STIMULUS GENERALIZATION OF SCHEDULE-INDUCED POLYDIPSIA

ROBERT J. HAMM, JOSEPH H. PORTER, AND GEORGE L. KAEMPF

VIRGINIA COMMONWEALTH UNIVERSITY

Five rats were exposed to an intradimensional discrimination by associating two tones of different frequency with the components of a multiple random-time 30-sec, extinction schedule of food presentation. After schedule-induced polydipsia developed and the intermittent schedule of food presentation established stable differential licking rates during the stimuli associated with the multiple schedule, a stimulus generalization test was conducted. When generalization testing was conducted by presenting stimuli that varied on the frequency dimension during the random-time 30-sec component of the multiple schedule, all five rats demonstrated moderately sloping symmetrical gradients. Thus, schedule-induced polydipsia can be brought under the control of stimuli other than the food pellet.

Key words: stimulus generalization, adjunctive behavior, interim behavior, polydipsia, licking, rats

Falk (1971) has proposed that "when certain schedules induce extra, concurrent phenomena which are strong enough to sustain schedule behavior in their own right, these phenomena be called adjunctive behaviors" (p. 578). Staddon and Simmelhag (1971) have proposed an alternative definition of these schedule-induced adjunctive types of behavior. They suggest that one can classify behavior according to when the behavior occurs during the interreinforcement interval. For example, if schedule-induced behavior is engaged in when the probability of reinforcement is high (i.e., in the latter portion of the interreinforcement interval), this behavior is labeled a terminal response. Thus, the behavioral phenomena of autoshaping (Brown & Jenkins, 1968) can be classified as a schedule-induced terminal response. If the schedule-induced behavior occurs at times when the probability of reinforcement is low (i.e., the first portion of the interreinforcement interval), this behavior is called an interim activity. Thus, the excessive drinking (polydipsia) that occurs after food-pellet delivery is a schedule-induced interim response.

One line of research in the area of interim or adjunctive behavior has been concerned with determining what schedule-induced behavior will occur and in what temporal pattern and intensity (e.g., Staddon & Ayres, 1975; Staddon & Simmelhag, 1971). Another research interest has focused on the similarities or differences between adjunctive (interim responses) and operant (terminal responses) behavior. For example, Porter and Allen (1977) delivered food pellets on a fixed-time schedule in order to induce an adjunctive licking response. The availability of water was then placed on various multiple schedules, and behavioral contrast (Reynolds, 1961) of adjunctive licking was observed. Similarly, Cohen (1975) used a concurrent variable-time schedule of food presentation and manipulated availability of water associated with one component of the concurrent schedule. Results demonstrated that the relative time spent drinking in each component varied according to the matching law (Herrnstein, 1970). In both the Porter and Allen (1977) and Cohen (1975) experiments, adjunctive licking behavior exhibited schedule interactions common to those seen with operant behavior, and thus supported the hypothesis that operant and adjunctive behaviors are similar. Recently, however, Hamm, Porter, and Oster (1978) failed to observe summation (see Weiss, 1972) of adjunctive licking under conditions that pro-

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duced summation of operant barpressing. An examination of the procedure employed by Porter and Allen (1977), Cohen (1975), and Hamm *et al.* (1978) reveals a procedural difference which may account for these divergent results. Both Porter and Allen (1977) and Cohen (1975) employed an intermittent schedule of food delivery to induce licking throughout the session, and the availability of water was placed on a lick-contingent schedule. Thus, these procedures, in effect, transform the licking response into an analog of an operant (terminal) response with respect to water delivery, and consequently it is not particularly surprising to find licking behavior exhibiting phenomena characteristic of operant behavior. In the Hamm *et al.* (1978) experiment water was continuously available while food pellets were delivered according to a response-independent schedule. This procedure maintains the interim nature of the licking response, and a phenomenon characteristic of terminal behavior was not observed. The absence of summation reported by Hamm *et al.* raises the question of whether licking will show phenomena common to operant behavior when it is not a terminal response. The specific purpose of the present experiment is to investigate the stimulus control of adjunctive licking under conditions designed to maintain the "interim" nature of the schedule-induced behavior.

