Anticipatory contrast as a function of access time and spatial location

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Intake of a 0.15% saccharin solution was suppressed when it was followed by a 32% sucrose solution in brief daily pairings. With equal access durations to the two solutions, intervals of intermediate duration (2 or 3 min) produced a larger contrast than more extreme intervals (1 or 10 min). There was no evidence of inhibition of delay with the 10-min interval (Experiments 1A and 1B). When access times were asymmetrical, longer access time to the first solution reduced contrast, whereas longer access time to the second solution enhanced contrast (Experiment 2). Contrast was greater when the two solutions were presented at consistent and separate spatial locations than when location was changed randomly or when both solutions were presented in sequence at the same location. However, a degree of contrast occurred in all conditions (Experiment 3). Experiment 4, conducted with the solutions in opposite arms of a T-maze, showed that anticipatory approach to the location correlated with the 32% sucrose solution developed prior to lick suppression on the saccharin solution. However, within daily sessions, there was a reliable increase in contrast without correlated changes in anticipatory-approach behavior. Access-time effects were attributed to altered reward values, whereas spatial-separation effects suggest that goal-directed responses contribute to, but do not cause, anticipatory contrast.

Intake of a 0.15% saccharin solution is suppressed when it is followed, in brief daily pairings, by access to a 32% sucrose solution. The suppression occurs relative to several control conditions: presentation of the saccharin solution twice; presentation of the first solution only; and presentation of 2% sucrose as the second solution (Flaherty & Checke, 1982; Flaherty & Rowan, 1985; Lucas, Gawley, & Timberlake, 1988). *Anticipatory contrast* is termed such because the decreased responding to the first solution is an anterograde process, based on a comparison of the first solution with the second solution received each day, rather than on solutions received previously (Flaherty & Rowan, 1985).

Experiments concerned with exploring the conditions under which anticipatory contrast occurs have shown that contrast varies as a function of: the concentration of the initial solution (Flaherty & Rowan, 1986; Flaherty, Turovsky, & Krauss, 1994); the concentration and/or quality of the second solution (Flaherty & Checke, 1982, Experiment 1; Lucas, Timberlake, Gawley, & Drew, 1990; Moss, 1994); the time interval between the availability of the two solutions (Flaherty & Checke, 1982; Flaherty, Grigson, Checke, & Hnat, 1991; Lucas et al., 1988); and the presence or absence of a lick requirement on the initial solution (Flaherty & Grigson, 1988). In regard to the relationship between

the two solutions, the results of most experiments suggest that a necessary, but not sufficient, condition is that the second substance is more rewarding or preferred than the first substance (Capaldi, Campbell, Sheffer, & Bradford, 1987; Capaldi & Sheffer, 1992; Capaldi, Sheffer, & Pulley, 1989; Flaherty et al., 1991; Flaherty et al., 1994; Lucas et al., 1988; Lucas et al., 1990). However, Moss (1994), using a soy solution, has reported data not consistent with this generalization.

The present paper presents four experiments concerned with two other parameters potentially of relevance to anticipatory contrast. Experiments 1A, 1B, and 2 were concerned with the degree to which contrast is influenced by the duration of access to each solution. The literature both from conditioned flavor preferences and from behavioral contrast indicates that contrast could vary with duration of access to each solution.

A second factor potentially of relevance is the spatial location of the first and second solutions. In most of the experiments conducted in our laboratory, the two solutions have been presented at spatially distinct positions. Informal observation of the rats in these experiments suggests that animals in contrast conditions (0.15% saccharin followed by 32% sucrose) approach the location of the 32% tube before the time of its availability. Such approaches would, of necessity, subtract from potential drinking time on the currently available saccharin tube. Similar anticipatory approach responses have been found in other situations in which there was an unavailable preferred reward (e.g., Flaherty, Hamilton, & Capobianco, 1974; Timberlake, Gawley, & Lucas, 1987). Experiments 3 and 4 were concerned with the analysis of the role of competing responses from spatial separation of the first and second solutions in contrast.

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EXPERIMENT 1A

The juxtaposition of anticipatory-contrast data with the extensive literature on taste-preference conditioning leads to the question of why intake is suppressed, rather than enhanced, in the contrast procedure. Substantial research on taste preferences has shown that a flavor mixed with a preferred substance becomes preferred itself, as measured by both differential-intake and two-bottle choice tests (e.g., Bolles, Haywood, & Crandall, 1981; Booth, 1985; Capaldi, 1991; Fanselow & Birk, 1982; Fedorchak & Bolles, 1987; Mehiel, 1991). This result is not surprising, but it highlights the paradoxical result obtained in the contrast experiments—namely, suppression rather than facilitation of intake of the initial substance when a preferred substance follows the less-preferred initial substance. One obvious difference between the two procedures is that whereas most of the taste-preference experiments mix a flavor with a preferred substance, the contrast paradigm involves the sequential presentation of two solutions without flavors. Simultaneity seems unessential, in that flavor preferences may also be conditioned when one substance precedes another (Holman, 1975; Simbayi, Boakes, & Burton, 1986). The addition of extra flavors per se does seem to be important, and this issue has been addressed by Lucas and Timberlake (1992) and by Flaherty, Coppotelli, Grigson, Mitchell, and Flaherty (1995).

A potentially relevant difference between the anticipatory-contrast and preference-conditioning experiments concerns duration of exposure to the solutions. In flavor-preference conditioning, the initial solution is typically presented for a long period—for example, 10 min (Capaldi & Sheffer, 1992; Elizalde & Sclafani, 1988); 30 min (Capaldi et al., 1987; Holman, 1975: Experiments 4 and 5; Simbayi et al., 1986); or 24 h (Mehiel, 1991; Mehiel & Bolles, 1988). In all of our anticipatory-contrast experiments, however, the initial substance has been presented for only 3 min (e.g., Flaherty & Checke, 1982; Flaherty & Rowan, 1985, 1986; Flaherty et al., 1994), and it has been presented for 5 min in experiments from Timberlake's laboratory (e.g., Lucas et al., 1988; Lucas & Timberlake, 1992; Lucas et al., 1990). Anticipatory contrast has been reported with an access period to the initial solution of 10 min (Capaldi & Sheffer, 1992), but the procedure was quite different from that employed in most of our experiments (i.e., it was within subjects rather than between subjects, it employed a home cage rather than an experimental apparatus—a factor that may be of some importance [Lucas et al., 1988]—and it used chocolate milk rather than 32% sucrose as the reinforcer substance).

