Travel Distance and Stimulus Duration on Observing Responses by Rats

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Observing procedures have differed qualitatively regarding the spatial arrangement of the food and the observing operanda within the experimental chamber. The effects of varying the distance between the operanda, however, remain unknown. The present study explored the effects of increasing the distance between the food and the observing lever using two stimulus durations in rats as subjects. A chamber containing two levers was used and presses on one lever were reinforced on a mixed random-interval 30 s extinction schedule with 60 s components alternating randomly. Each press on the second lever produced the component-correlated stimuli. Using a factorial design, combinations of 3, 9, or 18 cm distance between the levers with stimuli durations of 0.5 and 5 s were explored. Observing rate decreased as a function of both, increasing travel distance and shortening stimulus duration. As with concurrent schedules of food reinforcement, as travel distance increased changeover rate decreased and the duration of stays on each lever increased. Even when a travel distance was imposed, the rats moved to the observing lever but only when stimulus duration was 5 s.

Key words: Observing responses, conditioned reinforcement, travel distance, stimulus duration, lever pressing, rats

Wyckoff (1952, 1969) demonstrated the establishment of an operant when its only consequence was the presentation of discriminative stimuli. He used an experimental chamber equipped with a response key, a food tray, and a pedal located on the floor below the response key. Key pecking was reinforced on an analog to a mixed fixed interval (FI) 30 s extinction (EXT) 30 s in which both components of the schedule alternated randomly. The response key was illuminated with a white light during both FI and EXT unless the pigeons stepped on the pedal

that changed the light to red during FI (S+) and to green during EXT (S-). Whenever the pigeons stepped off the pedal the response key light changed back to white. Wyckoff reported that the pigeons produced the discriminative stimuli during more of the session time when the color of the response key correlated with the components of the mixed schedule than when it did not. Wyckoff named the responses that were sustained by the production of the discriminative stimuli *observing responses* and concluded that the discriminative stimuli functioned as conditioned reinforcers.

Given that the emission of observing responses does not affect the rate of the primary reinforcer, the observing-response procedure has become an useful technique to study the phenomenon of conditioned reinforcement (e.g., Lieving, Reilly, & Lattal, 2006; Shahan, Podlesnik, & Jimenez-Gomez, 2006).

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The observing procedure, however, involves a complex arrangement of concurrent food and stimuli availability that has raised several issues for interpretation. For example, Hirota (1972) suspected that Wyckoff's procedure may have resulted in accidental presses of the observing pedal.

In one of his conditions, Hirota replicated directly Wyckoff's procedure and reported that when the stimuli were correlated with the components of the mixed schedule, while the S+ remained on for 50 to 70% of the total session time, the S- remained on for only from 15 to 25% of the session time. These observing times were related to key pecking rates, food-reinforced responses were more frequent during the FI that during the EXT component. Hirota also found a decrease in observing time when the stimuli were not correlated with the components of the mixed schedule, similar to Wyckoff's result. Hirota, however, also found a correlation between observing time and key pecking rate in this condition. Furthermore, in other conditions Hirota reported that observing rate remained relatively constant even when a time out was contingent on pedal pressing. Therefore he concluded that given the spatial distribution of the food key and the observing pedal in Wyckoff's procedure, observing responses occurred accidentally whenever the pigeons approached the food key and not because of the stimuli functioning as conditioned reinforcers. Hirota suggested that it is necessary to separate the observing and the food operanda in observing procedures to eliminate the accidental reinforcement of observing responses. Hirota, however, recognized a problem with the latter suggestion. If the two operanda are spatially separated then food and observing responses would not be mutually independent (i.e., food and observing responses may compete).

Several observing studies produced results congruent with response competition (Kelleher, Riddle, & Cook, 1962; Shahan, 2002). For example, Shahan used a chamber with two levers separated 13 cm from each other. Pressing one lever produced food-reinforcement on a mixed random ratio (RR) 50 EXT. Each component averaged 60 s. Each press on a second lever produced the S+ or the S- for 5 s. Shahan found that the S- was produced more often than the S+. He suggested that response competition between food and observing responses during the reinforcement component reduced observing responses during this component.

