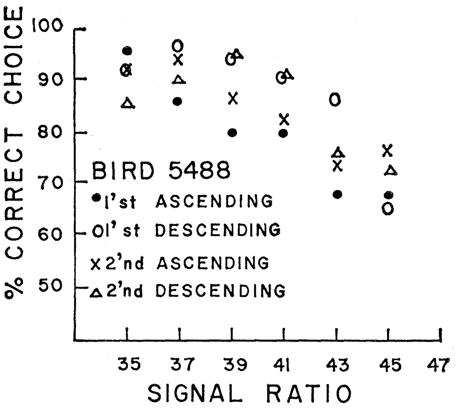

Fig. 1. Percentage of correct-choice responses for bird 5488 for each determination at each signal ratio.

below 60 percent at a signal value of fixed ratio 47. Since there are no systematic differences between the two series, we may conclude that the discrimination is not influenced by the signal ratio of the previous condition. The lack of improvement over the four sessions indicates that the data points represent asymptotic behavior.

The data were analyzed for detectability of the signals (see Fig. 2). The coordinates are the conditional probabilities of pecking the left key given the signal ratio, P (L|S), and of pecking the left key given the noise ratio, P (L|N). A peck on the left key was reinforced if the animal had just completed pecking the center key the number of times specified by the signal schedule. The positive diagonal is the locus of points at which the probability of pecking the left key is the same for either stimulus, that is, chance discrimination.

Points above the positive diagonal represent more correct responses than would be expected by chance. Points on the negative diagonal represent equal probabilities of correct choice or isobias toward either key, with the assumption of a signal a priori probability of $P = .50$. Proximity to the upper left corner is an index of the efficiency of the discrimination. Response bias increases, the greater the distance from the negative diagonal. Position habits on the right and left keys would have the coordinates 0,0 and 1,1, respectively. A point in the upper left corner would indicate errorless discrimination.

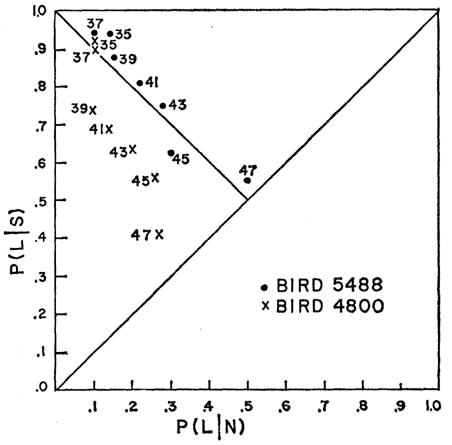

Fig. 2. Signal detectability functions. The ordinate is the probability of pecking the left key given completion of the signal ratio on the center key. The abscissa is the probability of pecking the left key given completion of the noise ratio. The number beside each point is the signal ratio with 50 as the noise ratio.

The decrease in the discrimination observed in Fig. 1 is reflected in Fig. 2, which shows that the points approach the chance line as the signal schedule increases. Response bias is slight for signal ratios 35 and 37, where the signal schedule primarily controls the choice behavior. Bird 5488 is not biased toward either key, while bird 4800 becomes more biased toward the right key. As control of the choice behavior by the stimuli from the ratios decreases, it is more likely that other stimuli, for example, the position of the choice key for bird 4800, will gradually acquire control of the choice behavior.

The choice behavior in the second step of the procedure provides a sensitive index of the discrimination between the two schedules which the animal completes in the first step. The procedure is sensitive to small signal-ratio increments. The gradual decrease in the percentage of correct discriminations suggests that the ability to discriminate ratios is a continuous, not an all or none, process.

This experiment demonstrates the usefulness of choice behavior as a dependent variable in the experimental analysis of behavior. The theory of signal detectability differentiates between response bias and discrimination, which are often confused in threshold measures obtained from animals. This procedure could also be used to investigate variables which influence response bias, for example, the a priori signal probability or the values and costs of the reinforcement matrix. The procedure may also provide a base line to investigate those variables, such as drugs, which influence the stimuli that control behavior on reinforcement schedules (*4*).