METHOD

Subjects

Five male Sprague-Dawley rats between the ages of 90 and 120 days old were reduced to 80% of their free-feeding weights and maintained at that level by restricting their daily ration of Purina Rat Chow. The rats were housed individually in an animal colony room (7 am/7 pm light/dark cycle) where water was continuously available.

Apparatus

Three Scientific Prototype (Model D700-1305) chambers were used. The interior dimensions of the chambers were 23 by 21 by 19 cm. The intelligence panel of each chamber had a food-pellet cup 4 cm from the left wall and 1 cm above the floor and a hole 1.5 cm in diameter located 4 cm from the right wall and 2 cm above the floor. The hole provided

access to a water bottle mounted on the outside of the chamber so that the end of the drinking spout (2.4 mm aperture diameter) was flush with the wall. Contact with the water tube was recorded by BRS contact relay (DR901/221-05). Auditory stimuli were generated by a Mallory Sonalert (Model SC 628-11), which was centered on the left side wall. Solid-state programming equipment (LVB Logic Box) was located in an adjacent room and controlled stimulus events and response recording.

Procedure

Discrimination training. Food pellets were delivered independently of the rat's behavior according to a multiple random-time 30-sec, extinction (mult RT 30-sec EXT) schedule, and licking of the water tube was recorded. The RT 30-sec schedule was produced by a probability gate pulsed at a rate of one per sec with an output probability set at .2. The output of the probability gate was then connected to a predetermining counter set to deliver a food pellet after six inputs. This programming arrangement yielded an average interpellet interval of 30 sec with a minimum possible interpellet time 6 sec.

The stimulus associated with the RT component of the multiple schedule was an intermittent tone with equal on-off phases and a frequency of 40 pulses per sec. An intermittent tone with a frequency of 10 pulses per sec was correlated with the EXT component. The RT- and EXT- component schedules alternated throughout each 40 min session. For R1, R2, and R3 a session consisted of 20 1-min presentations of both the RT- and EXT- associated stimuli. For R4 and R5 a session consisted of 10 2-min presentations of both the RT- and EXT- correlated stimuli. Thirty sessions were conducted following this procedure in order to establish differential licking rates during the stimuli correlated with the multiple schedule of food delivery.

Stimulus generalization testing. Test stimuli were intermittent tones of 5, 10, 40, 120, and 240 pulses per sec. A probe testing procedure was conducted by adding two presentations of each of the five test stimuli to the discrimination training procedure. Thus, for R1, R2, R3 a test session consisted of 20 1-min presentations of S⁺, 20 1-min presentations of S⁻, and two 1-min presentations of each of the five test

stimuli. For R4 and R5 a test session consisted of 10 2-min presentations of S⁺, 10 2-min presentations of S⁻, and two 2-min presentations of each of the test stimuli. After a six-component warm-up on the training schedule test stimuli were introduced in a random order. Test stimuli were presented where S⁻ normally occurred in the alternating mult RT 30-sec EXT schedule, and food pellets were not delivered during the test stimuli. Testing was conducted for five sessions so that there was a total of 10 presentations of each of the test stimuli during testing.

A second generalization test was conducted as described above except that food pellets were delivered during all test stimuli according to an RT 30-sec schedule, and the test stimuli were introduced into the multiple schedule where S⁺ normally would have occurred. That is, a test stimulus was always preceded and followed by the S⁻ component. An additional five sessions were conducted.

RESULTS

Mean licking rates (total licks/total time) during the stimuli associated with the mult RT 30-sec EXT schedule were calculated for each session. The mean licking rates for the last 10 sessions of discrimination training prior to testing are presented in Figure 1 (Sessions 21 to 30). The terminal acquisition licking rates for R1 showed considerable between session variability, and the licking rates for R2 steadily declined over the last five sessions of training. The remaining three rats emitted relatively stable licking rates during S⁺ (the RT-correlated stimulus). For the three rats (R1, R2, and R3) with the 1-min component duration, lick rates during S⁻ (the EXT-associated stimulus) were rather high in magnitude considering that no food pellets were delivered during the interval. Careful examination of a typical cumulative record (see Figure 2A) helps explain the degree of licking during S⁻. As the cumulative record illustrates, most licking during S⁻ is in fact "spill-over" from food pellets delivered during the S⁺ component. That is, a food pellet may be delivered near the end of the S⁺ component, and the licking induced by the pellet might continue into the S⁻ component of the multiple schedule. Examples of this spill-over licking are marked by an asterisk on the cumulative record. For the two rats (R4 and R5) with

