Simultaneous contrast in goldfish*

R. C. GONZALEZ and ALICE S. POWERS

Bryn Mawr College, Bryn Mawr, Pennsylvania 19010

Two groups of goldfish were trained to strike an illuminated target for food reward. The experimental group was reinforced with 10 worms for response to one color and with 1 worm for response to a different color. The control group was reinforced with 1 worm for response to each color. The experimental group gave clear evidence of discrimination of reward magnitude and also of simultaneous negative contrast. These results bear on the relation of the mechanisms of simultaneous and successive contrast.

Negative contrast is found in mammals both in successive and in simultaneous paradigms. The successive paradigm is a two-stage affair in which experimental animals first are trained with a larger (Crespi, 1942) or a qualitatively preferred (Elliott, 1928) reward than are control animals and then are downshifted to the reward level of the controls. The simultaneous paradigm is a one-stage affair in which experimental animals are given differential reinforcement with the two rewards in the context of a discrimination problem (large reward for response to one stimulus and small reward for response to a different stimulus), while the controls are given nondifferential reinforcement with the lesser reward for response to both stimuli (Bower, 1961). In each case, negative contrast is defined as poorer performance for the lesser reward by the experimental as compared with the control animals.

Despite the similarity of the two kinds of experiment and of the outcomes they yield, there is reason to believe that the processes which give rise to simultaneous and successive contrast may be different. One indication is that simultaneous, as compared with successive, contrast develops gradually and remains stable over long periods of experimental training. Another is the finding in the present experiment of simultaneous contrast in goldfish, which, under a variety of conditions in previous experiments, have failed to show successive contrast (Gonzalez, Potts, Pitcoff, & Bitterman, 1972; Lowes & Bitterman, 1967; Mackintosh, 1972).

METHOD

Subjects

The Ss were 18 experimentally naive goldfish, 4-5 in. long, obtained from a local dealer and housed in individual 2-gal tanks set on open shelves in a temperature-controlled laboratory.

*This research was supported by NIMH Grant 15902. The data were presented by the senior author as part of an address on "A Comparative Analysis of Contrast Phenomena" at a symposium of the Canadian Psychological Association, St. John's, Newfoundland, June 1971. Requests for reprints should be sent to R. C. Gonzalez, Department of Psychology, Bryn Mawr College, Bryn Mawr, Pennsylvania 19010.

Apparatus

Each S was trained in its 2-gal living tank. The tank was carried to an enclosure of black Plexiglas equipped with a hinged side and a hinged lid which were closed when the tank was inserted. Fixed to one end of the lid on a thin metal rod was a target, 1.25 in. in diam, which could be illuminated with white, red, or green light. Striking at or pressing against this target was reinforced with live *Tubifex* worms delivered by a feeder at the end of the tank opposite the target. As the reinforcement was delivered, the delivery area was illuminated for a few seconds with a diffuse white houselight. All events of the experiment were programmed automatically: a printing counter, driven by a pulse stream generator, was used to measure latencies and response times in units of 0.1 sec.

Procedure

After adaptation to the experimental situation, Ss were trained to strike at the target, which was illuminated with white light. Each contact of S with the target was reinforced with 1 worm for 14 randomly selected Ss and with 10 worms for the remaining 4 Ss. After response had stabilized, there were daily sessions of 10 trials each during which the number of target presses required to produce the reinforcement was increased gradually to five (FR 5). Then there were two daily sessions of 16 trials each with an FR 5 and an intertrial interval of 20 sec. On the basis of their performance in this stage of training, the 10-worm and 1-worm Ss were divided into two groups, the 4 10-worm animals and 8 of the 1-worm animals into Group 10-1 ($N = 12$) and 6 of the 1-worm animals into Group 1-1.

The first stage of the experiment proper consisted of 48 daily sessions of 16 trials each, 8 on which the target light was red and 8 on which it was green, the orders of presentation of the two colors following selected Gellermann (1933) schedules. Each trial began with the onset of the target light and the activation of the printing counter. The defined response (five presses) turned off the target light, activated the feeder (which discharged either 1 or 10 worms), and turned on the houselight for 10 sec. The intertrial interval was 20 sec. Latency of the first press and the time required to make all five presses were printed. For Group 1-1, response to each color was reinforced with 1 worm. For Group 10-1, response to one color (S+) was reinforced with 10 worms and response to the other color (S-) with 1 worm; for 6 of these Ss, green was S+ and red was S-; for the remaining 6 Ss, red was S+ and green was S-.

In the second stage of the experiment, which began on Day 49, 6 of the 12 Ss of Group 10-1 were shifted to the 1-1 condition. For the remaining animals, the conditions remained unchanged. Throughout the entire experiment, the total daily ration of food for all Ss was 166 worms plus a small portion of

Fig. 1. Discrimination of reward magnitude and simultaneous negative contrast in goldfish.

dry food. That portion of the ration not earned in the apparatus was postfed in S's living tank 30 min after each day's session.

