Simultaneous contrast in the goldfish*

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In this, as in two prior experiments, goldfish trained with small reward for response to one color and large reward for response to another color performed less well for the small reward than control animals trained with small reward for response to both colors. The results obtained in the present experiment (with liquid food as reward) cannot be explained in terms of postingestive inhibition (evidence from the prior experiments with *Tubifex* worms as reward being inconsistent on this point) or in terms of within-sessions decrement in drive. The results bear on the phyletic generality of simultaneous contrast and on the relation of simultaneous to successive contrast, a phenomenon that has thus far failed to appear in goldfish.

In a recent paper, Gonzales and Powers (1973) reported an experiment on simultaneous contrast in the goldfish that closely resembles an earlier experiment from the same laboratory by Fujio (1969). The results are alike in showing what might be taken as a contrast effect: In both cases, experimental animals trained with small reward for response to one color and large reward for response to a second color performed more poorly for small reward than did control animals trained with small reward for response to both colors. But there is also an important difference in the results that bears on the validity of the contrast interpretation.

As Fujio recognized, the poorer performance of the experimental group in such an experiment may be due to what may be called greater "demotivation" (Seward, Pereboom, Butler, & Jones, 1957) or "postingestive inhibition" (Bitterman & Schoel, 1970); whichever term is used, there is a good deal of evidence from work with rats that (perhaps because of a transient decrement in drive or because of competition from persisting consummatory responses) instrumental behavior may be suppressed temporarily by reward—more by large reward than by small. Fujio was unable to reject this interpretation of her results, because a trial by trial analysis suggested that the poorer performance of her experimental group could be due entirely to slower responding on trials following large reward.

Gonzalez and Powers report parenthetically that their own experimental group did not respond significantly more slowly to the small-reward color on trials following large as compared with small reward, but they present no data and they tell us nothing that helps to explain the discrepancy between their results and Fujio's on this point. (They do not, in fact, cite Fujio.) Yet, despite certain seemingly minor differences in procedure—for

example, Gonzalez and Powers gave 16 rather than 20 trials per session, and they failed for some reason to equate their groups with respect to amount of reward experienced in pretraining—the two experiments are very much the same. Gonzalez and Powers, like Fujio, used a target-striking response on FR-5, red and green target lights as discriminanda, 1 vs 10 *Tubifex* worms as amounts of reward, and a 30-sec interval between the delivery of reward on each trial and the start of the next trial. Taken together, then, the two sets of results leave room for doubt that simultaneous contrast has been demonstrated in the goldfish.

In the experiment now to be reported, a liquid-feeding technique was used to avoid the postingestive inhibition that Fujio had shown to be a prominent feature of the worm-feeding technique. The liquid food was delivered through a nipple in the center of the target (Holmes & Bitterman, 1969). Perhaps because of the nature of the food or because of the close topographical relation between consummatory and instrumental responding, the delivery of even a large quantity of liquid food in this situation was found to produce no appreciable postingestive decrement in performance.

METHOD

Subjects

The Ss were 21 10- to 12-cm goldfish, all experimentally naive. They were maintained in individual 2-gal tanks at 21°C on a daily ration of 2 cc of a special liquid food (Biorell and cornstarch cooked with water).

Apparatus

The animals were trained in black Plexiglas enclosures to which they were carried in their living tanks. Mounted on the lid of each enclosure was a target of translucent Plexiglas that could be illuminated by lamps of different color (red, green, or white). Contact with the target was detected electrically (Holmes & Bitterman, 1969), and at the target's center was a Plexiglas

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Fig. 1. Mean response times [$\log_e(t + 1)$] of the experimental group (E) to the colors associated with small and with large reward and of the control group to the two colors (both associated with small reward). For statistical purposes, a constant (1) was added to each time score before transformation to natural logarithms. These are pooled within-sessions curves plotted over five blocks of four trials each. They are based on the data of the last 16 sessions of training, during which the response requirement was the same and over which performance did not vary significantly (as shown by a groups by sessions by stimuli by trials analysis of variance).

nipple through which the liquid food could be delivered by a Davis pump. All events of the experiment were programmed automatically, and response times were recorded with a printing counter.