Gaynor and Shull (2002) acknowledged the difficulty in arranging the experimental space in observing procedures. According to these authors the food and the observing operandum must be close enough to allow the concurrent occurrence of food and observing responses but not so close that observing responses occur accidentally while the food-producing responses is being emitted. Gaynor and Shull described a procedure that solved this problem. In one of their rats Gaynor and Shull reinforced key poking on a mixed variable interval (VI) 60 s EXT schedule of reinforcement. The component duration was 60 s and the two components alternated randomly with the restriction that no more than two components of the same type could occur in succession. Each press of a lever located near the key produced the discriminative stimuli for 5 s (S+ or S- during VI or EXT components respectively). In this way, the food and the observing operanda were close to each other but could not be operated simultaneously. Gaynor and Shull reported that observing rate was higher during the VI than during the EXT component. They also reported that the latency of an observing response after the S+ was shorter than after the S- presentations. Such a result is congruent with the notion that the S+ associated with food delivery functions as a conditioned reinforcer for observing responses.

Even though an effort has been made to avoid response competition in observing procedures by keeping both operanda close to each other (e.g., Gaynor & Shull, 2002), longer distances between the food and the observing operanda, rather than confusing the interpretation of the results, may be used to assess the preference for the schedule of conditioned reinforcer relative to the schedule of food reinforcement. Given that observing procedures consist of concurrent food and conditioned reinforcement schedules, changing over from the food to the conditioned reinforcement lever may be a measure of preference for the conditioned reinforcement alternative. As Baum (1982) noticed, when two schedules of reinforcement are concurrently available, the travel distance from one lever to another imposes a "cost" for changing over. Baum exposed pigeons to two schedules of food reinforcement concurrently available on two keys. A single variable interval timer scheduled food reinforcement probabilistically for the two keys. The intervals averaged 40 s and reinforcement probability for the less preferred alternative was .25. When the travel requirement between alternatives was small, changeover rate was relatively high such that responses on each alternative matched the reinforcement rate. As the travel requirement increased, changing over decreased, thus the preference for the favored alternative increased resulting in strong overmatching.

Baum's (1982) rationale can be applied to observing procedures. For example, a weak conditioned reinforcer should result in almost exclusive preference for the food alternative when the distance between operanda is increased. A strong conditioned reinforcer should result in a relatively high rate of changing over even when the travel distance between the food and the observing operanda is increased. The present experiment tested this assertion by varying the travel requirement between the food and the observing lever in an observing procedure with rats. For comparison purposes two different conditioned reinforcement values were used.

According to Dinsmoor, Mulvaney, and Jwaideh (1981), in observing procedures the values of the stimuli as conditioned reinforcers are related to stimulus duration. Dinsmoor et al. used a three-key chamber. Pecks on the central key produced food reinforcement on a mixed VI EXT schedule. Pecks on one side key produced 27 s stimuli correlated with the schedule of food reinforcement. Pecks on the other key produced the same stimuli for 1, 3, 9, 27, or 81 s. Dinsmoor et al. found that the proportion of side-key pecks notably increased when stimulus duration was lengthened from 1 to 9 s and increased slightly when stimulus duration was further lengthened. The authors concluded that longer conditioned reinforcers have greater effects on the response that produces them. Therefore, in the present experiment the conditioned reinforcer value of the stimuli was varied by using two stimulus durations 0.5 and 5 s.

Method

Subjects

Six experimentally naive male-Wistar rats, 3 months old at the beginning of the experiment (280–305 g body weight), served as subjects. The rats were obtained from the vivarium of the Faculty of Psychology of the National Autonomous University of Mexico and were maintained under compliance with the ethical regulations of the University. The rat's welfare and health were constantly monitored by the researcher and the vivarium staff headed by a full-time veterinary. Throughout the experiment, the rats were kept at 80% of their ad-lib weight and were housed within individual Plexiglas cages $(33 \times 23 \times 15 \text{ cm})$ with free access to water.