Fig. 1. Mean licking rates during the stimuli associated with the mult RT 30-sec EXT schedule. Sessions 21 to 30 are the last 10 sessions of discrimination training prior to generalization testing. Sessions 31 to 35 and 36 to 40 show response rates during the two generalization tests.

Fig. 2. Representative cumulative records from R2 and R5 during discrimination training. Pen slashes represent food pellet delivery. The pen reset after each component of the multiple schedule. Clear examples of spill-over licking are indicated by asterisks.

the 2-min component duration, S^- lick rates were lower, and consequently, the degree of differential responding during the stimuli was better. Again, inspection of a sample cumulative record (see Figure 2B) shows that the source of reduced S^- licking is the reduced magnitude and frequency of spill-over licking during S^- . Less spill-over licking would be expected with a 2-min component since the number of S^+ to S^- transitions were one-half as frequent as in the 1-min component condition (i.e., 10 as compared to 20).

Licking rates on the training mult RT 30-sec EXT schedule during the first and second generalization test (Sessions 31 to 35 and 36 to 40, respectively) are presented on the right portions of Figure 1. The figure shows that all rats responded during S^+ and S^- at rates that were equivalent to the licking rates established during discrimination training (see Figure 1, Sessions 21 to 30). This indicates that the two

generalization testing procedures did not disrupt the behavioral control established by the training multiple schedule.

The mean lick rates (broken lines) for the five presentations of each of the five test stimuli during the first testing phase are presented in Figure 3. During this phase no food pellets were delivered during the test stimuli and test stimuli were preceded by the S^+ component. As in discrimination training the rats with the 1-min components (R1, R2, and R3) had higher licking rates during the test stimuli presented during extinction than rats with the 2-min components (R4 and R5). As before, the licking rate during extinction is primarily a function of the amount of spill-over licking from food pellets delivered during S^+ . All rats produced essentially flat gradients. That is, there appeared to be no systematic changes in the response rate as the frequency of the test tones are varied. Since test stimuli were always

Fig. 3. Mean response rates (total responses/total time) during the auditory test stimuli for both generalization testing procedures. The gradient represented by the broken line was obtained when no food pellets were delivered during the test stimuli. The solid-line gradient was obtained when food pellets were delivered under a RT 30-sec schedule during testing.

preceded by an S⁺ component, the licking that did occur during the stimuli may simply be spill-over from food pellets delivered during the preceding component.

In the second phase of testing (see Figure 3), food pellets were delivered during the test stimuli according to a RT 30-sec schedule and the test stimuli were always preceded by S⁻. The figure shows that lick rates (solid lines) were quite high and were within the same range as the lick rates emitted during S⁺ during discrimination training (see Figure 1, Sessions 21 to 30). The elevated rate of licking during this phase compared to the first phase can, of course, be attributed to food pellets being delivered during testing. Since each test stimulus was preceded by an S⁻ component, the licking recorded during the test stimuli could not be attributed to licking initiated in the preceding S⁺ component. The most relevant feature of the gradients is that all five

gradients have the point of maximal licking at the 40 pulses/sec frequency stimulus (the S⁺ of discrimination training). Also, all gradients exhibit a moderate slope and are approximately symmetrical around their peak. Only in the case of R3 is there any evidence of a peak shift, and in this case it is only a small shift in area away from S⁻.

