 was initiated. For Task 2, Harry was allowed to choose the positive stimulus. Task 2 was ended after 27 sessions were completed, because there were limited results showing that she was learning the task, and the staff time available to work on this study was cut back.

Nava

Nava did not reach criterion for the training task. In all, she participated in 55 sessions. She made 13 correct selections during Session 44, but during Session 45 she made only nine

correct selections, resulting in a criterion fail. As a result, she was never experimentally tested.

Discussion

Both Bugsy and Harry reached criterion for the training task, which demonstrated that they could discriminate between the white and gray stimuli. Thus, the apparatus, stimuli, and operant conditioning method used in this study were effective for testing visual discrimination in the Asian small-clawed otter. During testing, brightness differences were ever changing, because we varied the shades of the stimuli per trial. As can be seen in the example in Table 2, the color stimulus was darker nine out of the 15 times, which could have occurred at different times and in different positions. The size and placement of the stimuli in the surroundings were also controlled, as well as the movements of the experimenters, making color the pertinent cue. These are some of the key elements that Padgham and Saunders (1975) asserted can affect the appearance of a color. Specifically, they stated that the appearance of color can depend on the luminance level of the color, the field size, the color of the surroundings, and the luminance of the surroundings. This last point could not be fully controlled because of two skylights above the testing area; however, we found no evidence that the luminance of the surroundings affected the subjects' performance over the span of testing.

Bugsy's ability to reach both criteria for all experimental tasks except the last task, Task 6 (green vs. red), provides strong evidence that he was using color differences to discriminate the stimuli. This is not surprising, since sensory work on two related otter species showed the presence of blue and green cones, whereas the red cone was absent (Levenson et al., 2006; Peichl et al., 2001). As has been shown with other diurnal, terrestrial mammals, dichromatic vision most

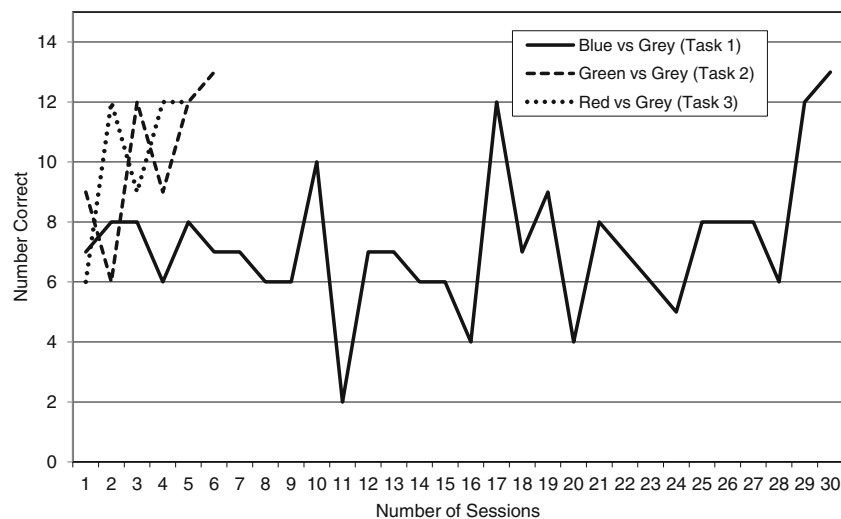


Fig. 4 Numbers of correct choices made per session by Bugsy during Tasks 1, 2, and 3.

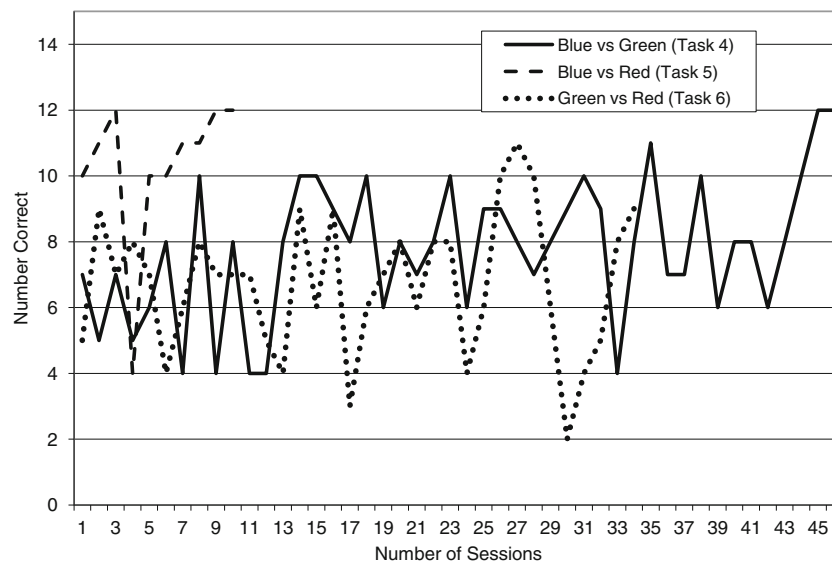


Fig. 5 Numbers of correct choices made per session by Buggy during Tasks 4, 5, and 6.