MARK RILLING
Department of Psychology,
Indiana University, Bloomington
COLIN MCDIARMID
Department of Psychology,
Stanford University,
Palo Alto, California

References and Notes

1. J. A. Swets, Ed., *Signal Detection and Recognition by Human Observers* (Wiley, New York, 1964).
2. C. B. Ferster and B. F. Skinner, *Schedules of Reinforcement* (Appleton-Century-Crofts, New York, 1957), pp. 39–41.
3. S. S. Stevens, Ed., *Handbook of Experimental Psychology* (Wiley, New York, 1951), p. 533.
4. R. Berryman, W. W. Wagman, F. S. Keller, in *Drugs and Behavior*, L. Uhr and J. C. Miller, Eds. (Wiley, New York, 1960), pp. 243–249.
5. Supported in part by NIH grant MH-07323-01 to the University of Texas.

18 February 1965

Preferential Settling of the Sea Anemone Stomphia coccinea on the Mussel Modiolus modiolus

Abstract. *In resettling after its "swimming" response,* Stomphia *shows a special behavior pattern when in contact with bivalve shells. Movements of the tentacles, oral disc and column, and huge swellings of the pedal disc are the chief features in a coordinated purposive sequence, which settles the anemone on the shell in a few minutes.*

The sea anemone *Stomphia coccinea* is well known for the swimming response it shows on contact with certain starfishes (*1, 2*) and with a nudibranch (*3*) and to electrical stimuli (*4*). By this response, unique among sea anemones, *Stomphia* detaches its basal disc quickly and, once free, "swims" away by flexing its body repeatedly.

I have recently observed a second complex behavior pattern in this animal in response to the shell of the mussel, *Modiolus modiolus. Stomphia coccinea* (the so-called "small" *Stomphia*) collected by dredging in San Juan Channel of Puget Sound usually comes up on the shells of *Modiolus*. This suggests preferential settling on these shells. In a trial experiment, 18 *Stomphia* were induced to swim by contact with the starfish *Dermasterias imbricata* (*1, 2*). After swimming ceased, each anemone was placed in a separate bowl contain-

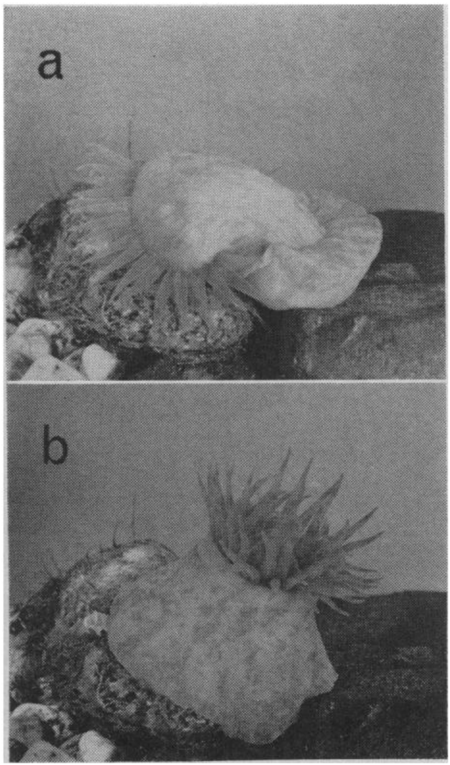

Fig. 1. (*a*) Response of *Stomphia coccinea* to *Modiolus modiolus*. The tentacles and oral disc are directed toward the shell; the pedal disc has expanded and is making contact with shell. (*b*) *Stomphia* sliding across shell toward final position on top. Time between *a* and *b*, 12 minutes.

ing flat stones, a living *Modiolus*, and an ample area of glass between. The animals were arranged lying on the glass so that the tentacles of six *Stomphia* and the pedal discs of six others were touching shells; the remaining six were touching stones. One hour later, 11 of the 12 animals touching shells had settled on shells. Of the rest, five had settled on the glass and two were still unattached.