Apparatus

Two experimental chambers (MED-Associates, model ENV-007) equipped with a food tray (ENV-200R1AM) located at the middle of the front panel were used. The chambers were also equipped with a sonalert (Mallory SC 628) that generated a 2900 Hz 70 dB tone, a house light and two bulbs that generated a dim light located above the food tray. Food pellets of 25 mg were delivered into the food tray by means of a pellet dispenser (ENV-203IR). The side wall of the chamber was modified to place two custom-built metal levers 4.5 cm above the floor. Each lever was 1 cm thick, 1.8 cm wide, protruded 2.5 cm into the chamber and operated by a downward force of 0.15 N. One lever (right) was 1 cm separated from the front panel. The left lever could be placed 3, 9 or 18 cm separated from the other lever. Each experimental chamber was placed within a sound-attenuating cubicle equipped with a fan and a white-noise generator. Experimental events were controlled from an adjoining room with an IBM compatible

computer, using Med-PC 2.0 software, connected to an interface (Med Associates Inc. model SG-503).

Procedure

The left lever was removed from the chamber and all rats were exposed to continuous reinforcement for 5 sessions. During the next 20 sessions the schedule of reinforcement was gradually changed to a random-interval (RI) 30-s schedule. This schedule was generated with a repetitive T cycle of 3 s. A reinforcement probability of 0.1 was assigned to the first response occurring within each T cycle (RI value = T/p; T= 3 s, p = 0.1). With this schedule, lever pressing was reinforced with one food pellet on average every 30 s. Each session ended after one hour or when 50 reinforcers were delivered, whichever occurred first. According to response rates during the 20 sessions, rats were assigned to two groups of three rats each, in such a way that each group included one rat with high, intermediate and low rates of responding.

Discrimination training. All rats were exposed to a multiple RI 30 s EXT schedule of reinforcement. The duration of both components was 60 s and each session ended after 30 RI and 30 EXT components were presented. The components of the multiple schedule of reinforcement alternated randomly with the restriction that no more than two equal components could occur in succession. The RI component was signaled with a blinking light (S+) and the EXT component was signaled with a tone (S-). A tone was selected as an S- for all rats to reduce the probability of unrecorded escape responses during S- presentations that could be favored with a light as an S- (i.e., had a light been aversive, the rats might have turned away to escape from its presentation; see Shull, 1983). This condition was in effect for 30 sessions.

Observing procedure. The left lever was installed into the chamber separated 3 cm from the right lever. The multiple schedule of reinforcement was replaced with a mixed RI 30 s EXT schedule. Each press on the left lever produced the S+ during the RI component or S- during EXT components. Stimuli were interrupted whenever a change in component occurred. All other variables remained as in the previous condition in discrimination training. The component duration and the value of the reinforcement schedule were similar to those used in the study by Gaynor and Shull (2002).

The effects of three distances between the levers 3, 9, and 18 cm were assessed in successive conditions of 30 sessions each. Stimuli duration differed for the two groups of three rats, either 0.5 or 5 s. Although such a brief duration of the stimulus has not been used in observing procedures using rats as subjects, it has been reported in previous studies on discrimination learning in rats (e.g., Reed, 2003). Immediately after exposing the subjects to the three different distances between the levers, the 3-cm distance was reestablished during 30 sessions.

Results

One question raised in the present study is whether increasing the distance between the food and the observing levers reduces the difference in observing rates between the RI and the EXT components. Such an effect would be consistent with the possibility that competition between the food response and observing response contributes to the puzzling effect found in some prior studies—namely that observing rates are sometimes lower during the RI component than during the EXT component.

Figure 1 shows the mean individual rate of observing responses in the last five sessions of each condition during the RI and the EXT components of the mixed schedule of reinforcement. Data from this and all subsequent figures are averages across the last five sessions of each condition. The disconnected points represent the data from a replication. The error bars show ±1 standard deviation (SD) of the data across the five-session block. The observing rates were corrected to avoid misrepresenting observing rates, by excluding both stimulus duration and travel time (i.e., the interval between two successive lever presses on different levers; see description of Figure 5) from the duration of each component of the mixed schedule of reinforcement. This was done because observing responses could not be emitted during this time.



Figure 1. Observing-response rates as a function of the distance between the levers. The top panels show the rates of observing with the 0.5-s stimulus duration and the bottom panels show the rates with the 5 s stimulus duration. Observing rates are shown separately for the RI (filled points) and the EXT (unfilled points) components of the mixed schedule of reinforcement. Data points not connected by lines are from a replication.