Procedure

The animals were pretrained in sessions of 20 discrete trials to strike at a white target. The first response to the illuminated target produced a "drop" (0.005 cc) of liquid food and started a timer that kept the target light on for a period of 5 sec, during which each further contact with the target produced another drop of food. At asymptote, the animals made about 10 responses in the 5 sec, earning about 0.05 cc of food per trial. The trials were separated by intervals in darkness of at least 10 sec, each response to the target during the intertrial interval postponing the start of the next trial (resetting the interval timer).

The animals were divided into two groups equated on the basis of their performance in pretraining, an experimental group of 11 Ss and a control group of 10 Ss. The two groups then were trained in 24 daily sessions of 40 trials each. Again (as in pretraining) the trials were separated by intervals in darkness of at least 10 sec. On half of the trials of each session (in Gellermann orders), the target was illuminated with red light, and on the remaining trials with green light. In Sessions 1-2, the first response on each trial to the red or green target delivered a drop of liquid food and changed the color of illumination to white for a specified period of time (the "reinforcement period"), during which each further response produced an additional drop of food. For the control group, the duration of the reinforcement period was 0.5 sec on red as well as on green trials; that is, the amount of reward for response to each color was small, since the typical animal had time only for one further response during the period, thus earning only 0.01 cc of food in all on each trial. For the experimental group, the duration was 0.5 sec on trials with one of the colors (red for half of the animals, green for the rest) and 10.5 sec on trials with the other color; that is, the amount of reward was small for response to one stimulus and relatively large for response to the second. The typical animal earned about 0.1 cc of food on each large-reward trial. A consequent difference between the groups in degree of hunger was, of course, avoided by concomitant variation in the daily food ration.

While in the first two training sessions only a single response to the red or green target was required for reinforcement on each trial, the requirement was increased in subsequent sessions, with the reinforcement conditions remaining the same. In Session 3 the second response to the red or green target produced a drop of food, changed the color of the target to white, and initiated the reinforcement period of specified duration. In Sessions 4-8 the number of responses required was increased progressively to six; in Sessions 9-24 10 responses were required. The ratio was used because, in various fishes studied (Behrend, Bauman, & Bitterman, 1965) as well as in pigeons (Graf, Bullock, & Bitterman, 1964) and in rats (Gonzalez, Bainbridge, & Bitterman, 1966), it has been found to produce better discriminative performance than does CRF. The measure of performance was the number of seconds (t) taken by the animal on each trial to make the required number of responses. For purposes of statistical analysis, the normalizing transformation $\log_e(t + 1)$ was applied to each measure.

RESULTS

Performance stabilized rapidly and did not vary significantly ($F < 1$) over the last 16 sessions (analyzed in blocks of four), for all of which the response requirement was the same. Pooled performance in these sessions is plotted in Fig. 1. For the experimental group, there are two such within-sessions curves, each plotted in blocks of four trials, one for the small-reward color and the other for the large-reward color. As these curves show, the animals responded more slowly to the small-reward color than to the large-reward color ($F = 54.71$, $df = 1/10$, $p < .01$). For the control group, the results for the two colors are averaged to provide a single within-sessions curve, since both colors were associated with small reward and the difference in time of response to them was negligible ($F < 1$). As Fig. 1 also shows, the experimental animals responded more slowly to their small-reward color than did the control animals ($F = 5.22$, $df = 1/17$, $p < .05$).

The results of a trial by trial analysis designed to test the postingestive interpretation are summarized in Table 1. In that analysis, the performance of the experimental group on any given trial (N) was studied as a function both of the amount of reward given on that trial and of the amount of reward given on the immediately preceding trial ($N - 1$). The results show a substantial effect of amount of reward on Trial N ($F = 70.4$, $df = 1/8$, $p < .01$) and a negligible effect of amount of reward on Trial $N - 1$ ($F < 1$). The interaction is also significant ($F = 19.2$, $df = 1/8$, $p < .01$), but the pattern of scores does not suggest postingestive inhibition, and the Newman-Keuls method shows the difference between response to the small-reward color on trials following large as compared with small reward to be unreliable ($p > .05$). An interpretation of the inferior performance of the control group in terms of postingestive inhibition, therefore, can be rejected.