When *Stomphia* comes out of its "post-swimming torpor" (*2*), it usually settles quickly on any available surface by attaching its basal disc little by little to that surface. *Stomphia* in contact with shells behaved differently. Some bent over shells with tentacles and oral disc extended outwards like an umbrella. Others leaned on shells with a few tentacles in contact. This tentacular-oral activity was followed by remarkable movements of the basal region. Sometimes it was extended horizontally as a huge plate which was turned toward the shell. In other instances, it swelled up into a hemisphere which was pushed towards the shell. These were slow flowing movements, just quick enough to be visible. The events beginning with the tentacle response and ending with the movement of the basal disc to the shell took only about 1 to 2 minutes. Figure 1 shows stages in this behavior pattern.

In a number of experiments the following observations were made.

1) If even a small area of the basal disc made contact with the shell, it adhered quickly and spread itself on the shell. When this happened, the oral-tentacular contact ceased and the column, which had been bent into a right angle, became straight again. If the basal disc failed to make contact with the shell in the first movement, it resumed its normal shape and position, but after a pause, during which the anemone's tentacles moved farther across the shell, the performance was repeated not once but several times if necessary.

2) *Stomphia* which had settled on other surfaces up to about 3 hours earlier transferred readily to *Modiolus* shells. With tentacles and oral disc on the shell, the basal disc was released from its attachment on the other surface and moved over to the shell. Sometimes this involved a long (up to 1 hour) process of advancing and retreating before the gap between the other surface and the shell was successfully bridged. Animals which had been settled on other surfaces more than 3 hours showed no tendency to transfer to shells.

3) This behavior was not specific to shells of *Modiolus* but was evoked by shells of other bivalve molluscs, for example, *Pecten*. An empty shell evoked the same response.

Films at ordinary and time-lapse speeds emphasize the purposive features of this behavior pattern. The muscular and hydrodynamic mechanisms involved and the nervous coordination are difficult to comprehend. Remembering that *Stomphia* is also able to swim in response to other specific stimuli, and recalling the behavior pattern of the sea anemone *Calliactis* in relation to hermit crabs (*5*), one realizes that the behavior of these so-called simple animals can be surprisingly complex.

D. M. Ross

Zoology Department,
University of Alberta,
Edmonton, Alberta, Canada

References and Notes

1. C. S. Yentsch and D. C. Pierce, *Science* **122**, 1231 (1955).
2. P. N. Sund, *Quart. J. Microscop. Sci.* **99**, 401 (1958).
3. E. Robson, *J. Exptl. Biol.* **38**, 685 (1961).
4. D. M. Wilson, *ibid.* **36**, 526 (1959); G. Hoyle, *ibid.* **37**, 671 (1960); D. M. Ross and L. Sutton, *ibid.* **41**, 723 (1964).
5. D. M. Ross and L. Sutton, *Proc. Roy. Soc. Ser. B.* **155**, 266 (1961).
6. This work was carried out at the Friday Harbor Laboratories of the University of Washington. Thanks are due to Dr. Robert Fernald and his staff for their hospitality and help. The financial assistance of the National Research Council of Canada (operating grant A-1445) is hereby acknowledged.

8 February 1965

Visual Accommodation in Human Infants

Abstract. By the technique of dynamic retinoscopy, we found that the alert newborn infant can focus his eye on targets only at a particular distance (median, 19 centimeters). Images of targets nearer or farther away are proportionately blurred. However, during the first few postnatal months the range of flexible accommodation increases and approximates adult performance by the 4th month.

Increasing interest in the vision of newborn infants is demonstrated by the growing amount of research on their acuity, form discrimination, preferences, and other visually controlled behaviors (*1*). In all such studies the focus of the retinal image limits the fineness of discrimination. Moreover, changes in focus may be confounded with other conditions that determine responses to visible objects. Nevertheless, in practically all research on infant vision, focal length has been an uncontrolled variable. Whereas accommodation of the lens in the eye of the young adult automatically focuses the retinal image for target distances ranging from 10 cm to optical infinity, we cannot assume comparable behavior in very young infants. The fragmentary data that are available suggest limited accommodative capacity, at best, in the newborn human (*2, 3*). Even if an infant's eyes are oriented toward a target, his optical system may be focused for any distance along his line of sight. The blurring of the retinal image that results from inadequate focusing may interact significantly with the effects of experimental variables. We now report the first data known to us on the course of acquisition of accommodative ability in human infants.

Changes in accommodation are largely accomplished by involuntary