Duration of exposure to the two solutions in the anticipatory-contrast paradigm is also potentially relevant to the behavioral-contrast literature. In most behavioral-contrast studies, when component durations are equal in length, both positive and negative behavioral contrast in key-pecking are greater with shorter component durations (McSweeney, 1982; Williams, 1989). Thus both the litera-

ture concerned with conditioned flavor preference and that dealing with behavioral contrast suggest that short access durations may give rise to greater anticipatory contrast.

Experiment 1A was concerned with gathering parametric data on the role of exposure time to the initial substance in the development of anticipatory contrast. Separate groups of rats were given access to 0.15% saccharin, followed 15 sec later either by 32% sucrose (contrast condition) or by a second access period to the 0.15% saccharin solution (control condition). Both the first and the second solutions were available for 1, 2, 3, or 10 min in different groups of rats.

Method

Subjects. Forty-eight naive male Sprague-Dawley-derived rats, approximately 100 days old and purchased from Camm, were used as subjects. The animals were housed singly, kept on a 14:10-h light:dark cycle and maintained at 82% of their free-feeding weight by one daily feeding approximately 30 min after the end of each daily session. All testing in this and subsequent experiments was done between 6 and 10 h into the light phase of the light:dark cycle. In all experiments, water was continuously available in the home cage.

Apparatus. Testing was conducted in three Plexiglas chambers measuring 30 × 25 × 25 cm. Three holes, 1.5 cm in diameter, were located approximately 10 cm apart on one wall of the apparatus, 4 cm above the hardware-cloth floor. Solutions were delivered via graduated glass cylinders with metal spouts. The cylinders were attached to motors that advanced the spouts or withdrew them from the access holes. Lick and latency measures were recorded through contact relay circuits and microprocessors.

Procedure. All subjects were presented two solutions in succession each day. For half of the animals, the first and second solutions were the same—0.15% saccharin (Group .15-.15); for the remaining animals, the first solution was 0.15% saccharin and the second solution was 32% sucrose (Group .15-32). For subgroups of these control (.15-.15) and contrast (.15-32) conditions, the two solutions were available for 1, 2, 3, or 10 min ($n = 6$ per condition). All intervals were timed from the point of the insertion of the bottle containing the solution, and there was a 15-sec interval between the retraction of the first solution and the presentation of the second solution. After an initial day during which the rats were habituated to the apparatus for 5 min, the solution pairs described above were presented once daily for 14 days. The experiment was conducted in two replications. In the second replication, Bottle 1 lick frequencies were recorded on a minute-by-minute basis rather than as total licks for each session. Also, in the second replication, the 10-min group was continued for 16 days rather than the 14 days for which all of the other groups were run.

The saccharin solution was mixed on a weight/volume basis from sodium saccharin (Sigma, St. Louis) and tap water. The sucrose was mixed on a weight/weight basis [sugar/(sugar + water)] from commercial-grade cane sugar and tap water.

The data were analyzed in two ways: (1) total licks converted to average licks per min so that the various access times could be compared (i.e., degree of contrast in 1-, 2-, 3-, and 10-min groups); and (2) in terms of actual licks in each minute, so that changes within the access period could be analyzed. Simple effects tests on significant terms from an analysis of variance (ANOVA; mixed effects) were made with the least significant difference (LSD) test ($p = .05$).

Four dependent variables were recorded—namely, lick frequency on Bottles 1 and 2, and latency to initiate licking on each bottle. Only the lick-frequency data will be presented, as the latency data were not revealing and not different from those obtained in other anticipatory-contrast experiments.

Results

Lick frequency: Bottle 1. The rats in the .15-32 groups licked less saccharin than the rats in the .15-.15 groups [$F(1,32) = 38.89, p < .0001$]. The degree of this negative anticipatory contrast effect varied as a function of access duration [group $\times$ time, $F(3,32) = 3.15, p < .05$]. Subsequent tests indicated that there was a reliable overall contrast effect (collapsed across blocks) in the 2-, 3-, and 10-min groups, but not in the 1-min group. Furthermore, degree of contrast was larger in the 3-min group than in any other group. These data are illustrated in Figure 1, which shows that anticipatory contrast was related to access time in a curvilinear fashion—the difference between contrast (.15-32) and control (.15-.15) conditions was greatest with a 3-min access period.

Contrast also developed differentially across blocks as a function of access time [group $\times$ time $\times$ block, $F(18,192) = 2.74, p < .001$]. Subsequent tests indicated the following pattern of results: Contrast was reliable in the 1-min access group only in Blocks 6 and 7; it was reliable in the 2-min group in Blocks 5–7; it was reliable in the 3-min group in Blocks 3–7; and in the 10-min group, contrast was reliable in Blocks 4–7. These data are illustrated in Figure 2.

Given the curvilinear relationship between degree of contrast and access time, there arises the question of how much of this relationship is due to differences in the contrast conditions and how much is due to differences in the control conditions. Comparison of the four control conditions (.15-.15) illustrated in Figure 2 indicated that the .15-.15 10-min group licked less than the corresponding 3-min group in Blocks 4–7, and less than the corresponding 1- and 2-min groups in Blocks 6 and 7. Thus, the reduced contrast effect in the 10-min group was due in part to a reduction in intake in the control group. Comparison of the four contrast conditions (.15-32) illustrated in Figure 2 indicated that the 10-min group showed less suppression than the corresponding 3-min group in Blocks 6 and 7, but more suppression than the corresponding 1-min

group in Block 5. Overall, these comparisons indicate that the smaller contrast in the 10-min group was due to differences in both the control and the contrast conditions.

The data were also analyzed by examining contrast in the initial portion of the daily session for the various access durations. In particular, contrast in the first minute was compared across all four access durations (1, 2, 3, and 10 min); contrast in the first 2 min was compared across the 2-, 3-, and 10-min conditions; and contrast in the first 3 min was compared in the 3- and 10-min conditions. These comparisons were conducted by following the reliable group $\times$ time $\times$ block term reported above with separate ANOVAs of the terminal acquisition data (Block 7) for each of the three time comparisons.

Examination of the first minute of access in Groups 1, 2, 3, and 10 min showed that there was an overall reliable contrast effect [$F(1,16) = 20.19, p < .001$], which, statistically, did not vary as a function of access duration [solution $\times$ time, $F(3,16) = 1.99, p > .15$].