typically involves the use of the blue and green cones. Buggy's performance over sequential tasks that included common characteristics improved over time, which also was noted in the giant panda (Kelling et al., 2006) and the coati (Chausseil, 1992). It seems that Buggy was able to cue into a characteristic, presumably a color, and to retain it for the following tasks. Referring to Fig. 4, Tasks 1, 2, and 3 all had gray as the negative stimuli. Task 1 took him 30 sessions to complete. However, Tasks 2 and 3 only took six and five sessions, respectively, even though they involved different positive stimulus colors and no learning period was provided between tasks. He may have learned to choose the positive color stimulus, or simply to avoid gray stimuli. In another example, Tasks 4 and 5 both had blue as a positive stimulus, but another

color (green or red, respectively) served as the negative stimulus (Fig. 5). Buggy took 46 sessions to pass Task 4, but then passed Task 5 in only ten sessions.

Buggy's inability to differentiate green from red in Task 6 could be the result of different factors. It may simply be that Asian small-clawed otters do not have the anatomical ability to distinguish green from red. It is also possible that the experimental setup confused him. The blue saturations were always positive stimuli, but the green and red were sometimes positive stimuli (Tasks 2 and 3), but at other times negative stimuli (Tasks 4, 5, and 6). Finally, since we do not know the exact peak sensitivity of the cones for Asian small-clawed otters, the colors cards used may not have been at ideal wavelengths to answer this particular question. Other species

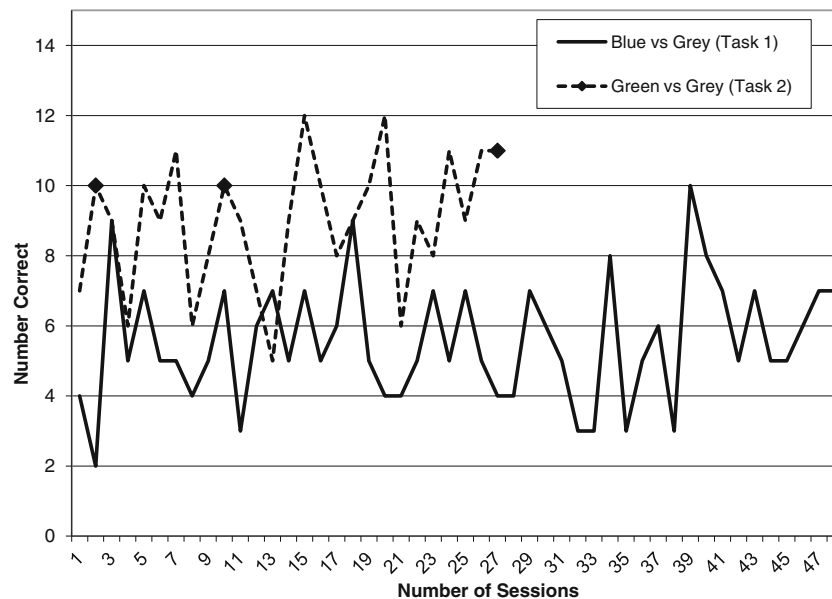


Fig. 6 Numbers of correct choices made per session for Harry during Tasks 1 and 2. On the line for Task 2, the three diamond-shaped markers represent the sessions in which Harry chose gray as the positive stimulus over the green.

have also had difficulty discriminating green from red. According to Neitz, Geist, and Jacobs (1989), during wavelength discrimination, domestic dogs performed best at around 480 nm, and discrimination became worse further away from this point. As Neitz et al. stated, “wavelength discrimination becomes effectively impossible for standard wavelengths of longer than about 520 nm” (p. 122). Hemmi (1999) found that the tammar wallaby performed best when discriminating wavelengths between 440 and 530 nm, but not above or below these values. American black bears failed a task involving green-versus-red discrimination, but passed all colors versus gray and blue versus green and red (Bacon & Burghardt, 1976). For the California sea lion and manatee (Griebel & Schmid, 1992, 1996), both species were unable to pass tasks involving red stimuli tested against gray. It was noted in both that as the grays got darker, performance became worse. Thus, Bugsy’s performance on the green-versus-red task was similar to that of other species, including carnivores.