For Rat 1 under the 0.5-s stimulus duration, as the distance between the levers was lengthened observing rate decreased in both components. For Rats 2 and 3 the rate remained low with all the distances explored. Reestablishing the distance between the levers at 3 cm resulted in observing rates that were higher than those found under the first exposure to this distance. For the rats that were exposed to the 5-s stimulus duration, as the distance between the levers was lengthened from 3 to 9 cm, observing rate decreased in both components for each of the three rats. Increasing the distance from 9 to 18 cm resulted in a decrease in observing rates for all three rats-substantially so for Rat 4 and less so for Rats 5 and 6. For the three rats, when the distance between the levers was 3 cm (i.e., the shortest distance) observing rate was higher during the RI than during the EXT component. Such difference was reduced as the distance between the levers was lengthened. Reestablishing the distance between the levers at 3 cm resulted in an increase in observing rates during both

components of the mixed schedule of reinforcement for the three rats. These rates, however, were lower than those observed during the first exposure to this distance between the levers.

Gaynor and Shull (2002) suggested that the follow-up latencies of observing are a sensitive measure of the duration of the observing episode of the S+ or the S- when the duration of the stimulus is controlled by the experimenter. For example, after a stimulus is turned off a rapid follow-up observing response can be conceptualized as a continuation of the previous observing episode that extends the contact with the previously produced stimulus. Figure 2 shows the follow-up latencies of observing responses separately after the S+ and the S- as a function of the distance between the levers. The error bars show ±1 SD of the data across the five-session block.

The follow-up latencies show a pattern consistent with the rate of observing. For all the rats exposed to the 5-s stimulus duration, the latencies were shorter after an S+ than after



Figure 2. Follow-up latencies a function of the distance between the levers. The latencies were calculated from the end of the stimulus to the subsequent observing response. The top panels show the latencies of an observing response after the 0.5-s stimuli and the bottom panels show the latencies after the 5 s stimuli. Other details are as in Figure 1.

an S- and such difference was less noticeable as the distance between the levers increased. For Rat 4 the latencies after both the S+ and the Sincreased slightly when the distance increased from 3 to 9 cm and markedly increased when the distance was increased to 18 cm. For Rats 5 and 6 the follow-up latencies increased noticeably when the distance between the levers was lengthened from 3 to 9 cm and increased slightly when the distance was lengthened to 18 cm. The redetermination of the 3 cm distance produced latencies similar to those observed during the first exposure to this distance between the levers. For Rat 1 under the 0.5 s stimulus duration, the follow up latencies in both components increased as the distance between the levers was lengthened. For Rats 2 and 3 there was no systematic effect.

Food-lever response rate is an index of the discriminative properties of the stimuli produced by observing responses. The rationale is that a mixed schedule of reinforcement should result in a relatively constant rate of responding across the components of the schedule. In observing procedures, the stimuli are expected to produce a response pattern consistent with multiple schedules of reinforcement (i.e., higher foodlever responding during the RI than during the EXT component). Figure 3 shows the mean individual food response rate during the RI and the EXT component of the mixed schedule of reinforcement for each condition. Food response rates were corrected by excluding travel time from the total duration of the components of the mixed schedule. The error bars show ±1 SD of the data across the five-session block. With the 0.5-s stimulus duration, food-response rate was only slightly higher during the RI than during the EXT component. Additionally, as the distance between the levers increased, food rates in both components increased to some extent for the three rats. With the 5-s stimulus duration food-response rate was notably higher during the RI than during the EXT component. Food-response rate during the EXT component did not vary systematically with the different distances between the levers for the three rats. During the RI component, food-response rate decreased as the distance between the levers



Figure 3. Food-response rates as a function of the distance between the levers. The top panels show the rates with the 0.5-s stimulus duration and the bottom panels show the rates with the 5 s stimulus duration. Other details are as in Figure 1.

was lengthened for Rats 4 and 5. For Rat 6 food-response rate decreased slightly when the distance increased from 3 cm to 9 cm and remained constant when the distance increased to 18 cm. For all rats the replication of the 3-cm distance produced food-response rates that were similar than those found during the first exposure to this distance.