When the first 2 min were analyzed in Groups 2, 3, and 10 min, there was again an overall contrast effect [$F(1,12) = 35.21, p < .001$], but in this case, degree of contrast did vary reliably with access duration [solution $\times$ time, $F(2,12) = 6.18, p < .02$]. Subsequent analysis of this term indicated that contrast was reliable in the 2- and 3-min conditions, but not in the 10-min condition. Furthermore, both the 2- and 3-min groups suppressed reliably more than the 10-min group in the .15-32 condition, but there were no differences in lick frequency in the control condition among these three groups. Thus, when terminal acquisition performance was examined, the greater contrast in the 2- and 3-min groups, compared with the 10-min group, was mediated largely by greater suppression under contrast conditions rather than by differences in the control conditions.

When the first three minutes were examined in Groups 3 and 10 min, there was an overall contrast effect [$F(1,8) = 15.73, p < .01$] and also a difference in contrast as a function of access duration [solution $\times$ time, $F(1,8) = 11.80, p < .01$]. Examination of this interaction indicated that the contrast was reliable in the 3-min group but not in the 10-min group. Furthermore, the difference between the two conditions was in degree of suppression, with the .15-32 group from the 3-min condition suppressing more than the .15-32 group from the 10-min condition. There was no reliable difference in lick frequency between the control (.15-.15) groups in the 3- and 10-min conditions.

These data, which are illustrated in Figure 3, suggest that having access to the two solutions beyond 3 min per day reduces contrast in the earlier access periods primarily by reducing, in the .15-32 condition, the degree of suppression that normally develops over the first few minutes of access.

The data from the 10-min condition were further analyzed on a minute-by-minute basis. This analysis indicated no obvious pattern of reliable contrast other than the fact that contrast tended to occur late in acquisition and was scattered throughout the daily session, with no evidence of inhibition of delay (i.e., contrast did not develop initially

Figure 1. Degree of contrast as a function of access time (lick frequency of contrast group [.15-32] minus lick frequency of control group [.15-.15]).

Figure 2. Mean licks per minute across 2-day blocks as a function of solution condition (0.15% saccharin followed either by 0.15% saccharin or by 32% sucrose) and access time to the solutions (1, 2, 3, or 10 min).

in the earlier minutes of access and then move to the later portions of the access period). Specifically, contrast was not reliable at all in Min 1, 3, 4, 7, 8, and 10. In Min 2, contrast was reliable in Block 5 [$F(7,28) = 428, p < .01$]; in Min 5, contrast was reliable in Block 6 only [$F(7,28) = 3.17, p = .01$]; in Min 6, contrast was reliable in Block 6 only [$F(7,28) = 5.85, p < .01$]; and in Min 9, contrast was reliable in Block 6 only [$F(7,28) = 3.09, p = .01$].

These analyses indicate that extended exposure to the first and second solutions interferes with the occurrence of contrast, at least partly by reducing the degree to which contrast would normally occur during the first few minutes of access to the initial solution.

Lick frequency: Bottle 2. The rats receiving 32% sucrose in the second bottle licked more ($M = 251$ licks/min) than the rats receiving 0.15% saccharin [$M = 63.5$ licks/min, $F(1,16) = 256, p < .0001$]. There was also an interaction between solution condition and access time [$F(3,16) = 6.37, p < .005$], which indicated that, of the groups receiving 32% sucrose, the 1-min group licked at a lower rate than all other groups, and that, of the groups receiving 0.15% saccharin, the 3-min group licked at a higher rate than the 2-min group.

Feeding. Because the animals receiving 10 min of access to 32% sucrose drank enough to alter their body weight, the ration fed to these animals in their home cage had to be reduced to maintain the 82% deprivation level. The range of ration given to animals in the other groups was approximately 17–22 g/day. However, by the termination of the experiment, the rats in the 10-min sucrose group (.15-32)

were given only approximately 8–12 g. The reduction in ration size was initiated on Day 6 of the experiment, when the body weights began to deviate from the target values.

EXPERIMENT 1B

Experiment 1A showed that duration of exposure to the two solutions affected degree of contrast. Although there was a reduced contrast effect in the 10-min condition relative to the 3-min condition, the unsystematic nature of the minute-by-minute data within the 10-min condition provided little indication of a mechanism of contrast reduction. Perhaps the lack of systematic change was related to the small number of subjects for which minute-by-minute data were available ($n = 3$ per group). Because of this, and because of an interest in determining whether inhibition of delay occurred with a long access period, the experiment was replicated with a larger number of subjects ($n = 6$ per group).

Method

Subjects. Twelve male Harlan Sprague-Dawley rats, approximately 100 days old and maintained as in Experiment 1A, were used.

Apparatus. The apparatus was similar to that used in Experiment 1A, except that different contact relay circuits and different computers (modified IBM PCs) were used.

Procedure. The procedure was the same as that used in Experiment 1A, except that (1) the data were recorded on a minute-by-minute basis for all animals, and (2) the experiment was conducted as a single replication. There were 6 rats in the contrast (.15-32) condition and 6 in the control (.15-.15) condition.

Figure 3. Degree of contrast during the 1st min of exposure (top panel), the first 2 min of exposure (middle panel), and the first 3 min of exposure (bottom panel), for each access-duration group. The data illustrate terminal (Block 7) mean lick frequencies in contrast (.15-32) and control (.15-15) conditions for the second replication of Experiment 1A.

Results

Analysis of the average lick-frequency data indicated no overall contrast effect [$F(1,10) = 4.27, p = .065$], but a contrast effect did appear in selected minutes [solution $\times$ minute, $F(9,90) = 4.08, p < .01$]. Subsequent analyses indicated that contrast was reliable in Min 1, 2, and 8. This interaction is illustrated in Figure 4.

Analysis of each minute separately revealed a slightly different pattern. Contrast was reliable in Min 2 in Blocks 2, 3, 4, and 7 [$F(6,60) = 2.77, p < .01$] and in Min 1 in Blocks 3, 4, 5, and 7 [$F(6,60) = 2.25, p = .05$]. In Min 7, there was a marginal overall contrast effect [solution, $F(1,10) = 4.68, p = .055$], but no solution $\times$ block interaction ($F < 1.00$). A similar pattern occurred in Min 8, where there was an overall contrast effect which did not vary as a function of block [solution, $F(1,10) = 6.53, p < .05$; solution $\times$ block, $F < 1.00$]. The development of con-

trast on a minute-by-minute basis for the 10-minute condition is illustrated for Blocks 1, 3, 5, and 7 in Figure 5.

Lick frequency: Bottle 2. The animals given access to 32% sucrose licked more ($M = 231$ licks/min) than the rats given access to 0.15% saccharin [$M = 35.8$ licks/min; $F(1,10) = 401.08, p < .001$].

