Anticipatory contrast: Within-subjects analysis

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Contrast in consummatory behavior occurs readily when a less preferred substance follows a preferred substance. A previous experiment indicated that contrast in consummatory behavior may also develop when a less preferred substance precedes a preferred substance in brief daily exposures. In the present experiment, the same animals sometimes received 0.15% saccharin followed, 15 sec later, by 32% sucrose (.15-32) and sometimes received 0.15% saccharin followed by the same 0.15% saccharin solution (.15-.15). One solution pair was given each day, and the two conditions, .15-32 and .15-.15, occurred in alternation across days. The two different solution conditions were correlated with different cues. Saccharin intake from the first tube was lower when the second tube contained 32% sucrose than when it contained .15% saccharin, both in original discrimination training and following a reversal of the cue-solution pairings. These results support the conclusion that contrast in this situation is based on the anticipation of the impending 32% sucrose each day, rather than on a retrograde comparison with the 32% sucrose received the previous day. These data are considered in terms of Pavlovian conditioning outcomes when the CS is a stimulus with hedonic value.

Contrast effects, exaggerated responding apparently based on the opportunity to compare different levels of reward, are ubiquitous in animal learning tasks (see Flaherty, 1982, and Williams, 1983, for recent reviews). The particular focus of the present paper is contrast that occurs in the consumption of sucrose and saccharin solutions. Although these contrast effects may be produced by a variety of experimental procedures, two are of particular relevance. The first of these occurs when animals are given repeated exposure to one reward and then shifted to an alternative reward. For example, if rats are given brief access to 32% sucrose each day for 10 days and then shifted to 4% sucrose, they consume about 50% as much of the 4% solution as do animals that have experienced only the 4% sucrose (see, e.g., Becker & Flaherty, 1983, and Lombardi & Flaherty, 1978). This contrast, termed a successive negative contrast effect, must be based on a comparison of the 4% postshift solution with the memory of the preshift 32% solution (Spear, 1967). If the interval between preshift and postshift solution is long, contrast does not occur (e.g., Gonzalez, Fernhoff, & David, 1973; Flaherty & Lombardi, 1977).

A second situation in which contrast may occur, and the one that is the major concern of this paper, is one in which animals are given a series of daily "pairings" of two solutions—in particular, a less preferred solution which precedes a more preferred solution. It has been

found that, in this circumstance, the intake of the less preferred solution is suppressed. For example, rats given access to saccharin typically show an acquisition curve—intake increases as a function of experience (e.g., Domjan, 1976). However, this acquisition function is suppressed if saccharin access is followed by a brief period of access to 32% sucrose (Flaherty & Checke, 1982). No suppression of saccharin intake occurs if the saccharin is followed by 2% sucrose.

The suppression of saccharin intake has been attributed to a contrast effect based on a comparison of the preferred 32% sucrose with the less preferred .15% saccharin solutions used in these experiments (Flaherty & Checke, 1982). A question arises, though, as to the locus of the comparison that leads to the contrast. That is, are the animals comparing the saccharin solution received each day with the memory of the 32% sucrose received the previous day, a comparison which would make the saccharin suppression effect just another case of successive contrast, or are they comparing the saccharin with the 32% sucrose they will soon receive on that day? This latter possibility would involve the daily anticipation of the preferred solution.

In order to evaluate these two possible loci of comparison, retrograde or anterograde, the intersolution interval was manipulated in several previous experiments. These experiments showed that contrast diminished as the intersolution interval increased in the range of 1 to 30 min. These results were interpreted to mean that the saccharin suppression was based on the anticipation of the impending 32% solution each day rather than on a retrograde comparison with the 32% received on the previous day. The rationale for this interpretation was as follows. If the locus of the comparison was the 32% sucrose received 24 h earlier, then a change of a few minutes in the daily

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intersolution interval should not have much effect. Since these small changes did reliably reduce contrast, it was assumed that the comparison was based upon a within-day anticipation of the preferred solution, with the intersolution interval functioning, perhaps, analogously to the CS-US interval in standard Pavlovian conditioning procedures.

The present experiment is concerned with another, perhaps more powerful, test of the hypothesis that contrast in this situation is a within-day anterograde process rather than a between-day retrograde process. In this experiment, the different pairings of solutions were manipulated entirely within subjects. That is, the same animals experienced conditions in which a 0.15% saccharin solution sometimes predicted a subsequent 0.15% saccharin solution and sometimes predicted a subsequent 32% sucrose solution. These two conditions were experienced in regular alternation across days. Thus, if the animals received the 0.15%-32% pairing on the 1st day, they received a 0.15%-0.15% pairing on the 2nd day, a 0.15%-32% pairing on the 3rd day, etc. This arrangement places the two potential loci of control for the contrast effect in direct opposition. That is, if the contrast is based upon the 32% received on the previous day, then lick-rates for the initial 0.15% saccharin solution should be lower on days when the animals receive the 0.15%-0.15% pairings, because these days always follow a 32% sucrose day. On the other hand, if the locus of control is the within-day anticipation of the solution when the animals receive the 0.15%-32% pairings, then the lick-rate for the 0.15% solution should be lower on these differential pairing days—when the 0.15% saccharin predicts the 32% sucrose.