Food-reinforcer frequency was calculated as a measure of the "cost" of observing. Given that the rats had to leave the food lever in order to press the observing lever, reinforcement frequency could decrease as a function of increasing the distance between the levers. The greater the reduction of reinforcer rate, the greater the cost of observing, by this measure. Figure 4 shows the mean number of obtained reinforcers per session for each condition. For the three rats that were exposed to the 0.5 s stimulus duration, the number of obtained reinforcers per session slightly increased as the distance between the levers was lengthened. In contrast, for the three rats that were exposed to the 5-s stimulus duration, the number of obtained reinforcers per session decreased as the distance between the levers was lengthened.

When the 3-cm distance between the levers was reestablished, the number of obtained reinforces increased for Rats 2, 3 and 4 and decreased for Rats 1 and 6 relative to the first exposure to this distance between the levers.

For comparison purposes, in the present study some dependent variables reported by Baum (1982) using different distances between the operanda with concurrent schedules of reinforcement were calculated. Even though in the present study the contingencies in the food and the observing levers are qualitatively different (e.g., a fixed-ratio 1 schedule for stimuli in one lever and an RI 30 s for food on the other lever) such dependent variables allowed to compare the preference for the observing schedule during the RI and the EXT components under the two stimulus duration in combination with the different distances between the levers.

Travel duration or the interval between one press on one lever and a second press on a different lever is shown in the top row of Figure 5. Each symbol shows the data for a different rat. For each rat there are two data points in each panel, one for the duration of the changeover from the food to the observing lever and



Figure 4. Number of reinforcers obtained per session as a function of the distance between the levers. The top panels show the number of reinforcers with the 0.5-s stimulus duration and the bottom panels show the number of reinforcers with the 5 s stimulus duration. Error bars represent ± 1 SD.

another for the changeover duration from the observing to the food lever. Additionally, the data are shown separately for the RI and the EXT components of the mixed schedule of reinforcement and for the two stimulus durations that were used (columns). The lines within each panel connect the three rats' mean. For all the rats, travel time increased as the distance between the levers was lengthened in all conditions. There was no systematic difference in travel time between the two directions of changeover (food to observing or observing to food) for the rats that were exposed to the 0.5-s stimulus duration. Also, for these rats no systematic difference was found between the components of the mixed schedule of reinforcement. In contrast, travel time was shorter in the two directions during the RI component with the 5-s stimulus duration. During the EXT component travel time from the observing to the food lever was noticeably longer than travel time from the food to the observing lever that was similar to the durations found during the reinforcement component.

The middle row of Figure 5 shows the average durations of stays on each lever measured from the lever press at arrival to the last press before changeover. Each panel shows separately the mean duration of stays in the food and the observing lever. For the rats that were exposed to the 0.5-s stimulus duration, the duration of stays in the two levers during the RI and the EXT component increased as the distance between the levers was lengthened. The duration of stays was notably longer on the food lever than on the observing lever and such difference was similar during the RI and the EXT component. With the 5-s stimulus duration during the RI component, the duration of stays increased on the food lever and increased and then decreased on the observing lever as the distance between the levers was lengthened. The duration of stays was considerably longer on the food that on the observing lever. During the EXT component the duration of stays increased on both levers as the distance between the levers was lengthened as was slightly longer on the food than on the observing lever.

The bottom panels of Figure 5 show the rates of changeover. As in Baum's (1982) study, travel time was excluded from the calculation of the rates. For all rats in all conditions change-



Figure 5. Travel time, duration of stays and changeovers per minute as a function of the distance between the levers. Symbols represent data for different rats. Left panels show the data with the 0.5-s stimulus duration and right panels show the data with the 5-s stimulus duration. For the top panels the filled symbols show the travel time from the food to the observing lever and the unfilled circles show the travel time from the food lever. For the middle panels the filled symbols show the duration of stays on the food lever and the unfilled symbols show the duration of stays on the food lever and the unfilled symbols show the duration of stays on the food lever and the unfilled symbols show the duration of stays on the observing lever. The lower panels show the changeover rate and each point represents the data for each rat under the different distances between the levers. Lines connect the rats' mean on each condition. The *y* axis is logarithmic.

over rate decreased as the distance between the levers increased. When the 0.5-s stimulus was used changeover rate was similar in both components of the mixed schedule of reinforcement. Changeover rate was higher with the 5-s stimulus duration than with the 0.5 s for all conditions. With the 5-s stimulus duration changeover rate was higher during the RI than during the EXT component.