Discussion: Experiments 1A and 1B

Whereas some degree of reliable anticipatory contrast was obtained under all exposure durations, degree of contrast was largest with the 3-min exposure interval. This suggests one optimal parameter for the occurrence of contrast, just as previous research with degree of concentration disparity between the first and second solutions has suggested an optimal level for that parameter (Flaherty et al., 1994; Flaherty & Rowan, 1986; Lucas et al., 1990). These data, and other studies previously cited, suggest that an animal's responsiveness to the first of two food items presented sequentially may vary by degree from enhanced intake to suppressed intake as a function of relative reward value, duration of access, time between the solutions, and deprivation condition.

The present data further suggest that increasing time of access to the first solution much beyond 10 min may possibly eliminate the contrast effect under the conditions of the present experiments. However, the present experiments also revealed a complicating factor in the manipulation of this variable. As the time of access to the second solution (which varied exactly with that of the first solution in these experiments) increases, the composition of the animal's diet changes. That is, the necessity of restricting the intake of rat chow in order to maintain body weight at the targeted 82% leads to a greater proportion of the animal's diet being shifted to carbohydrates (from the 32% sucrose). Thus, rats in the longer access periods will be at the same body weight as those with short access periods, but the different diets maintained by the two groups may influence their performance in the contrast task in ways that are

Figure 4. Solution $\times$ minute interaction: mean lick frequency of contrast (.15-32) and control (.15-15) groups given a 10-min access period to the two solutions. Data are averaged across the 14 days of Experiment 1B.

Figure 5. Mean lick frequency of 10-min contrast (.15-32) and control (.15-.15) groups as a function of access minute in each daily session. Data are presented from four different blocks in acquisition. The error bars represent standard errors of the mean.

currently unknown. One possibility is that a dietary imbalance itself might eventually devalue the second solution (32%), thereby adding another dynamic to the contrast problem.

Analysis of the minute-by-minute data indicated a different dynamic. With short access periods, contrast initially developed toward the end of the daily session. However, with a 10-min access period, contrast occurrence was less systematic, with a tendency for early development to be at the beginning or the middle of the session, and with no convincing sign of migration toward the end of the session with repeated training—that is, there was no indication of Pavlovian inhibition of delay (see Figure 5). The lack of any evidence of Pavlovian inhibition of delay is consistent with other data that indicate that inhibition, as it is usually understood, is not involved in the suppression that occurs in anticipatory negative contrast (Flaherty et al., 1994).

EXPERIMENT 2

Experiments 1A and 1B show that exposure to the two solutions beyond the optimum time (around 3 min) reduces degree of contrast apparently primarily by interfer-

ing with the suppression of intake of the first substance that normally occurs during the first few minutes of exposure. However, these results do not offer any compelling insights into the mechanism of reduced contrast with short or long exposure times. The smaller contrast in the 10-min group relative to the 3-min group appears to be due both to less suppression in the 10-min contrast animals and to reduced intake by the 10-min control animals. The reduction in the control (.15-.15) animals is unlikely to be due to anticipatory satiation because any such effect should be greater in the contrast (.15-.32) group, which would be anticipating a large caloric load—but this contrast group is *less* suppressed than the corresponding 3-min group (which consumes a much smaller caloric load in Bottle 2).

Experiment 2 was conducted to determine whether the reduced contrast that occurs with a 10-min access period is due primarily to the extra exposure to the first solution or to the extra exposure to the second solution. To this end, separate groups of contrast and control animals received either 3-min access periods to both solutions, 3 min of access to the first solution and 10 min of access to the second solution, or 10 min of access to the first solution and 3 min of access to the second solution.

Method

Subjects. Thirty-six male Sprague-Dawley rats purchased from Harlan and approximately 100 days old were used as subjects. The animals were maintained as in Experiment 1A.

Apparatus. The apparatus was the same as that used in Experiment 1B.

Procedure. The basic procedure was the same as that used in Experiment 1. There were six groups—three contrast (.15-32) and three control (.15-.15)—each composed of 6 rats. One pair of contrast and control groups was allotted 3 min of access to each solution; a second pair of contrast and control groups was allotted 3 min of access to the first solution and 10 min of access to the second solution; and the third pair of contrast and control groups was allotted a 10-min access period to the first solution and a 3-min access period to the second solution. As in Experiments 1A and 1B, there was a 15-sec intersolution interval (ISI).

In order to compare the various groups, the data were analyzed on a licks/minute basis. Reliable ANOVA terms were further analyzed using Fisher's LSD procedure.

Results

Contrast occurred in the 3-min/3-min and 3-min/10-min conditions, but not in the 10-min/3-min condition. These results are described in detail below and are illustrated in Figure 6.

Bottle 1 licks. Analysis of the 3-min/3-min groups showed that the .15-32 group licked less than the .15-.15 group [$F(1,10) = 81.60, p < .001$], and that this contrast effect was reliable from Blocks 2 through 7 [solution $\times$ block, $F(6,60) = 5.79, p < .001$].

Analysis of the 3-min/10-min groups showed that the .15-32 group licked less than the .15-.15 group [$F(1,10) = 81.54, p < .001$], and that this contrast effect was also reliable from Blocks 2 through 7 [solution $\times$ block, $F(6,60) = 9.20, p < .001$].

Analysis of the 10-min/3-min groups showed that the lick frequencies of the .15-.15 and .15-32 groups did not differ overall [$F(1,10) = 2.41, p > .15$], and that contrast was not reliable at any point in training [solution $\times$ block, $F(6,60) = 1.98, p > .08$].

Further planned analyses were conducted to compare the three contrast groups and the three control groups. The three .15-32 groups differed in Bottle 1 lick rate [$F(2,15) = 20.68, p < .001$]. Subsequent tests showed that the 3-min/3-min and 3-min/10-min groups did not differ, but both licked at a lower rate than the 10-min/3-min group. There was also a differential development of contrast across training [group $\times$ block, $F(12,90) = 3.37, p < .001$]. Subsequent analysis indicated that the 3-min/10-min group licked less than the 10-min/3-min group in Blocks 2 through 7, and less than the 3-min/3-min group in Blocks 3 and 4. The 3-min/3-min group licked less than the 10-min/3-min group in Blocks 2 and 5 through 7.

Thus the degree of suppression was greater in both contrast groups with a 3-min access period to Bottle 1 than in the group with a 10-min access period to Bottle 1. Moreover, there was a tendency for suppression to be greater in the 3-min/10-min group than in the 3-min/3-min group, particularly in the middle of the training period.