METHOD

Subjects

Twelve male Sprague-Dawley-derived rats (400-520 g) were individually housed under a 14/10 light/dark cycle. They were maintained at 82% body weight and fed once per day (Purina Lab Chow). Water was available continuously in the home cage. All but one of the rats had completed a glycemic conditioning experiment 30 days before the start of the present experiment.

Apparatus

Testing was conducted in three Plexiglas chambers measuring 30 × 25 × 25 cm. A 1.5-cm hole had been drilled in the center of one 30-cm side of each box, 4 cm from the wire-mesh floor. Solutions were delivered to each box via two motors, which could advance or withdraw graduated cylinders to align the drinking tubes with this opening. Licks were recorded by using a contact relay circuit and microcomputers. The menthol odor was produced with Mentholatum (a commercial pain-relieving ointment).

Procedure

All subjects received .15% saccharin in the first tube and either .15% saccharin or 32% sucrose in the second tube. These conditions were alternated over days, each condition paired with a different set of stimuli. The cue conditions used were either (1) dim light, tone, no menthol odor, and white noise or (2) bright light, clicking relay, menthol odor, and no white noise.

Pairing of cues with the solution conditions was counterbalanced. For half the subjects, Condition .15%-32% was paired with the first set of cues (dim light, tone, no odor, white noise) and Condi-

tion .15%-.15% was paired with the second set (bright light, click, menthol odor, and no white noise). For the other half of the subjects, the cue-solution pairings were reversed.

Phase 1. The initial phase of the experiment lasted from Day 1 to Day 20. Condition .15%-32% consisted of the following sequence of events: a 3-min access period to .15% saccharin solution, withdrawal of the tube and an interval of 15 sec with no tube available, then 5 min access to a 32% sucrose solution. In Condition .15%-.15%, the animals received 3-min access to a .15% saccharin, retraction of that tube, then a 15-sec interval followed by 5-min access to .15% saccharin solution. The timing of the access period was initiated by the rat's first lick after a tube became available.

Phase 2. In Phase 2, Days 21-32, the only change was that the intersolution interval was extended to 1 min.

Phase 3. In Phase 3, Days 33-52, the cue-solution pairings were reversed. The animals received a total of 52 days of training, with one pairing of the solutions given each day. Sucrose was mixed by weight (sucrose/sucrose + water) and made 24 h prior to use from commercial grade cane sugar and tap water. The saccharin solution was mixed on a weight/volume basis from sodium saccharin and tap water.

RESULTS

Mean licks for the 0.15% saccharin solution presented in the first tube are shown in Figure 1 for the various stages of the experiment. During Phase 1, the rats licked less for the 0.15% saccharin on days when the second tube contained 32% sucrose than on days when the second tube also contained the 0.15% saccharin solution [$F(1,10) = 12.23$, $p < .01$]. This pattern developed over training with reliable concentration differences appearing in Days 4 and 6-10 [concentration × days, $F(9,86) = 2.76$, $p < .01$, followed by least significant difference tests]. The same pattern of results was obtained in Phase 2, when the intersolution interval was extended to 1 min [$F(1,10) = 78.66$, $p < .001$]. Finally, in Phase 3, when the cue-reward pairings were reversed, there was

Figure 1. Lick rate for 0.15% saccharin on the first tube as a function of the solution in the second tube (0.15% saccharin or 32% sucrose) and stage of the experiment.

Figure 2. Lick rate for solutions available in the second tube (0.15% saccharin or 32% sucrose).

an initial loss of the discrimination followed by a reversal such that the animals again licked less 0.15% saccharin when it predicted sucrose than when it predicted more saccharin [solution $\times$ day, $F(9,78) = 3.08$, $p < .01$; solution, $F(1,10) = 46.70$, $p < .001$, over the last 6 days]. The precipitous drop in lick frequency on the 1st day of reversal was probably due to the fact that this was the first, and only, day on which the animals experienced the same cue events on 2 consecutive days.

The effect of the cues per se was not reliable in any of the three phases of the experiment [Phase 1, $F(1,10) = 1.91$, $p > .05$; Phase 2, $F(1,10) = 2.20$, $p > .05$; Phase 3, $F(1,10) = 3.23$, $p > .05$].