Discussion

Observing-response rate during the RI component was consistently lower with the 0.5 s stimulus than with the 5 s stimulus under the different distances between the levers. The 0.5-s stimulus produced a substantial rate of observing responses only for one rat during the first exposure to the shortest distance between the

levers and only after extended exposure to the procedure in another rat. This result is consistent with Dinsmoor et al. (1981) who found that in pigeons the proportion of observing key pecks that produced the reinforcementcorrelated stimulus of durations ranging from 1 to 81 s was a positive, negatively accelerated function of stimulus duration in that option. It can be concluded that the 5-s stimulus functioned as a more potent conditioned reinforcer than the brief stimulus. Although the rate of observing might be questioned as an index of the conditioned reinforcer value of the stimuli (see Shahan & Podlesnik, 2005), in the present study each press on the observing lever resulted in one stimulus presentation, thus the rate of observing is related directly to the exposure to the stimuli. As Dinsmoor (1983) noticed, subjects generate greater exposure to a valuable conditioned reinforcer than to a neutral or an aversive stimulus. This interpretation is supported by the fact that the follow-up latencies showed a similar trend to that found with observing-response rate.

Observing procedures were considered important for studying conditioned reinforcement given that the stimulus-producing response is independent from the operant that produces primary reinforcement, thus observing responses are considered to be sustained by the conditioned reinforcer properties of the stimuli and not merely by a collateral effect of food delivery (e.g., Lieving et al., 2006). In the present study aside from recording observing responses, a travel requirement for observing was gradually increased. Previous authors (e.g., Baum, 1982), have suggested that travel distance imposes a "penalty" for changing over. Baum reported that with concurrent food schedules, increasing travel distance between the alternative resulted in strong overmatching (i.e., responses for the most part occurred on the preferred option). The present experiment can be conceptualized as the case in which a penalty was imposed for changing from the food alternative to the conditioned reinforcement alternative.

When the 0.5-s stimulus duration was used, during the two components of the mixed schedule of reinforcement, both observing and changeover rate were relatively low in this condition. Increasing the travel requirement further decreased changeover rate and increased the number of food responses and obtained reinforcers per session. That is, when the travel requirement was short, the rats alternated between the levers, albeit infrequently. As the travel requirement increased, the rats stayed almost exclusively at the preferred food option, thus the number of obtained reinforcers increased. A related finding was reported by Boelens and Kop (1983). They exposed pigeons to concurrent VI 20 s VI 60 s schedules of reinforcement and increased the travel requirement by lengthening a partition between the response keys from 0 to 10 and 20 cm. Without the partition, changeovers were frequent and undermatching was found, that is the response proportion was shorter than the reinforcement proportion. When the partition was lengthened responses concentrated almost exclusively at the preferred option (VI 20 s), thus resulting in overmatching. A similar finding was reported in rats that had to climb barriers to change from one alternative to the other in concurrent RI schedules of reinforcement (Aparicio, 2001).

The effects of increasing travel distance were similar with the 0.5 s and the 5 s stimulus duration. That is, lengthening travel distance decreased changeover rate in both components of the mixed schedule of reinforcement. Several differences, however, were observed with the two stimulus durations. With the 5 s stimuli, changeover rate was higher than with the 0.5 s stimuli and was higher during the RI than during the EXT component of the mixed schedule of reinforcement. A notable finding was that as the travel requirement increased the number of food reinforcers decreased for the three rats. The latter finding suggests that in order to produce the schedule-correlated stimuli the rats had to travel from the food to the observing lever even when leaving the food reinforcement option resulted in a decrease in reinforcement frequency.

It is worth noticing that aside from the expected positive relation between travel distance and travel time, systematic changes in travel time were observed while keeping travel distance constant. Travel time from the food to the observing lever was noticeably shorter with the 5-s stimuli than with the 0.5-s stimuli for all travel distances. With the 0.5-stimuli travel time from the observing to the food lever did not differ systematically during the two components of the mixed schedule of reinforcement. In contrast, with the 5-s stimuli, travel time from the observing to the food lever was shorter during the RI than during the EXT component of the mixed schedule of reinforcement.