A separate analysis of the three control groups showed no difference in lick rate [$F(2,15) = 1.44, p > .25$], nor any

Figure 6. Bottle 1 (B1) mean lick frequency across acquisition as a function of contrast (.15-32) and control (.15-.15) conditions and as a function of access time to the first and second substances.

indication that lick rate diverged across training [groups $\times$ blocks, $F(12,88) = 1.02, p > .40$].

Thus, the reduced contrast effect that occurred in animals with a 10-min access period to the first solution was due to differences in degree of suppression in the contrast groups and not to any differences in the control groups.

Bottle 1 latency. The three solution conditions produced quite different results in the latency to initiate licking on Bottle 1—results illustrated in Figure 7. In the 3-min/3-min access condition, there was no difference in latency between the .15-32 group and the .15-.15 group [$F(1,10) = 1.55, p > .24$].

In the 3-min/10-min condition, there was a substantial contrast effect in latency, with the .15-32 group initiating licking after a mean time of 66.1 sec, in comparison with 12.6 sec for the .15-.15 group [$F(1,10) = 16.72, p < .01$]. Subsequent analysis of a reliable group $\times$ block interaction [$F(6,60) = 3.68, p < .01$] showed that the difference between the groups was reliable in Blocks 4 through 7.

In the 10-min/3-min condition, there was a reliable facilitation effect—the .15-32 group initiated licking sooner than the .15-.15 group [$M = 8.9$ and 14.1 sec, respectively; $F(1,10) = 5.57, p < .05$].

Figure 7. Mean $\log_{10}$ latency to initiate licking on Bottle 1 (B1) as a function of contrast (.15-.32) and control (.15-.15) conditions and as a function of access time to the first and second substances. The data are collapsed across the 14-day acquisition period.

Thus, the latency data paralleled the lick-frequency data—contrast in consumption was largest in the 3-min/10-min condition, and this condition also showed a large contrast in latency; contrast in consumption was somewhat smaller in the 3-min/3-min condition, and there was no contrast in latency in this condition; there was no contrast in consumption in the 10-min/3-min condition, and this group showed a facilitation effect rather than contrast in latency.

Bottle 2 licks. In all three temporal conditions, the rats licked substantially more for 32% sucrose than for 0.15% saccharin [3-min/3-min condition, $F(1,10) = 565.57$, $p < .001$; 3-min/10-min condition, $F(1,10) = 91.11$, $p < .001$; 10-min/3-min condition, $F(1,10) = 296.35$, $p < .001$].

Analyzed in terms of lick rate, neither the contrast groups (.15-.32) nor the control groups (.15-.15) from the three access conditions differed from one another in their responsiveness to the 32% sucrose [$F(2,15) = 2.79$, $p > .09$, and $F(2,15) = 1.34$, $p > .25$, respectively].

Bottle 2 latency. In all three access conditions, the rats initiated licking sooner for the 32% sucrose than for the 0.15% saccharin [3-min/3-min condition, $F(1,10) = 26.45$, $p < .001$; 3-min/10-min condition, $F(1,10) = 45.27$, $p < .001$; 10-min/3-min condition, $F(1,10) = 13.22$, $p < .01$].

A comparison of the three contrast groups showed that all were different from one another in terms of latency to initiate licking on Bottle 2 [$F(2,15) = 74.97$, $p < .001$]. Subsequent tests showed that the 3-min/10-min group had the shortest latency, that the 3-min/3-min had the next shortest latency, and that the 10-min/3-min group was the slowest.

A comparison of the three control groups also indicated differences in latency to initiate licking on Bottle 2 [$F(2,15) = 9.57$, $p < .01$]. Subsequent tests showed that the 3-min/10-min group was faster than the other two groups, which did not differ.

Discussion

Experiments 1A and 1B showed that access periods of 10 min to both the first and second solutions substantially di-

minished the degree of anticipatory negative contrast relative to access periods of 3 min to both solutions. The present experiment localized that effect to the extra access time to the initial saccharin solution. Indeed, extra access time to the 32% sucrose solution enhanced contrast, as seen both by the greater suppression in Bottle 1 lick frequency early in training and by the longer latency to initiate licking for the saccharin solution seen in the 3-min/10-min condition relative to the 3-min/3-min condition.

Two possibilities arise in regard to the interference with contrast produced by increasing the duration of access to the initial saccharin solution. First, increasing the duration also increases the time between initial access to the saccharin and initial access to the 32% sucrose. Thus, the reduction in contrast seen with increased access time to the initial solution might simply reflect the reduction previously seen with increased ISIs (Flaherty & Checke, 1982; Lucas et al., 1988). However, even though contrast is reduced with increasing ISIs, a very substantial contrast effect is still maintained with intervals ranging from 5 to as much as 30 min between solutions. Contrast was eliminated in Experiment 2 by having a 10-min access period to the first solution—a change that would add only 7 min to the ISI in comparison with the 3-min/3-min condition. Thus, it seems unlikely that an elongated ISI is the reason that contrast was reduced in the 10-min/3-min condition.

An alternative interpretation is that the extra access time to the initial saccharin solution increased its reward value. This possibility is supported by the latency data, which showed that the .15 (10-min) – 32 (3-min) group showed a facilitation effect in latency—initiating licking sooner than the control group. In comparison, the .15 (3-min) – 32 (10-min) group showed a large contrast effect in latency—initiating licking much later than the control group. The .15 (3-min) – 32 (3-min) group, which was intermediate in contrast, was also intermediate in latency—showing neither contrast nor facilitation.

The assumption that the access-time parameter functions by influencing the reward value of the solutions en-

ders the results of the added access time to the first or second solution interpretable within the same framework—a framework that is consistent with that of several previous experiments. Thus, extra access time to the 32% sucrose enhanced contrast because it increased the value of the 32% sucrose, just as increasing concentration or quality of the second substance has been shown previously to enhance contrast (Flaherty & Rowan, 1986; Lucas et al., 1990). On the other hand, extra access time to the initial 0.15% saccharin solution decreased contrast because it enhanced the value of the initial solution, just as increasing the concentration or quality of the initial solution, beyond some optimum level, also decreases contrast (Flaherty et al., 1991; Flaherty & Rowan, 1986; Lucas et al., 1988).