Before a contrast effect may be said to have been demonstrated, however, another possible interpretation must be considered. Since the experimental animals receive considerably more food in the course of each

training session than do the controls, their poorer performance for small reward may be due to greater within-sessions decrement in drive. (This interpretation, which should be distinguished from the "demotivation" interpretation, leads us to look for a gradual decrement in performance over trials in each experimental session rather than for transient postingestive effects correlated with the size of the immediately preceding reward.) Fujio was able to reject an explanation of her results in terms of within-sessions decrement in drive, because the difference in the performance of her groups was evident at the very outset of each session and did not increase in the later trials. Gonzalez and Powers make no reference to this problem. That the results of the present experiment cannot be explained in terms of within-sessions decrement in drive is suggested by Fig. 1. The shape of the curves suggests some initial warm-up as well as some terminal diminution in drive, but the difference between the groups is evident in the first block of trials, and variation in the difference between groups over blocks of trials is negligible ($F < 1$). Until yet another possible interpretation suggests itself, therefore, we shall assume that simultaneous contrast has been demonstrated in the goldfish.

DISCUSSION

Appearing as it does in animals as diverse as rat (Bower, 1961), pigeon (Brownlee & Bitterman, 1968), and goldfish, the phenomenon of simultaneous contrast begins to take on the appearance of phyletic generality. That the mechanisms of simultaneous contrast in the three animals are the same has not, of course, been established, although it seems reasonable on grounds of parsimony to assume that they are.

The present results bear also on the relation between simultaneous and successive contrast. That successive contrast may not be a general phenomenon of vertebrate learning is suggested by recent failures to find it in goldfish (Gonzalez, Potts, Pitcoff, & Bitterman, 1972; Lowes & Bitterman, 1967; Mackintosh, 1971) and in painted turtles (Pert & Bitterman, 1970). The demonstration of simultaneous contrast in goldfish suggests that—however much the two phenomena may seem intuitively to have in common—the mechanisms of simultaneous and successive contrast are not the same. If the mechanisms were the same, then any animal would show both effects or neither (Bitterman, 1965). It is interesting to note that an acceptable common theory of simultaneous and successive contrast in rats has not yet been developed. The frustration interpretation (Amsel, 1958), which seems to fit the successive case, can handle the simultaneous only on the dubious assumption of persisting confusion between the circumstances in which large and small rewards are encountered (Bower, 1961). The explanation of successive contrast as generalization decrement (Capaldi & Lynch, 1967) does not apply at all to simultaneous contrast. The fact that no

Table 1
Mean Response Times [$\log_e(t + 1)$] of the Experimental Group to Colors Associated with Large and Small Reward on a Given Trial (N) as a Function of Amount of Reward Received on the Immediately Preceding Trial (N - 1)

Amount of Reward on Trial N - 1	Amount of Reward on Trial N		
	Large	Small	Mean
Large	2.265	2.635	2.450
Small	2.293	2.590	2.442
Mean	2.279	2.613	

satisfactory common explanation of simultaneous and successive contrast has yet been found does not, however, prove that their mechanisms are different.

Given the demonstration of simultaneous contrast in goldfish, it still is possible to assume that the mechanisms of simultaneous and successive contrast are the same on the further assumption that all attempts to demonstrate successive contrast in goldfish have been somehow defective, perhaps because the techniques employed were insufficiently sensitive. Our view is that the demonstration of simultaneous contrast in goldfish should increase confidence in the negative results of the successive experiments, since work with rats gives no reason to think that the successive phenomenon is more subtle or difficult to demonstrate than the simultaneous. The technique used here does, however, differ to some extent from any used in the search for successive contrast, and the results may encourage the skeptic to use it in a further search for successive contrast. Careful study of the contribution to contrast of each feature of the simultaneous experiment which differentiates it from the successive experiment (such as the correlation between situational cues and magnitudes of reward or the distribution of trials) certainly is in order and may be expected to clarify the relation between the two effects.

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