THE ROLE OF VISION IN INTERSPECIES RECOGNITION
IN THE
RED-BACKED SALAMANDER

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Olfactory cues are very important in feeding, sex recognition and species recognition in many animals; this is particularly true of salamanders. Jaeger (1981) demonstrated the importance of olfaction in "dear enemy" recognition in the Red-Backed Salamander (*Plethodon cinereus*). He found that an individual could distinguish between a neighboring salamander and a stranger after a period of exposure to the neighbor's odor. As a result, the neighbors were not attacked as often as strangers. However, Jaeger did not consider the possible role of vision in recognition of individual salamanders.

Nevertheless, the importance of visual cues has not been overlooked. Lindquist and Bachmann (1982) found that the Tiger Salamander (*Ambystoma tigrinum*) detected prey most effectively when a visual cue, alone or with an olfactory cue, was present.

Colors, patterns, structural differences, postures and other movements of an animal are visual cues that can elicit a behavioral response from another animal. While working with a brightly colored species of newt (*Triturus alpestris*), Himstedt (1979) showed that the male uses color vision to recognize the female. The male significantly preferred artificial models having the female's natural color and pattern over models with other combinations. Many terrestrial salamanders are brightly marked in distinctive patterns and may also use color pattern cues for recognition purposes.

Red-Backed Salamanders and Zigzag Salamanders (*Plethodon cinereus* and *Plethodon dorsalis*, respectively) are two distinctly marked species.
which are sympatric over much of southern Indiana (Thurow, 1955). Individuals of both species are very similar in size, body proportions and general coloration: dark brown-gray with a reddish dorsal stripe. Also, both species have an unstriped ("lead") phase--brown-gray without the dorsal stripe. *P. cinereus* has a relatively straight-edged stripe and "salt-and-pepper" ventral coloration. In contrast, *P. dorsalis* has a wavy or lobed stripe, and its belly is mottled in orange or reddish pigments (Conant, 1958). Since the species are sympatric and occur in similar habitats--beneath logs, rocks, and other shelter (Reinbold, 1979)--individuals may frequently encounter each other and be faced with an identification problem. Odor is no doubt important, as Jaeger (1981) emphasized for "dear enemy" recognition, but can *P. cinereus* make the choice by using only vision?

**MATERIALS AND METHODS:**

**Experimental Animals:**

Specimens of both color phases of *P. cinereus* were collected in October 1984 and March 1985 at Ginn-Nixon Woods, 11 miles N, 3 miles E of Muncie, Delaware County, Indiana. *P. dorsalis* and a few *P. cinereus* were collected on wooded hills at two Monroe County, Indiana locations: 9 miles E of Bloomington on S.R. 46 and 5 miles ESE of Bloomington on Deer Trace. All salamanders used in the study were adults, ranging from 2.5-3.5 inches in total length. I chose 12 well-marked individuals of each species (six of each color phase) for the experimental animals. Plastic shoe boxes, 11.5 x 6 x 3.5 inches, perforated for ventilation and lined with moist paper toweling, housed the salamanders individually. The animals were kept on a 12-hour light/12-hour dark cycle and were fed weekly (vestigial-winged *Drosophila* and small earthworms).
I allowed little or no visual contact between individual salamanders for six weeks prior to testing to reduce possible influences on their behavior from recent encounters in the wild.

Hypothesis and General Testing Procedure:

To determine whether vision may play any role in a salamander's ability to recognize another individual, the following specific hypothesis was tested: The behavior of a Red-Backed Salamander that can see but not smell another salamander will depend upon whether or not the latter is a member of the same species. I looked for three specific types of behavior: threat/aggression, submission/avoidance and disinterest. All three types have been formally described and are easily recognized (Table 1 in Appendix).

Briefly described, each trial consisted of a ten-minute observation period of one salamander (the "test" salamander) which could see but not smell another salamander (the "stranger"). The behavior of the test salamander was noted, and the time spent in threat/aggression, submission/avoidance or disinterest behavior was recorded.

Each test salamander was randomly paired with a stranger salamander. This pairing resulted in the following test combinations: P. cinereus-red/P. cinereus-red, P. cinereus-red/P. cinereus-lead, P. cinereus-red/P. dorsalis-red, P. cinereus-red/P. dorsalis-lead, P. cinereus-lead/P. cinereus-red, P. cinereus-lead/P. cinereus-lead/P. dorsalis-red, P. cinereus-lead/P. dorsalis-lead. Each pair combination was tested 18 times for a total of 144 trials (Table 2 in Appendix).
Specific Testing Procedure:

Instead of placing the paired salamanders in a completely novel testing environment during the observation period, the housing boxes also served as the experimental boxes because they were clear plastic boxes with opaque lids. The two "test" boxes (test salamander and stranger) were placed side-by-side in the experimental set-up (Fig. 1 in Appendix).

Lighting for the set-up was provided by a 60-watt frosted, incandescent bulb in a gooseneck lamp that was positioned 25 inches above the boxes. The room was otherwise unlighted. The floor of each experimental box was shaded from direct light by the opaque lids of the boxes. Furthermore, the lamp was directed somewhat horizontally to reduce the intensity of light on the arena. In addition, to minimize any influence of the experimenter's presence on the behavior of the test animal, dark clothing was worn, and observations were made from behind a partial screen in the shadows.

To prevent the stranger salamander's odor from affecting the test animal's behavior, the plastic box of the stranger was sealed with a special lid, composed of a small board backed with polyurethane foam and covered with flexible vinyl sheeting. The lid was washed with soap and water between trials to remove residual odors. The test animal's box was not sealed, but the test animal was covered with a small cardboard box to calm it before starting the trial. Once the sealing lid was in place on the other box, the cardboard box over the test salamander was removed, the box's original lid was replaced, and the 10-minute observation period began.
Two Lab-Chron Timers--one for threat/aggression, one for submission/avoidance--recorded the time spent in a particular behavior category in seconds. If neither of these behaviors occurred, the trial was recorded as "disinterest" behavior.