The fact that some degree of contrast was obtained in both studies in which a 10-min access period was given to both the first and the second solutions (Experiments 1A and 1B), but that no contrast was obtained when access to the initial substance only was extended to 10 min (Experiment 2), suggests that the added reward value of the second substance may offset, to a degree, the added reward value of the initial substance. The possibility that access time functions as a reward parameter is supported by the Bottle 2 latency data—the contrast and control groups with the 10-min access periods initiated licking sooner than the other groups.

Overall, the present and previous data suggest that degree of anticipatory negative contrast varies in a systematic fashion according to the relative value (quality or access time) of the first and second substances—a phenomenon that, in foraging behavior, may be metaphorically related to the x birds in the hand versus y birds in the bush phenomenon—the more valuable the future bird(s), the less valuable are those already in possession.

EXPERIMENT 3

As mentioned in the Introduction, informal observation suggests that rats in anticipatory-contrast experiments tend to approach the location of the preferred second solution before it is available for consumption. These anticipatory-approach behaviors could detract from the time available for consumption, and thereby contribute to the degree of contrast effect obtained. However, it is also possible that these approach responses occur independently of suppression. In a quite different situation, Timberlake and colleagues have noted that under some conditions, anticipation of a richer food source contributed to suppression of responding on a progressive ratio (depleting patch) schedule, but that under other conditions, approaches to the better food source and suppression on the depleting patch occurred independently (Timberlake et al., 1987). Furthermore, anticipatory contrast has been obtained in operant studies in which there was a single signal location and a single food magazine (e.g., Buck, Rothstein, & Williams, 1975; Williams, 1991), as well as in consumption studies in which both the first and second solutions were presented in the same location (e.g., Capaldi et al., 1989; Capaldi & Sheffer, 1992; Lucas et al., 1990).

Experiments 3 and 4 were conducted to determine both the degree to which spatial-location factors, and correlated competing responses, contribute to the degree of anticipatory contrast and whether latency and consummatory measures of contrast are differentially affected by spatial-location factors. The latency measure must be based on context-taste associations rather than on taste-taste associations, and therefore may be more influenced by consistent spatial separation of the two solutions in a given context (Flaherty & Grigson, 1988).

Method

Subjects. Twenty-four male Sprague-Dawley-derived rats purchased from Blue Spruce, and approximately 100 days old, were used as subjects. They were maintained as in Experiment 1A.

Apparatus. The apparatus was the same as that used in Experiment 1A.

Procedure. Animals in the control group received daily access to two presentations of a 0.15% saccharin solution. The solution was available for a 3-min period on each presentation and there was a 15-sec ISI between the two presentations. Three experimental groups received a 3-min access period to the 0.15% saccharin solution, followed, after a 15-sec ISI, by a 3-min access period to a 32% sucrose solution. These three groups differed in the manner in which the two solutions were presented. For Group Separate, the saccharin was always presented through the right access hole and the sucrose through the left hole. This is the standard procedure used in most earlier anticipatory-contrast experiments. For Group Random, whether the saccharin solution was presented on the left or right varied from trial to trial according to a Gellerman series; sucrose was always presented in a different hole from saccharin. Finally, for Group Same, both solutions were always presented through the center access hole. In all cases, the saccharin solution was presented first and the sucrose solution second, following a 15-sec ISI. Two of the 6 animals in the contrast control group (.15-.15) were assigned to each of the spatial-location conditions. The experiment was continued for 18 days, with one pairing given each day.

The number of licks made to each tube and the latency to make the first lick on each tube were recorded. The first tube was made available approximately 30–45 sec after the animals were placed in the chambers.

Saccharin and sucrose solutions were prepared as in the previous experiment.

Results

Mean lick frequency to the first solution (which was always saccharin) is presented in Figure 8 and mean $\log_{10}$ latency to lick the first solution is presented in Figure 9.

There were no differences among the three subgroups of the control group [group, $F(2,3) = 3.17, p > .15$; group $\times$ block, $F(16,23) = 1.72, p > .10$]; thus, data from all animals were combined for purposes of analysis.

It is clear from Figure 7 that in all .15-32 groups, lick frequency for the 0.15% saccharin solution was suppressed (i.e., anticipatory contrast occurred). Analysis of Bottle 1 (0.15%) lick frequency showed an overall group effect [$F(3,20) = 9.99, p < .001$]. Subsequent analyses with the LSD test ($p = .05$) showed that lick frequency for the 0.15% solution was suppressed in all three experimental groups, compared with the control (.15-.15) group, and, furthermore, lick frequency was suppressed more in the separate-location group than in the random-location and single-hole groups.

Figure 8. Mean number of licks on Bottle 1 (B1) 0.15% saccharin as a function of solution condition (0.15% saccharin followed either by the same solution or by 32% sucrose) and spatial arrangement of the two solutions (fixed and spatially separated location for each solution [SEP-FIXED], location of Bottle 1 varied randomly between two locations [SEP-RND], or both solutions presented at the same location [SAME]).

The contrast effect developed differentially across blocks in the three experimental groups [$F(3,159) = 3.38, p < .001$]. Subsequent analysis with the LSD test showed that contrast was reliable from Block 2 on in the spatially separated group, and from Block 5 on in the single-hole and random-location groups. Thus, contrast developed sooner and was larger when the two solutions were in fixed, spatially separate locations.

Analysis of the latency to initiate licking for the 0.15% saccharin solution (Figure 8) indicated an overall group difference [$F(3,20) = 5.34, p < .01$], and subsequent (LSD) tests showed that only the group that received the two solutions in spatially separate locations showed a reliable contrast effect (the .15-32 group had longer latencies than the .15-.15 group). The group $\times$ block term was not reliable for the latency measure [$F(24,160) = 1.49, p > .07$].

Analysis of the Bottle 2 data showed that the three groups with 32% sucrose in the second tube licked more than the animals with saccharin in the second tube [$F(3,20) = 47.67, p < .001$, followed by LSD tests]. There were no differences among the three 32% groups.

Discussion

Consistent, spatially separate locations for the saccharin and sucrose solutions facilitated the development of anticipatory contrast and enhanced its magnitude. However, a substantial degree of anticipatory contrast in consummatory behavior was apparent even in the absence of distinctly different or predictable spatial locations. This result confirms that spatial separation of the two solutions is not necessary to obtain anticipatory contrast (Flaherty & Checke, 1982: Experiment 3).

The results obtained with the latency measure were different. In this case, contrast occurred only when there were different and consistent spatial locations for the two solutions.