DISCUSSION

Stimulus control of behavior is inferred when a change in some property of a stimulus produces a change in a response characteristic. As Figure 1 illustrated, at the end of discrimination training, the tone stimuli were correlated with different licking rates. The fact that the stimuli were associated with differential responding is not a sufficient condition to infer that the tones acquired control of the schedule-induced licking since the changes in the auditory stimuli were confounded with changes in the rate of food-pellet delivery. Therefore, a more specific test is required to determine whether the tones have acquired control over the licking behavior. The stimulus generalization gradient is a frequently used index of stimulus control. However, the assessment of stimulus control of adjunctive (interim) behavior is made difficult by the induced nature of the behavior. For example, generalization testing is typically conducted in extinction (i.e., when food pellets are not delivered). However, extinction testing may not be an appropriate testing procedure for schedule-induced polydipsia because of its induced nature. By definition schedule-induced licking is induced by the delivery of the food pellet. If testing is conducted in extinction (i.e., without food pellets), no schedule-induced licking will be initiated, and any licking recorded during the test stimulus was probably initiated during the preceding S⁺ component. Thus, it is not surprising that the data presented in Figure 3 when generalization testing was conducted during extinction exhibit no evidence of auditory stimulus control of licking. The lack of a peaked stimulus generalization gradient under extinction testing conditions does not necessarily imply the lack of stimulus control by the auditory dimension. Rather, the testing conditions must be designed so that they provide an appropriate test of stimulus control of schedule-induced licking. The need for an ap-

appropriate testing procedure is not unique to studies of adjunctive behavior. For example, if pigeons were reinforced for pecking an illuminated key during one tone while pecking was extinguished during a second tone, it would be impossible to assess the control of key pecking acquired by the auditory stimuli if testing were conducted with the key abruptly darkened since pigeons normally will not peck a dark key. In the case of adjunctive licking, food pellets must be delivered in order to induce the behavior so that changes in the behavior are measurable.

When generalization testing was conducted under conditions that maintained the schedule-induced licking (i.e., when the test stimuli were always preceded by S^- and food pellets were delivered during testing), all rats demonstrated clear evidence of stimulus control of licking. That is, all subjects exhibited orderly changes in licking behavior as a function of changes in the auditory stimuli. In order to explain the acquisition of stimulus control of an interim behavior, a more detailed examination of the procedure is necessary. Figure 4 presents a schematic illustration of the typical stimulus and response events during discrimination training. The top two lines represent the alternation of the S^+ and S^- auditory stimuli. The third line indicates the delivery of food pellets while the bottom line illustrates bouts of licking induced by the food pellet. An analysis of Figure 4 reveals several consistent stimulus and response correlations. First, the food pellet (S^*) is contingent on S^+ ($S^+ - S^*$ association). In addition, the stimulus condition that precedes the adjunctive behavior is the compound stimulus comprised of S^+ and S^* ($S^+ + S^* \rightarrow R$). Since S^* induced the licking and may be a more salient stimulus than S^+ , it could be hypothesized that S^* would mask or overshadow the tone S^+ from acquir-

ing any control over the licking behavior. This prediction is not confirmed by the gradient obtained during the second generalization test (see Figure 3). Another implication that might be inferred from Figure 4 is that S^+ may function as a CS for the food pellet and as such might itself directly induce licking. As the cumulative record (see Figure 2) shows, the presentation of S^+ alone was not sufficient to induce licking. Thus, simply pairing a stimulus with a food pellet will not result in that stimulus acquiring the ability to initiate the licking response. Similar results have been reported by Allen and Porter (1977). However, generalization testing indicated that stimuli other than the food pellet can exert some control over on-going adjunctive behavior.

Falk (1971) has argued that adjunctive behavior should be classified as a distinct behavioral class from operant behavior. However, since the present research, along with that of Cohen (1975) and Porter and Allen (1977), show that it is possible to demonstrate phenomena characteristic of operant behavior with adjunctive behavior, the utility of a separate adjunctive behavioral class must be questioned, particularly if the separate classification is taken to imply that adjunctive and operant behaviors is controlled by different mechanisms.

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Fig. 4. A schematic of the typical response and stimulus events during discrimination training. The top two lines show the alternation of S^+ and S^- . The third line indicates the delivery of food pellets while the bottom line shows the bouts of licking induced by the food pellet.

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