Although travel time has not been recorded in observing procedures it may be a useful measure of conditioned reinforcement value. For example, in some studies it has been reported that conditioned reinforcer value is related to

travel speed from a starting box to a goal box using runways (Wike & Farrow, 1962; Wunderlich, 1961). In one study, Wunderlich used a straight runway to determine the conditioned reinforcer value of stimuli previously paired only with food or paired with food on half of the trials and water on the other half. He found that travel time during the acquisition trials was shorter if the stimulus presented in the goal box was paired with food or water than if it was paired only with food. Additionally, travel time records were more resistant to extinction when the stimulus paired with food or water was presented in the goal box than if the stimulus paired only with food was presented. Wunderlich concluded that conditioned reinforcer value, measured as speed, increased as a function of primary reinforcer variation.

Wunderlich's (1961) findings are useful for interpreting the present data. If travel time from the food to the observing lever is considered a measure of the reinforcing properties of the stimuli, it can be said that the 5-s stimulus functioned as a more valuable conditioned reinforcer than the 0.5-s stimuli. Different from studies in which a runway was used, observing procedures also allow for recording travel time from the observing to the food lever, which may be considered as an index of the discriminative properties of the stimuli. According to this suggestion, while the 0.5-s stimuli in both components of the mixed schedule of reinforcement had no discriminative properties, the 5-s S+ functioned not only as a conditioned reinforcer but also as a discriminative stimulus for food responses. Subsequent studies on observing behavior could determine the suitability of considering travel time as an index of conditioned reinforcement value.

By exploring the distance between the food and the observing operanda, the present data are also relevant to observing literature. The spatial arrangement of the food and the observing operanda has posed problems for the interpretation of observing behavior. According to Hirota (1972) if the two operanda are too close to each other, observing responses do not occur by a conditioned reinforcement effect but only occur accidentally while the subjects emit the food-producing response (cf. Wyckoff, 1952, 1969). This arrangement was replicated when the distance between the levers was 3 cm, that is, both levers could be operated simultaneously. The fact that observing responses were more frequent with the 5 s stimuli than with the 0.5 s stimuli does not support an explanation based on accidental responding.

Hirota (1972) also suggested that if the two operanda are spatially separated then observing responses would interfere with food responses. A finding congruent with this suggestion is that in some studies observing responses were more frequent during the EXT component of the mixed schedule of reinforcement (Escobar & Bruner, 2002; Shahan, 2002). To avoid the problems of response competition and accidental responding, Gaynor and Shull (2002) located the observing lever close to a food button, such that the two operanda were close to each other but observing responses could not occur accidentally. Gaynor and Shull found that observing responses were more frequent during the reinforcement than during the EXT component.

The present experiment allows for examination of the effects of the distance between the levers on the relative rates of observing during the RI and the EXT component of the mixed schedule of reinforcement. The present results are congruent with a response competition account when the levers are spatially separated. For example, when the levers were close to each other (3 cm) observing rate was notably higher during the RI than during the EXT component. This finding is congruent with Gaynor and Shull's (2002) results even when two levers involving two topographically similar responses were used. As the distance between the levers was lengthened, observing rate during the RI component decreased such that when the distance was 18 cm observing rate during the RI component was similar to the rate during the EXT component.

It is important to notice that in the present study, even when the levers were separated by 9 and 18 cm, observing rate during the EXT

component was never higher than the rate during the reinforcement component as was found in Shahan's (2002) study. One explanation for such difference could be the interaction between the food and the observing rates controlled by the RI schedule used in the present study and the RR used in Shahan's experiment. These schedules are both generated as T/p; that is, only the first response within T has a probability of producing the reinforcer. The difference between the schedules relies on the duration of T, in RR schedules the "hypothetical" T value is shorter than the minimum inter-response time, and thus the reinforcer probability is assigned to every response. In RI schedules, the T value ranges from a few to several seconds (3 s in the present study); therefore, reinforcement probability is assigned only to one response every few seconds.