Collectively, these data suggest that the taste of the initial substance is sufficient to serve as a cue predicting the impending occurrence of the preferred second substance—with the resulting suppression of licking for the initial substance. The latency data suggest that animals require a spatial separation of the solutions in order for the context to activate the taste-taste association (cf. Flaherty & Grigson, 1988). There was a temporal sequence cue in all conditions (the saccharin always preceded the sucrose, whether or not they were spatially separated), which could have entered into a contextual association and supported contrast, but the formation of such an association was not indicated by the data. Although rats have a substantial ability to estimate the passage of time intervals (e.g., Meck & Church, 1984) and foraging birds are apparently able to integrate temporal aspects of reward availability into their foraging routine (Kamil, 1978), the present data suggest that rats are much less sensitive to temporal sequence than to spatial separation as a cue.

EXPERIMENT 4

In Experiment 3, as in previous anticipatory-contrast studies, informal observation suggested that the rats in the spatially separated .15-32 condition tended to move to the location of the 32% solution prior to its availability. These goal-directed behaviors appeared to develop at least in parallel to the growth in anticipatory contrast in consummatory behavior. Experiment 4 was conducted in order to obtain objective data regarding such goal-directed behaviors. The two solutions were located in the two arms of a T-maze, and in addition to lick frequency, the time that the animals spent in each arm, as a function of solution-availability condition, was recorded.

Method

Subjects. The subjects were 10 male Sprague-Dawley-derived rats, approximately 100 days old and purchased from Blue Spruce Farms. The rats were maintained as in Experiment 1.

Figure 9. Mean $\log_{10}$ latency to initiate licking on the first bottle as a function of solution condition (0.15% saccharin followed by either the same solution or 32% sucrose) and location condition (fixed and spatially separated location for each solution [SEP-FIXED], location of Bottle 1 varied randomly between locations [SEP-RND], or both solutions presented at the same location [SAME]). The data are averaged across blocks.

Apparatus. Testing was conducted in a wooden T-maze with the start box measuring $20 \times 19 \times 15$ cm, the choice box measuring $17 \times 25 \times 15$ cm, the left arm measuring $40 \times 14 \times 15$ cm, and the right arm measuring $40 \times 12.5 \times 15$ cm. The T-maze was covered with clear Plexiglas. The left arm, where Bottle 1 was presented, was painted black, and the right arm, where Bottle 2 was presented, was painted with black and white vertical stripes. One hole, approximately 1 cm in diameter, was located on the end wall of each arm approximately 3.5 cm above the floor. The last 22.5 cm of each arm were covered with hardware cloth, which served as one side of a contact relay circuit; the other side of this circuit was the metal drinking spout of the tube used to present the solutions. The solutions were delivered via these tubes, which were advanced and retracted by motors. The number of licks made on Bottle 1 and Bottle 2 was recorded through the contact relay circuits. The time spent in each arm was recorded via a circuit wired through a floor plate and microswitches. Time spent in the center (choice) area and in the start box was not recorded. The entire floor, except for the area covered by hardware cloth, was covered by a thin sheet of plastic.

Procedure. Following one week of adaptation to the colony room, the subjects were deprived to 82% of their free-feeding body weight. Each rat was then habituated to the T-maze for 5 min, 24 h prior to the first experimental session. The subjects in the control group ($n = 5$) received a 3-min access period to 0.15% saccharin in the left arm, followed by a 15-sec ISI during which no solution was available, and a subsequent 3-min access period to a second 0.15% saccharin solution in the right arm. The experimental group ($n = 5$) received a 3-min access period to 0.15% saccharin in the left arm, followed by a 15-sec ISI, and a subsequent 3-min access period to a 32% sucrose solution in the right arm. Testing occurred once per day for a total of 14 days.

Results and Discussion

Suppression of licking on the 0.15% saccharin solution developed in the .15-.32 group in Blocks 6 and 7 [solution $\times$ block, $F(6,48) = 5.79, p < .001$, followed by LSD tests]. These data are presented in Figure 10.

Analysis of the lick-frequency data on a minute-by-minute basis, collapsed across blocks, indicated that the contrast (.15-.32) group showed a decline in lick frequency for the saccharin solution across the 3 min, whereas the control (.15-.15) group did not [solution $\times$ min, $F(2,16) = 4.20, p < .03$]. Bottle 1 saccharin intake was reliably suppressed in Min 3 of access, relative to Min 1, in Group .15-

32. Furthermore, this group licked less than Group .15-.15 in both Min 2 and Min 3 of access. There were no reliable differences as a function of time in the .15-.15 group.

Examination of the time that the animals spent in each arm showed that the .15-32 group spent reliably less time than the control group in the left arm when .15% saccharin was available [$F(1,8) = 13.32, p < .01$]. This behavior developed across blocks, becoming reliable from Block 4 onward [solution $\times$ block, $F(6,48) = 7.43, p < .001$, followed by LSD tests]. These data are presented in the left panel of Figure 11. This difference in time allocation did not show reliable systematic development across the 3-min access period [solution $\times$ min, $F < 1.0$; solution $\times$ block $\times$ min, $F(12,96) = 1.15, p > .25$].

In parallel to the diminished time spent in the left arm, the contrast (.15-32) group allocated more time to the right arm when saccharin was present in the left arm [$F(1,8) = 24.48, p < .01$]. As illustrated in the right panel of Figure 11, this time-distribution effect developed across blocks [solution $\times$ block, $F(6,48) = 8.24, p < .001$], becoming reliable from Block 4 onward (LSD test). There was no indication of a difference in time allocation across the 3-min period of saccharin availability each day [solution $\times$ min, $F < 1.0$; solution $\times$ block $\times$ min, $F(12,96) = 1.35, p > .20$].

These data, in comparison with those illustrated in Figure 10, show that the development of anticipatory contrast in consumption was preceded by differential time allocation in the contrast and control groups. That is, the contrast effect in licking became reliable by Block 6, whereas differences in time allocation became reliable by Block 4. Thus, these data quantify what has been observed informally in past anticipatory-contrast experiments in our laboratory—the rats in the contrast group tend to move to the location of the preferred reward (goal tracking), and they do this before the contrast in lick frequency develops.

However, this differential development of time allocation and licking across blocks does not necessarily mean that the reduction of licking in the left arm is caused by movement to the right arm. Examination of contrast development, within daily sessions, shows that Group .15-32 decreased licking for the saccharin solution across the three 1-min access periods. But the time that this group spent in the left arm, where the saccharin was located, did not decline within the 3 min of saccharin availability. These data, for which statistical support was given above, are illustrated in Figure 12.