Licks on the second tube were reliably higher when the second tube contained 32% sucrose than when it contained 0.15% saccharin in all three phases of the experiment [Phase 1, $F(1,10) = 79.29$, $p < .001$; Phase 2, $F(1,10) = 56.57$, $p < .001$; Phase 3, $F(1,10) = 30.71$, $p < .002$]. These data are presented in Figure 2. Lick rate (licks/minute) was also higher on the second tube than on the first tube when the second tube contained 32% sucrose and the first tube contained 0.15% saccharin [solution $\times$ bottle; Phase 1, $F(1,10) = 68.19$, $p < .01$; Phase 2, $F(1,10) = 129.51$, $p < .001$; Phase 3, $F(1,10) = 66.33$, $p < .001$; followed by least significant difference tests]. However, lick rates (licks/minute) on the two tubes were not different when both contained the 0.15% saccharin solutions (same F values as above, followed by least significant difference tests).

DISCUSSION

In a series of experiments, we examined the effects of single daily pairings of a brief access period to 0.15% saccharin and brief access periods to a second solution presented a short time after the initial saccharin exposure. Previous studies had shown that the intake of a 0.15%

saccharin solution was suppressed when that solution preceded the later availability of 32% sucrose but not when the saccharin preceded the later availability of 2% sucrose. These earlier studies also showed that the degree of saccharin suppression was reduced as the interval between the daily presentation of solution pairs increased (Flaherty & Checke, 1982). These results were interpreted to mean that the animals learned the predictive relationship between the two solutions and that intake of the initial solution was suppressed when it predicted a more preferred solution. The effects produced by variations in the intersolution interval argued against the possibility that the saccharin intake was suppressed by a comparison of the saccharin with the memory of the 32% sucrose received on the previous day. That is, the intersolution interval data favored an interpretation in terms of anticipatory processes rather than in terms of a retroactive successive contrast.

The results of the present experiment show that suppressed intake of an initial saccharin solution can be obtained within subjects on days when one set of cues signal that the second solution will be 32% sucrose as compared to days when another set of cues signal that the second solution will be 0.15% saccharin. These results support an interpretation in terms of anticipatory processes for the following reason. The two different pairing conditions, 0.15% saccharin preceding 32% sucrose and 0.15% saccharin preceding 0.15% saccharin, occurred in daily alternation. If contrast (suppressed intake of the initial saccharin solution) had been based on the comparison with the 32% received on the previous day, then saccharin intake should have been lower on the 0.15%-0.15% days, since these pairing conditions always followed a 0.15%-32% day. The fact that this was not the case, and that intake of the initial saccharin solution was lower on the 0.15%-32% days, indicates that the locus of the comparison is within day, not between days.

The present paradigm seems analogous to a Pavlovian conditioning situation in that the regular pairing of two events alters the nature of the response to the first of these events. In addition, this alteration is dependent upon the length of the interval between the two events (Flaherty & Checke, 1982). A difference between the present procedure and standard conditioning is that some behavior on the part of the animal is necessary to obtain both the "CS" and the "US." Of course, in many conditioning procedures, some behavior on the part of the subject is necessary to obtain the US (e.g., Jenkins, Barrera, Ireland, & Woodside, 1978; Zener, 1937). And, in the conditioning aversion procedure, behavior on the part of the subject is necessary to obtain the CS (e.g., Garcia & Koelling, 1966). A second difference between the present procedure and the usual conditioning situation is that the "CS" in these experiments is not neutral; it has incentive value. This incentive value is apparently modified by the regular daily pairings of the two solutions. The fact that the "CS" has incentive value is also true in the conditioned aversion procedure, and this incentive value is also ap-

parently modified by the pairing process. It is interesting, though, that in both the present procedure and the conditioned aversion procedure the intake of the first substance is reduced by the pairing manipulation, although the US is noxious in the conditioned aversion experiment and preferred in the present procedure.

The fact that a preferred second substance reduces intake of the initial substance shows that the second solution (32% sucrose) is not functioning as a reinforcer in the usual sense of the term. That is, even though it is preferred to the saccharin and even though access to the sucrose is contingent upon licking of the saccharin (the second tube will not become available unless at least one lick is made to the first tube), intake of the saccharin is suppressed, not elevated, by access to the sucrose.

Our interpretation of these data, including the failure to obtain a reinforcement effect, is as follows. The animals learn the contingent relationship between the two solutions (Rescorla, 1968) and, once this learning is completed, the sampling of the first substance serves as a cue for the anticipation of the second—perhaps through a CS-elicited representation of the second substance (e.g., Pearce & Hall, 1980; Rescorla, 1978; Wagner, 1981). This representation of a preferred second substance may serve to devalue the first substance (Holland & Rescorla, 1975). This interpretation is consonant with aspects of Garcia's interpretation of conditioned food aversions. That is, the pairing of a toxin with a positively valued CS reduces the hedonic value of that CS (Garcia, Hankins, & Rusiniak, 1974). This interpretation is also consistent with many recent studies which indicate that anticipation of events that are more or less rewarding than a currently experienced stimulus alters responsivity to that stimulus (e.g., Capaldi, Nawrocki, & Verry, 1983; Chen & Amsel, 1980; Hulse & O'Leary, 1982; Williams, 1976, 1981, 1983).

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