An RI schedule produces a relatively low but steady rate of responding and an RR schedule, in contrast, results in a high rate of responding with few pauses (see Schoenfeld & Cole, 1972). In the present study, the rats alternated frequently between the food and the observing lever during the RI component. When the distance between the levers increased, changeover rate decreased but was still high enough to produce a similar rate of observing during both the RI and the EXT components. It is conceivable that in Shahan's experiment, using a RR schedule produced such high rates of food responding that changing over to the observing key rarely occurred, and only when the rate of food responding decreased during the EXT component the subjects changed to the observing lever. According to Shahan, this strong competition between food and observing responses during the reinforcement component resulted in a lower rate of observing during the reinforcement than during the EXT component. Further research, however, is necessary to clarify the effects of the reinforcement schedule on the competition between food and observing responses. Based on the present results, it can be concluded that the competition between the observing and the food responses rather than confusing the results of observing procedures is an important index of the value of the stimuli as conditioned reinforcers. That is, even when the rats could press exclusively the food lever they "pay the price" by traveling to the observing lever.

References

- Aparicio, C. F. (2001). Overmatching in rats: The barrier choice paradigm. *Journal of the Experimental Analysis of Behavior*, 75, 93-106.
- Baum, W. M. (1982). Choice, changeover and travel. *Journal of the Experimental Analysis of Behavior, 38*, 35-49.
- Boelens, H., & Kop, P. F. M. (1983). Concurrent schedules: Spatial separation of response alternatives. *Journal of the Experimental Analysis of Behavior*, 40, 35-45.
- Dinsmoor, J. A. (1983). Observing and conditioned reinforcement. *Behavioral and Brain Sciences*, 6, 693-728. (includes commentary)
- Dinsmoor, J. A., Mulvaney, D. E., & Jwaideh, A. R. (1981). Conditioned reinforcement as a function of duration of stimulus. *Journal* of the Experimental Analysis of Behavior, 36, 41-49.
- Escobar, R. & Bruner, C. A. (2002). Effects of reinforcement frequency and extinction component duration within a mixed schedule of reinforcement on observing responses in rats. *Mexican Journal of Behavior Analysis*, 28, 41-46.
- Gaynor, S. T., & Shull, R. L. (2002). The generality of selective observing. *Journal of the Experimental Analysis of Behavior*, 77, 171-187.
- Hirota, T. T. (1972). The Wyckoff observing response- a reappraisal. *Journal of the Experimental Analysis of Behavior, 18,* 263-276.
- Kelleher, R. T., Riddle, W. C., & Cook, L. (1962). Observing responses in pigeons. *Journal of the Experimental Analysis of Behavior*, 5, 3-13.
- Lieving, G. A., Reilly, M. P. & Lattal, K. A. (2006). Disruption of responding maintained by conditioned reinforcement: alterations in response–conditioned reinforcer relations. *Journal of the Experimental Analysis* of Behavior, 86, 197-209.

- Reed, P. (2003). The effect of signaled reinforcement on rats' fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, 79, 367-382.
- Schoenfeld, W. N., & Cole, B. K. (1972). Stimulus schedules: The t-T systems. New York: Harper & Row.
- Shahan, T. A. (2002). Observing behavior: Effects of rate and magnitude of primary reinforcement. *Journal of the Experimental Analysis of Behavior, 78*, 161-178.
- Shahan, T. A., & Podlesnik, C. A. (2005). Rate of conditioned reinforcement affects observing rate but not resistance to change. *Journal* of the Experimental Analysis of Behavior, 84, 1–17.
- Shahan, T. A., Podlesnik, C. A., & Jimenez-Gomez, C. (2006). Matching and conditioned reinforcement rate. *Journal of the Experimental Analysis of Behavior*, 85, 167-180.

- Shull, R. L. (1983). Selective observing when the experimenter controls the duration of observing bouts. *Behavioral and Brain Sciences*, 6, 715.
- Wike, E. L. & Farrow, B. J. (1962). The effects of drive intensity on secondary reinforcement. *Journal of Comparative and Physiological Psychology*, 55, 1020-1023.
- Wunderlich, R. A. (1961). Strength of a generalized conditioned reinforcer as a function of variability of reward, *Journal of Experimental Psychology*, 62, 409-415.
- Wyckoff, L. B., Jr. (1952). The role of observing responses in discrimination learning. Part I. *Psychological Review*, 59, 431-442.
- Wyckoff, L. B., Jr. (1969). The role of observing responses in discrimination learning. Part II. In D. P. Hendry (Ed.), *Conditioned reinforcement* (pp. 237-260). Homewood, IL: Dorsey Press.