Analysis of Bottle 2 lick frequencies showed that the animals receiving 32% sucrose licked more than the animals receiving the saccharin solution [$M = 214$ and 53 , respectively; $F(1,8) = 53.93, p < .001$]. This difference became reliable by the second block of trials [$F(6,48) = 26.11, p < .001$, followed by LSD tests]. The contrast animals also spent more time than the control group in the right arm when the second bottle was available [$F(1,8) = 32.69, p < .001$], and less time in the left arm [$F(1,8) = 24.85, p < .002$]. Both of these effects developed across trials, becoming reliable by Block 2 in the case of the right-arm data and by Block 3 in the case of the left-arm data [solu-

Figure 10. Mean lick frequency on Bottle 1 (0.15% saccharin) across 2-day blocks as a function of Bottle 2 solution (0.15% saccharin or 32% sucrose).

Figure 11. Mean time in each minute of access spent in the left arm (left panel) and in the right arm (right panel) during Bottle 1 (0.15% saccharin) availability in the left arm.

tion $\times$ block, $F(6,48) = 2.61$, $p < .05$, followed by LSD tests; and solution $\times$ block, $F(6,48) = 3.51$, $p < .01$, followed by LSD tests].

Thus, the sequence of consummatory and behavioral events was as follows: By Block 2, Group .15-32 licked more and spent more time in the right arm than Group .15-.15 when the second solution was available in that arm; by Block 3, Group .15-32 spent less time than Group .15-.15 in the left arm when the second solution was available in the right arm; by Block 4, Group .15-32 began spending anticipatory time in the right arm, where the sucrose was to become available; and finally, by Block 6, Group .15-32 developed a reliable suppression of licking for the saccharin solution in the left arm.

GENERAL DISCUSSION

These experiments have been concerned with two parameters that importantly influence degree of anticipatory contrast. Variations in the access time to either the first or second solution moderate contrast, with increasing access to the second solution enhancing contrast, and increasing access to the first solution decreasing contrast. These effects, which were interpreted in terms of alterations in the reward values of the two solutions, are compatible with earlier data. If anticipatory contrast is applicable to foraging

situations, the duration-of-access parameter may parallel factors that influence "giving-up-time"—that is, the longer the duration of availability of the second substance, the more likely the animals would be to give up consuming the first substance.

Experiments 3 and 4 were concerned with the influence of spatial separation or spatial consistency of the first and second substances on degree of anticipatory contrast. Although reliable time-allocation changes preceded reliable lick suppression by several days in Experiment 4, it is unlikely that goal-directed behaviors caused the contrast in lick frequency. In addition to the evidence from Experiment 3—and the earlier work by Flaherty and Checke (1982, Experiment 3)—the minute-by-minute data from Experiment 4 showed a dissociation between lick suppression and time allocation. That is, lick frequency declined across the saccharin-availability period, within a session, but there was no correlated change in the time that the animals spent in either arm. It seems likely that both lick suppression and the spatial distribution of the animals' behavior reflect the same underlying process—the development of signaling properties of the saccharin solution, and either its consequent devaluation or the inhibition of responding to it, as a result of a developing associative relationship between the saccharin and the impending sucrose solution.

Figure 12. Mean time spent in the left arm (left panel) and mean number of licks of 0.15% saccharin (right panel) in Group .15-32 as a function of Min 1, 2, and 3, of availability of 0.15% saccharin.

The role of anticipatory responses as competing responses has also been considered in other contexts related to the anticipatory-contrast procedure. Timberlake et al. (1987) found that suppression of responding on one lever (a progressive ratio, or depleting patch, lever) was correlated with anticipatory responding to a second lever on which a continuous reinforcement (CRF) schedule would be activated at some time in the future. These anticipatory approaches were directly related to suppression of responding on the progressive ratio lever in most conditions of their experiment. However, Timberlake et al. also presented data in which there was evidence for anticipation of the availability of the CRF lever but no response suppression on the progressive ratio lever. This effect occurred when there was a long time interval between the availability of the two reward conditions. Thus Timberlake et al. suggested that suppression and anticipatory responding may be independent in some circumstances and that response competition from anticipatory behavior may or may not be related to suppression of responding to the first available reward—depending upon the conditions of the experiment.

Taken together, the data suggest that anticipatory responses to spatially different future rewards may, in some circumstances, contribute to the degree of anticipatory contrast, but such competing responses do not seem necessary for the occurrence of contrast and, in fact, the contrast and the anticipatory responses may be mediated by the same common underlying mechanism—the development of signaling properties associated with the first available solution.

The laboratory phenomenon of anticipatory contrast may be related to processes involved in foraging. Foraging animals may be influenced by the reward value of the current foraging patch but also by the average expected reward in the foraging context (Kamil & Roitblat, 1985; Krebs, Ryan, & Charnov, 1974). When prey frequency in the current patch falls below the expected average or frequency of prey, the animals may give up on the current patch and move on to other locations (Kamil, Yoerg, & Clements, 1988; Shettleworth & Plowright, 1992). The anticipatory-contrast processes revealed in laboratory experiments may normally function to enhance this giving up to the extent that the animals are able to anticipate a greater reward quantity or quality in the next patch. Some of the factors previously shown to influence anticipatory contrast suggest conditions under which contrast would operate in foraging tasks. For example, contrast is enhanced with larger reward differences between the current and future reward and diminished as the interval between rewards increases. The present data suggest that access time (mediated via reward value) and spatial separation also play a role. In contemporary foraging theory, travel time to the next patch is thought to influence giving-up time—the greater the travel time, the more persistent the animal should be in the current patch, all other factors being equal (Kamil & Roitblat, 1985; Mellgren, Misasi, & Brown, 1984).

However, the present data suggest a possible countervailing factor, in that anticipatory contrast may be enhanced by spatial separation. To the extent that anticipatory con-

trast plays a role in giving-up time, greater spatial separation should enhance contrast and, therefore, enhance the tendency to leave the current patch. This presumed effect of anticipatory contrast may operate only with relatively short spatial separations because degree of contrast diminishes with increased time between the two solutions. Thus, if anticipatory contrast does play a role in foraging, the degree of its effect would be some function of the relative value of the two rewards, the degree of spatial separation, and the time between the two rewards.

Finally, the access-time data may argue against the role of competing responses as a mechanism that mediates contrast. Increasing the access time to the first solution, leaving all other parameters constant, would provide more opportunities for competing goal-tracking responses, and therefore should enhance contrast. However, the opposite occurred—contrast was diminished by increased access time to the initial solution. This result is consistent with the hypothesis that approaches to the location of the second substances reflect the development of anticipatory contrast—they do not cause it.

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