RESULTS

In Fig. 1, the performance of the 10-1 and 1-1 groups in the first stage of the experiment is shown in terms of mean log latency and mean log total time (to complete the FR 5 requirement) for blocks of 3 days. The curves show the development in the 10-1 group of differential response to the large (S+) and small (S-) reward stimuli ($F = 104.4$ and 75.2 , $df = 1/10$, $p < .01$ for latency and total time, respectively) and of negative contrast ($F = 7.7$ and 5.2 , $df = 1/16$, $p < .05$ for latency and total time of response for the small reward). The curves and analyses for Group 10-1 are based on the data for all 12 animals, since the difference in pretraining with 1 and 10 worms had no effect on subsequent performance. Although the 10-1 animals gave clear evidence of discrimination of reward magnitude, their overall performance to S+ was no better than the performance of the 1-1 animals, an outcome which was due in large measure to an interaction in the 10-1 group between the S+ and S- colors (red vs green) and amount of reward ($F = 7.1$ and 14.2 , $df = 1/10$, $p < .05$ for the two measures). The interaction took the form of slower response for the red than for the green S+ and no difference in response to the red and green S-. (For the 1-1 animals, there was virtually no difference in response to red and green.) Just why this interaction should have appeared is not clear, but its presence does not stand in the way of the basic finding of simultaneous negative

contrast in goldfish. (Nor can the effect be attributed simply to some response-suppressing tendency of the aftereffects of the large reward in the context of the relatively massed trials—for the difference in S- responding on trials following large reward as compared with trials following small reward, $F < 1$ for both measures.)

In the second stage of the experiment, half the 10-1 animals were shifted to the 1-1 condition. The major effect of the shift was to *increase* their speed of response to the S- color of the first stage of training ($F = 18.3$ and 10.3 , $df = 1/10$, $p < .01$ for the differences in latency and total time between the shifted and unshifted animals). After a few days, the shifted animals were responding essentially at the same rate to the two colors, and, in their response to the S+ color of the first stage, they gave no suggestion of negative successive contrast (i.e., their latency and total time scores were no higher than those of the 1-1 animals).

DISCUSSION

There has been a tendency among contemporary theorists to attribute simultaneous and successive contrast to a common mechanism, although there is disagreement about the mechanism itself. Bower (1961), for example, has proposed an interpretation in terms of frustrated expectancies (Amsel, 1958), and Black (1968) has proposed one in terms of associative inhibition (Spence, 1936). If, indeed, the processes responsible for simultaneous and successive contrast were the same, we should expect a given animal either to show both effects or to show neither, and the present results, taken together with those of previous experiments in which goldfish have failed to show successive contrast, suggest that the mechanisms of the two effects are different.

With respect to successive contrast, we are led—by the nature of the effect, by the comparative data on the problem, and by the results of a recent series of experiments with rats on its relation to certain extinction phenomena (Gonzalez & Bitterman, 1969; Gonzalez, Fernhoff, & David, in press)—to concur with the most commonly held view that it is the product of an emotional reaction to the discrepancy between anticipated and encountered amounts of reward. Simultaneous contrast, however, seems more likely to be the product of the development of inhibitory properties by the S- in the course of discriminative training. From this point of view, differential reinforcement with two reward magnitudes leads not simply to the development of greater excitatory potential by the S+ than by the S-, but to the development of inhibitory properties by the S- as well. On the assumption that in a simultaneous contrast experiment the excitatory tendency to respond for the small reward is essentially the same in experimental and control animals, the observed poorer performance of the experimental animals for the small reward is attributed to the added inhibition which is

generated by differential reinforcement.

Viewed as a basic product of discrimination, it is easy to understand why fish should show simultaneous contrast; it would be surprising, in fact, if the phenomenon were not a perfectly general one phylogenetically, depending for its appearance in any given species only on the capacity of that species to discriminate the reward magnitudes involved and on a set of experimental conditions appropriate to the measurement of that capacity. It is also possible, of course, that in mammals the phenomenon may be multiply determined—that processes of an expectational and evaluative nature may also play a part, at least under certain conditions. Such processes, however, do not seem necessary for the appearance of the phenomenon.

REFERENCES

- Amsel, A. The role of frustrative nonreward in noncontinuous reward situations. *Psychological Bulletin*, 1958, 55, 102-119.
- Black, R. W. Shifts in magnitude of reward and contrast effects in instrumental and selective learning. *Psychological Review*, 1968, 75, 114-126.
- Bower, G. H. A contrast effect in differential conditioning. *Journal of Experimental Psychology*, 1961, 62, 196-199.
- Crespi, L. P. Quantitative variation of incentive and performance in the white rat. *American Journal of Psychology*, 1942, 55, 467-517.
- Elliott, M. H. The effect of change of reward on the maze performance of rats. University of California Publications in Psychology, 1928, 4, 19-30.
- Gellermann, L. W. Chance orders of alternating stimuli in visual discrimination experiments. *Journal of Genetic Psychology*, 1933, 42, 206-208.
- Gonzalez, R. C., & Bitterman, M. E. Spaced-trials partial reinforcement effect as a function of contrast. *Journal of Comparative & Physiological Psychology*, 1969, 67, 94-103.
- Gonzalez, R. C., Fernhoff, D., & David, F. G. Contrast, resistance to extinction, and forgetting in rats. *Journal of Comparative & Physiological Psychology*, in press.
- Gonzalez, R. C., Potts, A., Pitcoff, K., & Bitterman, M. E. Runway performance of goldfish as a function of complete and incomplete reduction in amount of reward. *Psychonomic Science*, 1972, 27, 305-307.
- Lowes, G., & Bitterman, M. E. Reward and learning in the goldfish. *Science*, 1967, 157, 455-457.
- Mackintosh, N. J. Reward and aftereffects of reward in the learning of goldfish. *Journal of Comparative & Physiological Psychology*, 1971, 76, 225-232.
- Spence, K. W. The nature of discrimination learning in animals. *Psychological Review*, 1936, 43, 427-449.

(Received for publication September 5, 1972;
revision received October 9, 1972.)