Although Harry did not perform as well on the experimental tasks as Bugsy, she passed the training task more quickly. This most likely was because Harry was exposed to the stimuli for a greater length of time during her initial training. During this time, serious aggression within the family group arose, as well as a major illness. As a result, Harry’s training was disrupted for over 12 weeks, requiring the “select” command to be retrained; she was quick to relearn the steps involved. It is impossible to determine why Harry’s performance on the experimental tasks was below the level of Bugsy, but it could be related to many factors. Possibly, for Harry, the reward was not enough incentive to keep her focused on the task, or the sessions may have been too long. Additionally, Harry’s keepers noted that she can become easily frustrated if she does not receive regular rewards when learning new behaviors. It is worth noting that with less strict criteria, though still above chance performance, she could have passed. Harry had 12 out of 15 correct responses, individual probability of 1.758×10^{-2} , two separate times for Task 2, but did not pass Criterion 1 because this did not occur for two consecutive sessions. Additionally, she passed Criterion 2, because she made 59 correct responses out of 90, which resulted in a chance probability of 2.083×10^{-3} . The requirement for this criterion was 54 correct choices out of 90, or 60% correct. In this study, the subjects were required to pass both criteria to move on to the next task. Thus, Harry did not advance to the next task.

The procedure for Harry was changed for Task 2 (green vs. gray). Specifically, in this task she was allowed to choose the positive stimulus at the beginning of the session. This meant that the first stimulus she touched in the first trial of a session became the positive stimulus for that session. This change was made because Harry did not show evidence of learning Task 1, which resulted in an increase in aggressive behaviors, such as jumping at the experimenters and attempting to bite them. We were concerned that she would eventually refuse to participate

in the study, as Nava did, if we continued with the procedure used in Task 1. We discussed the situation with colleagues and decided to try a different procedure that gave Harry more choice. This new procedure also ensured that she received a food reward after the first trial of each session, and thus each session started positively. Although Harry failed the task, she chose green as the positive stimulus 24 out of 27 times. This could suggest that she had learned to select the blue color during Task 1, and then transferred that to the green color, because no learning period between the tasks was offered. Potentially, as Bacon and Burghardt (1976) stated in their analysis of the American black bear, she was making “correct, but not consistent, choice” (p. 31) during the whole session.

Nava did not successfully participate in this study, but she learned the overall concept of leaving Experimenter A and selecting a stimulus. She also showed early evidence of learning the training task by passing one session, but that was not repeated in another session. She was removed from the study because she did not pass the training task and because she eventually refused to participate in the sessions. Griebel and Peichl (2003) suggested that a negative result may not always indicate that the animal lacks the tested ability, but rather that it may not have “understood” or “attended to” the task. This may have been the case for Nava.

Conclusions

Concluding that an animal has color vision is complicated. It is, as Roth, Balkenius, and Kelber (2007) stated, difficult to actually know how a dichromatic species recognizes any color within their color space. Ducker (1964) suggested that it may not be correct to call it color vision, but should be referred to as a “reaction to certain spectral colours” (p. 572). We commonly discuss color vision in human terms, but we do not know how other species actually recognize color, an idea supported by work conducted with the ring-tailed lemur (Blakeslee & Jacobs, 1985). If ring-tailed lemurs have trichromatic vision, it is not the same as that of humans, because the lemurs’ thresholds are shifted higher in the color spectrum. So, comparing a species to humans or nonhuman species to each other may actually be misleading.

The reasons for the differences in performance among the subjects in this study are hard to determine, and could be related to a number of factors. These individuals displayed differences in their general behavior, which could affect learning aptitude, motivation, or attention. Additionally, Asian small-clawed otters are highly social, and thus they may rely more on social learning to solve problems and to acquire new techniques, because independent learning opportunities could be limited.

Nevertheless, this study provides preliminary evidence that Asian small-clawed otters have the ability to make color discriminations. Clear evidence was provided by Bugsy’s performance on five of the experimental tasks. Additional

behavioral testing will need to be completed with the Asian small-clawed otter to definitively state that it can be added to the ever-growing list of species that have color vision.

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