Easily repeated, the testing procedure provided a sufficient number of trials within a period of six weeks. This included a rest period between trials of at least 30 minutes for any one salamander. Testing occurred in May and June, 1985.

RESULTS:

Accumulated data from 144 trials showed that disinterest behavior occurred more often than threat/aggression and submission/avoidance behavior. When considering data from the eight possible pairing combinations, disinterest behavior ranged from 50-77.8% for each combination. Only three trials were recorded in which submission/avoidance behavior occurred; threat/aggression was also recorded in two of those three trials. This occurred during the first few trials of the experiment. The submission/avoidance behavior occurred too infrequently for statistical analysis. However, threat/aggression behavior was recorded often enough for analysis.

Since the data had been recorded into behavior categories, I converted the raw data (time in seconds) to categorical data. Because I was interested in the recognition ability of the species (P. cinereus) as a whole, not the individual's ability, the conversion to categorical data was warranted. An appropriate statistical test to use with this kind of categorical data is $\chi^2$ Contingency Table Analysis. Results of the analysis (Table 3 in Appendix) show that the pairing of P. cinereus-red/
P. cinereus-red did not differ significantly from the three remaining P. cinereus-red/"other" combinations. Chi-square values fell short of the rejection region ($p > 0.05, \chi^2 = 3.84$). When the P. cinereus-lead/P. cinereus-lead combination was compared with the three P. cinereus-lead/"other" combinations, only the P. cinereus-lead/P. dorsalis-lead combination was slightly significant ($\chi^2 = 4.02, 0.05 > p > 0.025$). Comparison of the two color phases, P. cinereus-red/P. cinereus-red versus P. cinereus-lead/P. cinereus-lead, also gave nonsignificant results.

**DISCUSSION:**

The results of this experiment clearly provide little support for the original hypothesis. I had anticipated the relatively large proportion of disinterest behavior on the basis of some preliminary observations of the salamanders before they were individually housed. However, the occurrence of submission/avoidance behavior only in the early trials surprised me. I might have misinterpreted some of the behavior in the first few trials. Many test salamanders showed much wandering around the boxes; they were even crawling up the sides of the boxes. Sometimes this behavior made interpretation difficult.

In addition, the salamander's eye may not be able to distinguish between similar coloration patterns under dim-light conditions. Perhaps the encounters of these species of small terrestrial salamanders are so limited to dark situations—under logs, stones and leaf litter, or on the surface of the ground at night— that recognition must depend largely upon olfaction, or perhaps bright light is needed to provide distinct color cues.

More investigation is needed before any definite conclusions can be made about P. cinereus' ability to recognize species by vision alone.
One must keep in mind that this was a small-scale experiment, using a few specimens from two extremely similar species. Other brightly marked species, such as other Plethodon or Ambystoma species, should be tested for their visual recognition abilities before visual cues, alone, are considered ineffective.

ACKNOWLEDGEMENTS:

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APPENDIX

TABLE 1. Behavior Category Descriptions.

**Threat/Aggression**

1) Threat/alert—all legs are extended downward so that the head, trunk and anterior aspect of the tail are raised above the substrate (Jaeger, 1981).

2) Snap—rapid opening and closing of the mouth; may be associated with a Lunge—forward thrust of the head and body towards the intruder (Lindquist and Bachmann, 1982).

3) "U" position of body—faces the other salamander in a "U" position so that it can strike like a snake (Thurow, 1976).

**Submission/Avoidance**

1) Submission—all legs are adducted so that the entire length of the body is flat against the substrate (Jaeger, 1981).

2) Retreat—all limbs are used to move the body backward to an opposite corner or area rapidly (Lindquist and Bachmann, 1982).

**Disinterest**

1) "Normal"—front legs are extended downward and the hind legs are adducted so that the head and anterior trunk are raised while the posterior trunk and tail are contacting the substrate (Jaeger, 1981).

2) Wander—seemingly aimless movement in any direction.

**Fig. 1.** (a) cardboard box (b) Lab-Chron Timers (c) gooseneck lamp (d) paired boxes of salamanders. (a) is used as a screen behind and around the sides of the boxes.
TABLE 2. Number of trials for each combination of species and color phase.

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TABLE 3. Results of the \( \chi^2 \) Contingency Table Analysis (Rejection Region: \( p \leq 0.05, \chi^2 = 3.84 \)).

- **P. cinereus-red/P. cinereus-red** vs. **P. cinereus-red/P. cinereus-lead** \( \chi^2 = 0.11 \)
- **P. cinereus-red/P. cinereus-lead** vs. **P. cinereus-red/P. dorsalis-red** \( \chi^2 = 1.00 \)
- **P. cinereus-red/P. dorsalis-red** vs. **P. cinereus-red/P. dorsalis-lead** \( \chi^2 = 0.11 \)
- **P. cinereus-lead/P. cinereus-lead** vs. **P. cinereus-lead/P. cinereus-lead** \( \chi^2 = 0.16 \)
- **P. cinereus-lead/P. cinereus-lead** vs. **P. cinereus-lead/P. cinereus-red** \( \chi^2 = 0.27 \)
- **P. cinereus-lead/P. cinereus-lead** vs. **P. cinereus-lead/P. dorsalis-red** \( \chi^2 = 0.64 \)
- **P. cinereus-lead/P. cinereus-lead** vs. **P. cinereus-lead/P. dorsalis-lead** \( \chi^2 = 4.02 \)
LITERATURE CITED


